A Personal History of the Royal Greenwich Observatory at Herstmonceux Castle 1948 – 1990

Volume 1– Narrative

George A. Wilkins

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This History is published in two volumes on the web-site of the Cambridge University Library, from where it may be downloaded and printed in whole or in part only for the personal use of the reader.

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PREFACE

The character of the Royal Greenwich Observatory was transformed during the period from 1948 to 1990 when it was based at Herstmonceux Castle. In 1948, when the move from Greenwich started, the programme of work was almost entirely concerned with *positional astronomy* and its applications to time and navigation. Then the director of the Observatory carried the title of Astronomer Royal and determined the programme of activities under the benevolent scrutiny of a *Board of Visitors*, which was appointed by the Admiralty. The transfer of the responsibility for the Observatory from the Admiralty to the *Science Research Council* in 1965 led to a series of changes that culminated in the closing of the Observatory in the autumn of 1998. When Sir Richard Woolley retired at the end of 1971, the title of Astronomer Royal was given to Sir Martin Ryle; the post now carries no recognised responsibilities. More significantly, the programme became increasingly directed by committees of the Council towards the support of research in *physical astronomy* by scientists from universities. In effect, the Director of the Observatory became a manager of facilities that were used mainly by astronomers outside the RGO and he had little control over the direction of the work carried out with those facilities. Most of the observing at Herstmonceux stopped before the new facilities on La Palma, in the Canary Islands, were ready for use. Eventually, the *Science and Engineering Research Council*, as it had become, decided to move the staff to a new building at Cambridge, leaving only the new satellite laser ranging system at Herstmonceux.

When I was appointed to the staff of the Observatory, in October 1951, the future was bright even though the building programme at Herstmonceux suffered from the economic difficulties of the post-war years. When my 60th birthday forced my retirement in July 1989, the morale of the staff was low; the last few years had seen drastic cuts in number of staff and more were to leave as a consequence of the scheduled move to Cambridge. Even those with a job to go to at Cambridge faced the uncertainties of the housing market and the problems of moving from one community to another. The move took place in the spring of 1990, less than a year after my retirement. At first the staff who moved were optimistic, but within a few years the future of the Observatory was once again put in doubt. It was finally closed in the autumn of 1998, with only a small number of staff being retained for work on La Palma, at the Astronomy Technology Centre at the Royal Observatory at Edinburgh and in H.M. Nautical Almanac Office at the Rutherford Appleton Laboratory.

My job expanded considerably during my 38-year period of service. By 1980 I was responsible for the management of a range of activities within the Observatory and yet I was able to participate on a personal basis in several international astronomical activities. The changes in the role of the Observatory and the reductions in the total number of staff during the following decade led to major reductions in the staff and activities for which I was responsible. Nevertheless, I obtained much job satisfaction from the success of the new satellite laser ranging project and from other activities in which I was involved.

In this account of the recent history of the Royal Greenwich Observatory I have not attempted to give a comprehensive account of the scientific and technical work that was carried out. Such activities are described in the annual reports of the Observatory and can be studied through the scientific papers and articles that were published by the staff concerned in them. Rather I have attempted to give a much more general and personal account of the decisions that were made and of both the official and unofficial activities that took place. I have concentrated on those aspects in which I was involved or in which I was interested. I have deliberately omitted, or made only passing references to, many important topics about which I have no personal knowledge. As a consequence of this approach, my own activities have been mentioned more frequently than would be the case in an account written by an independent observer. I hope that this personal thread will be found to be of interest and will serve as an example of the way in which a scientific career may develop and change as new interests and opportunities arise and as new functions, objectives and constraints are imposed from 'above'.

I hope that others who were concerned with the activities of other departments will fill in the gaps in this account of a fascinating period in the history of one of the world's oldest and best-known scientific institutions. Quite unexpectedly, a booklet containing personal reminiscences of life in the Observatory was published by the Herstmonceux Science Centre, which took over the Equatorial Group in the 1990s. The booklet was compiled by Anthony Wilson (formerly at the Science Museum) and contains contributions from eight members of the staff (including me). These have been skillfully blended in a basic historical framework to make a coherent account of many aspects of the work and of various incidents that would otherwise have gone unrecorded and of which I was unaware at the time.

The complete closure of the Observatory led to the publication of a collection of articles about a wide range of RGO activities by members of the staff in the final issue (no. 16, for October 1998) of the house journal *spectrum*. The subsequent formation of the RGO Society has provided opportunities for former members of the staff to meet and to exchange information by email and a website. The latter is being used to record the other recollections of staff about their work and experiences.

As far as I can recall all previous histories of the Royal Greenwich Observatory have used the periods of office of the Astronomers Royal to determine the main division into chapters. This is generally appropriate for this period and so the chapters of this account follow this my pattern, except that the change from the Admiralty to Science Research Council also made a major discontinuity in the work of the Observatory. The period between the retirement of Sir Richard Woolley and the appointment of Alec Boksenberg as Director may also be regarded as one chapter even though Margaret Burbidge, Alan Hunter and Graham Smith served as the director in quick succession. A short extra chapter about the period from 1990 to 1998 when the RGO was based at Cambridge has been added, although the title has been left unchanged.

In treating the story of H.M. Nautical Almanac Office (NAO) up to 1970, I tried to complement the account for 1930 to 1972 that had been written by the late Dr Donald H Sadler after his retirement from the post Superintendent of the Nautical Almanac, but some overlap has been unavoidable. I transcribed and edited his manuscript, but I was unable to find a publisher for his text. The original manuscript has been deposited in the RGO archives together with a copy of my edited version. A final version of my edited text has since been published on the web-site of H.M. Nautical

Almanac Office, which is now based at the UK Hydrographic Office in Taunton. It has the title *A Personal History of H.M. Nautical Almanac Office: 30 October 1930 – 18 February 1972*. I have here given some references to this text in the form [SPH, *nn*], where *nn* is the number of the chapter.

I had the intention of writing a similar account for my period in the Office, but I now realize that I am unlikely to do so. I have, however, given in this account for the RGO as a whole much more detail for the NAO and other activities with which I was directly concerned than for those of other departments. Consequently a separate account would largely duplicate what is in this account.

This account has been drafted in several stages with long gaps between them. The prologue was started in 1993 and the draft of the epilogue was completed in 2004. Over this long period there have been changes in both style and intention as I have appreciated the fallibility of my memory and the very limited extent of my knowledge of the wide range of activities with which I was not directly concerned. Although I have copies of many information bulletins and reports at home, there are many events for which I have so far been unable to find dates or other detail. In such an account as this it would be inappropriate to give references to all my sources or to leave a lot of question marks on the draft where information is lacking or doubtful. I have, however, given a few references and I have left some question marks.

I decided not to use endnotes and to give only indicative references in the text to sources of further information for use by persons who may wish for more information than I have given. I made much use of the duplicated information bulletins that were circulated staff to keep them informed about past and future events. These contain much more detail and a wider range of activities than is given in the printed annual reports of the Observatory.

Much additional detail is given in appendices that cover such topics as staffing, the RGO Club, facilities, publications and references. Other appendices provide summaries of this history from different viewpoints or they reproduce relevant material about specific aspects. For example, appendix A contains an outline of this account that is based on a lecture that I gave to the Bristol Astronomical Society in 2002, it also contains an article that I wrote about my experiences and views when I retired.

For convenience, the main text, or Narrative, is regarded as Volume 1, while the Appendices constitute Volume 2. I have not attempted to produce an index, but I have included detailed lists of the contents in each volume. Keyword searching of these lists (or even of the full text) should provide an alternative for readers with access by computer to this account.

I am hoping that it will be possible to publish this account fairly soon in an unpolished form on the Internet so as to ensure that it is available to a wide range of persons, some of whom will, I hope, provide corrections and additions to the text. Some sections of the appendices are not as complete as I had intended, but I hope that some additions may be made in due course. I regret too that I have not been able to take into account all the comments and additional material from those who have read my drafts of the early chapters (although I hope that I have corrected the errors). I will, however, try to produce supplementary material where this would be appropriate. Their notes will be available in my archival files. I hope to continue to check, and to correct when necessary, matters of fact, such as names and dates, by making further examinations of

the material that I have in Devon. I doubt whether I will make further extended visits to the RGO Archives, which are now stored in the Cambridge University Library.

I have not included any graphical or photographic illustrations with this text, but I hope to produce a separate file of digital images for the website to serve this purpose.

I intend to deposit in the RGO Archives in the Cambridge University Library a copy of my 'final' version and also a copy of the 2004 draft on which I have marked references to sources and question marks about detail for use by anyone who wishes to follow up any particular points. I hope that the RGO archivist will also accept, in due course, the additional material that I have at home. This includes manuscript notes, photographs, newspaper cuttings, copies of published articles, booklets and so on. I believe that I have a lot of such material that is unique or not readily available elsewhere.

I hope that readers of this draft will also tell me about any errors of fact that they may notice and about any topics on which they take different views or for which my account is inadequate. In many respects it will be necessary for me to rely on others to supply relevant information that I have forgotten or of which I have been unaware. I would be grateful also for suggestions on how this account could be improved either for the general reader or for the historian of the future.

For the reasons given above, a large part of this account is devoted to the many activities in which I have been involved during my career. My work has been very varied and has given me the opportunity to visit many interesting places throughout the world. Moreover, I made many friends in the Observatory and in the national and international organisations in which I was involved. I am heavily indebted to the late Donald Sadler, who appointed me to a post in the Nautical Almanac Office and who then gave me jobs that would widen my knowledge and improve my technical skills. It was through his example and encouragement that I participated in the activities of the International Astronomical Union and similar organisations. I must also acknowledge the support of my wife, Betty, who was frequently left to look after the children and the house while I was away, and who still makes it possible for me to keep up my astronomical activities.

I would also like to acknowledge the help that I have received from others in the preparation of this account. In particular, I would like to thank Adam Perkins, the RGO archivist in the Cambridge University Library, and Catherine Hohenkerk, who is on the staff of H.M. Nautical Almanac Office. Adam gave me free access during the 1990s to the RGO Archives in the Cambridge University Library, and has arranged for the publication of this account on the Internet. Catherine has, in her own time, converted my text from Word to pdf files and prepared the introductory and linking material for the Internet. I would also like to thank all those (here listed in alphabetical order) who have commented on extracts from the earlier drafts or who have helped in other ways: Mike Lowne, Arthur Milsom, Leslie Morrison, Andrew Murray, Bill Nicholson, Nathy O'Hora, Bernard Pagel, Joan Perry, John Pilkington, John Pope, Marion Rodgers, Andrew Sinclair, Don Taylor, David Thomas, Bert West, Roger Wood, and Bernard Yallop. More recently, Lee Macdonald has commented on some of a later version of the draft.

George A. Wilkins 2009 May 14

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1 PROLOGUE

1.1 A brief history of the Royal Observatory to 1948

"In order to the finding out of the longitude of places for perfecting navigation and astronomy", King Charles II resolved in 1675 "to build a small observatory within our park at Greenwich, ..., with lodging rooms for our astronomical observator and assistant, ...". The observatory expanded and became known as the Royal Observatory, Greenwich (ROG), while the 'astronomical observator' became known as the Astronomer Royal (AR). When the Observatory was moved from Greenwich to Herstmonceux Castle the name was formally changed to the Royal Greenwich Observatory (RGO).

The first three Astronomers Royal [John Flamsteed (1675-1719), Edmund Halley (1720-1742), James Bradley (1742-1762)] devoted their efforts to improving the observational data on the positions of the stars and on the motion of the Moon. Such data were required for the development of the method of lunar distances for determining Greenwich time, and hence geographical longitude, from astronomical observations made at sea.

Flamsteed was reluctant to publish his data in instalments and came into dispute with Isaac Newton who wished to use them to test his new theory of gravitation. As a consequence, Queen Anne appointed the President and some Fellows of the Royal Society to serve as 'Visitors' to oversee the affairs of the Observatory.

The fourth AR, Nathaniel Bliss (1762-1764), died shortly after his appointment, but his successor, Nevil Maskelyne (1765-1811), was responsible for the publication for the year 1767 of *The Nautical Almanac and Astronomical Ephemeris* (NA), which contained the data that were necessary for the application of the method of lunar distances. He also organised a geophysical expedition to 'weigh the Earth' by making observations of the deflection of the vertical by Mount Schiehallion in Scotland.

Maskelyne continued to supervise closely the production of the *Nautical Almanac*, for which the data were computed by individuals who worked at home, but his successor, John Pond (1811-1835) was more concerned with improving the accuracy of the observational work of the Observatory. In 1818, Pond was relieved of the day-to-day responsibility for the Nautical Almanac when Thomas Young was appointed 'Superintendent of the Nautical Almanac'. This was also the year in which the Hydrographer of the Admiralty began to play an important part in the running of the Royal Observatory. Young died in 1829 and for about two years Pond was again in charge of the work for the Almanac, but then W S Stratford was made Superintendent and the Nautical Almanac Office was set up in 1832. The Office remained independent of the Observatory until 1936.

Pond instituted the first public time-signal in the country when, in 1833, the daily dropping at precisely 1 o'clock of the time-ball down a mast on Flamsteed House was started. This signal could be seen by the ships in the port of London and allowed the navigators to check their chronometers. The determination and distribution of time was a major function of the Observatory until the move to Cambridge in 1990.

The Astronomical Society of London became ‘Royal’ in 1830 and soon afterwards William IV reconstituted the Board of Visitors so that it would include the President and five Fellows of the RAS as well as the President and five Fellows of the Royal Society and the Savilian and Plumian Professors of Astronomy at Oxford and Cambridge. The Board met at least once a year in June, when it received the annual report of the AR.

The next Astronomer Royal, George Airy (1835-1881), is now generally considered to have been the greatest Astronomer Royal and his influence was still clearly visible in the activities of the Observatory at the time of the move to Herstmonceux. He greatly increased the scope of its activities while also effectively acting as the chief scientific advisor to the Government on a wide range of topics. He paid meticulous attention to detail in the technical design of new instruments, in the observing and computing procedures used by the staff and in the keeping of records of all the activities. Airy considered that the main task of the Observatory was to make accurate astrometric observations for application to navigation and the related activities of land surveying (or geodesy) and timekeeping. The rotation of the Earth with respect to the stars provided the standard timescale against which mechanical clocks could be regulated. He saw the need for the widespread distribution of accurate time and he exploited the railway telegraph and later the international telegraph cables for this purpose. The culmination of his efforts came in 1884 when the meridian through the Airy transit-circle at Greenwich was adopted internationally as the zero of measurement for longitude; correspondingly, Greenwich Mean Time (GMT) provided the basis of the system of standard time-zones that is still used throughout the world.

Airy also saw the value of regular observations of magnetic, solar and meteorological phenomena and started long series of measurements that have since been of great importance. He also ‘weighed the Earth’ by measuring the variations with depth in a coal mine of the period of a pendulum. It is less widely recognised that Airy also initiated programmes of astrophysical observations on the spectra of stars and comets and on stellar photography.

Airy’s successor William Christie (1881-1910) devoted his main effort to equipping the Observatory with new telescopes and equipment for astrophysical observations. By the end of the century the Observatory had a 28-inch refractor for visual work, a 26-inch refractor for photographic work and the Thompson 30-inch reflecting telescope. These telescopes were used for the study of comets, satellites and planets as well as of stars. The Observatory also obtained a 13-inch refractor for use in a long-term international project to make a photographic atlas of the whole sky and from it a catalogue of positions. Christie also led several expeditions to observe total eclipses of the Sun.

Frank Dyson (1910-1933) had to cope with the disruption caused by World War 1 (1914-1918), but nevertheless he organised successful expeditions in 1919 to test Einstein’s prediction of the bending of light by the Sun. The Cookson Floating Zenith Telescope was used from 1911 to monitor the variation of latitude due to movement of the Earth’s axis of rotation within the Earth. In 1924, the BBC ‘six-pips’ time-signal was first introduced and the magnetic observatory was moved to Abinger in Surrey to get away from the interference caused by the electric trains at Greenwich.

Spectrohelioscopic observations of the atmosphere of the Sun were introduced to supplement the daily photographic observations of sunspot activity. Work started on

building the Yapp 36-inch reflector and a reversible transit circle (to replace the Airy transit-circle). The Observatory continued to undertake a wide programme of long-term observations, but it changed its programme as new techniques became available or as new requirements arose.

Harold Spencer Jones (1933-1955) was Chief Assistant at Greenwich from 1913 to 1923 and then served as H M Astronomer at the Cape of Good Hope until his return to Greenwich as Astronomer Royal. He soon started discussions about the need to move the Observatory to a better site and these eventually led to the move to Herstmonceux Castle. The work of the Observatory, as well as the discussions about the new site, were badly interrupted by World War 2 (1939-1945). Most, but not all, of the astronomical observations at Greenwich ceased, and the Time and Chronometer Departments were evacuated to Abinger and Bristol (and later to Bradford-on-Avon, Wiltshire), respectively. A reserve time station was set up at the Royal Observatory at Edinburgh.

Spencer Jones' interests were primarily in astrometry and time-measurement, and in 1939 he wrote a paper that fully established that the Earth's rate of rotation is not uniform and that eventually led to the introduction of new time-scales to replace Greenwich mean solar time for some purposes. He recruited Humphry M Smith to head the Time Department and introduce new techniques, such as quartz-crystal clocks. He also expanded the work of the Chronometer Department, which became very important during the war. He was also interested in geophysics and so it is not surprising that the Observatory's activities in astrophysics were not pursued with vigour. In any case, the atmospheric conditions at Greenwich were so bad that many types of observation were impossible. He did, however, join with H H Plaskett in pressing for the construction of the Isaac Newton Telescope, and this was to have a profound effect on the future of the Observatory, even though it was not intended to be a part of it.

In 1936, L J Comrie, who was then Superintendent of HM Nautical Almanac Office (NAO), was suspended from duty and his young deputy, Donald H Sadler, took over his position. The Admiralty decided that Sadler should report to Spencer Jones and not directly to the Admiralty as Comrie had done. The NAO became a part of the Royal Observatory, although it continued to be based in the Royal Naval College and then in Devonport House. At the outbreak of the war the NAO moved to Bath and it stayed there until it became, in 1949, one of the first departments to move to the new site at Herstmonceux Castle.

A concise historical review of the RGO by W H McCrea was issued on the occasion of its tercentenary in 1975. The origins of the Royal Observatory have been discussed by Frances Willmoth (1994), who is the daughter of a former member of the staff of the Observatory; she gives much of the credit for the foundation of the ROG to Sir Jonas More. Many references are given in appendix G.

1.2 The decision to move to Herstmonceux Castle

The decision to move the Observatory from Greenwich to Herstmonceux Castle was announced in April 1946 and very little astronomical work was done at

Greenwich from then on. During 1948 the Lords Commissioners of the Admiralty announced:

"Consequent upon the removal, now in progress, of the Royal Observatory from Greenwich to Herstmonceux, the title by which the Observatory should be known was considered. Because of the long association of the Royal Observatory with Greenwich since the year 1675, the adoption by international agreement of the Greenwich meridian as the zero of longitude, and the world-wide use of a system of time-zones based on that meridian, it was desired to retain the connexion with Greenwich in the new title. The King's pleasure has been taken as to a suitable new title and His Majesty's approval of the designation

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has been duly signified."

The buildings at Greenwich were taken over and restored by the National Maritime Museum and were opened to the public under the name of the 'Old Royal Observatory'.

The case for moving from Greenwich was summarised by Sir Harold Spencer Jones in the final section, "What of the future?", of his 1943/46 history of *The Royal Observatory Greenwich*; he wrote:

"When the Royal Observatory was founded, Greenwich was a pleasant village in open country several miles from London. The site for the Observatory, chosen by Wren, was an excellent one at that time. But London has grown so large that it has extended out to Greenwich and far beyond it. At the close of the Great War of 1914-18 there were still green fields and country lanes within easy walk of Greenwich to the south and south-east. But the urbanisation of the surrounding country has since proceeded so rapidly that these have long vanished. Along the river and in its vicinity are docks, power-houses, factories and works of every type. A power-house, like a Colossus, bestrides the Greenwich meridian immediately to the north of the Observatory. Densely crowded dwelling-houses add their quota of smoke to that from the works and factories. At Chingford in the Epping Forest, Pond in the year 1824 erected an azimuth mark, to control the azimuth of his transit instrument. The mark is still there, an object of curiosity to passers-by, but it has long since ceased to be visible from Greenwich, even on the clearest of days. The conditions for astronomical observations at Greenwich have for many years been far from good; within the last two decades there has been a rapid deterioration. A new trouble has arisen in recent years from the increasing use of powerful mercury-vapour lamps for street lighting, making the sky so bright that long exposures on fast photographic plates have become impossible. Many types of observation cannot be undertaken; others can be carried out only with great difficulty; all are seriously affected by the bad conditions resulting from a smoky and polluted atmosphere and from the great amount of scattered light."

Calls for a move from Greenwich had been made since the turn of the century, but it was the AR's report to a special meeting of the Board of Visitors in November 1938 that eventually led to the conclusion that the Observatory should be moved from Greenwich to a new site and that the magnetic observatory at Abinger should also be moved as it was suffering from disturbance by electric trains on the Guildford line.

At the end of 1938, Spencer Jones was considering a site adjacent to the Norman Lockyer Observatory (NLO), on Salcombe Hill near Sidmouth in Devon; Jones

was a member of the Research Committee of the NLO. The director of the NLO, Donald Edwards pointed out, however, that in the NLO statistics a ‘fine night’ was merely one during which “a photograph of some sort has been obtained” and that “the number of continuously clear nights was very small – perhaps 10 a year”. There was also concern that the proposed electrification of the railway to Sidmouth would have made the site unsuitable for geomagnetic observations. In the following year the Meteorological Office advised that the site should be near the South Coast between Swanage and Dungeness. Spencer Jones was then considering the Chichester area and Shopwyke House on the Goodwood Estate in particular.

During the war, the Observatory staff were scattered, many of the instruments were dismantled for safe storage, and some of the buildings at Greenwich were damaged, and so the conditions were appropriate for a move. The matter was taken up again before the end of the war and in February 1944 the Admiralty approved in principle the move of the Royal Observatory to a new site and the move of the magnetic observatory from Abinger. At this time a list of 61 sites had been identified from Ordnance Survey maps, a further 10 sites had been suggested by the estate agents Knight, Frank and Rutley, and the National Trust had drawn attention to Herstmonceux Castle with the comment that “Sir Paul Latham states that he is not a willing seller, but the idea of the Castle becoming the future home of the Royal Observatory appeals to him”. By 21 March 1944 a short list of 5 had been selected:

1. Herstmonceux Castle in Sussex.
2. Hackwood Park, near Basingstoke.
3. Amport House, near Andover.
4. Kingston Maurwood, near Dorchester.
5. Hinton Ampner, near Winchester.

The following year a committee of the Board of Visitors spent three days (15-17 April 1945) visiting each of these 5 sites in turn. On 28 May the committee reported in favour of Herstmonceux Castle (HC), with Amport House as second choice. Hackwood House was felt to be too close to Basingstoke and the last two were unsuitable for other reasons.

The Castle site was the best for absence of cloud at night, but, surprisingly, the worst for industrial haze; it was also best for sunshine, with an average of 4.9 hours per day; and it had the smallest number of foggy days, with an average of 12 days per year. It was the only one that would be available in the near future and it had some temporary buildings that would be useful while new buildings were being constructed.

The Board of Visitors met on 2 June 1945 (in Dorking) and agreed that Herstmonceux Castle would be preferable to Amport House, but the latter would be acceptable. It was then necessary to prepare more detailed plans and estimates of the cost of the move for submission to the Board of Admiralty for approval. The following extract from the letter of 20 July 1945 from Spencer Jones to the Civil Engineer-in-Chief at the Naval Dockyard at Chatham is of interest:

“Though I should have preferred a separate house, I am willing for the plans to go forward with the residence in the main building, in order to save expense.”

It is hard to imagine a house that would have matched the facilities and splendour of the AR's residence in the Castle, and it would be interesting to know whether there was any saving in expense!

On 27 September 1945 Spencer Jones wrote to the Hydrographer to say that Sir Paul Latham was anxious for a decision as the rates (£3000) were due on 1 October. He also pointed out that the War Office, which then had the use of Herstmonceux Place, a large house about half-a mile north of the Castle, wanted to rent the Castle for a period. Although the latter statement appeared to have led to a favourable decision, the details of the agreement with Sir Paul Latham were still in doubt six months later as Sir Paul had asked that the shooting rights be let to him. In April 1946 the Admiralty announced its intention to buy Herstmonceux Castle, but the purchase (for £76 000) was not concluded until October 1946 as it was necessary to establish the precise boundary of the estate.

1.3 The Herstmonceux Castle Estate

The Herstmonceux Castle Estate lies about 4 miles north of Pevensey on the northern edge of the Pevensey Marsh (or Levels). There is evidence of Roman occupation of the area and the manor of Herste (a name that suggests a clearing in the wood) is mentioned in the Domesday Book. The current name Herstmonceux results from the fusion with the family name 'de Monceux'. (The alternative, but erroneous, spelling 'Hurstmonceaux' appears to have been given in a standard atlas and was often used on letters to the RGO even when the writer/typist was replying to an RGO letter with the correct address on the letterhead!) The manor eventually came into the possession of Sir Roger Fiennes, who was then the Treasurer of the Household of Henry VI. In 1441 he applied for a licence to "enclose, krenellate, entower and embattle his manor of Hurst Monceux in the County of Sussex".

The Castle was built of brick, then a new material, in the style of a medieval fortress, but its position in a valley and details of its construction suggest that it was intended to be used only as an elegant country house. The interior of the Castle was demolished in 1776/77 and the bricks were used to rebuild Herstmonceux Place, which lies half-a-mile to the north. Fortunately, the massive south gatetower and the outer walls were left standing and they formed the basis of the present Castle. The south wing and parts of the west and east sides were rebuilt (by Lt Colonel Claude Lowther) between 1911 and 1929 and the rest of the square was rebuilt (by Sir Paul Latham) between 1932 and 1935.

The main difference between the present building and the original Castle is that the inner part of the square has been left as an open courtyard. There are many differences in the layout of the accommodation, but the style of the original was retained. Bricks were made specially, and the interior was fitted with wooden staircases, panelling and other early items from other old houses. Part of the moat was flooded again after being widened on the south and east sides of the Castle; the north-west and north sides of the moat are dry. Access to the Castle is normally by the West Entrance, but it also possible to walk across the South Bridge from the South Courtyard to the imposing South Entrance. A small bridge over the dry moat gives access to the formal walled garden on the north side of the Castle.

The principal rooms in the Castle are the Great Hall in the west wing, the Staircase Hall in the east end of the south wing, the Long Gallery on the first floor of

the north wing, the Chapel in the east wing and the Lady's Bower Room, with an oriel overlooking the moat, on the first floor of the east wing. There is also the small panelled Drummers Hall in the South Tower, overlooking the South Bridge. There are many small attic rooms, most of which were probably used as bedrooms for servants and guests. There are two brick-built cottages near the West Entrance and another at the West Gate opposite the Church. There was also a wooden cottage by the East Gate.

During World War 2 the Castle was occupied by the staff of the Hearts of Oak Friendly Society, which was evacuated from London. Large wooden huts were erected to the south of the South Courtyard and an air-raid shelter was constructed by the south-west corner of the moat. Two huts of lower elevation were built of breeze-block on either side of the South Courtyard. In addition a hut was built in the south-west courtyard of the Castle as an annex to the dining room.

The Castle stood in an estate of some 375 acres, with a perimeter of about seven miles. There was some parkland and woodland, but much of the estate was rented out for farming.

Herstmonceux Church stands on the hill to the west of the Castle, but the original settlement has disappeared. The name of Herstmonceux is now applied to the village that was known, until comparatively recently, as Gardner Street; it lies on the main road from Hailsham to Bexhill, about 2 miles to the north of the Church and Castle. The village of Boreham Street lies on the main road just over 2 miles to the east of Herstmonceux. A minor road runs south from near Boreham Street, past the east drive of the Castle, and across the Pevensey Levels to the main coastal road just to the east of Pevensey. The railway line between Eastbourne and Hastings passes just to the south of Pevensey village and the local trains stop at Pevensey Bay Halt on the road between Pevensey and Pevensey Bay. The ruins of Pevensey Castle lie between Pevensey and the village of Westham, where most London trains stop at Pevensey and Westham station. These ruins, the spire of Pevensey Church and the tower of Westham Church, which has Saxon origins, are easily seen on the skyline from the South Tower of the Castle

1.4 The preparations for the move to Herstmonceux Castle

The Castle and the temporary buildings provided a variety of accommodation that could be used for offices, workshops and hostel accommodation, but nevertheless a considerable amount of work was required to adapt and redecorate the rooms. The main obstacle to moving the staff to Herstmonceux was, however, the lack of suitable housing in the area for the many married staff who were not able to buy their own homes. It appears that Spencer Jones expected that married staff would be prepared to accept temporary accommodation in the huts, but this idea was soon rejected. The Hailsham Rural District Council was keen to help, but the building of new council houses took much longer than was anticipated. Some of the more senior staff, for example W A Scott of the NAO, bought and moved to houses in the area on the basis of the initial timetable. They then found that they had to live in lodgings in Bath during the week and to make long journeys to Sussex to be with their families at the weekends. On the other hand, after the move some married staff had to live in the hostel until suitable houses were provided for their families.

The modifications to the Castle and the other buildings were carried out by Works Department staff from the Naval dockyard at Chatham. It was first of all

necessary to finalise the AR's proposals for the use of the accommodation. In his letter of 20 July 1945 to the Civil Engineer-in-Chief at Chatham he had also written:

"I have not gone into the details of the arrangements on the second floor. There is ample accommodation for the Nautical Almanac Office with some removal of partitions to make a large room out of two smaller ones."

The accommodation referred to consisted of a series of tiny attic rooms, accessible only by a narrow steep stone staircase. It was immediately rejected by representatives of the NAO staff when they visited the Castle after the decision to move had been taken. Eventually it was agreed that NAO should use the huts on either side of the South Courtyard. Consequently, the attic accommodation in the North Wing was available for the Ladies' Hostel. A separate hut on the south side of the large wooden huts was used as the Men's Hostel.

A group of staff at Abinger expressed their disappointment that the library would not be in the Long Gallery (which they claimed would give more space for books and tables) and that the Great Hall would not be available for the meetings of the Board of Visitors, for luncheons and for hockey dinners! Their objection was over-ruled and the Long Gallery was divided by wooden partitions to make smaller rooms for the use of the staff of the Astrometry and Astrophysics Department. The floor of the Great Hall had to be strengthened to take the weight of the books and a balcony had to be constructed to provide sufficient shelf-space for the large number of journals that were held in the library.

Work started on the alterations to the Castle in 1947. The Works Department had the use of the large wooden huts, two of which were allocated for recreational use by the staff at lunch-time and in the evening. The cottages were allocated to the Head Messenger, the Head Gardener, the Leading Man of Works and the Chief Electrician. Work started on the construction of the new Solar Building and on the access road early in 1948. The building was designed by the staff of the Chief Engineer's Department in the Admiralty (?), and was built by staff from the Chatham Dockyard.

1.5 The background of the author

Before joining the RGO I had lived in Croydon. In 1939 I won a scholarship to the Whitgift Middle School and went on to obtain good results in the Higher Schools Certificate examinations in physics and in pure and applied mathematics. I also won a Royal Scholarship to study physics at the Royal College of Science, one of the colleges of the Imperial College of Science and Technology (IC), in South Kensington. As I was too young for National Service at the time, I was able to take my place in 1946 although most of the students were ex-servicemen. I completed the physics examination in 1948 and then studied mathematics during my third qualifying year. As a consequence of these unusual conditions, I was awarded in 1949 separate honours degrees in physics (2nd class) and mathematics (1st class) and I qualified for a two-year grant to study for a PhD degree.

My PhD supervisor was Professor A.T. Price of the Mathematics Department of Imperial College. He suggested that I should make a numerical analysis of data on the daily variations of the Earth's magnetic field using the automatic computer then being built in the College. When it became clear that the computer would not be

available in time I carried out a large amount of computation using desk calculating machines to demonstrate the validity of the technique that I had devised. Although my thesis was not quite finished I looked for a job that would allow me to continue in a scientific career.

As a young teenager I had taken a general interest in astronomy, but I did not consider looking for an astronomical post. In fact, I had accepted the offer of a post in the laboratories of the Electrical Research Association near Dorking (where I would have been designing electrical power lines) when Professor Price drew my attention to an advertisement for a post at the Royal Greenwich Observatory. The post was actually in HM Nautical Almanac Office (NAO), but Price considered that there would soon be an opportunity for me to transfer to the Magnetic Department and to continue my research in geomagnetism.

My background interest in astronomy and my new interest in computing led me to apply for the post. I have a vague recollection of being interviewed by a large board in the Admiralty. I also recall that I was asked a question about the ‘precession of the equinoxes’ and that my answer must have shown that I did not understand its significance. Nevertheless, I was offered the post and invited to visit the NAO at Herstmonceux Castle. My only recollection of that day is of walking around the grounds with the Superintendent of the Office, Mr D H Sadler. After lunch on a fine day I accepted the offer and have never regretted doing so!

2 THE FIRST PHASE OF THE MOVE

SIR HAROLD SPENCER JONES - 1948 TO 1955

2.1 Introduction

2.1.1 The initial moves to Herstmonceux

The first batch of moves of staff and activities to Herstmonceux took place in the second half of 1948. The Astronomer Royal and the Secretariat moved from Greenwich in August and the Chronometer Department moved in September.

The AR's private residence was provided in the north-east corner of the Castle, with the kitchen and dining room on the ground floor, a large panelled lounge and bedroom on the first floor and guest bedrooms in the attic. The administrative offices, including a very large office for the AR, were on the ground-floor in the south-east corner. The Chronometer Department was allocated space for offices and rating rooms in the north-west corner of the Castle, while the Chronometer Workshop was set up in one of the wooden huts, which had been fitted with extra north-facing windows. (Further details are given in section 2.4.)

During the following year 1949, the Solar Building was completed in April, and the telescopes and other equipment were then installed. The staff of the Solar Department and some of the staff of the Magnetic and Meteorology Department (M&M) moved from Greenwich. The Lady's Bower Room provided an open-plan office for the Solar Department and the M&M Department. Rumour has it that a fine painted ceiling was covered up during the conversion of this room.

The long-delayed move from Bath of the staff of H.M. Nautical Almanac Office (NAO) into the huts by the South Courtyard took place early in October 1949. There had, however, been no progress on the construction of the Meridian Group for the new Photographic Zenith Tube (PZT), the Reversible Transit Circle (RTC) and other astrometric instruments. Nor had work started on the buildings for the equatorial telescopes, and yet the target date for the completion of the move was still the end of 1953.

The delay was partly due to financial problems due to the poor economic situation in the country, but was also due to criticisms of the appearance of the new Solar Building. (See section 2.3.1). At the beginning of 1950 it was announced that Mr. B. O'Rourke, ARA, FRIBA, had been appointed by the Admiralty as the consulting architect for the Herstmonceux scheme as a whole. (See section 2.7.1) The completion of the move was to take seven more years!

2.1.2 Staff matters

2.1.2.1 Housing, the hostel and the canteen

Council houses on the Fairfield estate in Herstmonceux were ready in time for the move of the Chronometer Department, but the NAO staff had to move before the houses on the Denefield estate were ready. The single staff and the married staff who were waiting for houses lived in the hostel - the ladies were in the north attic of the Castle, while the men were in a hut to the south of the South Courtyard. The first Hostel Warden, who also looked after the canteen, was Mrs E Ramsey; she had rooms near to the kitchen, which was in the south-west corner of the Castle. The dining room was in the south side of the Castle between the tower and the kitchen. It was used by those in the hostel and also by the non-industrial staff at lunch-time. A hut in the courtyard of the Castle was used as a canteen for the industrial staff; it was linked to the dining room by a serving hatch. This was replaced by a window when the hut was demolished and a new serving hatch was made between the kitchen and the dining-room. Sylvia Chapman was the assistant warden.

By the time that I joined the RGO, Mrs Emily M. Patricia Marples, a war widow with a young son, Michael, had replaced Mrs Ramsey. Sylvia had left and was not replaced. Mrs Marples moved to a flat on the first floor; she used the room in the turret by the kitchen as her office. She was assisted by other ladies who lived in the village; one of them was Margaret Brett, who remained on the staff until 1990.

The Council houses on the Denefield estate became available gradually from the end of 1949. For example: George Harding moved into a flat in December 1949, Joan Perry moved in March 1950, and Albert Carter moved in soon after that; Gordon Taylor got a house on the Fairfield estate for his mother. The AR had concerns about housing; he wanted some houses on the estate, but the Admiralty decided against.

The men’s hostel was in a hut, built of breeze-block or similar material, with communal toilet facilities. Each room was plainly furnished with an iron-frame single-bed, a chest of drawers and a coat cupboard. Most rooms had a view to the south to the Pevensey Levels. The ladies had tiny single rooms in the north attic of the Castle. We all had our meals in the dining room of the Castle; breakfast was served on weekdays from 8 o’clock and on Sunday from 9; supper was at 5.30. Lunch was also provided on Saturday and Sunday, but otherwise we made use of the ordinary canteen facilities for lunch. The cost for one week in the hostel was £2 5s.

A high proportion of the non-industrial staff made use of the canteen for weekday lunches, which were served at 1 pm and which cost 1/6d each for two courses and a cup of tea. Meals had to be ordered in advance from a menu that was posted on the preceding day; there was usually a choice of three main courses. The meals were put out on the plates in advance, and kept in an oven, so that they could be served as quickly as Mrs Marples could take the money. There was always a good choice of second courses, with a variety of individual suet or sponge puddings being available. Some of us even had second helpings! The industrial staff were served at 12.30, although I believe that most brought packed lunches.

My recollection is that our beds were made and the rooms were cleaned by the hostel staff. I also recall a heated drying room and another room with an ironing board that we could use for our personal laundry, but I do not remember any special facilities

for the actual washing; I assume that we must have used the sinks in the communal bathroom.

With one or two exceptions, the men and women living in the hostel were mainly new recruits in their late teens or early twenties. Some civil engineers and other persons who came to work at the Castle in connection with the construction work also stayed in the hostel for a while. For example, I recall an elderly surveyor, Mr James, and the engineer in charge of the building work would sometimes also stay with us.

The men living in the hostel in October 1951 included: Mike Candy and Johnny Green (NAO), Arthur Milsom, Mike Nunn and Norman Rhodes (Solar), David Smith (Chron. Office), Keith Jarrett and John Lipscombe (Chron. Workshop), and Jack Pike (the forester). There may have been one or two others. Patrick Wayman (Solar), another S.O. like myself who had been working for his Ph.D., came about a month after me. Others who came later included Eric Mitchell (Chron. Workshop).

The women included: Audrey Crisford, Mavis Gibson, Angela James and Flip (=Iris) Restorick (NAO), and Scrap Ryall (Chron. Office). Others who came later included Virginia Papworth. Some of them married men whom they had met in the hostel. (See appendix C.12)

Each new recruit coming to the hostel from outside the area who needed to go to a dentist would be recommended to go to Mr Quinton, who had his practice in Bexhill, and so he gradually took on more and more RGO staff. I continued to go to him after I had left the hostel and was living in Westham, which was actually much nearer to Eastbourne than to Bexhill. At first, I would take the train to Bexhill and then take a no 15 bus to Herstmonceux; my recollection is that we could arrange for an Observatory vehicle to meet us on such occasions.

2.1.2.2 Transport arrangements

Public transport to the Castle was provided only at infrequent and usually inconvenient times by a single-decker bus from Hailsham. Only a very few of the staff owned cars and so the RGO provided home-to-duty transport between the Castle and Herstmonceux village, Boreham Street and Pevensey Bay Halt. The first two runs connected with the number 15 Southdown bus, which ran at half-hourly intervals between Eastbourne and Hastings, on an inland route via Hailsham, Herstmonceux and Bexhill. The third run connected with the half-hourly train service on the coastal route between Brighton and Hastings, via Eastbourne and Bexhill. The vehicles used were provided by the Royal Navy and included a lorry with a tarpaulin cover and wooden benches. A charge was made for each journey: 3d to the village and 6d to Pevensey Bay Halt. Tickets had to be bought in advance.

The journey across the Pevensey Levels was described in 1949 by Dr J G Porter, then on the NAO staff, in the introduction to one of his radio talks on astronomy ("The Night Sky in December") as follows:

"They take us to work in a lorry — five miles across the Marsh from Pevensey to the Observatory. It isn't a comfortable ride, it isn't even warm, but — well, if you know that part of Sussex, you'll know that it's about the only way to reach Herstmonceux Castle quickly. I'm sure you'd like to see us! — and by the way, what <u>is</u> the collective noun for a number of astronomers? There's a gaggle of geese, a herd of deer, a brood of chickens, — would it be a huddle of astronomers? Well, never mind, the ride is worth while, for all its discomfort. The Marsh has a beauty all its own, and

there is life there and movement, the air is clear and sparkling, and the morning mists go as soon as the sun rises. The blue sky is really blue, and the night sky has to be seen to be believed. That's why the Observatory has been moved down to this part of England, of course. So far only the Solar Observatory is working there, but already the results show that the move was justified."

"Down there, away from the street lamps, the nights are really dark, and the stars wonderful. The winter stars are always interesting, and at present there are four bright planets to be seen as well. But let me say something about the stars before I come to the planets; the stars of a winter's night. High in the east as soon as it is really dark, the eye catches the first glimpse of the Pleiades, that lovely little cluster of stars that is always difficult to count. Quite tiny — you can cover them with the finger of an outstretched hand — but very obvious all the same, once they have caught your attention. What a charming idea of the old astronomers to call these little stars after the daughters of Atlas, translated to the sky in answer to their prayer to be rescued from the giant Orion!"

The AR had a large green Daimler car and the services of two full-time drivers, Johnny Manser and Jim Clarke. The car was also used to take other members of staff to, for example, Polegate station when they needed to go to London on duty. For rail journeys, it was necessary to obtain in advance a rail-warrant, which would be exchanged for a ticket at the station.

2.1.2.3 Grading of staff

The Civil Service had a complex hierarchical grading structure with major differences in conditions between the white-collar non-industrial staff and the industrial staff. The main divisions in the non-industrial staff of the Observatory were for administrative classes, scientific classes and, later, the professional and technical classes.

In the AR's report for 1952 the astronomical staff were divided into three classes — the scientific officer class, the experimental officer class, and the assistants (scientific) — and to several grades within each of these classes. (Even then they were split between (a) Royal Observatory and (b) Nautical Almanac Office.) The grade of the AR is not given but he was a Chief Scientific Officer, while R. d'E. Atkinson (his Chief Assistant), and D. H. Sadler (Superintendent NAO) were Senior Principal Scientific Officers. The heads of the departments were Principal Scientific Officers, while their sections were usually headed by Senior Experimental Officers.

The staff in the secretariat (not yet called the General Office) were headed by H. G. Barker, a Higher Executive Officer, while his deputy, J. H. Whale, was a Higher Clerical Officer. There were several grades for the typists. There was a long list of the grades of the industrial staff, but no names were given.

2.1.2.4 Hours and leave

The Observatory hours were nominally from 9 am to 5 pm from Monday to Saturday, but (in common with rest of the Civil Service) we had the privilege of being allowed to leave at 1 pm on Saturdays. The times of arrival and departure of those using

the official home-to-duty transport were adjusted to suit the times of the buses and trains. As a legacy from the war, our pay included an extra-duty allowance and so we were expected to sign in and out each day and to make up any time that we lost through lateness or early departures. The total of 44 hours actually included 5 hours for the lunch breaks, which were also a 'privilege'.

Our annual leave allowances were reckoned in weeks of six days, but we could take short periods in units of half-a-day, except that an absence on a Saturday morning cost a whole day's leave; staff were therefore reluctant to take leave on Saturdays. Leave allowances depended to a large extent on 'class', rather than on length of service. For example, scientific officers had a generous allowance of 6 weeks, but the scientific assistants were not so favourably treated. Applications for leave had to be approved in advance.

Further information about conditions of service and the changes in later years are given in appendix C.

2.1.2.5 The staff club

During the early years of the RGO at Herstmonceux the 'Royal Observatory Social and Sports Club' played an important role in giving members of the staff in different departments, classes and grades opportunities to get to know each other through meetings in a social environment. This applied especially to the staff who lived in the hostel, but the club facilities were very popular at lunch-times and the occasional special events in the evenings. The sports teams also involved a wide cross-section of the staff and so a good community spirit was built up.

The Club had the use of a large two-roomed hut by the South Courtyard. This provided a lounge and facilities for billiards and snooker, darts and table tennis. It was also used for social events and for a pantomime for the children of the staff. The Club also had the use of a sports field on the side of the east hill and of a tennis court at the end of the formal gardens of the Castle. Very few of the staff owned cars at this time and so official vehicles were made available for use by sports teams for away matches and other occasions, as well as for home-to duty travel.

The Club produced small duplicated magazine with the title *The Castle Review*. This contained reports on many current Club activities, such as sports, pantomimes and parties, outings and some General Meetings. In addition, the early issues contained interesting articles relating to the history of the Observatory and about the past and current experiences of members in, for example, foreign travels. There were also humorous articles and some poems.

A fuller account of the Club's activities is given in appendix D.

2.1.3 My early days at Herstmonceux Castle (1951-1955)

In this section I hope to convey an impression of the first few years after I had left college and started work at the Observatory. For the first two years I was a single man and lived in the hostel at the Castle so that my work and most of my leisure activities shared the same environment and involved to a large extent the same people. Correspondingly my links with my family and friends in Croydon were largely limited

to short weekends. I married Betty Deane from Croydon in 1953 and we lived at Pevensey Bay and then in Westham (to the west of Pevensey Castle), about six miles away from the Observatory. At that time we did not have a car, so that I would use the home-to-duty transport from Pevensey or cycle.

I took up my appointment in H.M. Nautical Almanac Office (NAO) on Monday, 4 October 1951. I travelled by train from East Croydon to Lewes, where I changed to the local train to Polegate; from there I was taken by the RGO car to the Castle. After the initial formalities were completed — I had to sign an Official Secrets Act form — I went to the NAO, where I had been allocated a table in a room with Johnny Green , who was a young, bright Assistant Experimental Officer. If I looked out of the window, I could see only the wall of the wooden hut on the opposite side of the road.

Formally, I was responsible to Dr J Guy Porter, who was in charge of Astronomical Division II, but in practice most of my work was given to me by Mr Donald H Sadler, the Superintendent of the Office. The title ‘Superintendent of the Nautical Almanac’ was first used in 1818 when Thomas Young took over the responsibility for the production of the Almanac from John Pond, the Astronomer Royal. Further details of the structure and work of the NAO are given in section 2.2.

First of all, I had to go through the basic training in numerical calculation that was then given to all new recruits to the Office by Albert Carter. He, quite rightly, made me do the same initial elementary exercises as the assistants who came straight from school! I was also taught to use a manually-operated Brunsviga calculating machine. I was soon to find that these were more flexible for general use than the electromechanical calculators that I had used at College.

I do not recall the nature of my first real task, but it was not long before I was given the first of many sets of proofs to read. Most of the pages contained columns of numbers, but others contained the text for the explanatory parts of the almanacs. Proofreading took about two hours of my time on nearly every working day for almost the next twenty years!

For most of the time I would be working on my own task and there was little interaction with other members of the staff, except when I needed information or advice. Interruptions were provided by the welcome visits of the assistants, who took it in turns to make and bring around morning coffee and afternoon tea. I soon realized that Johnny and Evelyn Grove were ‘going out’ together, as when it was her turn our cups were the last to be served so that she could linger a while for a chat. Miss Joan E Perry, the secretary of the Office, also came round from time to time, and she would also stop and chat to us. Mr Wenban, the Office ‘messenger’ used to bring around the ‘transits’ [see later], but he only spoke if we spoke to him.

For almost two years I lived in the hostel and so I wasted no time in travel to the Office or in the preparation of meals as breakfast, lunch and supper were provided. While I was living in the hostel, I cultivated some of the ground alongside the hut. I recall that Jack Pike, the forester who also had a room in the hostel, gave me some strawberry plants. Arthur Milsom was also quite keen, but his principal crop was tobacco! Jackdaws used to nest in the Spanish chestnut trees by the Castle and I have memories of Jack bringing to his room to feed some chicks that had fallen from their nests. He and his assistants are said to have planted over a quarter of a million trees on the estate.

We had an hour's break at lunchtime; some of the staff brought sandwiches but the rest of us had lunch in the Castle. There was then time for a walk around the gardens and grounds or for a game of table-tennis or even for half-an-hour's tennis.

I can recall no details now, but Patrick Wayman and I were invited to have lunch one day with Sir Harold and Lady Spencer Jones in their residence. It was probably early in 1952.

At first I spent my evenings in my office completing my thesis, but when that was finished I was soon involved in other activities. In the winter, I used to play in the Club's second table-tennis team; this involved some travelling to away matches, in Eastbourne for example. During the weekends when I stayed at the Castle, I was able to enjoy walking in the Castle grounds or cycling to explore the area. I also played in the RGO mixed hockey team. Other indoor games, the preparations for the pantomime, and occasional social events made the winters pass quickly. In the summer, I played tennis, cricket and stoolball (a game played in Sussex by mixed or ladies teams), and occasionally some of us cycled to the beach at Pevensey Bay.

My initial appointment was as a 'Temporary Scientific Officer', but soon afterwards I was 'established', so that I had a permanent post and pension rights. Some months later I had a shock: my pay as a temporary SO had taken into account my two years of postgraduate study, but my pay in an established position should have been based on my age and so should have been significantly less. Moreover my establishment had been backdated to my initial appointment and I was expected to pay back the overpayment. I was dismayed and Mr Sadler was furious, but to no avail and so my monthly take-home pay was reduced even further for the next few months.

My NAO work gradually expanded as I was given new jobs. Some of them involved visits to other establishments in England and in the summer of 1955 I attended my first meeting of the International Astronomical Union (see section 2.2.7.2). This was held in Dublin, and it gave me a foretaste of the international cooperation and travel that were to dominate my later career, even though I continued to be based at Herstmonceux Castle. The technical activities will be described in their RGO context, while the associated social and personal activities will be described elsewhere in my separate autobiographical notes, which will also contain details of the RGO Club activities in which I continued to be involved.

2.2 H.M. Nautical Almanac Office (NAO)

2.2.1 The place of the NAO in the RGO

Until 1936 the Nautical Almanac Office (NAO) had been independent of the Royal Observatory, and the Superintendent, then L. J. Comrie, reported directly to the Hydrographer. Comrie was suspended from duty when an investigating team found that some of the staff were engaged on external work for which Comrie had not obtained prior approval. His young deputy, Donald Sadler, was appointed in his place. The Admiralty decided that Sadler should report to the Astronomer Royal, Spencer Jones, who in turn reported to the Hydrographer. Nevertheless, the budget and the staff complement of the NAO continued to be fixed separately from those of the RO and the change had little effect on the day-to-day work. The NAO was evacuated to Bath during World War 2 and Sadler took on the additional responsibility of the work for the

Admiralty Computing Service. Hence, for all practical purposes, the contacts between the NAO and the RO were negligible. It appears that Spencer Jones did not keep Sadler properly informed about the progress of the negotiations for the purchase of the Castle and of the arrangements for the move.

The feeling of separation between the NAO and the rest of the RGO must have been heightened when the move finally took place, since the NAO was accommodated in the two huts on either side of the South Courtyard while all the other scientific staff had offices in the Castle. Moreover, the NAO had its own secretary, Miss Joan Perry, and filing system, although it did make use of the services of the Typing Pool and all financial matters were dealt with by the Secretariat in the Castle. The NAO also had its own library and computing facilities; all the staff had calculating machines, whereas it appeared that a lot of the calculations in other departments were done with the aid of tables. By the time that I joined, the NAO had taken delivery of a set of punched-card machines.

There were also more subtle differences between the NAO and other Departments, although I was not aware of them at first since I had no contact with their work. Sadler had the reputation of being a ‘hard taskmaster’ as he insisted on high standards of work and timekeeping. The NAO staff were expected to have their morning coffee and afternoon tea at their desks, and to continue working, whereas other departments would gather for a general chat that could be quite lengthy. On the other hand, I think it was felt that he did his best to improve the conditions and advance the promotions of the NAO staff. One major difference in the conditions of service was that the NAO staff were not expected to undertake night-observing duties; this also meant they did not have the flexibility to arrive late and to take ‘time-in-lieu’ after scheduled observing duties. (This time off could be taken even if the person concerned did not come in for the duty when the weather conditions made observing impossible since the observer was expected to look out from time to time in case the conditions changed.) I am sure that there were quite strong feelings of ‘them’ and ‘us’ at first, but these diminished as staff got to know each other better. This was certainly the case for those of us who lived in the hostel and participated in the activities of the Social and Sports Club.

2.2.2 The structure and basic activities of the NAO

At this time the NAO was divided into four main parts:

Astronomical Division I, headed by Miss F M McBain (PSO);

Astronomical Division II, headed by Dr J G Porter (PSO);

Navigation Section, headed by Mr W A Scott (SEO);

and Machine Section, headed by Mr A E Carter (EO).

Within Astronomical Division I, Miss McBain was responsible for the oversight of the printing of all the publications; in particular, she monitored the quality of the proofreading of all members of the Office. She also organised the lunar occultation programme (see section 2.2.4.3). In these tasks she was supported by Miss M R Rodgers (EO) and Mr W G Grimwood (EO). Mr H W P Richards (SEO) had responsibility for the publication *Apparent Places of Fundamental Stars* and Mr J H Barry (SSA) prepared *The Star Almanac for Land Surveyors*.

Astronomical Division II was primarily responsible for the computations of the ‘fundamental ephemerides’ (see section 2.2.4.1) in the first part of the *Nautical Almanac*, which, in spite of its title, was used for astronomy and not for navigation. (The full title was *The Nautical Almanac and Astronomical Ephemeris*, but it was usually referred to as the NA. An ‘ephemeris’ may be described as calculated data about an astronomical event or about the positions of an astronomical body.) Dr Porter’s principal assistant was Mr E Smith (EO), who in turn was assisted by Mike Candy, then an SA. I was not expected to contribute to the normal work of the section, apart from proofreading.

The Navigation Section was responsible for the *Abridged Nautical Almanac* (ANA), for the *Air Almanac* (AA) and for other tables used in astronavigation. The section also carried out computations for the plotting of the hyperbolic lattices on charts for the Decca Navigation System (see section 2.2.5.3). Mr Scott’s principal assistant was Mr D A Harragan (AEO), who had served in the Royal Air Force.

The Machine Section, which occupied the hut on the west side of the South Courtyard, was responsible for the operation of the Hollerith punched-card machines (see section 2.2.6.4), which were used for calculations for the other three sections. My recollection is that Mr Carter also supervised the use of the National accounting machines (see section 2.2.6.3), but these were kept in the east hut as they were operated by the junior staff of all the sections. Mr G A Harding (also an EO) was the deputy head of the Machine Section.

The junior staff were Assistant Experimental Officers (AEO), who were usually qualified at Higher School Certificate level (now A-level), and Scientific Assistants (SA), most of whom were girls from the local grammar schools, who had General School Certificates (now GCSEs). (The grade title was, strictly, ‘Assistant (Scientific)’, but the name ‘Scientific Assistant’ was normally used.)

2.2.3 General aspects of work in the NAO

2.2.3.1 Training

All new recruits to the Office had to go through a basic training course in numerical calculation. Albert Carter, who was in charge of the Machine Section (see later), was the training officer. The exercises started with the writing of the digits 0 to 9 in unambiguous forms and included writing from left to right the answers to mental additions and subtractions of two numbers. We were soon to learn that checking columns of figures by forming the differences of successive values was to become a major part of our work and so speed and accuracy in this process were vital. [More details of the procedures that we used to guard against errors in our calculations are described in section 2.2.6.2.] We were also introduced to different types of calculating machines. I believe that almost all members of the staff had their own manually operated Brunsvigas, but there were also a few electromechanical calculators (Marchant and Friden). These had, for example, automatic multiplication and division and were faster for some jobs.

We were also all given training in proofreading. The Office was then producing many hundreds of pages of numerical data that were published in a variety of almanacs and publications. Not only did we have to ensure that the calculations were

correct, but we had to endeavour to ensure that there were no errors in the published volumes. Our numbers were set in type by Monotype-keyboard operators, who, not unexpectedly, occasionally made mistakes; moreover, mistakes could be made in the correction of errors that had been found on the proofs and even in the later stages of the printing process. Each member of the staff of the Office was expected to do two hours proofreading each day. This stint was usually done at the beginning of the day so that the Office would be free from the noise of calculating machines and other distractions.

There was a great deal of cooperation between the staff of the four sections of the NAO. This was certainly true of proofreading, and every member of the staff was expected to share in this task. As a consequence, all of the senior staff were familiar with all the publications and could contribute ideas for their improvement. The tabulations in the navigational almanacs (ANA and AA) were derived from the fundamental ephemerides computed for the NA and the computational techniques were largely the same even though the output had different purposes and format. The most important common factor was that all calculations had to be thoroughly checked so that any mistakes in them would be discovered before the final results were published. From an external point of view, the navigational work of the NAO was probably of the greatest importance, but it depended on contributions from all sections of the NAO.

2.2.3.2 Formalities

As was customary at the time, both dress and forms of address in the Office were rather formal, although conditions in, say, a bank would have been even more formal. Jackets and ties were standard for the men, and the ladies and girls were all neatly dressed — slacks were not worn in the Office! Senior staff were always given their titles — Mr or Miss, as appropriate — or were referred to by their initials, which were normally used on written lists and messages. For example, Mr Sadler was otherwise known as D.H.S.. As far as I can recall, I never used ‘Walter’ or ‘Harold’ when talking to Mr Scott or Mr Richards. (I shall not normally use titles in this text and I will often use forenames for staff that I came to know well.) Similarly, the Astronomer Royal was always referred to as the A.R..

2.2.3.3 Services

Morning coffee was served at our desks by the young Scientific Assistants, who did much of the ‘routine’ work of the Office. Although their work was referred to as ‘routine’ they had to understand what they were doing and to be on guard against errors that could arise in many different ways. These SAs were all attractive girls who had reached at least School Certificate level in mathematics at school; almost all of them had been recruited locally from the High Schools in Eastbourne and Bexhill. These girls used to take turns to make and serve the morning coffee and afternoon tea. I think that they enjoyed the break and the chance to go around the Office.

Other services that I appreciated were provided by the Messenger, Mr Wenban, who had served in the Royal Navy. He came around regularly to bring and take ‘transits’, which could be incoming or outgoing letters, internal messages, packets of work or sets of proofs sent from one person to another. Some items, such as Office Notices or lists of recent acquisitions to the library, were sent on circulation to an appropriate list of staff. He also used to ensure that when we arrived in the morning our calendars had been changed to show the correct date — all our work and notes had to be dated — and that we had clean glasses and a carafe of fresh water.

2.2.3.4 Cooperation and attribution

The work of the Office depended for its success on the wholehearted cooperation of the staff; very few, if any, jobs were carried out completely by one person, or even by a small group of persons. In particular, proofreading was always spread around the Office so the proofs were read by persons who had not prepared either the basic data or the copy. This was particularly important for the explanatory pages, and comments by proofreaders could lead to changes in the presentation of the data as well as to improvements in the text. Similarly, proposals for new tabulations or new methods of computation were circulated for comment amongst all the senior members of the staff. Junior members of the staff could, and did, make suggestions for improvements, with the result that it would have been impossible to assign credit individually.

The prefaces for the almanacs and other publications of the Office were attributed to the Astronomer Royal and usually stated that the publication had "been prepared under the immediate supervision of the Superintendent of H. M. Nautical Almanac Office". A list of the staff of the NAO was given in the preface to the *Nautical Almanac*, but the other regular publications did not give the names of those concerned. Scientific papers were usually, but not always, attributed to one or two individuals. In general, however, the techniques developed in the Office and the results of investigations were described anonymously in the publications.

In later years the policy gradually changed for two reasons. Firstly, the use of computers meant that sections of the Office, or even individual members of the staff, were assigned tasks that they could complete with very little assistance from others. Secondly, promotion became dependent on interviews in a competitive environment, rather than on the consideration by non-interview boards of annual staff reports and of the recommendations by the Astronomer Royal.

2.2.4 The astronomical work of the NAO

2.2.4.1 The fundamental ephemerides

The term 'fundamental ephemerides' refers to the tables of daily values of the positions of the Sun and planets and of hourly values of the positions of the Moon that were published in the first part of the *Nautical Almanac*. These fundamental ephemerides and other data printed with them were used not only for the tabulations in the ANA and AA, but as the basis for astronomical and navigational almanacs and for other calculations, such as those for tidal predictions, in many countries of the world. This was one of the U.K. contributions to international arrangements for the sharing of work of both computing and publishing astronomical data for use in astronomy, navigation, surveying and daily life. The other major contributor was the Nautical Almanac Office of the U.S. Naval Observatory (USNO), in Washington, D.C.. France, Spain, U.S.S.R. and Germany made lesser contributions. USNO computed the data for the second half of the NA and so, in general, the numbers in the *American Ephemeris and Nautical Almanac* were the same as those in the British NA, although they were printed separately in different styles.

Sadler had played a major role in setting up these arrangements before and after World War 2, and he was to extend them even further during the next few years.

He has described these activities in detail in his *Personal History* of the NAO [denoted by SPH for time being] and so I shall not attempt to do so here.

The fundamental ephemerides were not computed a year at a time, but were computed for about 20 years at a time. The current almanacs were based on pre-war calculations and the NAO was engaged on computing the ephemerides of the Sun, Moon and (major) planets for the period 1960 to 1980. The theory of the motion of each of these bodies was represented by a thick volume of printed 'Tables' containing complex instructions on how the various tables in the volume had to be combined to give the final results. These tables were designed for manual use, but the new punched-card machines were used to carry out the enormous numbers of additions and other operations that were required.

The largest single job was, probably, that of the computation of the ephemeris of the Moon. This was based on a theory due to E. W. Brown and the tables that represented his theory were printed in a volume that measured about 35 x 25 x 10 cm. It was said that an expert who was thoroughly familiar with the process could calculate one position in about 12 hours of continuous effort — and it was necessary to calculate positions at intervals of 12 hours! L. J. Comrie had been the first to use to use punched-card machines for this computation.

My introduction to these techniques came when Mavis Gibson and I were given the task of planning and supervising the calculation on the punched-card machines of an ephemeris of values of the 'nutation in longitude and obliquity' for each day for 100 years from a new theory that had been developed by E. W. Woolard at U.S.N.O. This involved summing only about 90 terms, compared with about 1500 for the Moon; even so, it kept us busy for a lot of our time over a period of about one year. I later wrote a brief account of the 'method of cyclic packs' that we used as it differed in detail from the method described by Comrie. The account was published in the *Improved Lunar Ephemeris 1952-1959* and our values were printed later still in the first number of the new series of *Annals of the Royal Greenwich Observatory*.

I had very little to do with the computation of the fundamental ephemerides, and so I cannot be sure how the work was split between the staff concerned. My impression/recollection is that the work was planned by Porter, who was responsible for breaking the job down into many stages and for setting out the formulae to be evaluated. He needed to discuss his ideas with Carter and Harding, who had the job of carrying through each stage on the punched-card machines or on the National machines, and he was supported by Smith and Candy, who provided starting data and check values for each stage. The intermediate sets of values would be combined until the final values were obtained. These would then have to be checked to find any mistakes that had occurred in the computation of individual values and also to verify (hopefully) that the adopted procedures and formulae correctly represented the theory of each ephemeris. Each ephemeris would be evaluated from the appropriate Tables at the widest practicable interval and would then be subtabulated to the required interval; for example, from 40 days to 1 day for the outer planets and from 12 hours to 1 hour for the Moon.

These fundamental ephemerides were printed one year at a time to form what was known as the *Advanced Proofs of the First Part of the Nautical Almanac* and about 100 copies were distributed, without charge, about four years in advance of the year to which they referred, to almanac-producing agencies around the world. The ephemerides

and other information for the Second Part were produced, using our data where appropriate, by the Nautical Almanac Office at the U S Naval Observatory. The US NAO sent us proofs, which were then used to prepare copy for use by our printer — then C. Tinling & Co. at Liverpool. At this time the *Nautical Almanac* and the equivalent *American Ephemeris* differed in typographical style and, to some extent, in content; for example, the ephemerides for lunar occultations were quite different. The other major almanacs produced by the French, Spanish and Russian ephemeris offices differed even more in style and content; in particular, the French used different theories for the ephemerides of the planets.

2.2.4.2 Planetary Co-ordinates

Apart from their publication in the NA and their use for the ANA and AA, the computed coordinates of the planets were also to be published to lower precision in the volume *Planetary Co-ordinates for the Years 1960-1980*, which was the successor to the previous volumes for 1900-1940 and 1940-1960. The main use of the volume was for the computation of predictions of the orbits of comets. Porter was the editor, while Candy and I were his assistants. My main task was to design the section of formulae on the various methods that were available for orbit computation. In addition we were to assist in the computations of the orbit of a fictitious comet, which we called NAO1, that would be used to exemplify the ways in which the volume could be used.

Porter had written the book *Comets and Meteor Streams* and was then Director of the Computing Section of the British Astronomical Association, some of whose members computed the orbits of comets.

At this time (1952/3), Professor Sam Herrick, from the University of California, was spending a sabbatical year at the Observatory in order to complete a book on celestial mechanics. He was accompanied by his wife and three children, and he was later joined by his graduate assistant, C G (Jeff) Hilton. He agreed that Jeff should spend part of his time on the computation of the orbit NAO1 by a method that Herrick had developed. (Jeff was based in my room, as Green had left to study at Imperial College, and we met again later in 1961 when I went to California.) As the ‘comet’ got further and further from the Sun, so our predicted coordinates differed more and more, but we could not find any mistakes that had caused this. We were relieved and surprised that our results came back together again when the comet returned to the Sun. Although I did not realize it at the time, this effect had been known to Norman Lockyer and later to Raymond Lyttleton, who used it in the ‘sandbank’ model of comets. The idea was that a comet was a diffuse cloud of particles when it was far from the Sun, but that the particles converged and collided when the comet approached the Sun, thus giving rise to the activity that is seen.

2.2.4.3 The lunar occultation programme

The Office was responsible for the international programme for the prediction of ‘lunar occultations’, that is of the times of disappearance and reappearance of stars at the limb of the Moon as it moves in its orbit around the rotating Earth. These are the times when the ‘lunar distances’ of the stars are zero and they depend on the geographical positions of the observers. The differences between the observed and predicted times could be used to give information about the variations in the rate of rotation of the Earth and about various other factors that affect the time, such as the very

small errors in the lunar theory. I did not realize then that the observation of the rotation of the Earth would play such an important during the last decade of my career.

In order to encourage the making of observations of the times of the occultations, the predictions were distributed throughout the world. The predicted times depended on the positions of the observers and so it was necessary to calculate the times for about 80 positions, known as standard stations, around the world. The observers participating in the programme, who were mainly amateurs, could either use the times for the nearest station or make use of the data for two nearby stations to calculate better predictions. Some predictions were published in each of the principal national almanacs, while others were published in handbooks and magazines such as *Sky and Telescope*. Predictions for 10 stations in the British Commonwealth were published in the NA and in the *Handbook of the British Astronomical Association* (HBAA). During the 1920s and 1930s the BAA had played a major role in the prediction of lunar occultations, but then, largely through Comrie's initiatives, the NAO took on a major part of the work of an international programme.

The task of deciding which conjunctions of stars with the Moon (when they have the same right ascension) might lead to an occultation somewhere in the world was carried out in the US NAO, which also calculated appropriate data, known as 'occultation elements', from which predictions could be calculated. These elements were used in the NAO to set up the 'occultation machine', which simulated the star (by a small lamp), the Moon (by a lens) and the Earth (by a globe on which the standard stations were marked); it might be described as an analogue computer in which the result was shown by a dial. The 'shadow' of the Moon cast by the star was represented by a circular column of light which moved across the rotating globe as the lens was moved through the beam of light from the lamp. The outline of the disc of light on the globe marked the locus of positions from which the star would be seen at the limb of the Moon. The operator turned a handle to drive the lens, the globe and the dial, which showed the interval of time from the initial starting position at the time conjunction.

The machine showed for each listed conjunction the stations from which occultations would be visible and the times when the stations were on the edge of the disc could be read from the dial. The machine also showed the many conjunctions for which the track of the shadow would not pass over any place where an observer might be expected. The approximate times given by the machine were then used as the starting times for calculations to give the more accurate times for publication.

I believe that Miss Marion Rodgers (whose initials became MR^2) carried out much of the machine work with the assistance of other members of the Section.

In addition to making the predictions, the Office also collected, 'reduced' and then analysed the results of the observations, some of which were sent to the Office by the observers, while the rest were obtained by scanning astronomical journals and reports. The reduction process resulted in the difference in each time being expressed as a residual that corresponded to an error in the adopted value of the semi-diameter of the Moon. (Or, equivalently, as an error in the predicted lunar distance.) The residuals were then analysed annually by Miss McBain to find the corresponding average errors in the latitude and longitude of the Moon over the period of the observations used. The results were published in short papers in the *Astronomical Journal*; in effect two small numbers resulted from a very large effort in both calculation and observing. The programme was coordinated through Commission 17 of the International Astronomical Union (IAU).

(See section 2.2.7.2) Miss McBain was the secretary of the Commission for many years. It is no wonder that, at the time, Sadler questioned whether it was worthwhile [SPH, 13], but the programme justified itself in later years.

2.2.4.4 Apparent Places of Fundamental Stars

Until 1941, each of the national almanacs for astronomers and surveyors contained tables giving the apparent coordinates (or 'places'), at an interval of 10 days, of a selection of bright stars. Such coordinates vary with time of year and from year to year and were used in determining time and geographical positions from astronomical observations. In 1938 the IAU adopted Comrie's suggestion that there should be a single international volume that would contain such data for a much larger number of stars than could be published in any single almanac. The computation of the data was shared between several national ephemeris offices, while the volume itself was prepared by the NAO and published as the *Apparent Places of Fundamental Stars* (APFS). The explanation of the use of the volume was printed in French, German, Spanish and Russian as well as English. Sadler had to carry through the project and make the detailed arrangements by correspondence. Mr Richards then had the task of implementing the decisions. When I joined the Office, the arrangements were, I believe, working well, but the proofreading of the volume entailed a considerable amount of effort.

Richards, who reported to Miss McBain, was largely responsible for the tedious work of collating and checking the incoming material and then of preparing copy for the printer. I got on well with Richards; I found that he had a very large range of knowledge and appeared to be very competent. So I was rather surprised that he did not have greater responsibility; it was not until I read Sadler's *Personal History* a few years ago that I realized that he had proved to be unreliable in earlier years. Before joining the NAO in 1931 he had served in the Colonial Survey in Tanganyika and prior to that he had been employed as a research student at the Norman Lockyer Observatory in Devon from February 1927 to April 1928.

2.2.5 The navigational and geodetic work of the NAO

2.2.5.1 The navigational almanacs and tables

From the point of the view of the Admiralty, the most important product of the NAO was the *Abridged Nautical Almanac* (ANA), which was produced for use in the Royal Navy but which also sold in large numbers for civilian use throughout the world. At the time, the profits from the sales of the ANA were retained by H. M. Stationery Office (HMSO) and were used to subsidise other publications. The *Air Almanac* (AA) was produced for the Royal Air Force and was also sold for civilian use, but in a much smaller market; the costs of production in the NAO were borne by the Admiralty. In addition, the Office produced auxiliary tables and diagrams for use in astronavigation. Most of these were published by HMSO, but some were produced to meet special requirements of the services.

The main computations for the daily pages of the almanacs largely depended on the interpolation, or 'subtabulation', of the fundamental ephemerides to a shorter interval of time. Initial lines of differences had first to be computed by using desk

machines from the differences of the fundamental ephemerides. Then the required values were formed by building up from their differences by using National accounting machines (see section 2.2.6.3) or punched-card machines (see section 2.2.6.4). These machines printed out the results, but the sheets had to be cut up into strips, which were then pasted on to thin sheets of white card in order to prepare the printer's copy. Headings and other individual items of information, such as the phase of the Moon, had also to be included on the copy. The process was obviously prone to error and so the copy had to very carefully checked before it was sent to the printer.

Mr Scott, who had joined the NAO on 10 May 1926, was the Head of the Navigation Section. He was a small, quietly-spoken man, who was extremely methodical and reliable. We were expected to put away our work and leave our desks tidy at the end of each day, but Mr Scott was the only person, as far as I was aware, who always left his desk bare of papers. He not only supervised very carefully the regular work of the section, but he also contributed much to the development and implementation of new work and to the investigations that were carried out from time to time. I learnt later that he felt that Sadler had taken the credit for some of his work, but I am sure that this was not a fair comment, even though Sadler might have been given the credit for it as a consequence of the anonymous character of our work.

2.2.5.2 Unification of the Almanacs

In the autumn of 1951, shortly after my joining the NAO, Sadler went to Washington for discussions with Dr Gerald M. Clemence, who was the Director of the Nautical Almanac Office in the U. S. Naval Observatory. They both then went to Montreal for a meeting of Working Party 53 of the Air Standardization Coordinating Committee of the Air Forces of the U.K., the U.S.A., Canada, Australia and New Zealand. At this meeting Clemence and Sadler jointly proposed that the (U.K.) *Air Almanac* and the *American Air Almanac* should be unified so that the contents would be identical. The Almanacs would continue to be printed separately in the two countries and would have different styles of cover and binding, but they would have a common title. The U.S. Office would be responsible for the preparation of the daily pages, while our Office would be responsible for the preliminaries and the Explanation. This proposal was "enthusiastically approved" by WP 53. [SPH, 12]

Firm proposals for the unification of the almanacs for marine navigation took a further three years to develop; partly because there were initially greater differences between the two almanacs. In this case our Office was to be responsible for the production of the daily pages on a new card-controlled typewriter that was delivered in 1953. Several different designs for the daily pages were tried and eventually a layout with the data for 3 days in each opening was agreed; the basic idea for this layout was put forward by Clemence, but the fine details evolved as sample pages were prepared and criticised. The unification of the contents took place in the editions for 1958, but the titles were not changed until the editions for 1960. (See section 3.3.1.1)

2.2.5.3 Decca charts

The Office was still responsible for the computation of the data used in drawing the charts for the Decca Navigation System, which had been developed during the war (under the name of Gee) and which was now widely used in western Europe for position fixing for both military and civilian purposes. [SPH, 8] (In North America the corresponding system was known as Loran.) The system depended on the synchronised

transmission of radio waves from a master station and three slave stations. The receiver was able to measure the difference in the travel times of the radio waves from the master and a slave; the points at which this time difference took any particular value must lie on a curve with the shape of a hyperbola. If the time differences were measured for two slaves it was then possible to fix the position of the receiver at the intersection of the two hyperbolae. The task was to compute data from which a complete series of such hyperbolae for an appropriate interval in the time-difference could be drawn on the charts for the area around the four radio beacons. The curves for the three combinations of master and slave were drawn in different colours.

The computations were complicated by the fact that it had been found that the effective speed of the transmissions was not the same over the whole area, but differed between land and sea and to a lesser extent depended on the nature of the terrain. It was also necessary to take into account the curvature of the Earth's surface. The staff of the Office had, however, had considerable experience of this work and had developed efficient techniques for use with the National machines. The requests for such computations came at irregular intervals as new 'chains' of stations were set up or as new charts were to be drawn for existing chains. When electronic computers became available the expertise was incorporated in a computer program and the work was done directly by the company.

2.2.5.4 The Star Almanac for Land Surveyors

The Army produced its own almanac for determining position and azimuth by astronomical techniques, but the Office was responsible for the preparation of *The Star Almanac for Land Surveyors* to meet the requirements of the surveyors in Commonwealth countries. [See SPH, 10] The design for the first issue for 1951 was so good that this little booklet sold very well and was only changed in minor respects in later years. The NAO in USNO did not produce any similar almanac as another publication for this purpose was produced by another government agency.

The bulk of the work of computation and copy preparation was carried out by Mr Barry, who reported to Miss McBain. He had been a non-commissioned officer in the Royal Artillery, and was a horseman with horse-drawn guns, before joining the NAO. He did not have any formal qualifications; he was graded as a Senior Scientific Assistant. He was always very respectful of the senior members of the Office and I got on well with him; he lived in Brighton and so I would often talk to him on the journey between the Castle and Pevensey Bay Halt.

2.2.6 Computational facilities and procedures

2.2.6.1 Computers and calculating machines

When I joined the NAO, 'computers' were people and were expected to be able to carry out the basic processes of arithmetic, to carry out repetitively a complicated sequence of operations starting from given data, and to produce intermediate and final results in appropriate formats. We had a variety of desk calculating machines that we could use for these processes and we had to choose the most appropriate machine(s) for the particular task and to design the procedures to make best use of the facilities provided by the machines available to us.

We also had a variety of foolscap and double foolscap ‘forms’ that we could use to record the results. These forms were printed on good-quality paper and each sheet normally had two holes punched in the top left-hand corner. We were also provided with special two-hole punches so that we could punch the holes in any covers or paper that had been supplied without them. A ‘Treasury tag’ passing through both holes was used to hold the sheets together; the current sheet was inserted on the top of the packet. I believe that this system was introduced by Comrie to reduce the risk of any sheet being lost from a packet of computations because of a tear at one hole, as sometimes happened in files of correspondence.

The forms had varying numbers of vertical rules, some thicker than others, to suit the number of columns and the number of figures in the numbers in each column. The number of lines on each sheet matched the number of lines (47 or 48) on a standard page of the Nautical Almanac — I found this annoying when I came to use the sheets for tables with 51 lines. Some of the forms had line numbers printed on them and some even had the symbols for the quantities and operations printed on them for very common jobs. Usually, however, we were expected to write the precepts on a separate sheet that could be placed alongside the current sheet so as to provide all the instructions required by a new computer and to act as a reminder to computers who had done the job previously. These sheets should have been tagged on the top of each packet when it was put into store, but unfortunately this was not always done.

The standard desk machine was the Brunsviga 20; this was a purely mechanical machine in which the computer turned a crank handle to multiply (or add, subtract or divide) one number by another. The digits of the multiplicand were specified by the positions of row of 12 setting levers. The digits position of the multiplier was determined by the relative position of the product register, which could be moved by the left hand, with respect to the multiplicand register. The machine could be used to multiply a 12-digit number by an 11-digit number to give a 20-digit product. (Leading figures were lost unless, as was usual, the full capacities of the multiplier and multiplicand were not used.) The main advantage of the machine was that it had a transfer facility so that the product could be transferred to the multiplicand register and then multiplied by another number, and so on. Most members of the staff had such a machine on their desks. Mr Barry was alone in having a Swedish ‘Facit’ mechanical calculator.

I have a Brunsviga 20 which I bought for a nominal amount just before the Observatory moved to Cambridge in 1990. I used it ‘for real’ in 1993/94 when I was developing examples for use in a simulation of the Babbage Difference Engine, which could add numbers with 31 digits. Most electronic calculators and normal arithmetical processors on electronic computers operate on numbers with only about 8 digits, while the Babbage machine was designed for 31-digit numbers.

For jobs involving a great deal of multiplication a Marchant electromechanical calculator was popular with the Assistants. This required the depression of numbered keys for setting numbers and carrying out multiplications, rather than the moving of levers and the turning of a crank handle; division was fully automatic. The Office also had a Friden calculator, but this was less popular because an input error could not be easily corrected.

All of these machines were noisy in operation, and so as a rule they were not used during the first two hours of each day when most members of the staff were doing their proofreading stint for the day.

2.2.6.2 Mistakes in computations

One major disadvantage of such desk machines was that the operator had to write down the results of each step of the calculation. (A step might involve more than one operation if, for example, the transfer facility could be used or if the required result could be accumulated in the product register.) Each intermediate result would be used again at least once and experience showed that the recording and resetting of such numbers were the points in the computation where mistakes were most likely to occur; such mistakes would then carry forward into the following steps of the computation.

In order to keep mistakes to a minimum it was a rule that all numbers should be written neatly in ink using a standard style for each of the figures. Moreover, when a mistake was found it was to be corrected by crossing through and by giving the new figure above it in red ink. Any consequential mistakes were to be found and corrected in the same way, unless the effects were so extensive that it was better to record the new results afresh. After the correction process had been completed the computer was expected to verify that the differences between the new and old results were consistent with the original mistake that had been made. Experience had shown that the process of correcting for a mistake was a more prolific source of mistakes than the original computation!

Whenever possible, checks were built into the procedures so that any mistakes would be discovered before a lot of further computation had been carried out. For example, many computations involved the use of printed tables to provide values of trigonometric functions, such as sin x and cos x once x had been calculated; the computer would verify that $\sin^2 x + \cos^2 x$ was equal to 1.0 before proceeding. In other cases, some quantities would be computed by two different methods and the results compared to ensure that they were in satisfactory agreement.

Most of the jobs involved the computation of one or more smoothly changing quantities (or functions), such as the celestial coordinates of a planet, at fixed intervals of time, say every 10 days. The differences of successive values could be calculated mentally and written down in the adjacent column (called the first difference); then the differences of this column could be formed in the same way (giving the second difference), and so on. If all the values (and all the differences) were correct it would be found that the numbers in the successive columns (or ‘orders’ of the differences) would become smaller and that successive numbers would oscillate in sign. If one or more of the function values, or of the differences, contained a mistake, then part of the table would start to diverge. With experience it was possible to determine the position and size of the mistake, and then, if necessary, to go back to the original work to find the cause and to correct the work. Very often the mistake would have been made in forming a difference, rather than in the original table! The method of differencing was fundamental to much of the proofreading done in the NAO and is described in *Interpolation and Allied Tables* (see section 2.2.7.4).

2.2.6.3 The National machines

The Office had two Class 3000 National Accounting machines, one of which had been specially modified so that it operated on sexagesimal numbers, i.e., it could be used for calculations in hours, minutes and seconds or in degrees, minutes and seconds. These machines could only be used for addition and subtraction, but they had special features that made them extremely useful for many jobs in the Office.

1. Each machine had 6 registers for 12-digit numbers.

2. The machine could carry out a sequence of operations in accordance with the 'instructions' given by a series of 'stops' on a metal bar.

3. At each stop the contents of a register, selected by the depression of a key by the operator, could be added to or subtracted from one or two of the other registers, selected by the coding on the stop.

4. The number in the selected register was printed on a wide sheet of paper.

One very important use of the National machines was for checking by differencing, but the major use was for 'subtabulation', that is for the systematic interpolation of a table of values to a smaller interval. The process involved the building up of a table of differences line by line from a high order of difference to form the next function value. The table was started from an initial line of differences that had been calculated from the original difference table. The method used was self-checking in that the original function values should be reproduced exactly. The arrangement of the stops on the bar and the sequence of operations to be carried out depended on the interpolation formula to be used and the ratio of the two intervals. All the information required to set up and operate the machine was written on a 'set-up' sheet, of which over a hundred were used. Bars with the appropriate set of stops were kept for the most commonly used processes. The operation of the National machines was largely carried out by the Assistants, who worked in two-hour stints. The machines were rather noisy in use.

The use of the National machines had been pioneered by Comrie, and further developed by Sadler and others in the 1930s and 1940s. Both the machines and the procedures were improved during this period. Most of the final batch of set-ups, which were written on preprinted forms, had been prepared by Carter and Harding. The technique depended for its success on the use of the 'method of bridging differences', about which more is given in the notes on the preparation of the booklet *Subtabulation* in 1956-1958 (see section 3.3.1.1).

It is of interest to note that Babbage designed his 'difference engines' to use the summation process, but they would have suffered from the grave disadvantage that they could only add, and not subtract. The computers of the day would have had to calculate the differences of the original function by hand. This would have been a very tedious and error-prone task with the very long numbers that Babbage had in mind. It seems that he was not aware of the possibility of checking by differencing or of using bridging differences in subtabulation.

2.2.6.4 The basic punched-card machines

During the 1930s and 1940s the Office, which was then based in Greenwich or Bath, used the punched-card machines of other Admiralty establishments and other

organisations. Such arrangements would have been quite impracticable at Herstmonceux and so the Office hired a basic set of Hollerith punched-card machines, which were installed early in 1951 in the hut on the west side of the South Courtyard of the Castle.

These machines used cards with 80 columns and 12 rows and the holes that represented the digits were rectangular. (The extra two rows could be used for 10 and 11 in commercial accounting or for control purposes, such as to indicate negative numbers.) The machines were hired from, and maintained by, the British Tabulating Machine Company (BTMC); they were compatible with the Hollerith machines made by IBM in the USA, which were used in the U.S. Naval Observatory. Machines that used cards with round holes were made at the 'Acc. & Tab' factory near to my home in Croydon; at the time I did not realize that the name was short for 'accounting and tabulating'.

The basic machines were a sorter, reproducer, collator and tabulator. As their names imply the sorter was used to sort cards into the sequence of the numbers in selected columns, while the reproducer was used to reproduce the numbers from selected columns of one set of cards into chosen columns of another set of cards; a common use was to make a duplicate copy of a worn set of cards so as to reduce the risk of misfeeds that would disrupt the operations. The collator could be used to compare the numbers on the cards in the two feeds and to use the result to direct the cards into appropriate hoppers. The functions of the tabulator were similar to those of the National machine, but the numbers were read from cards and the results could be punched on cards and/or printed. The printer had 120 [or 132?] printwheels so that the numbers could be spaced out; it could be used to produce printer's copy that required only a small amount of additional effort to prepare it for dispatch to the printer.

All the machines except the sorter were controlled by the wiring on a 'plugboard'. Most holes on the board would correspond to the columns on the input and output cards so that, for example, the number punched in one column of the input card could be directed to any chosen column of the output card by linking them by a wire with plugs on each end. Other holes corresponded to the operations to be carried out. The planning of the sequences of operations and the design of the wiring was a skilled task in which Carter and Harding, in particular, were experts. The task of making up a board from a wiring diagram took care and time, and so some boards were kept permanently wired for the standard jobs in frequent use. A loose wire could completely invalidate a run and so the checking at the start of a new run was critically important.

The machines were normally operated by the Assistants in the Machine Section; Audrey Nevell and Audrey Crisford can be seen on the photographs that we have, but Flip Restorick was the most experienced operator at the time. The cards had to be handled carefully to reduce the risk of misfeeds or, worse still, card jams, which would damage the cards so severely that they would have to replaced by repunching by hand, with the consequent risk of mistakes. Any such new card had to checked independently by another operator.

The punched cards were stored in metal trays, which were themselves stored in special racks. Each tray would hold about two thousand cards. Accidents in which cards were dropped were very rare, and every effort was made to ensure that cards were not misplaced. If necessary, the sorter could normally be used to restore the sequence of any set of cards since, with very rare exceptions, every card had a job number and a serial

number. The sorter could also be used to count a set of cards so that, for example, it could be verified that none were missing.

The cards were normally buff-coloured, but they were available with different coloured stripes along the top edge; some cards were of a different colour throughout, and some had a corner cut off. Most cards were printed in a standard way so the column and value of any hole could easily be identified. For some purposes the cards were specially printed to show, for example, the significance of numbers in particular groups of columns. These different devices helped to reduce the risk of mistakes and to draw attention to any mistakes that were made.

The bulk of the work carried out on the punched-card installation was for the publications of the Office, but some work was done for other departments of the RGO.

The machines required frequent maintenance by BTMC engineers and Arthur Burton, a jovial man who smoked a pipe and lived in Brighton, served the Office well for many years.

2.2.6.5 The IBM 602A calculating punch

As a result of Sadler's visit to the USNO in 1949, the basic punched-card machines, which were made in the UK by BTMC, were supplemented by a new machine that was made by IBM in the USA, but supplied to BTMC under a reciprocal marketing agreement. This electromechanical machine could multiply and divide, as well as add and subtract, and so it increased greatly the scope of the work that could be carried out on the machines.

According to Porter in a paper for the BAA "the speed with which the machine works is high because the most ingenious methods have been adopted for performing many mechanical functions simultaneously in one cycle". [JBAA 61(7),185-189, with 2 plates] He quoted the time for a calculation of the form $a + bc$ as 2½ seconds, even when b had only 4 digits. Today, this would be regarded as incredibly slow! The machine was also controlled by the wiring on a plugboard, which in this case had nearly 1500 sockets. Porter used the word 'programme' to describe the sequence of the instructions that were represented by the wiring, which could be extremely complex and very difficult to test.

The programmes became more and more sophisticated as experience was gained in the use of the machine. I believe that the 602A proved to be very reliable and it proved to be a major asset until it was replaced by an electronic computer after over 8 years in service.

2.2.6.6 The IBM card-controlled typewriter

Another new machine, an IBM card-controlled typewriter completely revolutionised the work of the Office. Again, Sadler had seen one in use at USNO and had obtained approval to add it to the original order for the punched-card installation. Unfortunately, delivery was delayed because of a break between BTMC and IBM and did not take place until March 1953.

The typewriter was used to produce copy for the publications that was of such a high quality that it could be used directly in the production of photolithographic printing plate. This obviated the need for the printer to set up each page in loose type and for the detailed proofreading that was needed to eliminate the mistakes made by the

printer before the final plate was produced. It did not, however, completely eliminate proofreading since it was still necessary to check that no mistakes had been made in the computation of the numbers or in the handling of the cards before or during the printing run. We also found that it was necessary to verify that the printer had not introduced any mistakes during his attempts to improve the quality of the printing by, for example, touching up a figure that appeared to be broken.

The typewriter could not produce the printed headings of various sizes for the pages and columns, nor could it print some of the special symbols, such as those for the phase of the Moon, that were required. Further, most of the pages for the regular publications used rules to separate the columns of figures and the different parts of the page, but it was found that the eye was very sensitive to the very small misalignments that were made if the typewriter was used to print these rules from short segments. The fixed headings and rules were therefore printed on large sheets of high-quality paper on which the numbers were printed by the typewriter. A special procedure had to be devised so that the operator could verify that the paper had been correctly loaded into the typewriter — otherwise the numbers would not be centrally placed within the rules throughout the page.

The special symbols, footnotes and other items that were not printed from the cards were then stuck on to make the final, complete page of copy. The extra pieces were stuck on using a special glue known as ‘Cow Gum’. This had the advantage over ordinary glues that any excess could be rubbed off once it had dried without leaving any mark on the paper; in fact, the operators found that an eraser could itself be built up from dried Cow Gum. The Cow Gum came in large tins and when the tins were open a vapour with a characteristic smell was given off. Several years later I used some of this Cow Gum myself and found that it made me dizzy unless I made sure that the room was well ventilated by an open window. I do not know if any of the Assistants suffered in the same way, and I wonder whether its use would now contravene the Health and Safety regulations.

The need for pre-printed forms meant that it was uneconomic to use the typewriter unless the publication contained a large number of pages of the same design. I believe that its first use was for the *Apparent Places of Fundamental Stars* and then for the daily pages of the *Abridged Nautical Almanac*. It was never used for the *Nautical Almanac and Astronomical Ephemeris* since most of the tabulations were of 8 pages or less. The pages were reduced in size by about 70 per cent before they were printed; this tended to make the final printing appear to be of higher quality than the originals.

Sadler states that the card-controlled typewriter was very unreliable, but I suspect that most of the staff of the Office greatly welcomed the reduction in the amount of proofreading that had to be done as the figures were printed correctly. The Office proofread these and other such pages (such as those for the *Air Almanac*, which were typed at USNO) by ‘eye’, with a combination of mental differencing and comparison with copy. On the other hand, at the USNO punch-operators were employed to punch all the data on the proofs and then these new cards were compared with those that had been used to prepare the copy. We were never convinced that this was the best method to use.

2.2.6.7 Thoughts of an electronic computer

When I was a postgraduate student at Imperial College, I attended lectures by K D Tocher and C Michelson on programming for an automatic electromechanical computer, ICCE (Imperial College Computing Engine), that they were building, using relays rather than electronic valves. [RGO 16, box 14, packet 1, supplement to NAO file 13P] My supervisor, Professor A T Price, had intended that I would use it for my research, but it soon became clear that it would not be finished in time and so I used desk calculating machines instead. In fact, the machine was never finished. Unfortunately, I later scrapped my lecture notes about this computer.

It seemed clear, however, that the Office ought to be looking ahead to the time when electronic computers would be available for use for the computations for the almanacs and especially for the computation of orbits by numerical integration. Accordingly, I spent a week in Cambridge in September 1954 attending a course on programming the EDSAC, which had been developed in the Mathematical Laboratory of the University. This used five-hole telex paper-tape for input and output. The programming system made much use of subroutines (I believe for the first time) and the course certainly influenced my approach later to programming for other computers.

I have a copy of the book (1951) that was issued for the course, but not of my notes. I am amazed that the word subroutine does not appear to be used in the book on programming for the IBM 650 that I used when I was seconded to USNO in 1957 to learn more about the programming and operation of electronic computers. (See section 3.3.1.2)

2.2.7 Other aspects of the work of the Office

2.2.7.1 Calendarial information

The Office was generally regarded as the UK authority for matters relating to the calendar and it used to issue a sheet giving the dates of the religious festivals, public holidays, eclipses and phases of the Moon for the use of diary and calendar publishers. It also distributed sheets giving the times of sunrise and sunset for London and other principal cities and it provided the Automobile Association and other organisations with lighting-up times for various places. This work was regarded as a public service and no charges were made. An article on the work was published in a Trade Union journal in an issue with Angela James on the cover. The Office also dealt with requests for such data for legal purposes, especially lighting-up times for road vehicles.

2.2.7.2 International Astronomical Union

The International Astronomical Union (IAU) played an important role in the work of the NAO as it provided the principal forum for discussions about cooperation in the production of astronomical almanacs and related activities. There were similar Unions for other areas of science and all were represented on the International Council of Scientific Unions. The IAU differed from the other Unions in that individual astronomers were admitted to membership and had voting rights during the plenary meetings at the triennial General Assemblies. In the other unions the voting was by the representatives of the National Committees of the countries that were affiliated to the Union. The IAU had about 30 Commissions for particular aspects of astronomy and membership of them was according to the interests of the individual astronomers.

Shortly after I joined the Office, Sadler asked me if I would like to attend the next General Assembly of the International Astronomical Union, which was to be held in Rome in the following year (1952). I would not be sent on duty, but he thought that I would get a young astronomer's grant towards the travel costs from the IAU. At the time I did not realize how important the IAU was to the work of the Office, nor how much my own career would be later affected by participation in its activities. Moreover, I was trying to save in readiness for my marriage and was concerned that the costs of staying in Rome would be high. I therefore declined the chance; I realize now that Sadler would have been disappointed at this decision. Patrick Wayman, who joined the RGO about one month after me, did accept the offer; when he returned he told me that he had lived very cheaply in a student hostel. Twenty-seven years later he became the General Secretary of the IAU.

Sadler became President of IAU Commission 4 on Ephemerides at the Rome assembly and he served for 6 years, so that he was responsible for organising the meetings of the Commission in 1955 and 1958, as well as other appropriate activities between meetings. (The title 'president' is a direct transcription from French; the word 'chairman' would really be more appropriate in English.) Some years later, the IAU decided that commission presidents should normally serve for only three years, presumably so that more persons would have the honour of the title. Unfortunately, some of the persons chosen did not have the ability, or the inclination, or the facilities to carry out the job effectively. On the other hand, a president with good ideas would develop them during the 3 years prior to the meeting at which he was chairman, would get them adopted by the commission, and might then find that the next chairman failed to carry them through.

At that time the meetings of Commission 4 were dominated by the affairs of the principal national ephemeris offices as it was necessary to get agreement on the basis of the ephemerides and on the sharing of the work between the offices. Sadler certainly made good use of his 6 years of office as many important decisions were taken during that time to follow up the proposals put forward by Sadler and Clemence at the 1952 Assembly. These proposals concerned both the basis of the ephemerides and the arrangements for the preparation and publication of the almanacs. The implementation of these changes will be discussed in some detail in later sections.

The principal changes in the ephemerides followed, firstly, from the recognition that the rate of rotation of the Earth is not constant (see section 2.2.7.3) and, secondly, from the availability in the USA of electronic computers that could calculate the orbits of the Moon and planets directly by numerical integration.

The changes in the arrangements for preparation and publication of the ephemerides followed mainly from the agreements between Sadler and Clemence with regard to the unification of the almanacs of the UK and USA. In addition, there was a steadily increasing use of English as the common language for astronomy, and this made separate national almanacs less necessary. (See section 3.3.1.1)

I did attend the next General Assembly, which was held in Dublin from 29 August to 5 September 1955. This was shorter than the usual 10 days from Tuesday to Thursday, but it was followed by a visit to Northern Ireland on 6-7 September. We stayed overnight in Belfast, and we also had a visit to the Armagh Observatory.

There were formal plenary sessions on the first and last days and commission meetings etc. on the intermediate days. I had no duties to perform and so, in addition to

attending the meetings of direct concern to the work of the Office, I was able to attend meetings of more general interest. I recall that Gerard Kuiper was the dominant figure in Commission 16 on the Planets. This was the meeting at which Ambartsumian put forward ideas about high-energy processes in some galaxies — these seemed very far-fetched to me at the time.

In addition there were special events — some scientific and some social. On the Sunday most of the delegates went by special trains to Killarney or Connemara — I chose the former. My main recollection of the trip is that Donald Menzel and Fred Whipple were in the party, and that the former played his guitar on the train on the way back; but it is all very hazy!

2.2.7.3 Ephemeris time

One topic that that was to be of major interest to me during most of my career was the introduction and definition of what was at first called *Ephemeris Time* (ET). In the 1940s it had become clear that the *Universal Time* (UT), which was the basis of GMT for civil use and astronavigation, was no longer appropriate for use for most scientific and technical applications. (See also sections 2.3.5 and 2.6.1) UT used the mean solar day as its unit and this had been shown to vary as the rate of rotation of the Earth is not constant. Long-term changes were shown by studies of the motions of the Moon and planets, while short-term changes were shown by the quartz-crystal clocks that had superseded pendulum clocks. The clocks provided a continuous timescale that was regulated by the observations of the transits of stars over the meridian.

At an astronomical conference in 1950 it was agreed that a new timescale, to be known as ephemeris time and to be based on the revolution of the Earth around the Sun, should be introduced. Dr G M Clemence, the Director of the Nautical Almanac Office in the US Naval Observatory, was a prime mover in the proposal of the resolution that was to be considered at the IAU General Assembly in 1952. He and Professor Samuel Herrick from the University of California, visited our NAO on his way to the Assembly and I was invited to sit in on a discussion between them and Mr. Sadler. (Dr Porter and Miss McBain were probably also present.) I have a recollection that I asked why it was not possible to wait until atomic time (AT) would become available (as I had heard that atomic clocks were close to completion). The reply was, if my memory is correct, a dogmatic statement that time should continue to be defined by an astronomical phenomenon that would be permanent and not subject to changes in technology. Unfortunately, the definition of ET that was adopted in 1952 soon proved to be inadequate and ET was eventually superseded by AT for general use and by other timescales for the most precise astronomical applications.

2.2.7.4 Interpolation and Allied Tables

My first major job that involved interactions with persons in other organisations was to act as editor for a completely revised edition of *Interpolation and Allied Tables* (IAT). This had first been published in 1936 by reprinting pages from the Explanation to the *Nautical Almanac for 1937*. Comrie had previously published similar extracts from the NA under the title *Interpolation Tables*, but he included additional material, such as formulae for computing derivatives from differences, in the 1936 booklet. Its price was low, it sold well and it was reprinted several times, but after 15 years its notation was obsolete and new techniques were in use.

Sadler realized that the scope of the work of the Office was rather limited and so he sought the assistance of Dr E T Goodwin, who had worked under Sadler in the Admiralty Computing Service (ACS) and who was the Superintendent of the Mathematics Division of the National Physical Laboratory (NPL) at Teddington in Middlesex. Other former members of the NAO/ACS, including Dr. Leslie Fox and Fred. W J Olver, also worked in the Mathematics Division.

I do not recall now what progress had been made when in 1953 Goodwin suggested that the IAT could be incorporated into the introductory volume of a proposed new series of NPL Mathematical Tables. Sadler agreed to this, but we eventually realized that NPL staff were intending to produce a volume that was in the style of a textbook and that they wished to include many lengthy, general formulae of high precision. On the other hand, Sadler was looking for another small, cheap booklet that would contain collections of formulae and tables that could be used directly by the computer (then still considered to be a person). We came to an amicable agreement to produce separate publications that would be complementary. They would use the same notation, but our booklet would contain, for example, special cases of the general formulae given in the NPL volume.

Our booklet was published in 1956 for a price of “five shillings net”; it was reprinted with amendments in 1961 and several times later. The NPL volume was published in 1956, with the title *The use and construction of mathematical tables*.

Although I had taken a course in numerical analysis at Imperial College, I learnt a lot more while I was preparing IAT. It consisted of three parts: an introductory text with numerical examples; a set of interpolation tables covering a wide variety of situations; and a final part that was a mixture of formulae, short tables and text for various aspects of numerical analysis. The first two parts were fairly straightforward, although the proposals and drafts were modified considerably before they were approved. The third part was ‘hard work’, as the material had to fit within each page, being neither too long nor too short.

Sadler, like Comrie before him, was extremely ‘fussy’ about the typographical appearance of the text and tables so that there would be the minimum risk of error by the user. I even visited the printer, John Wright and Sons Ltd in Bristol, so that I could better appreciate the problems of the printer in setting up complex mathematical material. We designed the tables so that vertical and horizontal rules were not required to separate the columns and rows — we relied on the use of spacing and type style.

The preparation of the Companion Booklet on *Subtabulation* is described in section 3.3.1.1.

2.2.7.5 Visits by H.M.S. Dryad

The RGO, and hence the NAO, reported to the Admiralty through the Hydrographer of the Navy, but there was no direct link with the Director for Navigation. I do not recall seeing any correspondence with him about the changes in the ANA, for example, although I assume that the Hydrographer would have consulted him. Our only other contact with the Royal Navy was through the visits to the RGO by the officers attending the courses on navigation at H.M.S. Dryad, which was a shore establishment near Portsmouth.

These visits came towards the end of the initial land-based part of each course, about every six months from late 1953, and were arranged by the NAO. There were about ten officers in each course, and several of them were usually from other navies. At the RGO, they visited the NAO and the Chronometer Department, had lunch in the canteen, and spent the afternoon, until it was time for tea, visiting the other departments of the Observatory.

2.2.7.6 The NAO Library

As it had been separate from the RGO until 1949, the NAO had built up its own library, which was moved to occupy one room in the hut where we worked. It was mainly a specialist collection of textbooks, astronomical and navigational almanacs, star catalogues and mathematical tables that were related directly to the work of the Office. The 'standard' complete set of the *Nautical Almanac* from 1767 was kept in Sadler's office. We had a second copy of the Almanac for 1768 that was, surprisingly, freely available; I used to take it to lectures with examples of our current publications. In addition, there were runs of several major serials, such as the *Monthly Notices of the Royal Astronomical Society*, and many individual unbound reports and minor serials, which were stored in pigeon-holes in alphabetical order of the country of origin. The latter items were mainly sent to the NAO in exchange for our almanacs, which were distributed quite freely to many observatories and institutions around the world.

At first my main interest was in the textbooks since I had to make up for my lack of a formal education in astronomy. I was dismayed to find that the books were arranged in alphabetical order of the names of the authors within very broad classes, such as astronomy and mathematics. This meant that books on specialised topics could be scattered within a whole bay of books, and were not grouped together as I would have expected. The arrangement of the library was fine if you knew which book or paper you wanted, but it was poor if you were looking for information on a particular topic.

I had not been in the Office very long before I suggested that the books should be classified more finely so that the books on a particular topic would be together. The library was looked after by Miss Joan Perry, who was the secretary of the Office. I think that she was pleased to have someone to take an interest in the library and I persuaded her that we should classify the books according to the Universal Decimal Classification system (UDC). I had become familiar with UDC while I was a postgraduate at Imperial College, where I used the Science Museum Library (as IC did not have a major library of its own). Moreover, UDC was to be used in the RGO library, which was to be moved from Greenwich into the Great Hall of the Castle (see section 2.6.5). I assume that we obtained Sadler's approval before proceeding; I believe that I did most of the rearranging in the evenings as I was then living in the hostel. I soon found that the printed classification was not adequate for such a specialist collection and so I introduced new classes as seemed appropriate.

The Office received quite a large number of journals and other serial publications. Before being put in the library, each item was circulated to those persons who had expressed an interest in the series concerned. One person was designated as the reviewer and was expected to look for papers or other items of direct relevance to the work of the Office so that those concerned would not miss them. Details of these items were entered on index cards by Miss Perry and were then filed, again in very broad classes in a special scheme.

Again I considered that UDC should be used for classifying such papers so that it would be easier to find the cards for the references on a given subject. I therefore started my own subject catalogue on index cards. I soon found that I had to introduce even more new subjects into the classification scheme, which soon began to lose its 'universal' character in the classes of particular interest to the Office. I also soon began to realize that many papers deal with more than one topic, and so two or more cards may be required for one paper. Moreover, most topics may be looked at from different points of view and it is often very difficult to decide how best to represent this in the classification scheme. (As I was to discover later, UDC has many different ways of dealing with such situations, and so the code that represents the classification of a paper or book may be very complicated.) My index gradually expanded as time went on, and I eventually made it available in the Library, but no one else seemed to be interested in using it.

I suppose that I would have to admit that the time I spent preparing the index was greater than the time I saved in finding references, but I always felt that the effort of classifying the content of a paper and of making the card helped to reinforce my understanding and memory of the paper. (In later years I became involved officially in the revision of the UDC class for astronomy: c.1974, 1988-9, 1993-98.)

The Office used to send copies of its publications to a large number of institutions on the understanding that they would send us copies of their publications. This was common practice in astronomy (and allied sciences) and it provided a way by which the stronger institutions could help the astronomers who were working in institutions that would not have been able to afford to buy even the basic astronomical publications. Formally, the material received was supposed to be of equivalent value, but this was interpreted as applying to the totality of the exchange, not to the exchange with each institution. There was much that was irrelevant amongst the material that was received, but occasionally there were unexpected items that proved to be of great value, either at the time or later when a new task was started. Some of the irrelevant items were of great personal interest and could be borrowed for reading at home.

2.2.7.7 'Copies'

The Office had a system for the circulation of 'Copies', which was a very effective way of keeping the more senior members informed about many different aspects of the work. Each day Miss Perry would circulate a folder containing carbon copies of outgoing letters, together with the incoming letters to which they were replies. Each person on the circulation list was expected to glance through the file and to read carefully items of direct relevance to their work and to take appropriate action. We were expected to initial each letter to show that we had read it; we were also expected to draw attention to any errors that we noticed. Many of the letters were of a routine character, but, for example, the exchanges between Sadler and Clemence about proposals for changes in the almanacs were of great interest.

2.2.8 Participation in external organisations

2.2.8.1 Royal Astronomical Society

Sadler attended every possible meeting of the Royal Astronomical Society; they were held on the second Friday of each month from October to May in the Society's rooms in Burlington House, Piccadilly. He had been one of the Secretaries of

the Society from 1939 to 1947 and had continued to organise meetings during World War 2, even though the Office had been evacuated to Bath. He later served as its President from 1967 to 1969. Miss McBain and Dr Alan Hunter, also from the RGO but based at Greenwich, were the two Secretaries when I first went to the RAS, firstly, as Sadler's guest and then as a Junior Member.

There was no official connection between the RGO and the RAS, but members of the staff were encouraged to join, to attend its meetings and to participate in other activities. Consequently, it seems appropriate to include here a general account of the character of its meetings and other activities.

The meetings, which lasted from 4 pm to 6 pm precisely, were preceded by tea in the Library. They began with formal business, which included the reading of the minutes of the last meeting, the "list of candidates for suspension", and the "list of presents received". It was some time before I realized that the first list referred to persons whose application forms for membership were to be suspended in the library. The presents were almost invariably books that had been given to the library. Finally, the President requested that "all those Fellows who have paid their admission fee and first contribution, but who have not yet been formally admitted, are invited to step forward and sign the book". Those who did were then addressed by the President, who said "Dr XYZ, in the name of the Royal Astronomical Society, I admit you a Fellow thereof" and then shook their hands, at which point everyone else clapped. Only then could the reading of the scientific papers begin.

These formalities were gradually reduced and eventually omitted from the 'ordinary meetings' of the Society. The Society also introduced separate specialist discussions for astronomy and geophysics that started in the morning and continued until mid-afternoon. These made it more worthwhile for members to travel to London from a distance and to attend the ordinary meetings that followed.

Usually there were four or five presentations by astronomers whose papers had been accepted for publication in the *Monthly Notices* of the Society. Each presentation was followed by an opportunity for questions, some of which revealed strong differences of opinion. These question and answer periods were often the most interesting parts of the meeting and so it was frustrating when the President announced promptly at 6 pm that "the meeting is now adjourned until 195x Month Day". The reason for the abrupt closure was that most of the senior Fellows were members of the RAS Club, which met nearby for dinner, preceded by drinks, at 7 pm.

Sir Harold Spencer Jones was the Treasurer of the Society from 1946 to 1952. The Presidents served for only two years. The President in 1951-1953 was Herbert Dingle, of Imperial College, who was then a small white-haired man. He gave a controversial presidential address "On science and modern cosmology" in 1953; he questioned the accepted view of the "Twin Paradox" that arises from the theory of relativity when one twin who goes on a journey into space and returns to Earth to find that his brother has aged at a faster rate. Dingle was associated with the Norman Lockyer Observatory (NLO) at Sidmouth and actually wrote the chapters of *The Life and Work of Sir Norman Lockyer* that are ascribed to Lady Lockyer and his daughter, Winifred Lockyer. I made much use of this biography when, after my retirement from the RGO, I moved to Sidmouth and wrote and lectured about Sir Norman.

Another period of great controversy was when Martin Ryle was trying to use the statistics of the variation in the numbers of radio sources with diminishing apparent

intensity to question the Steady State Theory of the Universe, which had been put forward by Bondi, Gold, Hoyle and Lyttleton. The meeting room was particularly crowded on such occasions, and latecomers would have to stand in the side-aisles, or even behind the raised seats at the back of the room. Eventually, the room became too small, and so the Society's meetings moved , firstly, to a room on the upper floor of the Geological Society's rooms and later to the Scientific Societies Lecture Theatre in Fortress House in Savile Row, about a quarter of a mile away. The meeting room in Burlington House was converted to make a smaller Fellows Room and offices for the Executive Secretary and other administrative staff.

(See sections 5.5.8.8 and 6.3.4.5 for later developments, including the periods when I served on the Council of the Society.)

Membership of the RAS Club was by invitation only and the maximum number of members was fixed. (I use the past tense, but I believe that these rules still apply.) Members were expected to attend regularly, and I suspect that this explained why Sadler would attend RAS meetings when there was nothing on the programme that was relevant to the work of the Office. Members were allowed to take a guest, and each was expected to make a short speech after he was toasted. Sadler took me as his guest on a few occasions, and he also asked me if I would like to be nominated for membership, but I declined. I enjoyed the dinners that I attended, especially as some of the guests were good after-dinner speakers and had interesting stories to tell. I did not feel, however, that I could justify either the expense or the time that would have been taken by regular attendance. I also felt some resentment that such a restricted-membership club should, as I saw it, effectively dominate the policy of the Society.

At the time, only male Fellows could be members of the Club and I suspect that only male guests were allowed. (I believe that these rules have since been relaxed.) A few of the wives of members of the Club used to meet separately for dinner and, some years later, I joined them on one occasion for dinner at Brown's Hotel. (I forget the circumstances for this.) The men's Club used to meet at the Athenaeum, but I recall that we had to go in by a side door. The Club would also meet when the Society held an out-of-town meeting and it appeared that the number of guests would usually be increased on such occasions. The Club also used to give members of the Council of the Society who were not members of the Club the opportunity to attend its dinners while they were in office, but I did not avail myself of this as far as I can recall.

I was a Junior Member of the Society for three years and then I was elected as a Fellow, and so entitled to write F.R.A.S. after my name. This acronym does not, however, imply that the person concerned has made a significant contribution to the advancement of astronomical knowledge. It does not even imply a professional role in astronomy. In fact Bye-Law 29 merely required that "a candidate for Fellowship must be proposed and recommended by at least three Fellows or Associates, one of whom must certify personal knowledge of the candidate's suitability". A person who supports astronomy financially may be deemed suitable; it almost appears that only astrologers are not welcome.

Many of the professional Fellows of the Society are not astronomers, but are geophysicists, whose work is more allied to astronomy than to classical geology. The RAS first produced a *Geophysical Supplement to the Monthly Notices* ... in 1922; this gradually expanded until it became a major source of income for the Society. It was renamed the *Geophysical Journal* in 1958, and later the *Geophysical Journal*

International. My personal interests tended towards geophysics, partly because of my earlier work on geomagnetism, but also because the variations in the rotation of the Earth, which were measured by astronomical techniques, had geophysical causes and consequences. (See especially section 6.3.4.4.)

2.2.8.2 Institute of Navigation

Sadler was also an enthusiastic member of the Institute of Navigation, of which he had been one of the leading founder members. At first he did a lot of the duties of an honorary secretary, but without the title. He was elected President in 1953 for a two-year term. In the same year he became chairman of a working party of the Institute on the "Accuracy of astronomical observations at sea". Mr Scott was also a member of the WP and did a large part of the basic work. (I wonder if George Harding took part in any way, as he had been to sea to gain experience in astronavigation.) The report of the working party was published in 1957.

I did not have much involvement in the work of the Navigation Section of the Office, although I did my share of the proofreading of the nautical and air almanacs and of some of the special publications. Consequently, I did not go to the meetings of the Institute regularly, . In fact, only a small fraction of the meetings and papers was related to astronavigation.

Bill Nicholson, who joined the NAO in 1954 after serving as a navigator in the RAF, naturally took a greater interest in the Institute and Sadler gave him, rather than me, the occasional special job that was related to navigation. Mr Scott, who was the Head of the Navigation Section, and who contributed to astronavigation in many different ways (including writing several papers that were published in the Journal of the Institute), was elected to the Fellowship in 1957. I became a member of the Institute in 1961 and was elected to the Fellowship in 1979.

2.3 The Solar and M&M Departments: solar/terrestrial relations

2.3.1 The building of the Solar Dome

The Solar Building, which was usually referred as the Solar Dome, was on the hill to the south-west of the Castle and was the first permanent building to be built for the RGO at Herstmonceux. Superficially, it consists of a small single-storey brick building, with a rotatable dome (made by Cooke) about 22 feet in diameter on it; access to the dome is by an external staircase. Much of the construction was actually under the ground as there was also a large cellar, accessible by a staircase from the room below the telescope, where spectrographic equipment could be used under constant temperature conditions. The massive concrete pier on which the telescope was placed extended down to bedrock.. The painted dome was made of wood and had an outer covering of zinc.

Construction at Herstmonceux was started in 1947/48; the Dome (and the Solar Department offices in the Castle) were completed in April 1949, by which time work on the cellar had been started. For reasons, which are now hard to understand, the Dome caused a furore in the House of Commons as it was claimed that it was an eyesore that was out of character with the Castle. Perhaps it was judged when it was still surrounded

by the spoil and scars of the building work. It cannot now be seen from the Castle since the hillside is now covered in trees.

2.3.2 Work of the Solar Department

The Solar Department was the first observing department to begin operations at Herstmonceux. The equipment included a photoheliograph on an equatorial mount alongside a visual 6-inch refractor by Cooke. It was sometimes used for ‘amateur astronomy’, such as the timing of occultations of stars by the Moon. There was also a coelostat, which reflected the light of the Sun down to the basement and hence to a spectrohelioscope that used a diffraction grating. The wooden dome and its track, the refractor and coelostat, together with appropriate auxiliary mirrors and eyepieces, as well as a Cooke sidereal and mean-time clock and a 3-prism solar spectroscope, were donated to the RGO by Mr A M Newbegin, who had been an active amateur astronomer, with his own observatory at Worthing.

The photoheliograph was essentially a camera with an aperture of 9 inches and a focal length of 8 feet; it formed an image of the Sun that was 8 inches in diameter on a photographic plate that was 10 inches square. It was used to take photographs of the Sun on every day that the Sun was visible, even if only for a short while or through thin cloud. Two photographs were taken if possible and the best was selected for measurement of the positions and areas of sunspots and other surface features. These data were subsequently published annually to continue the series that had been started at Greenwich in 1874 and that E W Maunder had used to prepare the ‘butterfly diagrams’ that show so graphically the changes in the latitudes of the sunspots during the solar cycle of about 11 years.

The Newbegin telescope was installed on 1949 April 25, and the photoheliograph from Greenwich was fitted on May 2. Photographs of the Sun were obtained on 287 days during the following 12 months; this may be compared with the totals at Greenwich for the preceding years (May-April): 250 in 44/45, 262 in 45/46, 255 in 46/47, 276 in 47/48 and in 48/49. The totals continued to be higher in the following years: 277 in 50/51, 297 in 51/52, 311 in 52/53 and 302 in 53/54. The Sun was photographed on 59 consecutive days in May-July 1952. More importantly, the quality of the photographs was considerably better and the granulation on the solar surface could be seen.

The cellar was almost ready for use by April 1951, but there was a seepage of water to be corrected. There were two spectrohelioscopes as the one previously used at Greenwich and the one given by Newbegin were both installed. These were used to monitor and study solar flares by looking at the Sun in the light of the principal line in the spectrum of hydrogen, known as H-alpha. (This technique had been first used, independently, by Norman Lockyer, then an amateur astronomer, and Jules Janssen, a French astronomer, in 1868 to observe prominences at the edge of the Sun.) These flares were known to be associated with the emission of charged particles from the Sun and hence with magnetic storms and the disturbance of radio transmissions. In fact, the Department had a recorder for picking up sudden enhancements of atmospherics (SEAs) to alert the staff to when they should observe the Sun with a spectrohelioscope.

A new Lyot H-alpha filter was delivered in July 1954 for fitting to the Newbegin refractor in the dome, thus reducing the need for the use of a spectrohelioscope in the cellar. It was in routine use from June 1955.

The Department had only a small staff and so it could not keep a continuous watch on the Sun. The Head of the Department was Harold W Newton (PSO), who had been first employed at Greenwich as a computer in 1910; he was a short, short-sighted man, who was an enthusiast for his job. He was delighted when he found that I had worked on geomagnetic variations for my PhD, since much of the interest at the Observatory was in studying the relationship between activity on the Sun and the disturbances of the Earth's magnetic field. It was appropriate that the Solar Department and the Magnetic and Meteorological Department should share a large room in the Castle. Newton was supported by H H J Barton (SEO), who had also had long service at Greenwich, and Phil S Laurie (EO), who had a particular interest in the history of the Observatory and who subsequently played a major role in saving its archives. Mike Nunn, a cheerful Temp. AEO, was in the Department when I joined the RGO, but he left fairly soon afterwards. There were two Assistants, Norman S C Rhodes, who was then the Chairman of the RGO Club, and Margaret Newman. Patrick Wayman was assigned to the Solar Department when he joined the RGO, presumably with the prospect that he would replace Newton in due course.

In 1953 the solar equipment of another famous amateur astronomer, John Evershed, who had an observatory at Ewhurst in Surrey, was presented to the RGO.

Newton retired as Head of the Solar Department on 31 May 1955. In his retirement, Newton wrote a book with the title *The Face of the Sun* (Penguin Books 1958) that reviews the observations of the Sun and the geophysical effects of solar activity. He died in 1985 at the age of 92. [See *EOS*, 75(8), 75 & 83, 1995; it includes a photo.] Wayman was promoted to SSO on 12 April 1955 and became head of the department.

In retrospect, I am sorry that I did not take more interest in the activities of the Solar Department. I suppose that I had a lot to learn in the NAO and, in any case, it would have been difficult to go to another department during normal working hours without good reason. I did attempt to use the telescope on a very few occasions to observe occultations, but it was not readily available for non-official use. I have a vague recollection of seeing the spectrohelioscope once, but not at a time when there was any activity to see. We were shown a film of the activity of large prominences on the Sun, but I do not recall the circumstances.

2.3.3 Work in geomagnetism

Observations of the variations in the Earth's magnetic field had been started by Airy at Greenwich in 1838 soon after he became Astronomer Royal. In 1847 the RO became the first observatory to use a system for regular continuous recording of the components of the field, using a photographic method. The recognition of a link between activity on the Sun and geomagnetic storms led to the acquisition of a photoheliograph from the Kew Observatory in 1873, and the RO played a leading role in the study of solar-terrestrial relations for the next 80 or so years.

A new magnetic observatory was established near Abinger in Surrey in 1924 and the recording equipment was moved from Greenwich to escape from the disturbances caused by the electric trains which ran through the town, only about half-a-mile from the RO. Later electrification of the railways in the area around Abinger led to a proposal in 1939 to move the observatory to Hartland Point in Devon, but the Second World War led to the deferral of the move. Owing to its isolation the site was used by

the Time Department during the war. The observations continued at Abinger without interruption until a new Observatory was established at Hartland in 1957. (See section 3.2.4.)

In addition to publishing the results of the observations, the Magnetic Department was responsible for the production of world-wide charts of the main magnetic field of the Earth every 5 years for use in navigation and other purposes. It therefore needed to collect geomagnetic data from other permanent magnetic observatories and from surveys that were made in other areas. [See RAR 45, 21, for proposal to make observations from the air over the north poles. See RAR 52, 29 for a general account.]

The Head and some of the staff of the Magnetic (and Meteorological) Department remained at Greenwich until they were evacuated to Abinger at the beginning of the war in 1939. The administrative and other staff of the RO were evacuated from Greenwich to Abinger Hammer in the autumn of 1940, and they returned to Greenwich in July 1945.

A small booklet with the title *Abinger and the Royal Greenwich Observatory: the recording of magnetism and time* has been written by Peter Tarplee and was published in 1996 by the Surrey Industrial History Group, which is part of the Surrey Archaeological Society. It contains a plan of the site and illustrations of some of the buildings as well as brief notes on the activities.

The first post-war report of the AR to the Board of Visitors to refer to the "projected removal of the Abinger magnetic station to an area free from rail disturbance" is that for 1949. The AR had previously raised the matter in November 1938 and the Admiralty had agreed to the move in 1944.) By this time, site testing was in progress near Hartland in north Devon. One site was selected, but the transfer was "deferred while the removal of the astronomical work was in progress". In 1954, the AR reported that the plans for the International Geophysical Year to be held in 1957/58 required that observations on the new site should begin not later than the middle of 1957. Building work did not start until the end of August 1955. There were to be five non-magnetic buildings for the measuring and recording of the Earth's magnetic field and for the testing and calibration of magnetic instruments. In addition there were to be an office block, with stores and darkroom, and a caretaker's residence.

Some of the staff of the Magnetic Department moved to Herstmonceux in 1949. The Head of the Department was H F Finch, who had joined the RO in 1921; for some years he had worked in the Time Department at Abinger. He was an excellent pianist, and gave recitals in the Castle from time to time. He was supported at Herstmonceux by Brian R Leaton, who had also joined the RO as a Junior Assistant before the war in 1937. [I have an audio tape of his recollections of that time.] He served in the forces from 1940 until 1946/7.

The staff who stayed at Abinger with the instruments included E A Chamberlain (SEO) and P L Rickerby (EO). [I did not know them personally, but they were involved in a bitter dispute with the Admiralty over some matter that used to come up at the annual meetings of the Association of Astronomers.] Peter J Willmoth joined as a TSA in 1949/50. The staff continued to improve the equipment at Abinger and they also developed and tested the new equipment for the Hartland station.

In addition to preparing the world magnetic charts for 1955, the Department started on a harmonic analysis of the Greenwich and Abinger data for 1916-1949 to

determine the solar and lunar diurnal variations. The data were punched on to cards at the Statistical Branch of the Admiralty, while master cards for the analysis were loaned by the Mathematical Laboratory at Cambridge.

The staff of the Solar and Magnetic Departments collaborated in studying, for example, the relationship between solar activity and magnetic storms. Newton and Finch used to produce a joint report on "Solar activity and magnetic storms" that was published in *The Observatory* each year. The special volume *Greenwich Sunspot and Geomagnetic-Storm Data, 1874-1954* was published by HMSO in 1955; it included new lists of sunspots and geomagnetic storms as well as data extracted from the annual volumes. There was also a 'butterfly diagram' covering the 80 years since the start of sunspot observations at Greenwich; in it the latitude of each sunspot is plotted against the date and the resulting plot for each of the 11-year cycles resembles a pair of butterfly wings. The first such diagram was prepared by E W Maunder, who joined the Royal Observatory at Greenwich in 1873. In 1922 [*JBAA* 32] he drew attention to the almost complete absence of sunspots and aurorae between 1650 and 1720; this period is now known as the 'Maunder minimum' and it occurred at the same time as a 'little ice age' in the 17th century when the River Thames was frequently frozen at London.

The Magnetic Dept. also carried out some service work in the testing of compasses for navigation and of variometers for geophysical prospecting. Some work on airborne magnetometers was also carried out.

It now seems surprising that I did not find or make an opportunity to visit the magnetic station at Abinger since my PhD project had involved the analysis of such data from around the world.

2.3.4 Work in meteorology

McCrea writes as follows (on p. 24-25):

"Early in his time at Greenwich, Airy was induced to start a full program [sic] of meteorological observations. He was always somewhat resentful about this, for even Airy could not impose law and order upon the Greenwich weather. Anyhow the unbroken record from 1842 to 1952 is one of the most valuable in existence. As a matter of organisational convenience the magnetic and meteorological work was always operated under the same member of the observatory staff, and since successive holders of the office happened to be notable personalities in their own right, it came to enjoy a measure of autonomy within the system."

A full programme of meteorological observations did not begin at Herstmonceux until 1952 November 1, but the full programme at Greenwich was stopped on 1950 May 31 and only a skeleton programme of daily observations was maintained until even that was stopped on 1952 July 31. [RAR 51, 17, states that a recording barometer from Greenwich had been placed in the basement of the Castle.] There was, however, an overlap of observations by sunshine recorders and night-sky cameras. At Herstmonceux, the sunshine recorder was set up in 1950 June on the East Signal Tower of the Castle while the night-sky observations were made from 1950 July from the roof of the Solar Building. In 1951 the AR reported that the sunshine recorded at Herstmonceux during the next ten months was 46% greater than that at Greenwich. The improvement in the number of clear nights was not so dramatic; the number of hours of clear night sky was about 10% higher. There was, however, a considerable increase in the transparency of the sky.

The meteorological station was in a small enclosure, with fence and hedge, on the East Hill (just off the approach road to the Equatorial Group). My recollection of the 'hut' is that it was in the form of an inverted U, with glass ends, and with a tall mast for a cup anemometer and wind vane. The hut, presumably, held a barometer [but see RAR 54, 15, which implies the barometer was still in the Castle], while the thermometers were in a separate louvred unit and the rain gauge was also placed away from the hut. A hedge was planted inside the wire fence of the enclosure.

The staff who dealt with the meteorological instruments and records were in the Magnetic and Meteorological, or M&M, Department. I am not sure who did the meteorological work or whether the work was shared amongst all the M&M staff. My recollection is that George Wells, an EO (prom. to SEO in 52/53) who had been at Greenwich, was involved. George was a tall, heavily built man, who always seemed to be cheerful. Later, Bob Lorton, who was an enthusiast for meteorology, joined as an SA.

The staff made no attempt to forecast the weather, and I have not yet noticed any references to scientific papers or popular articles about meteorology by any members of the M&M Dept. The results of the observations were communicated to the Met Office each month.

The programme of meteorological observations at Herstmonceux was reduced by Woolley at the end of January 1956 and stopped on 11 June 1956. Bob Lorton resigned in 1958 to join the weather bureau in South Africa.

2.3.5 Relationships with geodesy and geophysics

The geomagnetic and meteorological activities of the RGO were the most obvious signs of its considerable interest in matters relating to the Earth as well as in the rest of the Solar System and in the much more distant Universe of stars and galaxies. This interest was of long-standing since the Observatory was founded to develop a method for navigation around the Earth, rather than for astronomical research. Before he became the second AR, Edmond Halley had produced the first map of the 'magnetic variation' (that is the angle between the directions of true north and magnetic north) over the Atlantic Ocean; this had applications to navigation, but it also raised questions about the nature of the geomagnetic field. The third AR, James Bradley, discovered nutation, or nodding, of the Earth's axis of rotation, whose precessional motion was already well-known; the accurate calculation of these effects was essential to progress in mapping the stars. The theories of precession and nutation required a knowledge of the internal constitution of the Earth, but correspondingly, the astronomical observations were used to determine the required parameters of the Earth that were used in the theories.

The seventh AR, George Biddell Airy, had wide-ranging interests, as well as expertise in mathematics and engineering, and realized that accurate and continuous observations were the essential key to the understanding and prediction of global terrestrial phenomena as well as to the determination of the motions of the Moon and planets and to the cataloguing of the positions and motions of the stars. It is relevant to note that the astrometric observations of stars made at Greenwich during this period were the basis of Chandler's determination of the nature of the motion of the pole of rotation within the Earth that caused unexpectedly large 'errors' in the positions of stars. This in turn gave information about the interior of the Earth that could not be obtained

in other ways. Eventually, the fluctuations in the motion of the Moon that could not be explained by celestial mechanics, were shown to be due to variations in rate of rotation of the Earth that arose from a variety of causes.

The tenth AR, Spencer Jones, provided the convincing evidence that finally convinced the sceptics and led to the decision to introduce ephemeris time (ET) in order to provide a timescale that was free of the irregularities that were inherent in universal time (UT). (See also sections 2.2.7.3 and 2.6.1) While the NAO was endeavouring to determine these irregularities from the lunar occultation programme, the Time Department at Abinger was comparing UT, which it determined from observations of the transits of stars, with the more uniform timescale that it obtained by combining the results from a set of quartz-crystal oscillators (or 'clocks').

One of the minor tasks that I was given by Sadler during my early days in the NAO was to comment on a draft paper by S K Runcorn, who claimed that there was a correlation between the fluctuations in the rotation of the Earth and the occasional sudden changes in the secular variation of the Earth's main magnetic field. I did not find the evidence convincing and, as far as I am aware, the paper was not published. In later years I came to know Runcorn, who became Professor of Physics at the University of Newcastle, quite well. At about this time I realized that the study of the nature, causes and consequences of the variations in the rotation of the Earth would be of great interest as it would involve many different aspects of astronomy and geophysics. I was, however, given other jobs, and my interests developed into other areas so that I did not expect to find that the rotation of the Earth would dominate my activities during the last decade of my career.

The study of the relationship between solar activity and geomagnetic disturbances, and the associated effects such as ionospheric disturbances and aurorae was a major interest of the RGO during this period. It was relevant to the study of the Sun as star, and it was of great practical importance in connection with radio communications. As far as I am aware, however, no-one at the RGO was interested in the relationship between solar activity and meteorology; it is only since I have retired that I have realized that there was clear evidence that solar activity affects climate and the weather in ways that we do not understand.

There were tenuous links with other aspects of geodesy and geophysics. For example, in the supply (by the NAO) of ephemerides for the computation of tides and of the testing (by the Magnetic Dept.) of seismographs at Abinger.

2.4 The Chronometer Department

2.4.1 A brief history of the chronometer work of the RGO

The administrative responsibility for the Royal Observatory was rationalized in 1818 and was vested in the Lords Commissioners of the Admiralty. At the same time the responsibility for the preparation of the *Nautical Almanac* was transferred from the Astronomer Royal, then John Pond, to the newly appointed Superintendent of the Nautical Almanac, Thomas Young, who was secretary of the Board of Longitude at the time. Both Pond and Young reported directly to the Admiralty. The Board of Longitude was not abolished until 1828, and the Hydrographer of the Navy was not made a member of the Board of Visitors of the Royal Observatory until 1858. [McCrea, 16-17]

When I joined the Observatory, the Astronomer Royal reported to the Hydrographer, rather than directly to the Lords Commissioners, but I do not know when this practice was started.

One consequence of the change in 1818 was that in 1821 the RO was given responsibility for the storage, testing and issue of the chronometers and deck-watches of the Royal Navy. These had to be kept in tip-top condition since the safety of the ships depended upon them, as they provided an essential component of the system for determining longitude at sea. The chronometers were set to keep Greenwich Mean Time (GMT) and longitude was given by the difference from local mean time (LMT). The *Nautical Almanac* then provided data by which LMT could be determined from observations of the Sun and GMT could be determined from observations of 'lunar distances', that is of the angles between bright stars and the limb (edge) of the Moon. The observations and the subsequent calculations were, however, difficult and the method could not be used at all around the time of New Moon even if the sky were clear.

The chronometers were returned to the RO for checking and storage when the ships returned from their voyages. If necessary they were sent for repair to the chronometer makers and were again checked and rated against the pendulum clocks at the Observatory before being re-issued to the ships. The pendulum clocks were themselves regulated by reference to transits of stars across the meridian of the Observatory. No chronometer would keep time perfectly, but a good chronometer would gain or lose the same amount each day if it were kept in suitable conditions. Each chronometer would be accompanied by a rating certificate so that the time shown by the chronometer could be corrected by an appropriate amount corresponding to the rate and the time since the clock was set.

Lunar distances were omitted from the *Nautical Almanac* in 1906, but they had been superseded long before this as chronometers had become cheaper and widely used in ocean-going ships. High-power radio time signals were first broadcast from the Eiffel Tower in 1908 and soon became available in other parts of the world, but it was many years before most ocean-going ships were fitted with radio equipment and signals were available throughout the world. In any case, the chronometer was still necessary for giving accurate time between signals and in the event of a failure of the radio system.

In 1937 the RO set up its own repair workshop at Greenwich and so it had to employ skilled craftsmen, who could clean and repair the chronometers. During the Second World War the Chronometer Department of the RO was evacuated first to Bristol and then to Bradford-on-Avon, in Wiltshire, and its staff expanded. Even in 1945, however, it had only 7 'watch adjusters and repairers' in addition to the Head of the (Chronometer) Repair Shop, then H Warden, and an unspecified number of non-industrial staff concerned with the rating of the chronometers and the administration of the Department. A watchmaker apprentice had been recruited by the time that the Department moved to Herstmonceux Castle in the first wave in 1948, but otherwise the numbers remained the same. The number of watchmakers subsequently increased as the Department took on the responsibility of the navigational watches of the RAF and of the Army.

The staff of the Chronometer Department moved from Bradford-on-Avon to Herstmonceux in September 1948, just after the AR and the General Office had moved from Greenwich. The move was possible because the Hailsham Rural District Council

provided 6 houses (in Bagham Lane) for married staff ahead of the special allocation made for the Observatory. (The move of the NAO and M&M staff was delayed until more houses became available a year later.) Accommodation for single staff was ready in the hostel rooms in the Castle and huts.

2.4.2 The Chronometer Workshop

The name Chronometer Repair Shop continued in use in the annual Report of AR at least up to 1955, even though the name Chronometer Workshop was in general use. The term ‘adjuster and repairer’ was changed to ‘repairer’ in 1950 and to the more appropriate ‘watchmaker’ in 1953, by which time there were 12 watchmakers and two apprentices. The distinction between non-industrial and industrial staff was, regrettably, maintained in several ways, especially in conditions of service, such as pay, pensions, hours of duty and leave entitlements. It was also shown in other ways; for example, the annual report names even the most junior recruit in the clerical and scientific classes, but none of the industrial staff are named. The skilled craftsman who had managerial responsibility for the main engineering workshop, and hence for the production of new equipment and the maintenance of the telescopes, is listed only as the ‘Foreman of Observatory’.

The Chronometer Workshop was in the north-west end of the large huts on the south side of the road to the south of the Castle. North-facing windows were fitted and each place on the long bench had a desk-lamp and magnifying glass on a stand to help the watchmaker in his delicate task. As far as I can recall all the watchmakers were men throughout the whole of the time that the Workshop was at the Castle. Each chronometer would be stripped right down, each part would be cleaned and then the chronometer would be re-assembled, tested and adjusted as necessary before being transferred to the Castle for rating and storage.

At the time of the move the Head of the Workshop was David W Evans, who was a very pleasant, quietly-spoken man; he had been appointed in 1947. He was a Fellow of the British Horological Institute and an acknowledged expert in his field. He left the RGO at the end of 1960 to become a senior lecturer in horology at the Birmingham College of Arts and Crafts. William P Roseman was promoted to take his place.

When I joined the RGO in 1951, one of the watchmakers was Keith Jarrett; he was then living in the men’s hostel. He subsequently married Angela James, who was working in the NAO and living in the women’s hostel. He was a keen table-tennis player and we later played together in the RGO team; he was then in the A-team while I played in the B-team. Even after I had graduated to the A-team, Keith always seemed to be able to find the extra bit of determination to beat me in Club tournaments! Years later he left the Workshop to take up commercial work, but he returned after a few years. I suspect that he missed the friendship that was clearly evident amongst the men in the Workshop. When he and Angela retired they moved to a bungalow near my sister’s home, and so I used to see them from time to time.

Another watchmaker, George C Wilkins, shared my name, but he was much older than me. He was short and had a stiff leg, and so I was very surprised when I found that he also could beat me at table tennis, which he played close to the table with a pen-holder grip. The first apprentice to be trained in the Workshop was Johnny Lipscombe; he successfully completed his apprenticeship in 1953 and was then

employed as a ‘journeyman watchmaker’. He left after a while and had a career with IBM.

The total number of chronometers and watches repaired and adjusted in 1949/50 was 2204, so that each man must have dealt with at least one chronometer (or watch) each day. Apart from the regular work on the chronometers for the Royal Navy and the RAF, as well as on some for other Commonwealth countries, the Workshop took on special jobs from time to time. For example, the Report of the AR for 1950 mentions the fitting of a new gear train in a non-magnetic clock mechanism for use in a La Cour magnetograph. In that year it also dealt with an astronomical regulator (pendulum clock) for the Royal Observatory at Edinburgh, as well as with a Shortt free-pendulum clock for the National Physical Laboratory. New ideas for clock mechanisms were also tested and experimental work was carried out. Equipment for the testing of watertight watches was made in the Engineering Workshop and brought into use in 1952/53. From time to time the Harrison chronometers were cleaned and adjusted for the National Maritime Museum. [RAR 53; I have a slides of no 3 and of no 4 in pieces some years later] [See RAR 54 for other work, including that on a Dent clock for the Royal Yacht Britannia] The size of the workshop was increased and more staff were recruited in 1952/53.

A leaflet on Chronometers that was produced for visitors in the late 70s gives more about history and about modern quartz chronometers. Roseman has written an account of the Chronometer Section for the period 1914 to 1981 and also a chronological list of chronometers, clocks and depots for the period 1728 to 1919. [My copies were given to me by H E West in 2006 with photographs taken in the workshop.]

2.4.3 The Chronometer Office

The paperwork for the Chronometer Department was done in the office on the north side of the Library landing in the Castle. The Head of the Department was George W Rickett, who had served in the RO since 1918. Each year he used to write the script for the pantomime put on by the Club. His deputy was Arthur Shortland, but the Chronometer Office was mainly staffed by ladies, who kept track of the thousands of chronometers and watches that were received, maintained, rated, stored and issued each year; some 15000 watches were on charge to the RGO in 1950. The girls who did the rating were graded as Scientific Assistants.

The chronometers had to be rated under varying conditions of temperature, and rooms on the lower floor of the west-wing of the Castle were fitted out for this purpose. In addition to a main room kept at ordinary temperature there was a warm room and a large refrigerator. RAR 51 states that for RAF Mark 7A watches: “The test period for watches of this type occupies five days in two positions with a percentage of watches being tested in extremes of heat and cold”.

2.5 The Meridian Department

2.5.1 The work of the Meridian Department

The high international reputation of the Observatory was based largely on the long series of accurate observations to determine the positions of stars, and of the Sun, Moon and planets, that had been made with a succession of special-purpose telescopes,

most of which moved only in the plane of the north-south meridian through the instrument. The position of each star is represented by two coordinates: the declination (that is angle in the meridian measured from the celestial equator) was determined by reading an engraved circular scale, while the right ascension (that is the angle measured around the celestial equator from the zero point, which is, misleadingly, called the 'First Point of Aries') is given by the sidereal time at which the star is seen to cross, or 'transit', the meridian. Such instruments are known as 'transit circles' or 'meridian circles'. The sidereal time was given by a clock whose error was itself determined from observations of clock stars, whose right ascensions were assumed to be known accurately as a consequence of many earlier observations. A special eye-piece was used for such observations; many different precautions were taken and special observations were made to eliminate or determine the various small errors that arose from imperfections in the instrument and other causes. Each star was observed several times and the 'reduction of the observations' (that is the calculation of the positional coordinates for publication) was a tedious job that was carried out by human computers.

The most famous of the instruments used by the Meridian Department was the Airy Transit Circle, which was first installed at Greenwich in 1851. It was taken out of service during the war from September 1940 until May 1942 but then, after the destruction of the Pulkovo Observatory, it was brought back into use for a minimal programme of observations of the Sun and planets, with associated clock and azimuth stars, until 1949. A large programme of observations was then started to provide accurate positions for use with a new 'photographic zenith telescope' (or 'tube') that was then being made for use at Herstmonceux. Observations with the Airy Transit Circle continued until 30 March 1954, when the last observation was made by Gilbert Satterthwaite, then a junior member of the Department.

The Observatory also had two other transit circles. One was usually known simply as the 'Reversible Transit Circle' (RTC), but sometimes as the 'Cooke RTC', after the name of the manufacturer, Thomas Cooke and Co., to distinguish it from the 'Melbourne RTC', which had been retrieved from the Melbourne Observatory when it ceased operation.

A transit circle swings in the plane of the meridian (or north-south vertical plane) and the time at which a star is observed to cross the meridian is measured and then used to calculate the right ascension (RA) of the star. Timing contacts are made as the observer follows the star across the field of view of the telescope. The angle above the horizon, or rather the angle below the zenith (the point directly overhead), is measured (by means of six microscopes) with respect to a finely engraved graduated circle. This angle is used to calculate the declination (Dec) of the star. (RA and Dec correspond to longitude and latitude on the Earth.) Great care has to be taken to eliminate as far as possible the errors that may arise in various ways in this process. One of the ways in which this is done to use a reversible transit circle, which is such that its telescope may be lifted out of its pivots and then turned before being replaced. Observations are made in both positions in order to detect any misalignment of the instrument.

The Cooke RTC was still being commissioned when observations were stopped towards the end of 1940. A great deal of effort was expended during the recommissioning at Greenwich from 1946 onwards in order to determine and then to eliminate or reduce sources of error in the instrument prior to installation at Herstmonceux. No attempt was made to re-assemble the Melbourne RTC prior to the

move as the original intention was to install it in a new pavilion, and then to move its pavilion from Greenwich for use by the Cooke RTC. It was later decided that the Cooke RTC needed a new pavilion and that it should be moved first. It was then intended that the Greenwich pavilion and the Melbourne would follow. A few years later it was decided that the Melbourne RTC should also have a new pavilion, and some components of the instrument were set up at Greenwich to provide data for its design. Eventually, however, the plan to operate two RTCs at Herstmonceux was abandoned. (See section 3.2.3.).

The effects of refraction in the Earth's atmosphere are least at the zenith, and so several instruments have been designed for observations near the zenith to determine the variation of latitude due to the motion within the Earth of the axis of rotation of the Earth. The Observatory had at Greenwich, on loan from Cambridge University since 1911, the 'Cookson floating zenith telescope'. The observations were made visually by an observer and it was used until 1939. The Cookson FZT was dismantled in 1953 and was eventually passed to the Science Museum. In a photographic zenith telescope the stars are observed by photography as they cross the meridian very close to the zenith. Small photographic plates containing the images of the stars are measured and the results used to determine the variations in both the rate of rotation of the Earth and the direction of the axis of rotation. These variations show themselves as irregularities in sidereal time and as apparent changes in the latitude and longitude of the site.

The US Naval Observatory had developed a much-improved photographic zenith telescope (PZT) and it was decided that such an instrument should be designed and constructed for installation at Herstmonceux. This PZT was designed by Dr D S Perfect, who was then based at Abinger. In his article about the PZT he refers to it as a 'tube' rather than as a 'telescope'. (See appendix G.3.2) By September 1949 some of the components had been completed and assembled by the manufacturers, Messrs. Grubb-Parsons, for a demonstration during the meeting of the British Association at Newcastle. It was also on display in the Dome of Discovery during the 1951 Festival of Britain.

A new measuring machine was required for the small photographic plates to be used by the PZT, and a full-scale model was constructed in the Optical Laboratory at Abinger to test some of the new ideas in the design. In the event, the plates were measured on an early Zeiss 2-coordinate machine that was acquired as war reparations.

In 1945, Dr Atkinson, then Chief Assistant, put forward a proposal for a 'horizontal transit instrument', in which the light from a star near the meridian was directed into a fixed horizontal east-west telescope by a subsidiary optical system. This was accepted, but the project was given lower priority than the PZT. Subsequently, consideration was given to a 'mirror transit instrument' (sometimes erroneously called a 'mirror transit circle') in which a mirror was used to direct the light into two fixed horizontal telescopes to the north and south of the mirror. Work continued on this project for several years, but it is not mentioned in the AR's reports in 1954 or 1955. Atkinson continued to work on this project (undertaking the detailed engineering design himself) until his retirement. (See section 3.1.2)

The staff at Greenwich, as well as staff at Abinger, made observations with small transit instruments for the determination of sidereal time from which Greenwich mean time could be calculated), and they also tested and modified them. The time service used the small-transit instrument at Abinger from 1940-1946 and then at

Greenwich from 1946 to 1957. It was intended that a small pavilion should be built at Herstmonceux for observations with the Bamberg broken-transit instrument from Abinger (on loan from ROE). The Bamberg was, however, not used at Herstmonceux and instead the pavilion was used briefly for a small transit and, later, for the prismatic astrolabe. (See section 3.2.3.)

2.5.2 The Meridian Group and the move from Greenwich

In 1950, Spencer Jones reported that "the target date for the completion of the removal of the Observatory to Herstmonceux is still the end of 1953". But he went on to note that work had not then started on the meridian group of buildings and that the target dates had slipped to the spring of 1951 for the Cooke RTC, the summer of 1951 for the PZT and the middle of 1952 for the Melbourne RTC, which was still in the programme at that time. The pavilion for the Bamberg transit was not mentioned. The 'Meridian Group' was to be built on the ridge of the hill to the north-west of the Castle. In addition to the pavilion for the PZT, there was to be a separate building from which the 'observer' could operate it remotely. This PZT Control Building also had a rest room and kitchen facilities for the use of all the observers at the Group.

Work on the construction of the RTC pavilion and PZT buildings did not start until April 1953 and April 1954, respectively. By November 1954, the RTC, PZT and Bamberg buildings were complete, and it was then thought that work on the piling for the Melbourne pavilion would soon be started. The Cooke RTC was moved from Greenwich in 1955, and the first observations were made in 1956, but regular observations did not begin until after Spencer Jones had retired. Rather surprisingly, he had reported in 1955 that "the concentration of the available manpower of the Meridian Department on overtaking arrears of reductions has delayed completion of the installation of the instrument in its new housing". The PZT was installed in late 1955, the first plates were taken towards the end of 1955, and regular observations began in 1956. It was decided in 1956 not to proceed with the installation of the Melbourne Transit Circle.

The first member of the Department to be permanently transferred to Herstmonceux was Kenneth C Blackwell, then an Experimental Officer, in October 1953. He was followed in April 1954 by Dr Philip J D Gething, who was amongst the first Temporary Scientific Officers to be recruited. I am not sure whether it was by chance or design that the date of his move allowed him and his wife, Helen, to take the tenancy of the bungalow that my wife and I had been renting at Pevensey Bay.

The Head of the Department, L S T Symms (a PSO), together with Gilbert Satterthwaite and Virginia Papworth (SAs), moved in July 1954. The Department then started to build up the strength of its junior staff in anticipation of the large amount of work involved in making and reducing the observations to be made with the RTC and PZT. They included Pat P Scott (SA), the daughter of W A Scott in the NAO, and Ron W Teague, who was transferred from the Solar Department, but he resigned in September 1955. In March 1955, C Andrew Murray, who had been recruited as an AEO at Greenwich in 1950, was promoted to Scientific Officer; such class-to-class promotions were quite difficult to achieve, and was certainly well justified by his later contributions to astrometry. He moved to Herstmonceux in August 1954. The Meridian Department had the use of two rooms on the ground floor of the north wing of the Castle.

The Meridian Department made use of Crelle's and Cotsworth's arithmetical tables since a lot of their work was deliberately designed so that it involved arithmetic with small numbers. This was regarded as very old-fashioned by the NAO staff! It was clearly appropriate that the Meridian Department should use the NAO punched-card machines for its computations.

When the early observations were made with the PZT it was found that there was a discrepancy between the observed longitude (from the Greenwich meridian) and that given by the Ordnance Survey data. It was then realized the OS had continued to measure longitude from the Bradley meridian even after the adoption of the meridian of the Airy transit circle by the international conference in Washington in 1884.

Dr Atkinson, who had taken a particular interest in the instruments for the Department, transferred to Herstmonceux in August 1955; he had been responsible for the design of the astronomical clock that is in York Minster. (See section 2.6.3)

Owing to the delays in the completion of the buildings and the transfer of the instruments, Sir Harold Spencer Jones retired before the new programme of transit-circle observations started at Herstmonceux. The Meridian Group was later renamed the Spencer Jones Group.

2.6 Other departments

2.6.1 The Time Department

During the war the Greenwich Time Service (as it became known later) was maintained from two stations, Abinger and Edinburgh, at the Royal Observatory (ROE) on Blackford Hill. Astronomical observations with small transit instruments were made at both stations so that the clocks could be kept in synchronism with Greenwich Mean Time as given by the rotation of the Earth with respect to the stars. The bulk of the work of the Time Department was carried out at Abinger, but the computing work was carried out at Edinburgh — presumably to ensure that the staff had work to keep them occupied when they were not operating or maintaining the equipment. L S T Symms was the senior RO staff member there. There was a direct line between ROE and the Post Office Radio Station at Rugby for controlling the broadcasting of the GBR radio time signal.

The station at ROE was closed at the end of January 1946, and a reserve station was then installed at Greenwich so that it could be ready to send time signals to the BBC, but it was never required to do this. C C Harris was in charge of the time activities at Greenwich. Observations were made with the small transit instrument in the altazimuth dome. As a consequence of the delays in the construction of the West Building, the Time Department remained at Abinger for a further ten years, until after Sir Harold Spencer Jones had retired; major developments took place during this period. The activities are reported extensively in the annual reports of the Astronomer Royal to the Board of Visitors, and so only brief details are given here.

The Head of the Time Department was Humphry M Smith, who had been appointed to the post in October 1936; he acted as Officer-in-Charge at Abinger after Spencer Jones had returned to Greenwich. The members of the staff could be broadly divided into two groups: those who used the equipment and analysed the data from the astronomical observations and from the clocks, and those who were primarily concerned

with maintenance and development of equipment for the generation and distribution of time and frequency signals. The clocks were compared amongst themselves and with clocks at the National Physical Laboratory and the Post Office establishment at Dollis Hill, where new frequency standards were being developed. The RGO timescale was also compared with radio time-signals from other countries.

Staff in the first group included H F Finch and younger staff, such as C J A (Joy) Penny, N J P (Nathy) O'Hora and R H (Tommy) Tucker, whose names will come up in other contexts later; Joy Penny had been one of the staff at ROE and then at Greenwich. Apart from Smith the second group included G B Wellgate (a refugee from Germany – see appendix C.14), L J (Joe) Bates, Henry G Gill, John D Pope, A P Lamb, and Eric Shepherd, who moved to GCHQ (as did Gething) and eventually retired, like John Pope and myself, to Sidmouth. In addition, there was Dr D S Perfect, who at first was seconded from the NPL, but who transferred to the permanent RGO staff as a PSO in 1949; he was primarily responsible for the design of the new Photographic Zenith Telescope (see section 2.5.1).

The mechanical clocks, such as the Dent regulator and the Shortt free-pendulum clocks, were completely replaced by an ensemble of quartz-crystal oscillators, or quartz clocks. The final transfer took place in 1950. Some of the regulators continued to be used to control the drive motors for the telescopes. The Dent regulator itself was overhauled and installed in the Dome of Discovery at the South Bank Site of the Festival of Britain in 1951 as part of an exhibit showing the development of time standards. A Shortt clock was installed under the West Courtyard of the Castle at Herstmonceux for use as a standard by the Chronometer Department. Phonic motors continued to be used, moreover, for transmitting the six-pips time signal to the BBC — it was referred to as the six-dots signal until 1951. Improvements were made in the equipment and mode of transmission to increase the reliability of the system.

There was concern that the military radar station on the Pevensey Levels might interfere with the reception of time signals at Herstmonceux. The most obvious sign of the station was a set of three very tall masts, which looked like enormous electricity pylons, between which the aerial wires for receiving the returning signals were suspended; the transmitter aerials were much less conspicuous. They were about 2 miles due south of the Castle and near the road between Pevensey and the tiny village of Wartling. (The RGO vehicle used this road in the journey between the Castle and Pevensey Bay Halt; I cycled and later drove along it each day while I worked at the Observatory.) There was a group of typical military huts on the other side of the road. The system was replaced by modern equipment with an underground control centre some way away, at the end of the ridge that ran south from Wartling. The masts were eventually demolished, but some of the buildings remained for many more years even after the site was used for grazing. The RAF personnel were based near Little Common and had a long ride via Pevensey by coach to get to the operational site as there was no suitable road on the north-east side of the Levels. I recall going to the base once for a tennis match; the base was eventually converted to an open prison.

The timescale given by quartz clocks proved to be more uniform than the scale of universal time (UT) given by the rotation of the Earth as determined by observations of the stars. (The name GMT continued in use for ordinary civil purposes and for navigation, but UT was used for scientific purposes.) The latter scale was affected by seasonal variations in the rate of rotation and by the motion of the axis of rotation

within the Earth, which changed the position of the ‘true’ north pole and hence the latitude and longitude of each observing station. The nature of this ‘polar motion’ had been established by an American, S C Chandler, who showed that the ‘errors’ in the 19th century observations of star coordinates made at Greenwich were largely due to this cause.

The existence of seasonal variations in the rate of rotation of the Earth was demonstrated in 1936 and 1937 by studies at the Geodetic Institute at Potsdam and by N Stoyko at the Bureau International de l’Heure in Paris. Subsequent work at Abinger suggested by 1950 that the earlier estimates of the magnitude and phase of the variation were grossly in error. (See appendix G.3.2)

Most users of the time signals required a uniform timescale that gave a correspondingly stable standard of frequency, and so predicted corrections were applied to the observed values of universal time (UT0), to remove the effects of polar motion (giving UT1) and then the effects of the seasonal variation (giving UT2). The resulting timescale was largely free of periodic variations, but it was still affected by the long-term fluctuations in the rate of rotation of the Earth, which at this time were causing a gradual increase in the length of the day.

The RGO was the first (in January 1948) to apply the corrections for polar motion. Smith played a leading role in the international negotiations, especially in IAU Commission 31 (Time), that led to the formal introduction of this series of UT scales in 1955. The correction for polar motion was particularly important for the navigation of spacecraft to the planets as it corresponded to an error in the calculated orientation of the Earth in space and hence in the direction of the spacecraft with respect to the direction of the target planet. A Rapid Latitude Service was also established in 1955 so that the observational data would be sent quickly to the BIH in Paris for analysis.

Considerable improvements in timekeeping and in the distribution of time had been made through the use of quartz clocks, but the design for the West Building, on which work started in August 1954, took account of the expected development of atomic clocks, which would change fundamentally the character and accuracy of timekeeping. The Time-Department spur of the building included provision for an enormous (two-storey) ‘atomic-clock cellar’, as well as for many small rooms for quartz clocks in the sub-basement, below the Control Room. It was recognized that the Greenwich Time Service would play a vital role in any future war and so the building was also designed to withstand enemy attack.

2.6.2 The Astrometry and Astrophysics Department

The Astrometry and Astrophysics Department at Greenwich was headed by Alan Hunter, who had joined the ROG in 1937, and it included E G Martin, Ethel Moore (Harris), B J Harris, and C M (Mike) Lowne, who joined in 1950. The major project was the measurement of the large series of plates taken for the Cape Photographic Catalogue. There was also an informal optical section for testing equipment. It found that the objective that Flamsteed intended to use for his well telescope would have been useless!

2.6.2.1 Observing at Greenwich

The principal equatorial telescopes of the Observatory at Greenwich had been dismantled for safe storage and their domes were damaged during World War 2. The

Yapp 36-inch reflector was brought back in use in 1947/48 to obtain stellar spectra; it was decided to revert to the pre-war procedure of silvering the mirror every 6 months as it had been found that commercial aluminizing was unable to withstand the Greenwich atmosphere. The 13-inch astrographic refractor was brought back into use in 1950 for a programme of observations of the principal minor planets to provide a better determination of the position of the equinox, that is of the zero point of right ascension. Observations of the positions of other minor planets, comets and other objects were also made. It was, however, decided not to attempt to bring the other telescopes back into use until they could be rebuilt and recommissioned in new buildings at Herstmonceux.

Various tests were also carried out with these two telescopes. In early 1954, F J Hargreaves used the Yapp reflector to televise Jupiter and the Galilean satellites. A successful public transmission was made at the end of broadcasting on January 13, but the following evening, when a full programme was scheduled, the sky was cloudy.

2.6.2.2 Eclipse expeditions

Cine-film observations were made during the total solar eclipses of 1 November 1948 at Mombassa and 25 February 1952 in Sudan, Kuwait and Iraq in order to improve our knowledge of the profile of the Moon. The technique was devised by Atkinson and the work was done with the cooperation of C B Watts, at the US Naval Observatory, who was then preparing a new atlas of charts of the limb of the Moon. This was required mainly in connection with the use of observations of occultations of stars by the Moon for the determination of ephemeris time and the improvement of the lunar orbit (see section 2.2.4.3). Murray assisted Atkinson in this work. There were four stations for the eclipse in 1952, two on either side of the track. The observers were Atkinson, Blackwell, Cordwell and John Pope, who set up equipment in Iraq, but after many clear days it was cloudy on the important day! It was, however, clear at the other three stations.

Earlier, Dr Alan Hunter, who had been engaged on other Admiralty work during the war, was in a plane which crashed at Dakar on 13 April 1946 on a flight to Brazil to observe the eclipse on 20 May. Dr Hunter suffered only minor injuries, but the other two members of the expedition, who were not on the staff of the RGO, were killed. He and Thomas Gold (see section 2.7.2) went to Sweden in 1954 in an attempt to measure the Einstein displacement, but the eclipse was veiled by thin cloud.

The Astronomer Royal and Sadler observed the total eclipse of the Sun on 30 June 1954 from a Hastings aircraft flying at 8500 ft about 100 miles south-west of Reykjavik in Iceland. The flight was carried out as a navigational exercise, but M A Ellison (Royal Observatory, Edinburgh) and Joan Paton (University of Edinburgh) made measures of the colour of the sky during the partial and total phases. The corona was, however, too bright to allow them to see the aurora as they had hoped. The NAO produced a leaflet giving the circumstances of the partial eclipse in the British Isles.

2.6.2.3 Accommodation at Herstmonceux

Offices for the members of the Astrometry and Astrophysics Department were provided in the Long Gallery of the Castle on the first floor of the north wing, above the rooms for the Meridian Department. This involved the erection of partitions, since this was before the days of open-plan offices, and so the grandeur of the Gallery, with its panelled walls, carved-wood fireplace and ornamental ceiling was completely lost. The

Gallery had been designed for use as a ballroom and had a polished, sprung floor. We must be thankful, however, that the views of the staff at Abinger were not adopted — they proposed that the Long Gallery should be used for the library so that the Great Hall would be available for the annual meeting of the Board of Visitors, luncheons, and hockey dinners! In later years the Long Gallery was sometimes used for dances and other social functions, as well as for conferences, and so it was also referred to as the Ballroom. An anonymous proposal in IB 85/12 that only the latter name should be used did not, however, find favour. As far as I can recall, these offices were still empty when Spencer Jones retired.

2.6.3 The Observatory Workshop at Greenwich

The man in day-to-day charge of the engineering workshop at Greenwich was A C S Wescott, and he was assisted by about 5 men who were described as laboratory mechanics in the AR's annual report. Their first task was to maintain the telescopes and to make the required changes in the instruments that were used with the telescopes; this task included the re-silvering or re-aluminizing of the primary and secondary mirrors of reflectors. Their second task was to construct new instruments to the specifications of the astronomers; there is no sign of an engineering draughtsman in the list of staff so it seems likely that the foreman had considerable responsibility in respect of the detailed design of the new equipment.

Some of these 'instruments' were very unusual. For example, before the war the workshop constructed the 'occultation machine' that was used in the NAO. (See section 2.2.4.3.) The first such machine was constructed in wood for use by amateur members of the British Astronomical Association, but Mr Wescott redesigned it in metal, and it gave extremely good service for about 40 years.

The workshop staff also constructed the astronomical clock that was installed in York Minster as a memorial to RAF personnel who died in World War 2. It was designed by Dr Atkinson as a commission by the Dean of York during the RAS out-of-town meeting at Leeds in 1952. The work was carried out on a 'voluntary overtime basis'. It was unveiled by the Duke of Edinburgh on 1 November 1955. (See appendix G.1.3)

I have cause to be grateful to Mr Wescott for personal reasons as he took the dent out of the lens cell of a damaged telescope that I had been given by my dentist. I was then able to fit a new lens and take the telescope to evening classes for use by the students.

2.6.4 The General Office

The staff of the Secretariat, as it was called in the staff list in the AR's 1949 report, moved to Herstmonceux at the same time as the AR in August/September 1948. The main office comprised two rooms and a turret (used by the 'Secretary and Cashier', Mr H G Barker) on the ground floor in the south-east corner of the Castle, adjacent to the AR's office in the east wing. The typists had a room above the main office; it was adjacent to the room that was to be occupied by the Solar and M&M Departments.

The number of staff was then very small in comparison with the number in later years. Mr Barker's deputy was Mr John H Whale, and there were two clerical officers, two clerical assistants and two temporary clerks; of these Miss Joan Perry was in the NAO and Mr Fred A Everest (at least) was at Abinger. There were 5 typists, of

whom, presumably, at least one would have been at Abinger. By the time of the AR's 1952 report, Fred Everest had been promoted to the clerical officer grade (from temporary clerk) and the Hewerdine twins, Anita and Celia, had been recruited as additional typists.

The Typing Pool provided a secretarial service for all departments, including the NAO, which was the only department to have any clerical staff based in it. Anita and Celia used to take it in turns (I believe) to come over each morning to the NAO hut to take shorthand from Mr Sadler and any other of the senior NAO staff who dictated their letters (Miss McBain, Dr Porter, Mr Richards). Other NAO staff would draft letters, memoranda and scientific papers in longhand and send them in transit to the Typing Pool; I assume that other Departments were treated in a similar way. There were then two 'Varityper Operators', Miss Rosemary Weakley and Miss Shirley Page, who dealt with the scientific papers that included mathematical formulae, Greek letters and other special characters. The special typewriters used proportional spacing and so gave results that were comparable with typeset material and that could be used directly for printing by photolithography.

In these days of sophisticated photocopiers it is salutary to recall the effort that was then required to produce multiple copies of documents. For newly-typed letters and memoranda it was possible to produce up to about 8 copies at the most by the use of carbon paper and very flimsy paper, or 3 or 4 copies if better paper was used. When more copies were required it was necessary to cut a waxed-paper stencil and then to duplicate the required number of copies, one side at a time; I believe that the Typing Pool had an electric machine so that it was not necessary to turn the handle manually. Corrections could be made to a stencil by the use of a liquid ('correctine') that was like pink nail varnish; it filled the holes and allowed the correct material to be typed in — provided that it did not require more space. The correction of errors on carbon copies was very time consuming and so accurate typing was at a premium. The typists were very good and coped well with my writing, which got steadily worse as time went on.

It was difficult to prepare diagrams on a stencil and there really was no satisfactory way of producing locally multiple copies of complicated diagrams or of incoming documents or of papers in journals. Consequently, authors of papers would order multiple copies of reprints of their papers for distribution by post to persons who would be interested in receiving copies for their personal use. The NAO had a numbered system for reprints of papers produced by NAO staff and a standard list of persons or organisations to which they were sent. The Pool also had a machine for addressing envelopes from a set of metal 'addressograph' plates, but I do not recall seeing this in operation. It was possible to send diagrams away to an office in the Admiralty which would produce 'photostats', but this was rarely done. A photostat copying machine was installed at Herstmonceux at the beginning of 1954, but the results were poor by modern standards.

The NAO retained some of the independence that it had had before it moved to Herstmonceux, but all financial matters, such as pay and the purchase of equipment, were dealt with by the Secretarat. The NAO had its own filing system for correspondence and memoranda, but I subsequently learnt that the Secretariat kept one copy for its files of all letters (at least) that were typed for NAO staff. As far as I am aware, other departments (with the possible exception of the Time Department) relied upon the Secretariat to file their correspondence.

The NAO did, however, deal directly with H M Stationery Office on such matters as the printing of the publications. At that time HMSO supplied office stationery without charge, so that reliance was placed on local staff to be economical in their use. The NAO used the backs of proofs for drafts, internal memos, rough working, etc and it used to obtain superseded Admiralty charts, which were cut to various sizes, for use as backing paper for the pasting of strips of printers' copy prepared on the Hollerith tabulator or National machines. I used to like to use such charts for use as file covers for the many different jobs with which I was concerned. These 'white files' were distinctive and fitted into the solander cases more easily than the standard issue of brown file covers. Some of the charts were of very interesting areas; I remember that one batch covered the Solent and the Isle of Wight. I still have some of them in use today.

Reference has already been made in section 2.2.6.1 to the special stationery used in NAO for recording computations. This was also supplied by HMSO, as were the special double-hole paper punches. For a long time I used double-hole paper for text as well as numerical work, but I eventually reverted to the standard civil service system. Correspondence is always filed so the latest letter is on the top of the file. This has the advantage that the back end of the tag can be inserted through the hole in the front cover of the file and can be used for the filing of supplementary comments and notes. I still have a single-hole paper-punch and it is used many times each week!

The Secretariat was also responsible for the domestic support staff. The messenger service played a very useful role in moving letters and memos around the site and within buildings. The messenger on duty at the West Entrance to the Castle also acted as receptionist for visitors. At the time we took the efficient service for granted, but in later years of staff cuts its absence resulted in frustration and waste of time by highly-qualified staff. Kitchen staff were employed to provide breakfast and an evening meal for those living in the hostel and to provide lunches for those staff would did not wish to bring their own food. There were also cleaners for the Castle and for the offices. Many of these staff lived in Herstmonceux and special transport was provided for them.

2.6.5 The main RGO Library

There was no post for a librarian in the Observatory until Mr W P Preston was appointed as a 'trained Librarian' on a temporary bearing on 1949 February 3 to cover the full period of the reorganization caused by the move to Herstmonceux. I assume that up to that time the work was carried out by a clerical officer (or assistant) under the supervision of one of the astronomical staff. The post was listed as being part of the Secretariat, but I doubt whether Mr Barker took any interest in the Library and so I suppose that in practice Mr Preston reported directly to the Astronomer Royal, who would have had no time to take an interest in the details of the work. The NAO had its own library, which it retained until the move to Cambridge in 1990, and which was run by a Clerical Officer (Joan Perry) (see section 2.2.7.6). I assume that the Magnetic and Time Departments would have built up small collections at Abinger, and that the books would have been catalogued with those of the main collection at Greenwich.

At Herstmonceux the main library of the Observatory was housed in what had been the Great Hall of the Castle. I have been surprised to find that the main library had not been transferred to Herstmonceux by the time that I joined the NAO in October 1951, as I do not recall seeing any signs of the reconstruction work nor any specific occasion on which the Library was opened for use by the staff. The Great Hall did not

have a solid floor and so it was necessary to reconstruct the floor to enable it to carry the weight of the books. It was also necessary to build a gallery along the west side in order to accommodate the whole collection and allow space for acquisition of new books and current journals.

The work of reconstruction and fitting-out took an incredibly long time. The work of reconstruction of the floor was nearly complete in spring 1949. The steelwork for supporting the gallery was complete in spring 1950 and the method of lighting was under consideration. The adaptation was nearly complete in spring 1951, the lighting installation was still under consideration and tenders for the supply of shelving were soon to be invited. By spring 1952 the lighting was being installed, but otherwise the adaptation was complete and the removal of books from Greenwich to Herstmonceux had commenced. The lighting, apart from the reading lamps for the tables, had been completed by spring 1953. The bookcase for the collection of rare books was being made in spring 1954 and the recataloguing and rearrangement of the Library had been begun, but it was still in progress in spring 1955.

The large gothic windows on the east side gave good light for readers using the very large elliptical table that was brought from the Octagon Room in Flamsteed House at Greenwich. After dark, the main light was provided by three chandeliers that had been specially designed for the Castle — rumour had it that their cost was astronomical! Striplights were provided for the bookshelves. Most of the top shelves were too high for easy access.

The musician's gallery was used for the librarian's office. This must have suited Mr Preston, but it meant that readers could not easily obtain help from him. It was also used for the large cabinet for the collection of rare books; it was designed to keep the dust off the books, rather than for security as at that time their financial value did not appear to be recognised. Even many years later this was still true — even 18th century volumes were put out on the 'books for disposal' racks in the 1960s — the volume that I obtained in this way is now in the NLO Library at Sidmouth. Appropriate action was not taken until Janet Dudley was appointed as Librarian.

Mr Preston decided to use the Universal Decimal Classification System (UDC) to arrange the books on the shelves and the index-cards in the subject catalogue. This was appropriate for the collection, especially as Dr Hunter was able to participate in the updating of the classification that took place at the time of Preston's appointment. Unfortunately, apart from his being terribly slow in cataloguing the books, some of his classmarks were inappropriate and, as far as I am aware, he made no attempt to inform the readers about the system, either in talks or by an adequate provision of guides to the system. No attempt was made to classify the books before they were moved to Herstmonceux and so they could not be put on the correct shelves until much later — after April 1955, when the new class numbers were stamped in gold lettering on the spines of the books.

Since the NAO Library met most of my needs I did not make much use of the main Library, although I did go in during some lunch-breaks to look at the new acquisitions of periodicals that were displayed on the main table. The first AR to build up the Library was George Airy and he was responsible for the purchase of most of the early books in the collection. The Library had a very good collection of serial publications, both regular journals and the publications of other observatories and institutions for astronomy, geodesy, geomagnetism and related subjects. The AR's 1953

Report states that the removal provided the "opportunity to discard many volumes of meteorological observations, for which the Observatory has no use" — one hopes that they were offered to the Meteorological Office Library! In pride of place, just inside the main door, was a leather-bound set of the *Philosophical Transactions of the Royal Society*, which was one of the few scientific organisations that was older than the RGO itself.

The library had a collection of lantern slides that could be used by members of the staff who were asked to give talks about the Observatory or astronomy. They were made of glass and were 3¼ inches square. Some were made in-house, but others were bought from the Royal Astronomical Society. The projectors were usually made of brass and were large and heavy. The first projector for the new 2x2 slides (2 inches square) was obtained in December 1954. Each slide had to be inserted individually into the slide carrier, which was then pushed across so as to show that slide and allow the previous slide to be removed and replaced by the next one.

2.7 Other aspects

2.7.1 The design and construction of the new buildings

The criticisms of the Solar Dome (see section 2.3.1) were so vociferous that the Admiralty was forced to appoint an external architect for the design of all the other buildings on the site — in particular, for the design of the Equatorial Group, which was to be on the hill to the east of the Castle. The Admiralty announced in January 1950 that Mr Brian O'Rorke, ARA, FRIBA, had been appointed as the consulting architect for the Herstmonceux scheme as a whole. Nevertheless, the Civil Engineer-in-Chief retained responsibility for the Meridian Group of instruments and he decided that no building work should go ahead until *detailed requirements* for the buildings in *every group* had been supplied. This introduced additional delays and put an extra load on the senior staff of the Observatory as they had to complete the planning work more quickly than had been anticipated.

At this time, the AR had only two Chief Assistants, Dr Atkinson and Mr Sadler as Superintendent of the Nautical Almanac. As far as I am aware, Sadler was not then expected to play any role in the general administration of the Observatory. There was a vacancy for another Chief Assistant as Dr H R Hulme had resigned on 1945 December 15 and had not been replaced. In fact, he was not replaced until the autumn of 1952 when Dr Thomas Gold was appointed (see section 2.7.2), by which time the initial planning was completed.

A further cause of delay in the construction of the new buildings arose from the Consulting Architect giving priority to the design of two of the buildings for the South Bank Exhibition for the Festival of Britain in 1951 and to the alterations at the Memorial Theatre at Stratford-on-Avon. Some of the civil engineers responsible for the oversight of the work at Herstmonceux used to stay in the men's hostel and their frustration at the delays (some of which were due to purely financial stop-go situations) was very clear. One engineer was delighted that he was able to see one job through to completion while he was there: turf was laid along the verges of the road to the East Gate after the laying of the kerbstones had been finished. Another decided that the ornamental pool at the north end of the formal gardens should be emptied, inspected and cleaned. I took the opportunity to have a swim in the clean water, but it very soon became green again.

The Meridian Group was to consist of several largely independent buildings for individual instruments and there was little scope for architectural embellishment. The Nautical Almanac Office and the Time Department were to share a building on the hill to the south-west of the Castle. An engineering workshop and a chronometer repair shop (usually known as the chronometer workshop) were also required. [RAR 50, 3] These four units were eventually included in the West Building, which also included a store for equipment that was used on eclipse expeditions, a store for the records of the Observatory (later referred to as the archives), and a small canteen for use by staff who brought their own lunches. I do not know who was responsible for proposing that all these requirements were brought together in the one building.

There is no reference in the AR's 1950 report to the Works Pound, which was eventually built near the West Gate. The pound provided facilities for the heating plant for the West Building, the maintenance staff for the Castle and for the Observatory buildings, and a large garage for vans and industrial vehicles. The garage for the official car used by the AR and a gardeners' shed were adjacent to the Head Messenger's cottage near the west entrance of the Castle. I assume that these were there when the RGO took over the site. A modern single-storey cottage, with adjacent garages, contained homes that were used at first by staff of the Works Department. It appears on the aerial photograph that was taken in about 1949, but it may have been built by the Works Department.

There were air-raid shelters at the corner of the road to the south-west of the Castle; they were left there for many years before they were eventually demolished and the ground levelled.

The Equatorial Group on the hill to the east of the Castle was where the consulting architect had the greatest role and where his design had deleterious consequences for the astronomical functions of the Group. The original statement in the report for 1950 was as follows:

"The Equatorial Group is planned to have three isolated domes for the 26-inch, 28-inch, and Astrographic refractors, with a three-dome building in front of them to take the 30-inch and 36-inch reflectors, and also a Schmidt camera of about 25-38 inches, together with aluminising room and plant, plate-standardising laboratory, darkrooms for the whole group, and probably some spare space which can be used for storage until it is otherwise required."

There was no mention of an ornamental pool between the reflectors and the refractors nor of walkways and steps that presented serious hazards to observers walking between the domes in the dark. The impressive entrance and flint-faced retaining walls were features that added to the cost and hardly seem to be justified by the supposed improved appearance of the Group. The most damaging decision by the architect was that the domes and roofs should be clad in copper that would eventually corrode to green copper oxide. It was clear that this copper cladding would absorb the heat of the Sun, whereas the usual 'silver' domes reflect the Sun's rays. It was therefore necessary to take special steps to insulate the inside of the domes and shutters as it is desirable that the air inside the dome should be at the same temperature as the outside air when the shutters are opened at night. The extra weight of the copper and insulation meant that the domes and shutters were heavier than would otherwise have been the case, and this almost certainly contributed to the troubles that were experienced in

opening the shutters and rotating the domes. John Pope has described these troubles in his *Diary of a Telescope Engineer*. (See appendix G.7.3).

Work on the foundations of the Equatorial Group on the hill to the east of the Castle was started in 1953 and the erection of the domes was in progress in November 1954 [IB 31]. During the following year progress was so slow that no reports were included in the Information Bulletins circulated to the staff. In his retirement message at the end of 1955, Sir Harold Spencer Jones said that he "had hoped that the building programme would have been completed before my retirement but there have been many delays which have made that impossible".

One of the many non-functional features of the Group is a flint-faced wall on either side of the main entrance. The natural, irregularly-shaped flints were knapped to give a rectangular shape so that they would fit tightly together and make a flat wall. This job was carried out by a craftsman who worked for many months in a canvas shelter beside his pile of flints. I only wish that I had taken a photograph to provide a record of his craft and of the conditions under which it was carried out. As far as I know, there is no such photograph amongst the official record of the construction of the Group.

The basic building work in the Castle and around the Observatory was carried out by a team of men who were controlled and paid for by the Works Department at Chatham, although many of them may have been recruited locally. The foreman was Freddie Sampson, who had one of the semi-detached houses near the west entrance of the Castle. The other house was occupied by Eric Stoakley, who was the Head Electrician. Sampson moved on in 1955, but Stoakley remained until his retirement; his mate was Norman South, who also stayed with the RGO. They have both recorded their recollections of the early days at Herstmonceux. [RGO 94]

The early proposals for the Observatory included the provision of a permanent hostel and the building of houses in the grounds for other staff, but these ideas were eventually dropped.

The remains of six Roman urns were found in October 1953 when trenches for the Equatorial Group were being dug. There is a full report in IB 21; the urns were found to be from the first century AD.

2.7.2 Thomas Gold and the new astronomy

Humphry Smith told me on more than one occasion that he tried to persuade Spencer Jones that the Royal Observatory, as it was then still known, should become involved in the new technique of radio astronomy. He claimed that if Spencer Jones had responded positively the RO could have had the radar equipment that went to Jodrell Bank. I have not been able to find any memorandum about this, but the RGO archives do show that Spencer Jones did turn down opportunities to participate in this new aspect of astronomy. Pre-war observations had shown that radio waves were emitted by objects in the Milky Way Galaxy, and during wartime it had become clear that the Sun emitted bursts of radio waves that interfered with radar observations of terrestrial objects.

The scepticism of optical astronomers about the value of radio observations is illustrated by the following quotations from a letter from Jan H Oort in Holland to Spencer Jones [RGO 9/419 1950-04-11]:

"In your talk [you] mentioned the possible construction of a 250-foot moveable paraboloid. In Holland we are developing plans for a 25-meter paraboloid, ..."

"For it is by no means certain that there will be enough problems to make it worthwhile to have several costly paraboloids of large size."

"Mr Ryle did not at that time appear to know anything about plans for a large moveable paraboloid to be erected in Great Britain."

Professor P M S Blackett at the University of Manchester had suggested that it might be possible to use radar techniques to detect the ionization trails that would be left by incoming high-energy cosmic rays (charged atomic nuclei). Bernard Lovell and his team at Jodrell Bank looked for such trails, but found instead the ionized trails left by incoming meteors (particles of dust which were travelling at very high speed and which became incandescent when they hit the upper atmosphere). As early as 1946, J P M Prentice, who was then the Director of the BAA Meteor Section, suggested to Blackett that a Radar Meteor Observatory should be set up at Ipswich, near his home. The following year he wrote to Spencer Jones and suggested that the "R.O. might, in certain circumstances, take over the routine work on radar meteor observations". Nothing came of this suggestion. [RGO 9/641, 1946-12-08 and 1947-05-13]

Later, Blackett wrote to Spencer Jones on 1950-03-18 and "wondered whether you have ever thought of adding cosmic ray recording to the routine work of the Royal Observatory". Spencer Jones appears to have taken this up for on 1950-06-07 he wrote to the Hydrographer saying "the Board of Visitors adopted a resolution that RGO should purchase, maintain and operate ...", requesting a sum of £3000 for the equipment and an additional Experimental Officer on the complement, and noting that it would be desirable to wait and see if an SO were needed. On 1950-06-16 Mr Jowsey replied on behalf of the Hydrographer and asked "Can you get the EO from savings when the Hollerith equipment is fully operational?" The correspondence [RGO 9/147] continues until August of the following year when it appears that the purchase of the equipment was about to go ahead, but it is not clear that it did so at the time. [I can find no reference to the project in the AR's reports for 1950, 1951 or 1952, nor in the IBs for staff.]

Spencer Jones presumably, however, still had this project in mind when he wrote on 1951-06-16 to Professor O. R. Frisch to enquire about the possibility that Dr Thomas Gold, a Fellow of Trinity College, Cambridge, would make a suitable Chief Assistant to replace Hulme, who had resigned in 1945 [RGO 9/47 1951-06-16]. Gold was then "engaged, inter alia, on some cosmic ray investigations at the Cavendish Laboratory, Cambridge" [RGO 9/106 1953-03-03]. He had not, however, been Spencer Jones' first choice, but Hermann Bondi, also at Cambridge, had declined the offer. [Bondi and Gold had proposed the Steady-State Theory of the Universe in 1948. Hoyle and Lytlleton became associated with them later, I believe.] [See also RGO 12]

Gold took up his post in October 1952. Some cosmic-ray equipment arrived in April of the following year and Don R Palmer was appointed as an EO in the Cosmic Ray Department in September. Jim E Simes, an SA on secondment from the GPO, was in the department for a year from October 1954. [He has written a description of the equipment for the web-site of the RGO Society.] The equipment was set up in the Castle. The project is described in RAR 53, 9-10. The paragraph also noted that an investigation to look for light flashes due to Cerenkov radiation from cosmic rays had been started with members of the Atomic Energy Research Establishment. Equipment

had been set up in the Solar Dome, but unfortunately it was found that the slit in the dome was too narrow. The first major event recorded by the cosmic-ray monitor occurred in February 1956 and is described in section 3.3.3.1. [See also RAR 54, 8-9 and RAR 55, 12]

I did not have much contact with Gold, but he did invite me to his house-warming party and I was impressed by the way in which he approached such matters as the problems with the central heating! He was full of ideas, and I always found him clear and convincing when he spoke at RAS meetings, for example. He gave me high hopes for the future. (See appendix B.3 for further notes about Gold.)

2.7.3 The Isaac Newton Observatory

In his presidential address to the Royal Astronomical Society on 1946 February 8, Professor H H Plaskett (University of Oxford) advocated the erection of a large telescope to supply the needs of British astronomers under the best obtainable observing conditions. The Council of the Society followed up this suggestion by a formal request to the Royal Society for a sum of the order of £100000 to build the 'Isaac Newton Observatory' **in the United Kingdom**. In turn the Royal Society approached the Government and on July 15 the President was able to announce that the Chancellor of the Exchequer had agreed to ask Parliament to vote the sum required. The Observatory was to be sited at Herstmonceux and to have a 100-inch reflecting telescope. It was to be under the administrative direction of the Astronomer Royal, but it was to be controlled by a Board of Management and it was not to be regarded as an RGO instrument. (See appendix G.5.1)

Spencer Jones accepted the gift of a 98-inch disc of pyrex glass from the Trustees of the McGregor Fund while he was in America in 1949; the disc had been cast in 1935 for a 100-inch telescope for the University of Michigan, but the project had been abandoned. There were, however, seemingly interminable discussions about the design of the telescope. Spencer Jones was in a difficult situation; it appears that he tried to act as neutral chairman, rather as a project leader, as he did not wish to be accused of trying to impose his view. The project was to be a source of controversy for many years to come. Work started on grinding the mirror blank in 1951 and by 1953 the broad features of the design of the mounting had been agreed. A talk by a project engineer at Grubb-Parsons, Mr G. M. Sisson, about the grinding and polishing of the mirror was broadcast in December 1953. At about this time we were shown a film about the grinding of the mirror. The 'Isaac Newton Telescope' was eventually inaugurated by the Queen in December 1967. (See section 4.2.2)

A detailed account of the proposals, discussions and delays is given in an MPhil thesis by Lee Macdonald. (See appendix G.5.2)

2.7.4 The Castle, gardens and grounds

2.7.4.1 The Castle

The principal features of the Castle have been described in section 1.3. This section gives further details about it while describing the ways in which it was used by the Observatory during this early period. The exterior of the Castle was restored by a small number of men from the Ministry of Works. They were also responsible for work

on Battle Abbey and the work on the Castle progressed very slowly. As soon as scaffolding was taken down at one place, it would be put up at another, as the stonework in the windows was replaced. For a long time the south entrance of the Castle was surrounded by very ugly scaffolding and weather screening. It was said that the repairs to the brickwork during the early years of the century had been disguised by encouraging birds to peck at porridge smeared on the bricks!

Members of the staff were allowed to show visitors around the parts of the Castle not used for offices (subject to advance approval by the AR). The main attractions were the library staircase and landing, with its wood carving by Grinling Gibbons, the Long Gallery, with its Jacobean overmantel above the carved wooden fireplace, the 'chapel' and the Staircase Hall. The former chapel was used as a lecture room and had large, dilapidated tapestries on the walls. A round skylight could be seen above the platform at the east end, and wires had been placed across it to simulate the cross-wires in a meridian telescope. [See David Calvert's *History* for details of the origin of staircases etc]

The staircase in the Staircase Hall led to the Typing Pool. The carvings on the posts of the staircase were of particular interest; one post, for example, shows a variety of musical instruments. There were autographed photographs of Queen Elizabeth and Prince Philip on the wall opposite to the fireplace after the coronation in 1953. The main use of the Hall was for presentations to staff when they retired or married. There were several marriages of couples who both worked at the Observatory. My fiancée, Betty, came to stay at the Castle just before we were married, and so she was present when Sir Harold gave me a wedding gift, in the form of a cheque, from the staff in early August 1953. Sir Harold also used to appear at the top of the staircase when he acted as Father Christmas for the annual children's party.

The balcony of the Staircase Hall gave access to the Drummer's Hall above the South Entrance. This was a dark, panelled room, named after the ghost that was supposed to haunt the battlements. It was used in later years for committee meetings and for interview boards; it was hardly the sort of place to put candidates at their ease. It had, presumably, been used as a bedroom when the Castle had been a private residence. It had an en suite bathroom, whose door was next to the door that led to the west wing of the Castle. It is said that one candidate went through the wrong door and had to await until the next interview was over before he showed himself again.

Another staircase led up to the Green Room, above the Drummer's Hall, which was used as a bedroom for VIP visitors. My recollection is that Dr and Mrs G M Clemence stayed in it, for example. Yet another, narrow, spiral staircase led to the roof of the South Tower, where there was a large water tank. It was possible to walk to the front of the tower, where there were large holes by the battlements through which the enemy at the gate below could be attacked. It was also possible to go up the open stone staircases of the two signal towers, from where there were magnificent views over the estate and over the Pevensey Marsh to Norman's Bay, Pevensey and Pevensey Bay, Westham, and Eastbourne. Everyone that I took up there was very careful, but in later years this area was put out of bounds to staff and visitors for safety reasons. Each morning one of the messengers would raise the Union Jack on the western tower. The eastern tower was used for a sunshine recorder.

The AR had the use of the north-east tower and the northern half of the east wing for his private residence. The tower provided bathrooms for the adjacent

bedrooms. The ground floor was used for the kitchen and dining room, while the first floor was used for a large drawing room, which was panelled in light oak. The AR was allowed the "use of two cleaners for cleaning [his] official residence in view of the large amount of entertaining that [he had] to do". [RGO 9/47, 1952-06-05] The first time that I saw the drawing room was in connection with the children's party as Lady Spencer Jones used to have the little ones, while the older children played games in the Clubhouse.

The upper storey of the Castle contained attic-like rooms that were used for the ladies hostel in the north wing, for the AR's guests/family in the north part of the east wing, and for observers whose duties started or ended in the middle of the night in the south-east corner. The south-east tower contained a dove-cot, with bricks omitted to make pigeon holes around the walls. [The attic rooms in the south-west corner were probably used for storage.]

The moat of the Castle extends only along the southern part of the west-side, along the south-side, where it is crossed by a three-arch stone bridge, and along the east-side, where it widens out to form a shallow lake that stretches up into reed beds beyond the north-east tower. The dry bed of the moat on the north-side is much higher than the present moat. The moat contained very large carp that used to feed on the scraps thrown out from the kitchen in the south-west corner and on bread thrown by staff from the bridge after lunch in the canteen. A large piece of bread would be pushed at high speed across the moat by a fish as it tried to keep it from other fish.

Occasionally a swan would be seen on the moat; I have a photograph which shows a heron standing on a submerged tree-stump. In later years there were many Canada geese after Woolley had introduced a few.

2.7.4.2 The gardens and grounds

Staff had free access to the formal gardens on the north side of the Castle and to the grounds generally; they could also take visitors around them (with prior approval). The formal gardens were at their best in midsummer when the herbaceous flowers and roses were in bloom; in the spring the large magnolias in the walled garden came into flower and there was an expanse of daffodils in the rough grass to the west of the garden. The azaleas and rhododendrons gave colour to the woods in the spring.

The moat is fed by a stream which comes down the valley through a series of ponds, the last two of which are separated by a waterfall. There is a summer house by the upper of these two ponds; it was known to the staff as the Folly, but the grassy area leading to it from the gardens is marked on a pre-war map of the grounds as 'Temple Field'. A crude wooden bridge ran across the top of the upper pond, which was quite shallow; there was a platform in the middle, presumably for fishing or shooting. Water lilies grew in the lower of the two ponds.

There is a line of Spanish-chestnut trees running north from the west side of Castle. These were rumoured to be as old as the Castle, which was built about 1440, but this proved to be false when one was felled for safety reasons; the tree-ring count showed that it was planted in about 1710. Some of the trees in the line were obviously younger than the rest; I found it of interest that the spiral pattern in their bark was of the opposite handedness to that of the older trees.

This line of trees ran into an avenue of Spanish chestnuts that led in the direction of Windmill Hill. It was said that the track through them was the coach road from the Castle to London and that traces of the avenue could be found further north; I did not, however, follow this up and look for the trees. The track through the woods led to some wooden buildings that were known as the 'Kennels'; perhaps the dogs for the local hunt were kept there before the war.

The gardens were kept in order by Mr Dann, the Head Gardener, and five assistant gardeners. They may also have been responsible for mowing Temple Field and the verges along the approach roads, but this job may have been done by men from the Works Department (and classed as labourers). Mr Dann and his family lived in the house by the West Gate. The Head Forester was Mr Jack Pike; he was a widower, lived in the men's hostel and was close to retiring age. He was assisted by a young man, Cyril Taylor, who was probably classed as a labourer as he does not show in the staff list. They had the job of planting new trees around the estate — Jack claimed that, by the time that they had finished, they had planted a quarter of a million trees. Certainly, the estate is very different now from when I first saw it.

Visitors were allowed in the garden and grounds, but not in the Castle, on Wednesday and Sunday afternoons during the summer. [I am not sure whether there was any charge.] Their numbers were small as cars were a luxury then. I believe that the Southdown Bus Company did, however, run a bus from Hailsham to the Castle gate on those afternoons.

Occasionally the AR would allow local organisations to hold fetes in the grounds in order to raise money for charity. For example, IB 21 records: "The Astronomer Royal has been informed by Mrs Davies-Gilbert that the nett proceeds of the Fete held at the Castle on Saturday, 20th June [1953], in aid of the Hospital Comforts Fund amounted to £401. This result is extremely satisfactory and the Astronomer Royal desires to thank the many members of the staff who willingly gave their time and services for the cause and thereby helped greatly to make the Fete such a success".

2.7.5 The Old Royal Observatory at Greenwich

The AR reported in 1952 that the buildings of the Royal Observatory at Greenwich would be used as an astronomical and navigational annexe of the National Maritime Museum. It later became known as the Old Royal Observatory. Then after the closure of the RGO in 1998, it became the Royal Observatory Greenwich.

There the number of visitors was quite large and the RGO Club benefited as the porters on the gate used to sell picture postcards on behalf of the Club; they received a commission that must have made a useful supplement to their pay. [I visited the RO in November 1952 and discussed the arrangements with Jeffreys and Whittaker, as I was then the Treasurer of the RGO Club; I do not recall any official reason to visit the RO at that time.]

In the 1952 report the AR commented on the deterioration in the sky conditions at Greenwich since the end of the war and he bemoaned the slow progress of the transfer to Herstmonceux.

2.8 The role of the Astronomer Royal

2.8.1 The early career of H. S. Jones

Harold Spencer Jones was awarded a research fellowship at Jesus College, Cambridge, where he graduated in mathematics and physics in 1913, but later that year he was appointed by Frank Dyson as one of the two Chief Assistants at the Royal Observatory at Greenwich. He replaced Arthur S Eddington, who had been appointed Plumian Professor of Astronomy at Cambridge. The other Chief Assistant was Sidney Chapman, who had been entrusted with the task of supervising the building of a new magnetic observatory, even though he was a mathematician. Spencer Jones worked first of all on the analysis of the data from the Cookson floating zenith telescope, but during the war he worked on optical instrument design for the Ministry of Munitions. In 1923 he was appointed His Majesty's Astronomer at the Royal Observatory at the Cape of Good Hope. Here his interests remained primarily in astrometry.

2.8.2 Spencer Jones as Director of the RGO

On the retirement of Sir Frank Dyson in 1933, Spencer Jones was appointed the tenth Astronomer Royal. He then brought to a conclusion the work that he had started in South Africa and for which he is best known. In 1939 he showed conclusively that the fluctuations in the observed longitudes of the Moon, Sun and planets were due to fluctuations in the rate of rotation of the Earth. In 1941, he published a new value for the constant of the solar parallax (effectively the mean distance from the Earth to the Sun) that he had derived from observations of the minor planet Eros, many of which he had made in South Africa. (Work carried out after the war using planetary radar, showed, however, that his value was not as good as he had claimed.) His textbook on *General Astronomy* was first published in 1922, and his revision of *Elementary mathematical astronomy*, by Barlow and Bryan, was published in 1944. His booklet on the history of *The Royal Observatory Greenwich* was first published, by the British Council, in 1943. Otherwise he seems to have written only the occasional review article while he was AR. Instead he concentrated his efforts on national and international administrative activities. He also lectured widely.

He drew attention to the poor observing conditions at Greenwich in his report to the Board of Visitors in 1935. He considered the possibility of moving the telescopes while leaving the offices and workshops at Greenwich, but in November 1938 he submitted proposals for the total removal of the Observatory from London. The decision to move was taken in principle by the Board of Visitors in March 1939 and was approved by the Admiralty in February 1944, before the end of the Second World War. The choice of Herstmonceux Castle was announced by the Admiralty in April 1946 (see section 1.4 for further details). When he retired 10 years later at the age of 65, the move was still unfinished.

During the war the AR and Lady Spencer Jones moved to Abinger Hammer (with the Time Department). They returned to Greenwich in July 1945 until they were able to move into the Castle in August 1948. The Observatory was visited by many senior astronomers, whom they would entertain to lunch and often for overnight stays.

I have no recollection of the AR ever visiting the NAO nor even of my going to see him on any matter. This may have been because Sadler had a great deal of autonomy and Spencer Jones had no direct interest in the work of the NAO. I do not

know whether he was seen more often by the staff of other departments, but I have the impression that he was involved in so many other national and international organisations and projects that he had time to deal with only the general policy aspects of the running of the RGO. I suspect that most staff saw him only at presentations in the Staircase Hall and at the annual staff party!

There were two occasions during the year when the paternal attitude of the AR to the staff was clearly shown. In the spring, just before Easter, each of us was given a bunch of daffodils, and in the autumn we were each given a peach from the espaliers on the east-facing wall in the formal garden. The other 'perk' that we had was the opportunity to buy a 'cord' of wood from the estate for cutting up as firewood. My wife and I had such a cord for our first winter at Pevensey Bay; unfortunately, much of the wood was chestnut which shot out hot sparks, so that we were forced to use a fire-screen. Most of the cord was still left when we moved to our home at Westham. (See appendix B.1 for my personal assessment of Spencer Jones as Astronomer Royal.)

2.8.3 National offices and honours

Spencer Jones was the President of the Royal Astronomical Society for the years 1938 and 1939, he was its Treasurer from 1946 to 1952, and its Foreign Secretary from 1955-1960. He had served briefly as a Secretary in 1923-24 — presumably he had not anticipated going to South Africa when he accepted the nomination. (He was succeeded as Secretary by John Jackson, who also later succeeded him as H M Astronomer at the Cape.) The *History of the RAS* records that "he was of impressive presence and presided over the Society's proceedings with notable dignity". He was awarded the Gold Medal of the RAS in the same year, 1943, that he was knighted. He was made a KBE in 1955.

On Donald Sadler's suggestion, he was elected as the first President of the Institute of Navigation in 1948. [The Duke of Edinburgh became the Patron some years later.] He served as Master of the Worshipful Company of Clockmakers for the year 1954; a party from the British Watch and Clockmakers' Guild visited the Observatory in March.

He would almost certainly have been a permanent member of the British National Committee for Astronomy and probably also of the BNC for Geodesy and Geophysics. These were committees of the Royal Society and were concerned with policy in relation to the corresponding international unions. (See section 2.2.7.2.)

As has been mentioned in section 2.7.3, the AR was also the chairman of the Board of Management of the Isaac Newton Observatory, but he was unable to get agreement to the design of the telescope. He was, however, successful in obtaining the gift of the mirror-blank, and the work of grinding and polishing it was largely completed before he retired.

Spencer Jones received a number of honours during his final years at the RGO; for example, he was awarded the Honorary Degrees of Doctor of Laws by the University of Glasgow on 1952 June 18 and Doctor of Science by the University of Oxford on 1954 September 8. He and Lady Spencer Jones attended the Coronation of Queen Elizabeth II in Westminster Abbey on 1953 June 2. The annual meeting of the Board of Visitors was therefore postponed to Saturday, June 13.

Spencer Jones was, I believe, in great demand as a lecturer. I recall going to hear him talk about ‘time’ at a Friday evening discourse at the Royal Institution. I was very impressed when he finished his lecture exactly on the stroke of the hour!

One of his minor positions was as member of the Council of the Norman Lockyer Observatory Corporation from 1935 and of the Advisory Research Committee from 1936. This would account for his consideration of Sidmouth as a possible site for the Royal Observatory. He and his wife became friends of Lady Lockyer and used to stay with her. During the war he asked Lady Lockyer to store naval chronometers to avoid the risk of them being destroyed in air raids on Exeter, where they were then being kept.

2.8.4 International activities

The AR’s report for 1946 records the visit of H M Smith (in charge of the Time Department) to Germany in October 1945, but it does not mention the visit that the AR made at the same time — or else they went together at an earlier time on a visit that it is not mentioned. There is a photograph in the RGO Archives that shows them in naval uniform with an unidentified astronomer at an unidentified Observatory on an unspecified day! Spencer Jones played a major role in the transfer of part of the Astronomisches Rechen-Institut from Berlin/Potsdam to Heidelberg at the end of the war — the other part remained in the Russian Zone/East Germany. [DHS writes in SPH, chap 10: “The A.R. and H.M.S. later made a similar visit to Germany, and were able to arrange for the setting up of the A.R.I. in Heidelberg”. He also refers to ARI being transferred to Magdeburg when it was bombed out of Berlin-Dahlen, and being in imminent danger of being transferred to the Russian zone.]

Spencer Jones was elected President of the International Astronomical Union by correspondence amongst the members of the IAU Executive Committee following the death of A S Eddington in November 1944. His election was confirmed at a special conference in Copenhagen in March 1946, and he remained President until the first post-war General assembly in Zurich in 1948. In his *History of the IAU* Blaauw describes him as a “very dedicated President”. It would certainly have been a very difficult time as IAU activities had been largely, but not completely, suspended during the war and as there was controversy over the admission of astronomers from the defeated countries, such as Germany and Japan. He continued as a consultant member of the Executive Committee until 1952.

Spencer Jones represented the IAU at the meeting of the Executive Committee of the International Council of Scientific Unions in October 1954 and he attended its General Assembly in Oslo in the following year. He became the General Secretary of ICSU and remained so for the first three years of his retirement. He also took part in the preliminary meetings held in Paris in November 1954 that led eventually to the setting up of the European Southern Observatory. He was also heavily involved in the planning for the International Geophysical Year 1957/58 as a member of the Special Committee for the IGY.

Details of his overseas visits are given in many RGO Information Bulletins. 1955, his last year as AR, was a particularly busy year for Spencer Jones. He made an extended visit to the USA and Canada in April and May to receive the Rittenhouse Medal, to give several public lectures, to attend three conferences, and to visit

laboratories and observatories, where he would have given colloquia. He attended the IAU General Assembly in Dublin and meetings in Brussels, Oslo and Hamburg.

3 COMPLETION OF THE MOVE AND CONSOLIDATION

RICHARD van der RIET WOOLLEY – 1956 TO 1965

3.1 The impact of Richard Woolley

3.1.1 Career and appointment of Woolley

The appointment of Richard Woolley as the 11th Astronomer Royal was not unexpected as his career had followed the pattern of that of Spencer Jones. He attended All Hallows School in Honiton for two years before he moved with his parents to South Africa; it was at the Cape that Woolley's father had met his mother, Julia van der Riet. He went to the University of Cape Town at the age of 16 and obtained BSc and MSc degrees before going in 1926 to Gonville and Caius College as an undergraduate in the University of Cambridge . He started research in astronomy in 1928 and was a Commonwealth Fund Fellow at Mount Wilson Observatory from 1929 to 1931. He returned to Cambridge as an Isaac Newton Student and soon completed his Ph.D. work. He was a Chief Assistant at the Royal Observatory at Greenwich from 1933 to 1937, when he worked with meridian, time and solar instruments, and made double-star measurements. He also assisted the former Astronomer Royal, Sir Frank Dyson, with his book on solar eclipses. He returned to Cambridge and spent 2 years at the University Observatory as the John Couch Adams Astronomer before he became in 1939 the Director of the Commonwealth Solar Observatory at Mount Stromlo, near Canberra, Australia.

Woolley arrived in Australia in December 1939 after the start of World War 2. At first work continued normally but after the British evacuation from Dunkirk the Observatory was converted into a munitions factory. Later in the war Woolley was put in charge of the Army Inventions Directorate in Melbourne. After the war Woolley steered the Observatory away from solar astronomy to observational astrophysics and built up the work on stellar photometry and spectroscopy. The word 'Solar' was deleted from the name of the Observatory. He obtained funding for the construction of a 74-inch reflecting telescope for such work, but it was not delivered until November 1955 just before he left to become the eleventh Astronomer Royal. He also pressed that the Observatory should become part of the Australian National University, but this did not take effect until after his departure. (See appendix B.2.2 for comments about his work in Australia.)

Woolley's arrival in England was marked by the reporting of an off-the-cuff statement that interplanetary travel is "utter bilge". Even his obituary in *The Times* over 30 years later has the sub-heading "Major astronomer who jibbed at space travel". [My recollection is that the RGO archives contain a copy of letter to the Times that was written by his brother about the 'utter bilge' incident.] The incident was marked by a newspaper cartoon that shows 'spacemen' marching around the Solar Dome with banners saying "Unfair to spacemen". There is still a copy in the Dome, which is now used for satellite laser ranging.

It appears that his wife, Gwyneth, did not wish him to take up the post and she stayed in Australia for many months. Even when she did come, she was very rarely seen and she did not attend any social activities organised by the staff. Spencer Jones did not

move out of the Castle right away and so at first Woolley had to sleep in a spare room and eat in the canteen! [SPH, 14] Woolley's first introduction to the staff came at the Club's New Year staff party, at which he presented the Spencer Jones Indoor Sports Trophy to Donald Sadler.

Woolley was knighted in the New Year Honours List for 1963. [For further details of Woolley's career see McCrea, 1988.]

3.1.2 Policy on activities and administration of the RGO

3.1.2.1 Priority to astrophysical research

Woolley soon made it clear that his view of the role of the RGO was quite different from that of his predecessor, Sir Harold Spencer Jones. His gave priority to astrophysical research rather than to time and astrometry. This showed itself in several different ways. First of all he 'invited', or rather summoned, staff whom he considered appropriate to attend seminars on astrophysical topics in his office, which was in a large room in the Castle. I attended a few, but I incurred his displeasure when I declined his invitation to transfer from the NAO to astrophysics. He also recruited Bernard Pagel as an SSO and promoted him within a few months to PSO to head a research team. He gradually build up the staff engaged in astrophysics by recruitment and by transferring staff from other departments, often at very short notice.

Tommy Gold, one of the Chief Assistants, left the RGO in September 1956 to become a Visiting Professor at Cornell University in the USA. He went on to develop the enormous Arecibo radio telescope, whose dish was constructed in a large depression (quarry?) in the ground. The cosmic-ray research that Gold had started at Herstmonceux was abandoned. (See section 2.7.2.) It appears that his departure was due mainly to his failure to obtain support from Woolley rather than to better prospects in the USA. (See appendix B.3.) Gold was replaced by Olin Eggen, an American who had worked at Mount Stromlo with Woolley; he first of all came for one year.

Woolley became chairman of the committee for the Isaac Newton Observatory (see section 2.7.3) when Spencer Jones retired. The committee had spent a long time trying to agree on a new design for a multi-function telescope, but Woolley immediately pushed through a change to a conventional design so that the project could proceed more quickly. Even so it took more than ten years before the INT was inaugurated by the Queen on 1 December 1967. Consequently further consideration of the INT is deferred to section 4.2.2.

3.1.2.2 Attitude to space research and radio astronomy

An undated note that was written [probably in about 1958] by Woolley on "British participation in research with artificial satellites" shows very clearly his attitude to space research. He argued that the money being considered by the government for space research would be better spent on improved ground-based facilities. (The full text of the note is given in appendix B.2.1.) [The original is probably in the RGO Archives, but I do not have the reference to hand. I suspect it was written as a contribution to a memorandum by the Royal Society and so it may have been published.]

The first Russian satellite, Sputnik 1, was launched while I was in the USA attending lectures at the Yale University Observatory and so I was not involved in the satellite prediction service that was hurriedly provided by the NAO. By the time I returned the service had been transferred to the Royal Aircraft Establishment at Farnborough since Woolley would not have supported any bid for additional staff to continue the service indefinitely. [See SPH, 14]

His narrow-minded attitude to new developments in astronomy also showed itself in his failures to support the cosmic-ray monitoring unit that was just beginning to produce results and to consider suggestions by Gold and H. M. Smith for the involvement of the RGO in radio astronomy. (See appendix B.3)

3.1.2.3 New RGO publications

Woolley's decision in 1959 to introduce a new series of RGO publications was prompted (according to Sadler in an aside to me) by adverse criticisms by a referee of one of his research papers. Up to that time, most research papers by RGO staff were published in the *Monthly Notices of the Royal Astronomical Society* or other appropriate journals, but from then on most of them were published in a new series of *RGO Bulletins* that were edited and composed by RGO staff. Consequently, these papers were treated as in-house reports and did not receive the credit that is associated with refereed papers in the primary literature.

The accompanying decision to publish the results of the long-term routine observations in a new series of *RGO Annals* was certainly justified as this avoided the long delays involved in the preparation of the annual volumes of *Greenwich Observations.* Similarly, the introduction of *RGO Circulars* for time-service and other data that need quick distribution was appropriate. I suspect that Hunter and Sadler were the prime movers in the use of the names Annals, Bulletins and Circulars for three series, which were referred to as the A, B and C series.

The decision that the RGO should be directly responsible for the publication of the bulk of its scientific research did not lead to a significant increase in the number of typing staff, but it did involve the need for extra editing by scientific staff and so Harold Richards was transferred from the NAO to the AR's Department for this purpose. The RGO must also have incurred significant extra costs in effort and money for the printing and distribution that would otherwise have been the responsibility of the Royal Astronomical Society or other organisations.

3.1.2.4 Relationships with staff

In contrast to Spencer Jones, Woolley took an active part in the work of the Observatory and in its social and sporting activities and so he got to know, and was known by, many members of the staff. He was, however, very much an autocrat and often made decisions without consulting the persons who would be affected by them. He also used to treat even senior staff very abruptly so that, for example, Sadler would be expected to respond immediately to a telephone call that summoned him to see Woolley. Sadler was particularly annoyed by Woolley's failure to give him warning of the subject to be discussed and by his demanding an immediate response before Sadler had had time to consider the matter properly.

In spite of his rank, Woolley continued to carry out night observing and, even more surprisingly, he used to measure his photographic plates. I suppose that Woolley

took satisfaction in knowing that he had a major responsibility for the research papers that carried his name. (This contrasted with many university astronomers who added their names to papers that were primarily the work of their research students.) He also learnt at first hand about the capabilities and shortcomings of the telescopes and other equipment. On visits abroad to use large telescopes he did, however, take someone to assist him. John Pope certainly had this role in, I believe, both Australia and California, and he certainly benefited from the experience.

Woolley introduced one procedure that enabled him to learn more about the capabilities of the scientific staff. Up to that time the annual report on an individual member of the staff was regarded as confidential to the reporting officer, the countersigning officer, the head of the establishment (or group) and a staff-side scrutineer. Woolley held, however, an annual-reports meeting that was attended by all these persons. Each reporting officer would read out his draft markings and justify any particularly high or low marks. The markings could be questioned by anyone who felt that they did not properly reflect the work, character and potential of the person concerned. The most significant marks were the recommendations concerning suitability for promotion. The scrutineers were on the look-out for any case where an individual was marked down because of poor relations with the reporting officer or was given a much higher mark than seemed justified. Woolley, in particular, had ‘blue-eyed boys’ working in his field for whom he pressed for rapid promotion, while others who appeared to be comparable in terms of qualifications, length of experience and performance were passed over.

Woolley also supported a programme for training lectures for scientific assistants. I had initiated such lectures in 1955 on a weekly basis in the lunch break, but from October 1956 several series of lectures were given in official time with a different subject on each day of the week. These lectures were intended to make the assistants better able to carry out their duties, but also to help them to obtain the further qualifications that were necessary for promotion. Woolley later applied this policy to graduates, who were encouraged to take MSc degrees at the University of Sussex.

Spencer Jones appeared to rely on H G Barker, who was the head of the General Office and who had the title of ‘Secretary and Cashier’, to deal with all administrative matters. Woolley, however, eventually passed a lot of this responsibility to Dr Alan Hunter. He was made editor of all scientific publications (except NAO almanacs etc) from October 1956 and was promoted to SPSO on 1 May 1961. It appeared that Dr Robert d’E Atkinson, who had been a Chief Assistant since 1937, was largely sidelined. Woolley did, however, obtain his promotion to DCSO (Special Merit) so that he could continue to develop his ideas for a mirror/horizontal transit instrument. (See section 2.5.1) Its construction was approved in 1961, but the work was given low priority, and the project was abandoned when Atkinson retired in 1964.

As far as I am aware, Spencer Jones did not have a personal secretary, but Woolley gave this role to Anita Hewerdine who was promoted from Shorthand-Typist to Clerical Officer/Secretary in March 1957.

3.1.3 External relations

Woolley took very little interest in the affairs of the Royal Astronomical Society, although he did serve as its president from 1963 to 1965. Similarly, he did not participate actively in the International Astronomical Union, although he served as a

vice-president from 1952-1958. He was, however, very keen that RGO staff should be able to make use of the better telescopes and observing conditions that were available in other countries and he also wished to establish links with British universities.

3.1.3.1 Royal Observatory at the Cape of Good Hope

The fact that Woolley had lived in South Africa and had taken his first degrees at Cape Town University was probably an important factor in his establishing good relations with the Royal Observatory at the Cape of Good Hope (ROC) and with the Radcliffe Observatory at Pretoria. Patrick Wayman was the first to go to the Cape and Radcliffe for a 3-year tour of duty starting in April 1957. Soon visits of various lengths by RGO staff to the Cape and the Radcliffe, as well as to observatories in the USA and later other countries, became common.

The close relationships that developed between the two observatories led to what was in effect a merger. The formal position was stated in the introduction to the Report of the Astronomer Royal in 1960 as follows:

"On 1959 May 21 the Lords Commissioners of the Admiralty approved in principle a joint recommendation by the astronomer Royal and H.M. Astronomer at the Cape that the Royal Observatory at the Cape of Good Hope should be connected with the Royal Observatory at Herstmonceux, in the same manner as H.M. Nautical Almanac Office is connected."

The nature of this connection was ambiguous. At first the NAO had retained a large measure of independence but, after the move to Herstmonceux and the appointment of Woolley as AR, the Office gradually became more and more integrated with the rest of the Observatory. The most obvious sign of the merger was the renaming in 1960 of the RGO scientific publications that contained the results from both observatories; for example, *RGO Bulletins* became *RO Bulletins* [Notice by A Hunter, 18.5.60]. At first the AR's report included a separate section for the Cape, but by 1964 only the staff list was given as a separate entity. Eggen was seconded to the Cape in 1960. David Evans, then the deputy head of the Cape Observatory, spent six months at Herstmonceux in 1961. One permanent legacy of his visit was the numbering of all the rooms in the Castle!

The British Government continued to fund the Royal Observatory at the Cape even after South Africa became a republic in 1961. Eventually, in 1972, the link was broken when the South African Astronomical Observatory became an independent organisation with Woolley, who had just retired from the RGO, as its first director. The SAAO included the Radcliffe Observatory at Pretoria, which had been linked to the University of Oxford.

3.1.3.2 Use of other overseas telescopes

The growth of intercontinental travel by air made it possible for astronomers to go to use telescopes in other countries for short periods. Up to this time the normal tour of duty was 3 years, but in 1958 Woolley became a Research Associate of the Mount Wilson and Palomar Observatories. From then on he went on observing trips with increasing frequency, often taking other members of the RGO staff with him. In 1960 Pagel went to Sacramento Peak in the USA for 9 months and Derek Jones spent two years in 1961/1963 at the Mount Wilson and Palomar Observatories on a Harkness Fellowship. Later activity of this type is noted in section 4.5.2.

3.1.3.3 Anglo-Australian Observatory

Woolley had advocated the building of a large telescope in the southern hemisphere in his submission to the Royal Society in 1958. He was successful in pressing for the building of an Anglo-Australian Telescope in Australia, rather than for participation in the European Southern Observatory (ESO). He was accompanied by Hunter, Pope and R O Redman (Director of the Cambridge University Observatory) on a 3-week visit to Australia in June 1964, during which possible sites were inspected. The Anglo-Australian Telescope (AAT) was eventually [c. 1973] built on Siding Spring Mountain in New South Wales, Australia.

Woolley and others did attend ESO meetings in December 1960 and January 1961, but the UK did not become a member. Consequently, UK astronomers had little, if any, access to the ESO telescopes and facilities, which were on much better observing sites in Chile. Quite recently, however, the UK has finally agreed to join, but has had to pay a large membership fee.

3.1.3.4 Herstmonceux conferences

As in Australia, Woolley was keen to develop links with universities and he started a series of annual 'Herstmonceux Conferences', each of which was on a single topic, for RGO and university astronomers. The first was held on 9-11 April 1957 (when I was in the USA) on the subject of the teaching of astronomy. One or two prominent astronomers from overseas were usually invited to the meetings, which usually lasted two or three days. Accommodation for participants was provided locally. There were a few rooms in the Castle and more became available after the closure of the ladies hostel. One of the rooms for special visitors was the Green Room, which was over the Drummer's Hall in the South Tower.

A complete list of the conferences and workshops held at Herstmonceux and Cambridge (from 1990 to 1998) is given in the last issue of the RGO house journal *Spectrum* (No. 16, October 1998, 36-38). Reports on these meetings were published in *The Observatory* from 1961.

Woolley also started a series of summer vacation courses for university students. These proved to be very popular and almost certainly led to several students deciding to make a career in astronomy. Further details are given in section 3.4.5 and in appendix C.10.

3.1.3.5 University of Sussex

Woolley was a major supporter of the establishment of the University of Sussex in 1961 and of the Astronomy Centre in 1966. Astronomy was recognised as a subject for M.Sc. and D.Phil. degrees in 1965. Woolley and other RGO staff gave lectures and some RGO staff took the courses there. Further details are given in section 4.5.1. [See also McCrea, 62-63.]

3.1.4 Woolley's other interests

Woolley had been an enthusiastic hockey player before the war at Greenwich and he soon started playing tennis at Herstmonceux. We had a regular men's four on Sunday mornings with Sadler, Carter and myself. I recall that on one sunny morning as we walked back to the Castle he commented that the blue of the sky was as deep as in

Australia. He also joined in games of mixed doubles in lunch times; these normally took half-an-hour and usually involved only a short extension of the one-hour break. When he played, we would go on for at least another an hour, so that we did not get back to our desks until it was time for tea! Then in the summer he played regularly in the RGO cricket team; he took the game seriously and soon the matches were played on Sundays, rather than during weekday evenings when the matches had to be much shorter. His interest probably contributed to the decision to increase the area of the sports field and to build a pavilion on it in 1957.

He also suggested that one of the lawns in the formal gardens should be converted for use as a grass tennis court at the expense of the Club. I was treasurer at the time and argued that the Club's priority was to build up funds for the construction of a Clubhouse. This did not go down well as he liked to have his own way! Eventually the lawn was used as a croquet court.

He was also an enthusiastic folk dancer and soon started a group that met weekly in the clubroom in the huts by the south courtyard. There was, however, an unfortunate occasion when the Club wished to use the room for a special event on one of the evenings that would have been given to dancing. Shortly afterwards, Woolley had the office partitions in the Long Gallery in the Castle taken down. From then on, the country dancing group met in the Long Gallery and was organised separately from the Club. He also enjoyed playing the piano and, for a while, kept his grand piano at the east end of the Long Gallery. (See also section 4.3.1.)

Woolley enjoyed living in the Castle and its grounds and he introduced swans and then Canada geese on the moat. He also wanted to introduce trout fishing in one of the ponds near the 'Folly' (or summer house). He had the pond drained during a dry summer so that all the silt hardened and cracked. Eric Smith and I started to lift some of it for use as a fertiliser on the sports field and when Woolley realized its value he had the job done by the Works Department! He came to an arrangement with a local fishing club that they could net carp from the moat for their own waters in return for providing young trout to stock the pond.

Woolley supported the building of a clubhouse by the RO Social and Sports Club (later RGO Club) by the West Gate and he laid its 'foundation stone' (high in the end wall) in 1958. I do not, however, recall him using its facilities. This project is described in more detail in appendix D.2.

3.2 Completion of the new buildings and moves of staff

3.2.1 The West Building

The completion of the West Building in the autumn of 1957 made it possible to bring together almost all of the staff of the Observatory on the Herstmonceux site. I was at the Yale University Observatory in the USA at the time and so I returned at the end of February 1958 to find a completely transformed establishment. The last of the Greenwich staff had moved by April 1957, just after my move to the US Naval Observatory in February 1957, and were then accommodated in the Castle. Staff of the Time Department started to move from Abinger to Herstmonceux from about April 1957 so that there was an overlap in the ensembles of quartz clocks.

The NAO staff moved to the south (north/south) spur of the West Building from 7 October onwards, just as the first Sputnik was launched by the USSR.

Consequently, some staff were desperately trying to improvise a satellite prediction service as their furniture, machines and files were being transported from the huts to the new building. The spur had three floors with rooms on each side of central corridors. The connecting staircase was in the centre of the east side so that the full width of the block could be used for the two offices at the south end of the spur. On the top floor these two offices were used by Mr and Mrs Sadler and on the middle floor by Mr Scott and Dr Porter. They had views over the Pevensey Levels to Pevensey, the English Channel and the South Downs. The west side of the top floor was used for the library. In the centre was a large table faced by glass-fronted bookshelves for the 'standard set' of the publications of the Office. This included a set of the *Nautical Almanac* from 1767 to the current volume. Once again the library contained a set of pigeon-holes for the unbound serials, reports and reprints.

The middle floor was on the same level as the main entrance to the building and contained mainly offices, while the lowest floor of the NAO spur was on the basement level for the rest of the building, although it was itself above ground. This basement was used for the Hollerith punched-card installation, offices and a storeroom for NAO publications and, possibly archival material. This storeroom and the adjacent corridor at the north end of the spur were later taken over as part of a new computer room and for the air-conditioning plant.

The central (north/south) spur was planned for use by the Time Department, but Woolley decided to allocate the top floor to the Astrometry and Astrophysics Departments, which then occupied offices in the Long Gallery of the Castle. The A&A staff moved from the Castle at the beginning of November. A separate Electronics Department, under G B Wellgate, was formed out of the Abinger staff and this shared the middle floor with the remaining staff of the Time Department, who moved from Abinger at this time. The staff and equipment of the Electronics Laboratory had previously been transferred to Herstmonceux in the middle of 1956. They were temporarily accommodated in the former men's hostel.

The installation of the time service equipment began in October 1956 before the building was completed. The time service control room was at basement level and there was a sub-basement that contained small temperature-controlled rooms for the quartz-crystal clocks. The 'clock cellars' were later used for the caesium time-standards. The move of the bulk of the time-service equipment did not, however, take place until the autumn of 1957. The control room was partly below ground and so it had only high-level windows that could be protected by sandbags in a national emergency.

There was an enormous 'atomic-clock cellar' at the south end of the Time spur but this remained empty (apart from flood water!) for many years. The entrance was from the basement level and then there was drop into sub-basement level. It is only recently (2003) that I have realised why such a high room was planned. In the 1950s the early atomic clocks had long horizontal tubes and I did not then know of the proposal for a 'fountain clock' in which the atoms would be projected vertically. It appears that H M Smith, the head of the Time Department, had hoped to obtain approval for the installation of such a clock at Herstmonceux, but the proposal was blocked by Woolley. It is only in the past decade that such a clock has been built in the USA.

The new Chronometer Workshop was on the top floor of the northern (east/west) spur of the building and the benches for the watchmakers all had north-facing windows. The move from the hut by Castle did not take place until January 1958.

The remainder of the Chronometer Department, which was concerned with the testing and distribution of the chronometers and deck-watches, remained in the Castle.

The middle floor of the Chronometer spur was used primarily as a store for equipment for use on eclipse expeditions. The basement was used to store the extensive records (later called archives) of the Observatory and large stocks of unsold copies of *Greenwich Observations.* This basement was probably intended for use as the workshop in the event of war since its walls were made of thick reinforced concrete.

A large well-fitted engineering workshop was situated at the north of the West Building complex. It was linked to the Chronometer spur by a single-storey building that was used for stores and separated from it by a courtyard that was used for deliveries. There was also cycle shed, but my impression is that this was not fully used

. When I returned from the USA at the end of February 1958 work was still going on to complete the flagstone verges of the car park alongside the Time spur. The car park soon proved to be inadequate and a much larger one had to be provided at a lower level. The building itself appeared to well constructed and the polished parquet flooring gave the corridors and offices an appearance of quality. Unfortunately, the windows leaked and the basement was flooded from time to time so that a lot of noisy remedial work was eventually required.

The completion of the West Building allowed the demolition of the huts around the South Courtyard early in 1958. The air-raid shelter was dug out and filled in later.

3.2.2 The Equatorial Group

The buildings of the Equatorial Group on the east hill were largely complete before I left for the USA and the telescopes were being moved from Greenwich and installed in the new domes. The work was supervised by John Pope and Mick Dermody. (See section 3.3.5.) The work was still in progress when I returned a year later.

The three domes on the north side of the Group were connected by two-storey buildings that contained laboratories and a vacuum aluminising plant for recoating the telescope mirrors. The west (A) and central (B) domes contained the 30-inch and 36-inch reflectors from Greenwich. These reflecting telescopes were used primarily for spectroscopy and photometry for astrophysical investigations. The Yapp 36-inch reflector was brought into use in September 1958 to “complete the move from Greenwich”.

The east (C) dome was intended for a new Schmidt telescope, but it was never built. After a while it contained the Isaac Roberts 20-inch reflector that was on loan from the Science Museum, but this soon proved to be inadequate and was returned in 1961.

The three domes on the south side of the Group were used for nineteenth-century refractors from Greenwich with objective-lens diameters of 26-inches (E), 13-inches (D) and 28-inches (F). The 26-inch telescope was to be used for parallax observations that involved short exposures and so it was fitted with a rising floor to reduce the time spent in changing from one star to the next. The small 13-inch astrographic telescope was used for ‘mapping’ purposes and had originally been used in the international Carte du Ciel project, while the long focal length of the 28-inch telescope made it suitable for observations of binary stars.

As has been mentioned in section 2.7.1 the design of the buildings and domes gave rise to many problems in later years.

Work on the dome for the Isaac Newton Telescope, which was also sited on the east hill but to the south of the east-west road, did not start until 1964. (See section 4.2.2)

In 1953 the Ordnance Survey set up a triangulation pillar for use as the new primary point for the UK on the east hill on the south side of the east road near to where the dome for the Isaac Newton Telescope was built later. On one occasion, probably when I was still living in the hostel, I went up to the east hill one dark evening when they where making observations of a light on a pillar near Hastings.

3.2.3 The Meridian Group

The telescopes in the Meridian Group (which was renamed the Spencer Jones Group in 19xx) to the north-west of the Castle were used for the accurate determination of the positions of stars and of the rotation of the Earth, which still provided the basis of Greenwich Mean Time. The background to this work is described in section 2.5.1 and the early stages of the move from Greenwich are described in section 2.5.2. There were two principal instruments: the Cooke reversible transit circle (RTC) and the photographic zenith telescope (PZT). Spencer Jones had intended that the Melbourne transit circle would be brought from Greenwich, but this project was abandoned in the summer of 1956 following Woolley's appointment.

The RTC was brought from Greenwich; it had been installed and tested there, but it had not produced any results. Regular observations with the RTC began at Herstmonceux in October 1956. When it was being commissioned it was discovered, unexpectedly, that the spire of the church at Pevensey lay close to the meridian through the instrument. The new site proved to be much better than Greenwich and record numbers of observations were made.

Installation of the new PZT (see section 2.5.1) began at Herstmonceux in January 1955 and regular observations were being made early in 1956. It was then being operated by the Meridian Department. It did not, however, provide the basic source for the time service until the autumn of 1957. The PZT was operated remotely from a control system in an adjacent hut where the 'observer' could sit in the warm. This hut also had a separate lounge and other facilities for the observers working in the Group.

There was also a fourth pavilion that was used for observations with the 'small transit' that was brought to Herstmonceux and used on 23 April 1957 after having been used at Greenwich earlier in the day. Mike Lowne was the observer on both occasions. The instrument was used for the last time on 21 October 1957.

In RAR 55 (on p. 33) there is a passing reference to a plan to obtain an 'impersonal prismatic astrolabe' (designed by A. Danjon) for observations at Greenwich [check] during the International Geophysical Year (see section 3.3.3), as part of an intensive programme for the determination of the variations in latitude and hence of the motion of the pole of rotation within the Earth. It was eventually installed in the small pavilion at Herstmonceux in 1959. Its job was, however, also done by the PZT and so the astrolabe was transferred in 1964 to the Royal Observatory at the Cape of Good Hope (actually at Cape Town) in South Africa.

The Ordnance Survey set up a trigonometric pillar near the RTC. At first there was also an unexpected discrepancy of 19 feet between the longitude of the pillar as given by astronomical observations with the nearby PZT (and RTC?) and by the Ordnance Survey maps. [John Pope took part in simultaneous observations at Greenwich, Abinger and Herstmonceux, but I have not yet found a reference to this programme.] Eventually it was found that the maps were not based on the prime meridian through the Airy transit circle at Greenwich, but on the meridian of the transit instrument that had previously been used at Greenwich. The Ordnance Survey had failed to implement the decision of the International Meridian Conference of 1884!

3.2.4 Magnetic and meteorological stations

Building operations for the new magnetic observatory at Hartland Point (see section 2.3.3) began in August 1955 and the installation of equipment began in May 1956. The first observations were made in January 1957. Observations ceased at Abinger on 18 April 1957 and the remaining instruments were transferred to Hartland.

Observations at the meteorological station at Herstmonceux (see section 2.3.4) ceased in June 1956, and for a while the enclosure was used for the kinetheodolite (see section 3.3.3.3).

3.2.5 Visit by the Duke of Edinburgh

The completion of the move from Greenwich to Herstmonceux Castle was formally recognised by the visit by the Duke of Edinburgh on 14 November 1958. His tour included the Equatorial and Meridian Groups in the morning and the Solar Dome and West Building in the afternoon. The staff of the Observatory were in small minority (2/10) amongst the all-male guests at lunch in the Castle. The Magnetic and Meteorological Department was not included in the itinerary, although the subsequent information bulletin stated that “he was keenly interested in all aspects of the work carried out here”.

3.3 Departmental developments

This section is given in the sequence of my interests and reflects my limited knowledge of the activities of other departments.

3.3.1 H. M. Nautical Almanac Office

3.3.1.1 Publications

This period saw the culmination of the efforts by Sadler during the previous years to achieve a complete transformation of the publications of the Office and, especially, their unification with the publications of the Nautical Almanac Office of the US Naval Observatory. The increased level of cooperation between the two Offices led to me being seconded to the USA for a year from February 1957 to February 1958. My wife and son went with me and we spent the first six months in Washington D.C. before going to Connecticut, where I worked at the Yale University Observatory in New Haven. I gave an account of this period as an annex to my paper on the history of HM NAO in the proceedings of a symposium that marked the sesquicentenary of the US NAO in 1999. This visit provided a firm basis for the continuation of the cooperation

between the Offices and it gave me experience in using an electronic computer and an introduction to celestial mechanics. Clemence, the director of US NAO, set me on a project to study the orbits of the satellites of Mars and I later attended lectures by Professor Dirk Brouwer at Yale University Observatory on the theory of the motion of the Moon.

The *Abridged Nautical Almanac* was completely revised and unified with the *American Nautical Almanac* from 1958, but the two publications did not adopt the same title *The Nautical Almanac* until 1960 when the main British almanac finally changed to a more appropriate, shorter title. The UK and US editions continued, however, to have different covers. The data in the almanac were made available in a form that was suitable for photographic reproduction to the appropriate almanac-producing agencies in other countries. This not only saved a great deal of effort and cost in publication, but it had operational benefits as navigators could change ships and continue to use the same techniques. Ten countries using this facility were listed in 1991 edition. The number had been greater, but some countries stopped producing their own almanacs. It was said that about a quarter of a million ships used the data that were computed by HM NAO for the daily pages.

The unification of the two astronomical almanacs involved a much greater amount of discussion and effort as there were much greater differences in the contents and formats of the (UK) *Nautical Almanac and Astronomical Ephemeris* and the *American Ephemeris and Nautical Almanac.* It had been hoped that a common title would be adopted, but Clemence was unable to approval for the change. The UK edition became simply *The Astronomical Ephemeris* and the common abbreviation *A.E.* was used even in other titles, such as *Supplement to A.E. 1968.* The work of computation and typesetting was shared so that the UK was responsible for the first half of the volume while the US was responsible for the second half. This division was shown directly by the change in typeface and by the use of rules in the tables in the second half, but not in the first half. Differences in spelling are also present. Decisions about the content and layout of the tables and about the wording of the explanatory material were taken after discussions, sometimes lengthy, by correspondence and the occasional face-to-face meetings. I later realised that Sadler used to write long letters in manuscript to Clemence in addition to the official typewritten letters that were circulated to the senior members of our staff.

Sadler had put forward proposals for a much wider cooperation in the publication of the fundamental ephemerides so as to reduce the amount of duplicated effort and costs. These were not generally adopted and so the NAO continued to print and distribute, without charge, copies of *Advanced Data for the A.E.* for other countries to use in the production of their local almanacs. Professor Walter Fricke, who became the director of the Astronomisches Rechen-Institut in Heidelberg in 1955, did, however, obtain agreement to the cessation of the publication of the *Berliner Jahrbuch,* which was the corresponding German publication, and to the ARI taking over responsibility for the publication of the *Apparent Places of Fundamental Stars* from the edition for 1960. Fricke was also responsible for the change of the *Astronomisches Jahresbericht,* for which the editorial language was German, to *Astronomical and Astrophysical Abstracts,* which used English. The Institute of Theoretical Astronomy in Leningrad participated in this cooperative effort by publishing annually a volume of *Ephemerides of Minor Planets.*

It was intended that an *Explanatory Supplement* to the unified Ephemeris would be published in 1959, but the preparatory work took so long that it was not published until 1961. It was agreed that the drafting and checking should be shared, but that the volume should be edited and published in the UK. The preface states that it was "edited by G. A. Wilkins, assisted by Miss A. W. Springett", but Sadler took a detailed interest in the work and had the last word. By this time Clemence had become the Scientific Director of USNO and Edgar Woolard had taken over as director of the US NAO. He had a different style from both Clemence and Sadler and so it was not easy to obtain agreement on some sections. In a few cases Sadler wrote additional material where he felt that Woolard's draft was inappropriate. Ann Springett had just joined the Office as a 16-year old Scientific Assistant and she was well-suited to this work. When it was over she resigned to take a job with a publishing firm in Oxford. My recollection is that she was much more smartly dressed than the other girls and even carried an umbrella.

During this period the Office also published the new volume of *Planetary Co-ordinates… for1960-1980* and we contributed to a special volume for the *Improved Lunar Ephemeris*, although this was published in the USA. Before I went to the USA I had largely completed the compilation of the printers' copy for *Subtabulation*, a companion booklet to *Interpolation and Allied Tables*, but Bill Nicholson took over to see it through to publication in 1958. I had written the first and third sections, while Sadler had written the second section on the so-called end-figure method; Bill had helped him with the preparation of the tables. (I cannot now recall the principle on which it worked, but it was designed to obviate the need for the use of calculating machines and had long since fallen out of use.) I was particularly pleased with section 3 as I found the principle that underlay the many different bridging-difference formulae then being used for work on the National and Hollerith machines. (See section 2.2.6.3.)

During the preparation of *Interpolation and Allied Tables* it had become apparent that it would be possible to reduce considerably the number of pages required for the tabulation of the high-precision ephemerides, such as the lunar ephemeris, if they were represented by 'economised polynomials'. I spoke about our ideas at the IAU General Assembly in Berkeley, California, in 1961 and I was subsequently invited by Professor Walter Fricke to go to the Astronomisches Rechen-Institut in Heidelberg to discuss this and other topics of common interest. We did not, however, use this technique in our publications until much later.

Sadler had also obtained agreement to the publication by HMSO of the US Hydrographic Office series of *Sight Reduction Tables for Air Navigation* as *Air Publication 3270* and several volumes were issued during this period.

Dr J Guy Porter retired from the NAO in 1961 and I took his position as head of Astronomy Division II in the NAO and so became responsible for the supervision of the day-to-day work of computing the fundamental ephemerides and other data for the publications and other programmes. Eric Smith, who had joined the RGO as a computer in 1924 and the NAO in 1930, dealt with this work with the support of Brian Emerson, a graduate who joined the NAO in 1957. Eric was promoted to Senior Experimental Officer in 1962. Mike Candy, who had joined the NAO as a Scientific Assistant at Bath in 1947 was transferred to the Astrometry Department in 1958. He had developed (in his own time) an expertise in computing the orbits of comets and he worked with Porter on the orbit of Comet Crommelin. He succeeded Dr Porter as the Director of the Computing Section of the British Astronomical Association in 1958. He also had the

distinction of successfully predicting the return of Comet Ashbrook-Jackson and of discovering a new comet that then bore his name. He later moved to the Perth Observatory, where he was director from 1984 to 1993.

3.3.1.2 Computers

During 1956 (and possibly part of 1955) I studied the capabilities of the electronic computers that were then on the market in order to judge their suitability for use by the NAO and other departments of the RGO. I cannot now recall the names of all the companies and computers concerned, but BTMC (HEC 4), Elliot (503?), Lyons (LEO), Ferranti (Pegasus) and English Electric (DEUCE) come to mind. In the end I recommended that we should seek approval to purchase a DEUCE, which was based on the ACE Pilot Model that had been developed at the National Physical Laboratory. My experience of such computers was limited to the course that I had attended at Cambridge in 1954, but I was the only person in the Office with even this knowledge. Apart from its power, a major argument in favour of the DEUCE was that we could expect to receive much help from the NPL staff with whom we had good relations.

The case for this choice was put forward with the RGO bids for funds and I took a copy of the DEUCE programming manual with me to the USNO. There I gained experience in programming for the IBM 650 computer and in operational aspects of the use of computers. While I was away this bid was rejected, but instead it was decided that the RGO should rent a HEC 4 from BTMC, which already supplied our punched-card machines. Superficially this must have appeared reasonable to Sadler as we wished to have a computer that used cards, rather than paper tape, for input and output; moreover, it would provide continuity with a company that had previous experience in computing equipment. When the computer was eventually delivered in 1959 its name had changed to ICT 1201 as BTMC had merged with another company to form International Computers and Tabulators Ltd. By coincidence the other punched-card company, which used cards with round holes, had its factory, known locally as the “Acc & Tab”, very near to where I used to live in Croydon.

Details of the various computers that we considered are held in the RGO Archives at the Cambridge University Library [RGO 16, Box 40]. Most of the early computer manuals that I accumulated while comparing the available computers were transferred to the Science Museum Library in 1979.

When I returned from the USA at the end of February 1958 it was too late to attempt to change the decision, although formal approval was not received until later. I soon realized that the new computer would be much less powerful and much more difficult to program than the IBM 650 computers that I had been using in the USA. One major drawback was the almost complete lack of software for basic programming operations and for scientific applications. I therefore had to design and write some of this software before other members of the NAO, such as Albert Carter and Bill Nicholson, could start to write programs for our applications. For example, the ordinary programmer needed to be able to write his programs using decimal digits and letters, rather than binary codes. Similarly, a programmer needed to be able to write the sequence of instructions without having to specify the exact locations in which they should be placed on the rotating magnetic drum that was the main store of the computer. We were able to test this early software by using a computer in London but this was a time-consuming process.

Then I started to give talks to more of the staff who would need to be able to write programs or to specify tasks in an appropriate way for others to complete. Towards the end of 1958 I also started to produce a series of NAO Computer Circulars to give guidance and reference information for the programmers.

The NAO Computer Circulars show very clearly the depth of detail that had to be considered by the programmers who had to write one instruction for each basic arithmetical or logical operation to be carried out by the computer. They had to be aware of the binary character of the operations, whereas on the IBM 650 the programmer did not. The 650 was one of the few computers that actually carried out arithmetic with the binary representations of decimal digits and did not convert to and from ‘pure’ binary numbers.

One circular [CC 4] is a table of “bi-octal arithmetic” based on groups of 4 bits. At that time I was not aware of any term for a group of 4 bits and so I invented ‘bi-octal’, for what later became known as ‘hexadecimal’ for numbers to base 16 (or 2 x 8). Later the term ‘byte’ was introduced for a group of 8 bits. The table gave the results of multiplying one bi-octal number by another. The circulars also used the term ‘denary’ when the information being processed was represented by decimal digits rather than by the binary digits 0 and 1.

Another circular [CC 7] described the “routine relocation routines” that were used to simplify the task of assigning instructions written in symbolic code to appropriate locations on the drum. A lot of time would be wasted in waiting for the next instruction if they were not placed at the optimum interval. Further such “program assembly routines” were added as time went on [CC 29].

“The Model 1201 electronic computing machine” was delivered on 30 June 1959. It occupied the space of a large room on the ground floor of the NAO spur of the West Building. It had a large processor unit that stood about 7-foot high, with a comparable width and a depth of about 2 feet. A duct took away the excess heat from the valves and other components, including the magnetic drum storage unit. Then there was a tabulator that acted as the printer. This was faced by the control desk, with lights and switches corresponding to the 40-bits of the contents of each of the registers that held ‘words’ that represented either numbers or instructions or other forms of data. A reproducer that was used for the input and output of data on punched cards occupied the fourth side of the rectangle.

Two of our young scientific assistants, Valerie Cann and Lynn Ellis, acted as the operators for the ordinary use of the computer. Only rarely did programmers operate the system themselves. When programs went wrong — and they almost invariably did during the early test runs — the programmers could run a trace routine that showed the progress of the computation and hence the point at which the program had gone wrong. It was then usually possible to see where the error had been made. Sometimes the computer itself went wrong and then the resident ICT engineer would be called in. Friday afternoon was usually set aside for preventive maintenance and then several engineers would often be involved.

The work of the NAO provided the main initial application for the computer, but it gradually became used more and more by other departments for both routine data

processing (for example by the Meridian Department) and for research purposes. At first Woolley was sceptical about the value of the computer, but he took interest in its use for determining the periods of variable stars. One day of the Herstmonceux Conference in 1962 was devoted to the applications of computers in astronomy and this provided an opportunity to invite Jean Kovalevsky from Paris and Trudpert Lederle from Heidelberg to visit the RGO and to discuss matters of common concern with the NAO.

One activity that was stimulated by the increased availability of electronic computers was the interchange of astronomical data on punched-cards. The almanac offices had used this medium for ephemerides and some star catalogues before the introduction of computers, but the practice spread more widely and encompassed a much greater range of catalogues. A list dated April 1962 included 40 different data sets that were held at the RGO. The bulk of the larger catalogues was a deterrent, but the later introduction of magnetic tape stimulated this activity more widely. (See section 4.3.4.7 for my involvement in an international working group on this topic.)

As early as 1961 we started to negotiate for the replacement of the 1201and we obtained agreement within the Admiralty to the purchase of an IBM 1410 to match that the one that had already replaced the 650 at USNO. This was, however, blocked by the Treasury, which insisted that we went to competitive tender. In the event this was for the best as the 1410 was soon superseded by the IBM 360 series. In the meantime we obtained approval to hire time on an IBM 7090 system in London. This proved to be extremely useful as it gave experience in the use of Fortran, which became one of the two principal programming languages used for scientific work. (The name Fortran was derived from “formula translation” as it was intended primarily for the evaluation of numerical formulae.) In particular, I was able to adapt a Fortran program written by Neil Block at the Jet Propulsion Laboratory for the computation of the lunar ephemeris. (See also section 4.3.4.1) The other popular language was Algol, which tended to be favoured by academics for systems using paper tape, rather than punched cards, for input and output.

Tenders for the supply of a new computer were invited in August 1964 and eventually the review team, which included representatives of the Admiralty, the Treasury and the Post Office Technical Support Unit, as well as of the RGO, reported in February 1965. Tenders were received from a final short list of four companies, although the main competition was between an IBM 360/30 system and an ICT 1909 system. The latter was a special system that was aimed at the university market rather than the general commercial market and it was clear that it would be faster and cheaper than the IBM system. After our disastrous experience with the lack of software for the 1201, I was inclined to favour the 360, especially as it would have made possible the easy interchange of programs with USNO. The unwritten “buy British” policy outweighed this consideration and the order was given to ICT. The computer was not installed until the spring of 1966 and so the discussion of the new computer room and the performance of the system is given in section 4.2.1.

In 1963 we took delivery of an IBM card-controlled typewriter that was based on the IBM 870 Document Writing System. This replaced the machine that was installed in 1953. (See section 2.2.6.6) Dorothy Hutchings, who was a Cambridge graduate and who had joined the NAO as an AEO, was put in charge of the operation of this machine.

3.3.1.3 Research activities

Woolley was keen that the staff of the RGO should carry out research rather than routine programmes of observation, even though the results from the latter often led to new discoveries and the improvement of the data on which research was based. Consequently the work of the NAO was extended wherever possible.

Occultations. The lunar occultation programme (see section 2.2.4.3) was regarded by Sadler (and others) as a routine activity for monitoring the errors in the lunar ephemeris and long-term variations in the rate of rotation of the Earth. During the late 1950s it received a boost as it was recognised that this technique provided the best way of establishing the scale of ephemeris time (ET) over the past and of determining (via the intermediary of UT) the relationship between ET and atomic time (AT).

Atomic time was based on the adoption of a value the frequency of a particular transition of the caesium atom. This standard value was, however, based on an early determination by W Markowitz at USNO of the frequency with respect to the ephemeris second, which he derived from observations with Moon cameras. (See section 3.3.2.1). In later years, Leslie Morrison, who was transferred to the NAO from the Meridian Department in 1962, was to play a major role in improving the quality of the determinations of ET – UT and of the relationship between ET and International Atomic Time (IAT). (See section 5.5.4.4)

The other boost came from the use of lunar occultations to determine the positions and structures of extended radio sources and from the unexpected observation during an occultation in 1962 that one powerful radio source (3C 273) showed the characteristics of a point source — hence the term ‘quasar’ for quasi-stellar radio source was coined. Bill Nicholson carried out the reduction of the data from the measurements at Jodrell Bank and so has his name on the letter in *Nature* that announced this fundamental discovery. The technique was also applied to determine the positions of X-ray sources that were observed from rockets and later from satellites.

Satellites of Mars. In so far as time allowed, I tried to continue the work on the orbits of the satellites of Mars that I had started at the US Naval Observatory. I did not have the time to develop a more sophisticated program for the analysis nor to obtain more and better observations, but I rewrote the programs to run on an IBM 7090 since the 1201 was quite inadequate. I spoke about the work at IAU Colloquium no. 25 in Thessaloniki in 1964.

Earth satellites. Although the Office had given up responsibility for the satellite prediction service (see section 3.1.2.2) some members of the staff continued to take an active interest in observation and theory. Gordon Taylor became a dedicated observer who obtained many accurate observations of the positions of satellites. I believe that Scott and Candy also made many observations in their own time. The NAO did, however, provide assistance when regular observations of satellites were made at Herstmonceux with a kinetheodolite. (See section 3.3.3.3)

Scott and Nicholson looked into the theory of the use of satellites for the determination of position for navigation and land surveying.. Their efforts were, however, dwarfed by those engaged in the development in the USA of the ‘Transit’ satellite navigation system that depended on the measurement of the Doppler shift in the frequency of the radio signal that was emitted by the satellite. The Ordnance Survey

took up the use of the system for geodesy and later made observations from Herstmonceux. (See section 3.3.2.1)

Orbits to the Moon. In 1958 I had an unexpected request from the Royal Society to make a report with Desmond King-Hele (of the Royal Aircraft Establishment at Farnborough) about orbits between the Earth and Moon. King-Hele had developed (before the launch of Sputnik 1) a theory of the effect of various perturbations on the orbits of artificial Earth satellites. He had been (amongst?) the first to deduce an improved value for the oblateness of the Earth, but he had not considered orbits to the Moon. I had certainly not done so either, but we were able to use papers that had been published by Russians in anticipation of the Soviet programme to send spacecraft to the Moon.

3.3.1.4 International Astronomical Union

The officers of the International Astronomical Union were well aware of Sadler's high abilities as an administrator as not only had he been effective president of Commission 4 on ephemerides, but he served as chairman of the Finance Committee for several years. In 1957 he was asked by the President to become Assistant General Secretary with a view to becoming General Secretary at the next General assembly in Moscow in 1958. At first Woolley refused to allow Sadler to accept, but he was eventually persuaded to drop his objection. Sadler served as General Secretary for six years until 1964. This was a time of rapid growth in the membership and activities of the IAU and so Sadler obtained the full-time services of an assistant to act as his secretary. Nel Splinter, who was from Holland and who had had previous experience of the work, came to the RGO in January 1959 and was treated in all respects as a popular member of the NAO staff. She became internationally known as Miss IAU.

Sadler tried to keep to the minimum the time that was lost to the work of the NAO. For example, he and Nel used to work in the office on Sundays. Nevertheless, he was often away for meetings as he also represented the IAU on other organisations, such as the International Council of Scientific Unions. It soon became clear that he was no longer able to take a close interest in all the work going on in the office. One of his tasks was to edit the *Transactions of the IAU.* This was first of all prepared as *Draft Reports* and distributed with paper covers before the Assembly to all members of the IAU. They included the reports by all the presidents of the commissions on the activities of the members and their organisations during the past three years. Reports on the meetings during the Assembly were added to complete the volume. Sadler aimed as usual for high standards and so he prepared a "style book" that covered all aspects of typography and usage, such as notation and abbreviations. He then asked for volunteers amongst the staff to read the proofs in their spare out-of-office hours. He probably paid a small amount per page, but I do not recall the details now. His successor, Jean-Claude Pecker, edited this style book and published it in 1966 in the *Astronomer's Handbook* as a separate part of the *Transactions.* The distribution of the complete set of draft reports was soon abandoned and it was left to the presidents of commissions to distribute their reports to their members.

At this time my efforts outside the current work of the Office were mainly devoted to the improvement of the system of astronomical constants that were used in all high-precision ephemerides and positional catalogues. In 1963 I prepared a review paper for an IAU symposium that was held at the Paris Observatory to review the system in the light of new determinations by radio astronomy and from observations of

Earth satellites. I was then appointed secretary of a working group under the chairmanship of Professor Fricke to make formal proposals for the adoption of a new system at the next General Assembly of the IAU in Hamburg in 1964. The group met in my office in January 1964 and our recommendations were adopted by the IAU. An account of the new system and of its effect on the ephemerides was given in a *Supplement to the A.E. 1968.*

3.3.2 Meridian, Time and Chronometer Departments

The RGO Information Bulletin for 1 January 1962 announced that "the Photographic Zenith Telescope and the Danjon Astrolabe, together with the relevant staff, have been transferred from the Meridian Department to the Time Department". This was a logical development as the Time Department had a strong interest in the determination of universal time (UT) from the PZT and astrolabe, while the results from the Cooke reversible transit circle (RTC) were primarily of relevance to the research activities in the astrometry and astrophysics departments.

Mr Symms was retired as Head of the Meridian Department in 1963 and was succeeded by Wayman (PSO), with Tucker (SSO) and Blackwell (SEO) in support. Murray (SSO) in the Astrometry Department continued to take a close interest in the work of the Meridian Department. Smith was Head of the Time Department, with Thomas (SSO) being responsible for the astronomical observations with the astrolabe and PZT. He was supported by C C Harris (SEO), who had joined the RGO in 1928, but he died in service and was succeeded by O'Hora. Miss Penny (SEO) supervised the work for the time service. The Electronics Department was responsible for the maintenance of the equipment.

3.3.2.1 Observational activities

The better observing conditions at Herstmonceux made possible record numbers of observations on the Cooke transit circle from 1957 onwards. For example, over 28000 observations were made in the first three quarters of 1959, compared with the maximum of over 16000 in 1913 with the Airy transit circle. Milsom, who was on the staff of the Solar Department, and Clements together observed a record number of 507 objects in one night in January 1959. The RTC also became the point with the most accurately determined geodetic constants in the country and so Herstmonceux replaced Greenwich in the primary triangulation by the Ordnance Survey. A meridian mark in a special housing on the marsh near Pevensey was used to establish the azimuth of the RTC.

The operation of the PZT did not require observers at the telescope as once the system had been set up, with the photographic plate in position, it was operated remotely from the nearby control room. Consequently, some of the scientific assistants who measured the plates and carried out the calculations requested that they should also operate the equipment at night. As most were teenage girls, there was some concern about their safety at night, but they were persuasive and none of them came to any harm! Women also became observers on the equatorial telescopes. (See appendix C.4.2)

The Danjon astrolabe was installed during the summer of 1959 [RAR 60, 1]. It provided UT-data for the time service while the PZT was out of regular service for a year during 1962/63 when it was extensively overhauled and when improvements were

made to the timing system. The astrolabe was then taken out of service for overhaul prior to its transfer to South Africa in 1964. Thomas and Wallis went to the Cape at this time. The programme ended in 1969.

Ordnance Survey staff used the astrolabe pavilion when making observations of artificial satellites in 1964/65, as part of a European campaign of satellite triangulation to improve the geodetic network in the area.

Markowitz came to RGO in May 1957 for the installation of a Moon camera for use during the International Geophysical Year to determine ephemeris time. (See section 3.3.1.3). It was installed on the 13-inch astrographic telescope and was operated by the Time Department. The plates were measured on a digitised 2-coordinate Mann measuring machine, which was presented to the RGO by the US Naval Observatory. The machine was later transferred to the Astrometry Department and then to the University of Sussex.

3.3.2.2 Time service

Throughout this period the Time Department relied on its ensemble of quartz-crystal clocks for the day-to-day generation of the Greenwich timescale. New high-precision quartz-crystal oscillators were installed in 1964. The formal request for an atomic time-standard was not made until February 1965 and the first was not installed until 1966. (See section 4.3.3.1) A rubidium time-standard was, however, obtained on a short loan in 1964. The frequency of the timescale was checked regularly against the caesium atomic-clock at the National Physical Laboratory.

International time comparisons were made routinely and the time signals were received by various sets of aerials, including an ‘umbrella aerial’ that was situated in the field to the east of the NAO. It had a tall central mast and wires connected it to a ring of smaller masts. Snow in the bad winter of 1963 brought down 15 out of the 40 wires and so caused a gap in the reception of some signals.

The first use of satellites for time comparisons was made in August 1962 when the satellite ‘Telstar’ acted as the relay-link across the Atlantic. Then in 1964 use was made of ‘flying clocks’ that were carried by aeroplanes. The first experiment made use of quartz-crystal clocks, but caesium clocks were soon used for this purpose. At that time the discrepancies arising from the use of radio time signals were about 0.5 milliseconds. Such flying clocks were later used by USNO to test Einstein’s theories of relativity. USNO was funded by the US military and played a major role in the improvements of the methods of time transfer.

In 1964 the Time Department ceased to be directly responsible for the accuracy of the ‘speaking clock’ telephone service operated by the Post Office. The PO clocks were synchronised against the time signals transmitted from Rugby; these were, however, monitored by both RGO and NPL. When the speaking-clock service was introduced in 1936 the RO had sent time signals by landline every hour.

3.3.2.3 Chronometers

Early in 1962, the Chronometer Office, and the work on rating the chronometers, moved from the Castle to what had been the ‘eclipse store’ in the West Building, below the Chronometer Workshop. The Chronometer Department formally became a section of the Time Department in September 1962, but this appeared to have

no operational significance. In addition to the routine servicing of the chronometers of the Navy and RAF, it undertook special assignments. In 1962 it tested a "modern quartz-crystal chronometer" with overall dimensions of 9¾ x 5½ x 4 inches. This was, presumably, an early ancestor of the quartz wrist-watch!

In 1963 the Harrison no. 4 chronometer, which won the Longitude Prize, was cleaned and rated in the workshop before it was sent to the U.S. Naval Observatory to go on display in a special exhibition in the new Simon Newcomb Laboratory. The chronometer was sent on H.M.S. Lowestoft and 'Jock' Roseman, a Scotsman who was the head of our chronometer workshop, flew to Washington to supervise its unpacking and setting up. He returned in 1964 to repack it. It and the other Harrison chronometers were also serviced for the National Maritime Museum on other occasions. (I have a slide showing no. 4 in pieces on the bench in 1976.)

In 1960 a clock made by John Harrison was received on semi-permanent loan from the Royal Astronomical Society. This clock was mounted in the main entrance of the West Building. Later information bulletin 120 stated that a high-grade regulator clock that was manufactured by the famous marine chronometer-making firm of Victor Kullberg was installed in the entrance hall of the N.A.O. in 1964, but I do not recall this clock. Roseman was awarded a Silver Kullberg Medal and a Silver Schweder Medal in Sweden in 1964. (See also appendix C.8.2)

At the beginning of 1964 the work of the Chronometer Office, and in particular the rating of the chronometers, was taken over by clerical staff. George W Rickett, who had headed the department since 1939?, was transferred to the Solar Department, and the Scientific Assistants were gradually moved to other departments. Rickett's successor, W B Harvey, was a Higher Executive Office and was then shown on the complement of the Secretariat.

3.3.3 Solar and geophysical studies

3.3.3.1 Solar observations

Woolley allowed the solar observations to continue, but he gave them low priority. Whereas Spencer Jones had appointed Patrick Wayman to the Solar Department, Woolley transferred him to the Meridian Department and seconded him to South Africa in 1957 for a period of three years. Phil Laurie, who had served in the Solar Department for many years, was made its head in 1957. David Thomas, who had joined the department as an SO in November 1956 was soon transferred to the Meridian Department and then to the Astrophysics Department.

Copies of the daily photographs of the Sun were sent to the Fraunhofer Institute in West Germany as from 1 January 1955 for use in the compilation of daily maps of the features on the Sun.

On 23 February 1956 a very large cosmic-ray solar flare was recorded by the cosmic-ray monitor that was then in the Castle. (See section 2.7.2.) Gold collected data from all over the world about 'this remarkable solar event'. The recording apparatus was moved from the Castle to a new 'hut' near the West Building in 1958. The cosmic-ray monitors were maintained by the Electronics Department until the end of 1959, when responsibility was transferred to the Imperial College. As far as I am aware, no attempt was made by RGO staff to utilise the data after Gold had left in September 1956. The data were then collected purely as a service operation, primarily for the

International Geophysical Year. [I have not found any further reference to the cosmic-ray work in Reports of the AR. The equipment was probably taken to IC, but I do not know when, nor what happened to the hut.]

3.3.3.2 Magnetic and meteorological operations

Woolley also reduced the effort for the work of the Magnetic and Meteorological Department. Full scale meteorological observations ceased one month after Woolley's arrival, but observations were continued at a lower level for a few months. The report for 1956 contains a summary of the results for the year. The range of observations was drastically reduced from 11 June 1956. The Observatory's long series of meteorological publications were transferred to the Meteorological Office Library in the autumn of 1957. By 1961 the word 'Meteorological' had been dropped from the name of the department.

The magnetic work did, however, continue, although not as originally envisaged. For example, it was stated in the report for 1956 that observations would continue at Abinger during the IGY but in the event they stopped in April 1957. The new observatory at Hartland had, however, commenced operations during the previous autumn and so there were a few months of overlap.

The other main task of the department was the compilation of world-wide magnetic charts, which were of direct interest to the Admiralty. This major computational task was greatly eased by the availability of electronic computers and use was made of hired time on IBM computers in London. The task was expanded by the availability of much more data from, for example, airborne magnetic surveys.

3.3.3.3 Kinetheodolite observations

At the request of the Royal Aircraft Establishment (especially of Desmond King-Hele) the RGO operated an Askania kinetheodolite for the tracking of artificial satellites from July 1963 to support the RAE prediction service. The instrument had been developed by RAE for tracking rockets after launch, but it was adapted for observing the positions of satellites. These positions were analysed by King-Hele and others to determine the changes in the orbits of the satellites, and these in turn gave information about the density of the atmosphere and about the gravity field and shape of the Earth.

The observer followed the satellite with the telescope of the instrument and the altitude and azimuth were recorded regularly. The RGO was requested to operate one of them and Woolley reluctantly agreed to do so. A small team was formed and based in the NAO, although it was not formally part of it. (This may have been the first occasion in which the NAO gave up a store-room to make another office.) The team consisted of Wally Grimwood (o/c) from the NAO, Norman Rhodes from the Solar Department and Arthur Cordwell from the Chronometer Department. These staff are not listed anywhere in the AR's Report for 1964; perhaps they were paid by RAE!

The kinetheodolite was installed in a small dome on the east hill in the meteorological enclosure, which was not then being used. Regular observing began on 7 October 1963. One innovation was the use of fibre-glass for the construction of the pre-fabricated dome, which was about 6 feet in diameter. The results were sent directly to RAE, which provided the predictions, and were not analysed in RGO, although some

members of the NAO took an interest in its work. (See section 4.3.4.6 for later developments.)

3.3.4 Astrophysics and astrometry

3.3.4.1 Appointments

Woolley gave the greatest priority to research work in astrophysics and astrometry, and especially in galactic astronomy. To this end he recruited Dr. Bernard Pagel as an SSO in July 1956 and secured his promotion to PSO in the following September and to SPSO in 1961. John Alexander joined the A&A Dept. as a graduate SO in October 1956. George Harding was transferred from the NAO to A&A at the beginning of 1957.

The AR's Report for 1958 shows that the Astrometry and Astrophysics Department had been split into three parts: (1) a new separate department, known as the "Astronomer Royal's Department"; (2) an Astrometry Department under Alan Hunter; and (3) an Astrophysics Department under Pagel. Woolley's Department included Wayman, who was seconded to South Africa, and John Pope, whom he had made head of the Engineering Workshop.

The resignation of Gold left a high-level vacancy and this was filled by Dr. Olin Eggen from Mount Stromlo in Australia, where he had previously served under Woolley. Initially he had a temporary appointment for 1 year from August 1956, but this was extended. Eggen served for various periods at the Radcliffe Observatory, at the Cape and in the USA; he finally left the RGO in November 1965. My contacts with him were very limited, but I was aware that he gained a poor reputation amongst the more junior members of the staff. He will also be remembered for one incident in connection with the archives. (See section 3.4.3)

Dr. Victor Clube, an Oxford cricket blue, joined the AR's Department as an SSO in September 1962, but soon moved to the Astrometry Department. Another person who was recruited to strengthen the research effort was Dr 'Wal' Sargent. He joined from the California Institute of Technology (which included the Mount Wilson and Mount Palomar Observatories) as a Senior Research Fellow in November 1962. He resigned, however, two years later, after marrying Annelia Cassells, who was then working as an AEO in the AR's Department, to return to the USA. His wife became President of the American Astronomical Society and a George Darwin Lecturer at the Royal Astronomical Society in 2003.

Hunter was made editor of the RGO publications in the autumn of 1956. He was given more and more administrative duties and a few years later, in 1961, he was promoted to SPSO and became in effect Deputy Director, although this term was not then used. Andrew Murray was then given charge of the Astrometry Department. He had joined the Meridian Department at Greenwich in 1952 as an AEO and had moved to Herstmonceux in 1954. He was promoted to SO in 1955, SSO in 1957 and to PSO in 1962. At this time, the Astrometry Department was concerned only with the work that was associated with the equatorial telescopes, such as photographic astrometry and the measurement of parallaxes, and not with the work of the Meridian Department.

At the beginning of 1965, the Astrophysics Department was split into "Research Teams", initially just two led by Pagel and Eggen, and the AR's Department also became a research team. This was not announced in an Information Bulletin, but

details are given in an unsigned, undated memorandum that was sent to Sadler for information. By this time, Pagel had been given (in 1961) a special merit promotion to SPSO at the early age of 31. By contrast, Wayman was promoted to PSO at the same time.

3.3.4.2 Observing at Herstmonceux

Woolley's outlined his plans for the observations to be made with the telescopes in the Equatorial Group in his address to the Association of Astronomers on 15 January 1957. He was, however, uncertain whether the sky conditions would be good enough for accurate photoelectric observations with the 30-inch reflector and so he envisaged the possibility of sending expeditions to better sites once the equipment had been developed and proven at Herstmonceux. Solar and meridian observations had already shown that the number of clear periods was greater than at Greenwich. It was later found that there was a 50% increase in the number of parallax observations with the 26-inch refractor for a virtually unchanged programme, and this was ascribed "more to better transparency than to reduced cloud cover", but other factors may have contributed to the increase. Arrangements were made to set up an area around the Observatory where planning restrictions were imposed on new developments that might lead to light pollution.

The nature of the astrophysical and astrometric work carried out during this period has been summarised by McCrea in his Tercentenary booklet on pp. 55-56.

3.3.4.3 Use of telescopes in other countries

During this period the telescopes that had been brought from Greenwich to Herstmonceux were unable to match the scope of overseas telescopes on better observing sites and the construction of the dome for the Isaac Newton Telescope did not start until 1963. Woolley therefore started to make use of overseas telescopes in various ways. He arranged for a series of staff to go out to the Royal Observatory at the Cape and the Radcliffe Observatory in South Africa (see section 3.1.3.1) for periods of three years and to other observatories for shorter periods. The first to go to South Africa was Patrick Wayman in April 1957, but others (at least 14) followed, both in order to gain experience and also to provide general assistance in the work there. (See appendix C.9) Eggen went to the Radcliffe Observatory in South Africa in 1958 and Woolley himself went to Mount Wilson in California in 1959 for over three months. Hunter also went to Mount Wilson for 6 months at about the same time. Pagel went to Sacramento Peak in California for 9 months in 1960 and later to Mount Stromlo in Australia and the USA for a year in 1963/64. By 1964, visits were also being made to Kottamia in Egypt.

3.3.5 Aspects of Engineering

The various aspects of engineering became more and more important during this period as more sophisticated equipment was needed for the time service and for astrophysics in particular. The Electronics Department was formed out the Time Department at the time of the move from Abinger to Herstmonceux in 1958. It was, however, located in close proximity to the time-service equipment and its engineers did not appear to be called on for other applications.

Some of the machines of the Engineering Workshop had been transferred from Greenwich to the huts at Herstmonceux and the final transfer to the West Building began in January 1958. The foreman, Mr Wescott retired in January 1956 after 42 years

service. Mick Dermody was appointed in September 1956 to replace him as the foreman, and John Pope was selected by Woolley to supervise the activities and to recruit staff for a drawing office to design new instruments. The circumstances in which he was given this job were recounted by John and included in a note in *Gemini 10* about his career when he retired. John had trained as an electrical engineer, but he was very successful in his new field as a telescope engineer. In 1959 the Workshop produced its first instrument, a successful grating spectrograph designed to work on the 36-inch Yapp reflector.

The name Engineering Department was not formally introduced until February 1964 when a distinction was made between the Workshop (with Dermody as the foreman) and the Drawing Office (with two men). It was another year before Phil Cottrell was recruited to support John Pope, and eventually to become head of the department.

John Pope accompanied Woolley on several of his observing trips and he also made independent visits abroad, such as a visit in USA to study the design of spectrographs. He was also included in the party that went to Australia in 1964 for discussions about the proposed Anglo-Australian Telescope.

The memorandum on the setting-up of the Research Teams for astrophysics also stated that “Mr. Palmer, assisted by Mr. Harmer and Mr. Standen, will work on the design and adjustment of instruments”. He was shown as reporting in the same way as John Pope directly to the A.R.. Palmer had initially joined the RGO to work on the cosmic ray monitoring project, but he had then been given other jobs in the Electronics Department. Woolley also encouraged him to widen his experience by sending him to South Africa in 1964 to set up the optics for the 40-inch telescope. In March 1965 Woolley, Pope and Palmer went to the observatory at Kottamia in Egypt. Woolley held Palmer in high regard and a few years later (in 1968) he was promoted to Chief Experimental Officer. Unfortunately, he had to retire on medical grounds in 1974 and he died in the following year.

The staff of the RGO had no formal role in the design of the construction of the Isaac Newton Telescope and dome. This project had been delayed by the inability of the astronomers to agree on the basic design until Woolley forced through a decision. Then detailed design work and the placing of contracts was delayed by government stop-go policies. The progress on the Isaac Newton Telescope was given in only one sentence at the end of the AR’s Report in 1958. Work did, however, begin on the INT dome in October 1964, while the telescope itself was being constructed by Grubb-Parsons at Newcastle.

3.4 General matters

3.4.1 Annual reports

During this period the annual *Report of the Astronomer Royal to the Board of Visitors* provides a fairly comprehensive record of the activities of the Observatory up to the end of March 1964. There were, however, changes in the sequence and depth of detail given to different aspects of the work. The last report in 1964 illustrates very clearly the priority that Woolley gave to research. For the first time, the report was split into two parts, a narrative report, “to be read as a synoptic account of research activity”, and an appendix for “the routine work which, important though it is, changes little from

year to year". Some of the splits between the two types of activity look peculiar in retrospect. For example, details of the time service signals are given in the narrative report, while the NAO studies of the system of astronomical constants are mentioned in the appendix.

One change for the better as far as the historian is concerned was the inclusion from 1958 onwards of a table showing the allocation of staff to departments at the end of the report year. These tables cover, however, only the non-industrial staff who then numbered 127, while the industrial staff numbered 79. A separate section and a staff list for the Cape Observatory were given in 1960.

The 1965 meeting of the Board of Visitors was cancelled as the Board was abolished when the Science Research Council took over the responsibility for the Observatory. Consequently, there are no AR's reports for 1964/65 onwards. Reports on the activities were, however, published in the *Quarterly Journal of the Royal Astronomical Society* from 1962 onwards under the general heading of Proceedings of Observatories. These do not, however, include any details about the staff and the 'domestic matters' described in this account. Their main emphasis is on the research work of the observatory, but short accounts are also given of the changes in equipment and of the service activities.

In February 1965 I wrote a note to Sadler complaining that the RGO report for 1964 in QJRAS made no mention of the NAO or of the work of the Magnetic and Solar Departments. In his reply, Sadler mentioned that Woolley had drafted a report for SRC (before it had formally taken control) about the work of the RGO and had asked Sadler at very short notice to add a note about the research work of the NAO. He found that Woolley had concentrated on the astrophysical work and had omitted to mention the Magnetic, Time and Meridian Departments!

3.4.2 The RGO and NAO Libraries

It appears that Spencer Jones gave the RGO librarian, W P Preston, a fairly free hand in the running of the RGO library (see section 2.6.5) and recommended his promotion, but unfortunately the results did not justify this trust and assessment. (The promotion appears to have gone through since in 1956 he was graded as a 'temporary assistant', but in 1958 he was an Executive Officer.) In an attempt to remedy this situation a Library Committee was set up in the autumn of 1956 under the chairmanship of Donald Sadler. A few months later it reported that "The contents of the library are being arranged in a manner in which the Library Committee considers will afford the maximum convenience to those doing serious astronomical work". The details of the proposed arrangement, the catalogues and the borrowing arrangements, which relied upon the honesty and conscientiousness of the borrowers, were described.

The operation of the library continued to be a matter of concern and in it was announced that "certain changes were agreed in the organization and working of the Committee", which now included 7 members of the scientific staff. Laurie was given special responsibilities for 'Records' and for 'Slides, films, etc', while I was given responsibility for 'Acquisitions'. I must admit that I cannot remember what this duty entailed. Although Preston had the services of a labourer for domestic duties and the shelving of books it appears that the committee found itself having to make arrangements for "considerable use … in afternoons of a vacuum cleaner for removing dust from books". I do remember, however, that Sadler became more and more

exasperated by Preston's poor performance and eventually he persuaded him to resign in 1965 'for health reasons'. His position was taken over by Joan Perry, who was then a Clerical Officer/Secretary in the NAO, where one of her duties had been to look after the NAO Library. (See section 2.2.7.6.) She was promoted to Executive Officer and, in turn, Pat Hanning was transferred from the Typing Pool to the NAO and promoted to CO/Sec.

During this period the NAO Library continued to operate almost independently of the main library and some books and series of journals were duplicated. It was therefore used by staff of other departments in the West Building to avoid extra journeys to the Castle. Della Parker was appointed as a Clerical Assistant in 1957, just after the move to the West Building, to deal with the routine work in the NAO Library as well as to help Joan Perry in other ways. She left in 1962 to train as an actress and was followed by Doris Hobden, the sister of John Hobden, a storeman. A year later she was transferred to the Solar Department as a Scientific Assistant and was, in turn, followed by Alison Gaydon.

3.4.3 The RGO Archives

In IB 61, issued in 1957, the following statement is given under the sub-heading RGO Library.

"The Astronomer Royal has agreed that, while advantage should be taken of any special interest shown by individuals in the records of the Observatory, there should be continuing responsibility for their safe keeping vested in the Library Committee."

I was at USNO at the time, but I doubt whether I would have appreciated the significance that this statement would later have for me. I doubt whether I was even aware of the existence of a large volume of 'records' that later became known as the "RGO Archives". It is possible that this statement was issued at the request of Phil Laurie when he found that Eggen was 'weeding' the records, which were then stored in the basement of the Castle, and was sending some of them to the boiler room for burning. I only heard about this incident much later and its significance only became clear much later still. Eggen lived in a flat in the Castle at the time and used to visit the records room in the evening. It appears that the stoker drew his actions to the attention of Phil Laurie and he and Dick Leaton used to recover the papers. Many years later it was realized that Eggen had taken some of the records for his own use. (See end of section 6.3.5.4.) The records were later transferred to the basement of the Chronometer Block of the West Building with surplus copies of past RGO publications.

The introduction to the AR's Report for 1960 contains, without further comment, the following statement.

"In compliance with the Public Record Act, 1958, a catalogue has been prepared of all Royal Greenwich Observatory manuscripts for the period 1675-1881."

Section I of the Report for 1963 includes the following paragraph.

"The Lord Chancellor has exercised his powers under the Public Records Act, 1958 to designate the Royal Greenwich Observatory as the official repository of its own records and of those of the Cape Observatory. The Greenwich records from 1675 to 1881 have been arranged by regime and listed in the form prescribed by the Public Record Office. This work is being extended to 1910, and the Cape records will then be similarly dealt with. This unique collection covering the whole history of the oldest

scientific establishment in the U.K. will then be available for the first time to students of the history of science."

I believe that at that time Laurie was the person who was responsible for the records on a day-to-day basis and I assume that it was he who prepared the catalogue referred to in the AR's Report. He was then in the Solar Department. I have not yet, however, come across any formal reference to him being given this extra duty, although I recall that he was eventually given the job on a part-time basis in the first instance. The catalogue could only have given very brief details of the records since it took many man-years of effort in the 1980s to prepare the current catalogue.

My ignorance of the arrangements for the storage of records continued until the mid-1970s when I was given responsibility for them! In the early 1970s I was instructed to give up one of the rooms in the NAO Block that were then used for the storage of files past correspondence and calculations. As a consequence a large number of packets of numerical work that had been done during the 1930s and later were scrapped. I tried to keep samples of each type of page, but I was unable to find them when I looked for them at Cambridge.

There was no clearly stated policy about the retention of documents relating to the scientific and technical work of the Observatory and this is now apparent in the extent to which the work of the various departments is represented in the RGO Archives in the Cambridge University Library.

3.4.4 The Secretariat

When Hunter took up administrative duties on a full-time basis in 1961, H G Barker was still the 'Secretary and Cashier' of the Observatory, although he had reached the normal retirement age in 1959; he had held that position since 1936 and had reported directly to Spencer Jones. Although he held the most senior non-scientific post in the Observatory and his responsibilities must have increased considerably over the years, he was not promoted above Higher Executive Officer; I assume that the Admiralty used a rigid formula based on number of staff and size of budget. He was disestablished in 1962 and the position passed to John H. Whale, who was promoted to Higher Executive Officer. The corresponding position in the Cape Observatory was then held by Harry Cook, an Executive Officer, who had been seconded from Herstmonceux.

The name 'Secretariat' was used only in the annual reports, which give little indication of the range of duties of the staff concerned. These have been partly described in section 2.6.4 under the heading 'General Office', although this term was usually used in the more restricted sense of the executive and clerical staff who were responsible for all general administrative and financial matters. There was a steady growth in staff numbers that reflected the growth in the numbers and activities of the scientific staff, but otherwise there appeared to be little change in the nature of the work or of the procedures that were followed.

Other functions for which the Secretary and Cashier had various levels of responsibility included:

The provision by the typing pool of a secretarial service for all departments. This included the use of Varitypers for the preparation of high-quality copy for the photolithographic printing of the RGO scientific publications.

The purchase, storage and distribution of stationery, workshop materials etc.

The placing of contracts for the supply of new instruments, etc, although the contracts for major projects may have been placed in the Admiralty.

The maintenance of the fabric of the buildings. Power supplies, heating, water and sewage – there was a small filter bed to the south of the Castle. The Navy Works Department at Chatham would have had the prime responsibility for the buildings etc.

Cleaning, furniture and office equipment

Security and messenger services. Fire precautions and volunteer fire service. (Mr A. Lankford retired as Head Messenger in 1968; he and his wife had lived in a cottage on the grounds near the west entrance of the Castle.)

The Canteen and accommodation for the AR and for visitors, including vacation students, who stayed in the Castle.

The Library and the Archives, even though policy for the former was made by the Library Committee and the policy for the archives was minimal.

The gardens and grounds, including forestry and, presumably, the tenant farmers (although they may have been dealt with mainly by the relevant Admiralty department at Chatham). (See section 1.7.4.2) When Mr Dann retired as Head Gardener in 19?? his position was taken by Jack Pike, the forester, who was given general responsibility by Woolley for the grounds.

Transport services. There were three full-time drivers (Hutchins, Clarke and Manser) during this period. Car Parking. The internal roads, which were named after former Astronomers Royal in January 1964.

Foreign travel services for staff going abroad on duty for observing or conferences, etc.

Recruitment of staff. Organisation of annual staff reporting exercises. Consultation with staff about local arrangements through the Whitley Committee.

Telephone services. The RGO had its own telephone operator for external calls. Telex was first installed in 1965.

3.4.5 Training and students

Woolley was supportive of proposals for the further education of staff and the lunch-time lectures for scientific assistants that I had organised in 1955 were followed up in the autumn of 1956 by a comprehensive series of daily lectures in working time. The series was organised by a committee under the chairmanship of Sadler, while Leaton and I had responsibility for the mathematics lectures. Promotion from one class to another depended largely on the acquisition of appropriate qualifications and so some staff attended evening classes, but these lectures probably helped them in their studies. They may also have helped temporary staff to become established. I gave a course on mechanics and 15 Scientific Assistants took an examination in December at the end of the first term. [My notes may still be available.] The lectures continued in the new year, but I left to go to Washington early in February.

Some polytechnics (and universities?) provided sandwich courses during which each student spent a year in industry to gain practical experience of working conditions and current techniques. The Observatory supported this system both by taking on

students and by allowing our own staff to take such courses and to spend their 'sandwich year' at the Observatory.

One example of a successful sandwich student was Ann Coleman, who joined the NAO as a scientific assistant in February 1965. She was clearly capable of going further and so she started a sandwich course at the Brighton College of Technology in the autumn of 1966. Much to Sadler's dismay she spent her sandwich period in the Electronics Department and not in the NAO, and she was allocated to the AR's Department on her return. She went on to take an MSc at the University of Sussex before moving to the Royal Observatory at Edinburgh and then to Siding Spring in Australia. Eventually she was awarded a PhD, but she did not get the further promotion in ROE that she had hoped for. She retired in 1995, but she kept up her interest in astronomy and wrote articles for the local *Coonabarabran Times* .

In 1956 Woolley also introduced summer vacation courses for university students. These gave the students both work experience in various departments, although at first the work appears to have been largely for astrophysics! They were also given lectures on astronomy and related subjects; for example, I gave lectures on computing as this topic did not feature in the usual undergraduate courses. The courses usually lasted for six weeks (eight weeks from 1966) and the demand was so great that two courses were held from 1958 to 1962. There were about a dozen students on each course and they were provided with accommodation and meals in the Castle. The Observatory benefited from the work that the students carried out; some of it was routine, but some was on special projects for which the staff did not have time. Staff time was, however, taken up in training the students and in preparing and giving lectures to them.

The students gained useful experience and also had a very enjoyable 'holiday' as they were able to enjoy living in a castle with extensive grounds and both indoor and outdoor sporting facilities. The beach at Pevensey Bay was within easy cycling distance on a fine evening, while Eastbourne, Bexhill and Hastings were accessible by bus at weekends. It was no wonder that some of them came back again. More importantly, several students took up careers in astronomy after graduating, and some joined the staff of the RGO. (See list in appendix C.10.)

The courses also led to several marriages. For example, Sadler claimed that Michael and Margaret Penston first came together at his home on one of the occasions when he and Flora invited some of the students to dinner. Derek and Thelma Jones also met on a course in 1957. Philip Hill came in three successive years and later married Sheila Osbon from the Meridian Department.

Sometimes the students celebrated the end of the course by a prank. Perhaps the most notable was in 1986 when they put a large 'face' on the empty INT Dome. Others are described, together with other aspects of the courses, in *Astronomers at Herstmonceux.* (See appendix G.4.1). The students took part in night observing and at least one fell into the ornamental pond in the Equatorial Group.

3.4.6 The RGO Club

There were major changes in the arrangements for sports and social activities during this period as results of the influx of staff from Abinger and Greenwich, and of the demolition in 1958 of the huts that had been used as a clubhouse. The RGO Club was then able to use the West Building for evening table-tennis matches, although it

was far from ideal for this purpose, but there were no facilities for lunch-time activities or for snooker at any time.

The new secretary L. J. (Joe) Bates, was very go-ahead and soon there were plans for a self-build clubhouse by the west gate. Work started in the spring of 1959 and the Clubhouse was opened in the autumn of 1960. Major improvements were made to the sports field on the east hill. The Club was renamed, simply, the Royal Greenwich Observatory Club and its activities increased in scope. Further details are given in appendix D. Tragically, Bates died at the age of 41 while on duty in South Africa in December 1964.

3.4.7 NAO Reunion in 1963

Before the war the NAO staff went on seaside outings together and then the evacuation to Bath served to strengthen their community spirit. Consequently many of them kept in touch with others even after many of them had left the Office. In February 1963 Sadler wrote to former members of the staff inviting them to attend a party to be held in the Castle Ballroom during the evening of Saturday, 27 April 1963, with the option of visiting the Castle and grounds in the afternoon. This proved to be very popular and the group photograph in front of the south tower of the Castle includes 66 persons.

4 CHANGE OF CONTROL - PHASE 1 – 1965 TO 1971 WOOLLEY AND THE SCIENCE RESEARCH COUNCIL

4.1 The change from control by the Ministry of Defence

4.1.1 The establishment of the Science Research Council

At the end of 1964 it was announced that the Science Research Council (SRC) would be established to direct and finance scientific research in the U.K. and elsewhere. In particular it would take over the activities of the National Institute for Research in Nuclear Science (NIRNS) and responsibility for the Radio Research Station (RRS), the Royal Observatories (including the RO at Edinburgh) and the scientific space research programme.

The SRC also took over from the Department of Scientific and Industrial Research (DSIR) the role of the funding of scientific research projects in universities, but not the applied research work in, for example, the National Physical Laboratory, nor research in the defence departments. These changes had been recommended by Trend Committee and were incorporated in the Science and Technology Act (1965). In due course, NIRNS took on a wider remit and it split into the Rutherford Laboratory, the Daresbury Laboratory and the Atlas Computer Laboratory. Similarly, RRS took on space research and its name changed to the Radio and Space Research Station (RSRS).

Moreover, the SRC was only responsible for the physical sciences since the Act also set up the National Environment Research Council (NERC) and the Agricultural Research Council (ARC). As far as I can recall there was no explicit mention of research that would have applications in engineering, although this was eventually clarified when SRC became the Science and Engineering Research Council in 1980. Not unexpectedly, this division of responsibility led to bureaucratic nightmares for projects that straddled the boundaries of two or more research councils or of two or more government departments.

The British National Space Centre (BNSC) was set up as the link between the government and commercial companies with activities in space. BNSC was also the link between the UK and the European Space Agency, which had taken over the European Space Research Organisation (ESRO). BNSC was funded by the Department of Trade and Industry, while the SRC and NERC were funded by the Department of Education and Science (DES). Consequently the funding of space research was by no means straightforward!

The name Science Research Council was used in three senses. Strictly it applied to the Council formed by the group of persons (mainly men) from universities, industry and commerce who determined the policy of the organisation (within the constraints imposed by the DES, which appointed them). The name was, however, also used for the bureaucracy that had the task of implementing this policy. This bureaucracy consisted of civil servants and a network of committees made up mainly of members of the universities. These committees had to decide which of the projects submitted to them should be funded. The third sense of SRC was that of the totality of the staff of the

head office and of the out-stations, such as the laboratories and observatories. The head office was initially in State House in London.

On 1 March 1965, just before the Act came into force, a high-powered delegation visited the RGO. It was led by Lord Bowden, the Minister of State for Education and Science, and Christopher Mayhew, M.P., the Minister for Defence for the Royal Navy, and it included another M.P., an Admiral and a Rear-Admiral, and two senior civil servants. One can only surmise about what important decisions required them to travel to Sussex! By this time the Admiralty had become part of the Ministry of Defence, but this change had little effect on the administration of the RGO. The effects of the change to the SRC were very much more significant and long lasting.

4.1.2 The immediate effects on the RGO

Surprisingly, the RGO Information Bulletins contain no mention of the change of control from the Ministry of Defence (MoD) to the Science Research Council, but there must have been other notices about the effects of the change. The most obvious were that the Chronometer Department and the Magnetic Department were no longer departments of the RGO since the former remained a part of the MoD, while the latter became part of the Natural Environment Research Council. It was clear that the maintenance of chronometers was not a research activity and change took immediate effect. The position of the Magnetic Department was not so clear cut and its change of control did not take place until 1 September 1967. The variations of the geomagnetic field were largely due to effects of the Sun and originated in the ionosphere and magnetosphere, while the main field originated in the core of the Earth. The conditions were completely different from those studied by the geologists in the British Geological Institute in which the department was to be located. I suspect, however, that Woolley was only too glad to lose this part of the observatory.

There were also doubts about whether the NAO and the Time Service should be funded by SRC. The name of the Office suggests that its main purpose was to produce the navigational almanac used by the Royal Navy, but in practice the production of the navigational almanacs was a by-product of its astronomical activities which were directly relevant to scientific research. Moreover, some of the staff were themselves engaged in ‘pure’ research. Similarly, it was considered by some that the provision of the time service was not an appropriate activity for SRC, especially as Woolley had denied the department the opportunity to participate in the development of better atomic clocks. The Greenwich timescale was, however, still dependent on the determination of the variations in the rotation of the Earth from observations of transits of stars and the link between the observatory and time was widely recognised. The National Physical Laboratory then produced the atomic timescale that provided the national standards of frequency and time-interval.

Both activities remained in the RGO, but the MoD agreed to pay for the costs of producing the almanacs and other tables for the RN and the RAF. The profits on the sales of the *Nautical Almanac* were, however, almost certainly more than enough to cover these costs. At first, Sadler’s estimates of the costs of this work were accepted, but eventually SRC insisted on a full costing exercise that took two men several days to complete. The result was within a few percent of Sadler’s estimate that took only a few minutes. It is said that even the cost of cleaning the windows was taken into account by the bureaucrats! There was no department of government, or other user of the time service, that could be identified to pay for the time service. This was used by the

defence services, industry and commerce as well as in everyday life and so SRC funded this activity in full.

The staff of the Chronometer and Magnetic Departments continued to be treated as members of the RGO in all respects except their pay and grading. In particular, they remained members of the RGO Club and even participated in SRC sports events. One person who benefited from the change was Dick Leaton, who had succeeded Finch as head of the Magnetic Department and who been promoted to PSO in 1964. His promotion to SPSO in NERC in 1967 would not have occurred if he had still been reporting to Woolley. I did not, however, regret my decision not to accept Woolley's suggestion that I should transfer from the NAO to become head of the Magnetic Department when Finch retired.

The SRC was one of the increasing number of organisations that were funded by the government but which were not formally part of the Civil Service. This had the cosmetic effect of reducing the number of 'civil servants' and it was supposed to allow a greater freedom of action by reducing bureaucratic constraints. This did not appear to happen in SRC as the persons in the 'London Office' (as the headquarters was called) were mainly former civil servants from DSIR and so they applied the practices to which they were accustomed. NIRNS had been formed as an independent offshoot of the Atomic Energy Authority at Harwell, which was itself outside the Civil Service and which had its own conditions of service and superannuation scheme. Consequently the NIRNS staff had AEA conditions, while most of the rest of the staff in SRC had civil service conditions.

The SRC therefore embarked on the task of producing a complete set of "Conditions of Employment Memoranda" (CEMs) that were a compromise between the two sets of conditions. This took many hours of negotiation, spread over several years, between the SRC and the various trade unions that represented the many different types of staff in the different constituent organisations. (I believe that the distinction between industrial and non-industrial staff was retained so that two sets of CEMs were produced.) SRC continued to use the concept of the Whitley Committee for negotiations between the official and staff sides at different levels in the organisation. One procedure that was eventually lost in the change-over was that of staff-side scrutiny of the annual reports on the performance of each individual. (It appears that we followed the Admiralty system until 1968 as I have a note that I was a scrutineer from 1962 to 1968.) We did, however, retain the conditions of the Civil Service Superannuation Scheme, although a separate organisation was set up to administer the scheme for the research councils. The staff who were in the AEA superannuation scheme were able to stay in it.

In the RGO most of the scientific and professional staff were members of the Institution of Professional Civil Servants and we formed the Herstmonceux Section of the SRC Branch of the union. Our secretary was Joy Penny, an SEO in the Time Department, and she spent an enormous amount of time on these negotiations about the CEMs. I was the chairman of the section from 1965 until 1969 and I also served on the Computer Subcommittee of the Scientific Staff Group of IPCS. The meetings were held in normal working hours and so the time lost to science must have been very large when aggregated over the whole of SRC. My recollection is that the chairman of the SRC Branch was Alec Spurway of the Rutherford Laboratory and that he was engaged almost full-time on IPCS activities! IPCS called a half-day token strike on 6 March 1974. I was in London on that day and I do not recall the reason or how much support it got. I sat on the fence in my note to staff on the previous day!

The other major effect of the change to SRC was that the RGO became much more subject to detailed control from 'above'. Under the Admiralty, the RGO would be allocated funds each year for the day-to-day running of the Observatory and the Astronomer Royal would then have a large measure of independence in the decisions about how they were spent. Similarly, the AR could allocate staff within the agreed complement as he thought fit. The AR reported each year in general terms to the Board of Visitors and he would seek their support for separate bids for large projects that required external expenditure. The SRC demanded, however, much more detailed estimates and reports each year and this involved considerable effort from persons who had not previously been concerned with such activities. Under SRC the RGO did obtain increases in both staff and funding, but there was also a considerable overhead in administrative effort.

At this time there was also an unresolved conflict about the role of the Observatory. Under Spencer Jones the RO had been largely a service organisation that provided large compilations of astronomical data for other astronomers to use, as well as time, almanacs, magnetic charts, etc for general use. Most of the papers listed in the annual report for 1956 are by-products of the 'routine' programmes rather than research papers in refereed journals. Very few, if any, members of the staff would have regarded research as their primary activity. Woolley, however, changed the emphasis to that of a research organisation by reducing the effort allocated to routine work and increasing the number of young staff engaged on short-term research projects.

The SRC tended, however, to regard the primary function of its establishments to be that of providing support services for the universities. For example, the Rutherford Laboratory ran a synchrotron that was used by university groups to run experiments in nuclear physics. Sometimes the SRC committees had to choose between funding a proposal from a university or from an establishment and it would then appear that the former would be better value than the latter. This arose because the university did not need to ask for funds to cover its overheads, since these would be met automatically from other funds, while the establishment had to include all its costs.

There was one anomaly that favoured staff in the establishments and, I suspect, made some university members of the committees resentful of our conditions of employment. We had well-established rules for the payment of travel expenses and subsistence allowances when we were expected to work away from home. They applied when we attended international conferences and fully covered all reasonable expenses. On the other hand, most university staff had to apply for travel grants from the Royal Society and these did not usually cover all the costs. I met this in 1965 when I was urged by my Ph.D. supervisor to present the results of my work at a conference in Brazil. Woolley considered that this could not be regarded as duty since it was not part of my normal work, but I obtained a travel grant from the Royal Society as my application was supported by Professor Sydney Chapman. (See section 4.3.5)

The meeting of the Board of Visitors that had been scheduled for 12 June 1965 was cancelled and a new 'RGO Committee' was appointed in its place. This held its first meeting on 12 February 1966, under the chairmanship of Professor McCrea, of the University of Sussex. He was sympathetic to the RGO and he may have helped Woolley to maintain his emphasis on research. Some of the later chairmen of the RGO Committee held different views and so Woolley's successors were unable to resist the pressure to concentrate on support services and greater changes took place in the 1970s. The change meant that the detailed annual reports on the activities of the RGO were no

longer made generally available, although the reports in the *Quarterly Journal of the Royal Astronomical Society* were continued. (See section 3.4.1.)

4.2 Major new developments

4.2.1 The installation of the ICT 1909 computer

The decision to replace the ICT 1201 computer by an ICT 1909 computer was taken just before the change-over to SRC and so we did not have to persuade SRC of our need for much better computer facilities. The 1201 computer was taken out of service in September 1965 as we needed a much larger computer room with air-conditioning and with a false floor so that the cables connecting the many different units could run safely under the floor. We decided to use the full width of the north end of the basement and so we took over the corridor and the publications store, which had been on the east side. I do not recall who was responsible for planning and carrying out the work, but I do recall being very pleased that the air-conditioning equipment fitted into a much smaller space than I had seen in other installations.

There was a short delay in the delivery of the new computer and this took place on 29 April. There was then a period of a month while it was installed and commissioned by the ICT engineers. Then a further week was taken up by acceptance trials that were very closely specified and scrutinised so as to confirm that the computer met its specification within very tight limits of reliability. We had to devise a set of tests for the central processing unit (CPU), the control desk and all the peripheral units, which included 4 magnetic-tape drives, a very fast line-printer, punched-card reader and punch, and paper-tape reader and punch. Moreover we had to be able to verify, as far as it was practicable, that it was performing these tasks correctly. One important feature of the operating system, called the Executive, was that it was able to run four different programs together in such a way as to maximise the use of the CPU. For example, it would switch from one program to another when the first was waiting for the execution of an input or output instruction before it could proceed to the next instruction in its program.

The set of tests was repeated several times during the course of the week and a record was kept of the number of faults that occurred. I believe that the engineers were about to carry out maintenance checks between each set of tests. The system passed the trial and was formally handed over on 23 May. We have a celebration photograph of the team of engineers and of our staff who were involved in the trial. From then on, ICT supplied a ‘resident engineer’, who was on call at short notice if any part of the system developed a fault. In addition, Friday afternoon was set aside for routine maintenance and other ICT engineers would come to carry out extensive tests and to replace any components that appeared to be liable to fail.

Our first resident engineer was Arthur Hoadley, who had a ginger moustache, and he was succeeded after a few years by Alan Dilly. One technique used by the engineers during routine maintenance was to set the CPU on a repeated set of instructions and to connect a loudspeaker to an appropriate circuit to produce a signal with a pattern of sound. Any change in the pattern would be noticed immediately, even if the engineer was engaged on another task, and would indicate that a fault had occurred. Then an engineer realized that the computer could be made to play a tune and

I understand that the appropriate programs were circulated amongst the engineers. One afternoon our engineers connected an amplifier and a large powerful loudspeaker to the system and the whole building reverberated to Bach's Toccata and Fugue!

Although the speed and capacity of the computer was trivial by today's standards, the 1909 represented an enormous increase in power compared with the 1201and the earlier punched-card machines. Moreover, the 1909 proved to be reliable by the standards of the time and the operating system was effective and robust. I was surprised to find several years later that the US Naval Observatory ran only 1 program at a time in their IBM 360 system.

4.2.1.1 More about the comparison with other contemporary computers

The tendering procedure that led to the acquisition of the ICT 1909 computer has been briefly described in section 2.3.1.2, but some further details of the computers that were available at the time may be of interest. Eleven companies were asked it they wished to tender for the new computer for which the specification was deliberately left wide since we really did not know what we could expect to obtain for the amount for which we hoped to get approval. Amongst those that expressed interest was English Electric with the KDF 9 computer. Some of the tenders were withdrawn or ruled out right away and that left a short list of De la Rue Bull M.40, IBM 360/30, ICT 1909 and National-Elliott 4120 for which formal tenders were invited and submitted. At that time, the hardware and basic software were still being developed and so we could not have carried trials for comparison purposes even if we had had appropriate programs.

I attended (probably at IBM expense) a special seminar about the IBM 360 series at the Selsdon Park Hotel on 30 April and 1 May 1964. The series 360/30, 360/40, etc consisted of computers with CPUs of increasing power and cost, but with a common 'architecture' so that programs written for one computer would run on a computer of a higher grade or even of a lower grade if it had sufficient storage capacity. Similarly the peripheral units were compatible with different CPUs and the power and cost of the system depended on the type of CPU and the peripherals attached to it. A 360/40 would have been my choice, but its price was above our range and so a 360/30 was considered by the evaluation team.

ICT had a similar 1900 series that was based on a Hewlett-Packard design, but manufactured by ICT in Manchester. (By this time, ICT had taken over Ferranti, which had links with Hewlett-Packard.) The series ran from the 1901 up to the 1906, and was intended for commercial use with punched cards as the basic input/output medium. The 1909 was not the most powerful CPU in the series, but it was aimed at the university market, which at that time tended to favour punched-paper tape, rather than cards. ICT was, however, able to offer us a system with both media at a price that was cheaper than the less powerful IBM 360/30, which would, however, have given us compatibility with USNO.

4.2.1.2 The hardware characteristics of the ICT 1909 computer

The principal characteristics of the central processing unit of the ICT 1909 computer were a main store of 16384 (= 16 K) words, each of 24 bits, and a cycle time of 6 microseconds. The operating console had a typewriter that was used for both the input of instructions by the operator to the computer and for the production of a log of the jobs that were carried out. It also had two paper-tape readers with speeds of 300 characters per second. A character was represented by 6 bits as in standard teletype

working. On the other hand, the IBM 360 series used the 8-bit byte that eventually became the industry standard as it allowed for a much larger character set. The characteristics of the other peripherals were as follows.

The card reader was able to read 900 80-column punched cards per minute, while the card punch was able to output up to 100 cards per minute.

The line printer was able to print 1350 lines of 120 characters per minute. Each page of 66 lines (at 6 lines per inch) was printed in about 3 seconds. The 64-character set included upper and lower case letters as well as numerals and signs.

The four magnetic-tape drives, each had a transfer rate of 20800 characters per second at a density of 556 characters per inch. These were known as 7-track tapes as a parity bit was associated with each 6-bit character so that any errors in recording or reading would be detected. Such tapes were eventually superseded by 9-track tapes.

The availability of magnetic tapes that could store large quantities of data greatly reduced the number of cards that had to be punched, read and stored. They were also used for the international exchange of data for the almanacs, star catalogues and theoretical and observational results.

The system also included a Calcomp graph-plotter, with a plotting width of 29½ inches, a resolution of 0.01 inches, and a maximum plotting speed of 12000 steps per minute. This was not delivered until the beginning of 1967. A program timer and real-time clock were fitted at the same time.

The computer had two major upgrades during this period. Firstly, in 1967 the size of the core store for random-access memory (RAM) was doubled from 16 K words to 32 K words. (A word contained 24 bits and so was equivalent to 3 bytes, giving a capacity of 96 KB. My 1999 Tiny desk-top PC has 128 MB of RAM and its hard disc holds 13 GB, where 1 GB = 1000 MB and 1 MB = 1000 KB. This is tiny in comparison with current laptops in 2009.) Secondly in 1969, two exchangeable disc-storage units were added. Each unit was the size of a washing machine, while the discs were at least the size of a vinyl LP record and there were 6 discs in a cartridge that was several inches thick. The capacity of one cartridge was 8 million characters. There was effectively random access to the data on the discs and so it was much faster and more convenient in use than magnetic tape.

The usefulness of the computer was further increased by the addition in July 1970 of three remote consoles that could be used for program development, thus beginning the change away from punched cards for such purposes.

4.2.2 The completion of the Isaac Newton Telescope

Work on the construction of the dome for the Isaac Newton Telescope (INT) began at Herstmonceux in October 1964 and my slides show that the pier for the telescope was well above ground level in April 1965, although the rest of the site was a sea of mud!. From then on the progress was clearly visible as the pier grew in height and was surrounded by a framework of girders and then the aluminium cladding. The two main dome arches were lifted into place in February 1966. (I was there to watch and photograph some of the operation!) The ribs were added and the cladding of the dome was completed in May. Further interior work was required before the building was ready for the telescope, which, in the meantime, had been constructed by Grubb-Parsons at Newcastle. The first major components arrived in September 1966 [slides]

and assembly was almost finished in November. The commissioning of the telescope took place while the interior work in the building continued. The building and telescope were completed in August 1967. The INT was formally inaugurated by HM The Queen during the evening of Friday, 1 December 1967.

Only a small number of persons were able to be present at the ceremony, but it was shown on closed-circuit TV in the Ballroom of the Castle, where a reception was held for official guests and a small number of RGO staff. Other staff were able to watch TV monitors elsewhere in the Castle and to watch the Queen arrive and depart. Unfortunately it was a foggy day and so the Queen was unable to observe with the telescope after the reception. The Castle was floodlit for the occasion, but the fog also spoilt this.

As a memento of the occasion the Queen was presented with a replica of the original telescope that was made by Isaac Newton and she signed the Visitors Book. These were later put on display in the Staircase Hall. A second replica was mounted in a glass case in the INT dome. These replicas were made in the workshops of the Observatory and another one was made much later as a retirement present for John Pope.

There was separate entrance and stairway (but no lift?) for public admission to a viewing gallery for the INT. There was also a special car-park near to the East Gate. At this time, there were no arrangements for the public to see the telescopes in the Equatorial Group.

The story of the project has been written up by Graham Smith and Janet Dudley and its effect on the RGO has been discussed by Lovell. References to these and other papers about the INT are given in appendix G.5.2.

4.2.2.1 Commissioning and use of the INT

As McCrea pointed out (p. 65) in his Tercentenary booklet about the RGO, the INT was to be under the general administration of the Astronomer Royal, though not as part of the RGO. Consequently, the RGO had no separate group for the INT and appeared to be ill-prepared for the task of providing a service for the operation and use of the telescope by the university astronomers for whom it was built. Not unexpectedly, the reputation of the RGO suffered.

At first the INT was used by RGO staff for direct photography at the prime focus. The grating spectrograph from the 36-inch telescope was fitted in April 1968 and was used until August when the planned Cassegrain spectrograph was completed and installed. A third camera was fitted to this spectrograph later. The coude spectroscope proved to be unsatisfactory because the building was poorly insulated so that the internal temperature changed considerably during the night and this adversely affected the stability of the long-focus spectroscope.

Closed-circuit television equipment made by Marconi was fitted to the 8-inch guiding telescope in January 1969. This displayed a star field of about 1^{o} on a 9-inch monitor on the console. The primary mirror was re-aluminized for the first (?) time in June 1969. Some observations were made in the infra-red during daylight when the sky was cloudy.

SRC set up a Large Telescope Users Panel in April 1967 to allocate time on the INT and the 74-inch telescope at the Radcliffe Observatory at Pretoria. The first ‘guest

observers' on the INT were V C Reddish and H Seddon from the Royal Observatory, Edinburgh, who had consecutive weeks starting on 23 October 1968.

4.2.3 The new Physics building

It was clear that the future progress in astronomy would depend on the development of new instruments and a new building for this purpose was constructed on the ground to the north of the Engineering Workshop. It was ready for occupation by November 1969 and was known as the Physics Building. It was used by the Instrument Development Department as well as by the new Physics Department; the distinction between their functions was by no means clear!

4.3 Other departmental matters

4.3.1 Astrophysics and astrometry

The main priority continued to be given to research in astrophysics and astrometry and this emphasis on research led to the abandonment in September 1965 of the long-term, 'routine' observing programmes with the reversible transit circle. It continued to be used for short programmes, such as the FK5 star catalogue and Solar System objects.

There were many comings and goings during this period. Donald Lynden-Bell came from Cambridge as PSO in September 1965 and was promoted to SPSO on special merit in July 1968. Eggen left in November 1965 to go to the Mt Wilson and Palomar Observatories. Bill Nicholson was transferred from the NAO to the Astrometry Department in March 1966. Other transfers from the NAO included W. L. (Bill) Martin to DLB RT in January 1968 and Geoff Harvey to ARD in February 1968. There were also many visits by staff to overseas observatories.

Some of the highlights of the work during this period are mentioned by McCrea, on pp. 55-58, and more details are given in the annual reports in QJRAS.

Woolley was anxious to have the research staff in the Castle and so he moved his office into the ground floor of the residence in May 1968. This made available his original large office for the use of Lynden-Bell's research team and led to other changes in the disposition of the rooms in the east wing of the Castle. It also led to Woolley and his wife using the east end of the Ballroom as a private dining area. He already kept his grand piano there and made it available for recitals in aid of charity. Louis Kenter gave a recital in aid of the Council for the Preservation of Rural England on 12 June 1971.

Amongst the various new items of equipment that were purchased was a Zeiss Ascorecord measuring machine, which was installed in February 1967.

Woolley decided that the visual use of the 28-inch refractor in Dome F for tasks such as the observation of double stars could no longer be justified. The telescope was returned to the Old Royal Observatory at Greenwich in October 1971.

4.3.2 Engineering and instrument development

The Engineering Department was responsible for the maintenance of the existing telescopes, auxiliary instruments and various measuring machines. A Cooke 6-inch refractor (dating from 1874) was renovated and installed in Dome C in December

1965. The installation and commissioning of the Isaac Newton Telescope was its main task during this period. (See section 4.2.2) It also constructed some new instruments.

In September 1967, John Pope was seconded to the Anglo-Australian Telescope project (see section 4.5.3) and so Phil Cottrell was in charge until John returned 4 years later. After his return John was called to meetings at State House for discussions on the proposed new Northern Hemisphere Observatory, which was eventually to play a major role in the activities of the RGO. He has commented that Woolley was concerned that his involvement in the NHO was interfering with his 'proper' duties as head of the Engineering Department.

The Electronics Department had special responsibilities for the maintenance of the time service equipment as any major failure would of national concern, but it also carried out maintenance and construction work for other departments.

Initially, the work on instrument development was led by Don Palmer, who had originally been appointed to set up the cosmic-ray monitoring equipment. (See section 3.3.5) He was joined in July 1968 by Peter Gillingham from the Weapons Research Establishment in South Australia. He came, initially, for one year, but he stayed for three. He had hoped to write a PhD thesis while he was here, but he did not do so. He and his wife, Mary, rented a house in Westham and so at first Peter often came to work with me. Mary was a highly qualified secretary and she later worked in the team under Sadler that made the arrangements for the IAU General Assembly in Brighton in 1970.

The Physics Department was formed at the beginning of 1969 and was headed by Dennis McMullan, from Cambridge, who took up his appointment in January. He was preferred to Alec Boksenberg., who was developing an 'Image Photon Counting System' (IPCS) at University College London. McMullan was then developing an 'electronographic camera', while Professor M cGee was developing 'spectracon image intensifier tubes' at Imperial College and he tested them at RGO. There was also a group at AERE Harwell who tested image intensifier tubes on the RGO telescopes. John Pilkington, who had been involved in the discovery of the first pulsars at Cambridge, joined the Physics Department on the same day as McMullan.

The first model of an 'image-tube spectrograph' was built in 1970 for use at the Radcliffe Observatory. Eventually the work on electronographic cameras and similar devices was superseded by the introduction of CCD cameras that are now ubiquitous.

At this time computers were being brought into use in other observatories for the control of telescopes and instruments and for data capture, but I was told that Woolley was reluctant to approve (if not opposed to) their use in the RGO. The term 'process controller', rather than computer, was used in requests for equipment that required Woolley's signature.

G B Wellgate became deputy head of the Physics Department in September 1969 and Henry Gill took his place as head of the Electronics Department. In September 1971 the AR "placed responsibility for the group of activities comprised by the Physics Department, Electronics, Instrument Development, Drawing Office and Workshop under Dr McMullan". This grouping proved to be a precursor of the divisional structure that was introduced later by Hunter.

4.3.3 Time Department

The head of the Time Department, Humphry Smith, made certain that the rest of the RGO was made aware of the activities of the Time Department. Almost every issue of the Information Bulletin contains a paragraph or two about its activities.

4.3.3.1 Atomic frequency standards

The department acquired a series of commercial (Hewlett-Packard) caesium-beam frequency standards. The first was due in August 1965, but was not installed until 6 May 1966. This was surprisingly small at the time (only 20 x 9 x17 inches) and its frequency was very much more stable than that of the quartz-crystal oscillators that were eventually replaced by these atomic standards. The link with the fundamental frequency standard at the NPL was maintained. The second H-P standard was delivered in March 1967and a third one was installed on 29 August 1968. This was modified so that it could be used as portable clock to produce either atomic time or UTC, which then had a variable frequency.

The development of more accurate methods for international time transfer (see section 3.3.2.2) was a major activity during this period and there were many visits to the observatory with ‘flying clocks’. Normally, the portable clock was brought by road from the airport to the RGO, but in September 1970 the comparisons were made directly with a clock in a French aircraft that flew over the Observatory and went on to make similar passes over Ottawa and Washington.. The measured scatter was about 50 nanoseconds even in poor conditions, while the difference between the USNO and RGO timescales was 41 microseconds. Radio signals were used for the day-to-day comparisons and in December 1968 the department acquired a Loran-C receiver for this purpose. (Loran-C is a US radio-navigation system that used the same principles as the British Decca navigation system for which the NAO used to make computations.) This was used for comparisons in Europe and across the Atlantic Ocean.

4.3.3.2 Universal time and latitude

The photographic zenith telescope continued to provide the RGO’s contribution to the international service for the determination of universal time and of the variations in the position of the pole of rotation of the Earth with respect to the axis of figure, which is the geographical axis. These variations have to be taken into account when an international scale is derived from the local scales of ‘universal’ time. (See section 2.6.1)

A knowledge of the state of rotation of Earth was particularly important for the tracking and control of planetary spacecraft and so the BIH provided a rapid service and at critical times special efforts were made to measure, reduce and send the PZT observations as quickly as possible. The encounter of the Mariner 9 space-probe with Mars in 1971 was one such occasion and the RGO was specially thanked for its contribution to the success of the mission.

The observing programme of the Danjon prismatic astrolabe that was sent to the RO at the Cape in 1964 came to end on 30 April 1969. It observed 36000 star transits during four years of operation. David Thomas was in charge until April 1967 when he returned briefly to the Time Department and then to the Astrometry Department to take charge of the parallax programme. The instrument was returned to the RGO in 1969. A new reflecting prism was fitted, but it was not used again. It was

later loaned to the National Observatory of Brazil and to the observatory at Quito in Ecuador.

4.3.3.3 Contributions by Humphry Smith

A major contribution to international timekeeping was made by Humphry Smith himself. He was elected President of IAU Commission 31 on Time in 1964 and he became chairman of the newly-formed Directing Board of the Bureau International de l'Heure (BIH) in 1966. In 1967, he became Vice-President of the complementary IAU Commission 19 on the Rotation of the Earth. More significantly, however, he was involved in the international committees, which included physicists and radio engineers as well as astronomers. He was a member of the Consultative Committee for the Definition of the Second (CCDS) that recommended the adoption of the atomic second, instead the ephemeris second, as the SI unit of time. He also served on the committee that recommended a new definition of 'Coordinated Universal time' (UTC) and he was the chairman of the working group that prepared the detailed instructions for its introduction at the beginning of 1972. (See section 5.5.6.1)

Humphry Smith received several awards, including the 1967 award of the American Watchmakers' Institute for outstanding contributions to the science of horology.

4.3.3.4 Changes in international timescales

During the 1970s adjustments were made to the time signals in an attempt to meet the conflicting requirements of technology for a readily available standard for the unit of time, the second, and the requirements of astronavigation and geodetic surveying for a readily available timescale, such as Greenwich mean solar time, that was directly linked to the rotation of the Earth. The gradual long-term slowing down in the rate of rotation of the Earth meant that the mean solar day, and hence the second derived from it, was gradually getting longer. Moreover the length of the day varied over periods of a few years and with the season. These changes were clearly shown by comparisons between atomic time and universal time (which was actually determined from observations of the transits of stars, not of the Sun). In the 1960s the time signals compensated for the slowing down by making step changes in the frequency from time to time and for the short-term variations by introducing steps in the timescale itself of 0.1 seconds. These steps were too small to be noticed by the ordinary users of the time signals or even by navigators, who were trying to time their observations to better than 1 second. The dates on which these discontinuities took place were agreed in advance and so the name UTC was introduced when the signals of the UK and USA were coordinated in this way. Other countries adopted the system and the BIH became responsible for the system in 1964.

This led to the proposal for a new system in which there were no changes in the frequency of the time signals, but in which the steps were made larger and could be detected by a good chronometer. The aim was keep the difference between UT and UTC less than 0.7 seconds while making them only at the end of the year or half-year. The time signals contained coded information that gave the current value of the difference. Even so, Sadler considered that the change would degrade the accuracy of astronavigation since only a few navigators would be able to pick up the correction. On the other hand, for most navigators this small error in the time was not of crucial

importance. The change was introduced at the beginning of 1972 and so its effects are considered in section 5.5.6.1.

4.3.4 H. M. Nautical Almanac Office

The NAO, like the Time Department, tried to ensure that the RGO Information Bulletins gave details of its activities; for example, by announcing the publication by HMSO of the almanacs, navigational tables and other volumes. Attention was also drawn to any research results that were derived from the occultation programme. The NAO continued to have responsibility for the general computer services for the whole of the Observatory and information of general interest about major changes was given in the Information Bulletins.

At the beginning of 1970 Donald Sadler was seconded to other duties, namely the organisation of the General Assembly of the International Astronomical Union that was to be held at the University of Sussex in August. Pat Hanning continued to act as his secretary. As a consequence, I was appointed Acting Superintendent, with a temporary promotion to Senior Principal Scientific Officer. Ann Ballard was transferred from the Typing Pool to provide direct secretarial services for the Office. Mrs Audrey Turner had been recruited in 1969 to replace Alison Martin for clerical duties, such as the NAO library, and so it was a case of all change!

Sadler continued to hold the title of Superintendent until he formally retired from the position on 18 February 1971. Woolley resisted the confirmation of my promotion to SPSO, but SRC eventually did so at the end of August 1971.

4.3.4.1 NAO publications

The adoption by the IAU in 1964 of a new system of astronomical constants (see section 3.3.1.4) led to flurry of activity in respect of the *Astronomical Ephemeris* since almost all of the tabulations were affected even if only by very small amounts. It was impracticable to recompute all the ephemerides on the new basis and, in any case, we issued the *Advanced Proofs of the A.E.* four years in advance. Consequently, we decided to issue a *Supplement to the A.E. 1968* to give details of how the changes affected the ephemerides and of how corrections could be applied by those who needed the highest accuracy.

The most important effects were on the ephemeris of the Moon and I had the task of making the appropriate changes to Brown's *Theory of the motion of the Moon* and then of using it to evaluate a new ephemeris for publication in the almanacs for 1972 onwards. I had one major piece of assistance in this task as Neil Block, who worked at the Jet Propulsion Laboratory, sent me a copy of the Fortran program that he had written, presumably for use in the Apollo mission. I had to check it — I believe that I found only one small error — and then make the necessary changes to the formulae. I also had to change the 'dialect' of the Fortran so that the program would run on the IBM computers in London. (I had to change it again later to run it on our ICT 1909.)

We used the program to compute the coordinates of the Moon at a half-day interval for the whole of the 20th century. We applied independent checks to verify that I had done my job correctly and we also differenced all the values in case the computer had made any isolated errors. We found that the values for one instant, out of over 73000, were wrong by small amounts. We expected that the correct values would be

obtained if we reran the program for that period, but this did not happen. After a lot of effort I eventually managed to trace the cause to an error in the execution of a particular part of the program. I convinced myself that a particular 'DO-loop' had been executed once too often just this once. I could find no explanation for this and I sought help from the IBM staff in London but could find no one who could explain why it should have gone wrong on this one occasion. I even took the opportunity when I was in New York in September 1965 to draw it to the attention of the IBM systems programmers there. They were, however, not prepared to follow it up and so the source of this one-off error was never found.

The navigation section continued to produce new volumes of the various navigational tables, such as the *Sight Reduction Tables for Air Navigation, A.P. 3270.* Walter Scott, the Head of the Navigation Section, retired at the end of 1966 after over 40 years in the NAO, preceded by 5 years in the RO. He was awarded an MBE in the 1965 New Year Honours list. He was replaced by Gordon Taylor, who was accordingly promoted to SEO. Scott went to the US Hydrographic Office for a year to assist in the preparation of a new set of navigational tables for marine navigation.

The *Astronomical Ephemeris for 1967* and the *Nautical Almanac for 1967* both contained special supplements to mark the bicentenary of the first *Nautical Almanac and Astronomical Ephemeris.* In addition the National Maritime Museum arranged (with assistance from the NAO) a special exhibition in the Old Royal Observatory at Greenwich. Sadler designed for it a device to simulate the measurement of a lunar distance. It was called a 'Sadlerium', but it was not made robustly enough and soon fell out of use, I believe. A party from the NAO made a pre-arranged visit to the NMM to see the exhibition, but we were kept waiting by Commander Waters and Sadler was furious! Sadler also drafted a booklet to accompany the exhibition with the title *Man is not lost: A record of two hundred years of astronomical navigation with the Nautical Almanac 1767-1967.* He was appalled at the way that the NMM treated his draft and the printing was so long delayed that it was not published until 1968. The exhibition was, however, continued for a second year.

The visit to the *Man is not Lost* exhibition on 16 September 1967 was the first NAO outing to Greenwich by coach. The exhibition was in Flamsteed House and the group also visited a new exhibition on instruments in the old Transit Room before going to a special demonstration by Mr C Daniel of the planetarium in the New Building. From there the group walked down to the National Maritime Museum for lunch before going to see the four Harrison chronometers and other exhibits in the Museum. Then the group went to the Royal Naval College, where the Office was based for a while before the war. The programme mentions also the possibility of visiting the old sailing clipper *Cutty Sark*. Finally, the coach went to the Festival Hall and later in the evening most went to see the film *The Life of Mozart* at the nearby Queen Elizabeth Hall. The coach was due back at the West Building at 12.30.

In 1970, shortly after I became Acting Superintendent, I was told that the ASR Board of the SRC had decided on Woolley's advice to stop the publication of the *Astronomical Ephemeris* and to rely on the availability of the American version. Neither Sadler nor I had been consulted, but luckily the Board had a meeting at Herstmonceux and I was allowed to present the case for continuation. It appeared that the Board did not realize that we produced the data and reproducible material for half of the almanac and that this was part of a general agreement that covered also the almanacs and tables for marine and air navigation. The decision was rescinded. Woolley had criticised the

Ephemeris on the grounds that it did not contain the data required by astrophysicists. We therefore produced experimental editions for several observatories, including Herstmonceux, of an *Astrophysical Observers Almanac* for the second half of 1971 that contained topocentric (local) data and positions of variable stars and other objects that were of astrophysical rather astrometric interest. We continued to produce copies of this almanac for several more years.

4.3.4.2 Computer composition

Another major development during this period was that of a computer composition of printers' type so that we did not have to rely on human typesetters for the printing of the *Astronomical Ephemeris* and the *Star Almanac*. (We had already bypassed them by the use of a card-controlled typewriter for producing the daily pages of the *Nautical Almanac*, but this technique was not sufficiently flexible to be used when the number of pages of each layout was quite small.) In this work we were greatly helped by Arthur Phillips of H M Stationery Office, who was concerned with the development of new projects. He had worked with Sadler before and so he was aware of our needs.

At the time there were many stages in the printing of the AE by 'letterpress'. First of all, we used a tabulator to list the numbers to be printed and we provided separately the instructions for the headings and for the fonts and spacing to be used. The printer then keyboarded this material to produce a paper tape, which was in turn used to drive a Monotype 'hot-metal' typesetter that made and arranged individual lead characters for the page. The printer made a proof, which we checked and marked up with the corrections that were required. This process was repeated and then a solid 'stereoplate' was formed for use in printing the published pages. This procedure was very time consuming and costly.

Phillips arranged for a sandwich student at the National Physical Laboratory to write a program in Algol that would produce from the numbers in the computer the paper tape to drive the typesetter. The program contained all the appropriate information about the fixed headings and about the fonts and spacings for one particular page layout. A trial proved to be successful and so my task was to generalise this procedure by writing a set of subroutines that could be combined together in a Fortran program for any required layout. We used this procedure for the first time in 1968 for the A.E. for 1972, but it had the great disadvantage that we had to produce a reel of paper tape for each page and so quite a lot of manual effort was required. Moreover, the manual stages between the computer and the printing plate introduced the risk of error.

For the following year Phillips was, however, able to arrange for us to use a new system that was introduced for printing telephone directories. He first of all had to overcome the objections of the trade unions who realized that their members' jobs could be lost. We supplied our output on magnetic tape, instead of paper tape, and a Linotron phototypesetter produced a sheet of film that was used for printing by photolithography. This was completely satisfactory and our computer programs were gradually extended to cover extra facilities. It was sometimes quite a challenge to find a way of implementing some of Sadler's suggestions for further improvements. The system was also used for the *Star Almanac*. It was designed solely for numerical tables and I did not attempt to include word-processing facilities in it, although it could handle simple footnotes. John Carey and, later, Catherine Hohenkerk became experts in using it until it

was replaced by a commercial package. (See section 6.3.3.1) I regret that I did not have the time to write up a description of the original system for publication.

Around this time Xerox photocopiers were coming into use and in 1969 the copies of *Advanced Data for the Astronomical Ephemeris for 1973* were produced from computer listings on a Rank-Xerox Forms Duplicator by HMSO.

Another innovation in 1971 was a UDS 6000 Automatic Typewriting System for the preparation of high-quality copy from paper-tape input. It replaced the IBM card-controlled typewriter and consisted of an IBM Model 725 "Golf Ball" Selectric typewriter linked to two paper-tape readers and a paper-tape punch. The paper tapes could be prepared on the ICT 1909 computer or manually. A type ball could print 86 characters and different type balls allowed the printing of documents with special characters. It was very versatile as the operator could, for example, merge two paper-tape files and make insertions or deletions by hand. It was used for preparing tables by combining a tape for the headings with one for the numbers. Drafts could be corrected and insertions could be made in semi-standard letters by typing new material into a pre-prepared outline. This proved to be a very useful acquisition. One of its earliest uses was to prepare the RGO Telephone Directory.

4.3.4.3 Occultations

The NAO continued to provide an international service for the prediction, reduction and analysis of the occultations of stars by the Moon. The effort involved was greatly reduced once the necessary programs had been written for the ICT 1201 computer. Nevertheless, the occultation machine was used for selecting the cases for which accurate predictions should be made. This avoided the waste of a lot of computer time. There continued to be a considerable interest in other types of occultation.

Gordon Taylor's predictions of occultations by major and minor planets and by satellites led to several successful observations by groups around the world. For example, photo-electric observations were used to study the atmosphere of Jupiter, while the timings were used to make a new determination of the diameter and flattening. Observations of occultations by Io led to a more accurate determination of its diameter.

Leslie Morrison became an enthusiast for the occultation programme. (See section 5.5.4.4) His predictions of a second occultation by the Moon of an X-ray source in September 1971 led to a successful observation from a Skylark rocket launched from Woomera and hence to accurate coordinates and the identification of the source with a 16th magnitude star.

4.3.4.4 Dynamics and planetary sciences

John Griffiths was appointed as an SSO in September 1965 in order to increase the research effort in the NAO. He was in my division, but he really reported to Sadler (as I had done when Porter was head of the division). He had previously been a lecturer at the Royal Military College of Science at Shrivenham. He and I attended a summer school in celestial mechanics at Bressanone in the Italian Tyrol in May 1967. I gave two seminars about the techniques that I had used for the analysis of the orbits of the satellites of Mars. One of the other lecturers was Irwin Shapiro from the Massachusetts Institute of Technology; he and I played table tennis! Another participant was Roy Jady from the University of Exeter, who came to the RGO in the following year to talk about the variation of latitude. The summer school was organised by Professor Bepi Colombo,

an Italian who had explained the rotation period of Mercury. I suspect that he had heard me speak at one of Professor Runcorn's NATO Advanced Study Institutes at Newcastle. Colombo was very friendly and took some of us to Cortina on a free afternoon. Colombo's name has been given to a spacecraft mission to Mercury.

John Griffiths resigned the following year to take up an appointment at Lakehead University at Port Arthur in Canada. He stayed there until he retired. Fortunately, we were able to replace him right away by Andrew Sinclair, who had earned his PhD at the University of Liverpool under the supervision of Jim Message. Andrew stayed with us, and he took over my work on the satellites of Mars in addition to his theoretical work on the orbits of minor planets (asteroids) and on resonances amongst the satellites of Saturn.

During this period I continued to give talks about the satellites of Mars and other aspects of planetary dynamics at conferences and to several astronomical societies. I was also a member of the SRC Working Group on the orbits of artificial satellites, which was chaired by Desmond King-Hele.

Professor Runcorn invited me and Leslie Morrison to speak at NATO Advanced Study Institutes at the University of Newcastle in 1966 and 1970. He also invited me to join a Royal Society Planetary Sciences Study Group that had the aim of developing greater interest in planetary sciences in the UK. Most of the meetings were held at the Royal Society premises in Carlton Terrace in the late afternoon and were followed by a dinner in the RS restaurant in the basement. One was held at UMIST in Manchester in September 1971.

4.3.4.5 Computer Section

One of our first actions in preparation for the installation of the ICT 1909 computer was to arrange for a member of the ICT staff to give a course of lectures on programming in Fortran. We soon realized that I had had more experience than he had and so I was able to help him from time to time. In the following December (1965) I attended an ICT course in London on programming in the assembly language PLAN, which was based directly on the basic instructions used in the central processing unit of the computer. (Programs written in Fortran, and similar 'high-level' languages, have to processed by a 'compiler' that produces an equivalent program in a 'low-level' language such as PLAN. This program is in turn compiled into machine code.) We used Fortran to compute the numbers that we wished to print, but this was not suitable for the development of the routines for computer composition. (See section 4.3.4.2) For these we needed the ability to process the individual digits and to insert special characters to indicate spacing and other aspects of the printed page. The extra facilities needed for this purpose and for other data-handling utility routines were available in PLAN.

We operated the computer on a 'closed-shop' basis with full-time operators, Brenda Harris, Valerie Cann and Lynn Ellis in the first instance. Two were normally needed in the computer room: one would be at the control desk, while the other would load and unload the various peripherals. Brenda Harris became the senior operator and was given a responsibility allowance until she was eventually promoted to the grade of Senior Scientific Assistant. Doreen Elphick was appointed as a Machine Operator at the beginning of 1966 just before the installation of the 1909. Her main task was the punching of cards for programs and she was both fast and extremely accurate. Olive Kirby was appointed for the same type of work later in the year since the workload increased rapidly as more and more use was made of the system. In 1967 Barbara

Aldridge was appointed as a computer operator to replace Valerie Cann, who had emigrated to Australia.

For most jobs the programmers would hand in an appropriate tray of punched program and data cards with a white card on which they had written the information about that particular run of the job. In particular the operators needed to know about the form and amount of input and output. They also needed to know how long the run should take in case an error in the program caused it to run without producing any useful results. With this system it was possible to make efficient use of the computer. Moreover, the programmers did not have to learn how to operate the computer and did not have to waste time waiting for their turn and for the run to take place. Not unexpectedly, some programmers were impatient and wanted the results of their run right away!

Detailed information and advice for programmers was issued in *NAO Computer Circulars* and at first I wrote most of them. After no. 62 in October 1967 they were written by Albert Carter, then Brian Emerson and then Dorothy Hobden. Carter obtained promotion to Chief Experimental Officer in 1967.

At first, time on the computer was made available to the University of Sussex prior to its obtaining a 1900 system, but it was not long before the RGO staff were making full use of it. My note on the "Forward Look for Division II – January 1968" starts as follows:

"The economic squeeze followed by the A.R.'s change of policy will unfortunately mean that the hoped-for expansion of the work of the Division will not take place. In particular, … the proposal to recruit extra staff to run a double-shift on the computer has been postponed."

Agreement to the recruitment of extra operators was not obtained until 1972 after Woolley's retirement.

4.3.4.6 Kinetheodolite observations of satellites

The Kinetheodolite Section (see section 3.3.3.3) was not formally part of the NAO, but it had an office in the NAO Spur and members of the NAO took an interest in its work. In 1966, W. L. (Bill) Martin wrote a prediction, or 'look data', program for the ICT 1909 computer for use by the observing team. This program was later used by the Radio and Space Research Station at Slough when it took over from RAE the responsibility for the national prediction service for artificial satellites.

Improvements were made to the instrument in mid-1966. Unfortunately, Norman Rhodes, one of the observers died suddenly after a short illness in November 1966 at the age of only 42. Good results were obtained at Herstmonceux, but observations ceased there on 9 January 1967 and the instrument was then transferred to the Cape of Good Hope. W. G. Grimwood went to the Cape in April and additional observers were recruited locally; observations were made from July onwards. Grimwood stayed in South Africa and died there in 1982 after his retirement.

4.3.4.7 Participation by Donald Sadler and others in IAU activities

Donald Sadler continued to serve on the Executive Committee of the IAU for some years and he also represented the IAU on the Council of the Federation of

Astronomical and Geophysical Services (FAGS). Its main purpose was to secure funding for about a dozen small organisations that collected, published and analysed data from all around the world on a variety of topics, such a time, solar activity and glaciers. They provided services to the community as a whole, but the work was often regarded as routine and the small groups concerned often had difficulties in obtaining funding from their parent organisations. The long-term series of data proved to be very useful, but the research on interpreting the data was usually carried out by others. The approval by FAGS, small grants from international organisations, including UNESCO, and the prestige of providing an international service were usually sufficient to ensure national funding for the bulk of the costs. The NAO occultation programme provided this type of service, but we did not need to seek external funding for it as it was regarded as part of the wider remit of the Office. Sadler became Vice-President in 1965 and then President of FAGS in 1968. He also continued to attend international meetings relating to time, such as the introduction of UTC. (See section 5.5.6.1)

During this period (1964-1970) I served as secretary of an IAU Commission 4 working group on space ephemerides. We were primarily concerned to adopt standards for the interchange of data between astronomical and space research institutions, such as the Jet Propulsion Laboratory in California. We held one of our meetings at the COSPAR (ICSU Special Committee on Space Research) General Assembly in Prague in May 1969. As was usually the case this meeting was held at a place and time where many of the members of the group would be going to attend the scientific sessions. In this case there was a symposium on the dynamics of satellites. The representative from JPL was W. G. (Bill) Melbourne, who was later to be a member of the MERIT Steering Committee. (See section 6.3.4.4)

In 1964 I was elected Vice-President of IAU Commission 4 on Ephemerides and then in 1967 I became its President. (The term ‘president’, rather than ‘chairman’ stems from the time when French was the principal language in international organisations.) This position was usually filled in turn by one of the heads of the principal ephemeris/almanac offices, but Sadler had already served for at least two terms and so the job was given to me. My main duties were to prepare a report on the activities of the members of the Commission and to arrange and chair the meetings at the General Assembly in 1970. The report consisted mainly of the reports of the 5 principal ephemeris offices, together with information about any work by individuals on the theories of motion of the Moon and planets. The 1970 meeting was held in Brighton and so visits to the RGO were arranged. I took the opportunity to invite a few of the members to come home to tea. One of them was Professor Chebotarev from the Institute of Theoretical Astronomy in Leningrad, and he returned the compliment a year later.

Sadler was asked to take charge of the local arrangements for the IAU General Assembly that was to be held in Brighton, at the University of Sussex, in 1970. At first, Woolley refused to allow him to accept the appointment, but he eventually agreed after lobbying from other senior astronomers. This was in August 1968 and the workload soon built up until it became full-time for both him and Pat Hanning, the NAO secretary, who thoroughly enjoyed the new activities. This was recognised at the beginning of 1970 when they were both formally seconded to this work and I was made Acting Superintendent of the Office. (See section 4.3.4)

Humphry Smith was the only other member of the staff who was formally involved in the arrangements for the IAU GA as member of the Local Organising Committee. He was responsible for the transport arrangements. The SRC did, however,

second a member of the Rutherford Laboratory to deal with the financial arrangements. Peter Gillingham's wife, Mary, was recruited for secretarial work, but she was paid from IAU, not RGO funds. The arrangements for the Assembly worked smoothly and Sadler and his helpers were warmly congratulated afterwards.

4.3.4.8 Retirement of Donald Sadler

Sadler continued to deal with the aftermath of the Assembly until he formally retired on 18 February 1971. Until this time he retained the title, but none of the duties, of the Superintendent of the Nautical Almanac. He was then re-employed on 'special duties' in a disestablished capacity in the grade of PSO for a further year, but he took no part in the current work of the Office. (See section 5.5.4.1.)

Sadler was honoured in various ways during the last few years of his career. He was awarded the Adion medal of the Nice Observatory in 1969, an honorary doctorate by the University of Heidelberg in 1970 and the Janssen medal of the Astronomical Society of the Pacific in 1972. He served as President of the Royal Astronomical Society from 1967 to 1969. He also continued his involvement in the Royal Institute of Navigation and in the International Association of Institutes of Navigation.

4.3.5 The Solar and Magnetic Departments

The transfer of responsibility for the Magnetic Department from SRC (and the RGO) to NERC reduced still further the RGO's interest in geophysical studies. This indirectly reduced the motivation for the work of the Solar Department on the links between solar activity, as shown for example by sunspots, and terrestrial phenomena, such as magnetic storms. Consequently the work of the Solar Department was kept at a minimal level.

The Magnetic Department, however, flourished. Except for pay and travel, its staff were regarded a members of the RGO and, by reason of their membership of the RGO Club, they were able to participate in the SRC Sports Days. They also used the computer facilities, but I suppose that SRC insisted on payment by NERC.

In September 1965, I presented the results of my Ph.D. work on the geomagnetic daily variations at an international conference in Brazil; I had travel support from the Royal Society. (The substance of my thesis and some other later work had been published in the *Philosophical Transactions of the Royal Society* in 1963.) I went from Brazil to the USA to present the paper at the Goddard Space Flight Center, where satellites for measuring the geomagnetic field were being developed. The methods that I had developed were not, however, appropriate for the work carried out by the Magnetic Department at Herstmonceux.

4.3.6 The RGO and NAO libraries

As was to be expected, Joan Perry, who had been promoted to RGO librarian in March 1965, carried out her new duties very diligently. The Information Bulletins carried lists of the new books and reported re-shelving and other changes from time to time. She was assisted by a series of assistants, the first of whom was Marilyn Harris; she joined as a clerical assistant, but was promoted to clerical officer in 1967. Marilyn married Brian Carter, the younger son of Albert Carter of the NAO. Brian was then a scientific assistant in the Meridian Department and was sent to South Africa on duty

just after the marriage. Marilyn resigned to go with him and Sue Cowen was transferred from the General Office and was promoted to clerical officer at the same date.

The NAO library continued to operate independently of the RGO library during this period. Alison Gaydon, who looked after the NAO library amongst other duties, was promoted to clerical officer in 1965. Marilyn, Alison and, later, Sue were sent on introductory courses for 'special library and information work'.

Alison married W L (Bill) Martin, who had joined the NAO as an AEO just after Alison, in 1967. The service was in Herstmonceux Church and the reception was held in the dining room of the Castle [photos]. She resigned in 1969 in order to start their family. She accompanied Bill to the Radcliffe and Cape Observatories in South Africa in 1971-1977. They were divorced some years later. Alison married the son of George Harding (who had been Deputy Director of the Cape at the time that Alison was there!) and Bill married Joy Hamblyn, who had joined the Typing Pool at Herstmonceux and had moved to Cambridge.

Joan wrote an article about the history of RGO Library and added some notes about the NAO Library and the current situation in August 1971. More detail about the contents and organisation of the NAO Library are given in NAO Technical Note no. 14, April 1968.

I do not know the circumstances of a decision to dispose of old books that appeared to be no relevance to the RGO. They were put on a trolley and members of staff were invited to take any of interest. I do not know what happened to those that were left. I took a copy of the first volume of the *Proceedings of the Cambridge Philosophical Society* and I later passed it to the Library of the Norman Lockyer Observatory at the University of Exeter. There were other books of a similar character that should have been retained or sold through a dealer.

4.4 General administrative matters

The level of administrative effort to run the RGO increased during this period , partly as a result of the change to control by SRC, but also because of the expansion in the activities. In particular, there was a large increase in overseas duties for both short and long periods. The addition of the Isaac Newton Telescope and the extra technical work in instrument development also required additional administrative support. This was recognised in two ways: firstly, Alan Hunter, who was, in effect, the deputy director, was promoted to DCSO in 1967 and, secondly, John Whale, the Secretary and Cashier, was promoted from HEO to SEO in 1968. Moreover, John was supported by a finance officer, Frank Evans, an HEO, who was transferred from RSRS in 1969. He carried out his duties to the letter and so had a reputation as a bureaucrat, but I would have been more concerned if he had not been so careful.

The Castle was considered to be a significant fire risk and was situated several miles from the nearest fire station (Hailsham?) at the end of a two-mile narrow lane. Consequently, we had a volunteer fire squad, of which I was member from 1962 or earlier, and we were given training in the use of the mains fire hoses as well as of portable fire extinguishers. One day after one of our practices we heard reports of a broken water main between the Castle and the village, and I suspect that we had turned off the hoses too quickly and had caused a vibration in the pipe.

In August 1965 Woolley appointed me as 'Fire Officer' in place of W B Harvey, an Executive Officer, who had come to manage the work of the Chronometer Department. After an inspection by the local fire brigade in January 1966 I put forward several recommendations for changes, but Woolley refused to adopt them and appointed Mr Whale in my place. Later the job was passed again to Mr Harvey. Fortunately, we did not have any fires as I recall that one of the escape routes from the attic rooms involved the use of a ladder on a roof!

Mr Lankford, the Head Messenger, retired on health grounds in 1968. He had held the post since he joined the staff at Greenwich in 1946 and he and his wife lived in a cottage by the West Entrance of the Castle. He was, presumably, a retired soldier as he wore a neat handlebar moustache and always stood smartly in his uniform, with its white peaked cap. He was succeeded by Vic Hill, who could hardly have been more different; he acted as assistant fire officer and serviced the equipment. (He may have been a fireman before joining the RGO.)

The RGO Club continued to provide for a wide range of activities. Many members participated in the SRC sports days, which were held at the Civil Service Sports Ground at Chiswick with the support of the Science Research Council. Further details of Club activities are given in Appendix D.

4.5 External affairs

4.5.1 University of Sussex

The establishment of the Astronomy Centre within the newly founded University of Sussex provided Woolley with the opportunity to establish closer links with the academic astronomical community. (See section 3.1.3.5) He, Pagel and Lynden-Bell became visiting professors and others gave lectures to the postgraduate students. Other members of the staff attended the lectures and gained M.Sc. and D.Phil. degrees. Bob Dickens was awarded a D.Phil. in 1970, although Woolley confided to me on Lewes station one afternoon that he had needed some help in his oral examination!

At first a few RGO staff attended seminars at the University, which was conveniently placed in Falmer on the outskirts of Brighton. Then joint seminars were also held in the Castle so that more RGO staff could participate and so that the university staff would learn more about the RGO and its facilities.

The university staff were mainly engaged on theoretical studies, but some postgraduate students undertook observational projects and so spent much time at Herstmonceux. Some joint projects developed.

4.5.2 Use of telescopes overseas

The increasing use of telescopes in other countries, especially South Africa and the USA, has been mentioned in section 3.1.3.2. The RGO staff usually used existing facilities, but in Egypt (United Arab Republic) at the Helwan Observatory's out-station at Kottomia and in Spain in the Sierra Nevada the RGO staff contributed to the development of the equipment, and so engineers as well as observers participated in these visits. Woolley and Derek Jones went to Kottomia to observe with the 74-inch telescope in November 1964, but in later visits in 1966 Woolley was accompanied by

Pope and Palmer in Mar/Apr 1965, by Harding in June 1965, and by Dermody (Engineering) and Standen (Instrument Development) in 1966. In August 1968, he was accompanied by Wellgate, Harding and Dermody when he visited a small Jesuit observatory with a 12-inch reflector at 9000 feet in the Sierra Nevada in southern Spain.

In 1967 onwards, Woolley also acted as an advisor to the University of Riyadh, of which he was Vice-Rector, on the setting up of a new observatory in Saudi Arabia, and RGO staff were engaged on site-testing operations. For example, Woolley, Hunter, Dermody and Dr M F Ingham of the University of Oxford went on a site-testing expedition in 1968.

4.5.3 Anglo-Australian Telescope project

As has been mentioned in section 3.1.3.3, Woolley's advocacy of the Anglo-Australian Telescope project, rather than participation in the European Southern Observatory, was successful. The agreement was signed in 1967. John Pope was seconded to the AAT project from September 1967 until September 1971. He continued to oversee the manufacture at Grubb Parsons of the optics and tube for the telescope.

Shortly after Pope's return, Peter Gillingham left the RGO to join the project team in Australia and he became the chief engineer. He later moved to an observatory on Hawaii before finally returning to Australia.

The AAT was built as part of the Anglo-Australian Observatory (AAO) on Siding Spring Mountain in New South Wales, near to the town of Coonabarabran. Pope returned in 1974 to oversee the lifting of the mirror into its cell and its connection to the support system. He and Ben Gascoigne, who spent some time at Herstmonceux, were the first to see a star through the telescope and to test the focussing system that John had designed. The AAT proved to be very successful in spite of the low altitude. The UK Schmidt Telescope (UKST) was also built on the same site for survey purposes. It was manned and managed by staff from the Royal Observatory at Edinburgh (ROE). The headquarters of the AAO were in Epping, a suburb of Sydney.

4.5.4 Royal Astronomical Society

Woolley did not attend the meetings of the Royal Astronomical Society regularly, but he served as its President for the period 1963 to 1965. He was awarded a Gold Medal by the Society in 1971, just before his retirement. Other members of the RGO did, however, take a greater interest in the affairs of the Society. Alan Hunter, who had served a Secretary from 1949 to 1956, served as Treasurer from 1967 to 1976.

Others served on the Council. For example, I served on Council from 1967 to 1970. My recollection is that we had animated discussions about the role of the Society in respect of geophysics, for which there was no separate society. The Society had published a *Geophysical Supplement to Monthly Notices* until it became the *Geophysical Journal* in 1958. In 1964 it awarded a second Gold Medal to give astronomy and geophysics equal standing, although there was also a separate Eddington Medal. There were then proposals for further medals, but these were not accepted until 1972 when it was agreed that Chapman and Herschel Medals should also be awarded triennially for specific investigations. Professor Sydney Chapman, who had died in 1970, was the external examiner for my PhD thesis.

4.6 The retirement of Sir Richard Woolley

Woolley did not wish to retire from the post of Astronomer Royal, but it became known that he would do so at the end of 1971. An international conference on the determination of distance in the Universe was held in the Castle in his honour in August 1971. An international cricket match — RGO v the World — was held during the conference.

Just before the conference Hunter circulated a note dated 21 July to senior staff to tell us that SRC was about to announce that after Woolley's retirement the title of Astronomer Royal would no longer go automatically to the Director of the RGO. The two arguments given in a statement from No. 10 Downing Street were that the appointment of the Director was a matter for the Science Research Council, rather than for the Queen, and that the SRC wished to be able to include foreign nationals amongst those to be considered. Amongst many RGO staff this decision was seen as another way in which the university staff on SRC committees were attempting to diminish the standing of the RGO and to transfer the prestigious title to one of their number. Joy Penny, the secretary of the Herstmonceux section of IPCS, correctly predicted that this was the beginning of the end for the RGO.

Surprisingly, the RGO Information Bulletins do not mention either this statement or the appointment of Professor E Margaret Burbidge as the next director. (These would probably have been the subjects of separate Circulars.) She spent a few days at Herstmonceux in November 1971 when she visited England for discussions at SRC London Office. She was British, but at the time she held an appointment in the University of California. She could not take up her appointment until July 1972 and Alan Hunter was appointed Acting Director in the meantime.

Information Bulletin 181 for 23 December 1971 stated that:

"Sir Richard Woolley retires from the post of Astronomer Royal on 31 December and will leave for South Africa on 1 January 1972, to take up his five-year appointment as the Director of the new South African Astronomical Observatory. Sir Richard has been Astronomer Royal for exactly 16 years."

The SAAO brought together the Royal Observatory at the Cape, the Radcliffe Observatory at Pretoria and the Union Observatory at Johannesburg. A new observatory was established at Sutherland on a much better site.

In August 1979, after the death of his wife Gwyneth, Woolley married Mrs E M Patricia Marples, who had been the canteen and hostel manageress at the Castle from about 1951 to 1975 and who had been awarded a BEM earlier in 1979. They were later married in Eastbourne, but they moved to South Africa. Woolley died in December 1986. Lady Patricia survived him and also died in South Africa.

Professor W H McCrea asked me for my comments about Woolley when he was writing an obituary of Woolley for the Royal Society. A transcription of my letter is given in appendix B.2.3. He did not use my comments directly, but I have his letter of thanks and a signed copy of the obituary.

5 S.R.C. TAKES CONTROL – 1972 TO 1981

A DECADE OF GROWTH AND TRANSITION

5.1 Introduction

The decade following the 16-year term of office of Sir Richard Woolley as Astronomer Royal was a period of rapid change in the character of the Observatory. Up to this time there had been only 11 Astronomers Royal in 296 years but, following the loss of the title, there were three Directors in the next decade. More significantly, the main function of the Observatory changed dramatically. Instead of carrying through long-term programmes of observation and associated research, it became primarily a developer and manager of overseas observing facilities for other astronomers. There was considerable growth in the budget and some increase in the complement, especially in respect of the design of telescopes and instruments. The programmes of observation and research continued, as did the provision of general services for almanacs and time, but at a reduced priority.

The three Directors were Professor Margaret E Burbidge, Dr Alan Hunter and Professor Francis Graham Smith. They had three quite different backgrounds and styles. Burbidge was an observational astronomer from a university environment and had had no experience of managing a multi-purpose organisation. Hunter, on the other hand, had joined the Royal Observatory at the start of his career, had been seconded to Admiralty work during the war, and had, in effect, been deputy-director to Woolley. He had the task of carrying through the restructuring of the RGO for its new role while overseeing the celebration of its 300-year history. In contrast, Graham Smith had had a university career in radio astronomy in Cambridge and Manchester, where he had been involved in major multi-user telescope projects. He had also had experience in management at the Appleton Laboratory, which was another SRC establishment. His main task was to oversee the building of the ‘Northern Hemisphere Observatory’ on a good overseas site.

5.2 The Burbidge period, 1972 to 1973

Professor Margaret Burbidge was unable to take up her appointment as Director of the RGO until 12 July 1972, although she did visit the Observatory at the beginning of June for two days. The title of Astronomer Royal was conferred on Sir Martin Ryle, FRS, who was the senior radio astronomer in the University of Cambridge. Dr Alan Hunter was the Acting Director of RGO during the first half of the year. He instituted a series of Senior Staff Meetings (SSM) the object of which was “to advise the Acting Director (and further ahead the new Director, if she concurs) on policy matters; and to promote discussion of, and diffuse news on, matters of departmental interest”. We held the first of the new Senior Staff Meetings on 13 December 1971. The members were Lynden-Bell, McMullan, Murray, Pagel, Whale and myself. Other department heads were co-opted as appropriate. Murray and I were given oversight of the Solar and Time Departments, respectively. Lynden-Bell resigned later in the year to become Professor of Astrophysics in the University of Cambridge.

The appointment of Margaret Burbidge created considerable attention in the national press and a 3-page article about her was published in the *New Scientist* (28 September 1972) under the heading “The astronomer who came back”. She was

described as “a delicate silver-haired figure” and the writer continued “Her manner is attractive. Her warmth, charm, and the breathless enthusiasm of her voice, as if everything were new and fresh, give an aura both of innocence and total self-certainty.” On the other hand, her husband Geoffrey was described as “a large, loud man, well known (and unpopular in some circles) for saying what he thinks, and saying it in no uncertain terms”. Her technical abilities were recognised by the award of the degree of Honorary Doctor of Science by the University of Sussex during the IAU General Assembly in 1970. Then it was said that she was “not only a distinguished astronomer but also a wife and mother. She has done outstanding work in many branches of astronomy, including abundances in stellar atmospheres, galactic rotation and the study of quasars, and she also discharges the important task of preventing the speculations of Geoffrey Burbidge, Fowler and Hoyle from departing too far from the observational evidence.”

Margaret Burbidge did continue the SSMs, but she also invited her husband to attend, even though he had no position within the RGO. (He had, I believe, an unpaid position in the University of Sussex.) The contrast between the two of them soon became apparent. There was, however, one point on which they were agreed: the Isaac Newton Telescope was in the wrong place and should be moved to a better site overseas. She was, however, away from Herstmonceux for quite long periods and so Hunter, in effect, continued as the acting Director!

By this time the campaign for a ‘Northern Hemisphere Observatory’ on a mountain-top site was well under way. Some (probably including Geoffrey Burbidge) argued that the job of managing the construction of such an observatory should not be given to the RGO since, it was claimed, the RGO had failed in the building of the INT. They did not recognise (or realize) that the RGO had originally been excluded from responsibility for the INT, but had found itself having to take on the job at a late stage without being given appropriate resources. Some initial studies were, however, carried out at the RGO. In particular, by March 1972 Pope, who had returned from his duty in Australia for the AAT, had examined a number of optical configurations for a large altazimuth telescope and had prepared a table of comparative costs.

Under SRC it had become necessary to prepare much more detailed proposals for new expenditure and so in January 1973 five committees were set up to deal with the coordination of budgeting, of decisions and of action. The names and chairmen of these committees were:

1. Telescopes and telescope instruments – Pagel;
2. Detectors – McMullan;
3. Laboratory and workshop equipment – McMullan;
4. Measuring – Murray; and
5. Computers – myself.

A further committee, no. 6, on Information services, chaired by Hunter was also set up; it covered libraries, archives, publications, dissemination of information and public relations. The last two activities were becoming more important and took up more and more staff time. I was a member of this committee.

The formation of the South African Astronomical Observatory led to a very considerable reduction in the RGO’s involvement. The SAAO decided to set up a new

observatory at Sutherland in the Karoo and to move the 74-inch telescope from the Radcliffe Observatory in Pretoria to Sutherland. There was a corresponding reduction in the complement of the RGO.

The extent of Margaret Burbidge's absences from Herstmonceux are shown clearly in the Information Bulletins that were circulated to the staff. Shortly after taking up her appointment she "visited Washington at the end of August for a meeting of the Space Science Board, and went on to the Lick Observatory for a few nights' observing". During the autumn she was away from 25 September to 13 October, during which time she attended a meeting of the Anglo-Australian Telescope Board in Canberra. Then she left on 2 November to attend a meeting of the Space Science Board in Washington, followed by an observing run in Arizona, and she returned on 13 November. This was followed by an absence in the USA from 6 to15 December.

A similar pattern of foreign travel followed in 1973: she was away 6 February to 3 April; she went back to the USA for meetings on 11 to 13 April and then again from 25 April to 7 May and from 2 June until 4 July; she left on 16 July for a prolonged visit overseas from which she returned early in September. During this visit she attended the IAU General Assembly in Sydney. She was at Herstmonceux for the weeks beginning 10 September and 1 October. In between she went to meetings in the USA and Brussels and afterwards she went back to USA between 9 and 16 October.

Shortly after her return she was involved in a car accident for which she required treatment in hospital and then convalescence in a nursing home. This may have been the trigger that prompted her resignation, but she had probably already concluded that she could not combine all her earlier interests with the task of directing the RGO. We were also aware that she was unhappy because her daughter had accompanied her husband back to California after a wet summer in Sussex. The following quotation is from Information Bulletin No. 198 for 10 December 1973.

"Dr A Hunter succeeded Mrs Burbidge as Director on 1 December. Mrs Burbidge made a rapid recovery from the quite serious injuries she sustained in a road accident on 20 October, and was able on 15 and 16 November to direct packing from a wheelchair at the Castle, within two days of first being allowed out of her bed by her consultant. In an astonishing feat of endurance she fulfilled her last international engagement as Director by travelling (using crutches and a wheelchair) by air via California to Australia to attend the Anglo-Australian Telescope Board meetings in Canberra from 23-27 November. In what must be the understatement of the year, she writes "I am glad I made the effort to go, although it was indeed an effort!". She has cabled the following message for inclusion in this Bulletin.

"Regret accident prevented my giving personal farewell message. Regret also circumstances were not different so we could have had a long association together. My best wishes to all of you for a successful future. MARGARET BURBIDGE."

5.3 The Hunter period, 1973 to 1975

When Alan Hunter became Director he was promoted to the grade of Chief Scientific Officer, but his previous position as Deputy Director in the grade of DCSO was left unfilled. Instead, David Thomas was appointed to a temporary position as Assistant to the Director at SPSO level; this was later made permanent when Graham Smith became Director. He was given direct responsibility for the information services,

library and archives. and the RO Annals and Bulletins. Shortly afterwards, in February 1974, Mr. R. (Bob) Gordon, who had been a Senior Executive Officer in SRC London Office, joined to fill a new post at Principal level as Head of the Administration Section.

Hunter continued to hold monthly Senior Staff Meetings with some of its members acting for other departments. Then in May 1974 it was announced that this would be formalised in a divisional structure. I was given responsibility for the oversight of the Time Department as well as for the NAO. The Computer Section of the NAO became a separate department within the "Almanacs and Time Division". The Library and Archives were added, together the responsibility for the editing of RGO publications, to my Division in 1977.

The other divisions were: Astrophysics, with Dickens as acting head since Pagel had 'asked to be relieved of as many administrative duties as possible'; Astrometry and Galactic Astronomy, headed by Murray; Instrumentation and Engineering, headed by McMullan; and Administration, headed by Gordon. Surprisingly, the NHO pre-project team was excluded from this divisional structure. Advisory Panels involving a much larger number of staff were set up for some activities. Accordingly, the Information Services Committee later became the Advisory Panel on 'Information activities'

The proposals for the Northern Hemisphere Observatory were considered by a Review Panel of the Astronomy, Space and Radio Board (ASRB) of SRC and it recommended that the RGO should have the prime responsibility for the construction and operation of large national ground-based facilities, including the proposed NHO. As a consequence, an RGO Restructuring Panel, chaired by M O Robins, an SRC Director, was set up in May 1974 to advise on the changes in the character of the RGO and on the redeployment of its staff that would be necessary. Much of the discussion concerned the complement required for the new activities and the extent to which current activities would need to be reduced.

In August 1974 it was announced that Professor F Graham Smith, FRS, would be the next Director of RGO after Hunter retired at the end of 1975. Before the announcement Pope had been called to State House to meet an unnamed person about the NHO. He found himself being introduced to Graham Smith and told, confidentially, that he was going to be the next director of the RGO. He wanted to learn all about the present state of planning at the RGO for the NHO. He took up the vacant DCSO post as Director-Designate on 1 October 1974 and devoted himself primarily to NHO matters. Thomas continued to act as the Assistant to the Director as an SPSO. W A (Bill) Goodsell joined as Project Manager for the NHO in March 1975; he had previously been the project manager for the Anglo-Australian Telescope.

Hunter restored the publication of an annual report that covered all the activities of the Observatory and included a staff list and organisation chart. The first of them was for the calendar year 1974 and it had a monochrome blue cover with a picture of the dome of the INT. It also had 4 pages of photographs and graphs from selected projects. The report for 1975 covered only the first 9 months and thereafter the reports were for the academic year. The last one was for the year 1979/1980.

When Hunter retired he generously refused any personal present, but instead the proceeds of a retirement collection were given to the RGO Club for the installation of a filtration pump so that the swimming pool at the north end of the formal gardens could be brought into general use.

5.3.1 The Northern Hemisphere Observatory

The proposals for the NHO envisaged three new telescopes for complementary programmes with mirrors of diameters 1.0, 2.5 and 4.2 metres. At first the feeling amongst the RGO astronomers was that the Isaac Newton Telescope should stay at Herstmonceux and I used to hear the arguments to support this view discussed at lunch. Then one day in November 1974 Graham Smith announced that it had been decided at a meeting on the previous day that the INT should be moved to the NHO site. (I understand that Lovell has said that it was FGS' proposal.) I was then surprised to hear the same astronomers backing this decision, which was surely the second nail in the coffin of the RGO as it took away the most important telescope from Herstmonceux.

There were two principal arguments for leaving the telescope at Herstmonceux. Firstly, that it would be almost as cheap, and possibly cheaper, to buy a new telescope to a modern design without incurring the costs of moving and modifying the INT, which is an equatorial telescope, for a significantly different latitude. Not only was it necessary to make considerable changes to the mounting, but it was also decided to replace the mirror. (This would, however, have been needed even if the telescope had not been moved.) Secondly, a large telescope in Sussex could be used for appropriate types of astronomical programmes without incurring the expense and time of long-distance travel. Moreover, it could be used for testing new instruments and for giving new observers experience in the use of a large telescopes without using telescope time that could otherwise have been used for more valuable observations. The engineers at Herstmonceux later found that they had to build a build a telescope simulator when they came to build large, heavy instruments for use on the telescopes on La Palma. My understanding is that these arguments were ignored because it was considered that it would weaken the case for the NHO if it were argued that the INT could make useful observations at Herstmonceux. Moreover, it was considered that the RGO would devote effort to using and maintaining the INT instead of giving priority to the NHO.

The site-testing expeditions, which were started in 1973, led eventually in 1975 to the choice of the island of La Palma in the west of the Canary Islands as the first choice for the site of the NHO. The Observatory itself would be at the top of a mountain ridge overlooking the caldera of an extinct volcano. It would be at a height of 2300 m, and so was expected to be above the clouds that often engulfed the lower slopes of the island. The occurrence of earthquakes in the southern part of the island appears to have been discounted. Then there followed protracted negotiations with the Spanish Government before the conditions for the new international observatory were agreed. Ireland and Holland joined with the UK in funding what became known as the Isaac Newton Group of telescopes, while Sweden and Germany also wished to place telescopes on the mountain-top site. The observatory was given the Spanish name for the mountain, which was known as La Roque de los Muchachos — the Rock of the Boys. Spanish astronomers were entitled to a significant proportion of the observing time on the telescopes. It was necessary to build a road up the mountain before construction work could begin and so our engineers found themselves with time in hand. An RGO office was established in the coastal town of Santa Cruz and RGO staff on extended tours of duty lived there.

The events leading up to the establishment of the observatory on La Palma have been described in an unpublished illustrated article, which was written in 1999 by John Pope, with the title "Where on Earth shall we put our big telescope ?". There is a copy in RGO Archives. John took part in some of the exploratory expeditions. The teams

that evaluated the sky conditions were led by Bennett McInnes from ROE, while George Harding was responsible for the general direction of the work. RGO staff were also involved in the commissioning of the Anglo-Australian Telescope, and later in its use. Assistance continued to be given to the SAAO.

5.3.2 Celebration of the Tercentenary

The Royal Observatory was founded at Greenwich in 1675 and so there were many special events to celebrate its Tercentenary in 1975. It was appropriate that Hunter, who had joined the RO some 38 years earlier should be Director for this period, and that Humphry Smith, who had joined in 1936 before Hunter, should be Chairman of the Tercentenary Committee that organised the events at Herstmonceux. The Tercentenary was also celebrated by the National Maritime Museum at Greenwich, which had care of the Old Royal Observatory, as it was then known.

A preliminary outline of the proposed activities at Herstmonceux was circulated in July 1974 and staff were asked to volunteer for overtime and weekend working during the first two weeks of August 1975. There was a trial run for Dome B (36-inch telescope) in August 1974. A list of the planned activities is given in IB 210 for 8 May 1975 and a short account of them is given in IB 211 for 14 August 1975. A 4-page account of the events is given in the annual report for 1975. Some highlights are mentioned here.

The Queen visited Greenwich on 20 May, nominally as part of the celebration of European Architectural Heritage Year, and she re-inaugurated the 28-inch telescope, which had been moved back to Greenwich from Herstmonceux, and she toured the special Tercentenary Exhibition in Queen’s House.

Princess Anne attended a Garden Party at Herstmonceux on 18 July during which she unveiled a bust of Flamsteed, the first Astronomer Royal, and inaugurated a large commemorative sundial made from stainless steel. There were many special guests and all present staff and many long-serving former members of the Observatory were invited to attend, giving a total attendance of nearly 900. It was a fine, warm sunny day. My job was to escort the High Sheriff of Sussex and his wife, and so I had a good view of the ceremony — as can be seen in the photograph in the annual report!

There had been a competition amongst the staff for suggestions for a permanent memorial of the anniversary. Gordon Taylor had originally suggested a large garden sundial in the south courtyard of the Castle, but he had then designed the equiangular sundial that was adopted. It is an unusual design and the shadow of the vertical gnomon shows Greenwich Mean Time, rather than local apparent time. It was intended that it should be adjusted to show British Summer Time, but during the ceremony Hunter announced that it would always show GMT as a sign of the link with Greenwich. Consequently part of the mechanism was never used. I was given the job of verifying that Taylor’s design was valid before the contract for its construction was placed.

The bust of Flamsteed was carved by G (Danny) Elliott, a stone-mason who was working on the Castle at the time. I do not know whether it was his idea to carve the bust; he had to work from a portrait. A bronze copy was presented to the Royal Society. Some years later the plinth was moved from the upper part of the formal garden to a place close to the Castle; this was probably the time when the original stone bust was moved inside the Castle and a copy put in the garden.

An international conference on “The origins, achievements and influence of the Royal Observatory, Greenwich, 1675-1975” was held at the National Maritime Museum just before the Garden Party. Nine present and former members of the staff were amongst the speakers; I presented a paper on the changing role of the NAO. In addition an international scientific symposium was held during the following week at Herstmonceux on “The Galaxy and the Local Group”. I was not concerned with the scientific programme, but I was responsible for the local arrangements. My secretary, Pat Hanning, was in her element as she had had a lot of experience with the organisation of the IAU General Assembly when she was Sadler’s secretary. The only room that was large enough was the Long Gallery (or Ballroom) and so we even had to obtain carpeting to deaden the sounds of people moving around.

The telescopes and various other aspects of the work were put on display during two periods. During a week at the end of June about a thousand members of scientific societies and establishments visited the site by invitation and during two open weeks in August (including the weekends) nearly 22000 visitors were admitted. Surprisingly, this caused much less disruption to the work than might have been expected. An illustrated booklet, postcards, slides and various free duplicated pamphlets were made available to the visitors.

Professor W H McCrea of the University of Sussex was commissioned to write a short history of the RGO and this was published as an 80-page illustrated booklet. In addition, a three-volume history of the *Greenwich Observatory* was published by Taylor and Francis. The authors were Eric Forbes (early history), Jack Meadows (Airy onwards) and Derek Howse (buildings and instruments) and I later became friends with all three of them. I regret, however, that I did not buy a set of these volumes; I did not realize at the time that I would later become so interested in the history of the RGO. *The Times* and *Nature* produced special supplements and many individual articles were published in a wide variety of popular magazines and scientific journals.

In addition, there were TV programmes, the Royal Mint struck a set of three commemorative medals and the Post Office issued first-day covers with a stamp featuring Flamsteed House. A commemorative plate featuring the first 11 Astronomers Royal and scenes at Greenwich was produced by Wedgwood; it is illustrated on the cover of the annual report for 1975.

The RGO Club celebration took the form of a Country Dance Party, with displays and music appropriate to the time of Charles II, as well as dancing to the Magham Ranters. (Magham Down is a nearby village.)

5.4 The Graham Smith period, 1976 to 1981

When Graham Smith took over from Hunter on 1 January 1976, he had already been at Herstmonceux for over a year and so he was familiar with the activities and many of the staff. He did not live in the Castle, but rented a cottage at nearby Bodle Street. His primary concern was with the Northern Hemisphere Observatory, but he took an interest in, and was generally supportive of, the other activities. Several significant changes and developments during his period of office are mentioned in this section, while further details are given in later sections of this chapter.

Graham Smith felt that it was important to cultivate the public image of astronomy and of the RGO in particular, and so he followed up the Tercentenary celebrations by creating an exhibition in the Castle. This had the bonus of giving

visitors the opportunity to see a little of the interior of the Castle as well as the gardens. Creating the exhibition took a lot of effort by astronomers and by the staff of the Engineering Workshop and Drawing Office, but I believe it was eventually judged to have been worth the effort. (See section 5.5.8.4) Members of the public were able to see the Isaac Newton Telescope from a visitors' gallery and arrangements were also made to allow them to see some of the telescopes in the Equatorial Group.

Graham Smith also wanted to move the other astronomers from the Castle to the West Building so that they would be closer to the NHO project team and to the instrument development and engineering departments with whom they were expected to collaborate in planning the new observatory and its equipment. Moreover, increases in the staff of the NHO team were planned. Consequently, office space was at a premium and it was decided to make new offices for the NHO team in the basement of the Chronometer spur of the West Building. This basement had been designed to withstand enemy attack and to provide a secure environment for the time service in the event of war. It was partly below ground and had only narrow high-level windows. In the spring of 1976, holes for full windows were laboriously cut in the thick reinforced concrete walls. The first step was to use circular diamond drills to cut holes that were about 4 inches in diameter. (The discarded pieces of cores were about 9 inches long and I still have one in my shed as a souvenir.) Consequently, the cost of providing these extra rooms was probably very much more than the original estimates.

At the time, this basement was used for the storage of the archives and unsold copies of the Royal Observatory publications and of the large volumes of *Greenwich Observations* in particular. The archives were transferred to the bottom of the atomic-clock cellar at the south end of the Time Block and the stocks of publications were drastically reduced. I believe some were offered to other astronomical organisations, some were offered for sale to the public and the rest were dumped in unused wells in the grounds.

A few years later the Labour Government was looking for ways of providing extra work for the construction industry and the RGO was able to able to obtain special funding for the construction of an extra spur on the West Building. This was parallel to the Chronometer Block, but started from the south end of the Time Block. This new wing was occupied by the Astrophysics Division in November 1979. The STARLINK VAX 11/780 computer was installed in its basement in March 1980. (See section 5.5.3.4).

There were several changes in the senior staff of the RGO during this period. H J (Joe) B Paxton was appointed Head of Engineering in March 1976, presumably so that McMullan could concentrate on the development of new instruments. David Thomas moved to a post in the administration of SRC at the beginning of July 1979; the office had moved from London to Swindon by this time. His post as Assistant to the Director was taken by George Harding, who combined it with his duties as Project Scientist for the NHO. Shortly after this, it was announced that Dr Jasper Wall had been appointed as Head of a new Division of Astrophysics and Astrometry, which came into being on 1 November 1979, the day that Wall took up his appointment. He later became the last Director of the RGO. Murray continued his research in astrometry without any managerial responsibilities, although he continued to take a direct interest in the GALAXY measuring machine as well as in the work of the Meridian Department.

In his New Year message for 1980 Graham Smith announced that he would be leaving the RGO to become the Director at Jodrell Bank, in succession to Sir Bernard Lovell, and that he planned to return there in April 1982. In the event he left at the end of September 1981. There was an open advertisement for his successor. I understand that Bernard Pagel and Bob Dickens applied, but the appointment of Alexander (Alec) Boksenberg was announced in an SRC press release on 20 March 1981. The Science Research Council became the Science and Engineering Research Council (SERC) on 1 April 1981.

Denis McMullen resigned in April 1979 to return to Cambridge. George Harding retired in November 1980 on his 60th birthday; he had joined the NAO at Greenwich in 1938 and had transferred to the A&A Department in 1957. He was Officer-in-Charge at the RO at the Cape from 1969 to 1971 and was Deputy Director of the new South African Astronomical Observatory from 1972 to 1975. His place as Assistant to the Director was taken by Peter J Andrews at PSO level. Harding had, in effect, acted as Deputy Director at RGO, although he had neither the title nor the grade (DCSO) that had been held by Hunter. Graham Smith needed another senior member of the staff who could act for him in his absence but who would not otherwise be involved in the administration of the Observatory. He asked me to do this and so for about a year I had the title of Deputy Director. As far as I can recall, the only occasions on which I had to act in this capacity were to make presentations to staff who were retiring or leaving after a significant length of service. Bob Gordon, as Head of the Administration Division, was able to deal with the paperwork when Graham Smith was away. My penultimate task was to make the presentation of a cheque to Graham Smith just before his retirement and to receive from him a cheque for twice the amount to be used for the establishment of social and recreational facilities at the La Palma Observatory. The next evening the RGO Club organised a social evening in honour of Professor and Mrs Smith.

5.5 Departmental matters 1972 to 1981

The following sections for Engineering and Technology and for Astrophysics and Astrometry are very short since I had no involvement in these activities and full accounts are given in the annual reports for the period.

5.5.1 Engineering and technology

5.5.1.1 The La Palma Division

In the annual report for 1974 the Northern Hemisphere Observatory Project Team is listed with 4 persons. W A (Bill) Goodsell was appointed as NHO Project Manager on 17 March 1975. (Goodsell was in the grade of Superintending Engineer, which was equivalent to a Deputy Chief Scientific Officer.) John Pope became his deputy and George Harding the Project Scientist. By the end of the year the NHO Division is listed with 10 engineers and scientists, and by September 1977 it had doubled in size. Pope was head of the telescopes department, J W Gietzen and J S Beales, headed the instruments and computers departments, while R P Milner was the civil engineer. The project received its formal approval in May 1979 when the international agreement for the use of the Spanish *Roque de los Muchachos Observatory* on the island of La Palma in the Canary Islands was signed. From then on

the name *Northern Hemisphere Observatory* and the acronym *NHO* were dropped, but for convenience the name *La Palma* was used in connection with the RGO activities on the island. The NHO Division became the La Palma Division. The first *La Palma Newsletter* was issued in July 1979. J W Gietzen was promoted to SPSO on 1 October 1980 as officer-in-charge on La Palma.

The Isaac Newton Telescope was dismantled and the parts were lifted out of the dome early in June 1979 and taken to Grubb Parsons at Newcastle for rebuilding for the new latitude. The task took 6 days. The aluminising plant was removed from the dome on 9 February 1981, for modification prior to its transfer to La Palma.

Graham Smith announced during National Astronomy Week in 1981 that the new 4.2 metre telescope would be known as the William Herschel Telescope. The costs of the 1-m telescope were shared with the Netherlands and Ireland. It was named the Jacobus Kapteyn Telescope (JKT).

In addition to the 3 reflectors for astrophysics, the UK agreed to share with Denmark the costs of construction and operation of an automatic transit circle, for which the basic instrument would be provided by Denmark.

5.5.1.2 Engineering Division

The change in the character of the RGO is shown by the growing numbers in the Engineering Division, which was headed by Joe Paxton, who had transferred from RAL. The staff list in 1980 shows 65 persons in the following groups: Electronics and Electrical Engineering Department; Engineering Workshop; Design Office and Site Services.

Neil Parker transferred from RAL to the Electronics Dept in October 1976. He became deputy director in the final years of the RGO.

5.5.1.3 Instrumental Science Division

The team in the Instrumental Science Division, headed by Dennis McMullan, was strengthened by both internal transfers and by the recruitment of a series of well-qualified staff. Richard Bingham headed the optical instrumentation group and also acted as deputy head of the division. In addition, Charles Wynne of Imperial College was appointed as a consultant and was often at Herstmonceux. Two of the recruits were, however, lost to the division, but were gained by the A&T Division when they were promoted to PSOs. John Pilkington succeeded Humphry Smith as head of the Time Department in 1976 and Ken Hartley succeeded Albert Carter as Head of the Computer Department in 1978. John Powell became head of the Vacuum Physics Department and Ian van Breda came in 1976 to head the Automation Department. The twin brothers, Tony and Paul Jorden, did not join at the same time, but Tony came in 1977? and Paul came in 1978?. David Thorne joined them in 1978.

Important developments during this period included the use of CCD arrays to replace both film and the new electronographic cameras. Mini-computers, such as the PDP11/34 for the PDS measuring machine, and micro-processors came into use. (The Herstmonceux Conference in 1977 was on Digital methods in Astronomy.) The RGO was given responsibility for 3 instruments (including CCD detectors) for 4.2 m telescope.

5.5.2 Astrophysics and astrometry

5.5.2.1 Research teams

The annual report shows that in 1980 most of the 37 persons in the Astrophysics and Astrometry Division were allocated to research teams. These changed with the staff who were available and with the development of the research projects themselves. The Division was headed by Jasper Wall, who was supported by Bernard Pagel, as an Individual Merit (IM) DCSO, and two IM SPSOs, Bob Dickens and Andrew Murray.

The research is described in detail in the annual reports. Murray successfully presented the scientific case for the HIPPARCOS astrometric satellite, but this sophisticated mission did not produce its results until the 1990s.

5.5.2.2 Meridian Department

The Meridian Department was headed by R H Tucker. The primary programme of observations on the Cooke RTC continued and the results were prepared for publication. Murray and Graham Smith visited Brorfelde in Denmark in 1975 for discussions with Danish astronomers in meridian astronomy. Later an agreement was signed with the Copenhagen University Observatory to automate the Carlsberg Meridian Circle for operation jointly on La Palma.

5.5.2.3 Photographic Astrometry Department

The Photographic Astrometry Department, headed by Bill Nicholson, was primarily concerned with the use of the GALAXY measuring machine for the automatic measurement of astrometric plates from major surveys, such as the Second Cape Photographic Survey, but it was also used for many smaller projects. This machine was installed in 1972. It was so large that it had to be assembled in the sub-basement of the West Building, which had been previously used for quartz-crystal clocks. The main frame was delivered in January and the installation was completed in August. The associated computational work added considerably to the workload of the 1909 computer. A Nova mini-computer was added in 1975. The new software for processing the data from GALAXY was written by Nicholson and Dorothy Hobden, who had been transferred from the NAO for this purpose. GALAXY was used by students from Sussex and by astronomers from overseas, including Floor van Leeuwen, a student from Leiden, who later joined the RGO staff to work on the HIPPARCOS project. (See section 6.3.2.2)

In addition, a Zeiss Ascorecord measuring machine, which was digitised but operated manually, mainly by E D Clements, was used for many programmes, such as the optical positions of radio sources and the determination of the Einstein deflection at eclipses.

5.5.3 Developments in computing

5.5.3.1 The central computer facilities

The load on the ICT 1909 computer continued to increase so that double-shift working was introduced in 1972. The use of the remote consoles, which had been introduced in the autumn of 1970, had to be restricted as they made inefficient use of the computer since the Executive operating system had been designed before such facilities were available. The duties of the shift leader are set out in a note by the head

of the NAO Computer Section (Albert Carter) in a note dated 1974 April 26. He also pointed out that the payment of a responsibility allowance was being sought since the staff for computers used for administrative purposes were in a higher grade.

NAO Computer Circular no. 73 contained advice to programmers about the various sources of information about computers and programming techniques. It included a list of the circulars that were still relevant and a list of the manuals and books that were available. These lists show clearly that new programmers faced a daunting task before they could expect to become proficient. The series of NAO Computer Circulars, which provided mainly information about local facilities and procedures, ceased, however, in December 1971 with the revised version of no 74, although no. 75 on the use of "JEAN on remote consoles" was issued in the previous August. Their place was taken by short NAO Computer Notices of only short-term validity and by "The NAO Computer Users Guide", in which the material was presented in a more systematic fashion.

The Users Guide took advantage of the availability of new manuals provided by ICL. It was edited by David Chapman, an AEO who had joined the Computer Section in 1969 and who had been regraded as an SO in 1971. Unfortunately, he left in November 1973 on promotion to HSO in the Magnetic Dept. At this time Carter was also supported by Dorothy Hobden and John Carey, who had been promoted to HSO in 1971 and June 1973, respectively, so that David realized that he could not expect an early promotion in the Computer Section. Catherine Hohenkerk was transferred from the Solar Department to the Computer Department at the end of 1974. The experience that she gained there proved invaluable when she was later transferred to the NAO.

A GEC 2050 remote job-entry terminal was installed in June 1973 to provide access to the much more powerful computer ICT 1906A computer at the Atlas Computer Laboratory, but it was many months before the link became fully operational. The first useful work carried out by the link was for a trivial, but urgent, task for me on 14 December 1973. It later gave us access to the IBM 360/195 at the Rutherford Laboratory.

Proposals for the upgrading of computer facilities were considered by the SRC Computer Review Panel, whose chairman was Dr. Geoff Manning of the Rutherford Laboratory. I was the representative of the RGO and I submitted an initial bid for the replacement of the central processing unit (CPU) of the 1909 in April 1970. My recollection is that Manning and others took the view that we should change to IBM or rely on the link. I took the view that we did not wish to suffer the disruption that would be caused by changing the computer and the software. Eventually the central processor of the 1909 was replaced by an ICT 1903T CPU in January 1974 and it completed its acceptance trials in the following month. The main store was increased from 32 K to 96 K words and the computing speed was increased considerably. Two extra exchangeable-disc drives were installed at the same time to provide quicker access to data-files than was possible with magnetic tape, but we did not then get approval to add two 9-track magnetic tapes as we would have wished. This would have given us compatibility with new IBM and other systems using 8 bits (a byte) instead of 6 bits for each character, as well having greater speed and capacity. We did, however, obtain them later in the year and we obtained 4 more disc drives (from ACL) in 1975.

The Executive program for the 1909 was replaced by the more sophisticated GEORGE 3 operating system on the 1903T. This allowed greater use of remote console

typewriters so that programmers could interact directly with the 1903T. David Chapman wrote a guide to the new GEORGE operating system that was to be introduced on the 1903T computer before his transfer. These improved facilities led to a drop in the use of the GEC 2050 link to ACL, but a note by Carter and myself argued the case for retaining it. This was accepted and it remained in use until June 1983. The new operating system made possible a greater level of interactive working and 5 alpha-numeric visual display units (VDUs) simulating teletypewriters were installed at the end of 1974 to supplement the 3 teletypewriters that were already in use. A scanner for 16 terminals was installed in January 1979.

One aspect of the work in which I took a personal interest, although I was not a direct user, was that of astronomical data in machine-readable form. NAO Computer Circular no. 74, which was compiled by Dorothy Hobden, contained a list of the files for ephemerides and catalogues that were then available. The topic was the subject of a "literature discussion" on 21 June 1971 and was taken up in Computer Notice 6/71. Our efforts were dwarfed by those of the Stellar Data Centre at Strasbourg and thoughts turned to the possibility of a central data bank for the UK with access via remote terminals.

In December 1975 there was a cash crisis within the RGO (and SRC?) and staff were requested to economise in their use of computer consumables, such as line-printer paper, and double-shift working was stopped. Stringent economy measures were called for in July 1976, but as far as I can recall there were no further cuts in the level of working.

5.5.3.2 On-line and other computer facilities

By this time I had ceased to be a user of the system and so I found it more difficult to keep up with operational details, but my position on the SRC panel did, however, mean that I learnt about the new developments in other establishments. The RGO Advisory Panel on Computers that was set up at the Senior Staff Meeting on 1 January 1973 had its first meeting the next day under my chairmanship, and with Carter as its secretary. In addition to the central processing facilities the panel was responsible for the oversight of all "on-line computer projects" for the control of instruments, for data recording and real-time processing. The minutes record 5 such projects for telescopes and instrumentation and 7 for measuring machines.

In addition the panel considered the acquisition for programmable desk calculators that would replace the manual and electromechanical desk machines previously used. It was then expected that such machines would cost less than £500, but Dickens requested a calculator costing £2000. He was asked to circulate a proposal giving the reasons for this particular choice, but I do not recall whether his arguments were accepted. A Commodore PET desk computer was in use in the Time Department in 1979. These devices were much more powerful than the small programmable pocket-sized calculators that came into widespread use during this period and for which the NAO (especially Yallop and Sinclair) developed techniques for their use for astronavigation. This led to the publication in 1981 of *RGO Bulletin* no. 185 giving *Compact data for navigation and astronomy for 1981-1985*.

This decade saw major developments in computing as mini-computers were introduced and eventually became powerful enough to do the work previously done by large main-frame computers. An example of this has already been mentioned in connection with the new GALAXY measuring machine as after a few years a Nova

mini-computer was attached to it for control purposes and for carrying out some of the data-processing previously done on the ICT 1909 computer. A two-week training course in the use of mini-computers was held in June 1974. The lectures during the first week were given by RGO staff, while those during the second week were given by staff from the Rutherford Laboratory. Demonstrations were given on the mini-computer for the INT. The development of new instruments with microprocessors saw the introduction of yet another programming language, FORTH.

5.5.3.3 New facilities for document preparation

In the NAO we had had a direct interest in the introduction of new facilities that could be used for the preparation of our printed publications and of other reports and documents with a high-quality appearance. The use of computer composition was refined and the more flexible UDS 6000 automatic typewriter was used for tables, reports and other text documents. (See section 4.3.4.2]

Two Data Logic word processors were installed for use for secretarial work at the end of February 1980. One was for the NAO, since I had taken the primary role in obtaining them, and one was for the typing pool, which had moved from the Castle to the new wing of the West Building. At this time word-processing software was quite new, as was the ability to display a large range of characters on the monitor screen of a computer. The printers used interchangeable “daisy wheels” and the text could be stored on a “diskette” for printing or amendment. The cost was considered to be very high, but they significantly increased the productivity of the typists. I suspect that my drafts became rougher as corrections and amendments became so much easier. As far as I am aware they were not then used at all by scientific or technical staff.

The need for the use of punched cards for input to the computer was reduced when an ICL ‘Matador’ system was installed in January 1972 to provide direct encoding on magnetic tape from a keyboard.

A facsimile machine (fax) was installed in 1981 to improve the link between RGO and La Palma.

5.5.3.4 Changes of staff and new developments

Dorothy Hobden was transferred to the Astrometry Division on 1 January 1975 and her place as deputy-head of what had become the RGO Computer Department was taken by John Carey. Albert Carter retired on 30 June 1977 and his place was taken (six months later) by Dr. Ken Hartley, an SSO in the Physics Department. He was well-fitted to deal with the next major developments in the computer facilities.

At about this time there was, however, a wasteful diversion as Graham Smith, the new Director of the RGO, suggested that the RGO should install new computers to a design that was then being developed at Jodrell Bank for the control of the radio telescopes and for the processing of the large quantities of data that they generated. This project was allocated to Dr John Beale, who had joined the RGO from CERN in 1973 and who, from the middle of 1976 onwards, was concerned with the computers for the NHO. I did not support this idea as I considered that it would require RGO staff to be involved once again in the development of basic software rather than in applications programming. The project was eventually abandoned in favour of the SERC-wide STARLINK project. This involved a network of VAX 11/780 computers coordinated by the RAL and using common software, especially for the new field of “digital-image processing”. The new computer was installed in the new wing of the West Building in

March 1980 and was brought into operation in May. There was an official inauguration in October 1980.

The RGO Computer Committee was re-formed under my chairmanship in July 1980. It was concerned with both Starlink and the 1903T, which remained in use for other computing work until March 1983. There was a sub-committee on the training of staff in computing as this type of activity was becoming more and more dominant throughout the Observatory. There was also a separate Starlink Local Management Committee that included representatives of external users.

5.5.4 H. M. Nautical Almanac Office

5.5.4.1 Retirements of Donald and Flora Sadler

Donald Sadler retired from the RGO on 18 February 1972 after a year during which he had been 'disestablished' and free from any routine duties. He had hoped to do some research in celestial mechanics, but he soon realized that he was not likely to be able to make any useful contribution and so I believe that he spent most of his time sorting, weeding and annotating the archives of the Office. I then had very little knowledge of the archives and I did not have time to take any real interest in them. When I examined these archives in the Cambridge University Library in the 1990s I saw the evidence of his work, but I wondered whether he had discarded papers that a trained archivist would have saved. He did, however, write a very interesting historical account of the 'records and files' of the NAO as well as a description of what he had found. He may also have made notes for use in writing his history of the NAO.

The presentation on his retirement was made by Dr Hunter, then Acting Director, in the Long Gallery, and it was followed by a talk by Phil Laurie about the early history of the Nautical Almanac and of the NAO. The retirement present from the staff took the form of a dining chair.

After his retirement he continued to take an active interest in astronavigation and in time systems. He started to write a general history of the NAO, but he could not find enough original unpublished information and so he abandoned this task. Instead he drafted "A personal history of H.M. Nautical Almanac Office, 30 October 1930 – 18 February 1972". He also collected reminiscences from long-serving members of the staff, but he did make much use of them in his account. His papers were passed to me after his death and I transcribed and edited the personal history (of nearly 180 A4 pages). I could not find a publisher in the 1990s, but it has now been 'published' on the website of the NAO, which is now at the UK Hydrographic Office at Taunton. I hope to transcribe the letters from the staff 'one day', before they are passed to the RGO archives at Cambridge.

Further details of his life are given in an article in *Gemini* (by me) and in other obituaries that were published after his death on 24 October 1987 at the age of 79. (See appendix G.7.)

Flora Sadler continued to work in the NAO as a PSO (part-time) until her retirement on 11 April 1973. She had joined the staff on 20 September 1937. While at Herstmonceux, she had been responsible for the oversight of the printing of the publications and for the occultation programme. She had been the first woman secretary of the Royal astronomical Society from 1949 to 1954 and the Secretary of IAU Commission 17 (The Moon) from 1955 to 1964. She and Donald continued to live at

Cooden Beach, but she moved to Aberdeen in the 1990s. She died on Christmas Day 2000.

Other long-serving NAO staff who have died since their retirements are Walter Scott, Harold Richards, Albert Carter, Eric Smith, Miss Marion Rodgers and George Harding. (See also appendices C.7 and G.7).

5.5.4.2 Other NAO staff matters

My review of the NAO staff position in June 1972 shows that the Office was then split into three sections: the Publications and Information Services Section with 5 members of staff, although Eric Smith was just about to retire; the Computer Section with 15 members; and the Occultations and Dynamics Section with 7 members. In addition, Pat Hanning and Audrey Turner (part-time) provided secretarial and library services. Some proofreading was also done by former members of the staff. Unfortunately, I do not have at hand "the accompanying 'summary review' of the work of the Office", but the notes in the staff review show that much of the work required contributions from more than one section. Moreover, I was concerned that the pressure to extend the computer service and to carry out more pure research meant that there would be insufficient resources to meet future requirements for major changes in the principal ephemerides. The effects of the introduction of computers are shown clearly by a comparison with the NAO staff list in the *Nautical Almanac for 1954* as it shows 27 members, of whom only 5 worked in the Machine Section.

The retirement of Mrs Sadler and the subsequent promotion and transfer of Dr. Bernard Yallop from the Astrometry Department on 1 October 1973 led to a reorganisation in which he took charge of the Publications and Data Services section and Leslie Morrison headed the Occultations and Dynamics Section. Brian Emerson moved to the former and Gordon Taylor moved back from navigation to occultation work. In the meantime we had recruited Fred Watson and Jane Biggin, while Graham Appleby transferred from the Solar Department. Audrey Turner resigned shortly afterwards and her place was taken by Mrs Valerie Bacon.

The formation of the Almanacs and Time Division in May 1974 had little direct effect on the NAO, but it did mean that I had less time for direct involvement in its work. At the beginning of 1976 the staff of the Time Department, then 8 in number, moved into the NAO spur as Graham Smith wished to move more astronomers from the Castle to the West Building. (See section 5.4.) Later in the year the NAO gave up another room to accommodate a member of the staff of the Meteorological Office, which had decided to make regular observations from the site. Although we had General Notices for the Division we did not have a formal meeting for all the staff of the Division until Humphry Smith's retirement in June 1977.

Other staff changes in the NAO included the loss of Jane Biggin, who resigned in 1975 soon after gaining an MSc at the University of Sussex, and Fred Watson, who moved to the Royal Observatory at Edinburgh in December 1976, and the gain of Catherine Hohenkerk in 1978, who moved from the Computer Department. She had previously served in the Solar Department; she obtained a BSc degree by part-time study in 1981. Don Taylor joined as an SO on 1 February 1979 to work mainly with Andrew Sinclair on dynamical astronomy. He had been a PhD student at the University of Glasgow.

My promotion meant that I was expected to become more involved in the administration rather than the practice of science and so I attended Senior Management Seminars at the Civil Service College at Sunningdale in Berkshire in October 1972 and June 1975. I served on various SRC and Royal Society committees. For example, I was an ex officio member of the British National Committee for Astronomy. I was a member of the SRC Central Review Board for Group C, which dealt with the promotions of scientific staff, from 1978 to 1981, and I was chairman of Panel C3 (mainly for ASOs) in 1980 and 1981. I also chaired SRC working groups on librarians and information officers and on the training of ASOs.

An NAO staff reunion was held on 19 October 1974 to mark the 25th anniversary of the move from Bath to Herstmonceux. There was a large attendance of about 100, including guests and some other RGO staff who had strong connections with the NAO. There were tours of the Observatory in the afternoon followed by a slide show as the weather forecast suggested that it might not be suitable for walks around the gardens and gardens. A supper was served in the dining room before a social dance to records in the Long Gallery. Unfortunately, I do not have any photographs of the event. The previous year on 1 August 1973 there had been smaller gathering of 15 members of the NAO staff who had been evacuated from Greenwich to Bath in September 1939; five of those still in post were present, but 4 were unable to attend.

Pat Hanning continued as my secretary until the end of 1976, when she was promoted to Senior Personal Secretary and became secretary to the Director, Graham Smith. She was replaced by Lynne Stuart, who had been the head of the Typing Pool.

5.5.4.3 NAO publications

The publication of the *Astronomical Ephemeris for 1973* did not take place until October 1972, much later than usual and than was desirable. The delay was only partly due to our use of the Linotron 505 filmsetter for composing the main pages in our half of the volume. I do not recall whether USNO were late in sending the material for their half of the almanac, but I am fairly sure that we did not succeed during the decade in again achieving publication a year in advance. Although the printed volume was late we did make available data in advance to organisations that needed them. During the IAU General Assembly in Sydney in 1973 I sought opinions about the changes in content and arrangement that astronomers would like to see. Most were content, but the discussions led to my preparing *NAO Technical Note 31* in 1974 setting out some ideas on the future publication of astronomical ephemerides. In October 1975 Ken Seidelmann, who was to replace Ray Duncombe as director of the US NAO, came to Herstmonceux for discussions about the revision of the AE, and we were able to present a mock-up of AE 1981 at the IAU General Assembly at Grenoble in August 1976.

We had hoped that USNO would be able to prepare a new set of planetary ephemerides using a newly adopted set of astronomical constants in time for publication in AE 1981, but they were delayed until AE 1984. We did, however, go ahead with the other changes and we were finally able to agree on a common title, namely *The Astronomical Almanac*, to replace the two titles, *The Astronomical Ephemeris* and *The American Ephemeris* which had same content inside the covers. This also made it possible for printing to be carried out only in the USA, although we continued to supply reproducible copy for those parts for which we had the prime responsibility. The sales of the AE in the UK did not justify a separate printing, but the AmE was used in the USA by astrologers, as well as by astronomers! The change of title depended on there

being an amendment to the Act of Congress that authorised the production of *The American Ephemeris*. Ken and I persuaded the Scientific Director of USNO, Gart Westerhout, to try to obtain agreement for the change when we had a working lunch in October 1978 during one of my visits to Washington. He did obtain the agreement of the US Navy Department and then an amendment was attached to a Bill that otherwise had no relevance to astronomy!

We continued to distribute printed copies of *Advanced Data for the AE* up to 1980, but for the years 1981 onwards the data were made available only on magnetic tape. We did, however, start to publish jointly (in 1979 for 1981) a booklet called *Astronomical Phenomena* that contained the information about eclipses, risings and settings, etc, that were needed for minor local almanacs.

We also continued to produce the *Astrophysical Observers Almanac* for 1972 onwards, but after a few years the lists of stars and other objects were omitted and the Almanac contained mainly the rising and setting data for the Sun and Moon for particular observatories. The number of observatories gradually rose and reached 32 for 1977, but we only needed to produce one copy for most places. We also supplied other ephemerides for special purposes as well as diagrams of daylight and moonlight conditions. Data on sky brightness due to twilight and moonlight were also supplied to the SRC Panel on the allocation of telescope time.

The Office also provided astronomical data for civil purposes for newspapers and other organisations and individuals, either regularly or to meet special requests. A series of *Astronomical Information Sheets* was started in 1976.

The Office continued to produce the *Nautical Almanac*, the *Air Almanac* and new editions of the *Sight Reduction Tables* for both marine and air navigation in cooperation with the Americans. At first Gordon Taylor was in charge of the work, but then Bernard Yallop took over the responsibility for the navigational publications. There was little change in the almanacs and tables, although the NA for 1977 was published with a stiff paper cover, instead of the traditional plain blue hard cover. The availability of small computers and programmable hand-held calculators gave rise, however, to an increasing requirement for the supply of data in forms that were suited to these devices. *NAO Technical Note no. 44*, which was prepared by Andrew Sinclair, gave data for astronavigation in 1978, while no. 46, by Yallop, gave appropriate formulae, which were based on the use of economised polynomials as described in *Interpolation and Allied Tables* in 1956. Eventually in 1981 *Compact data for navigation and astronomy for the years 1981-1985* was published as *RGO Bulletin* no. 16. Although I had drawn attention to this technique at the IAU General Assembly in 1961 we did not use it in the AE until 197?, and then only for a half-daily ephemeris of the true geocentric distance of the Moon. I did, however, persuade Ken Seidelmann to agree to use it in the *Astronomical Almanac* for1981 onwards to replace the hourly ephemeris of the Moon, which gave first differences, by a daily tabulation of the coefficients of fifth degree polynomials. This not only made interpolation much easier, but it also reduced the number of pages from 122 to 23.

The Star Almanac had been almost unchanged since its introduction for 1951 and so I sought the opinions of users about possible changes. As a consequence new material was introduced in SA 1973 and 197?. The tabulations in the previous volume were composed automatically from our magnetic tape on a Linotron 505 phototypesetter. (See section 4.3.4.2) A few years later there was an industrial dispute

within H.M. Stationery Office and the Unions refused to accept our magnetic tapes and so SA 1977 was composed manually and we produced copies of *Advanced Data for A.E. 1980* by xerography from computer listings.

A new edition of *Planetary Co-ordinates* (see section 2.2.4.2) was needed for 1980-2000 and so I decided that we should extend its scope so as to make it useful for a much wider variety of purposes. Consequently it included geocentric as well as heliocentric planetary coordinates, lunar coordinates, information on eclipses and the phases of the Moon, and 'observability data' for the planets. We also made it a joint publication with USNO, although we produced all the copy. We knew that the new planetary ephemerides that were being developed by USNO would not be available in time and so we published in 1978 the booklet *Planetary and Lunar Coordinates for the years 1980–1984* as an interim measure.

We would have liked to prepare fully revised editions of the *Explanatory Supplement* and of *Interpolation and Allied Tables*, but we had to be content with making only minor amendments or with unaltered reprints. The Supplement was reprinted with amendments in 1972, 1975 and 1977), while IAT ran to at least 7 impressions. In 1975 HMSO even reprinted *5-figure Tables of Natural Trigonometric Tables*, which had been first published in 1947. We did not receive any 'royalties' from the sale of our books, but on the other hand we did not have to subsidise the *Astronomical Ephemeris*, whose sales probably did not cover the costs, nor did we have to expend effort on keeping records and accounts.

The Royal Navy continued to send its trainee navigating officers from HMS Dryad and HMS Mercury to the RGO for a tour of the activities, with the NAO acting as host. There were also visits by parties of Canadian naval officers who were attending a Maritime Advanced Navigating Course.

5.5.4.4 Occultations

During the 1970s there was a considerable expansion in 'research activities' by the staff of the Office. The main programme for the prediction of occultations of stars by the Moon was followed up by a major effort to use past occultations, eclipses and transits to determine the past variations in the rotation of the Earth. The prediction of occultations by planets, minor planets and satellites gave rise to successful observations. Theoretical studies of the orbits of the satellites of the planets were supplemented by new observations. The interest in the orbit of the Moon and the rotation of the Earth led to an involvement in observational programmes for lunar and satellite laser ranging. The interest in time scales and the system of astronomical constants was maintained and new activities included the analysis of observations of spectroscopic binaries. The results of this work were published in refereed journals, RGO Bulletins or NAO Technical Notes.

There was an increase in the number of observations of the times of occultations of stars by the Moon, probably because the computer made it feasible to reduce the observations as they were received and to inform the observers quickly about the results, and so encouraged them to make more observations. About 8500 observations were received in 1971. The computer also made it possible to re-reduce all the observations (over 50000) that had been collected since 1943. The results were published in 1978 in *RGO Bulletin* no. 183 under the title *Catalogue of observations of occultations of stars by the Moon 1943-1971*. The 16 pages of explanatory notes are printed on paper, but the catalogue itself was provided as a set of 5 microfiche, each

containing 7 rows of 14 pages, each 12 mm x 9 mm. Another departure from tradition was that the catalogue was ascribed to one person, L V Morrison, although it did acknowledge that many members of the NAO staff had been involved in its production.

The computer was also used to take into account 'limb corrections' that were derived from a digitised version of the Watts' charts of the limb of the Moon. These charts were printed in a large volume and so their digitisation using the D-Mac was itself a major task. These charts had been prepared by C B Watts at the US Naval Observatory from a very large number of photographs of the Moon and they showed how much the apparent shape of the Moon differed from a circle as it appeared to wobble in its orbit around the Earth. When these limb corrections were included in the reduction the occultation observations gave improved estimates of the differences between the 'observed and computed' positions of the centre of Moon. These differences were only partly due to errors in the theory of motion; they mainly reflected the differences between the scale of universal time (UT) in which the times of the observations were recorded and the scale of ephemeris time (ET) used in the theory. The differences UT – ET were themselves due to variations in the rate of rotation of the Earth.

Atomic Time replaced ET as the uniform time-scale for current use, but it was necessary to use ET for studies of the past variations in the rotation of the Earth, the causes of which were of considerable geophysical interest. Leslie Morrison then used occultation data to improve the estimates of these variations over the period since 1663, when it first became possible to measure UT with sufficient accuracy. The analysis of the data also yielded information about the stellar reference frame and other factors that affected the timings. Special predictions of 'grazing occultations' were issued as these give information about the latitude of the Moon, whereas most of the observations gave greater weight to its longitude. In appropriate cases, local 'expeditions' were organised with observers placed along the expected track. Morrison also collected observations of the transits of Mercury and, with C G Ward, a sandwich student, analysed them to determine an accurate value for the orbital acceleration of the Moon. This value was later confirmed by the lunar laser ranging observations.

Reports of 'fading occultations' were collected and studied by Graham Appleby as these often indicated that the stars were double. Photoelectric observations were made by some observers, including David Evans who had moved from South Africa to Texas, when the stars were considered to be double or of large angular diameter. For example, Morrison collaborated with Ian Glass at SAAO to determine the diameter of the star 31 Leonis. Predictions of lunar occultations of non-optical sources, such as radio and X-ray sources, were issued and sometimes Morrison assisted in the analysis of the data.

Gordon Taylor continued to predict occultations of stars by planets, minor planets and satellites in order to obtain better values of their diameters. Photoelectric observations were also used to look for the effects of atmospheres. One such prediction, made in 1973, led to the discovery in 1977 of the rings of Uranus by observations made from the Kuiper Airborne Observatory. This led to Gordon's appearance on the TV programme "The Sky at Night".

By the end of the decade it was clear that the timing of lunar occultations of stars was no longer useful for the determination of the difference UT – ET and the staff concerned were needed for other tasks. Consequently, the lunar occultation programme

was handed over to the Hydrographic Department in Tokyo at the beginning of 1981. Morrison was transferred back to the Meridian Department to work on the programme for the new automatic transit-circle on La Palma. Appleby and Harvey were transferred to the Time Department to work on the satellite laser ranging project. Taylor returned to the Publications and Data Services Section, but continued some work on occultations.

5.5.4.5 Dynamics

Andrew Sinclair took over my work on the orbits of the satellites of Mars. At first he was unable to get a significant value for the secular acceleration of Phobos, but after obtaining more observational data from the USSR he obtained a small value that was consistent with the accepted theory of tidal friction. Consequently, it was he who went to the USNO in August 1977 to attend a conference to mark the centenary of the discovery of the satellites. I did, however, present an historical review at an RAS Discussion Meeting that was held in May 1977. Dan Pascu from USNO, who had made recent observations of the satellites, also spoke about his work. I had been disappointed that I had not had the time to complete the work myself but many years later I came across a reference to my work that showed that it had, after all, been useful. The following quotation is taken from an article in a book on planetary satellites.

"At the time the Mariner 9 spacecraft went into orbit about Mars [in 1971] and began its observations of Phobos and Deimos, Wilkins' theory provided the best predictions of the satellites' positions. … Sharpless' ephemeris is in clear conflict with the most recent observations of Phobos' position; …" [J. B. Pollack, 1977, in J. A. Burns, ed., *Planetary satellites,* pp 339-340. University of Arizona Press.]

Sinclair's main work was, however, on trying to explain, for example, the relationships between the periods of the satellites of Saturn. (Many of the ratios of the periods are close to the ratio of two small integers, such as 2:1 or 4:3. There are also similar 'commensurabilities' amongst the orbits of the planets.) He and I wrote a review paper on the dynamics of the planets and their satellites that was published in the proceedings of a symposium on planetary science that was held by the Royal Society in 1973 to mark the 500th anniversary of the birth of Copernicus. The paper was based on the lecture that I had given at the conference. We also prepared an exhibit on occultations and dynamics for a Royal Society conversazione and this was also displayed at the University of Newcastle and at the museum of the City of Portsmouth. Sinclair also made observations of the satellites using the 13-inch and 26-inch telescopes and he used them to provide improved predictions.

Brian Emerson developed a program for the determination of the periods in data that varied with time and he used it in collaboration with other astronomers, especially R F Griffin at the University of Cambridge, to analyse data on spectroscopic binaries.

5.5.4.6 Lunar and satellite laser ranging

A new phase in the work of the NAO and, later, of the Time Department began when Professor Stuart Ramsden, of the Physics Department at the University of Hull, sought the help of the NAO in connection with a project to build a lunar laser ranging system. (I have a vague recollection that he first telephoned Sadler, who then referred him to me; if so, it must have been before February 1972.) The project needed a powerful laser system that could be used with a large telescope to send laser pulses to the retroreflectors that the American astronauts in the Apollo project had placed on the surface of the Moon. The Soviets also used unmanned spacecraft to place Lunakhods,

fitted with retroreflectors, that could move over the surface. The role of the NAO was to provide predictions for the observers and to assist in the analysis of the data, which consisted of the times of transit of the light to the Moon and back. The project had clear applications to the study of the motion and rotation of the Moon and to the determination of the rotation of the Earth and it was said to provide a test of Einstein's theory of general relativity. By this time, observations had already been made successfully at the Macdonald Observatory in Texas using a 104-inch reflector, but observations from several stations around the world were needed if the full benefits of the project were to be obtained.

I readily agreed to assist. The initial proposal involved cooperation with a group in South Africa, but this was abandoned when it became clear that the SRC would have to meet almost all the costs of establishing and operating the system there. Instead we turned to cooperation with a group in Australia in the Division of National Mapping, which was the equivalent of our Ordnance Survey. This group had plans to build a special-purpose observatory near Canberra on a mountain that was close to the valley containing the large radio telescope of the American Deep Space Tracking network at Tidbinbilla. Our initial contact was with Peter Morgan, who visited the RGO in September 1974.

Just before that I had visited the Macdonald Observatory while on holiday in the USA and so I had a better idea of the nature of the project. I was on duty for the visit itself as I made a special journey by air from Washington to Texas and then to Omaha in Nebraska to rejoin my family and our hosts Dr & Mrs Duncombe from the US Naval Observatory.

In 1975 we obtained approval for this LLR project, in which Hull would provide the laser and Andrew Sinclair would spend a year in Australia to work on the programs for data reduction and analysis. He went in June 1975 and gained experience that was to prove invaluable in the later UK project for satellite laser ranging (SLR). Andrew's wife Janet took special unpaid leave to go with him and I believe that she obtained a job at the Mount Stromlo Observatory. In 1976 I attended a conference on LLR in Austin, Texas but, for reasons that I do not recall, the formal cooperation with Australia was abandoned. I did, however, visit the site in 1979 while observations were being made; I was then attending the IUGG General Assembly in Canberra.

In 1974 Desmond King-Hele and others developed a proposal for a UK SLR project in which the RGO would participate. My recollection is that Humphry Smith was the contact as the main RGO interest was in the determination of the variations in UT and in polar motion. I did, however, endeavour to publicise both the LLR and the SLR projects by, for example, talking about them at a meeting of the Association of British Geodesists in November 1974. The SLR proposal was, however, not approved by SRC, probably because it appeared to be more relevant to NERC and to have less astronomical interest than the LLR proposal. The Royal Society held a discussion meeting on lunar and satellite ranging in February 1976 and so the value of this new technique came to the attention of a much wider and more influential group of scientists. A meeting to discuss a revised SLR proposal was arranged for 5 July 1977 (my birthday) and I was invited to attend. I did not do so as I had learned the previous afternoon that my elder son, Michael, had been killed in a mountaineering accident near Chamonix. Nevertheless, I was asked by the group to act as secretary and to prepare the formal proposal to be submitted to SRC. The proposal was approved by the ASR Board in the following July, by the Council in October and by the Department of Education

and Science in November. This proposal involved the RGO playing a major role in operating the system at Herstmonceux.

At this time there was a delay in the negotiations for the NHO and so Graham Smith decided that John Pope should examine the proposal for the telescope for the new system. He reported that the telescope proposed by the team at the University of Hull would not be adequate for the job and he recommended that we bought a telescope from an American company. Unfortunately this involved a significant increase in the cost of the project and so we had to go back to SRC. I had the task of presenting the case to the committee, but I was successful and the project went ahead. The responsibility for the day-to-day management of the project within the RGO was given to John Pilkington, who had replaced Humphry Smith as head of the Time Department. (See section 5.5.6.4)

5.5.4.7 Other international activities

My involvement in the preparation of the IAU (1964) System of Astronomical Constants and my subsequent position as President of IAU Commission 4 led naturally to my becoming chairman of another working group to consider the need for further changes in the system and in the definition of ephemeris time (ET). In particular, it was necessary to take into account relativistic effects in timekeeping. I must admit, however, that my knowledge and understanding of the theories of relativity was insufficient to allow me participate fully in the discussions that led to the introduction of ‘dynamical timescales’ by the IAU in 1976. It appears that I was not the only one in this position as the names and definitions were changed yet again in the 1990s. Even the new values for the constants proved to be premature as further changes were made during the preparation of the new set of ephemerides for 1984 onwards. Nevertheless, I contributed a paper about nutation at an IAU Symposium at Kiev in 1978. Sinclair and I also participated in an IAU working group on cartographic coordinates and rotational elements of the planets and satellites that was set up in 1976. This was chaired by Merton Davies of the Rand Corporation; we became good friends and he used to send me a Rand Calendar each year. He played a major role in the mapping of Mars after the Mariner and Viking missions and he was given full credit for this in a book by Oliver Morton.

At the IAU General Assembly in 1970 I was asked to take on two new roles that were only indirectly related to the main work of the NAO. It is probable that Sadler put forward my name as his replacement as an IAU representative on the Council of the Federation of Astronomical and Geophysical Services (FAGS). (See section 4.3.4.7) It is likely that he also suggested me for the position of chairman of the IAU Working Group on Numerical Data and hence of representing the IAU on the ICSU Special Committee on Data for Science and Technology (CODATA). I accepted both invitations although I did not know what would be required of me, nor did I realize that these activities would continue for the next 9 years and that I would find them so interesting and rewarding.

The meetings of the Council of FAGS were usually held in Paris, but every four years they were held during the General Assembly of the International Union of Geodesy and Geophysics so that there could also be a meeting with the heads of the various services in the Federation. My first meeting was held on such an occasion at Moscow in August 1971 and I took the opportunity to visit the Institute of Theoretical Astronomy in Leningrad on the way. I took my elder son, Michael with me, as he was

learning Russian at school. The head of the Institute, Professor Chebotarev, together with his son, showed us around Leningrad on the Sunday and in the evening we went to his apartment for supper to celebrate his birthday! One of the members of the Institute, Dr V Shor, was interested in the satellites of Mars and he subsequently sent us the Russian observations that were used by Sinclair.

It was the custom for the Unions represented on the Council to take in turns to provide the secretary. I did not know of anyone else in the IAU who would take on the job and so I served as secretary from 1975 to 1979. I had been made a Vice-President in 1973 and one of the members of the Council expressed his surprise at my becoming secretary instead of waiting my turn to become President! The meetings of the Council took only half a day and I found that I could get an early plane from Gatwick to Paris and return home the same evening. I resigned the position after I had taken on the much more time-consuming post of chairman of the MERIT working group. (See section 6.3.4.4)

When I succeeded Charlotte Sitterley, who was then about 70, as chairman of the IAU Working Group on Numerical Data I found that it was primarily concerned with physical and chemical data of interest to astronomers, rather than with astronomical data. One of my first tasks was to prepare a survey of astronomical data activities. Over the next 6 years I widened the scope of the activities of the group and I convinced the IAU Executive Committee that it should be replaced by a working group on astronomical data within Commission 5 on Documentation. At that time this commission was primarily concerned with libraries and abstracting services and so it had members who were interested in the problems of computer databases and information retrieval that were of concern to the working group. The President of the Commission asked me to prepare a survey of abstracting and information services in astronomy and so I became more familiar with the scope of these activities. I continued as chairman of the group for another term and then in 1979 I became Vice-President of the Commission, which broadened its name to ‘Documentation and astronomical data’ to emphasise the scope of its interests. (See also section 5.5.7)

During this period the working group organised two international conferences at Strasbourg, where there was a stellar data centre (CDS) within the university. The first, in 1976, was on the ‘compilation, critical evaluation and distribution of stellar data’; I was chairman of the scientific organising committee and Carlos Jaschek (the head of CDS) and I edited the proceedings. One of my papers advocated the use of SI units in astronomy as I felt that astronomers should abandon c.g.s. units, which were no longer used in physics, nor taught in schools and universities. I was a member of the organising committee for the conference in 1981 on ‘automated data retrieval in astronomy’ and I contributed a paper on ‘aids to the retrieval and evaluation of astronomical data’.

I found that CODATA was different in many ways from the astronomical organisations with which I had so far been concerned. It held an annual general assembly that was only for representatives of national committees and interested scientific unions. The former usually came from major organisations such as the National Bureau of Standards in the USA and they tended to dominate the proceedings. Once again, I found that it was primarily concerned with physical and chemical data and so I and other Union representatives agitated for a broadening of its scope to cover the geosciences (including astronomy) and the biosciences. As a result I was made chairman of an advisory panel on the geosciences and I prepared a *Guide for the presentation in the primary literature of numerical data derived from observations in*

the geosciences that was published in 1979 as *CODATA Bulletin 32*. I later prepared a *Guide to the presentation of astronomical data* that was published in 1982 as *CODATA Bulletin 46*.

CODATA held a general conference every two years to which all were invited. The general assembly was held at the same time. These meetings were almost invariably held in interesting locations and so my collection of travel slides increased dramatically! I ceased to be the IAU representative in 1979, but I remained in touch and I attended the CODATA conference in Ottawa in 1986.

During this period the IAU General Assemblies were held in Sydney (1973), Grenoble (1976) and Montreal (1979). I took leave before the assembly in Sydney to go on a coach tour of the observatories in New South Wales. We started from Canberra and so I visited the Mount Stromlo Observatory before the tour started. We first went to the Parkes Radio Observatory and then to see the Anglo-Australian Telescope in the final stages of its construction on Siding Spring Mountain. From there we went to the Culgoora Solar Observatory, which has a large circle of radio dishes as well as some optical telescopes. Finally we saw the stellar interferometer at Narrabri. While in Sydney I renewed my friendship with Peter and Mary Gillingham and with Denis and Elza Winch. Both Peter and Denis had worked at the RGO and, at different times, they had lived in the same house quite close to my home. Denis came to work in the Magnetic Department on sabbatical leave in the spring of 1968 for 4 months. I also saw them, and their families, again when I attended the IUGG General Assembly in Canberra in 1979 in connection with Project MERIT. (See section 6.3.4.4)

5.5.5 Solar Department and meteorology

The work of the Solar Department continued with low priority during the early years of the decade. Phil Laurie, who had been its head since 1957 was transferred to full-time duty as Archivist on 1 October 1974. His place was taken for a short time by Alan Powell and then by David Stickland on a part-time basis. There were two assistants to take the daily photographs of the Sun (in both white light and Hα) and to measure the positions and areas of the sunspots and other features on the surface. There was also continuous monitoring of radio reception to detect sudden atmospherics and ionospheric disturbances. Current information was distributed in *Solar Activity Circulars*, but the measurement and publication of the photoheliographic results was many years in arrears.

I had made enquiries about the value of the RGO data when I was at an Australia solar observatory in 1973 and was told, in effect, that the RGO was far behind the times. Not surprisingly, Graham Smith decided that the service should be closed and he obtained the agreement of IAU Commission 10 (Solar activity) at the IAU General Assembly in Grenoble in 1976. The centenary plate had been taken on 17 April 1974 and the last daily plate was scheduled for14 January 1977. Weekly photographs and monitoring were continued while efforts were made to catch up on the backlog of photoheliographic results. Stickland left in 1978 to serve at the control centre for the International Ultraviolet Explorer satellite in Madrid. Responsibility for the completing the work was then transferred to Yallop in the NAO. The last optical observations were made in March 1979. The service was formally closed on 31 August 1979. The photoheliographic results for 1972-1976 were finally published in 1980. Yallop and Hohenkerk prepared and published in 1980 a ‘butterfly diagram’ showing the variations in the distribution of the sunspots with latitude and time over the period 1874-1976. It had been agreed that the Heliophysical Observatory at Debrecen in Hungary would

continue the series and so some duplicate plates were sent there for use in tests to ensure a homogeneous continuation of the Greenwich series.

The solar plates and prints were transferred to the archive store in the atomic-clock cellar in the West Building. The solar building became available for later use for the SLR project. The 6.25-inch refractor, which had been given by Newbegin, was transferred to the Old Royal Observatory at Greenwich for educational use.

Woolley had stopped the RGO's daily recording of the meteorological conditions at Herstmonceux, but the Meteorological Office decided that the series should be resumed. A site visit was made in January 1976 and the first observer moved into an office in the NAO spur in October. A full series of observations began on 1 November 1976.

5.5.6 Time Department

John Pilkington replaced Humphry Smith as head of the Time Department on 1 October 1976, but Smith stayed on 'special duties' until 3 June 1977. He also continued as chairman of the Directing Board of the Bureau International de l'Heure. Smith had served as Head of the Time Department for 40 years and had held many international offices. He was awarded the O.B.E. in the New Year Honours List in 1973. Unfortunately, the Time Department lost the services of Joy Penny at this time as she took voluntary premature retirement (VPR) in order, I understand, to look after her mother. She had joined the department in Edinburgh in 1944. Her retirement meant that the staff of the Observatory, and of SRC, lost "a formidable fighter for the rights of the staff".

5.5.6.1 Introduction of the new definition of UTC

The beginning of 1972 saw the introduction of the new system of Coordinated Universal Time (UTC) that was derived directly from International Atomic Time (TAI). It differed from it by an exact number of seconds and leap seconds were introduced occasionally so that UTC remained close to Universal Time (UT), which depended on the variable rotation of the Earth. (See section 4.3.3.4)

The change had two additional consequences for the UK. Firstly, the BBC 6-pips time signal was changed in two ways. The addition of a leap second was marked by the emission of a seventh pip and the last pip was always lengthened so that if only 5 pips were heard the listener would know whether it was the first or last pip that been lost. Secondly, the signal continued to be known as the Greenwich time signal and it was normally referred to as GMT. Thus once again, the meaning of GMT was ambiguous, as this abbreviation was used for both Greenwich mean solar time, which closely followed the variations in the rotation of the Earth and was the argument in the tables in the navigational almanacs, and for coordinated universal time, which was based on International Atomic Time (TAI). A change in the meaning of GMT had previously occurred in 1925 when the start of the day in the *Nautical Almanac* was changed from noon to midnight to conform with civil practice and with the recommendations of the prime meridian conference in 1884. The *Nautical Almanac* continued to use GMT with its original meaning, but it eventually changed to the heading "UT (GMT)". Sadler mourned the change in the meaning of GMT and used to wear a black tie to mark the occasions, usually on New Year's Eve, when a leap second was introduced.

I do not know whether Smith proposed the form of the change in the 6-pips signals, but it is possible that he did so. (There ought be correspondence about this in the RGO archives.) The 50th anniversary of the start of the 6-pips time signal was celebrated on 5 February 1974 and Smith was interviewed on both BBC radio ("Today") and TV ("Nationwide"). (See also section 6.3.4)

5.5.6.2 Atomic time and related activities

John Pilkington had been involved in the discovery of pulsars at Cambridge in 1967, but he had to catch up on developments in time-keeping and in the methods of transferring time accurately from one place to another. He and Henry Gill took an atomic clock to the National Physical Laboratory (NPL) and the Post Office Research Centre in November 1976. At the end of the month he and Smith went to Washington to attend the annual meeting on Precise Time and Time Interval (PTTI). Afterwards he visited various establishments in the area that were concerned with time and the related satellite programs.

The Time Department maintained several caesium frequency standards in operation to form the Greenwich atomic timescale, which it compared with the timescales distributed by other countries. The results were then used, in arrears, to form the international atomic timescale, which existed only on paper! The RGO continued to be responsible for sending the UTC signal to the BBC for rebroadcasting in the UK and throughout the world on the BBC World Service programmes. Although the pips gave the time to low precision with an error of about 0.05 seconds, the time delays in passing it around the world were greater than this and so they were not suitable for some applications. The NPL was responsible for providing the signals that were broadcast by the BBC from Rugby for those who required time to a much higher precision. Smith and I visited the NPL in May 1976 (before I knew who would replace Smith) for a discussion on future cooperation in time-service matters and it was agreed the two sets of standards should be used to form a single scale. One of the RGO standards was kept in operation for 10 years, and set a world record for this type of atomic-beam tube.

In 1975 the US Naval Research Laboratory lent the RGO a receiver for time signals from the first Timation satellite (NTS-1) and special aerials were installed on the roof of the West Building. The RGO started tracking NTS-2 in July 1977, shortly after its launch; it carried two caesium clocks. A PET personal computer was used for the automatic control of the tuning of the receiver for the signals from the satellite in the spring of 1979. The programming language used was BASIC. Later in the year the PET was used for the RGO's first computer-controlled altazimuth 'radio telescope' for automatically tracking such satellites. At the beginning of 1980 the department monitored to the time signals from the Meteosat geostationary satellite in order to assess their suitability for providing the time service for the La Palma observatory.

There was conference on intercontinental time comparisons by satellite at the University of Sussex early in September 1977 and the participants visited the RGO. Pilkington went to Paris later in the month for discussions on the program. In March 1980 I attended the first meeting (in Toulouse) of a working group of the European Space Agency (ESA) on the LASSO project to test the feasibility of using lasers to synchronise clocks using a satellite in a geostationary orbit. It was hoped that the RGO's SLR system, then under development, would be used in the experiment. More appropriately, Pilkington attended the second meeting that was held in Paris later in the

year, but in the end the RGO did not participate. He also attended the meeting of the Consultative Committee for the Definition of the Second (CCDS).

5.5.6.3 Earth rotation and geodesy

The Time Department continued to use the PZT to monitor the variations in UT compared with the Greenwich atomic timescale and the apparent variations in the latitude of the telescope that were due to 'polar motion' (PM), that is the motion of the axis of rotation of the Earth within the Earth. In 1978 Pilkington and I attended an IAU symposium on 'Time and the Earth's rotation' that was held at San Fernando in Spain, where the Spanish nautical almanac was produced. It was clear that the astrometric methods for determining UT, PM and accurate geodetic coordinates on the Earth's surface would be superseded by new methods using the techniques for navigation by satellites, for laser ranging and for radio interferometry. At the end of the symposium I was appointed the chairman of an IAU working group on the determination of the rotation of the Earth that would study the relative advantages of the available techniques and make proposals for future international services. This activity led to Project MERIT, and eventually to the new International Earth Rotation Service (IERS). The discussion of this project is deferred until section 6.3.4.4.

In 1979 the department participated in a campaign of observation of signals from the Transit navigational satellites to determine precise geodetic coordinates of the observing stations. The following year it participated in a similar campaign that was aimed at linking the geodetic networks in eastern and western Europe. A receiver was borrowed from Oxford University. Such Doppler measurements were not made during the MERIT Short Campaign in August to October 1980, although PZT observations were scheduled on every day. Just before this there was a thunderstorm on the night of 14/15 July 1980 and some electronic components were damaged in the PZT and RTC buildings.

5.5.6.4 Satellite laser ranging

The Time Department was given the responsibility within the RGO for the installation of the satellite laser ranging system, which had been approved in the autumn of 1978. (See section 5.5.4.6) Pilkington, Sinclair and I immediately visited the Institute for Satellite Geodesy at Kootwijk in Holland to gain a better appreciation of what was involved. We were accompanied by John Pope, who had been temporarily seconded to the SLR project while also working on the NHO project, and by Phil Cottrell, who was in charge of the Engineering Workshop. Sinclair and I went in November to a meeting in Bavaria of the European SLR group, which had adopted the acronym EROS, to discuss the distribution of predictions and observations. We took the opportunity to visit the nearby SLR station at Wettzell. Pope and Cottrell went there the following week and then went on to the French station at Grasse, near Nice, to study the requirements for the telescope. Later there were discussions with the Technical University of Graz in Austria and, early in 1980, the same telescope was ordered by both of us from Contraves Goerz in Pittsburgh.

At first, Appleby, who became available when the occultation programme was closed, and Harvey, who was transferred from the Astrometry Department, worked on the software for the PDP 11/34 computer while in the NAO, but they were transferred to the Time Department at the beginning of 1981. Although Sinclair remained in the NAO he was regarded as a full member of the SLR team and he played a major role in the

development of the computer software. Dr Paul Sharman was recruited in February 1981 to strengthen the effort available for work on the hardware, which was done in close collaboration with staff at the University of Hull, especially with Dennis Hall and Bob Hyde, who became our main contact and made frequent visits to Herstmonceux. The university group was responsible for the laser, the detector package and the timing system.

The building that had been used for solar observations was available, but modifications were required. A new 'eyelid' dome was installed in February 1981 so that the telescope would be able to follow the satellites across the sky without any need for a rotation of the dome. The room beneath the dome was converted for use for the laser, timing and computer systems, while the adjacent office on the north side was used for the control desk. Our use of the system was conditional on the approval of the Civil Aviation Authority, which required that we shut down the laser if any aircraft were to approach the beam The concern was that the beam would blind any pilot or passenger who looked directly into it. Consequently, we had to have a radar system for distant aircraft and we had to have an observer in the dome to look for low-flying aircraft or gliders. We were able to obtain a surplus military radar and it was mounted in a small radome on the roof of the control room. It too had to be under computer control so that it would automatically follow the movements of the telescope.

The telescope was installed on its pier on 3 July 1981. It is illustrated and described as follows in the Information Bulletin for 1 October 1981. "The 'dustbin' shaped tube housed the 50 cm Cassegrain receiving telescope, the secondary mounting of which can be seen through the end of the window. The smaller tube on the right houses the 10 cm refractor transmitting telescope, which is fed by the Coude optical path, part of which can be seen on the extreme right. The large square balance weight at the Cassegrain focus will be replaced by the detector package at present being manufactured at the University of Hull. The SLR telescope can now be driven under computer control."

The subsequent stages of the installation and the use of the system are described in section 6.3.4.2

5.5.7 Libraries and archives

During the first few years of this period the RGO library, the NAO library and the RGO archives were run largely independently, although an Information Services Committee, chaired by Hunter, was set up January 1973 to coordinate the work on them, on publications and the supply of information to the public. This became known as the Advisory Panel on Information Activities in December 1974. Joan Perry was the RGO librarian, while Audrey Turner and later Valerie Bacon (from January 1974) looked after the NAO library as part of their clerical duties. Phil Laurie was formally given full-time responsibility for the archives on 1 October 1974 until his retirement in March 1977. He was awarded an M.B.E. in 1975.

In May 1977 the Library and Archives Department was formed within the A&T Division so that I had overall charge of these activities. It was agreed that the department should be headed by a professionally-qualified librarian/archivist and Janet Dudley took up her appointment on 1 February 1978. She had previously been an assistant librarian at the Royal Aircraft Establishment at Farnborough. Valerie resigned in December 1978. Joan Perry remained in post until her retirement in February 1979, and was replaced by David Clarke. Janet was extremely keen and very competent so

that major changes were made. The NAO library was integrated with the main library and became, in effect, the West Building library. Some books and journals were interchanged between the two buildings so as to reduce the need for the scientific staff to go to the Castle. She also introduced a loan-slip system to replace the use of a book in which borrowings were recorded.

While reorganising the bookstock Janet made full use of UDC (see section 2.2.7.6), which she had used at RAE. She also paid greater attention to the rare books and in July 1980 she arranged an exhibition of them at the time of a visit by a group of Government librarians (who were probably members of the 'Circle of State Librarians'). At the beginning of 1981 the name 'Airy Collection' was introduced as Airy had collected many of them during his period as Astronomer Royal. Janet also arranged the sale of some duplicates on the understanding that the receipts would be used for the rebinding of other books in the Collection.

The Information Bulletins show that Janet was an active traveller and made visits to the USA, as well as to many meetings and organisations in the UK. She and I attended a meeting of astronomy librarians that was held at the Institute of Astronomy at Cambridge in March 1978. This may have been when Kemp, the ROE librarian, was preparing a union catalogue of the holdings of astronomy serials by the UK libraries.

5.5.7.1 Archives

In July 1978 Graham Smith wrote to the Keeper of Public Records and others drawing attention to need to provide extra facilities and staff for the processing and conservation of the RGO archives at Herstmonceux or to transfer them to the Public Record Office. Janet argued strongly for the former and her arguments convinced me, Graham Smith and the SRC that they should be retained by the RGO.

The archives and the remaining surplus publications had been dumped in the atomic-clock cellar when the basement of the Chronometer Wing was converted to offices for the NHO team. (See section 5.4) The first step was to provide proper arrangements for the use of the cellar as a permanent store for them. Consequently, they had to be moved yet again early in 1979 from the cellar to off-site storage while an extra floor and shelving were installed. Temporary storage space had also to be found for NAO files and publications that had been kept in room 90 on the top floor of the NAO spur that was taken over by staff dealing with public information. The NAO archives were added to the main collection; most of them dated from Sadler's appointment as Superintendent in 1936 as almost all of the earlier material had been scrapped when Comrie needed the room for other purposes. The solar records and photographic plates were also transferred to the atomic-clock cellar.

Work started at the end of 1978 on the long-term task of microfilming the early archives to reduce the amount of handling by researchers and for extra security. The work was done by the Public Record Office at Kew. The archives were supplemented by the acquisition of the papers of the late Professor R. O. Redman that related to the AAT and the NHO. Janet also obtained from the Meteorological Office some early material from the Kew Observatory. Historical items were loaned to other organisations, such as the Hastings Museum, for use in their exhibitions. Astronomy books and other items were also loaned to a local girls' school, Ancaster House, as part of an exhibition to celebrate the 75th anniversary of the school. Portraits and other historical pictures

and artefacts, some of which were quite valuable, also received her attention, as did the slide collection, which was of both current and historical interest.

Janet also obtained approval for the recruitment of a conservation officer and the setting up of a conservation laboratory for the care of the valuable documents in the collection. Tony Bish was recruited from the conservation department of the East Sussex County Council in January 1981 and the laboratory was set up in the east wing of the Castle.

The use of the archives increased during this decade and visitors to the RGO to use them included Professor A J Meadows (3 months in 1973), Derek Howse (National Maritime Museum), Eric G Forbes and Professor W H McCrea, all of whom wrote books on the history of the RGO. There were also visitors from overseas, including Professor J Ed. Kennedy from Canada.

5.5.7.2 Information retrieval

During the years 1970 to 1976 I was a member of an international working group that was concerned with the revision of the Universal Decimal Classification for astronomy (UDC 52). This was used for both the shelving books in libraries and the retrieval of information from abstracting journals and various indexing systems. (Public libraries in the UK tended to use the similar Dewey decimal classification, while most libraries in the USA, and the Royal Astronomical Society, used the Library of Congress classification, which was much less appropriate for scientific and technical applications.) The chairman of the working group was Alasdair Kemp, the librarian at the Royal Observatory Edinburgh. Valerie Bacon helped me in the work of preparing the revised schedule for publication and in producing a guide for users. Unfortunately, the guide was never published as other jobs had to be given higher priority.

My interest in books and ‘library affairs’ had led to becoming a member of IAU Commission 5 on Documentation, although I do not recall when I first attended a meeting of the Commission. My involvement became much stronger when ‘astronomical data’ was added to its title (see 5.5.4.7) and this was recognised when I was appointed Vice-President in 1979. Commission 5 has an unusual status as it is regarded as a sub-committee of the Executive Committee and membership does not count against the normal maximum of membership of 3 commissions by any member of the IAU. Moreover the President (and Vice-President) serve for two terms and so I was committed to serve for 12 years, so taking me beyond my retiring age. My duties as Vice-President were, however, negligible.

My involvement in library activities also led to my being appointed in 1979 as the chairman of a working party on the groups for librarians and information officers within the SRC Central Review Board for Group C.

5.5.8 General matters

5.5.8.1 Administration Division

At the beginning of this period the head of the General Office, John Whale, carried the title of Secretary and Cashier and the grade of Senior Executive Officer. Bob Gordon was appointed at the higher grade of Principal in February 1974 to head the Administration Section, which became the Administration Division later in the year. At first there was a rather unusual arrangement in that he acted as understudy to “Mr.

Whale in preparation for his assuming the duties of Secretary and Cashier when Mr Whale retires in the Spring of 1975".

Throughout the period there were changes of structure as well as a high turn-over in the staff. For example, in 1974 there were 8 Clerical Officers, but only one of them was still in post in 1980 when there were 9 COs. A comparison of the reports for 1974 and for 1980 also shows that the contributions of the industrial staff became more clearly recognised. In 1974, they are given in a single list without any indication of their jobs, but in 1980 they are shown with their grades in the appropriate department.

Canteen. Following the retirement of Mrs Marples in 1975, a new manageress was appointed from outside, but she left in 1978. Then Margaret Brett, who had been a young assistant when I joined the RGO in 1951, was promoted to Head Cook/Supervisor at a time when the canteen was to be run with a reduced staff level. Staff were asked to reduce their "demands for waitress service to the minimum". In earlier years the canteen staff frequently served the 'top table' that was used by senior staff, especially when visitors were present.

Mrs Marples was awarded a BEM in 1979. This was several years after her retirement, but only a few months before her marriage to Sir Richard Woolley.

5.5.8.2 Conferences and education

Throughout this period the annual Herstmonceux conferences were continued. In 1975 there was also a special international symposium to mark the Tercentenary of the Observatory. In 1976 the second AAT Symposium was held in Herstmonceux. The first had been held during the previous year in Sydney.

The summer vacation courses for students also continued. The 1979 course left without any prank, but IB 240 records that the following poem was left in an astronomical book.

We three observers from Herstmonceux are
Bearing plates we travel afar
Telescope mounting
Timing, counting
Guiding on a yonder star

Star of wonder, star prolate
Shine at all those working late
Westward driving
Still surviving
Guide until the perfect plate.

Sandwich students were taken on and pre-university students were employed as temporary ASOs. My own son, David, worked with Pagel from January to July 1978 before going to Trinity College to read mathematics, and he was taken on again in 1979 and 1980 so, presumably, Pagel must have found him to be a useful assistant.

A new series of lunch-time talks for staff about the work of the RGO was given in November 1979. This proved to be popular and so another series was started in April 1980. The talks were not restricted to astronomy and engineering. Janet Dudley spoke twice about the library and archives and Derek Ellwood, the head gardener, gave a slide show on ‘a year in the Castle grounds. He gave the show again during the evening of Friday, 16 December 1980, so that family members and friends could enjoy it. Another innovation was a hobbies and handicrafts exhibition, without fees or prizes, that was held in the Drawing Room of the Castle at the end of January 1980.

A special conference for about 100 teachers from East Sussex schools was held in the Castle in July 1981. The theme was the importance of the RGO as a resource in environmental and heritage education. Half a dozen members of the staff gave talks and there was an exhibition of books and periodicals. Nathy O’Hora, an RGO Information Officer, organised the RGO side of the arrangements.

IB 254 (1 Nov. 1980) refers to the start of the work on the ‘RGO Lecture Theatre’. IB 259 (1 April 1981) refers to the completion of the ‘Conference Room in the Castle’ and lists the various items of projection and recording equipment that were available. I assume both of these items refer to the Lady’s Bower room (in the south of the east wing) that was used first of all by the Solar and the M&M Departments and then by the General Office. The Office staff must have moved to the ground floor rooms after the astronomers had moved to the West Building. See section 6.4.1.1 for the later use of this conference room.

An almost complete list of the conferences and workshops held in the Castle is given in final issue (no.16) of the RGO house journal *spectrum* that was issued in October 1998 just before the final closure of the RGO.

5.5.8.3 Training

Training courses on topics of interest to many staff were held in-house, but otherwise, members of the staff attended specialist training courses elsewhere. [The IBs contain many examples; 246] Attendance at MSc and PhD courses at the University of Sussex was encouraged and many staff gained additional qualifications and promotion as a result. Various members of the staff acted as Training Officer in turn. Humphry Smith is listed in 1976 and was succeeded by Yallop in 1977. Geitzen was an additional Technical Training Officer from 1978 to 1980, when Alfred Heath was appointed.

5.5.8.4 Public exhibition

Graham Smith had hoped to open the public exhibition in the Castle for the summer season in 1976, but it was not ready and so another period of open days was organised during August. The exhibition was, however, opened on Monday, 4 April 1977, by Patrick Moore prior to its opening to the general public on Good Friday. 8 April. The opening ceremony in the Long Gallery was attended by 45 representatives of the press and about 85 guests from local and national organisations. The resulting publicity boosted the number of visitors over the Easter weekend from 1610 in 1976 to 4188. The RGO Club arranged a “very successful social” during the evening after the opening ceremony.

The exhibition occupied the two room on the ground floor of the north wing that had previously been occupied by the Meridian Department. There was a management committee chaired by Graham Smith, while Paxton and Thomas were responsible for the procurement and arrangement of the exhibition. Other members of the staff prepared

particular areas; for example, Humphry Smith supervised the Time and Navigation area. There was also a shop.

A series of free leaflets about different aspects of the work of the Observatory were produced for visitors at about this time. (I have 14.) A glossy booklet with colour photographs and an orange cover was produced for the Tercentenary and it served for the rest of the decade. It was priced at 30 p. the inside front cover shows Graham Smith and Hunter on the south bridge of the Castle. David Calvert, a Senior Photographer, who had developed an amateur interest in local history, wrote a booklet on *The History of Herstmonceux Castle* a few years later. It is undated, but it went on sale for the first time in 1982. It acknowledges the help of Hunter, Laurie and O'Hora and it was printed by SERC.

Graham Smith also encouraged the use of the Castle and grounds for other events, such as the fete that was held in June 1981. Further publicity was gained from tree-planting ceremonies by the Men of the Trees in November 1979 and 1980.

5.5.8.5 Public Information

The post of Public Information Officer was part-time and was allocated to members of the staff in turn. Roger Wood held the post in 1977 and he was succeeded by O'Hora in 1979, by which time 3 part-time post were assigned to the Public Information Unit. The NAO supplied much of the basic information in its *Astronomical Information Sheets*, but its staff did not have to deal with all the telephone calls and correspondence that was involved.

The Unit also dealt with the 'media' as the Castle and astronomy continued to interest the general public. An example was the 'Horizon' programme on Gravitation in 1973; some members of the RGO staff took part.

5.5.8.6 Miscellany

The published annual reports that cover the years 1974 to 1980 give details of the official activities. The internal Official Circulars announced major changes and events, but the Information Bulletins record a variety of other activities and events. The IBs were compiled at irregular intervals by Anita Hewerdine and Pat Hanning, and then more regularly and frequently by Sylvia and Sarah Smith. They were circulated to the staff and mainly contain information about staff changes and about visits and visitors. They contain occasional references to the activities of the RGO Club, about which further information is given in appendix D. There are also occasional paragraphs about new developments and events, such as the following items.

The moat provided a temporary nursery for cygnet named Copper which had been taken as a young chick to a local RSPCA nature reserve.

Sodium street lights were installed in the grounds in 1979.

The Staff Suggestions Scheme generated several useful ideas for safety and savings.

A course of 12 lectures on First Aid was given by a member of the St. John's Ambulance Association.

5.5.8.7 Scientific societies

Hunter continued to serve as the Treasurer of the Royal Astronomical Society while he was Director of the RGO. Graham Smith served as President for the period 1975-1977. Pagel (1973-1975) and Murray (1975-1977) served as Foreign Correspondents. Members of the RGO spoke about their work at the meetings of the Society

Sadler continued to play an active role in the Institute of Navigation and was almost certainly responsible for my election as a Fellow in 1979.

5.6 Overview

The period 1972 to 1981 was a period of great change for the RGO. It seemed, however, that its future was assured as it had three clear purposes:

> to build and then operate the new UK components of the new observatory on the island of La Palma and to participate in the development of new instrumentation;
>
> to carry out astronomical research and related programmes of observation and measurement; and
>
> to provide national and international services in astronomy.

During his last few months in office Graham Smith had even been seeking an increase in the complement so that the RGO would be able to carry out this large range of activities.

This period also involved major changes in the character of the work as electronic computers and microprocessors began to play a dominant role in almost all fields. Moreover, film was being replaced for the recording of images by new charge-coupled devices (CCDs) that gave images as digital arrays. The CCDs were more sensitive than film and, although they were then of lower resolution, the digital arrays could be processed by powerful minicomputers to remove blemishes and to give striking images in false colour.

The role of the astronomers had also changed dramatically as they were no longer needed to use their eyes to guide the telescopes or to measure the images on photographic plates. The RGO remained a predominantly optical observatory, but the research astronomers had to take into account the data from other wavelength ranges.

New techniques were also about to supersede the traditional use of observations of stars for the measurement of sidereal time and for the monitoring of the variations in the rotation of the Earth.

6 END OF AN ERA – ALEC BOKSENBERG – 1981 TO 1990

6.1 A change in administrative style and policy

6.1.1 Changes in the senior administrative staff

Alexander Boksenberg formally became Director of the Observatory on Thursday, 1 October 1981, but his first day of duty at Herstmonceux was on Monday, 5 October. As a consequence my last act as Deputy Director was to welcome the Federation of Astronomical Societies on the Saturday morning at the start of its annual meeting over the weekend at the Castle. Boksenberg did come later that day, as did Patrick Moore. My recollection is that he told me on the Monday that he would not wish me (or anyone else) to hold the title of Deputy Director as he wished to appoint members of the senior staff to this position on an ad hoc basis whenever he expected to be away. I soon became glad that I no longer had this extra responsibility as I found myself in disagreement with the policies that he pursued. I continued, however, to make presentations to retiring staff from time to time!

Boksenberg, who was always referred to as Alec, rather than Alexander, was 44 years of age and had been Professor of Physics at University College London since 1978, the year in which he was elected a Fellow of the Royal Society. I knew little about him, except that he had developed a new instrument that was called an ‘image photon-counting system’ and known as an IPCS. He did not move to Herstmonceux with his family, but relied on the use of a small flat in the Castle when he was at the Observatory. He was, however, frequently abroad for observing and conferences and I understand that he returned home, rather than to the Castle, after meetings in the UK. (I understood that one of the reasons that he gave for not moving his family was that he considered that the rent for the apartment in the Castle was too high. He did, however, have teenage children and his wife may have been involved in many activities in London.) His wife attended the occasional function at the Castle, but I do not recall seeing his two children.

In 1984 Boksenberg obtained approval for the appointment of Dr Peter Davies as Secretary of the Observatory and Head of the Administration Division on transfer from the Swindon Office of SERC. He was an SPSO and so was senior to Bob Gordon who had previously held that title. Peter Davies resigned from SERC and left the RGO in January 1986. He was replaced by W E A (Tony) Davies from the Daresbury Laboratory, to which he returned after less than 2 years. In turn, he was replaced on 1 October 1987 by Bennet McInnes from the Royal Observatory Edinburgh.

Peter Davies wrote to Boksenberg on 28 June 1985 to explain his resignation and he sent copies of this letter to the Staff Side as well to Division Heads. In it he wrote:

“Over the last eighteen months I have become convinced that I no longer wish to have a career in SERC. I disagree with many attitudes and motivations that I meet. I feel strongly that the way SERC is organised, to be both a proxy customer for research and a major contractor to itself (in the Establishments), has lead [sic] to muddled thinking, unproductive conflicts and unwarranted interference.”

His criticisms of SERC appear to have been borne out by the way that it subsequently treated the RGO!

6.1.2 Other senior staff and the divisional structure

The divisional structure that had been introduced by Hunter was continued but with changes of title and constituent departments during the decade. I am not able to describe these changes as, unfortunately, there is a dearth of published reports during this decade. The Senior Staff Meeting became known as the Division Heads Committee and my recollection is that it met less frequently and that more decisions were taken without prior discussion by the Committee.

At the beginning of the decade Bill Goodsell was head of the La Palma Division and was in a higher grade than the other senior staff. Joe Paxton was head of Engineering, Richard Bingham was the acting head of Instrument Science, Jasper Wall was head of Astrophysics and Astrometry, I was head of Almanacs and Time, which then included the Computer Department, while Bob Gordon was the head of Administration. Other senior staff included John Pope, who was head of the Telescopes Department, and R P Milner, who was head of Civil Engineering . Bernard Pagel, Andrew Murray and Bob Dickens held Individual Merit grades. They did not, however, usually attend senior staff meetings. By this time the grade titles for scientific staff had been changed from SPSO and DCSO to grades 6 and 5, but the former are usually used here.

The 1985 report shows many changes in structure and in personnel. The Divisions were listed as follows.

Astronomy Support and Research, headed by Jasper Wall; this included the Computer Department as well as departments for various aspects of astronomy.

Facilities, headed by Mike Morris; this included instrument science, electronics and computing as well as La Palma Construction and Mechanical Engineering.

La Palma Operations, headed by Paul Murdin; this included a small Herstmonceux support team as well as about 40 staff members on the island. Murdin and Wall interchanged roles in April 1987.

Dynamical Astronomy and Space Geodesy, which was still usually known as Almanacs and Time (A&T) and of which I was the head. The Time Department, which was responsible for the satellite laser ranging system, is shown with only four members! This was smaller than the number of staff in Library and Archives. In the 1987 report the name has been changed to Almanacs, Space and Documentation (ASD).

Administration, headed by Peter Davies; this included 6 scientific staff in Scientific Administration.

6.1.3 Publicity and reports

Boksenberg placed a great deal of emphasis on publicity and what might now be called ‘spin’. One of his early actions was to stop the production and publication of the annual report for 1980/1981. The style that Hunter had introduced in 1974, and which Bernard Yallop and I had followed in editing the report for 1979/1980, was not considered to be ‘sexy’ enough! (This was the first time that I had heard the word used

with such a connection.) Unfortunately, the next published report was not produced until the end of 1985 and was for the 5-year period 1980/1985. It is a high-quality production with a glossy illustrated cover; the editors were Paul Murdin and Jasper Wall. It contains interesting articles about selected aspects of the activities of the Observatory, but it ignores others. About one-third is devoted to the research in astrophysics and astrometry, rather more to telescopes and instrumentation, and the rest to the other activities and aspects of the RGO. It starts with a one-page diary of a representative selection of events at the RGO and on La Palma. It makes no attempt, however, to trace the overall development of the activities during the period; nor does it show the changes in the staff and structure. Unfortunately, the Royal Astronomical Society ceased to publish reports on the work of observatories in 1982.

The 1980/1985 report was preceded in 1983 by a 32-page 'publicity brochure' with the title *The Royal Greenwich Observatory to 1990.* This was primarily concerned with the RGO's activities in providing telescope facilities for the new observatory on La Palma. The final short section on other programmes started with the statement that "The RGO will continue to devote a small fraction of its resources to the study of the dynamics of the solar system and to the application of astronomy to geodesy, navigation and civil life". My copy indicates that my drafts for this section were drastically cut and changed. It was made clear that the costs of providing services to other Government departments and to the public would be recovered from charges.

Boksenberg attempted to replace the RGO Information Bulletin (which was circulated only within the RGO) after April 1982 by a magazine-style publication with a wider circulation. It was called *Gemini* in order to reflect its purpose of covering the activities at Herstmonceux and La Palma. Fortunately, it was soon realized that *Gemini* could not both meet the needs of the RGO staff and be of interest to astronomers and others outside the RGO and so a new un-numbered series of RGO Information Circulars was started immediately in May 1982.

Gemini was aimed at a wider readership and so gave greater detail about some of the activities and contained more and better illustrations than the bulletins. The first issue was for May 1982 and was edited by Margaret Penston. It contained articles on a wide variety of topics. One of them announced an "initiative, inspired by RGO's new Director, Alec Boksenberg," to start of a series of astronomical workshops as "part of a plan to exploit the potential offered by Herstmonceux Castle as a Visitor and Conference Centre for astronomy". (See section 6.4.1.1) There was a special (un-numbered) issue of *Gemini* to record the Royal Inauguration of the international observatory on the Roque de los Muchachos on La Palma in June 1985.

The last issue of *Gemini* that I received before my retirement was issue no. 24 for June 1989. The last full opening includes photographs of some of the staff who had retired or resigned over the previous year. The last page illustrates the 'farewell party' that was held in the Castle in April, just before the hand-over to the developer who had bought the Castle and grounds. (See section 6.5.2)

There was also a series of *Not! Gemini* that contained humorous articles and drawings that often mocked the policies of the Director and SERC. There were 6 issues and the flavour can be judged from the articles on the first pages.

1. 1 April 1983. "Easter message from the Director", Bosen G. Laceberk.

2. Christmas 1983. "A Christmas message from your very own Director", now Bob Greenslack.

3. Christmas 1984. “INT to return to Herstmonceux”. (After which the telescope’s building on La Palma was to be turned into a Conference Centre.)

4. January 1986. “Roque and Roll Extravaganza”. (A take-off of the opening ceremony on La Palma with an appeal for “Looker’s Aid” by Bob Gendenberg, astronomical impresario of the RGO.)

5. Summer ’86 (12 pages). “Relocation of the RGO: Chairman’s Statement”, by the man who put the “er” in SERC.

6. 6 January 1989 (1 sheet only). “Secrets Case Continues”. The back page announced “The RGO Share Offer” for selling off the RGO and the departure of the editor, Sue Dennim, who was generally assumed to be Chas Parker.

The RGO Information Circulars were replaced in November 1985 by a new series of RGO Information Bulletins that were in the same style apart from the use of large type for the section headings and the inclusion of more illustrations. Unfortunately, in an endeavour to make it more interesting, the new series no longer included the detailed lists of factual information, such as staff changes, visits and visitors, etc., although these were given (presumably) in the RGO Official Circulars. Bennet McInnes changed the policy in March 1988 when he introduced a new series known simply as *Reporter* to replace both the Circulars and the Bulletins. The Reporter was issued as single sheets, each containing a few numbered items about administrative matters only.

The next ‘annual’ report was for the 2-year period 1985 to 1987 and was similar in style to the previous 5-year report, but was much slimmer and contained reports on only a small selection of the activities. It made no attempt to give a general overview of the work, although it did give a list of the staff and lists of the departmental publications and of the scientific papers by individuals. Otherwise the only reference to the work of my division was a article about the ‘satellite laser ranger’. My division was initially known as the ‘Almanacs and Time Division’, but Boksenberg did not consider that this was ‘sexy’ enough and so it became the ‘Dynamical Astronomy and Space Geodesy Division’ in the 1985 report and the more appropriate ‘Almanacs, Space and Documentation Division’ in the 1987 report. The name Astrodynamics Division and the abbreviation ASD Division were sometimes used. As far as I am aware no further reports of this type were published for the subsequent activities at Herstmonceux and Cambridge, but much information about the RGO’s activities after 1987 is given in the house journal *Gemini* and its replacement in 1994 by *Spectrum*.

In the following sections of this chapter, I have frequently given references to articles in these two reports as it would inappropriate for me to attempt to include more than a brief indication of the activities in which I had no direct involvement.

Boksenberg continued Graham Smith’s policy of encouraging greater public access to the Castle, the grounds and the Equatorial Group. A revised edition of the illustrated booklet about the RGO was issued in 1982. In addition, he improved the facilities in the Castle for conferences and, especially, for smaller workshops so that, apart from the intrinsic value of these meetings, astronomers generally would become more aware of the RGO and of its wide range of activities. (See section 6.4.1.1)

6.1.4 The ‘brown-envelope exercise’

My recollection is that fairly soon after he arrived Boksenberg told the SSM that he had said at his interview board that he considered that the staff of the RGO could be cut by about 25%. If this was the case it was not surprising that SERC decided in 1983/1984 to use the “voluntary premature retirement” (VPR) scheme in order to achieve such a reduction in staff numbers without formally declaring staff to be redundant. Some staff were, however, transferred compulsorily to other SERC establishments. There was a similar (but probably less favourable) “job release scheme” for the industrial staff. The letters inviting the staff to take VPR were distributed in ordinary government brown envelopes and this gave rise to the name of the ‘brown-envelope exercise’.

I forget the details, but I believe that it allowed staff over 50 to retire early and draw a pension based on an age of 60 right away. The terms certainly proved attractive to many staff.

The Division Heads were given the task of selecting those persons who should be offered VPR and we were told to choose more than the number by which the department or activity was to be cut. We were also told that if more than this number offered to take VPR we would be able to choose those who should stay and who should go. In practice this did not happen and I believe that everyone who volunteered was allowed to go. The NAO suffered badly since, for example, Brian Emerson unfortunately treated the receipt of a “brown envelope” as a sign that I did not appreciate his talents and the quality of his work and so he took VPR even though I had explained the circumstances and had told him that I did not wish him to leave.

The 1985 report shows that the total complement fell from 237 in 1981 to about 195 in 1985 and was predicted to fall to 128 in 1990, a fall of 46 %. In general, those who retired were not replaced by new staff. This led to a major change in the age profile for the staff, with the majority between 30 and 50, while there were very few young staff under 25.

6.2 A second round of reviews

During the 1970s the Observatory had been subjected to reviews that led eventually to the agreement that its main task should be the provision of technical support for UK astronomers, especially through the construction of the new northern-hemisphere observatory (NHO). It was also recognised that it needed to have staff who were engaged on astronomical research and that it should continue to provide services for both the government and the general public. The future of the Observatory seemed to be assured and Graham Smith was bidding for additional staff when he left to return to Jodrell Bank. We were therefore surprised and dismayed when Boksenberg took the opposite stance and SERC reduced the staff through the brown-envelope exercise. Unfortunately, this was not the end of the attacks on the RGO as the cost-cutting policies of the Conservative Government led to a series of reviews during the 1980s and eventually to the move to Cambridge in 1990 and closure in 1998.

So far I have found hardly any mention of these reviews in the documents that I have at home as I try to complete this section, but I hope that there are no major errors or omissions in it.

6.2.1 The Rayner Review 1983

The first of these reviews was that by the Rayner Committee on Stores and Estate Management in the SERC. It recommended in April 1983 that the SERC should make major changes in the infrastructure for astronomy. For example, it recommended that savings should be made by concentrating the activities on two sites instead of three — the Royal Observatories (RGO and ROE) and the Rutherford Appleton Laboratory (RAL). It recommended disposing of the Castle and surrounding land. Incredibly, it also recommended the sale of the Equatorial and Spencer Jones Groups of telescopes1 It also recommended that the RGO archives and the rare books should be transferred to the Public Record Office even though the PRO does not accept books. Boksenberg argued against most of the recommendations, which were referred to an SERC panel.

6.2.2 The Willmore Panel 1983/4

Peter Willmore, a bearded space-research scientist at the University of Birmingham, was the chairman of the 'Manpower and Site Review Panel' appointed by the Astronomy and Space Research Board (ASRB) in September 1983. Apart from manpower requirements for the forward-look period it was asked to consider the implications of the recommendations of the Rayner Review. I was one of the persons interviewed by the panel when it visited RGO. The Panel gave as its 'marginal preference' that the RGO should stay at Herstmonceux, rather than be merged with the ROE in Edinburgh. This was accepted by the ASRB.

6.2.3 The SERC Secretary's Panel 1985

It is clear that some members of the Council of SERC, who were from universities or industry, and possibly some of the administrative staff, were determined that the RGO should be split up or moved and cut still further. Consequently, the advice of ASRB was rejected and another panel was set up under the chairmanship of the Chairman of the Council (then Professor John Kingman) to "consider future arrangements for the Council's support in the UK of the overseas facilities for ground-based astronomy, both regarding management and location". This confirmed the statement by Kingman to RGO staff on 23 April 1985 that the panel would not take into account the other aspects of the work of the RGO. Kingman invited comments from astronomers and so I (and 20 others) wrote to him on 22 May pointing out my concerns for the NAO, SLR, Library and Archives, but I did not receive even an acknowledgment of my letter. Patrick Wayman, the Director of the Dunsink Observatory near Dublin, also drew attention to the other activities of the RGO when he wrote on 3 June. He commented that "it seems that influential scientists and administrators are dedicated to the task of removing the RGO from Herstmonceux Castle" and that "committees will go on being formed until the 'right' recommendations are made". He ended by suggesting that other related services should be based at Herstmonceux.

The Panel reported in December 1985; it did not come to any firm conclusion but merely left as one of the options "a move of the RGO to a university site". It stated that "when considering the options, the non-La Palma activities of the RGO have not been included" and that "financial projections for the various options have not been considered". The links with the University of Sussex were discounted as "the two are not well matched". In a statement attached to the report, Professor W.H. McCrea, who

was a member of the panel, states his view that the Council should decide "against any fundamental change in the status quo of RGO and ROE".

Kingman was succeeded by Professor E. W. J. Mitchell, who made it clear to the Staff Side, which met him on 13 February 1986, that he was determined to move the RGO. The Universities of Cambridge, Edinburgh and Manchester, were invited to 'tender' for the 'privilege' of hosting the RGO. The former director, Graham Smith, persuaded the University of Manchester to put in a bid, which was based on the RGO using the unwanted Victorian Christie Building of the John Rylands Library for its offices. (It even produced an illustrated brochure.) Desmond King-Hele wrote on 6 March to Mitchell expressing the dismay of the Optical Tracking Subcommittee at the threatened closure and I wrote a long letter on 7 March to Dr. J. A. Catterall, the Secretary of SERC, giving arguments against a move. I am sure that others also wrote. The journal *Nature* took the view that "the real reasons for the change appear to be political" and considered that the net cost of the move would be £5 million and would be better spent on research. Nevertheless the Council decided that the RGO should move, but the press release of 20 March still left three options: a merger with ROE on Blackford Hill, to Cambridge or to Manchester.

My personal file for the period before the next press release on the 19 June shows an enormous volume of interest in the proposal, but little support for it. Patrick Moore arranged a special meeting of the Royal Astronomical Society on 6 June and there were only two dissenters to the motion that the SERC should reconsider its decision to move the RGO. Nevertheless, the Council decided on 18 June 1986 that the RGO should be moved to Cambridge. Four members of the RGO staff side had visited the three proposed sites and considered Cambridge to be the best of them, but I doubt whether this was taken into account by Council. The decision required ratification by the Department of Education and Science but, even before this, SERC set up a Relocation Steering Committee and a Relocation Project Group to oversee the projected move, which was then scheduled to start at the end of 1989. A new series of Relocation Bulletins, which were separate from the ordinary Information Circulars, was started to keep staff informed about the subsequent plans and changes.

6.2.4 The "Hands-off" and "Save RGO" Campaigns

The RGO Staff Side continued its campaign to stop the move in the hope that the minister would intervene. A petition with 17000 signatures was presented to the House of Commons and the campaign received the support of Patrick Moore and many astronomers.

Some members of the staff (Janet Dudley and Margaret Penston) were disciplined for their participation in this campaign. I was admonished for writing to our local Member of Parliament, Charles Wardle, who had passed on my letter to SERC.

The consequences of the decision to move the RGO to Cambridge are discussed in section 6.5.

6.3 Departmental activities 1981 to 1990

This section gives only brief details of the main activity of the Observatory — the construction, development and use of the observing facilities on La Palma and elsewhere — since I am not able to add to the detailed accounts in the RGO reports and other publications. The main emphasis is in sections 6.3.3 to 6.3.6 on those activities for

which I had administrative responsibility as Head of the Almanacs and Time Division or in which I had a special interest. I have included a variety of other topics in sections 6.3.7 and 6.4, while activities that were directly related to the move to Cambridge are described in section 6.5.

6.3.1 La Palma and related activities

By the time that Boksenberg had replaced Graham Smith the preparatory work for the new observatory on La Palma was well advanced. The building for the Isaac Newton Telescope appears to be almost complete in the photograph in IB 265, for 1 October 1981. Boksenberg visited La Palma for the first time at the beginning of November in the company of Bill Goodsell, head of the La Palma Division, and Paul Murdin, who had just been promoted to SPSO as the chief project scientist.

The Royal Inauguration by King Juan Carlos of Spain of the International Observatory on the Roque de los Muchachos on La Palma took place in June 1985. It is fully reported in a special issue of *Gemini.* The other countries that shared in the construction of the Observatory, namely Spain, Denmark, Ireland, the Netherlands, Sweden and the UK, wer all represented at high levels. The RGO was responsible for the Isaac Newton Group (ING), whose main telescopes were the Isaac Newton Telescope from Herstmonceux and the new, larger William Herschel Telescope. In addition there was the Jacobus Kapteyn Telescope, which was partly funded by the Netherlands and Ireland, and the Carlsberg Automatic Transit Circle, to which Denmark made the major contribution. At this time the building for the WHT had been completed, but the telescope was in store pending shipment to La Palma.

6.3.1.1 Organisation and staffing for La Palma

A new La Palma Operations Division was formed in May 1982 and later in the year a new Facilities Division was formed by combining the separate divisions for La Palma construction, for engineering and for instrumental science. (Joe Paxton returned to the Rutherford Laboratory in January 1982 and Bill Goodsell retired in September 1982.) The Facilities Division was headed by M. C. (Mike) Morris, who transferred (on promotion) in August 1982 from the Daresbury Laboratory. In 1985 the Facilities Division included not only the La Palma construction team, but also groups for electronics and computing, instrument science, vacuum physics and mechanical engineering. The Operations Division was split into two groups; the group on La Palma was headed at first by J. W. (Joe) Gietzen and the Herstmonceux Group was headed by Paul Murdin, who was later made the head of the division. Gietzen was also promoted to SPSO, but took VPR in 1984 and Keith Tritton became the head of the ‘Island Team’, which numbered 32 in 1985. This number included some locally recruited Spanish staff, who did not count against the RGO complement.

Jasper Wall became head of the Operations Division in 1987 when he and Paul Murdin interchanged roles. Keith Tritton returned to head the Herstmonceux Support group. Another person who changed roles between the reports of 1985 and 1987 was Neil Parker. He had been made Head of the Electronics Department in November 1981, when Henry Gill took VPR, and was Head of Electronics and Computing within the Facilities Division in September 1985. By September 1987 he had transferred to the Operations Division and was Head of the Engineering Group on La Palma. He later became officer-in-charge on the island in the 1990s.

In the following notes I have referred to only a few of the many RGO staff who contributed to the success of the La Palma project and I have given only brief details of it since I have neither the background knowledge nor the time to study the reports on the work in detail. Unfortunately, there is no published general report on the activities after 1987. Reports on current activities are given in the issues of *Gemini*.

6.3.1.2 The telescopes and instruments on La Palma

The first telescope to be brought into operation in the Isaac Newton Group on La Palma was the Carlsberg Automatic Meridian Circle. The basic instrument was made by Grubb Parsons in 1952 to the same design as the Cooke Reversible Transit Circle at Herstmonceux and it was used at the Copenhagen University Observatory until 1976. The enhancements and the installation on La Palma was funded by Denmark (with support from the Carlsberg Brewery!) and the UK and it is operated jointly. The first observations were made in November 1983.

The second telescope was the 1-m Jacobus Kapteyn Telescope. This was, I believe, purchased 'off-the-shelf' and delivered to La Palma in October1983. It came into use in May 1984. It had a wide-field photographic camera, but it also had a CCD camera, photometers and a spectrograph.

The first major British telescope to be brought into operation on La Palma was the 2.5-m Isaac Newton Telescope, which had required considerable structural modifications as well as a new larger mirror and instrumentation after its removal from Herstmonceux in 1979. John Pope, who had gained his experience of large telescopes while observing with Woolley and then with the construction of the Anglo-Australian Telescope, was the RGO's senior telescope engineer for this project. One of the members of his small team was Brian Mack, who had transferred from the Rutherford Laboratory in 1975 and who in 1987 was responsible for the telescope installation on La Palma. The building was handed over in January 1983, by which time the mechanical structure of the telescope was already in place. The first stars were seen at the prime focus in February 1984 and the first scheduled observing took place in May 1984. New cameras and spectrographs were installed and commissioned during the following years.

The 4.2-m William Herschel Telescope is the largest telescope on the site and when it was completed in July 1987 it was the third largest in the world. Again, John Pope and Brian Mack were strongly involved in its design. It was built by Grubb Parsons in Newcastle, where it was tested before it was dismantled, packed and put into store in December 1984 before the company closed. John Pope retired in April 1984 just after the telescope had been tested in the factory. The WHT is an alt-azimuth telescope with a wide variety of instruments. It was finally delivered to the site in May 1986 and 'first light' was in June 1987. Brian Mack was responsible for the installation on La Palma and was subsequently awarded an MBE.

The 1985 and 1987 reports contains several other interesting articles about the design, construction and use of the telescopes and instruments for La Palma and other observatories, and so reference may be made to them for further details of this work. In particular, I have made no attempt here to discuss the Carlsberg Automatic Meridian Circle, nor topics such as: the remote operation of telescopes; the conditions and users on La Palma; Dutch cooperation; and the data archive. (See appendix E.3.5 for a note about the CAMC.)

The success of the telescopes depended on a large variety of factors apart from the quality of the intrinsic mechanical and optical design and manufacture. Electronic and computing systems have revolutionised observational astronomy since I joined the RGO, but we must not overlook the fact that these highly complex facilities depend upon many people to design, construct, operate, maintain and use them. In turn these depend on administrative and support staff on the island and in the UK, but they too are omitted from this account.

6.3.1.3 Engineering and instrument development

Some of the work carried out by the engineering and instrument sciences departments on the design and construction of the telescopes and their instruments is described in articles in the 1985 and 1987 report, and in the issues of *Gemini*. It was found to be necessary to build a simulator for testing large and heavy instruments that were built in the workshops at Herstmonceux. Some of the work was in projects with and for other observatories. Some of these are mentioned in the 1987 report in an article on optics at the RGO.

6.3.2 Astrophysics and astrometry

During this period the former Astrophysics and Astrometry (A&A) Division was called the Astronomy Support and Research Division in the reports. It was headed by Jasper Wall and then from 1987 by Paul Murdin. It included Bernard Pagel, in the higher grade of DCSO, and Andrew Murray and Michael Penston as SPSOs, all of whom had had Individual Merit promotions so that they could concentrate on research and be free of administrative responsibilities. In 1981 the majority of the staff of the Division were in research teams, with the rest in the Meridian Department, headed by Tommy Tucker, and the Photographic Astrometry Department, headed by Bill Nicholson. Tucker retired in 1982 and his place was taken by Leslie Morrison, who had returned to the Meridian Department in 1981 after serving for over 18 years in the NAO.

The organisation chart for 1985 shows that the number of staff in these activities had declined, but the total for the Division had only fallen slightly since the Computer Department had been transferred from the Almanacs and Time Division in 1983. By then it was clear that the bulk of the work on the computers was for A&A, rather than for the A&T, and, moreover, I was no longer directly involved with any of the computer work. Ken Hartley continued to be the head of the department.

The Observatory kept up its links with the University of Sussex, and Boksenberg joined Pagel as a Visiting Professor there. Other RGO staff members acted as readers and lecturers; they both provided MSc lecture courses and supervised the theses for MSc and DPhil degrees. Apart from the monthly joint seminars, alternately at Falmer and Herstmonceux, staff and students attended other meetings at both centres and there was cooperation in research. Some members of the RGO staff took higher degrees there. Further details of the cooperation with Sussex and other universities are given in the 1985 report.

6.3.2.1 Astrophysical research

The astrophysical research programme of the RGO was extensive and productive. It was the subject of 15 double-page articles at the front of the 1985 report. The titles of the articles were: From here to quasars; Extragalactic HII regions; HII

regions and the chemical evolution of galaxies; The gaseous halo of our Galaxy; The stars of the Galactic halo; Weighing the black hole; Power for LINERs; Cen A - the nearest active galaxy; Are Elliptical galaxies really dead?; Ellipticals and doubles; Violent star formation; The jets of SS433; Star clusters; Probing the South Galactic Cap; Stellar cataclysms. The report concludes with an 11-page list of references to scientific papers, the majority of which are related to this astrophysical research programme. The 1987 report has an article on 'M dwarfs, brown dwarfs and the missing mass' and ends with nearly 7 more pages of references. The discovery of the supernova SN1987A in the Large Magellanic Cloud early in 1987 was of particular interest to those RGO astronomers who were working at the AAO at the time.

6.3.2.2 Astrometry

The primary aim of the astrometric programme was the improvement of the inertial reference frame with respect to which the motions of stars and galaxies may be determined from observations made on the Earth or in its neighbourhood. Various techniques are used to determine and link the reference frames for the Earth, for the Solar System and for the Galaxy to each other and to the extragalactic reference frame determined from VLBI observations of very distant extragalactic radio sources. The articles in the 1985 report on 'Inertial frames', on 'Astrometric and space geodesy' and on the 'Rotation of the Earth' discuss these matters and show clearly that much of the work in the Almanacs and Time Division was directly related to the astrometric work in the ASR Division. The work in ASR was in three main areas in optical wavelengths: (1) observations with the Carlsberg automatic meridian circle; (2) measurement of southern-hemisphere photographic plates using GALAXY; and (3) participation in the HIPPARCOS satellite mission of the European Space Agency (ESA).

The last observations with the Cooke reversible transit circle were made at Herstmonceux in April 1982, just before the retirement of Tucker, who had been in charge of the work since 1964. Attention was then given to completing the reduction and publication of all the observations up to that date. The Cooke RTC was later transferred to the Copenhagen University Observatory, where it was used to develop software for the Carlsberg Automatic Meridian Circle (CAMC), which had been built in 1952 by Grubb Parsons to the same design as the Cooke circle. The CAMC was delivered to La Palma from Denmark in August 1983 and regular observations began on 1 May 1984. As its name implies this circle is controlled by a computer and an impersonal photo-electric moving slit micrometer records the transits of stars and minor planets. The instrument was run jointly by the Copenhagen University Observatory and the RGO, whose small team of five was led by Leslie Morrison.

The use of the 26-inch Thompson refractor for the measurement of trigonometric parallaxes ceased at the end of 1981. The use of the 13-inch astrographic telescope probably also ceased, but the GALAXY measuring machine continued to be used for the measurement of plates for the Cape Photographic Catalogue. Such fundamental work was not consistent with the short-term policies of the SERC and funding was withdrawn for two years. (See the 1985 report.) It was reinstated when it was realized that it would be required to measure the wide-field plates to be taken with the new JKT on La Palma. The leader of the group of four was Nicholson, who retired in May 1986 (without comment in the IB, apart from an item about the farewell party in the Clubhouse). The 1987 report does not mention GALAXY, the JKT or any other aspect of photographic astrometry.

Until his retirement in 1986 Murray led a ‘galactic astronomy’ group of three that was primarily concerned with the preparation of the input catalogue and of programs for the reduction of the data to be obtained from the HIPPARCOS satellite. This international project had very long gestation period. I have a vague recollection of a very early presentation about the concept at an IAU meeting and it was then difficult to appreciate how it would operate and how parallaxes, positions and proper motions of high-precision of over 100 000 stars would be derived from the observations. The satellite was launched in August 1989 so that the bulk of the data processing and publication of results was carried out in the 1990s. The RGO team was led by Floor van Leeuwen (from Holland), who has written a review of the work on both the Carlsberg telescope and HIPPARCOS in the last issue of *spectrum*.

6.3.2.3 Developments in computing

This decade saw much further development of computing activities throughout the Observatory. The Computer Department, which was responsible for the major computers, was transferred from the A&T Division to the A&A Division in 1982 and I was replaced as chairman of the RGO Computer Committee in 1983. The VAX 11/780 computer, which had been obtained in March 1980 as the RGO node for the Starlink computer network, and which was used mainly for image processing, was supplemented in March 1982 by a VAX 11/750 for general purpose computing. This made it possible to close down the ICT 1903T computer in the following year on 25 March 1983.. The VAX was not only more powerful but, like the 780, it was available all the time. Users, rather than a dedicated team of operators, were responsible for running their own programs. By this time, disc storage had obviated the need for frequent loading and unloading of magnetic tapes. The GEC 2050 link to the Rutherford Appleton Laboratory was closed on 1 July 1983 as it was superseded by Starlink.

The Computer Department, which was headed by Ken Hartley, continued to supervise the use of the computers and to provide support for the users. At first it made significant contributions to the development of software for the STARLINK network, but the loss of experienced staff left little time for further such work. The background to Starlink and the RGO contributions to its development are described by Ken Hartley in *Gemini 3* and in the 1985 report. There are illustrations showing the VAX 11/780 computer and the use of the image-processing software to improve the images from the new detectors by removing the fixed-pattern and other noise. The article in *Gemini 3* includes a brief history of the use of computers in the RGO.

The VAX 11/750 was used mainly for astrometry, such as processing the data from the Carlsberg telescope and from GALAXY, and for dynamical astronomy, including the production of the almanacs, studies of orbital motions in the Solar System, and satellite laser ranging. It was also used for the development of software for the HIPPARCOS project and later for processing the data from the satellite. The load on the system soon grew to the point where users could no longer use the system interactively, but had to organise their jobs so that they could be run in a batch queue.

Minicomputers were used for applications such as the control of telescopes, while microprocessors were used as integral parts of many instruments. The FORTH programming language was adopted for such purposes and its use in the RGO is described in the 1985 report.

The introduction in the 1970s of electronic desk and hand calculators has been mentioned in section 5.5.3.2, and of word processors in 5.5.3.3. The 1980s saw the

introduction of much more powerful general purpose desk computers that became known as ‘Personal Computers’. At first there were many different incompatible systems and so the SERC Computer Coordination Panel, on which I represented the RGO from 1980 to 1983, was keen to select a system that would be the standard for its establishments and for universities seeking grants. A team went to the USA and came back with a recommendation that a computer known as PERQ should be adopted. We were given a demonstration and I was very impressed. One feature that I particularly liked was that the monitor screen was in portrait, rather than landscape, mode so that the whole of an A4 page could be seen in full-size type on the screen. Moreover, the image was in black on white, rather than in colour as was then the norm. Unfortunately, the introduction of the IBM PC made this a useless exercise and, as far as I am aware, no PERQs were purchased by SERC.

Our Data Logic word processors were replaced by ‘Diamonds’ and eventually by PCs. Diamonds were used elsewhere in SERC and were linked by a separate network. Throughout my time at the RGO the senior staff continued to have secretarial help and so our letters and papers were typed for us. A typing pool continued to provide a service, but many scientific staff began to type their own documents. (I purchased an Amstrad PCW word processor for use at home, but when I retired I found that the floppy discs were incompatible with the IBM discs used at the University and so I replaced it by a PC.)

A major development during the decade was that of international networks for correspondence by electronic mail for as well as for the distribution of large data files. My first introduction to this was in connection with the MERIT project when Peter Morgan, an Australian, persuaded us to use a GEC network for the transmission of MERIT data and for messages. An email link to La Palma was introduced in 1987.

6.3.3 H. M. Nautical Almanac Office

The description of the work of H.M. Nautical Almanac Office in the RGO 1985 report refers only to the work on the publications and data services. The work on dynamical astronomy is described earlier in an article on the motions of natural satellites without any indication that it was carried out in the NAO by staff who shared in the other work.

The team work in the NAO was probably a major factor that led to good attendances by former staff at reunions that were held in September 1982 and June 1987. The first of these was held to mark the sesquicentenary of the establishment of the NAO, although it may have been almost a year after the actual 150th anniversary. Some of those present had worked in the NAO over 50 years before and some of them also attended the later reunion. In particular, Donald Sadler was present at both and appeared to be in good health. The second one was held at his request, but he died in October 1987.

Professor George G Bennett, of the University of New South Wales, Australia, spent six months in the NAO while on study leave from June to December 1983. He worked mainly with Bernard Yallop. When he left he presented the Office with a plaque from the NSW Society for Surveyors. The Office also had two younger long-term visitors from China. The first was Mr Xia Jiongyu from the Institute of Geodesy and Geophysics at Wuhan and he stayed from May 1984 to July 1986; he was most interested in the work on the rotation of the Earth and he took part in the analysis of

SLR data . The second was Mr. Shen Kaixian from the Shaanxi Astronomical Observatory at Lintong, near Xian, and he stayed from June 1985 to July 1986; he worked with Sinclair and Taylor on the motions of natural satellites and he continued his collaboration with Taylor after the move to Cambridge. They lived in rooms in the Castle and they had the use of a small kitchen so that they could prepare Chinese food – Mr Xia had quite a shock when he was served with fish and chips for lunch in the canteen on his first day. I met Mr Xia and Mrs Shen during my visit to China in 1987, but Mr Shen was then in hospital.

The Office continued to collaborate with similar organisations throughout the world, and we maintained especially good relations with the Nautical Almanac Office of the US Naval Observatory in Washington. During a visit there in July 1985 I spoke at a colloquium about Project MERIT and then about Simon Newcomb, who had been a Director of the (US) NAO and one of the most well-known members of the Observatory! I also spoke about Simon Newcomb at RAS and IAU meetings.

6.3.3.1 NAO publications and data services

The Astronomical Almanac for 1981 onwards was printed in the USA, but for 1982 and 1984 the copies for sale by HMSO did not arrive until very late in the preceding year. Major changes in the basis of the ephemerides were introduced in the issue for 1984 in accordance with resolutions that were adopted by the International Astronomical Union in 1976. The fundamental ephemerides of the motions of the Sun, Moon and planets were computed by numerical integration at the Jet Propulsion Laboratory in California. The Office was still responsible for the computation from them of the ephemerides published in the first part of the Almanac. The type-styles in the printed volume showed clearly which pages were prepared and typeset in the UK and which in the USA. A Supplement that was printed in the 1984 edition gave details of the new system of constants and of the changes that had been made.

By 1985 the system used for automatic typesetting had been changed to reflect the developments in computer techniques since I had written the first system in 1968. Instead of producing a magnetic tape that was used directly by the phototypesetter the Office produced a file that specified exactly the format and content of each page. This file was then processed by HMSO to produce a new file that was appropriate to the particular model of typesetter to be used. The new system was known as TOPPS (Tables OutPut for Printing System). The programming system for the first stage was developed by Catherine Hohenkerk, while the interface program was written by Mr P Felgate of HMSO. A brief description of the system is given in the 1985 report and a user's manual, written by Catherine with the assistance of Ann Strong, was issued as *NAO Technical Note no. 66* in October 1987. The user's job was to write a program (in Fortran) that would combine 'commands', which specified the required layout (headings, type fonts and sizes, spacing), with the numerical data from a previously computed file. This program might modify the initial data when this was required for the particular table to be printed. The output from this program was printed on the line-printer for checking for formatting errors before the magnetic tape was sent to HMSO. This was a difficult task as the character set and spacing on the line-printer were so limited.

The availability of the new fundamental ephemerides meant that we could prepare the volume of *Planetary and Lunar Coordinates for the years 1984–2000*, and this was published in 1983. In addition the Office started a new series of booklets with

the title *Compact Data for Navigation and Astronomy* to provide low-precision data in a form that was suitable for programmable calculators and personal computers. The first volume was published by HMSO in 1985 for the years 1986-1990. (The data for 1981 to 1985 had been published in 1981 for trial purposes as *RGO Bulletin 185*.) This and the succeeding volume for 1991-1995 were prepared by Bernard Yallop and Catherine Hohenkerk.

As far as I can recall, there were no significant changes to *The Air Almanac* (except that it was published in one volume per year instead of two from 1987) or to *The Star Almanac for Land Surveyors.* A new section on sight reduction procedures was, however, included in *The Nautical Almanac* for 1989 so that separate volumes of sight reduction tables were no longer necessary. The final draft of this new section was prepared at USNO when Yallop attended a meeting of the ASCC WP 53 in Washington in March 1987. Nevertheless, we continued to update the *Sight Reduction Tables.* Further details of these and other activities are given in the 1985 and 1987 reports.

Although he had been retired since 1972, Donald Sadler participated in the design of *The Macmillan and Silk Cut Nautical Almanac*, which was issued annually from 1981, and he also compiled the set of sight reduction tables that were published in *The Macmillan and Silk Cut Yachtsman's Handbook*, which was first published in 1984.

The NAO issued its last worldwide predictions of occultations of stars by the Moon for the year 1982, but it did continue to prepare predictions of grazing occultations and it published the results of the observations made up to 1980 in *RGO Bull*. 192. Leslie Morrison, although no longer in the NAO, continued his collaboration with Richard Stephenson at Durham on the determination of the past variations in the rotation of the Earth. They produced a definitive paper in 1995 on the long-term fluctuations during the period 700 BC to AD 1995.

In addition to preparing data on astronomical phenomena for the almanacs, the Office continued to provide such data to publishers of calendars, etc, and to the general public, usually in the form of *RGO Astronomical Information Sheets*. The Public Information Unit was, however, transferred to the Administration Division and renamed the Public Relations Unit as its scope was widened; it took over the distribution of the data computed in the NAO.

A major disappointment during this period was our inability to prepare a new edition of the *Explanatory Supplement.* Changes that had taken place since 1960, and especially those for *The Astronomical Almanac for 1984*, had rendered it obsolete and so it was allowed to go out of print. I had originally intended to ask Leslie Morrison to act as editor for the revised edition and to spend a lot of time on it myself. Leslie was, however, transferred back to the Meridian Department and I found that my many other activities, including Project MERIT and the 'defence' of the RGO, used up almost all of the time that would otherwise have gone to the Supplement. Consequently, the editing was undertaken by Ken Seidelmann in USNO, and the completely new *Explanatory Supplement to the Astronomical Almanac* was published in 1992 by a commercial publisher, not the US Government Printing Office. My contribution was limited to writing (after my retirement) with Seidelmann the introductory chapter, but Catherine Hohenkerk, Bernard Yallop and Andrew Sinclair were responsible for other chapters. Seidelmann invoked the assistance of some astronomers from other organisations, such as the Jet Propulsion Laboratory, in addition to staff of USNO. The Supplement

includes a list of many of the *NAO Technical Notes* that had been published to give details of the techniques of computation that had been used.

6.3.3.2 Dynamical astronomy (except SLR)

The work on dynamical astronomy by Andrew Sinclair and Don Taylor was mainly concerned with the orbital motions of natural satellites. Taylor continued his studies of the three-body problem, and in addition Sinclair was heavily involved in the satellite laser ranging programme.

Good relationships were established with dynamicists in universities and during this period we organised three workshops in the Castle. (See section 6.4.1.1) We (ATS, DBT and GAW) also prepared and manned an exhibit at the annual Royal Society Exhibition in 1987 about satellite dynamics and SLR.

6.3.4 The Time Department and space geodesy

The decade saw a drastic change in the work of the Time Department and in 1987 it was named the Space Geodesy Department to reflect the character of the new work. The adoption in 1972 of coordinated universal time (UTC), which was derived directly from atomic time, as the basis of the international system of time scales led to a diminution in the value of the contribution that the RGO could make to the national and international time services. Moreover, such work was more appropriate to the National Physical Laboratory, rather than to an SERC establishment, and so the scale of the RGO effort was considerably reduced. Then, as the MERIT project clearly showed, the technique of optical astronomy for the determination of universal time was superseded by new techniques of space geodesy based on laser ranging and VLBI. Consequently the operation of the PZT was replaced by that of a satellite laser ranging system that made a significant contribution to the international services for monitoring the rotation of the Earth and for improving the geodetic reference frames. In addition, the transfer of the Hewitt satellite tracking camera from Malvern to Herstmonceux led to a major increase in its productivity.

In addition to international workshops for SLR and MERIT (see later) the RGO hosted a Summer School in Space Geodesy in September 1984.

The public interest in Greenwich time and the Greenwich meridian was boosted by the celebration of two anniversaries. Firstly, the 60th anniversary of BBC 6-pips time signal occurred on 5 February 1984. Separate interviews with John Pilkington were broadcast on nine BBC stations. (I drafted notes about the early history of the 6-pips, but I did not have time to polish them for publication. See appendix G.3.4) The 100th anniversary later that year of the recommendation by the International Meridian Conference in Washington that the Greenwich meridian should be used as the prime meridian of the world was much more significant. This eventually led to Greenwich Mean Time becoming the basis of standard time zones around the world and to the Greenwich meridian, defined by the Airy transit circle, being used for ‘longitude zero’ on maps. Members of the RGO staff contributed to the Longitude Zero Symposium that was held at the National Maritime Museum at Greenwich in July 1984. The participants also visited Herstmonceux. In October there was an evening reception at the Old Royal Observatory to mark the event and in November Sadler and I presented a paper about the International Meridian Conference at a special meeting of the Royal Institute of Navigation. (See appendix G.3.2) The anniversary is not mentioned in the 1985 report.

The occasional insertions of leap seconds in GMT (= UTC) usually involved radio interviews with Pilkington. The RGO's activities in time and geodesy led to my being invited to give, in January 1986, the Christmas lecture to the British Astronomical Association on the subject of 'Greenwich Time and the rotation of the Earth'. Later, in December 1988, members of the Eastbourne Astronomical Society came to the Castle for a talk on 'Space Geodesy'.

6.3.4.1 The Greenwich Time Service

RGO Information Bulletin 270 reported that on 29 January 1982 "The Director, Dr G A Wilkins and Dr J D H Pilkington visited the National Physical Laboratory, to discuss the responsibility for time matters. The meeting was held at the suggestion of Mr B W Oakley, Secretary of SERC, who was also present. It was agreed that the time-service activities at both establishments were fully justified and that the accuracy of the timing link between them ought to be improved".

Unfortunately, the level of funding and staffing failed to match this conclusion, and in late 1985 an article in *Nature* sparked a flurry of media interest in the 'demise of GMT'. Consequently, John Pilkington wrote an article headed "What's happening to the Time Service?" for the November issue of the RGO Information Circular for staff. In it he stated that "it has now been decided that the RGO will no longer aim to maintain an independent scale, and will rely instead upon timescales maintained elsewhere to provide the time-tags accurate to 1 millionth of a second that we need for our SLR observations". He also stated that we "intend to maintain our connection with the BBC to ensure that the '6-pips' Greenwich Time Signal will continue to provide GMT with an accuracy and reliability appropriate for normal civil use".

Pilkington later reviewed the activities of the Greenwich Time Service in an article in the 1985 report. The references to the *Time Service Circulars* and *Notices* that were issued by the Department were, however, omitted from the published report, although they are listed in the 1987 report.

The BBC took responsibility for the generation of the 6-pips time signal from 5 February 1990. I do not know when the Department ceased to monitor international time signals. I believe that two of the caesium standards were transferred to the SLR dome for use there.

The operation of the Photographic Zenith Telescope (PZT) ceased on 30 June 1984 even though we were the participating in the MERIT Main Campaign (see section 6.3.4.4), which did not end until 31 October. Moreover the cuts in the staff were so severe that we were unable to reduce and publish all the observations that had been made. Consequently, a lot observational effort was wasted. I suspect that even the data have now been lost and so it would be impossible to recover the results for the variations in local sidereal time and in the latitude of the PZT with respect to the pole of rotation of the Earth.

The PZT control building was subsequently let to a commercial company for office accommodation. I do not know what happened to the control desk — we were not consulted — but I do recall being horrified when I saw that the cables connecting the desk to the PZT itself had been roughly ripped out. I last saw the PZT itself in pieces in a Science-Museum store. The Greenwich Time Service control cabinets that featured in many published articles and in our postcards are also in store there.

6.3.4.2 Satellite laser ranging

The events that led up to the decision that the RGO should be responsible for the procurement and operation of the satellite laser ranging system are described in section 5.5.4.6 and the initial stages of the installation are described in section 5.5.6.4. The laser itself was installed in April 1982 by staff of the Physics Department at the University of Hull, who had designed and built it. The primary target, the satellite Lageos was first observed on the TV monitor shortly afterwards on 11 May. There was, however, a lot of commissioning work to be completed before the first laser returns from Lageos, and the smaller, lower satellite Starlette, were detected at night on 31 March 1983. Returns in daylight were obtained a few weeks later. The system was fully operational by October 1983, soon after the start of the MERIT Main Campaign.

The responsibility for the SLR system was assigned to the Time Department and we were fortunate in that John Pilkington had the necessary breadth and depth of knowledge to oversee the technical operation and maintenance of the system. In addition, the SLR team included Andrew Sinclair in the NAO, who not only had expertise in orbital mechanics, but who had also had practical experience of laser ranging during his year of secondment to the LLR team at Orroral in Australia. Graham Appleby was transferred from the NAO to the Time Department and became a valuable member of the team in developing the data analysis package and in collaborating with university groups in its use. Phil Cottrell, who was then the head of the Engineering Workshop took a particular interest in the project and after he had taken VPR we were able to keep his expertise as he was re-employed on a part-time basis. The initial team included also an electronics engineer, Bill Matthews, who kept the system in a highly reliable state, and Geoff Harvey, who developed the control software and then maintained and documented it. Graham , Bill and Geoff all acted as observers. Others who joined the team later included Peter Standen and Philip Gibbs.

An article about the system is given in the 1985 report and a longer article is given in *SERC Bulletin 3(1)*, January 1985. (An earlier article was published just after the installation of the telescope.) A technical description of the system is given in *SLR Technical Note 1*, May 1982. This was written by a newly recruited HSO, Paul Sharman, who left after a short while when he realized that the finance companies in the City of London offered salaries that were substantially greater than those in the Scientific Civil Service. The unusual nature of this hi-tech system aroused a lot of media interest and a photograph by David Calvert of the dome, telescope and green beam at night featured in July 1985 on the cover of a special issue of *Nature* on twenty-five years of lasers.

The laser system in the room below the floor of the dome generated a succession of pulses of light, each of which lasted a few tenths of a nanosecond (ns) and was a few centimetres long — roughly the size of a fist! (1 second contains 1000000000 ns) These pulses, each of which contained many trillions of photons, were eventually transmitted in a very narrow beam by a refracting telescope with aperture 10 cm to the target satellite. The principal target was Lageos, which was a sphere with a diameter of 60 cm (the size of a large beach ball!) that was covered in optical retroreflectors. Lageos was in orbit at a height of 6000 km so that the distance to the target was often as much as 12000 km. During a successful observation the satellite was illuminated by the beam and a small fraction of the photons were reflected back in a slightly diverging beam towards the telescope which had moved while the photons were going to satellite and back. Returning photons were detected individually by a special detector at the focus of a reflecting telescope, which has an aperture of 50 cm. The time-interval between the

emission of a pulse and the return of a photon was measured with a precision of about 0.1 ns by a special timing system. This interval was usually less than the interval of 0.1 s between the pulses themselves.

This complex system was controlled by a computer that had to continually calculate the direction to the satellite and record all the times of emission of the pulses and detection of photons. The telescope was continually receiving enormous numbers of photons, even at night, and so it was arranged that only those photons with the appropriate wavelength that arrived at close to the expected time were recorded. A graph on the computer monitor showed for each time of detection a point indicating the difference between the actual and expected time-interval. For real returns these points gradually built up a curve, while the other unwanted detections gave points that were scattered at random.

The system was operated by a single observer whose principal task was to initiate the observations, to monitor the progress of the recordings for each pass of a satellite and to take appropriate action if it became clear that returns were not being detected. In addition he had to look out for low-flying aircraft, including gliders, that might pass through the laser beam close to the Observatory. More distant aircraft were detected by a radar system that was slaved to follow the motion of the telescope and to switch off the laser system if an aircraft entered the radar-beam, which was very much wider than the laser beam. Consequently, during each pass the observer had to use a mini-console by the telescope rather than the main control desk in a warm room on the ground floor. A retroreflector on the empty INT dome was used for calibration purposes.

The system eventually worked extremely well technically and produced results of high precision. Moreover, the system was extremely productive in spite of the English weather. For several years we were at the top, or close to the top, of the annual table of passes observed by the SLR stations around the world. This was due largely to the excellent team-spirit shown by the observers, who tried to ensure that observations were made on all possible occasions when the weather permitted. The flexible conditions for observing duties outside ordinary office hours contributed, as did the fact that the system could be, and was, operated by only one person. At some (perhaps most) stations the systems were operated by shift teams that were not funded for full 24-hour 7-day working.

Pilkington and Sharman attended an international SLR Workshop at the University of Texas at Austin in October 1981 to learn from other groups with experience of operating such systems. The high level of interest in the RGO system was indicated by the attendance at the workshop to discuss the processing, analysis and exploitation of SLR data that was held in the Castle on 5-7 January 1983. There were 26 participants from UK universities and research establishments and 10 from the RGO.

A meeting of the European group for Range Observations to Satellites (EROS) was held in the Castle on 15/16 March 1984. The main topic was the planning of a special campaign [MEDLAS] to measure the motions of the tectonic plates around the eastern Mediterranean. RGO acted a reference point for the mobile stations. The fifth international laser ranging workshop was held in the RGO on 10-14 September 1984; there were 76 participants from 18 countries in addition to the RGO team. The opportunity was taken to hold meetings of the MERIT working group and of an ESA working group for international time transfer using lasers (LASSO). (See section

5.5.6.2) I was on the organising committee for the main workshop and this involved my attendance at a meeting in March in Prague, where the chairman, Professor Karel Hamal, was based. I recall that during dinner on one evening Carol Alley produced from his pocket a retroreflector of the type that was used in the arrays left on the Moon by the Apollo astronauts.

The results from satellite ranging were used not only in the monitoring of the rotation of the Earth, but also to establish the geodetic coordinates of the stations to high precision for use in defining an international geodetic reference frame. An Ordnance Survey trigonometric pillar was placed near the SLR building and was linked to the pillar near the INT dome so that the UK network could be linked accurately to the international network. The RGO results were used in NASA's Crustal Dynamics Project and the members of the team received Group Achievement Award certificates in 1986. Observations by receivers of the American Global Positioning System (GPS), which was then under development, were made in 1988 and 1989 from the pillar in order that the GPS coordinate system could be related to the international system.

A series of *SLR Technical Notes* was started in 1982, but the list of the early issues was omitted from the 1985 report, although some were listed in the 1987 report. These notes give details of the equipment and operational procedures and also results from the analysis of SLR observations from around the world — little can be derived from observations at only one station. A progress report by Andrew Sinclair on the observations of satellites by the SLR system and the Hewitt camera (see next section) was published in *SERC Bulletin* 4, Spring 1990. It describes how the SLR system was also used in photometric mode to study, for example, the rotation of the discarded rocket body of Cosmos 1844 and the occultation of a star by Titan, a satellite of Saturn.

6.3.4.3 Other satellite tracking activities

The NAO had provided the UK prediction service for artificial satellites during the first few months after the launch of Sputnik 1 in October 1957, but it had passed this job to the Royal Aircraft Establishment which had already recognised the need to determine regularly the orbital parameters of satellites for a variety of purposes. (See section 3.1.2.2) Desmond King-Hele at RAE was a leader in using the changes of the orbits for studies of the upper atmosphere and of the shape of the Earth. He was elected a Fellow of the Royal Society. He probably paid a major role in persuading Woolley to agree to the siting and operation of a kinetheodolite at Herstmonceux in 1963 and, later, at the Cape of Good Hope. (See section 3.3.3.3 and 4.3.4.6) I had first met King-Hele in 1958 (see section 3.3.1.3) and had continued to meet him from time to time as we both served on Royal Society and SRC Committees and Working Groups relating to orbit analysis and tracking. (He also came to Herstmonceux occasionally and we would then try to fit in a game of tennis as we were of a comparable standard!) It was therefore not surprising that we should collaborate in obtaining agreement for the installation of a Hewitt satellite-tracking camera at Herstmonceux.

The Hewitt camera is a large wide-field (angle of view) reflecting telescope that may be moved rapidly across the sky. It is not a conventional alt-azimuth telescope since it has three axes so that it has to be turned about only one axis when following a satellite during its pass. The mirror has a diameter of about 1 m, and there is thin corrector plate with a similar diameter at the aperture of the tube. The telescope was designed by Joseph Hewitt at the Royal Radar Establishment at Malvern for use in tracking the Blue Streak ballistic missile. Two such cameras were made; one was

operated at Malvern (or rather at Sheriffs Lench, near Evesham) until it was transferred to Herstmonceux. The second was operated by the Royal Observatory Edinburgh, but it was mothballed from 1975 until it was moved to Siding Spring in Australia in 1980. The Malvern camera was operated by the Ordnance Survey for geodetic triangulation from 1967 and then by the Earth Satellite Research Unit of the University of Aston from 1978 onwards. There is a photo of the camera in the 1985 report with some notes about it. Peter Knight, who now owns the site at Sherriffs Lench, has started to compile a history of the work there.

King-Hele and Clive Brooks from Aston visited Herstmonceux on 23 June 1982 to discuss the move of the Hewitt camera into the empty Dome C in the Equatorial Group. The camera was installed on 25 October 1982 and the first observations were made soon afterwards. The observing team, which continued to be employed by the University of Aston, moved with the camera and had the use of the adjacent B laboratory as their office. The move was extremely successful as there were productivity gains from the better weather conditions at Herstmonceux and from the fact that the observers lived close to the observing site and did not have to make long journeys to Malvern from their homes in Birmingham. The original members of the team were Vanda Bennett (leader), Roger Clarke, Robert McNaught and Max White. In February 1986 the Hewitt camera was used to provide support for the launch of a satellite by an Ariane 5 rocket.

One possible application of the Hewitt camera was to a project known as COGEOS. This was intended to obtain better information about the Earth's gravity field by studying the perturbations of satellites in geostationary orbits. An enthusiastic Italian couple came to Herstmonceux to talk to us about it and I attended a meeting in Pisa in 1988, but, as far as I am aware, the project did not go ahead.

Max White was an extremely active and knowledgeable member of the Kettering Group of amateur observers who been the first to (publicly) name the launching site for the Sputnik satellites. The Group was awarded the Prince of Wales Trophy for 1983 for its later work on various Soviet space missions. His description of the team's involvement in the media excitement about the re-entry of the Russian satellite Cosmos 1714 is given in IB April 1986 and there is a brief report in *Gemini 5.* He was also a reviewing editor and contributor in 1987 to an official US report on the space programme of the USSR.

These three observers also went to Australia to operate the second camera there. McNaught used the camera as an astronomical survey instrument and recorded the initial outburst of the famous supernova SN1987A in the Large Magellanic Cloud — unfortunately, he did not examine the plate until the following day, by which time the discovery had been announced. Max and Vanda married after their return from Australia and Vanda then worked in the exhibition prior to the birth of their son.

There were other activities related to satellite tracking. In December 1982 I gave an account of the NAO's satellite prediction service at meeting at the Royal Society to mark the 25th anniversary of the launch of Sputnik 1. A meeting for amateur observers of satellites was held in the Castle over the weekend of 9/10 March 1985; this was organised by a committee of the Royal Society. The participants were able to see the SLR and Hewitt systems in operation. In 1987 I received an unexpected invitation to attend a "Space Forum" in Moscow to mark the 30th anniversary of the launching of Sputnik 1. I obtained SERC approval to attend, but used annual leave since the event

was not directly to my work in the RGO. Most of my travel and accommodation expenses were met by the Soviet Government. It was a very interesting and enjoyable experience. I have written recently written a brief account in an article to be published in *The Antiquarian Astronomer*.

6.3.4.4 Rotation of the Earth — Project MERIT and the IERS

In 1978, as has been mentioned in section 5.5.6.3, I was appointed chairman of an IAU working group to make a comparative evaluation of the techniques for monitoring the rotation of the Earth and to make recommendations for a new international programme for observation and analysis. I did not realize then that I would be involved in this activity for the next ten years. The activity itself was very interesting, but it also gave me an opportunity to travel to many places around the world and to make friends with scientists from many countries. The group organised an international project that was known by the acronym MERIT (see below) and this provided the basis for the new International Earth Rotation Service that began operations in 1988. All of the activities — meetings and operations — were funded directly by the organisations taking part so that no time or effort was needed for fund-raising. My work and travel, as well as the SLR observations at Herstmonceux, were funded by the RGO. A general description of the project and a summary of the initial conclusions is given the 1985 report.

My role as chairman had several aspects. First of all, I convened and chaired the meetings of the group, whose members were usually nominated by the major organisations taking part. Secondly, I prepared the reports on the meetings and in doing so it was usually necessary to fill in detail, to sharpen up the conclusions of the discussions and to edit the technical contributions from the members. Thirdly, I prepared and distributed summaries of our objectives and of our proposals for the organisation of campaigns for observations and analysis. I issued newsletters and spoke about the project at conferences so as to make it known to a wider community.

When we started the principal method used regularly for monitoring the rotation of the Earth was that of optical astrometry using instruments such as photographic zenith telescopes to measure the variations in the rate of rotation (or in universal time) and in the orientation of the axis of rotation (or in the geodetic coordinates of the axis). The Bureau International de l'Heure in Paris was responsible for collecting and analysing the data for the former, while the International Polar Motion Service in Japan dealt with the latter. Additional data from Doppler observations of the orbits of navigational satellites was used for a 'rapid service' for UT. It had been shown that radio interferometry and laser ranging to satellites and the Moon could give accurate data on the rotation of the Earth, but appropriate observations were not made regularly.

The first meeting of the working group was held at Columbus, Ohio, in October 1978 at the invitation of Professor Ivan Mueller; he was not a member of the group but he played a major in the eventual success of the project. It was there that Martine Feissell, from BIH, proposed the acronym MERIT for 'Monitor Earth Rotation by International Techniques', but this was modified to '… and Intercompare Techniques' to match more closely the terms of reference of the group. The group also agreed to organise a short campaign in 1980 to develop interest and test ideas for the later organisation of a main campaign lasting at least a year in 1983/1984.

Our draft proposal was submitted to the IAU at Montreal in August 1979 and then to the International Association of Geodesy during the General Assembly of the International Union of Geodesy and Geophysics in Canberra in December 1979. From then on the group reported to both the IAU and the IAG; it also received the support of COSPAR (the international Committee on Space Research). The group met fairly regularly for short (half-day) meetings during conferences. In addition, it also organised several workshops lasting up to three days for the scientists who were involved in the operations. The initial rivalry between techniques and countries was soon replaced by a real spirit of cooperation and the level of participation increased as the project developed. It also became clear that the work for the determination of Earth rotation parameters (ERPs) must be integrated with complementary work for the determination of the geodetic coordinates of the stations and for monitoring the changes due to the motions of the tectonic plates. Consequently joint meetings were held with another IAG committee, known as COTES, for the establishment of a new terrestrial reference system. This was chaired by Ivan Mueller. Later we formally became a joint committee, with me as chairman and Mueller as vice-chairman. We made the final proposals for the new service, IERS, that would replace BIH and IPMS and would also be responsible for maintaining the celestial and terrestrial reference systems that are linked by the ERPs.

The first workshop was held at Grasse in southern France in May 1981, to review the lessons learnt from the Short Campaign and to make plans for the Main Campaign. The second workshop was at Herstmonceux in May 1983 to review the arrangements for the Main Campaign and to look ahead. The third workshop was held in July 1985 in Columbus, Ohio, in conjunction with a conference organised by Mueller on closely-related topics. After that workshop I was so busy preparing for the presentation of our proposals to the IAU at New Delhi in the following November that I had to put on one side the preparation of the full report on the workshop. I did not pick it up again until 15 years later, but it was then published in 2001. Our proposals were accepted by the international community and our working group became the Provisional Directing Board of the International Earth Rotation Service. The new service formally commenced operations on 1 January 1988, but the arrangements of the MERIT Main Campaign had remained in place during the meantime. I chaired the meeting of the IERS Board at the Paris Observatory in April and then at the IAU General Assembly in Baltimore in August 1988. As my retirement from the RGO was due the following year, I then handed over to Yaroslav Yatskiv, director of the observatory at Kiev in the Ukraine, then still part of the USSR. Incidentally, it was Yaroslav who sponsored my attendance at the Space Forum in Moscow in October 1987. He had stayed in our home after the workshop at the RGO in 1983, and we became good friends. By chance we were in adjacent rooms at the IAU GA in Manchester in 2000.

Apart from these workshops the members of the group met whenever possible at other conferences, either formally for general discussions or informally to discuss particular aspects of the work. Formal meetings and/or presentations took place at:

Dubrovnik, during an IAU European regional meeting, in October 1981;

Tokyo, during a general assembly of the IAG, in May 1982;

Patras, Greece, during the IAU GA, in August 1982;

London, at an RAS discussion meeting, in May 1983, just before the 2nd workshop at Herstmonceux; the group visited the Old Royal Observatory at Greenwich on the day after the RAS meeting;

Herstmonceux, during the international laser ranging meeting, in September 1984;

Paris, at the IAG Central Bureau in June 1985;

New Delhi, during the IAU General Assembly in November 1985;

Austin, Texas, during a meeting on positioning by satellites in April 1986; there was a demonstration of the way that VLBI techniques could be used to obtain very accurate positions from GPS satellites without using the secret military codes;

Prague, in September 1986, during an international symposium on the figures and dynamics of the Earth, Moon and planets;

Coolfont, Virginia, in October 1986, during IAU Symposium 128 on 'The Earth's rotation and reference systems for geodesy and geodynamics'; this was in essence a review of the achievements of Project MERIT and the proceedings were edited by Alice Babcock, of the US Naval Observatory, and myself;

Pasadena, California, in March 1987 at the Jet Propulsion Laboratory at the time of a NASA meeting of principal investigators for its crustal dynamics program(me);

China in April 1987; this was five-centre lecture tour at the invitation of the Chinese Academy of Sciences during which I spoke about MERIT/IERS and other topics [87/04]; the invitation was made at the suggestion of Madame Ye Shu-hua, who was the director of the Shanghai Observatory and a member of the MERIT group; she visited the RGO in August 1989;

Paris, at the Observatory, in April 1988;

Baltimore, during the IAU General Assembly, in August 1988;

and Potsdam, East Germany, later in August 1988, during a conference on the physics of the Earth, when I reviewed MERIT and IERS.

I also gave several talks about MERIT in other meetings in the UK. For example, I spoke about MERIT during my contribution about the fluctuations in the rotation of the Earth during a Royal Society meeting on 'Rotation in the Solar System' in 1984.

Shortly after my retirement, I attended two further conferences that were directly related to my involvement with MERIT. The first was IAG Symposium 105 on 'Earth Rotation and Coordinate Reference Systems' at Edinburgh in August 1989 and I subsequently edited the proceedings with the assistance of Claude Boucher (France). Then in October 1989 I gave a review of reference systems at IAU Symposium 141 on 'Inertial Coordinate System on the Sky' in Leningrad (now St. Petersburg again). Later in the decade, I gave an informal historical review of Project MERIT at an IERS workshop in Potsdam in September 1998 and a formal paper during IAU Colloquium 178 on 'Polar Motion' at Cagliari, Sardinia, in September 1999. The publication in 2001 of my report on the 3rd MERIT workshop marked the end of my participation in MERIT/IERS.

There were two scientific results that derived directly from the MERIT/COTES activities, which were aimed at not only improving the accuracy of the determinations but also at increasing the frequency of the determinations and at densifying the network

of stations. The first was that the short-period variations in UT were due largely to changes in the angular momentum of the atmosphere and the second was the demonstration that the current motions of the tectonic plates were largely in agreement with estimates made by geophysicists from geological studies. For the first of these we needed the support of meteorologists and Professor Raymond Hide of the Meteorological Office did much to encourage the necessary data collection and calculation. A permanent service for the computation of atmospheric angular momentum became part of the IERS. In recent years the name has been extended to 'International Earth Rotation and Reference Systems Service', but the acronym has been left unchanged.

6.3.4.5 Other national activities

Our involvement in satellite laser ranging and the rotation of the Earth led to our attending meetings concerned with geophysics and geodesy as well as meetings of the RAS. The Joint Association for Geophysics linked members of the RAS and of the Geological Society, which also had premises in Burlington House in Piccadilly. I believe that this organised the Geophysical Discussions that were held on the same day as the ordinary meeting of the RAS. In addition it sponsored UK Geophysical Assemblies that were organised annually, in turn, by universities with strong geophysical groups. These lasted 2 or 3 days with parallel sessions as they covered a large number of specialist topics. The timekeeping was, however, very strict so that it was possible to go from one session to another without missing the end of one talk or the start of the next.

I also attended some meetings of the Association of British Geodesists, but its role was taken over by JAG and it was wound up. I also spoke at a meeting of the Royal Institute of Chartered Surveyors. We also made a presentation at a 'Mason Conference' during the annual meeting of the British Association for the Advancement of Science in Glasgow in 1985. These meetings were intended to give the BAAS members the flavour of a meeting of a professional society, but we soon realized that we had to explain our work in considerable detail as only the other speakers were familiar with the background.

During such meeting I came to know geodesists in the Ordnance Survey and in the Department of Military Survey and, as a consequence, I was invited in 1979 to join the Geodesy Subcommittee of the Royal Society. I was unexpectedly nominated to be the chairman of the subcommittee in 1982. I accepted, but I was embarrassed when I realized that Alwyn Robbins, a Reader in Geodesy at the University of Oxford, had expected to continue as chairman. This position led to my becoming a member of the British National Committee for Geodesy and Geophysics (also within the Royal Society) and the chief UK delegate at the General Assembly of the International Association of Geodesy in Tokyo in May 1982.

6.3.5 The libraries and archives

The expansion of the activities on libraries and archives that followed the appointment of Janet Dudley in 1978 has been described in section 5.5.7. During the 1980s her enthusiasm and professionalism led to an even greater expansion of the work on the archives and it was sad day for the RGO when she resigned in 1987. She was joined by Jon Hutchins as a qualified assistant librarian in December 1981. Jon gave the first of a new series of lunch-time talks about the work in the RGO on 30 June 1982; his title was "Why librarians are not boring". He was promoted to Librarian grade in 1987,

but he left suddenly in 1989 before the move to Cambridge. Some students of librarianship gained useful experience in the RGO library; one was Nick Wyatt, who later joined the staff of the Science Museum Library.

The library was vital for the current work of the RGO, but its books and archives were a valuable resource for the history of astronomy and other fields of science, technology and even social history. Consequently, exhibitions of some of its holdings were prepared for display in the Castle and elsewhere. At the RAS Conversazione on 13 February 1987 there was an exhibition that linked William Herschel's original 40-foot telescope, which was first used in February 1787, to the new WHT on La Palma. A second display marked the centenary of the Astrographic Conference in Paris in 1887. An illustrated overview of the Library and Archives is given in the 1985 report.

6.3.5.1 Changes in the library services

The period saw further transfers of journals and books between the Castle and the various sub-libraries in the West Building, the Physics Building and on La Palma so as to make journals and books required for current use more readily available. Unfortunately, the sub-libraries were not supervised and stock checks revealed that many books were 'missing'. A listing of the holdings of periodicals was prepared and distributed widely. The library's book catalogue on index cards was transcribed so as to make an on-line catalogue that could be searched remotely and more quickly. This catalogue was mounted on a computer at the Rutherford Appleton Laboratory. Details about such changes, requests for missing books, etc., were given in the RGO Information Bulletins and Circulars and occasionally in *Gemini*; for example, an article by Jon on 'Libraries unlimited or Text retrieval in the machine age' was given in *Gemini 18*.

There were further sales of surplus rare books and the Airy Collection of rare books was transferred to new cabinets in the chapel in 1984.

The library became the custodian of artefacts of historical interest. Amongst them were copies of an ivory relief of a bust of the first Astronomer Royal, John Flamsteed. These were made by John Le Marchand, at the time of the RGO Tercentenary in 1975, from an original which was presented to the Observatory in 1777. Janet appealed for information about their whereabouts in February 1987. She must have been successful since she gave me one of the copies. There is an article by Adam Perkins on 'The treasures of the RGO' in *Gemini23*, and a short article by Robin Catchpole on 'Historical artefacts at the RGO' in the last issue of *Spectrum.* These artefacts were to go to ROG when RGO closed. The NAO had an arithmometer and various items relating to computation, but I do not know where they are now.

One of the casualties of the great storm (or hurricane) of 16 October 1987 was G. B. Airy's very large commemorative vase that stood on a plinth in the east end of the chapel. Unfortunately the glass skylight (which had wires across it to mimic the wires in a transit circle) fell on it and smashed it into small pieces. Subsequently, Rosemary Yallop drew attention to a report by Flamsteed of a hurricane in 1703 and Adam Perkins appealed for photographs of damage for the archives. Some are shown, with the meteorological records and with a photograph of the vase before it was smashed, in *Gemini 18*.

6.3.5.2 The conservation laboratory

Tony Bish's work in the new conservation laboratory (see section 5.5.7.1) did not attract much attention, but its worth will be appreciated by the historians of the future. He resigned in March 1984 to take up a more highly paid post at the Wellcome Institute in London and he was replaced by Ian Maver, from the University of Glasgow, who joined in October 1984. In November 1986 he spoke at a conference on 'photographic conservation' about the work done on the RGO collection of solar plates; his interesting report on the conference is in IB 85/12.

The conservation laboratory was moved to the SW turret of the Castle, above the kitchen, so that the first site could be converted to make more accommodation for visitors. The laboratory was not moved to Cambridge, but I believe that Ian was able to buy much of the equipment so that he could set up an as an independent conservator after taking VPR.

6.3.5.3 The archives and the Laurie Project

The Laurie Cataloguing Project was started in 1983 by the award of a grant of £36000 by the Manpower Services Commission under the Community Programme Scheme for the cataloguing of the RGO archives. The grant met the cost of employing a professionally qualified supervisor, 6 archive assistants and two administrative staff for a period of one year. The name recognised the major contributions to the archives made by Phil Laurie, who had died in 1982. The work was so successful that the project was continued almost up the move of the RGO to Cambridge. The supervisor, Adam Perkins, started work in the Castle on 11 April and the rest of the team started by the end of the month. Most (all?) of them were graduates who were pleased to get an interesting job and so they worked with enthusiasm. For the fourth year of the project the number of staff in the team rose to 18 and for the fifth year the grant was £800000.

A brief account of the first two years of the project is included in the 1985 report. The names of the members of the team are listed there, but their appointments were not given in the IBs, presumably since they were not employed by the RGO. I trust that the team kept full reports and staff lists for the archives! I believe that the team was based in the Castle, but where?

The main collection of documents was stored in the Castle. The older ones were in the room off the library landing and through which Janet Dudley passed to her office in the NW turret. Others were in rooms under the library. The astrographic plates, most of which had been moved from Greenwich, were in the EQ group, while the solar plates, also mainly from Greenwich, were in the newly converted atomic-clock cellar in the West Building. (See section 5.5.7.1) The archives of the NAO and Time Department were also moved there.

In addition to sorting and listing the documents the team carried out a variety of other tasks, including listing the large stock of solar and astrographic plates and prints. It carried out conservation work on documents and plates under the direction of Ian Maver. It prepared a series of educational work packs for schools on such topics as 'Voyages of Discovery', as well as on topics more directly related to the Observatory and the Castle. (See appendix F.2) It also started a sound archive based on interviews with long-serving members of staff. Adam Perkins gave a lunch-time talk about the archives and the project on 23 June 1986. He also gave talks to other local organisations. I cannot, however, find any published article by him or Janet about the

archives and the project, but I feel sure that some must be available! There are some items about individual aspects in the information bulletins and circulars. The final issue of *spectrum* contains an article by Adam on 'All Astronomers Royal: the legacy of Airy', but only a small part of this is about the archives themselves.

When the Castle was sold prior to the move to Cambridge, the archives and the team had to be moved from the Castle to the West Building. The Laurie project came to an end on 31 August 1988, but it was replaced by another (CHART) with a small team to deal with the relocation of the archives to the Cambridge University Library. A short article about the Laurie project by one of the team members, Andy Shaw, is attached to the Reporter sheet for item 88/89.

6.3.5.4 The use of the archives

There was a steady stream of visitors to the RGO to use the archives, and some of them used to have lunch in the canteen so that I got to know them. A few examples:

Dr John A Chaldecott, who had retired from the Science Museum and lived in Eastbourne (or nearby), came many times in connection with his work on scientific instrument makers of the 17th and 18th centuries and on other topics.

David Harries came about chronometers. He remembered me in 2001 when I gave a lecture to the Wiltshire Astronomical Society and he also remembered that we had attended the same school in Croydon, although he was there before me. My memory was not so good!

Derek Howse, author of *Greenwich Time and the Longitude*, was a frequent visitor.

David Hughes, from the University of Sheffield, came to study Edmund Halley as he was particularly interested in comets.

Professor Ed Kennedy, from Saskatoon in Canada, came in 1984 in connection with an interest in sunspots and related phenomena, but I recall his interest in surveying. The obituary in *A&G* 41, 2.36, mentions his interest in Airy and the Maine-New Brunswick border surveys. (Airy's assistants, Mason and Dixon, had surveyed the boundary between Canada and the USA.) My wife and I became friends with Ed and his wife Caroline, and they visited us in Devon after my retirement.

Lesley Murdin, wife of Paul Murdin, was occasionally employed as a short-term CO, but she also came to use the archives from time to time as she was particularly interested in the Flamsteed papers.

Others included Carole Stott from ROG, who later married David Hughes; Frank James, from the Royal Institution; and Patrick Wayman.

By far the largest and most-used class of the early archives is that for the Airy period. This reflects both his wide interests and his insistence on keeping copies of all his correspondence. One topic of particular interest is his involvement in the search for the planet (later named Neptune) predicted by J C Adams to explain the perturbations of the orbit of Uranus. The correspondence was found to be missing. Laurie had suspected that they had been taken by Eggen and so in 1981 Graham Smith wrote to him to enquire if he had any knowledge of the whereabouts of these and other papers that were missing. Eggen denied any such knowledge. The loss of the 'Neptune papers' was the subject of articles in astronomical journals in 1988 and later. (See appendix G.11)

Eventually the Neptune papers were found in Eggen's office at Cerro Tololo after his death in 1998 and were returned to the RGO archives with enough other archival material to fill three tea chests!

6.3.6 Other international activities

Throughout this period I was involved from time to time in international activities that followed from my participation in IAU Commission 5 on Documentation and Astronomical Data. I had been elected Vice-President of the Commission in 1979 and served the standard term of 6 years while Heintz Wolff was President. This did not require much action on my part, as far as I can recall, except that in 1985 I was asked to represent the IAU on the International Council for Scientific and Technical Information (ICSTI). This organisation had replaced the ICSU Abstracting Board in which the IAU had an interest because of *Astronomy and Astrophysics Abstracts* and *Physics Abstracts*, which contained much of interest to astronomers. I attended my first meeting in Baden-Baden in 1985.

I also attended other ICSTI meetings, including general meetings in York in 1986 and New York in 1987. I also arranged a meeting of the ICSTI Numerical Data Group at the RGO in December 1986. It seemed to me, however, that the activities of ICSTI had little relevance to the IAU and, on my recommendation, the IAU discontinued its affiliation after 1987. I renewed my link with CODATA and attended its confrence in July 1986 in Ottawa, where I presented a poster paper about the data activities in Project MERIT.

I became President of Commission 5 at the IAU General Assembly in Delhi at the end of 1985. By this time the attendance by librarians had fallen away, but Brenda Corbin, from USNO, and Robyn Shobbrook, from AAO, were present and convinced me that the Commission should try harder to keep up its links with librarians and documentation. In 1979 the Commission had taken over the role of the Working Group on Numerical Data and its meetings had become increasingly dominated by this type of activity. Moreover, librarians had found it more difficult to obtain funds to attend the meetings since so little of the discussions were related to their interests. As a consequence I obtained the agreement of the IAU Executive Committee to the holding of IAU Colloquium 110 on *Library and Information Sources in Astronomy (LISA)* at the time of the next General Assembly, which was to be at Baltimore in 1988. In addition Brenda obtained the support of Gart Westerhout, the Scientific Director of USNO, to holding the meeting at USNO in Washington during the week before the GA. This meeting proved to be extremely successful and led to a series of such meetings. I edited the proceedings of LISA 1 with Sarah Stevens-Rayburn of the Space Telescope Science Institute at Baltimore, and after my retirement I attended LISA 2, which was held in 1995 at the headquarters of the European Southern Observatory, near Munich. (Incidentally, I stayed at the home of Bob and Tricia Fosbury, who had worked at RGO, even though they were away most of the time.) The later meetings were not, however, held close to the IAU GAs and so only a few astronomers attended them.

While I was President I used to prepare and distribute a newsletter about activities by, or relevant to, the Commission. I suppose, however, that my most significant contribution was the preparation of a completely revised version of the *IAU Style Manual*, which was published as Chapter 8 of the *Transactions of the IAU* for the 1988 GA and made available as a separate booklet. The manual was dedicated to the memory of Donald Sadler as he had been responsible for the original version when he

was the General Secretary of the Union and edited the Union's publications. It was hoped that the manual would also be used by other astronomical journals but, unfortunately, Helmut Abt, the editor of the *Astrophysical Journal*, objected to the standard international recommendations for the abbreviation of the names of journals in references. He used the very short forms that are understood by astronomers, but not by readers from other disciplines. A meeting of editors of astronomical journals was held in Paris in May 1988, before the new manual was ready; Abt pressed his view and most other editors followed his lead.

After my retirement I attended the IAU GA in Buenos Aires in 1991, while I was still President of Commission 5, and the IAU GA in La Hague in 1994. I was then chairman a small working group on the revision of UDC 52. I spent a lot of time on this project, and some short papers were published in 1994 and 1995, but the detailed proposals went into a black-hole at the British Standards Institution and I abandoned the project. I also attended the IAU GAs in Kyoto in 1997 and Manchester in 2001.

6.3.7 Administration

Bob Gordon continued as head of the Administration Division until his retirement on medical grounds at the end of October 1984. His role as the Secretary of the Observatory had, however, been taken by Peter Davies. My understanding is that Davies dealt with policy, while Gordon supervised the day-to-day running of the Division. The 1985 report shows that Davies formally became head of the Division and Gordon's role was taken by Jim Sadlier in a lower grade than Gordon. The 1985 report distinguishes between 'general administration', headed by Sadlier, and 'scientific administration', with many fewer staff but headed by Peter Andrews in a higher grade. These activities are described under 'public relations' in section 6.4.1. The structure chart in the report also shows 'Herstmonceux site services' within the Administration Division, but no staff are listed under this heading; the staff of the 'Works Unit' are, however, listed under general administration

In the 1987 report the responsibility for the grounds is included in scientific administration, but the works unit is no longer shown. This report also shows a 'Relocation Officer', P J Bradbury, with the same grade as Sadlier.

Canteen. The staff canteen was privatised in January 1985 and some of the staff transferred to the new organisation. Miss Margaret J Brett, who had been on the staff when I joined in 1951 and who had risen to become Supervisor in the report for 1979/80, is, however, shown as a messenger in the 1985 and 1987 reports. A cafeteria service for the public was started in what had been the garages by the West Entrance of the Castle. A trolley service was introduced in the West Building, but it was withdrawn in October 1988. The contract for the canteen terminated at the end of 1988. A six-course Christmas lunch (costing £5.50) was served on 21 December in the Ballroom, rather than the dining room. It was announced that a new service would start in the West Building, but there was change of mind and it continued in the Castle until this was vacated at the end of April 1989. The new service offered take-away fish and chips for 99 p on Fridays! The public cafeteria was used for staff lunches when the Castle was vacated at the end of April 1989. There was, however, an unexpected delay and some staff went hungry on 2 May.

Safety. I was chairman of the RGO Safety Committee from 1982 to 1988. We had an enthusiastic safety officer, Alfred Heath, who had come from RAL in 1978 and who

also served as training officer for a while. By 1985 A D White had replaced Heath, who did not retire until October 1986.

Training. The 1985 and 1987 reports do not, however, show anyone with specific responsibilities as a Training Officer, although two such part-time positions are shown in the 1979/1980 report. Talks on topics related to the work of the RGO were given from time to time in the lunch-hour.

An innovation was the series of "RGO Lectures" on non-astronomical topics. The first was given in October 1988 by Dr Hellen Rendell of the University of Sussex on "Dating human evolution: early man in Pakistan". It was given at 3.30 pm in the conference room in the Castle; all staff were 'welcome to attend, provided supervisors agree', but clearly not all were expected! The second was given in January 1989 by Dr. Michael Rycroft of the British Antarctic Survey on "The springtime Antarctic depletion". The third was given in the Clubhouse in July 1989 by Professor Margaret Boden of the University of Sussex on "Artificial intelligence".

6.4 General activities in 1981 to 1990

6.4.1 Scientific administration and public relations

Public relations became a much more prominent activity under Boksenberg although it was disguised under the term 'scientific administration'. Whereas the supply of information to the public used to be dealt with on a part-time basis by one person (see section 5.5.8.5), seven persons are listed for this activity in the 1985 report, which includes further information about it. One of them, in a non-complement position, was Nigel Henbest, who became Heather Couper's partner in the production of many books and television programmes.

One innovation was the introduction of a programme for "Artist and composer in residence", later called 'vision and sound residencies', whereby the South East Arts organisation funded posts for artists to produce works of art that would result from the stimulus of the scientific environment of the RGO. The initial period was for six months from 1 April 1987 for the composer Ron Geesin (of *Sunday, Bloody Sunday*) and the artists Susan Gamble and Michael Weynon. The scheme appears to have been extended for a further six months as the two artists returned in June 1988 to say goodbye to those who had helped them or shown an interest in their work. Their activities are described in two articles in *Gemini 17*.

The observatory on La Palma and new discoveries in astronomy attracted the attention of the media and so RGO staff were involved in radio and TV programmes about them. Many of them are noted in the IBs. Even the archives of the RGO attracted media attention as Adam Perkins spoke about them on Radio Devon in March 1989.

6.4.1.1 The Castle as a visitor and conference centre

The annual Herstmonceux Conferences were held in the Long Gallery (Ballroom) and they are listed in the last issue of the RGO house journal s*pectrum*. Smaller short meetings, such as the joint seminar with the University of Sussex, talks by visitors and training lectures were given in the former chapel. The West Building Canteen was brought into use for such meetings after all the astronomers had moved

from the Castle. Boksenberg decided, however, that much more use should be made of the Castle as a conference centre. New antique-style tables and chairs were purchased for the Lady's Bower room, which had been converted for use as lecture theatre (see section 5.5.8.2). This room was accessible either from the Staircase Hall or the grand staircase in the centre of the east wing. The Lady's Bower window gave a view over the moat and towards the Equatorial Group. Many of the events were for small groups of UK participants, but some were for international workshops. It was also used for appropriate RGO meetings. The adjacent smaller room that had been used by the typing pool was used as an ante-room for poster displays. In addition, improvements were made to the accommodation for visitors.

My recollection is that the panelled room that had been used as lounge by Sir Harold Spencer Jones was used for occasional meetings by the SERC Council, Boards and committees. IC 83/04 mentions the completion of a lecture room on the ground floor; this may been previously used for the conservation laboratory or perhaps it was where Spencer Jones had his very large office.

Workshops. Most of the workshops were for astrophysics or instrumentation and are listed in the 1985 report, but the A&T Division organised several meetings to make use of this attractive facility. The international meetings were:

the second MERIT Workshop in May 1983;

a meeting of the European group for laser ranging to satellites (EROS) in March 1984;

the fifth International Laser Ranging Workshop in September 1984;

a meeting of the ICSTI Numerical Data Group in December 1986; and

a conference on celestial mechanics in September 1987 to mark the 300th anniversary of Newton's *Principia*;

while the UK meetings were:

a workshop on dynamical problems in the Solar System in September 1983;

a summer school in space geodesy in September 1984; and

two meetings on Project Longstop (for long-term integrations of the motions of the planets) in October 1984 and March 1985; and

meetings for artificial-satellite observers (mainly amateurs) in March 1985 and September 1987.

The closing dinner of the MERIT Workshop was held at the nearby White Friars Hotel, while that for the celestial mechanics conference was held at Drusilla's, near Wilmington.

Exhibition. The exhibition in the north wing of the Castle (see section 5.5.8.4) was improved and continued to provide some public access and views of the inner courtyard. Otherwise, public access to the Castle was normally limited to events in the Long Gallery, which was reached by the west entrance and the library staircase. Some outside organisations were allowed to arrange musical concerts and other such events in aid of charity. In September 1983 the Men of the Trees held their AGM and Jim Clark, the Head Gardener, and I spoke to them. (I was a member.) In September 1985 the Women's Institute was allowed to hold a major event that involved several rooms in the Castle and stalls in the gardens.

The exhibition, apart from the section on the history of the Castle, was transferred to the Equatorial Group and was formally opened in May 1986 by the Spanish Ambassador. Visitors were allowed to see some of the telescopes. A travelling exhibition to mark the 20th anniversary of the establishment of SERC was mounted in the Equatorial Group and 1200 invited schoolchildren came to see it and various parts of the RGO.

Other events. The Federation of Astronomical Societies held its annual meeting in the Castle from 1981 onwards. Lectures were given in the Long Gallery and Clubhouse, while the dining room was used for trade stands. I recall a Solar System display in the courtyard and a colourful comet banner over the door of the library. The participants were given the opportunity to see various aspects of the work of the Observatory.

The Nature Trail was also improved by the provision of more signs around the 2-km walk and by the inclusion of new waterfalls and rock pools. More material was provided for teachers and school parties were encouraged to visit the Castle and its grounds. A workshop for teachers was held in January 1984.

Radio and TV science-programme makers came from time to time. The Castle and its grounds were also sometimes used as settings for scenes in films that had no connection with astronomy.

“The John Dunn Programme “ of BBC Radio 2 was broadcast live from RGO on Monday, 1 April 1985. It included interviews with about ten members of staff. A photo by Norman King in IC 85/05 just shows me being interviewed beside the SLR telescope. Shortly afterwards BBC Radio 1 held a “Family day out” on Bank Holiday Monday, 27 May 1985, in the grounds and thousands of visitors were expected. There was a live broadcast of the Radio 1 Roadshow during the afternoon. .

A display of hot-air balloons was held at the Castle on 19-20 September 1987, but unfortunately the weather was unfavourable and some of the twenty balloons did not fly. Another show was held in the following year on 17-18 September 1988.

6.4.1.2 National Astronomy Week & Comet Halley

National Astronomy Week was held in November 1985 at a time when Comet Halley was in the northern sky and approaching its perihelion passage in the southern hemisphere. Special arrangements were made to allow members of the public to observe the comet through the Yapp telescope. A special exhibition with historical material from the RGO archives was prepared and this was also open during the day. Images of the comet were obtained on La Palma and were shown on TV programmes. Members of the staff gave talks and were interviewed for radio broadcasts. There were nearly one thousand visitors. The EQ Group also featured on a special postcard and a first-day cover to accompany the special Comet Halley stamps.

A display from the RGO’s archives and rare books was mounted at the Royal Institution in October 1985 to accompany a lecture by Carl Sagan about Comet Halley.

6.4.2 Various staff matters

During this period many members of the RGO received honours and awards of various kinds and I have attempted to compile a list of them in appendix C.8. The

highest civil honour was an OBE to Paul Murdin in the 1988 New Year Honours. A summary of his career was given by Chas Parker in IB 88/02. The former Director, Graham Smith, was made Astronomer Royal in November 1982 and an account of his career is given in *Gemini 5*. After his knighthood in 1986 he became known as Sir Francis.

Some members of the staff also served as officers of the Royal Astronomical Society or of other such societies. For example, Gordon Taylor, who took VPR from the NAO in 1984, was appointed Director of the Computing Section of the British Astronomical Association in 198?; he is still in that position in 2009. I served on the Council of the RAS for a second term of three years in 1983/1986 and then as a Vice-President for one year, 1986/1987. I also served on its Library Committee. In March 1987 Heather Couper, who was then the President of the BAA, and I arranged a joint meeting of the RAS and BAA on the interactions between amateur and professional astronomers; several members of the RGO took part.

The retirements of several staff who had served for long periods are included in a list in appendix C.7. For most of them brief details of their careers are given in the IBs or in *Gemini*. Sometimes, photographs taken at the retirement presentations and/or parties were reproduced, rather poorly, in the IBs. For example, Bill Nicholson, who had served for 10 years as the secretary of the RGO Club, retired on 11 May 1986 and was given a farewell party, with a kissogram girl and a descriptive poem, in the Clubhouse. The deaths of staff-in-post and of retired staff are also noted in the IBs and in appendix C.13.

The RGO Club continued to play an important role in providing sports and social activities for its members and helped to keep up the morale of the staff even when faced, first of all, with the cutting of staff numbers and, later, with the relocation to Cambridge. An account of the Club activities is given in appendix D.

6.4.3 Other events and activities

There was some severe weather in January 1987 as the February IB starts with “Phew! What a freezer!”. It appears that roads were blocked by snow for a while. Later that year the ‘hurricane’ of 16 October caused much damage in the grounds, as well breaking Airy’s Vase. There is an article with charts and photographs in *Gemini 18*.

The Chronometer Department, which was no longer part of the RGO, was closed in 1986 and the work was transferred to a contractor. A note by Bert West is reproduced in appendix B.4. Its workshop on the top floor of the West Building, with its north-facing windows, was taken over by the drawing office. See also the notes by Bill Roseman that are listed in appendix G.1.3.

6.5 The relocation to Cambridge

The Information Bulletin for October 1986 started with the heading RELOCATION REPORT, and it reviewed the actions that had already been taken by SERC in advance of receiving the formal approval from the Department of Education and Science and the Treasury. The outline timetable for the construction of the new building at Cambridge envisaged that the move would start at the end of 1989. From then on information about relocation matters was promulgated in a series of 11

Relocation Bulletins between 17 October 1986 and 5 December 1988, and then in individual paragraphs in the *Reporter*.

For convenience I kept a 'personal set of papers' that supplemented (and partly duplicated) the official papers in the A&T Division files relating to the relocation. The following sections have been written from memory with only occasional attempts to verify the statements that are included.

6.5.1 Administration

A major change in the structure of the Administration Division was made on 1 September 1988. Jim Sadlier remained head of general administration and a new SEO, Peter Bradbury, was put in charge of 'relocation and site disposal'. The latter included the staff for the Castle, grounds and exhibition who would not be needed in Cambridge. A new structure chart was issued in March 1989.

6.5.2 Castle

The SERC needed to recover the costs of the move to Cambridge as soon as possible and so it was envisaged right from the start that the buyer might wish to occupy the Castle and much of the estate before the move was completed. Ray Foord, who had taken VPR in 1984, was temporarily re-employed to look into the implications of this possibility. The Castle was put on the market in May 1988 and the sale to James Developments was announced on 21 October 1988. The guide price was between 6 and 10 million pounds, but the agreed price was not stated. The developer intended to build a championship golf course and other leisure facilities, while the Castle would be used as a hotel. The purchase of the Castle and most of the grounds, including the EQ Group but not the West Building, was to be completed in May 1989. Most of the activities in the Castle had ceased by the end of 1988; for example, accommodation was no longer provided for short-term visitors. All use ceased at the end of April as the developer formally took possession on 2 April 1989.

In addition to the West Building and SLR dome, the hand-over arrangements allowed for the continued use of the cafeteria by the Castle, of the EQ Group, of the outdoor sports facilities and of the Clubhouse. Staff could also continue to walk around the gardens in working hours. The west gate was closed at night, but staff could enter by the east entrance by opening the barrier with their APT cards.

The requirement to vacate the Castle in advance of the main move meant that much effort was wasted in moving facilities and staff to the West Building. Other materials became surplus to requirements and so were sold at knock-down prices, as is shown by the price list for bedlinen. The editors of *The Observatory* were forced to dispose of their stock of back issues of the magazine, including some long runs, and offered them to staff, but most were scrapped.

The Royal Commission on Historical Monuments took the opportunity to make a photographic record of the Castle.

The last public opening of the Castle and grounds took place over 10 days in April 1989 with a total attendance of 9000 visitors. A craft fair was held in the Castle over the weekend and there were 4000 visitors.

A "Farewell to the Castle" party was held during the evening of Saturday, 22 April 1989. Current and former members of the staff were invited to bring one guest.

Food and some drink was provided, and pay-bars were available. Some photographs taken at the party are to be seen in *Gemini 24.* I have been surprised to see that it includes a photograph of me with Marcia King (wife of Norman, with whom I had won the SERC men's doubles tennis tournament), Jean Nicholson (wife of Bill, with whom I had shared a room in the NAO for many years) and my own wife, Betty. The photographs were probably taken by Norman King as he was a keen photographer. Over 500 past and present staff attended with their guests.

I do not know the fate of the many paintings and other objects of historical interest in the Castle. I trust that those relating to the RGO were taken to Cambridge or transferred to ROG, but I suppose that those relating to the Castle may have been sold to the developer.

6.5.3 Library and archives

The decision to move the RGO to Cambridge had major consequences for the library and the archives. Initially it was stated that that "it remains the intention of the RGO to maintain the archive in its building at Cambridge", but in the event the archives were transferred to the care of the Cambridge University Library. Nothing was then said about the future of the library, which was then probably the finest astronomical library in the world, and in the event it was split into several parts.

The decision to move to Cambridge, coupled with the disciplinary proceedings, probably prompted Janet Dudley to apply for the post of Head Librarian at the Royal Signals Research Establishment at Malvern. She was successful and the RGO was the loser. A special lunch was held in the Ballroom on 13 May 1987 to mark her move and Ron Geesin, the composer in residence played "Janet's passion" in her honour on a xylophone. I believe that Jasper Wall made a presentation from the staff and Joy Hamblyn presented her with a bouquet from IPCS. Jon Hutchins became librarian (and was promoted) and Adam Perkins, as head of the Laurie Project team, became fully responsible for the archives. Peter Andrews was given responsibility for the oversight of the library and archives from April 1989, when my responsibility for the ASD Division ceased. Shortly after this Hutchins resigned suddenly and two temporary assistants (wives) were appointed. Another qualified librarian, Ingrid Howard, was eventually appointed.

The Laurie Project office was moved to the West Building in August 1988 but the project stopped at the end of the month. A small nucleus of the team, led by Andy Shaw, formed a new group, known as the Cambridge Herstmonceux Archives Relocation Team (CHART), to deal with the move of the hundreds of boxes of documents and of the solar plates. Not surprisingly, Shaw left the RGO in March 1989 when he had the opportunity to work at the County Records Office in Lewes. The archives in the Castle were transferred directly to the Cambridge University Library by April 1989, but those held in the West Building were not moved until later

In May 1989 all staff were "advised to make an immediate start on the task of weeding through their office contents, disposing of as many items as possible to archives, stores, the library or the dustbin". This led to a later instruction that "Adam Perkins should be consulted on what should be archives". I suspect that historians of the future will find more gaps than usual in the records of the work for this period.

The accommodation provided for the library in the new building was quite inadequate and so the librarian had the difficult task of deciding which books and

journals should be taken to the new building, which should be passed to the Cambridge University Library and which should disposed of in some other way. In the meantime, some of the stock was moved from the Castle to the West Building and made available in the old ICL computer area of the NAO spur, but the rest was put into boxes to await the removal to Cambridge. Surplus back numbers of astronomical journals were offered to staff and the stocks of RGO publications were drastically weeded. Some material must have been 'lost' in the move as I found copies of a computer journal from the NAO library for sale in a bookshop in Eastbourne.

6.5.4 EQ Group

My understanding is that the SERC failed to make any explicit provision for future of EQ Group and merely relied upon the intentions of the developers, as stated in their press release in October 1988, "to establish the continued and probable increased use of the scientific buildings and their equipment, in order to attract and expand worldwide public awareness and participation in science and industry". (The draft press release is on the back of IC 88/129.) The press release referred to discussions with Professor Richard Gregory of the University of Bristol, who was responsible for the science exhibition centre (The Exploratory) in Bristol. He and Patrick Moore had visited Herstmonceux on a beautiful day in May 1988 and were shown around by Paul Murdin, Chris Benn and myself. Public access to the Group and to the exhibition in it continued more or less as before, with ex-members of the RGO acting as stewards.

I do not know what conditions were attached to the empty INT dome, which lay to the south of the EQ Group. I have a recollection that there was a proposal in the 1980s that it should be demolished, but this was rejected as it was said to be a navigational aid for shipping in the English Channel. The dome and was fitted with a retroreflector so that it could be used in calibrating the SLR system.

6.5.5 Astrodynamics

6.5.5.1 H. M. Nautical Almanac Office

The proposal for the NAO after my retirement envisaged a considerable reduction in staff. I feared that such a small group would not be viable and that it would be better if the production of the almanacs were to become part of the responsibility of a larger group within the RGO. This would imply, however, that it would be inappropriate to retain the name of the Office. Accordingly I drafted a proposal along these lines and passed it for comment to Bernard Yallop, who was expected to take full responsibility for the almanacs when I retired. He was, however, very much in favour of keeping the name, and so I changed the thrust of my draft. I passed the revised version to Andrew Sinclair, who was the other PSO in the NAO, as well as to Yallop. Sinclair, who had not seen the original draft, argued that the name should be dropped "while we all have respectful memories of the achievements of the Office". I decided, however, to stay with Yallop's view as Sinclair was expected to move out of the NAO to take charge of the SLR team. My memorandum prompted the following comment from Boksenberg: "I consider that there is a good long-term prospect for the work of the NAO and its development. My decision is to retain the name of the Office in full and I wish to encourage the exploitation of its potential".

6.5.5.2 Satellite tracking

King-Hele and I (with the backing of others outside the RGO) continued to argue for the retention of the SLR system at Herstmonceux even after the SERC had decided that the RGO should move to Cambridge. The original suggestion was that the system should be moved to Cambridge and I was disappointed to find that Andrew Sinclair, who would be in charge of it, was resigned to such an action. We were, however, able to convince SERC that it should stay in place. The main arguments for this were as follows. Firstly, the value of maintaining the continuity of the observations from the same site so as to improve the accuracy of the measurements of the coordinates and motions of the site with respect to other SLR stations; such results were used in the improvement of the International terrestrial reference frame and in studies of the movements of the tectonic plates. Secondly, the fact that we had shown that good results could be achieved at Herstmonceux, whereas the weather conditions at Cambridge were much poorer. Thirdly, that the move would involve a loss of observations for some considerable period, especially if the experienced staff did not move to Cambridge, and that the costs of a new building, and possibly of new equipment, would be considerable and unnecessary. I was also concerned that the project would be abandoned once the Herstmonceux system had been dismantled. There was also a suggestion that responsibility for the system should be transferred to the Rutherford Appleton Laboratory, but this was rejected by the SERC Director for Laboratories. The developers agreed to the operation of the SLR being continued for up to 15 years.

The RGO took over from the University of Aston on 1 April 1988 the responsibility for the operation of the Hewitt cameras at Herstmonceux and at Siding Spring Observatory in Australia, but the project was expected to stop in March 1990. The Australian camera was used by another group for a few more years.

6.5.6 Other instruments and equipment

The PZT and RTC in the Spencer Jones (Meridian) Group had already been taken out of action and had been mothballed. The PZT and its control panel are now held by Science Museum in a store. The control panel for the Greenwich Time Service is also there, perhaps with other Time-Service equipment, such as the phonic motors that transmitted the 6-pips signal to the BBC, and the display cabinet containing early valves and other such items of historical interest. Some of the caesium frequency standards went to the SLR.

The occultation machine that had been used by the NAO for the prediction of occultations by the Moon was transferred to ROG, although the earlier version of the machine is held by the Science Museum.

Surplus machines from the Engineering Workshop were sold and I suppose that the VAX computers and similar items were sold for scrap.

I do not know what happened to other substantial items of equipment but I hope that information will be on file in the archives. It would be interesting to know, for example, what happened to the GALAXY measuring machine; as far as I am aware, it did not go to Cambridge for use there and I have not found any mention of it in the information circulars or in the last issue of *spectrum*.

Many minor items of equipment were offered for sale. For example, I bought for a small sum a Brunsviga mechanical calculating machine. The short period allowed for the move did not allow for proper consideration of the historical and commercial value of such items. I do not know what happened to items that were not bought by the staff.

6.5.7 University of Sussex

One of the arguments for moving the RGO to a new site was so that it would benefit from interactions within a university. This ignored both the value of the existing strong links with the astronomy centre of the University of Sussex and the deleterious effects of a move on the astronomers of the centre. The last joint seminar was held in what had been the West Building canteen on 23 February 1990, when Professor McCrea spoke on “Mind and the Universe”.

6.5.8 Effects on the staff

The work of the staff of the Observatory throughout most of the 1980s was affected for the worse by the uncertainties about whether or not their jobs were secure and about whether or not they would have to move, either to La Palma or to a university city or to a new job elsewhere. Time was taken up in reading and discussing the proposals and in trying to understand the various regulations concerning redundancy and transfers, as well as in the grass-roots campaign “to save the RGO”. In addition, much of the effort of senior staff was spent, not in planning the scientific and technical work nor in thinking about theory or observational results, but in reading, discussing and writing reports and memoranda related to the future of the work of their groups or of the RGO as a whole. Consequently, during these years the scientific output of the Observatory must have been considerably less than would otherwise have been the case.

Staff who saw their jobs at risk, in either the short or long term, were faced with the options of resignation if they could find another job, or of VPR if they were eligible, or of transfer to another establishment in SERC or the Civil Service generally, or of being given redundancy terms. The issues of the *Reporter* show that many good staff chose to resign. Some staff made early moves to Cambridge, while others found jobs with the developers at the Castle. A small number of staff stayed with the SLR at Herstmonceux, and they included some who had not previously worked in the team. Some of the staff whose jobs moved to Cambridge decided to keep their homes in Sussex, especially if they were expecting to retire within a few years. But others wished to avoid the upheaval of a change of house and garden and the loss of contacts with relatives and friends or they did not wish the members their families to have to change schools or jobs where they were well established. The results in June 1989 of a survey of ‘mobile staff’ who would be expected to move to Cambridge showed that only 38 out of 70 intended to transfer, although a further 9 would go if the transfer terms were sufficiently favourable and others were expected to go if their other options failed. Even so, it was “clear that there will be some shortfall of staff transferring to Cambridge”. As a consequence, it is likely that the productivity at Cambridge was low for some time after the move was nominally completed.

The chairman of SERC visited the RGO on 18 May 1989 and he had the courage to talk to the staff after lunch! The meeting was in the Clubhouse as none of the meeting rooms in the West Building were large enough.

6.5.9 New building at Cambridge

The new building at Cambridge was not in a prominent position on the Madingley Road as Boksenberg had hoped, but instead was relegated to the back garden of the Institute of Astronomy. The foundation stone was laid on 27 October 1988 and staff were later offered free copies of photographs of the ceremony!

The Tercentenary Sundial was also moved from its place in the garden at Herstmonceux to Cambridge and a member of the staff gave me a copy of a photograph of it on the back of a lorry being driven up the lane to the village! I next saw the sundial in the yard at Cambridge and it was sometime before it was re-erected in a suitable position. It has since been returned to the formal garden at Herstmonceux Castle.

6.5.10 Changes and events on my retirement

Although I was not due to retire until 4 July 1989, it was decided that I should give up my responsibilities as Superintendent of the NAO and Head of the ASD Division at the end of March. (Incidentally, I had previously refused an earlier oral invitation to take voluntary premature retirement!) Bernard Yallop became Superintendent and Andrew Sinclair became Head of the Space Geodesy Group. John Pilkington continued to be in charge of SLR operations and the remaining activities of the Greenwich Time Service, but he moved to new duties at Cambridge. Paul Murdin took the NAO and Space Geodesy into the ASR Division, while the Library and Archives were transferred to Scientific Administration. I was grateful to Bernard for the continued the use of my room, with its views over the Pevensey Levels, until the final move took place in April 1990.

Just before my retirement I gave a talk entitled “The RGO at work and play: 1951-1981” giving a personal view of the events and changes during that period. It was given at 3.45 pm in the Clubhouse and all staff were invited to attend. I also wrote an article on “Nearly 40 years at the Royal Greenwich Observatory”, which was published in *Gemini 23*. The Club organised a lunch in the Clubhouse on 3 July and I was presented with various mementos of the RGO and Castle as well as a substantial cheque. Betty received a bouquet. We have a booklet of photographs and signatures, many with goodwill messages. I was surprised to be given a large photograph by Norman King of the Castle in sunshine with a black cloud behind it; this is now on the wall in our lounge. The cheque was used to buy an unusual globe of the Earth. When set and illuminated it shows correctly the boundary between day and night and the various levels of twilight. Another event to mark my retirement was attendance with my wife at a Garden Party at Buckingham Palace.

I continued to go to the Observatory regularly, but I gradually transferred surplus copies of information bulletins and memoranda, as well as my personal copies of books and journals, to my garage at home. The former have since proved to be invaluable in the writing of this account. I paid £10 for some racking, which I re-erected in the garage and which I later moved to the garage at our new home, Windward, in Sidford, Sidmouth, in Devon. My last visit to the West Building was in the late afternoon of 4 April 1990 when I left some correspondence and notes for posting and distribution internally before clearing my files on the VAX computer. In the evening I played my last table-tennis match for the RGO Club versus Saffrons T T Club; I was pleased to record that we drew 5-5 and that I won two sets!

7 THE MOVE TO CAMBRIDGE AND CLOSURE – 1990 TO 1998

7.1 Introduction

Some staff moved to Cambridge during the autumn of 1989 and the move was completed during April 1990. I do not appear to have any notice about the final timetable and arrangements. The new building was formally opened by the Duke of Edinburgh on 14 June 1990. A coach was provided to take invited ex-staff from Sussex to Cambridge and lunch was served in a marquee in the grounds. It was cloudy, but dry. We were able visit the adjacent Institute of Astronomy (via a connecting corridor) as well as to look around the new building. I also took the opportunity to deal with some incoming and outgoing correspondence.

I subsequently visited the RGO while I was in Cambridge to work on the RGO archives in the Cambridge University Library or for other reasons. My visits were brief and I spoke to only a few members of the staff, but my general impression was that those who had moved their homes were quite happy with their new surroundings and life in a university environment. Andrew Sinclair, for example, felt that the move had had positive results. Not unexpectedly on the other hand, those who had left their families in Sussex were resentful of the disruption of their lives that the move had caused. The flexible working hours arrangements were stretched so that such staff need spend only 4 days in Cambridge each week, this was poor compensation and retirement was eagerly awaited.

Since I made only short visits to the RGO and did not have direct involvement in its activities this chapter contains only brief notes on a selection of the activities of the observatory during this period, which was unexpectedly brought to an end by the decision to close it completely. It had been widely assumed that the move from the historic castle, the drastic cuts in the levels of staffing and the success of the La Palma operations would free the RGO from the succession of reviews that had dominated the previous decade. Unfortunately this was not to be the case, as the costs of providing and operating top-quality observing facilities overseas rose faster than the funds that were made available by the government as it favoured applied research over ‘blue-skies’ research on which it could not see any immediate return.

One of the actions of the government was to split (in 1994) the Science and Engineering Research Council into the Engineering and Physical Sciences Research Council (EPSRC) and the Particle Physics and Astronomy Research Council (PPARC). By this means it could determine the relative levels of the research funding without having to interfere directly in the running of the councils. This left ground-based astronomy in direct competition with the particle-physics and space-research communities, both of which participated in very expensive international projects in CERN, ESA and NASA. Moreover, it appears that the administrators and many of the university members on the committees took the views that it was wasteful to have two Royal Observatories responsible for supporting the overseas facilities and that universities gave better value for research-council funds since their overheads were met, at least partially, by other funding agencies.

7.2 Reviews of policy by SERC and PPARC

The next review of the future of the RGO started within less than one year of the move to Cambridge and in 1991 the 'Hughes Panel' of SERC recommended that the RGO and the ROE should have a unified management structure with both observatories under one director. This idea was extended in 1992 when Boksenberg was given the oversight of both of the Royal Observatories and also of the Joint Astronomy Centre on Hawaii and the Isaac Newton Group on La Palma. This arrangement was, however, short-lived as the PPARC panel for the 'strategic review of optical infrared and millimeter astronomy' recommended in 1995 that the island sites should be given greater autonomy and that an Astronomy Technology Centre should take over the functions of both RGO and ROE. As a consequence Boksenberg moved to the Institute of Astronomy and Jasper Wall became the Director of RGO in November 1995.

The decision on the site for the Astronomy Technology Centre took longer to resolve, but in July 1997 it was announced that it would be at the ROE. The RGO was encouraged to develop a proposal for it to become an independent institute that would be funded by contracts from research councils and from commercial activities, such as the development and sale of robotic telescopes. The Council of PPARC rejected the proposal in December 1997 and decided that the RGO should close at the end of October 1998. Protests by almost the whole of the astronomical community, including the Astronomer Royal, then Martin Rees (*A&G 39*), and by many others were ignored and so the arrangements for the continuation of some of the activities and for the disposal of its assets had to be made in an incredibly short time.

7.3 Activities at Cambridge

The principal activity of the RGO at Cambridge was the support of the telescopes of the Isaac Newton Group on La Palma, but in addition some RGO staff were involved the new Gemini project. This involved the construction of two 8-m telescopes, one of which would be set up in Hawaii, while the other would be in Chile. One minor consequence of this project was that the RGO house journal *Gemini* was renamed *spectrum*. Articles about this project and of the development of instruments for La Palma are given in the final issue of *spectrum* for October 1998. There are also articles about other aspects of the work such as is shown by the following summary of the contents. Further details are given in appendix F.6.

The RGO 1978-98; A Personal View. Jasper Wall, Director, 1995-1998.

Gemini - RGO's Contribution. Neil Parker.

Report of the ING Visiting Panel, April 1998. Rene Rutten, ING.

Prime Time Telescope Stories. Sue Worswick.

RGO CCDs - Review, Highlights and Update. Paul Jorden, Paddy Oates, Percy Terry.

The Evolution of Computers at the RGO. Ralph Martin.

The INT Wide Field Camera. Derek Ives, ATC (formerly RGO).

Fun and Games with WYFFOS/AUTOFIB-2. Terry Bridges, IoA (formerly RGO).

Extending the Wavebands at ING. Shaun Hughes, IoA (formerly RGO).

RGO, AAO, and the City of London. Paul Jorden.

The ING Archive and RGO Data Centre. Jim Lewis and Ed Zuiderwijk.

Astronomy Research at the RGO. Max Pettini.

A Staff Photograph 1996.

The Herstmonceux Conference Series. Margaret Penston.

RGO Preprints. Julie Loaker.

Holding the PATT baby. Bill Martin.

Towards a 3D Stellar Reference Frame. F. van Leeuwen.

The UK Satellite Laser Ranging Facility. Graham Appleby.

Eclipses and the Rotation of the Earth. L. V. Morrison (RGO) and F. R. Stephenson (Durham University).

The NAO - Past and Present. Catherine Hohenlerk.

New Generation Robotic Telescopes. Anon.

All Astronomers Royal; the legacy of Airy. Adam Perkins.

Historical Artefacts at the RGO. Robin Catchpole.

Public Understanding of Science. Margaret Penston.

The Interview. Margaret Carter (ex-RGO) and Robin Catchpole.

Spelling Existence. A poem by Anne Reynolds.

The Equatorial Group, Herstmonceux, 1958-63. Derek Jones (IoA, formerly RGO).

Views of Gemini. Two photographs.

Bread and Cheese Lunch. Andrew Johnson.

First Sighting. An appreciative letter.

Friday the 13th. Bernard Yallop (RGO, retired)

Cambridge Young Astronomers at the RGO. Peter Ingram, Cambridge Young Astronomers.

I hope that copies of this issue *spectrum* have been distributed widely and will be available to readers of this account. **Consequently, I have made no reference to the activities on La Palma.** The remainder of this chapter is concerned only with activities in the UK and, in particular, with some topics that are of particular interest to me.

7.3.1 H. M. Nautical Almanac Office

Catherine Hohenkerk's article in s*pectrum* gives an interesting and comprehensive account of the work of the Office in Cambridge and so this section is only intended to summarise the principal aspects. After the move the scientific staff of the NAO was reduced to three: Bernard Yallop, Catherine herself and Don Taylor. In addition, Joy Hamblyn assisted with the secretarial and other work involved in the preparing the 'copy' for the printer. TOPPS was used for the tabular pages (see section 6.3.3.1), while a word-processor system was used for the explanatory pages. Steve Bell and David Harper were added to the staff in 1993 and 199? respectively.

PPARC had insisted that the work of the Office should be completely self-financing and this was made possible because the returns from the sales of the *Nautical Almanac* were sufficient to make good the losses on other publications and data

services. This had been the case in earlier years when the almanacs were published by H. M Stationery Office, which was concerned only with recovering the printing costs and not the costs incurred in the production of the copy. We then did not have to concern ourselves with the financial arrangements for the publications as all the costs of salaries and equipment were met by the Admiralty and later by SRC/SERC. (At that time the work that was concerned directly with the publication of the almanacs was only a small part of the activities of the Office.) Even with the reduced staff at Cambridge Don Taylor was able to continue his research on the orbits of satellites.

The production and publication of the almanacs was critically dependent on the cooperation with the Nautical Almanac Office of the U.S. Naval Observatory. All the copies of the *Astronomical Almanac* and of *Astronomical Phenomena* were printed in America, but the separate printing of the *Nautical Almanac* and the *Air Almanac* continued in both countries. The Royal Air Force decided that had no use for the daily tabulations in the *Air Almanac* and so from the edition for 1998 an abridged version containing mainly rising and setting for the Sun and Moon was published as *The UK Air Almanac.* The Office continued to produce *The Star Almanac for Land Surveyors* and five-yearly editions of *Compact Data for Navigation in Astronomy.* The edition of the latter for 2001-2005 was largely prepared at Cambridge and was renamed *NavPac and Compact Data 2001-2005.* It contained a CD-ROM and a printed manual for the use of the NavPac software package for astronavigation with the aid of a marine sextant and an IBM-compatible PC.

In 1996 the Office published *A Guide to the 1999 Total Eclipse of the Sun.* This was written by Steve Bell and proved to be a ‘best seller’. Its reprinting in 1997 as *The RGO Guide to …* was an indication of the commercialisation of the NAO’s activities. It included a mylar eclipse viewer. Unfortunately, many people, including me, were disappointed when cloud covered almost the whole of Cornwall for the period of the eclipse! The Office continued to prepare astronomical and calendarial data for distribution by the Public Information Unit of the RGO. Data for observers and observatories was also made available on the world-wide web. There was growing demand for information for legal purposes and David Harper was given the task of preparing statements of witnesses that would be accepted as authoritative statements of fact by the courts.

Bernard Yallop retired in September 1997 and his place was taken, as an interim measure on a part-time basis, by Andrew Sinclair, who had moved from the Office in 1989 to take charge of the SLR Department. He used the term ‘Head’ rather than ‘Superintendent’. He had the unenviable task of trying to ensure that the work of the Office could be continued under appropriate conditions after the closure of the RGO. It was eventually decided that the Office should become part of the Space Science and Technology Department of the Rutherford Appleton Laboratory. It was then headed by Patrick Wallace, although Steve Bell supervised the day-to-day work. The staff, except David Harper who took a post at the Sanger Institute, moved to Chilton in 1999. The Office formally became part of the UK Hydrographic Office in Taunton, Devon, on 1 April 2006, but the Steve Bell and Catherine Hohenkerk did not move until later. Don Taylor is still at RAL.

7.3.2 The RGO Library

The library was in a large pleasant room opposite to the main entrance. It held mainly recent books and current issues of journals and this was probably sufficient for

most purposes as the library of the Institute of Astronomy was not far away. Moreover older volumes were stored in the tower of the Cambridge University Library; they were, however, moved later to shelves in a newly built part of CULib. where they were not freely accessible. The new building did not have a suitable place for the Airy Collection of rare books and these were stored in their boxes. The newly appointed librarian was Ingrid Howard. Unfortunately, when the closure of the RGO was imminent she moved to PPARC central office and this may account for the absence of any article about the library in the final issue of *Spectrum.*

In 1991 the library was formally named the *Michael Penston Library*. (See *Gemini* 32) Michael had been one of the RGO's leading research astronomers and had been promoted on individual merit to grade 6 (formerly SPSO) in 1985. He died from cancer in December 1990 at the age of 47 and his obituary in *The Guardian*, which was written by Martin Rees, was headed 'Astronomy's bright quasar'. He had been chairman of the Education Committee of the Royal Astronomical Society and a Michael Penston Astronomy Prize is now awarded annually for a thesis on an astronomical topic. (This complements the Blackwell Prize for a geophysical thesis.)

The library needed space for new material and so weeding of the stock that had been selected in haste during the move from Herstmonceux took place. It was decided that the collections of the RGO and IoA should be merged and so a large number of duplicate items became available for disposal. This process had not been completed when Ingrid left and the IoA librarian, Julie Nicholas, continued the task. So far my attempts to find out what decisions were made about the library when the RGO was closed have been unsuccessful. Some other books, including the Airy Collection, went to the (Old) Royal Observatory at Greenwich. My enquiries have, however, revealed that large numbers of books were dumped in skips for disposal. Some were rescued by a member of the staff of the IoA, who regarded this episode as one of the darkest in an altogether shameful saga.

7.3.3 The RGO Archives

The RGO archives that were transferred from Herstmonceux were stored in crowded conditions in a large room on the 6th level of the tower of the Cambridge University Library. Adam Perkins was appointed to a post in the Manuscripts Division of the Library and was able to continue as the RGO archivist. He was, however, expected to undertake other duties in the Division and he no longer had the resources of the Laurie Project Team to continue sorting and listing the archives. I understand that SERC/PPARC paid part of his salary.

The archives are arranged in 'classes' and there are numbered boxes for each class. For the classes that were catalogued by the Laurie Project the documents are listed in 'pieces' and each 'folio' is numbered. A piece may consist of few or many pages, or it may be special item such as a photograph or visitors book. The lists are in computer files and print-outs are available in the library. For other classes, such as departmental records and recent acquisitions, there are no detailed lists.

I have made 8 visits, each of several days, to the RGO archives since the move in 1990. I was then privileged to have direct access to the collection so that I did not have to request items to be brought to the Reading Room. At first, I was particularly interested in the archives of the NAO. I found, for example, that the batches of correspondence files were scattered throughout the boxes in which they had been placed

for the move. Consequently, I spent much of my time sorting the files into sequence and arranging other material in a more logical way. On my return home, I revised the lists of the contents of the boxes and sent copies of my computer files to Adam. I also used to make manuscript notes about the contents of the listed pieces or unlisted classes of particular interest to me. Most of these notes are, however, still in manuscript. (I hope, however, that they will eventually be deposited in the archives and be of use to later researchers.)

Adam encouraged the staff of the RGO at Cambridge to transfer their out-of-date files to the archives and it appeared that the NAO staff did this, but I do not know whether this was true of the other departments. When the RGO was closed a large number of boxes of files were passed to CULib and are in store there. As far as I am aware, Adam has not been able to examine them in any detail. I fear that a lot of archival material went into the skips with the unwanted library books!

7.3.4 The RGO collection of astronomical plates

The collection of astronomical plates and photographs did not go to the Cambridge University Library with the archives, but instead were transferred to the new RGO building where appropriate accommodation was provided for their storage and for access by interested astronomers. In this respect the move gave some benefit, but the closure of the RGO certainly did not. The plates were put into a commercial store and it was reported at first that they were not accessible to users. My enquiries in 2003 elicited, however, the following response from Dr C Vincent of PPARC central office.

> With respect to the collection of glass plates, these are still in storage in London. The reasons for this are that the company which houses them is able to provide ideal conditions for storage, whilst also allowing limited access for users through request to PPARC). We did not inherit a proper inventory for the plates from RGO Cambridge but have undertaken a full assessment since they have been in store. Most of the plates are still in their wrappings from the move to Cambridge from Herstmonceaux. [sic]
>
> We get about 2-3 requests for plates per year from the community and try to meet these by offering access to the plates required through Cambridge or Edinburgh Universities, where suitable plate measuring machines at housed. Neither Cambridge nor Edinburgh have the space nor facilities to house the collection.
>
> In the longer term, we have been talking to our colleagues in Europe (through the IAU) about options for either scanning the plates or setting up a central European plate facility. To date, attempts to fund such a scheme have not been successful.
>
> So whilst we remain committed to keeping the plates in as good a condition as possible, I am afraid that the majority to astronomers would not give a high priority to developing this facility (against, say, access to the latest world-class telescope facilities).

It would be of interest to know whether information is readily available about the content and accessibility of the collection. Elizabeth Griffin (at or c/o IoA) is playing a major role in an international effort to ensure that collections of observatory plates are not lost, but are made available to the whole community.

7.3.5 Satellite Laser Ranging Department

Andrew Sinclair became head of the SLR Department and Graham Appleby moved with him to Cambridge to assist in the analysis of the data and in similar tasks. Roger Wood, who had not previously been involved in the SLR work, was made officer-in-charge of the team at Herstmonceux. There were other changes of staff, but the team continued to hold its place in the international ‘league tables’ for SLR stations.

The team was also responsible for monitoring the GPS transmissions in the area. A small hut was built by the dome to provide office accommodation to replace that lost by the move from the West Building. (See *Gemini* 32)

When the RGO closed the responsibility for the SLR work was transferred from PPARC to the Natural Environment Research Council (NERC). Sinclair took VPR and Appleby and Roger Wood became joint heads of the team. Appleby moved to the NERC Centre for Ecology and Hydrology at Monks Wood in Huntingdon, although the team was attached to the Science Programmes Directorate in the Swindon office for administrative purposes. The team made no less than 8 presentations at the 12th International Laser Ranging Workshop in 1999 and Appleby was elected to the governing board of the International Laser Ranging Service. Clearly, the decision that the observations should continue at Herstmonceux after the move of the RGO to Cambridge was justified by the subsequent results. When Wood retired in 2001 his place as station manager was taken by Philip Gibbs.

I do not know what happened to the Met Office observers, but I believe that the observations were continued.

7.3.6 The RGO Club, reunions and the RGO Society

As compensation for the loss of the Clubhouse and sports facilities at Herstmonceux, the RGO Club was provided with limited accommodation at the end of the engineering wing of the new building. I gained the impression that this was used mainly at lunch-time and that the activities of the Club were much more less than those at Herstmonceux.

A reunion for current and former members of the NAO was held at the National Maritime Museum at Greenwich on 22 May 1993. RGO staff who had close connections with the NAO were also invited, as were family members. Many arrived in time to meet informally for lunch in the Museum's cafeteria before the main get-together in a room that was generously made available by the Museum. Some brought photographs to enhance the conversations. Bernard Yallop, the Superintendent, described the current staffing of the Office and the requirement for the work to be self-financing. After tea many walked up the hill to look around the Old Royal Observatory. Amongst the 99 persons present were Marion Rodgers and Flora Sadler, both of whom worked in the NAO from before the war until their retirements. Unfortunately, both have since died: Flora on 25 December 2000 at the age of 88 and Marion on 3 April 2003 at the age of 93. There is an illustrated report on the reunion in *Gemini 42*.

An RGO staff reunion was held in Herstmonceux Castle over the weekend of 5 & 6 October 1996. Peter Willmoth, who had stayed in Sussex, was the principal organiser. It was interesting to see the changes that had been made to the Castle as well as to meet again many friends. On the Saturday afternoon we were able to go around the gardens and visit the Science Centre in the Equatorial Group. After tea I gave a slide show on "The RGO at Herstmonceux Castle 1949–1990". I had also set up a display of photographs. Later in the evening there was a Buffet Supper and drinks at the bar in the Long Gallery. On Sunday morning there was chance to visit the West Building and I saw that my office was now an executive bedroom with TV and en-suite facilities. Then I repeated my slide show. We had coffee and lunch in the dining room, which was in the Great Hall that had been used for the RGO Library. My diary shows that David Spencer Jones was there.

One of the last events organised by the RGO Club was a staff reunion on 21 June 1998. This proved to be a warm, sunny day and a barbecue was held in the grounds behind the RGO building.

When the RGO closed the sports trophies and some other memorabilia were transferred to the SLR station at Herstmonceux. One large item was the plaque that commemorated the building of the Clubhouse at Herstmonceux. It had been remounted on the wall in the clubroom at Cambridge. [Philip Gibbs sent me a list in email on 28 April 2003.]

On the first anniversary of the closure of the RGO Jasper Wall, who then had a position in the University of Oxford, sent a letter to recent staff members inviting them to form an RGO Society. This must have produced a positive response as it was followed up on 20 February 2000 by a letter of invitation to a much larger number (234) of ex-members. It suggested that there should be annual dinner at about the time of the anniversary of the closure. The first, and so far only, such dinner was held on 28 October 2000 at Jesus College Cambridge. This was enjoyed by those who attended (I did not), but the following year a much larger number attended a reunion in Herstmonceux Castle on 30 September 2001.

Jasper Wall has returned to Canada and Neil Parker took his place as chairman of the Society. Further successful reunions, or ‘gatherings’, were held at the Castle on 23 October 2005 and 30 September 2007. Roger Wood has set up a web-site for the Society and this contains several articles giving recollections by members about their experiences in the RGO.

7.4 Herstmonceux Castle and the International Study Centre

The developers who bought Herstmonceux Castle had difficulty in obtaining planning approval for the changes that they wished to make and there was massive fall in the property market in the early 1990s. Consequently they eventually decided to sell the Castle and the estate. It was bought by the Queen’s University of Ontario, Canada, and converted for use as an international study centre by 1994. The Castle was used for the lecture facilities, offices and the refectory. This was in the Great Hall, but the balcony that had been built for the RGO Library was removed, so restoring the hall to its original form. The West Building was converted for use for accommodation for the students. The Equatorial Group became the Herstmonceux Science Centre, covering a variety of topics in addition to astronomy.

The Centre published *A History of Herstmonceux Castle* in 1994. This was written by David Calvert and Roger Martin of the Queen’s University. It complements Calvert’s earlier *History,* since each contains text and illustrations that are not in the other.

In January 1997, Dr Anthony Wilson (formerly at the Science Museum) wrote to me about plans for the “Herstmonceux Memoirs Project”. This led in 1999 to the publication of the booklet *Astronomers at Herstmonceux: in their own words.* The recollections of 8 former members of the RGO staff of their experiences were linked together by Wilson to give an account of the activities and of some of the events that would not have found their way into formal reports. He used some paragraphs from the article that I wrote for *Gemini* just before my retirement. The booklet contains much that was quite new to me and it may be strongly recommended to all with an interest in the RGO while it was at Herstmonceux.

In 2001 the Centre obtained a large lottery grant (c.£800000?) for the refurbishment of the telescopes and domes of the Equatorial Group. Brian Mack, who had succeeded John Pope as the RGO's senior telescope engineer, had moved back from Cambridge and was acting as a consultant for the project. He was seeking more information about some of the telescopes, but he mentioned that he arranged for all the engineering drawings to be transferred to the Centre from Cambridge when the RGO closed.

The original mirror for the Isaac Newton Telescope is now displayed in the Equatorial Group at the side of the steps leading up the pool. The laboratory blocks and the courtyard now contain a larger number of hands-on science exhibits for children, Special events, open evenings and courses in astronomy for beginners are arranged. The words 'and Discovery Park' have been added to the name on its leaflets and the Science Centre is now a popular tourist attraction.

7.5 Old Royal Observatory at Greenwich

As far as I can recall there were very few links between the RGO and the Old Royal Observatory except at the times of special anniversaries, such the bicentenary of the *Nautical Almanac* in 1967, the tercentenary of the Observatory in 1975 and the centenary of the adoption of the Greenwich meridian to define 'longitude zero' in 1984. There was, however, one indirect link in that Stuart Malin, who had worked in the RGO in geomagnetism as well as in astronomy, was Head of the Department of Navigation and Astronomy in the National Maritime Museum from 1982 to 1996?. (His wife, Irene, and I were tennis partners until she went to South Africa in 1963, shortly after her marriage. We later won the SRC mixed-doubles tournament at Chiswick in 1974, 1975 and 1976 before she and Stuart moved to Edinburgh with the Magnetic Department. Tragically, she died of cancer in 1997.)

When the RGO closed the Old Royal Observatory was renamed the 'Royal Observatory Greenwich', without the comma that had been customary before 1948. Robin Catchpole transferred to a joint appointment with ROG and the Institute of Astronomy in Cambridge. I believe that he is primarily concerned with the public information work, which the ROG took over from RGO.

My understanding is that the following items were transferred from RGO to ROG: the Airy Collection of rare books; various artefacts, such as the bust of Isaac Newton and paintings; and some library books, although the ROG did not expect to keep them all. I wonder what happened to the Harrison clock that was on loan from the RAS and that used to hang in the main entrance to the West Building.

7.6 Conferences relating to the RGO and NAO

During this period and the first few years after the closure of the RGO I attended several conferences that included papers relating to the history of the RGO and/or NAO. In some cases I presented a paper and I hope that the following personal notes will be of general interest.

In 1993 I prepared a poster paper about "the contributions of L. J. Comrie to dynamical astronomy" and this was displayed at conferences in both Cambridge (in June) and Oxford (in September). The first was an international conference on Optical Astrometry and Solar System Mechanics at Robinson College, Cambridge, while the second was a conference organised by the British Society for the History of

Mathematics on the History of Computation at Rewley House, Oxford. At the latter I also gave a demonstration of my simulation program for the Babbage Difference Engine at the Science Museum. Unfortunately, the engine lacks some of the features of the National accounting machines that Comrie introduced so successfully for the work of the NAO.

There was a conference at the National Maritime Museum at Greenwich with the title *Flamsteed at Greenwich* on 28 October 1995. This marked the publication of the first volume of Flamsteed's letters; the book had been edited by Frances Willmoth, the daughter of Peter Willmoth, a long-serving member of the RGO staff. The speakers included Adam Perkins, the RGO archivist.

In December 1995 I gave a paper on "An historical review of the variations in the rotation of the Earth, with special reference to the contributions of the Royal Greenwich Observatory" during a special session on earth-rotation studies at the fall meeting of the American Geophysical Union. The organiser of the session was Jean O. Dickey from JPL, who had been a member of the MERIT Working Group.

In March 1999 I attended the sesquicentennial symposium of the Nautical Almanac Office of the U.S. Naval Observatory in Washington, D.C.; my expenses were covered by USNO. I gave a talk about the history of H. M. Nautical Almanac Office and a paper with greater detail was published in the proceedings of the symposium. An annex gives a short account of my period of duty at USNO in 1957. At USNO the NAO became part of the Astronomical Applications Department and its staff list in 1999 contained only four names, whereas the list in the *American Ephemeris for 1957* contains 19 names.

On 8 January 1999 the Royal Astronomical Society held a special meeting to mark the contributions of the Royal Greenwich Observatory and the Royal Observatory Edinburgh to astronomy. Among the speakers was Sir Francis Graham Smith for whom I provided a note on A&T activities. (See appendix A.2) Bernard Pagel gave a few reminiscences of early days of the RGO at Herstmonceux. Some 25 former members of the RGO signed a special attendance sheet, but only Professor Malcolm Longair signed for ROE.

In September 1999 I attended IAU Colloquium 178 on 'Polar Motion: Historical and scientific problems' at Cagliari in Sardinia. and presented a paper on 'Project MERIT and the formation of the International Earth Rotation Service'.

At a meeting of IAU Commission 41 on the history of astronomy at Manchester in August 2000 I spoke about the archives of the Norman Lockyer Observatory, but I also distributed copies of a note by Adam Perkins and myself about the RGO archives.

In September 2001 I gave a paper on "the making of tables in H. M. Nautical Almanac Office" at another BSHM conference in Oxford. The proceedings were published by OUP in 2003 under the title *The making of mathematical tables: from Sumer to spreadsheets*.

The British Society for Mathematics held a conference with the title *Greenwich: some mathematical connections* in the Museum on 29 May 2002. Amongst the speakers was Mary Croarken who spoke about some of the computers of the *Nautical Almanac* in the 18th century. (Her book on *Early scientific computing in Britain* included two chapters about Comrie and the developments in the NAO in the first half of the 20th

century.) An extended version of her Greenwich paper was published in 2003 in the *IEEE Annals of History of Computing*.

A meeting to celebrate the 50th anniversary of the last observation with the Airy Transit Circle was held at Greenwich on 30 March 2004. It was organised by Gilbert Satterthwaite, who had made that observation. There is an account of the event in *The Observatory* for August 2004.

In response to an invitation from Andre Heck of the Strasbourg Astronomical Observatory I wrote an account of 'the Genesis of the IAU Working Group on Astronomical Data'. This was published by Springer in 2006 in volume 7 of the series on *Organisations and Strategies in Astronomy*.

At the autumn meeting of the Society for the History of Astronomy in October 2007 I gave 'a personal review of the Royal Greenwich Observatory at Herstmonceux Castle, 1948–1990'. This was subsequently published in issue 4 of *The Antiquarian Astronomer*, which is the journal of the Society. In effect this is an illustrated summary of this volume!

During 2008 I drafted an article on my "Personal links with astronomers of the USSR and Eastern Europe, 1970-1989" for inclusion in issue 5 of *The Antiquarian Astronomer*, but publication has been delayed owing to illness of the editor.

8 EPILOGUE

REVIEW, WITH HINDSIGHT, OF PRINCIPAL DECISIONS

The story of the Royal Greenwich Observatory during the fifty years between the start of the move from Greenwich and its closure at Cambridge was largely determined by a small number of major decisions. The purpose of this epilogue is to review those decisions and some of the alternative options. We can wonder what might have happened if the decisions had been different, but even with hindsight we cannot know what would have happened. I hope, however, that these thoughts will be found to be of interest.

8.1 The move to Herstmonceux and the location of the INT

There was no doubt, even before the second World War, that the observing conditions at Greenwich were such that a move to a better observing site was necessary if the Royal Observatory was to continue to make observations of high quality. The option of leaving the headquarters in Greenwich and moving the instruments to an outstation was rejected since the main programmes required regular observations whenever the weather conditions permitted. Consequently, the observers needed to live close to the observing site. Moreover, a new site would make it possible to bring together the various departments that been dispersed during the war and to provide better accommodation for the growing technical facilities, such as the time service and workshops, as well as for offices and the library.

There is also little doubt that Herstmonceux Castle was the most appropriate place amongst the options that were available. Not only did the Castle and the war-time huts that were there provide immediately available accommodation for some of the work, but the estate was large enough to allow the new offices and workshops to be well separated from the new domes for the telescopes. Moreover, the observing conditions were expected to be better than anywhere else in the U.K. and, as far as I am aware, there is no evidence to suggest that this was not the case.

It is hard to understand why the new Solar Dome aroused so much antipathy that the Admiralty was forced to build the Equatorial Group to a design that sacrificed function to appearance and that consequently involved higher costs and hence further delays in the completion of the buildings. (At that time the building work was subject to stop-go periods in government expenditure.) The failure to obtain funding for a new Schmidt telescope for dome C may also have been due to the higher building costs.

In retrospect the decision to site the Isaac Newton Telescope at Herstmonceux appears to have been a mistake, but it must be remembered that the conditions in 1946 were very different from those in 1967 when it was finally brought into use. If it could have been in use from 1957, when the Equatorial Group was opened, the decision could have been well justified. In the immediate post-war years there seemed little prospect that air-travel would become so commonplace and comparatively cheap that it would have been possible for observers to make short visits to overseas stations. In the early 1950s the Burbidges applied for a travel grant to observe in the south of France, but this was refused. “They learnt later that at that time the astronomical establishment disapproved of anyone going abroad to observe”. [New Scientist, 28 Sept. 1972, p.575]

The standard period for duties abroad was three years and even in 1957 I was sent by sea for duty for one-year in the USA. Moreover, there was less emphasis on the need for deep-sky observations of very faint objects as there were many problems that required observations that were not possible with the 36-inch Yapp telescope (the largest then available in the UK) but which were within the scope of the 98-inch INT. Such a telescope at Herstmonceux would also have made it possible for young astronomers to gain experience of using a large telescope at a time when there were no opportunities for them to go overseas. It was after all Woolley that went to Mount Palomar in 1958, not postgraduate students. Unfortunately, there were long delays in the construction of the INT.

There was, however, one decision about the INT that proved to be a grave mistake. The telescope was intended for use by all astronomy groups in the UK, not just by the RGO, but the responsibility for the design and procurement was left to a committee. As a consequence the design was still not agreed when Woolley replaced Spencer Jones as chairman of the committee. He got agreement on the design, but the committee did not set up a clear management structure for the procurement and operation of the telescope. Consequently, RGO staff (both engineers and astronomers) found themselves having to commission the telescope on a part-time basis, without having been involved in the earlier stages of the project. I believe that visiting astronomers also felt that they did not get the support that they had expected.

8.2 Opting out of radio and space astronomy

The Herstmonceux site would probably have been an ideal site for radio astronomy as the Pevensey Levels to the south provided a flat, uninhabited area that was several miles in extent, and there were no nearby major towns to the north. There was an RAF radar station in the middle, with three enormous towers to support the receiving aerials, but this soon became obsolete. Unfortunately, neither Spencer Jones nor Woolley was willing to consider the possibility of the RGO moving into this field of astronomy.

Spencer Jones did, however, recruit Gold to develop a cosmic-ray monitoring station, but Woolley failed to support Gold and the work soon ceased after Gold went to the USA. Woolley also refused to support the NAO’s satellite prediction service in 1957 and so this moved to the Royal Aircraft Establishment and then to the Radio Research Station at Slough, which became the Radio and Space Research Station and later the Appleton Laboratory. When SRC decided to close the Slough site the work was not transferred to the RGO, but to the Rutherford Laboratory, where the main emphasis was on particle physics, not astronomy. This was the appropriate decision as by this time as the engineering, computing and managerial support facilities were stronger.

Some RGO staff undertook duties at the control centre for the International Ultraviolet Explorer satellite (IUE), but on the whole the RGO astronomers were directly involved in only ground-based astronomy. A few, such as David Strickland, moved to the RAL to participate in space astronomy there, but I do not recall any collaboration between RGO and RAL staff.

8.3 Relations with South Africa, Australia and Europe

Woolley recognised the importance of making use of overseas telescopes in much better climatic conditions and the need for more observations from the southern hemisphere. Consequently, RGO astronomers were sent to the Royal Observatory at the Cape of Good Hope for 3-year periods of duty and they made shorter visits to observatories in Spain, Egypt and the USA.

There was a clear need for a new observatory with a large telescope in the southern hemisphere and the funding situation was such that a choice had to be made between collaboration with Australia in a joint project or participation with a group of European countries to establish a European Southern Observatory (ESO) in Chile. Woolley, who had been the Commonwealth Astronomer in Australia, favoured the former and his arguments were accepted. Site-testing in Australia led to the adoption of Siding Spring Mountain in New South Wales as the site for the Anglo-Australian Telescope. A new UK Schmidt telescope for survey purposes was also built there to complement a similar telescope on Mount Palomar in the northern hemisphere. (The responsibility for this telescope was assigned to the ROE, not the RGO.) The telescopes themselves were successful and they still produce good results, but the conditions at the AAO do not match those on the higher and drier mountains in Chile. As a consequence, UK astronomers did not have the use of the ESO telescopes in Chile until eventually PPARC decided to pay the subscription to ‘join the Club’ after the RGO had been closed.

8.4 Transfer to the Science Research Council

The immediate effects of the transfer of the funding and control of the RGO from the Ministry of Defence to the Science Research Council have been discussed in section 4.1.2. This was a logical administrative change, as were the decisions that the NAO but not the Chronometer Department should be funded by the SRC. The decision to transfer the Magnetic Department to the Natural Environment Research Council was also appropriate, especially as Woolley would not have supported it fully. The transfer did, however, ignore the link between the Solar and Magnetic Departments and it probably contributed to the run-down and eventual closure of the Solar Department.

There were strong parallels between the RGO and the US Naval Observatory (USNO) in Washington, DC. There, however, a different approach was taken and the Scientific Director of the Observatory reports to a naval officer with the title of Superintendent. Moreover, the dominant activities of USNO are those that can be seen to be related to the interests of the US Navy — the time service, for example, provides the primary time-scale for the Global Positioning System, while the NAO is part the Astronomical Applications Department. Astrometric programmes, including the use of space and radio techniques, are favoured over short-term astrophysical research. On the other hand, the transfer of the RGO to the SRC ensured that Woolley’s view of the role of the RGO prevailed and its traditional activities were cut back.

The loss of the title of Astronomer Royal for the director of the RGO was unexpected as there was no other function that the holder of the title could be expected to perform — after all, we did not expect the newly appointed AR to cast a horoscope for the Queen. It also appeared that the SRC did not make clear to Margaret Burbidge the extent of the duties that she would need to perform as director when she succeeded

Woolley. Her resignation after less than two years was probably largely due to her realization that she would not be able to also keep up her observing and research interests. (See section 5.2.)

The RGO was lucky to have Alan Hunter at hand as director until the end of the year that the RGO celebrated its Tercentenary. It was a pity that he did not also have the title of AR at this time. Although Graham Smith was best known as a radio astronomer and was given the procurement of the Northern Hemisphere Observatory as his main task, he soon showed that he saw the value of the other work of the RGO and was prepared to seek support for it. It was, however, clear that the Solar Department was no longer able to produce useful results since neither its site nor its equipment were up to current standards. His early support for the satellite laser ranging proposal was a major factor in its eventual success.

The responsibility for funding the Royal Observatory at Edinburgh was also transferred to the SRC in 1965. This was to have unfortunate consequences as the SRC was forced to split the tasks of designing and building new instruments and of establishing and managing overseas observatories between to the two Royal Observatories. This led to inefficiencies in scale, especially as there was often rivalry, rather than cooperation, between them. On the other hand, it would have been impossible for political reasons to make ROE a purely university organisation and to concentrate new engineering work for SRC projects at the RGO. The uneasy relationship with ROE was seen clearly in 1970s, again in 1980s and finally in the 1990s when the RGO was closed and the Astronomy Technology Centre was sited at ROE.

8.5 The overseas observatories

The two Royal Observatories did cooperate in the site testing that led to choice of La Palma for the new Northern Hemisphere Observatory. As far as I am aware there is no reason to doubt this choice for a site with reasonable access from UK and other countries in Europe. For the reasons given in section 5.3, I am not, however, convinced that it was the right decision to move the INT from Herstmonceux to La Palma. There would been no justification for moving the RGO to Cambridge if the INT had still been in use at Herstmonceux for appropriate programmes.

The decision to be build the James Clerk Maxwell Telescope for infra-red observations led to the choice of Hawaii for the site as it was at a higher altitude than La Palma. The ROE was, not unexpectedly, given the responsibility for management of this project.

8.6 Move to Cambridge and closure

At the end of the 1970s the future of the RGO appeared to be assured as the SRC had recognised its three functions: support for UK astronomy on La Palma, research and national services. Moreover it had agreed to the building of a new wing on the West Building to avoid splitting the staff between there and the Castle. It had also accepted that the RGO should be responsible for the care its archives and that a conservation laboratory should be provided for this purpose.

All this changed in the early 1980s when Boksenberg replaced Graham Smith as Director and when the senior staff and board members in SERC changed. Cuts in staff were followed by a series of reviews that led to the decision to move the RGO to Cambridge. The most appalling features of this decision were that it was based on only one aspect of the work of the observatory, that the financial and other costs were ignored and that the views of the astronomical community were disregarded. The first two of these criticisms are based directly (see section 6.2.3) on the statements in the report of the 1985 Panel that "when considering the options, the non-La Palma activities of the RGO have not been included" and that "financial projections for the various options have not been considered".

Once the move to Cambridge had taken place, experienced staff had been lost and the range of activities had been reduced, it was, perhaps, not surprising that SERC and then the newly formed PPARC should subject the activities of the RGO and ROE to two more reviews. The second of these led to the closure of the RGO within an interval of less than one year. Again the views of the astronomical community were ignored and no statement of the reasons for the decision and of its financial and other consequences was ever published, as far as I am aware. (See section 7.2) The chief executive officer of PPARC, Ken Pounds, must have been well pleased for the earlier attempt to close the RGO in the 1980s, when he was chairman of the Astronomy, Space and Radio Board, had failed.

I accept that an organisation such as the RGO should not be kept in existence simply for traditional reasons, but I find it hard to believe that the conclusions of the reviews of the 1980s and 1990s would be justified by an impartial examination of all the relevant factors and alternative options. I can only take some comfort from the continuance, in spite of the closure, of three activities for which I had been responsible in the 1980s, namely:

H. M. Nautical Almanac Office; the Satellite Laser Ranging Group; and the archives of the RGO.