EXTRACT FROM

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

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

4.1 The change from control by the Ministry of Defence

4.1.1 The establishment of the Science Research Council

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

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

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

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

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

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

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

4.1.2 The immediate effects on the RGO

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.2 Major new developments

4.2.1 The installation of the ICT 1909 computer

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

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

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

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

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

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

4.2.1.1 More about the comparison with other contemporary computers

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

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

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

4.2.1.2 The hardware characteristics of the ICT 1909 computer

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

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

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

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

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

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

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

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

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

4.2.2 The completion of the Isaac Newton Telescope

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

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

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

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

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

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

4.2.2.1 Commissioning and use of the INT

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

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

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

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

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

4.2.3 The new Physics building

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

4.3 Other departmental matters

4.3.1 Astrophysics and astrometry

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

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

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

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

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

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

4.3.2 Engineering and instrument development

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

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

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

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

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

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

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

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

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

4.3.3 Time Department

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

4.3.3.1 Atomic frequency standards

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

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

4.3.3.2 Universal time and latitude

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

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

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

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

4.3.3.3 Contributions by Humphry Smith

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

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

4.3.3.4 Changes in international timescales

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

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

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

4.3.4 H. M. Nautical Almanac Office

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

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

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

4.3.4.1 NAO publications

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

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

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

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

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

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

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

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

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

4.3.4.2 Computer composition

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

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

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

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

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

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

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

4.3.4.3 Occultations

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

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

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

4.3.4.4 Dynamics and planetary sciences

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

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

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

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

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

4.3.4.5 Computer Section

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

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

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

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

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

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

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

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

4.3.4.6 Kinetheodolite observations of satellites

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

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

4.3.4.7 Participation by Donald Sadler and others in IAU activities

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

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

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

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

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

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

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

4.3.4.8 Retirement of Donald Sadler

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

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

4.3.5 The Solar and Magnetic Departments

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

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

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

4.3.6 The RGO and NAO libraries

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

just after the marriage. Marilyn resigned to go with him and Sue Cowen was transferred from the General Office and was promoted to clerical officer at the same date.

The NAO library continued to operate independently of the RGO library during this period. Alison Gaydon, who looked after the NAO library amongst other duties, was promoted to clerical officer in 1965. Marilyn, Alison and, later, Sue were sent on introductory courses for 'special library and information work'.

Alison married W L (Bill) Martin, who had joined the NAO as an AEO just after Alison, in 1967. The service was in Herstmonceux Church and the reception was held in the dining room of the Castle [photos]. She resigned in 1969 in order to start their family. She accompanied Bill to the Radcliffe and Cape Observatories in South Africa in 1971-1977. They were divorced some years later. Alison married the son of George Harding (who had been Deputy Director of the Cape at the time that Alison was there!) and Bill married Joy Hamblyn, who had joined the Typing Pool at Herstmonceux and had moved to Cambridge.

Joan wrote an article about the history of RGO Library and added some notes about the NAO Library and the current situation in August 1971. More detail about the contents and organisation of the NAO Library are given in NAO Technical Note no. 14, April 1968.

I do not know the circumstances of a decision to dispose of old books that appeared to be no relevance to the RGO. They were put on a trolley and members of staff were invited to take any of interest. I do not know what happened to those that were left. I took a copy of the first volume of the *Proceedings of the Cambridge Philosophical Society* and I later passed it to the Library of the Norman Lockyer Observatory at the University of Exeter. There were other books of a similar character that should have been retained or sold through a dealer.

4.4 General administrative matters

The level of administrative effort to run the RGO increased during this period , partly as a result of the change to control by SRC, but also because of the expansion in the activities. In particular, there was a large increase in overseas duties for both short and long periods. The addition of the Isaac Newton Telescope and the extra technical work in instrument development also required additional administrative support. This was recognised in two ways: firstly, Alan Hunter, who was, in effect, the deputy director, was promoted to DCSO in 1967 and, secondly, John Whale, the Secretary and Cashier, was promoted from HEO to SEO in 1968. Moreover, John was supported by a finance officer, Frank Evans, an HEO, who was transferred from RSRS in 1969. He carried out his duties to the letter and so had a reputation as a bureaucrat, but I would have been more concerned if he had not been so careful.

The Castle was considered to be a significant fire risk and was situated several miles from the nearest fire station (Hailsham?) at the end of a two-mile narrow lane. Consequently, we had a volunteer fire squad, of which I was member from 1962 or earlier, and we were given training in the use of the mains fire hoses as well as of portable fire extinguishers. One day after one of our practices we heard reports of a broken water main between the Castle and the village, and I suspect that we had turned off the hoses too quickly and had caused a vibration in the pipe.

In August 1965 Woolley appointed me as 'Fire Officer' in place of W B Harvey, an Executive Officer, who had come to manage the work of the Chronometer Department. After an inspection by the local fire brigade in January 1966 I put forward several recommendations for changes, but Woolley refused to adopt them and appointed Mr Whale in my place. Later the job was passed again to Mr Harvey. Fortunately, we did not have any fires as I recall that one of the escape routes from the attic rooms involved the use of a ladder on a roof!

Mr Lankford, the Head Messenger, retired on health grounds in 1968. He had held the post since he joined the staff at Greenwich in 1946 and he and his wife lived in a cottage by the West Entrance of the Castle. He was, presumably, a retired soldier as he wore a neat handlebar moustache and always stood smartly in his uniform, with its white peaked cap. He was succeeded by Vic Hill, who could hardly have been more different; he acted as assistant fire officer and serviced the equipment. (He may have been a fireman before joining the RGO.)

The RGO Club continued to provide for a wide range of activities. Many members participated in the SRC sports days, which were held at the Civil Service Sports Ground at Chiswick with the support of the Science Research Council. Further details of Club activities are given in Appendix D.

4.5 External affairs

4.5.1 University of Sussex

The establishment of the Astronomy Centre within the newly founded University of Sussex provided Woolley with the opportunity to establish closer links with the academic astronomical community. (See section 3.1.3.5) He, Pagel and Lynden-Bell became visiting professors and others gave lectures to the postgraduate students. Other members of the staff attended the lectures and gained M.Sc. and D.Phil. degrees. Bob Dickens was awarded a D.Phil. in 1970, although Woolley confided to me on Lewes station one afternoon that he had needed some help in his oral examination!

At first a few RGO staff attended seminars at the University, which was conveniently placed in Falmer on the outskirts of Brighton. Then joint seminars were also held in the Castle so that more RGO staff could participate and so that the university staff would learn more about the RGO and its facilities.

The university staff were mainly engaged on theoretical studies, but some postgraduate students undertook observational projects and so spent much time at Herstmonceux. Some joint projects developed.

4.5.2 Use of telescopes overseas

The increasing use of telescopes in other countries, especially South Africa and the USA, has been mentioned in section 3.1.3.2. The RGO staff usually used existing facilities, but in Egypt (United Arab Republic) at the Helwan Observatory's out-station at Kottomia and in Spain in the Sierra Nevada the RGO staff contributed to the development of the equipment, and so engineers as well as observers participated in these visits. Woolley and Derek Jones went to Kottomia to observe with the 74-inch telescope in November 1964, but in later visits in 1966 Woolley was accompanied by

Pope and Palmer in Mar/Apr 1965, by Harding in June 1965, and by Dermody (Engineering) and Standen (Instrument Development) in 1966. In August 1968, he was accompanied by Wellgate, Harding and Dermody when he visited a small Jesuit observatory with a 12-inch reflector at 9000 feet in the Sierra Nevada in southern Spain.

In 1967 onwards, Woolley also acted as an advisor to the University of Riyadh, of which he was Vice-Rector, on the setting up of a new observatory in Saudi Arabia, and RGO staff were engaged on site-testing operations. For example, Woolley, Hunter, Dermody and Dr M F Ingham of the University of Oxford went on a site-testing expedition in 1968.

4.5.3 Anglo-Australian Telescope project

As has been mentioned in section 3.1.3.3, Woolley's advocacy of the Anglo-Australian Telescope project, rather than participation in the European Southern Observatory, was successful. The agreement was signed in 1967. John Pope was seconded to the AAT project from September 1967 until September 1971. He continued to oversee the manufacture at Grubb Parsons of the optics and tube for the telescope.

Shortly after Pope's return, Peter Gillingham left the RGO to join the project team in Australia and he became the chief engineer. He later moved to an observatory on Hawaii before finally returning to Australia.

The AAT was built as part of the Anglo-Australian Observatory (AAO) on Siding Spring Mountain in New South Wales, near to the town of Coonabarabran. Pope returned in 1974 to oversee the lifting of the mirror into its cell and its connection to the support system. He and Ben Gascoigne, who spent some time at Herstmonceux, were the first to see a star through the telescope and to test the focussing system that John had designed. The AAT proved to be very successful in spite of the low altitude. The UK Schmidt Telescope (UKST) was also built on the same site for survey purposes. It was manned and managed by staff from the Royal Observatory at Edinburgh (ROE). The headquarters of the AAO were in Epping, a suburb of Sydney.

4.5.4 Royal Astronomical Society

Woolley did not attend the meetings of the Royal Astronomical Society regularly, but he served as its President for the period 1963 to 1965. He was awarded a Gold Medal by the Society in 1971, just before his retirement. Other members of the RGO did, however, take a greater interest in the affairs of the Society. Alan Hunter, who had served a Secretary from 1949 to 1956, served as Treasurer from 1967 to 1976.

Others served on the Council. For example, I served on Council from 1967 to 1970. My recollection is that we had animated discussions about the role of the Society in respect of geophysics, for which there was no separate society. The Society had published a *Geophysical Supplement to Monthly Notices* until it became the *Geophysical Journal* in 1958. In 1964 it awarded a second Gold Medal to give astronomy and geophysics equal standing, although there was also a separate Eddington Medal. There were then proposals for further medals, but these were not accepted until 1972 when it was agreed that Chapman and Herschel Medals should also be awarded triennially for specific investigations. Professor Sydney Chapman, who had died in 1970, was the external examiner for my PhD thesis.

4.6 The retirement of Sir Richard Woolley

Woolley did not wish to retire from the post of Astronomer Royal, but it became known that he would do so at the end of 1971. An international conference on the determination of distance in the Universe was held in the Castle in his honour in August 1971. An international cricket match — RGO v the World — was held during the conference.

Just before the conference Hunter circulated a note dated 21 July to senior staff to tell us that SRC was about to announce that after Woolley's retirement the title of Astronomer Royal would no longer go automatically to the Director of the RGO. The two arguments given in a statement from No. 10 Downing Street were that the appointment of the Director was a matter for the Science Research Council, rather than for the Queen, and that the SRC wished to be able to include foreign nationals amongst those to be considered. Amongst many RGO staff this decision was seen as another way in which the university staff on SRC committees were attempting to diminish the standing of the RGO and to transfer the prestigious title to one of their number. Joy Penny, the secretary of the Herstmonceux section of IPCS, correctly predicted that this was the beginning of the end for the RGO.

Surprisingly, the RGO Information Bulletins do not mention either this statement or the appointment of Professor E Margaret Burbidge as the next director. (These would probably have been the subjects of separate Circulars.) She spent a few days at Herstmonceux in November 1971 when she visited England for discussions at SRC London Office. She was British, but at the time she held an appointment in the University of California. She could not take up her appointment until July 1972 and Alan Hunter was appointed Acting Director in the meantime.

Information Bulletin 181 for 23 December 1971 stated that:

"Sir Richard Woolley retires from the post of Astronomer Royal on 31 December and will leave for South Africa on 1 January 1972, to take up his five-year appointment as the Director of the new South African Astronomical Observatory. Sir Richard has been Astronomer Royal for exactly 16 years."

The SAAO brought together the Royal Observatory at the Cape, the Radcliffe Observatory at Pretoria and the Union Observatory at Johannesburg. A new observatory was established at Sutherland on a much better site.

In August 1979, after the death of his wife Gwyneth, Woolley married Mrs E M Patricia Marples, who had been the canteen and hostel manageress at the Castle from about 1951 to 1975 and who had been awarded a BEM earlier in 1979. They were later married in Eastbourne, but they moved to South Africa. Woolley died in December 1986. Lady Patricia survived him and also died in South Africa.

Professor W H McCrea asked me for my comments about Woolley when he was writing an obituary of Woolley for the Royal Society. A transcription of my letter is given in appendix B.2.3. He did not use my comments directly, but I have his letter of thanks and a signed copy of the obituary.