EXTRACT FROM

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

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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 is 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.