MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 1999 January 8 at $16^h\ 00^m$
in the Scientific Societies' Lecture Theatre, Savile Row

D. A. WILLIAMS, *President*
in the Chair

Secretaries: M. J. PENSTON
I. D. HOWARTH

The President. May I welcome you to this first meeting of 1999 and wish you all a very happy New Year. I have a number of announcements to make before we move to the advertised programme. The first of these is a rather sad one. Professor Patrick Arthur Wayman, retired Professor at the Dublin Institute for Advanced Studies and former Director of the Dunsink Observatory, and also former General Secretary of the IAU, died on 1998 December 21 after a short illness. He was made an Associate of the Society in 1982. I ask you to stand for a moment in his memory.

Thank you. I would like to make a short announcement about membership: as of 1999 January 1, eleven fellows will have attained membership for 50 years, and I'm going to read their names out [Laughter]; and I suggest that we make this an annual custom. They are: D. E. Blackwell, R. N. Bracewell, Sir Bernard Lovell, P. C. Moore, J. A. Moos, J. F. Pell, W. P. Preston, N. J. Smith, T. R. Tannahill, R. H. Tucker, and J. L. White. [Applause.] It's good to see that some of those persons are actually present here today.

The next announcement I'd like to make to you concerns the New Year's Honours list. I'm sure we are all delighted to know that Professor Jocelyn Bell-Burnell was awarded the CBE in that list and we would wish to congratulate her; I'm delighted to see that she is here today. [Applause.]

Now we can move to the advertised programme and we are going to have this afternoon a celebration of some of the highlights from the long history of the Royal Greenwich Observatory and the Royal Observatory Edinburgh. Our first presentation this afternoon is from Dr. Allan Chapman and his title is '*For use, and but little for Pompe*, the founding and early history of the Royal Observatory'.

Dr. A. Chapman. Thank you ladies and gentlemen. I want to talk this afternoon about the early history of the Royal Observatory — or perhaps not quite so early. I want to look from the period of its founding in 1675 until the office of the sixth Astronomer Royal, or more correctly in the order, the seventh, Sir George Airy. I want to look at something of what happened in a period of about 170 years which gave the Royal Observatory one of its undoubted great distinctions.

Why I call it 'For use, and but little for Pompe' derives from the original founding charter for the Observatory in 1675. The Observatory is significant for many things, and one of these I think is the almost Gilbert-and-Sullivanesque character of its original foundation. It is often said that great things from humble beginnings come, and the Royal Observatory's very humble beginnings did lead to great things.

We have to bear in mind what lay at the heart of the foundation in 1675; this was the pressing problem of finding the longitude at sea. The first approaches to the Royal Society, and then to King Charles II through his mistress Louise

de Kerouelle, the Duchess of Portsmouth (it was always regarded that through one of Charles II's mistresses one got to the King best), was a suggestion by a le Sieur le St.-Pierre, a French gentleman of whom we know very little. He approached the King with a suggestion of the way to find the longitude at sea using observations of a small number of stars and the position of the Moon. It was given to the Royal Society to solve as a problem and the Society then referred it to a man fortunately visiting London from Derby, who although then not a member of the Royal Society was a close friend and a regular attender of meetings when he was in London. This was John Flamsteed.

John Flamsteed was regarded as one of the finest practical astronomers in Britain, and having been given Monsieur le St.-Pierre's account of how to find the longitude, he supplied a detailed critique to the Royal Society which was then passed on to the King. In a nutshell, what Flamsteed said was that this method could work, but le St.-Pierre had little understanding of practical astronomy, because to make it work one would require a total revision of the heavens. The finest available tables, those of Tycho Brahe and the newly available tables of Hevelius, were simply not good enough.

Charles II, who was one of the most astute and intellectually sophisticated figures ever to sit on the throne of Britain — in spite of his numerous moral, diplomatic, and financial lapses [Laughter] — then threw it back to the Royal Society and Flamsteed. If His Majesty provided the money for the building of an observatory could the Royal Society find someone to direct it? Now, the monies for the founding of the Royal Observatory — and this is where I said there was a certain element of Gilbert and Sullivan in the whole thing — were cobbled and scratched together from the most extraordinary of sources. Charles II was permanently bankrupt and in consequence of which the monies were raised essentially from the sale of 'decayed gunpowder' — that was gunpowder where the three ingredients had settled out so they were no longer useful as an explosive — in the Tower of London. The money was then used to purchase second-hand building materials from the recently demolished Tilbury Fort. And then they got the finest architect in Europe, Sir Christopher Wren FRS, to put the whole thing together, and produce one of the great architectural feats of 17th-century England. I may say that the building of the Royal Observatory only cost about £14 more than the wooden 'Great Model' which Wren had recently had commissioned for the future St. Paul's Cathedral — if you go to St. Paul's crypt you will see this original 'Great Model'. The Royal Observatory cost £519; Wren's 'Great Model' cost just over £505, so you can get some idea of the economies involved in building the Royal Observatory.

Flamsteed was then appointed and in office by the autumn of 1675. They chose Greenwich Hill as the location, for as it was royal land nothing had to be purchased, and there were the foundations of Greenwich Castle, recently destroyed in the civil wars. Because they were using the foundations of a former medieval building this meant that the Royal Observatory was off-axis, which was to provide a minor problem for future Astronomers Royal.

Flamsteed, of course, had no university qualifications, though Cambridge University granted him an M.A. degree and he was ordained. He was a gentleman of private means who later described himself as "the son of a rich merchant"; a brewer in fact. And of course brewing and astronomy ran hand in hand in terms of their financial relationship well into the 19th century. He was appointed on a salary of £100 a year. This was not a very large sum of money but it is not as bad as some people have tended to imply. The main problem,

however, is that he was left to provide his own instruments, his own assistants, his own books, his own everything; so in other words it was a £100-per-year total grant. Moreover, it was only erratically paid, and Flamsteed sometimes had to engage attorneys to go chasing after the Lords of the Treasury even to get his money, sometimes very late indeed. Hence Flamsteed's insistence of the fact that he was a man of means, especially after his father's death in the mid-1680s, otherwise he could never have done the job.

My argument is that the first six Astronomers Royal were all men of considerable financial independence. For only with the appointment of Sir George Biddell Airy in 1835 was an Astronomer Royal appointed who was what you would now call a professional in the modern sense: a man who had no private money, must be paid a proper salary, worked full-time and did not, save periodically, go away to do something else, such as manage a parish. This, I think, is where in the 19th century, after 1835, you see the Royal Observatory turning in a much more professional and more organised direction than it was in previous centuries. This to some degree is also part of the way in which science itself was changing.

Flamsteed was appointed to map the Heavens. He was of course given no instruments, and his main purpose was to determine the position of the lunar orbit in relation to the fixed stars to within less than half an arcminute. The only way in which this could have been achieved, and why I think the Royal Observatory was so significant, in spite of its somewhat Gilbert-and-Sullivan-esque mode of administration at first, is that it called upon three new technologies, which were themselves in the experimental stages. These were, firstly, the telescopic sight — the device devised by Gascoigne in Yorkshire over 30 years before, and brought before the Royal Society by Hooke in 1666 — whereby one could point an astronomical measuring instrument 40 to 60 times more accurately than one could with the naked eye. The second major innovation was the use of the micrometer: one could not only perceive stars and the Moon and their mutual relationships with much greater precision than one could do with the naked eye, but one could measure them to a single second of arc. And thirdly, following Christiaan Huygens' and Robert Hooke's work in the 1660s, the pendulum clock gave a new way of measuring time, and hence right ascension, to a level of precision hitherto undreamt of. So, what was possible in 1675 would have been impossible 20 years before. Imagine what modern astronomy would be without radio, without computing, without the CCD, without gravitational-lens imaging — what it is today and what it was, let us say, 40 years ago. This was the kind of shift that took place in the third quarter of the 17th century.

Flamsteed paid for all of his own equipment, though some of it was bought for him by Sir Jonas Moore who was an old friend and was also a senior civil servant. When his father died in 1684, John then inherited money from Derby. He also married a lady and acquired the rectory of Burstow in Sussex, which brought him that characteristic which was to become so important in the future history of English astronomy — a clerical benefice subsidising a scientific function. It is important to bear in mind that, at second hand, the Church of England did an enormous amount to advance scientific research by giving many, many educated gentlemen the leisure and socially secure position whereby they could undertake fundamental research.

With his mural arc, his large sextant, and his magnificent clocks by Tompion, he set about the business of what was, after all, a long, long slog: the business

of observing the right ascensions and declinations of celestial bodies. It is in Flamsteed that we first notice a major feature that we now take for granted in astronomical research: the fact that your developing research techniques render your equipment obsolete, so that ten years down the line you need better instruments. The first instrument that Flamsteed used for measuring the stars was a sextant of seven-feet radius, a device of great novelty set upon an equatorial axis — the first ever instrument in England to be set in the equatorial plane, I think. This instrument allowed him to measure what Flamsteed called the "intermutual distances" between the Moon and the stars. But over the course of time he found that this instrument developed faults: the micrometer wheel began to develop a lot of play, and the whole stand had various dithers and shakes within it. He realised that henceforth it was going to be much more reliable to confine everything to the meridian.

Then in 1689, he launched out £120 of his own private money — more than his annual salary — to provide one of the first, large mural quadrants ever to come into use. It was the first to have telescopic sights and micrometers and it was to be the ancestor of every major astronomical measuring instrument until the development of photography over two centuries later. It was a seminal instrument and major astronomical innovation. With this instrument Flamsteed started to 'plough the meridian' night in, night out, year in, year out. The three fat volumes of his *Historia Coelestis Britannica*, the British account of the Heavens, which his assistants and his widow published after his death, give testimony to his enormous concern.

Flamsteed was a crucial figure in the history of practical astronomy. He was very much concerned with instrumental error: the recognition that before you can make a reliable observation, you have to remove all known systematic errors and try to track down as many random errors as possible. He realised that instruments themselves were not only useful, but also great sources of potential mischief. He came to realise, amongst other things, that the wall on which his great mural arc was hanging was slowly sinking into Greenwich hill by a tiny fraction each year. He therefore had to put corrections into everything that he did; he also came to realise as well that you can't reliably find the longitude by astronomical means unless you are sure that the Earth's axial rotation is even, and in 1675 no one knew that. The setting up of the great 13-foot pendulum clocks in 1676 made it possible for Flamsteed, by timing the transits of Sirius, to establish the length of the sidereal day, which was found to be pretty close to $23^{h}56^{m}04^{s}$. Flamsteed started not only by defining his constants, defining his errors, going on to improve his technology, and laying out the heart of the whole problem with the longitude — showing how, in fact, instruments were made to work in conjunction with theory — but did it all entirely out of his own pocket.

How far therefore one can call Flamsteed a professional astronomer I find hard to believe. In 1715, he claimed that his work at Greenwich had cost him £2000 out of his own money. Now £2000 in 1715 would easily be £250 000 in modern money — I don't think that many observatory directors today expect to spend such sums of their own pocket money on their own observatories! But this is part of the way in which the Royal Observatory grew.

Flamsteed never found the longitude, and the reason why he never found it was quite straightforward: though he wasn't aware of the fact at the time, the accurate prediction of the Moon's place in the ecliptic needed instruments that were much better than those that he had.

Flamsteed fell out with Newton; he also fell out with Halley — a man not

easy to fall out with because Edmond Halley was a remarkably genial and easy-going man in many ways. When Flamsteed died on New Year's Eve in 1719, and there was to be a new Astronomer Royal, Mrs. Flamsteed and his assistants were shocked and clearly disgusted to find Edmond Halley appointed in his stead, for Halley had been seen for so many years as the *bête noire* of Flamsteed and of his establishment. Halley, moreover, was 64 years old, and came to the office of Astronomer Royal with two clear intentions: the first of these was to observe the Moon through an entire lunar cycle of 18·6 years — not a bad ambition for a 64-year-old; the second one was to win the newly enacted longitude prize under the Act of 1714.

I have often wondered why Halley wanted to become Astronomer Royal. He was a man very unlike Flamsteed; a man who was essentially a *bon viveur*, a man who enjoyed friends, who was an intensive worker, but not the kind of man who by temperament wanted to be marooned on top of a wind-swept hill for most of the days of the year for the rest his life. Moreover he was not especially poor, and precisely why Halley wanted the Astronomer Royal's job, with the possible exception of wanting to cock a snook at Flamsteed's ghost, is not easy to establish. Now bear in mind that to become Astronomer Royal at age 64 was a considerable achievement — most people after all didn't live to the age of 64 in the 17th century — and Halley's robust health, with the assertion that he would observe for over 18 years, and the subsequent *acquittal* of that assertion, says a great deal about him.

Now Flamsteed was a man working largely from his own resources, providing his own equipment, and paying his own assistants' wages. Halley, by contrast, was a much more business-like character. Halley was a Londoner, the son of a wealthy city merchant, a man born and bred to business, and the first thing he did was to put it quite clearly to the Lordships of the Admiralty that he needed funding. The £100-a-year salary still survived, but he got £500 out of the government of King George I to re-equip the Observatory with the finest equipment of the day — the instruments of the celebrated George Graham. Halley's and Graham's careers worked close in hand, in the division of precision instruments, the development of micrometers, and in particular the development of high-quality clocks.

For many years Halley worked upon Greenwich Hill, and yet never succeeded in getting figures good enough for predicting the lunar orbit, which would thereby permit the determination of the longitude. He did however have a long-term friend and associate whose youthful talent he spotted: James Bradley, who also became an Oxford professor. Whilst for over 200 years Cambridge has had a particularly close association with the Royal Observatory, the first major group of Astronomers Royal — with the exception of Flamsteed, who wasn't a university man — were all members of Oxford University. So, the idea that Oxford did not provide much input into British astronomy is quite wrong. Bradley was a Fellow of Balliol; Halley was a Fellow of Queen's, and during the years when Halley was Astronomer Royal, combining this office with his Oxford chair, not to mention the fact that he got his salary augmented by the stipend of a post-captain in the Royal Navy which took it up considerably, Halley became a man of considerable means, clout, and influence.

Halley was undoubtedly the most influential figure in the Royal Society by the time of his death in 1742. Some people have said that Halley really achieved little as Astronomer Royal, but I don't think that's true: he put the Royal Observatory onto a proper business-like footing; he made the government realise that he was not going to pay for instruments out of his own money, and

neither were his successors expected to pay. The government henceforth was to pay for the instruments, and take some responsibility for publishing the results of the work. Halley was also a crucial figure, in so far that he was, unlike Flamsteed, a great encourager of bright, young men. Flamsteed by contrast had been a much more insular figure. But Halley was a public man, and by the time that he died — under the most felicitous of circumstances, at the age of 86, having downed a large bumper of wine when he had been banned from having it by his doctor, he sat there on his chair and died [Laughter] — the Admiralty at least had taken his wise prior suggestion of appointing the Reverend Dr. James Bradley as his successor.

Bradley came into the Royal Observatory on the same terms as Halley: he was to be Astronomer Royal and also an Oxford professor at the same time, and discharge his Oxford duties as well as his Greenwich duties. Bradley recognised that the instruments which Halley had commissioned from Graham 25 years earlier were out of date. They were not sufficiently accurate, and Bradley made a crucial discovery which was to lie at the heart of precision mechanics from then on: he recognised that heat affects precision instruments. Halley's main instrument which had been built by Graham, the great eight-foot mural quadrant, was now found to be several minutes out of true. The reason for this, as Bradley recognised, was that the quadrant had an iron frame and a brass limb — there was a bi-metallic tension. He therefore got a *thousand* pounds out of the government of George II to re-equip the Observatory, in addition to which he had also his own fine instruments, including an excellent zenith sector at his private observatory at Wanstead in Essex. (If you think of modern astronomers as figures who regularly jet between observatories, I think Bradley is in many ways the first. He was certainly the first major astronomer to work from three bases: from Oxford, from Greenwich, and his own private observatory in Wanstead on a regular basis. And it would have taken you as long to travel by horse between Greenwich, Wanstead, and Oxford in 1750 as it would take today to travel from England to La Palma and Hawaii in a 747.)

So Bradley was working from three astronomical bases with instruments partly his own, and partly provided by the government. The reason Bradley was also maintaining his own instruments at Wanstead was because he had set up a zenith sector there in 1727, and the purpose of this instrument was to see if he could determine the Earth's orbital velocity in space. Shortly after he set it up he discovered the aberration of light, which was the first clear physical proof of the Earth's orbital motion. Twenty years later he discovered the nutation, caused by the Earth's axial nodding. And the necessary courses of observations could only be done with instruments that were left set, and unmoved, for a couple of decades.

Bradley was not only Astronomer Royal and an Oxford professor, he also married money, just like Flamsteed. He married one Miss Mary Peach who was the part heiress to wealthy Minchinhampton woollen mills in Gloucestershire. Astronomy alone, from Greenwich, Oxford, and lecturing, brought in an income which I have calculated to be at least £680 per year, not to mention the dividends from his Gloucestershire properties; so he was a wealthy man. And this was at a time when many a country vicar made less than £200 a year, and still regarded himself as a comfortable gentleman. Bradley spent avidly on his equipment, and he was the man who pioneered the techniques of instrumental accuracy, was greatly concerned with quantifying astronomical constants — the aberration, the nutation — and getting very close to measuring the stars and the Moon accurately enough to determine the longitude.

When he died in 1762 Bradley was succeeded by another Oxford man, the Reverend Dr. Nathaniel Bliss, who tragically was only in office for two years before he died suddenly. Bliss received very little historical recognition, largely because he died before he had achieved anything of major significance at Greenwich. It was from this time onwards that the Royal Observatory switched into Cambridge hands: the Reverend Dr. Nevil Maskelyne was appointed as Astronomer Royal. It was Nevil Maskelyne who used the instruments of Bradley and of Halley and started to see if he could complete Bradley's great work.

In many respects Halley and Bradley had been seen as major innovators at Greenwich. Maskelyne has something of the reputation of a man who kept the show going without any particular major contributions, though this is not historically the case. He was of course a figure of immense thoroughness. I was rather disappointed the other evening to see on television a programme on the longitude in which Maskelyne was cast in the rôle of a reactionary figure — the man who was stopping the ingenious John Harrison from winning his prize. The reason, of course, why Bradley, Halley, and Maskelyne backed the lunars method rather than backing the chronometer method was *cost*. After all, it was cheaper to supply every captain in the Royal Navy with a volume of tables made in Greenwich and a number of basic instruments, and require them to make an observation and calculate their longitude, than it was to give every ship in the Royal Navy a Harrison chronometer. This still happens today, and of course the whole way of cost cutting, of which perhaps the RGO itself is now a victim, is simply a way in which governments have always operated. It wasn't so much that none of these people liked Harrison or disliked Harrison but rather that his method was seen as overcomplicated and grossly overexpensive. Unfortunately, most of the officers in the Royal Navy were not all that numerically sophisticated, and hence not good at finding their positions using higher mathematics. This led to the simplification of the chronometer by Thomas Earnshaw and John Arnold, and Nevil Maskelyne's simplification of the mathematics needed to calculate a lunar, so that most Royal Navy Sailing Masters could use them.

When Maskelyne died, though, in 1811, he had already been shown to be working with inadequate instruments. John Pond, a private gentleman then in his forties, the owner of a fine private observatory in Somerset, had commissioned from John Troughton an instrument of novel design, a four-foot circle called the Westbury Circle. Sadly, it no longer survives. Pond had shown that the circle was a much more accurate instrument for taking star positions for use at sea than was the quadrant. Using the newly developed techniques which had been perfected by Maskelyne, and in particular the *Nautical Almanac* which Maskelyne had issued after 1767, what Pond did at Westbury was to repeat the published observations with the old Greenwich quadrants with his new Westbury Circle, which showed that the 60-year-old quadrants were no longer adequate. In other words, the errors of observation of a professional astronomer made in a professional observatory were made manifest by a private gentleman using his own instruments in a private West Country observatory. And when the 79-year-old Maskelyne died in 1811, John Pond was offered the job of Astronomer Royal — the first job of his life.

Pond negotiated a salary of £600, and whilst by this time the longitude was safely found, he became increasingly burdened at Greenwich not by astronomical activities but by mechanical regulatory ones. The Navy was now using much cheaper chronometers than Harrison's and the Royal Observatory was getting saddled with the task of testing their accuracy before they were commissioned into warships.

Pond was a man also who did not enjoy good health; certainly over the last ten or twelve years of his life he seems to have been failing. In fact during that period too the Royal Observatory seems to have been falling into a not-very-efficient state. Thomas Taylor, whom George Biddell Airy later described as "a drunkard", was the Chief Assistant, being also corrupt, dishonest, and insubordinate, so that the poor, sickly Pond didn't know what to do with him. By this stage, moreover, the Royal Observatory's figures had become so suspect that a Nautical Almanac Office was set up to take the *Nautical Almanac* away from the Royal Observatory because the Royal Observatory could not be trusted with its accuracy — quite a disgrace. In fact there is a story which is part of the legends which come out of the early history of the Royal Observatory, that somewhere in the period after 1815 when Britain and the rest of Europe were at peace, an English frigate and a French frigate met somewhere on the great oceans of the world. As they were no longer at war, the two sets of officers dined with each other and had a jolly day in each other's company. At the end of the day the French officers gave their English counterparts several crates of fine Bordeaux wine; the English captain gave the French captain a copy of the latest *Nautical Almanac*. The French frigate was never seen again. [Laughter.]

This probably fictional narrative is symptomatic of the slide in quality that led to a fundamental shake up of Greenwich in 1835, the realisation that Mr. Pond really should be urged strongly to retire, and be replaced by a man who would bring in a professionalism, a ruthlessness, and a rigour which pulled the Royal Observatory round in an extraordinary way. This was George Biddell Airy, former Fellow of Trinity, Cambridge, and former professorial director of the Cambridge University Observatory. He brought to Greenwich a new thoroughness, weeding out the old assistants, getting rid of Tom Taylor, disciplining others, totally overhauling the instrumentation, and not only bringing the Royal Observatory into the heart of mainstream European astronomy, but also leading the way in engineering, meteorology, geodesy, and the recognition that it was the duty of the men on Greenwich Hill to monitor *all* of Nature. Not just the heavens, but also the terrestrial magnetic field, and the weather, to see if one could find systematic connections between them.

Airy was to remain in office until 1881. Tragically some people have given Airy a rather bad press, largely because of his quite innocent inability to find Neptune in 1846, which was in no way his fault whatsoever. We tend to forget that Airy created the modern Observatory. He took it from being a place run by semi-amateur but extremely qualified, competent, dedicated gentlemen, and turned it into a major institution, not only of government, but of international scientific research. Airy's impact was to stay effectively with the Royal Observatory right through until its demise. I have been told by a number of people who have worked both 'up the hill' and also at Herstmonceux, that Airy's ghost never ceased to walk the Royal Observatory in so far that many of Airy's standards and procedures survived well into the 1960s and perhaps beyond.

The President. Thank you very much Dr. Chapman for an absolutely fascinating talk. There may be time for a question or two.

Professor B. E. J. Pagel. When was the title 'Astronomer Royal' first used as such?

Dr. Chapman. It's rather paradoxical. Flamsteed was never officially called 'Astronomer Royal'; he was called 'Our Astronomical Observator'. Virtually from the beginning it started to be used in common parlance; sometimes he was called the 'Greenwich Professor of Astronomy', since he gave some lectures at the National Maritime College, but also of course in those days the title of

'Professor' was not always associated with a university appointment — he professed astronomy, and as Astronomer Royal he professed astronomy on top of Greenwich Hill. Certainly by the time of Halley, he was called 'Astronomer Royal'. As there were relatively few legal documents relating to Flamsteed's position in 1675, at the appointment of Halley the term becomes conventionalised, so by 1720 it was 'Astronomer Royal'.

The President. I think we should perhaps move on, as we have a number of very interesting things to hear about, so thank you again Dr. Chapman. We now move to a presentation by Professor Sir Francis Graham Smith, 'RGO, the backbone of UK astronomy'.

Professor Sir F. Graham Smith. I have on my wall a commemorative plate, issued in 1975 at the tercentenary of the founding of the Royal Observatory at Greenwich. On it are the dates and the portraits of the first eleven Astronomers Royal, from Flamsteed to Woolley. Their prime task was to provide the essential information to enable Their Majesties' Navy to navigate over the high seas of the world. Incidentally to their duties, they made many fundamental advances in the science of astronomy; we remember Halley for his comet and for magnetic surveys, Bradley for aberration (due to the Earth's orbital motion), Maskelyne for weighing the Earth. These first three centuries, however, were concerned throughout with the accurate measurement of time and the positions of stars and planets. Under Woolley a fundamental change occurred, which was signalled in 1965 when the newly-formed Science Research Council took over responsibility for the Observatory from the Royal Navy.

The Navy had regarded the Observatory in purely utilitarian terms. A stock-taking in the 1930s listed the telescopes as either "useful" — such as transit circles — or "other" — including research telescopes such as the 36-inch reflector. At Woolley's retirement in 1971, Sir John Carroll referred to "the superannuated scrap heaps that constituted most of British astronomy when we were both young men, or even to a greater extent at the time of his (Woolley's) appointment as Astronomer Royal." We owe to Woolley the dramatic transition in optical observational astronomy that has led to opportunities for using first-class telescopes in La Palma, Hawaii, and soon in Chile.

Fifty years ago the RGO moved to Herstmonceux Castle. The "useful" telescopes were the transit and the photographic zenith tube. The "others" were in the architectural Equatorial Group. These were great days for the Nautical Almanac Office (NAO) and the Time Department; the RGO was leading the world in the definition of time scales and in the merging of UK and USA effort on the *Astronomical Ephemeris*. The NAO is still very much alive, and publishing *The Astronomical Almanac*, *The Nautical Almanac*, *Explanatory Supplement*, *The UK Air Almanac*, *Astronomical Phenomena*, *Compact Data for Navigation and Astronomy 1996-2000*, *Sight Reduction Tables for Air Navigation*, *Star Almanac for Land Surveyors*, and the *RGO Guide to the 1999 Total Eclipse of the Sun*.

The NAO also provided the first predictions of artificial satellites, and lunar occultations, leading *inter alia* to the identification of the quasar 3C273. Observationally the emphasis shifted to Earth rotation and polar motion, to which a new Satellite Laser Ranger is a major contributor. This has the highest accuracy, about 1 centimetre, and near-highest record of observed satellite passes. Astrometry is still alive and well at the *Carlsberg Automatic Transit Circle* on La Palma — another world-beater provided by RGO in collaboration with our Danish colleagues. RGO astrometry also played a major rôle in the ESA satellite observatory *Hipparcos*, which has provided the fundamental sky refer-

ence frame for many years to come, measuring positions and parallaxes of 120 000 stars to an accuracy of 1 milli-arcsecond.

Woolley got the *Isaac Newton Telescope* (*INT*) built after 20 years of delay. It was necessarily on an imperfect site, and with only elementary instruments, but it nevertheless restarted observational astronomy in the UK. It also inspired the major leap forward of the *Anglo-Australian Telescope* (*AAT*). The sequence of major RGO telescopes — 2·4-m *INT* at Herstmonceux; 3·9-m *AAT* at Siding Spring; 2·5-m *INT* at La Palma; 4-m *WHT* at La Palma; and 8-m *Gemini* at Hawaii and Chile — represents an evolution in concept as well as size, and even more in instrumentation. This arose from wise decisions in the Research Council (SRC) after the Southern and Northern Hemisphere Reviews. The telescopes and their instruments were to provide for research in all UK universities, and RGO was to be the focal point both for the engineering and to provide a nucleus of astrophysical research. The *AAT* in the south was the first. Derived from Kitt Peak, it demonstrated the advantages of real precision engineering and instrumentation.

When I joined RGO in 1974 Hunter had cleared the decks for work on the Northern Hemisphere Observatory (NHO), and we rapidly assembled a top-ranking team of astronomers (Pagel, Wall, and Michael Penston among them), telescope engineers (Pope, Mack), optical designers (Wynne), detector and electronic experts, and mountaineers (with the help of ROE). We decided on La Palma, an untouched remote mountain top. The site testers lived on the mountain for about 18 months in primitive conditions; their optimism and our measurements of thermal conditions have been fully justified by the excellent image quality and the many cloudless nights which so many UK astronomers have enjoyed.

Site testing on La Palma nearly caused an international crisis: the island was in a military zone, and Franco was still in power. We were allowed to continue only after enlisting international collaboration, with Dutch, Swedish, and German colleagues: so started the Spanish international observatory which we now all enjoy. The royal inauguration in 1985 was attended by royalty and presidents from the European participants. There are nine participants now, including Spain, UK, France, Norway, Italy, Ireland, and a high-energy gamma-ray team, *HEGRA*, led by Germany.

The Isaac Newton Group (ING) is still the largest presence on La Palma. In building the ING the RGO collaborated with the Instituto de Astrofisica de Canarias (IAC) in providing the essential infrastructure. Spain provided the road; a remarkable engineering feat.

The plan was to build three new telescopes on La Palma: a 1-m, 2·5-m, and 4-m. An early decision was to rebuild the *INT* for the 2·5-m, with a new Cervit mirror. A massive building provided for a coudé spectrograph (overtaken by other designs) and for the ING headquarters. The 1-m telescope was built in partnership with Irish colleagues (Belfast and Dublin), the Dutch then joined us, and the telescope became the *Jacobus Kapteyn Telescope* (*JKT*). We learnt as we built and observed with the 1-m *JKT* and the new *INT*, and we provided some outstanding instrumentation which many of you have learned to love. On the *INT* everything had to be clustered at the Cassegrain focus, along with the acquisition and guidance (A&G) unit.

Our experience, and the work of the team both at Herstmonceux and on the island, led to the outstanding performance of the *WHT* and its instrumentation. The alt-azimuth telescope design was a collaborative effort between RGO,

universities, and industry (Grubb Parsons). Dome design is vital: the excellent seeing at the *WHT* matches the excellence of the mirror surface. The result is singularly beautiful, even in its ghostly manifestation in the well-known transparent-dome picture. All telescopes now operate with less than 5% downtime.

Each of the ING telescopes had a complete set of instruments: A&G box, CCD imaging-cameras, and spectrographs. Most of the instrumentation was designed and built in close collaboration with universities in the UK and the Netherlands. And much of it was ground-breaking. Consider the following: the *Intermediate Dispersion Spectrometer* (*INT* workhorse); *ISIS* spectrograph (*WHT*); *Taurus* Fabry-Perot etalon interferometer; *Faint Object Spectrographs* (*FOS*, for *INT* and *WHT*); *Low Dispersion Survey Spectrograph* (*LDSS*); *Utrecht Echelle Spectrograph*; *Wide-Field Fibre-Optic Spectrometer* (for *Autofib*); *INGRID* Infrared detector/camera; and VX-works control system.

Much depends on the array detectors: RGO has developed CCD detectors from the start, leading to extraordinary cameras with 100 million pixels, with 80% quantum efficiency, and readout noise almost down to a single electron. Both the *WHT* and the *INT* now have wide-field prime-focus cameras: the *INT* covers half a degree with an 0·1-arcsec pixel size. A 10-minute exposure reaches magnitude 27 per-square-arcsecond, and the seeing is often down to 0·7 arcseconds. Infrared versions are now arriving: *WHIRCAM* from Oxford and *CIRSI* from Cambridge.

Finally (regretfully), *Gemini*. The *Gemini* telescopes could not have been built without RGO. The nine-million-pounds worth of contracts which RGO fulfilled on time and within budget included: the A&G unit with wavefront sensing for active and adaptive optics; the *Gemini* telescope-control system; the mirror-support system; and the mirror coating plant, with new sputtering technology. The mirror support is derived from the RGO designs for the *WHT*.

And to celebrate the success of the whole La Palma story, here is the evidence of the excellence of the site and the telescopes: a multiple-lens image with 0·7-arcsecond resolution, and the first image of a star's surface; the adaptive-optics system *MARTINI* now gives 0·2-arcsecond images; deep galaxy surveys reaching $z = 4{\cdot}41$ are in progress, including a lensed star-forming galaxy at $z = 2{\cdot}515$. The ING is much in demand, producing over 200 papers a year. It is also flexible; it was the first to respond within hours of an alert and detect the optical afterglow of a gamma-ray-burst source.

RGO is justly famous for its first three centuries. The last quarter century of front-line research achievements and innovative world-beating technology have been equally glorious. Your three Directors here today are proud indeed to have served through this time.

The President. Well thank you very much for an absolutely fascinating and stimulating presentation. We will now pass on to the next presentation in the series which will be by Professor Bernard Pagel, 'A few reminiscences of the early days of the RGO at Herstmonceux'.

Professor Pagel. I joined in summer 1956, when the move to Herstmonceux had been mostly completed and the new Astronomer Royal, Dr. Richard Woolley as he then was, had been in residence for about 6 months. The Equatorial Group was built, though not yet occupied, and the West Building was not yet built, so all departments were housed in the Castle or in temporary huts in the square on the south side of the moat. The Long Gallery was partitioned into offices and the partitions did not reach the ceiling, so one tended to overhear conversations in adjoining offices that were sometimes quite indis-

creet. Later, after the West Building was completed, the Long Gallery was restored to its former glory and used for social functions, the main one in those early days being country dancing, supplemented in later years by major conferences and eventually pantomimes.

The administrative structure reflected developments that had taken place since Airy's time. It comprised eight divisions: Meridian, Time, Electronics, Solar, Magnetism & Meteorology, Astronomy & Astrophysics, Chronometer Workshop, and Nautical Almanac Office. The Administration consisted of only four persons and one of the duties of the Astronomer Royal himself was to count the petty cash every week. The divisional structure reflected the strong emphasis on astronomy related to the environment that had developed at Greenwich over the centuries, and indeed the major scientific discovery made by the previous Astronomer Royal, Sir Harold Spencer Jones, had been the variability of the rotation rate of the Earth.

The atmosphere was also rather different from what it became later under the SRC régime. As befitting an Admiralty establishment, it was rather more like a ship, with messengers and drivers in blue uniforms and ropes serving as hand rails along the spiral staircases of the Castle. The head messenger, Mr Lankford, was a colourful ex-policeman with a waxed moustache whose very aspect was enough to make one come along 'quiet-like'. Another messenger was a rather disreputable character with a pet parrot on his shoulder who always loved to bring some item of bad news which he announced with particular unction.

Observing was considered an overtime duty, somewhat like keeping watch at sea, with special allowances and time off in lieu. (I have been told that Airy used to check that scheduled observers were actually present at the telescope during nights when it was raining.)

There were clear class divisions, especially between industrial and non-industrial staffs and different rituals concerning signing on and tea breaks. Every morning in the West Building, at 10 a.m. the staff of the Chronometer Workshop would troop past my office to get their tea at the other end of the building, whereas our tea was made by the lady assistants and brought to our desks. Later on we changed this arrangement to have social tea and coffee breaks where we could get together and discuss science. Woolley's attitude to the staff was autocratic, though sometimes amenable to argument, and essentially paternalistic; he was certainly concerned for their good and his enthusiastic sponsorship of country dancing and cricket and tennis did a lot to enhance the *esprit de corps* of the establishment.

Despite the rather rigid departmental structure, there was also a tradition going back to Airy of hiring outstandingly able young scientists, usually from Cambridge, as Chief Assistants, and giving them a lot of freedom, *e.g.*, Eddington, Sydney Chapman, Spencer Jones, and Woolley himself had all been Chief Assistants early in their careers, and Dyson & Woolley had written a nice textbook on *Eclipses of the Sun and Moon*. In this tradition, Spencer Jones had appointed two Chief Assistants, the late Robert Atkinson and Tommy Gold, to whom I return shortly.

Woolley came to the RGO with a very clearly defined agenda, basically to transform the RGO from largely environmental concerns into a national centre for astrophysics, to be eventually centred on the *INT*. For this purpose he had one ace up his sleeve in being able to attract a renowned and very dynamic US astronomer, the late Olin Eggen, as a Chief Assistant. Later he also recruited another outstanding astronomer, Donald Lynden-Bell, and in the meantime he

gathered a supporting cast, partly from outside like myself and Derek Jones, and partly from existing departments, like the late Patrick Wayman, who unfortunately died a few days ago, and Bob Dickens who was seduced out of the NAO into the study of globular clusters with highly successful results. Pending completion of the *INT*, which was eventually opened by the Queen on a cloudy 1967 December 1, he initiated substantial observing programmes in South Africa, at Mount Wilson, and in Egypt, sending various staff members out on long-term assignments to the Cape and Radcliffe Observatories. I myself went on an observing trip to Israel at the instigation of Woolley, who followed me there for the opening of the Wise Observatory.

At the same time the profile of the RGO was strongly enhanced in the UK context by two initiatives that have been enormously valuable to UK astronomy in general. One was the Herstmonceux Conferences, which I think were started on an initiative by Eggen who took a major rôle during his two periods there, 1956–61 and 1964–65; these are listed in the final issue of *Spectrum*, and they were the cause for a steady stream of distinguished international visitors. The other was the summer vacation course, with which I was associated from the outset; this, like the Conferences, has continued up to the end and involved something like 500 students, including such prominent names as Donald Lynden-Bell, Jayant Narlikar, Brian Marsden, Steven Hawking, Carole Jordan, Russell Cannon, and Michael Penston, to name just a few.

On the national level, Woolley took two important decisions which have had a profound effect on the subsequent development of British astronomy.

The first concerned the design of the *INT*. There had been many ideas on this, culminating in the adoption of a Schmidt-type telescope. However, owing to lengthy discussions and financial constraints, so little progress had been made in manufacture that it was decided to let Woolley take the final decision when he came. He decided on a conventional paraboloid instead, which attracted some fierce criticism, notably from Peter Fellgett at the Herstmonceux Conference in 1964, but I think history has proved him right.

The second was the decision not to join ESO. The idea for ESO had arisen during a visit by Baade to Leiden in 1953 which resulted in a resolution signed in 1954 January by 12 prominent European astronomers including Professor Redman from Cambridge, and Spencer Jones and Stoy from the Cape Observatory who had also been involved in the early discussions, which were then centred around South Africa, rather than Chile where ESO finally ended up. When Woolley arrived he replaced Spencer Jones on the ESO Committee chaired by Jan Oort on which Redman continued to serve and it seems that up to 1960 at least a substantial part of the BNC including, notably, Redman was in favour of joining. In 1960 July, however, Woolley informed Oort to the effect that the BNC preferred participation in a Commonwealth telescope with participation in a European venture only as a second preference, and raised some reservations about the proposed formulae for allocation of telescope time and voting strength on the ESO Council. To me he quoted a piece of doggerel originally due to Lord Canning:

> "In matters of commerce, the fault of the Dutch
> Is giving too little and taking too much!"

According to Adriaan Blaauw's valuable book on the early history of ESO, these matters might have been negotiable, but that stage was never reached because Woolley evidently had set his heart on a Commonwealth collaboration which eventually came to fruition much later with the *AAT*. This decision

caused great disappointment to Oort in particular, and Danjon commented bitterly "L'Angleterre n'appartient pas a l'Europe", a comment which has some resonance in political arguments that are still going on today. The *AAT*, of course, has been a brilliant success and also paved the way to the equal success of La Palma still later, so again Woolley's controversial decision seems to have been vindicated by subsequent history, but I believe that in the next century ESO will be quite difficult to compete with.

I'd like to introduce here another example of British astronomers' isolationism with regard to Europe which, so far as I know, Woolley had nothing to do with, and nor did I, but I was aware of the arguments at the time. Towards the end of the 1960s, several European astronomical journals were amalgamated to form *Astronomy & Astrophysics*, which first came out in 1969, and the RAS was warmly invited to join. The RAS refused, again upsetting some people, but I am quite sure that the decision to keep *Monthly Notices* as a separate journal was the right one. From experience as an editor I know how useful it is to have two journals of comparable accessibility and status, like the *Astrophysical Journal* and the *Astronomical Journal* in the USA, rather than just one enjoying a monopoly, and for this reason alone I am glad that the *Monthly Notices* has kept its independence.

When I arrived at the RGO in 1956, the ornamental Equatorial Group, sometimes compared to an Indian temple, was nearing completion. Its history has been nicely described by Derek Jones in the final issue of *Spectrum*. The problem was that objections had been raised on aesthetic or environmental grounds to the Solar Dome, the first scientific building to be erected on the Herstmonceux site, and so the Royal Fine Arts Commission had been called in and appointed an architect who did what may be considered a good job from the point of view of aesthetics, but with apparently little or no scientific input. The RFC's intervention also led to substantial delays. The late Olin Eggen liked to tell a story about the Equatorial Group which is probably apocryphal. One of its decorative features was a western wall of knapped flints. According to the story, there was only one qualified flint-knapper left in Sussex, who trained an apprentice to help him, and after that there was a newly qualified flint-knapper looking in vain for a job.

Later I was engaged in spectroscopic observing with the *Yapp* 36-inch reflector. Derek has given a somewhat romantic description of the nocturnal scene, with aurora displays and nightingales singing in Wartling Wood, but what I remember from those nights is mainly the screech of an owl. Two incidents stand out in my memory from observing with the *Yapp* reflector. One relates to the visit by the Duke of Edinburgh in 1958 November, shortly after all the telescopes had been installed. My task was to show him a star in daylight (I forget which; Derek, manning the 28-inch refractor, showed him Arcturus) through the telescope, which I did successfully, but on that very morning I had discovered to my horror that the main mirror was far from clean. Fortunately Prince Philip did not ask to see it! The other incident took place several years later, I think in the severe winter of 1962–63, when in my enthusiasm to keep on observing in dubious weather I was caught with an open dome through a snow shower and was compelled to do a lot of sweeping afterwards to remove the traces. I got really warm on that night.

The two Chief Assistants, left over from the previous Spencer Jones régime, were Tommy Gold and the late Robert Atkinson, both outstanding scientists in their different ways. Tommy had a clear vision of the future of the RGO that was orthogonal to Woolley's ("your friend", as he bitterly described him to me).

In particular, there was an outstanding instrument physicist at the RGO named Don Palmer who had built a world-class cosmic-ray detector which Tommy was intending to use in a major programme which Woolley vetoed, so Tommy left late in 1956 for Cornell University, where he still is, and Don Palmer's outstanding talents were diverted into optical design. Atkinson was distinguished for pioneering work with Houtermans on nuclear reactions in stars in the late 1920s; Houtermans was a colourful character with an extraordinary history whom I had the privilege of meeting when he came to visit Atkinson at the RGO in the late 1950s. In Germany in the 1920s he had organised a series of evening seminars under the name of 'Eine kleine Nachtphysik'. A communist, he had emigrated from Germany to the Soviet Union in the 1930s, been arrested by Stalin, and handed back to Hitler after the Nazi-Soviet pact in 1939. He had then been saved by Heisenberg who engaged him in the German nuclear project which in the end turned out to have had little military significance. To return to Atkinson, since coming to Greenwich from the USA just before the war, he had turned his attention to meridian astronomy and then during the war he made outstanding contributions to the problem of degaussing. After the war he once again distinguished himself by designing the War Memorial Clock at York Minster. During the years that I overlapped with him, he was engaged in a long-term project to build a mirror transit circle which, through lack of funding, never came to fruition. He was never happy under the Woolley régime (or perhaps I should say the Woolley-Eggen régime) and in 1964 he retired (I think unwillingly) at age 60 and left for Indiana University where he remained until his death in 1982.

It was Olin Eggen who came first about the same time as I did who did the most to shape the direction of scientific research and exerted a profound influence on my own scientific development, partly through his own researches and partly through his contacts with leading astronomers in the USA such as Gerry Kron, Albert Whitford, Olin Wilson, Allan Sandage, and Jesse Greenstein. Kron, Wilson, and Sandage, all of whom made extended visits to the RGO and greatly added to the excitement. Also Gascoigne came from Mount Stromlo, but the bad part from my point of view was that I was in Australia during his visit, swapping houses with Gascoigne. Eggen had an unparallelled knowledge of the sky which made him a constant source of interesting stars to study in detail, in my case for abundance analysis, and it was mainly owing to him that I was able to do work during that period that I am still fairly proud of. Almost as soon as he arrived, Olin was anxious to get going with photometric observations, and in the absence of the telescopes from Greenwich destined for the Equatorial Group he managed to borrow from the Science Museum the telescope used in the nineteenth century by Isaac Roberts. However, he soon convinced himself that Herstmonceux was not a photometric site.

For the two years preceding my marriage in 1958, I shared attic quarters with Olin on the top floor of the wing of the Castle occupied by the Woolleys. Richard's wife Gwyneth was rarely seen, but sometimes I played two-piano duets with Woolley, followed by snacks which she had prepared, and in later years she emerged to give children's Christmas parties which were a great success. One of the problems with living up there was the mice, which (as I then discovered) had no interest in cheese but loved wax paper with fatal effects on my packets of biscuits. Olin liked to describe how he had got a mouse to be quite tame by offering it titbits, and then finally trapped it.

Olin spent most of the cloudy evenings in the library, which was well stocked

but at that time very poorly run, and he more or less rearranged it single-handed, which I think basically only caused yet further confusion. A library committee was formed, chaired by Donald Sadler, which eventually became obsolete once the library was in the efficient hands of Miss Joan Perry. Apart from the Woolleys and Olin and myself, the Castle was inhabited by the excellent Canteen Manager, Mrs Patricia Marples, who would entertain Olin and me with tea and cakes in the evening, and who eventually became the second Lady Woolley after Gwyneth's death.

(During that period I used to drive to London and back every weekend, frequently with Bob Dickens who had lodgings in Pevensey. Getting him there involved driving the long way round through Pevensey marshes, and on one occasion this detour may well have saved my life because it was a very stormy night and I found out the next morning that a tree had been blown down across the Church Road which I would normally have taken to get to the Castle.)

A significant policy initiative by Woolley and Eggen related to RGO publications. Previously there had been the 'Greenwich Observations' containing tabular material, special reports, and miscellaneous papers published in scientific journals, notably *Monthly Notices*. The new policy was to have regular series of in-house publications and this raised a problem, because Eggen maintained that in accordance with what he alleged to be the policy at the Lick Observatory all scientific papers should appear as in-house publications, and this policy was adopted with, I think, disastrous results. Three series of publications were instituted, the *Royal Observatory Annals*, *Bulletins*, and *Circulars*, and Alan Hunter was assigned the unenviable task of getting all these publications off the ground through HM Stationery Office, which (needless to say) involved long delays. The *Annals* were fine for major catalogues, like the famous one on Omega Centauri, and the *Bulletins* were useful to Olin as a means of publishing shorter catalogues and related discussions, and also conference reports, and there was nothing wrong with that, but the bad part was that the rest of us were forced to use them. Thus for several years until this unfortunate policy (about which I had complained to Woolley in vain) was finally reversed at Donald Lynden-Bell's instigation, we were not allowed to publish in *Monthly Notices*, we had only very limited opportunities to speak at RAS meetings, and some of the choicest papers from myself, Derek Jones, Pat Wayman, and other colleagues in the first half of the 1960s lie buried in *Royal Observatory Bulletins* that are available in few university libraries and hardly ever consulted.

On a more positive note, those early days at Herstmonceux were noted for the inauguration of the Herstmonceux Conferences and the vacation students programme as I mentioned earlier. The vacation students naturally got up to a variety of pranks at different times showing varying degrees of imagination. One of the more interesting was a hot-air balloon, of which I think Stuart Malin was the prime mover, prominently marked 'EGGEN', alleged to be an acronym for 'Extragalactic Geophysical Experimental Nephoscope', and another was to encourage a local window-cleaning firm to tender for the job of cleaning the *INT* mirror. Sometimes things got out of hand. A now highly respected astronomer whom I do not name drove a small car onto the footbridge over the moat and on another occasion there were shenanigans on the roof of the Castle which raised genuine concerns about safety. Consequently when Woolley went away on an observing trip, I was required to pernoctate, *i.e.*, to move back into the Castle and sleep there during the vacation course. I remember whiling away the time by reading the *Feynman Lectures*, so it must have been 1964 or 65.

A summary of the Conference series has been published in the final issue of *Spectrum*, but I can add a few personal memories. In 1958, just before the IAU General Assembly in Moscow, we had two Soviet astronomers, Zverev (from Pulkova) and Severny (from Crimea), who were keynote speakers in the conference on 'Stellar Motions' and 'Solar Physics' respectively. Zverev was a genial guy who later entertained my wife and myself most hospitably in Leningrad later that year; he spoke very little English, but we had taken Russian classes laid on at the RGO, so this was not too bad an obstacle. On the other hand, Severny — an outstanding scientist who was excited and nervous about facing Cowling at the conference — was a hard-nosed character who didn't pull any punches. He inspected the tunnel underneath the Solar Dome, intended for a long-focus solar spectrograph, and pronounced it unsuitable owing to the thermal air currents, which he detected by watching the smoke from a cigarette. He was right about that, and all plans for a spectrograph were abandoned forthwith. His parting shot to me, which I shall always remember, was "You are astrophysicist at Pulkova"! However, he was much more friendly when I met him again later, and it is deeply regrettable that he died in 1987 just when about to be elected President of the IAU. A few years later I hosted an international colloquium on stellar atmospheres and in 1964 Olin organised a very prestigious colloquium on 'Clusters and Stellar Evolution' that brought in Martin Schwarzschild, Bengt Strömgren, Allan Sandage, George Herbig, Fred Hoyle, and others, which small fry like myself and Leonard Searle who was visiting at the time were not allowed to attend even to listen, and I have to say that that is something that still rankles. However, there were plenty of excellent conferences during the '60s, notably from my point of view the NATO course on 'The Kinematic and Chemical History of the Galaxy' in 1965 and some years later a conference on abundances attended by Hubert Reeves and Peter Fowler.

Despite a common interest in stellar atmospheres my scientific interaction with Woolley was fairly limited, apart from his kindness in including high-resolution spectra of stars for my benefit during his observing trips to Mount Wilson. I made some return for this later by acting as his support astronomer during the early years of the *INT*. It was a bit embarrassing that my paper with David Lambert on the ionization equilibrium of H^- was inspired in part by a passage in the textbook by Woolley and Stibbs that I disagreed with. Around 1962 I translated the French classic *Astronomie Populaire* by Camille Flammarion, including a special supplement on space exploration that had been produced for the English version. Woolley, whose unfortunate hostile attitude to space research has been notorious, thought I had written this myself and made a wry face about it, but he never held it against me. It was also from Woolley that I got my first lessons in stellar dynamics, but Donald Lynden-Bell taught me a lot more later. In 1968 Philip Daly and Nigel Calder made a *Horizon* programme for BBC Television called 'The Violent Universe' in which leading astronomers were interviewed along with their instruments. The most memorable shot in that programme, to my mind, was one of Allan Sandage sitting on the edge of the lily pond in the Equatorial Group, talking about the oscillating universe; when I looked up the book recently, I was disappointed to find Sandage's picture alongside a telescope at Mount Stromlo Observatory instead. I also figured in that programme, sitting at the *INT* muffled in my flying suit and muttering about the difficulty in searching for primordial stellar abundances. For some reason connected with an earlier triangular dispute between Eggen, Woolley,

and Daly (which I believe had precipitated Eggen's second departure from the RGO in 1965), Woolley refused to take part in this exercise, but again he placed no obstacles in the way of my doing so. In fact he was wandering about the *INT* dome in earnest conversation with Bernard Levin while Daly and his team, to whom Woolley wasn't talking, were doing the filming.

In 1965 the Astronomy Centre at Sussex University was inaugurated, with Sir William McCrea as first director, later to be followed by Roger Tayler. This development, and the close collaboration with the RGO, in which Woolley played a major part, brought enormous pleasure and stimulation to me and it did a lot for British astronomy, as can be seen from the list of graduates. I also had the pleasure of the company of Donald Lynden-Bell and Mike Penston, both of whom did a lot for my scientific development. In fact it was really Donald who got me interested in the theory of chemical evolution of galaxies. When Donald was living in Barcombe and I in Ringmer, we had a car pool, and in addition to that we used to go for walks in the grounds after lunch discussing science. When Donald left for Cambridge in 1972, I inherited his Sussex MSc course on 'Galactic Dynamics', and in preparation for this he taught me virtually all I know about the subject during those walks in the gardens.

The years up to the opening of the *AAT* in 1975 were in some sense an interregnum when first-class ground-based observational facilities were not yet available except on visits to foreign institutions, notably Mount Wilson, where we were always treated very generously, but I look back on those years as a very happy time, able to do what I liked and with admirable technical assistance particularly from Dianne Harmer, who now works at Kitt Peak, and able to enjoy the company of so many talented individuals like Woolley, Eggen, Wal Sargent, Donald Lynden-Bell, Louise Webster, Paul Murdin, and my research students of that period, especially Bob Fosbury and Hagai Netzer.

The President. Thank you very much for reminding us of the greatness of those heady days and of how it was to take part. I think it might be wiser not to ask any questions now as I think we really should move on to the final talk this afternoon, by Professor Malcolm Longair, on 'The Royal Observatory Edinburgh: selected highlights'.

Professor M. S. Longair. In this brief celebration of the Royal Observatory Edinburgh, I take as read the distinctive features of its recent history — its contributions in innovative instrumentation, in astronomical research, and in the support of the astronomical community in the era of the national facilities. I will mention briefly those aspects of recent work which have given me particular pleasure, but I want mostly to concentrate upon the earlier history. In preparing this talk, I have been struck by the extraordinary resonances with the issues which we have had to deal with in the current astronomy programme — there is nothing new under the Sun.

The 'Town's College', later to become the University of Edinburgh, was founded in 1583. There was a strong connection with astronomy through the appointments to the Chair of Mathematics. James Gregory, the inventor of the Gregorian telescope, was appointed to the Chair in 1674, and the great mathematician Colin Maclaurin in 1725. In 1736, Maclaurin made the first proposals for an Observatory to be built in the University's Old College. He had already placed telescopes on the roof of the Old College and given practical demonstrations of their use. Maclaurin was especially unlucky in the timing of his proposals. As recorded by William Maitland in his *History of Edinburgh* of 1753,

"An Observatory for making Astronomical Observations being much wanted in the college, the City Magistrates were frequently applied to for their assistance to accomplish so desirable a work; especially in the year 1736 when it was almost agreed to; but a stop being put to the same by the troubles which befell Edinburgh on the unhappy Murder of John Porteous a Lieutenant of the Town Guard, by the populace, all proceedings were set aside until the year 1741".

Undaunted, Maclaurin revived the proposals in 1741 and delivered a subscription series of lectures on experimental philosophy to fund the new Observatory. The lectures given by Maclaurin and his assistants raised £160 for the Observatory which was to be built in the reconstructed buildings of the Old College. This sum was supplemented by other gifts, including a gift of £100 from the Earl of Morton. The Earl had invited Maclaurin to survey his properties in Orkney and Shetland, but Maclaurin, being unable to accompany the Earl, recommended James Short instead. Whilst on Barra, the party was attacked by the retainers of Sir James Stewart of Barra and several of the Earl's servants were badly injured. Short was out of the way observing 'heavenly bodies'. Morton received £400 in compensation and gave £100 towards the building of the Observatory and £200 for the building of a Tolbooth in Kirkwall, presumably to house the miscreants. The timing was again unfortunate. In the 1745 Jacobite uprising, Maclaurin organised Edinburgh's defences against Charles Edward Stewart. With the Young Pretender's success in Scotland, Maclaurin fled to England. After the rebellion, he returned exhausted to Edinburgh and died in 1746.

The next initiative came from Thomas Short, the brother of James Short, the great astronomical instrument builder. When James Short died, Thomas took over his brother's business and completed a number of outstanding orders for telescopes, including two twelve-foot, 12-inch aperture telescopes, one for the King of Denmark which was claimed to have a market value of 12 000 guineas. Unfortunately, the King was deposed and so in 1776 Short took the telescope to Edinburgh. He applied to the Town Council for the lease of land on Calton Hill to build a popular observatory. The original agreement was that Short would build the observatory with his own funds and take all the receipts from observers, but the telescope would become the property of the town. The cost of the building was originally estimated to be £110. However, he became more ambitious and launched an appeal in the same year to raise 1200 guineas for the observatory building. The residue of the Observatory Fund set up by Maclaurin was used for this purpose. The funds were enhanced by £100 from the Duke of Hamilton. This was the King's Purse which the Duke's horse 'Hercules' had won at the Edinburgh Races at Leith. A grand and imposing building designed by James Craig was to be built and, under a new agreement, the Observatory could be used by the University as well as the public. The foundation stone was laid on 1776 July 25 by the Lord Provost. The Observatory was to be an octagon thirty feet across and forty-eight feet high to house the 12-foot telescope. The building was well underway when in 1779 Robert Adam intervened, proposing an even more ambitious design. In the words of Hugh Arnott, writing in 1779,

"He conceived the idea of giving the whole the appearance of a fortification with buttresses and embrasures, and having Gothick towers at the angles. The beauty of the design was so much admired that the main object was forgot. The workmen left the Observatory, already half-built, and turned themselves

to raise a tower on the south-west brow of the hill, ... Upon this building, was exhausted all the money destined for the Observatory; besides a considerable arrear was incurred to tradesmen".

The legal complexities which followed this débacle are wonderfully described by D. J. Bryden in his splendid paper 'The Edinburgh Observatory 1736-1811: A Story of Failure' (*Annals of Science*, **47**, 445, 1990). Short and his family immediately occupied the Gothic tower, Short's wife Jacobina playing a major rôle in the events which followed. Short was 66 when he married Jacobina in 1777 and by the time he died in 1788 had fathered nine children. A legal dispute broke out over the custody of the Observatory and the instruments, at one point Jacobina resorting to an evening raid to repossess the tower, her companions armed with pistols, a blunderbuss, and cutlasses. This raid failed and some of her companions were fined and jailed.

So far, the Town had contributed nothing to the Observatory, but it eventually contributed the cost of completing it. Short's grandson James Douglas tried to run it as a popular observatory, but it did not generate enough income to cover costs. The Observatory was not used by the University and it rapidly fell into disuse. To the chagrin of the publishers of the 1810 edition of the *Encyclopaedia Britannica*, published in Edinburgh, they had to report that "There is an observatory on the Calton Hill in Edinburgh, but it is in very bad repair".

The fortunes of the Observatory were, however, about to revive. The Chair of Practical Astronomy was established by the University in 1785 and Robert Blair was appointed. However, he took no interest in the Observatory. Then, in 1811, the Astronomical Institution of Edinburgh was founded, nine years before the Royal Astronomical Society. Plans were approved for a new scientific observatory, with the understanding that the Gothic tower would be used as a popular observatory. William Playfair provided the design, based upon Palladio's Villa La Rotonda in Vicenza. In 1818, building began and was completed in six years. In 1822, George IV visited Edinburgh and, following a loyal address by the Astronomical Institution, the King was "graciously pleased to permit the Observatory on Calton Hill to be styled the 'Royal Observatory of King George the Fourth'". The appendage 'of King George the Fourth' was dropped after the King's death, the loyal address by the Astronomical Institution to William IV on his accession referring only to the Royal Observatory. The change of status was important for astronomy in Edinburgh since it paved the way for access to government funding for the support of the Observatory.

Blair died in 1828 and in 1834, the University of Edinburgh, the Astronomical Institution of Edinburgh, and the Government came to a new agreement according to which the Institution handed the Observatory over to the University, the Government provided a Principal Observer as its head and an assistant to support him, and the posts of Principal Observer and Regius Professor of Astronomy were to be combined in the position of Astronomer Royal for Scotland. The first Astronomer Royal for Scotland was Thomas Henderson. He is remembered as the first astronomer to measure the parallax of a star. His first measurements from the Cape Observatory of the parallax of Alpha Centauri were made in 1834, but only published in 1839, when the motion in right ascension as well as in declination was measured. Unfortunately for Henderson, Bessel published his parallax of 61 Cygni three months earlier. In ten years, Henderson measured 60 000 star positions from Calton Hill.

Henderson was succeeded by Charles Piazzi Smyth, a remarkable character, as described in the delightful book by Hermann and Mary Brück. From his colourful career, I select only two highlights. The first was the inauguration of the public time service in 1852. A time ball was erected on the 100-foot high Nelson monument on Calton Hill. The ball was dropped at exactly 1 p.m. and could be seen all over Edinburgh and by ships sailing in the Firth of Forth. In 1861, a 4000-ft electrical cable was stretched from Calton Hill to Edinburgh Castle so that an electrical signal from the Observatory could set off a time-gun. Experiments were made to find out the right amount of gunpowder so that the signal could be heard far away and yet not shatter nearby windows. At the inauguration, the ball fell but the gun did not go off, to Piazzi Smyth's dismay.

Piazzi Smyth was an inveterate traveller and was the first to appreciate fully the advantages of carrying out astronomy from the tops of high mountains. He is particularly remembered for his pioneering site-testing activities in the Canary Islands. He left behind a remarkable series of stereographic images of his expeditions as well as his own painting of the peaks of the island of La Palma, as seen from Tenerife, well above the cloud layer.

During Piazzi Smyth's tenure, relations with the University and the Government reached a low ebb. The buildings on Calton Hill were inadequate for a modern observatory, the instruments were poor and outmoded. There was no library. Furthermore, Piazzi Smyth had not carried out his professorial duties so far as the University was concerned. In 1888, the Royal Commission on the Scottish Universities recommended that the Regius Professor of Astronomy should no longer be Astronomer Royal, that the institution of the Royal Observatory be abolished, and that the Calton Hill Observatory cease to be a national institution and be handed over to the University.

Lord Lindsay, the 26th Earl of Crawford and Balcarres and Scotland's Senior Earl, came to the rescue of the Observatory. He had built a magnificent private observatory at Dun Echt, 12 miles west of Aberdeen, with a far superior set of instruments to those of the Royal Observatory. At Dun Echt, Copeland, then the principal assistant and who was to become the third Astronomer Royal for Scotland, made the discovery of helium in the Orion Nebula, showing that helium was not only present in the Sun. In his evaluation of his instruments and observatory, Lindsay estimated that the instruments were valued at about £10 000 and the buildings a further £10 000. In addition, Lindsay had a magnificent library of scientific and astronomical texts. He was probably the most prolific book collector of his day, having his agents seek out rare books all over Europe. The result of their efforts was that his library contained most of the great books on astronomy since the invention of printing, including first editions of Copernicus, Tycho Brahe, Galileo, Kepler, and Newton.

Lord Lindsay presented, as a gift to the Scottish nation, the instruments of his observatory and his collection of 15 000 books, pamphlets, and manuscripts, on condition that the Government would build and maintain a new Royal Observatory to replace the Calton Hill Observatory. This extraordinary act of generosity was accepted and the new Royal Observatory on Blackford Hill was constructed at a cost of £30 000.

As they say, the rest is history. From my perspective, the distinctive feature of the Observatory's programme has always been in advanced astronomical instrumentation. In 1915, for example, E. A. Baker pioneered photoelectric stellar photometry and in 1921 the stellar spectrophotometry programme was

begun. With Professor Brück's appointment as the seventh Astronomer Royal for Scotland in 1957, an instrumentation group was set up under Dr. Peter Fellgett, subsequently Professor of Cybernetics at Reading University. This marked the beginning of the Observatory's interests in Schmidt-telescope science and the first high-speed measuring machine *GALAXY*. In 1965, the Science Research Council took over responsibility from the Scottish Office and the days when the Astronomer Royal could fix the Observatory's budget over a glass of sherry with the Scottish Secretary were over.

During the era of the national facilities, the Observatory took responsibility for the *UK Schmidt Telescope*, the high-speed measuring machines *COSMOS* and *SuperCOSMOS*, the *UK Infrared Telescope*, and the *James Clerk Maxwell Telescope*. I have many very happy memories of the time when I was directing these operations. Let me end by mentioning just a few of the achievements of the Observatory which have brought me particular pleasure. The *UK Infrared Telescope* was the world's first large thin-mirror telescope. It carried out, and continues to carry out, much of the pioneering science in the infrared wavebands and was a crucial stimulus to infrared astronomy in the UK, which has been central to our involvement in the *Gemini* project. The telescope pioneered many of the instruments which are now standard requirements of all large optical-infrared telescopes — the first common-user IR cameras, the first common-user cooled-grating spectrometers, and the first instrument-support unit to allow up to four instruments to be available for immediate operation. The first images taken with the infrared array cameras were spectacular and opened up the whole of infrared science for the community at large. The *James Clerk Maxwell Telescope* remains the world's largest telescope for imaging and spectroscopy in the submillimetre waveband and *SCUBA*, the world's first common-user submillimetre camera, has opened up completely new areas in star formation and astrophysical cosmology.

In its latest incarnation, the Royal Observatory Edinburgh is an amalgam of the Institute of Astronomy of the University of Edinburgh and the UK Astronomy Technology Centre. The one thing which history tells us is that the future is unpredictable and it will be a challenge to maintain and enhance the recent levels of achievement of UK astronomical technology into the future. I wish all those involved every success.

The President. Well thank you very much for a really stimulating and exciting presentation; we knew it would be. It's been a wonderful afternoon celebrating the achievements of the Royal Greenwich Observatory and the Royal Observatory Edinburgh. We know the future will be exciting so we can look forward to that. We don't have time for questions for all the speakers, but we do have a drinks party in the room outside here, where there will be an opportunity to talk to the speakers. The next meeting of the Society will be here on 1999 February 12. I look forward to seeing you then.
