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JOINT MEETING OF THE ROYAL ASTRONOMICAL SOCIETY AND THE SCIENCE RESEARCH COUNCIL

Friday, 1974 March 1 at $14^h\ 00^m$
in the Scientific Societies' Lecture Theatre, Savile Row

SIR ERIC EASTWOOD *in the Chair*

Professor R. J. TAYLER
Dr. H. H. ATKINSON } *in attendance*

Professor R. J. Tayler. I should like to start by welcoming everybody to this meeting and by saying that I am sitting here because the President is unfortunately unwell.

The Royal Astronomical Society has been hoping to hold a meeting of this type for a long time. As astronomy is a subject in which most financial support comes from the Science Research Council and in which the amount of money which is provided by the University Grants Committee is unlikely to increase dramatically, it is particularly important for the astronomical community to know how decisions concerning the expenditure of SRC money are taken and to be able to participate in them. We are happy to be able to put on this meeting at which representatives of the SRC will describe both how the support of astronomy is organized and what projects are in hand or in early stages of planning. This should be an opportunity for those astronomers not on SRC Committees to see how things are arranged; even those astronomers, like myself, who have been Committee members do not often get an overall view of arrangements.

Invitations to this meeting were sent not only to Fellows of the Royal Astronomical Society but also to all University departments and other groups involved in work in astronomy or space and to members of the scientific press. We are happy to welcome their representatives today. We are also pleased to see a powerful group from the SRC including the Chairman, Professor Edwards, and Secretary, Mr. Walker.

Now it is my pleasure to hand the Chair to Sir Eric Eastwood who is Chairman of the Astronomy Space and Radio Board, Past President of the Institute of Electrical Engineers and Director of Research at the General Electric Company.

Sir Eric Eastwood. I would first like to thank the Royal Astronomical Society on behalf of the Science Research Council for arranging this meeting and so providing an opportunity for us to explain the new arrangements which the Council will be implementing for the organization of our support for astronomy and geophysics and to outline future plans, especially for major facilities.

I am grateful to Professor Tayler for his introduction and for handing the Chair so graciously to me; I am sure you are wondering how a non-astronomer comes to occupy this position. The reason is to be found in the symbols ASRB which are the abbreviation for the Astronomy Space and Radio Board. I happen to come within the category R, for Radio research, which is one of the three activities covered by the Board.

As you are probably all aware the SRC itself was set up in 1965, and Dr. Atkinson will be telling you more about its origins, activities and the Royal Charter which defines its function. An illuminating comment on the function of the Council was given in the White Paper following the famous report by Lord Rothschild on Government research and development. There it was suggested that the primary purpose of the Council should be to sustain standards of education and research in universities. The Council is served by four Boards, and each Board is intended to sub-serve the same primary function as the Council but in its specialized field of science or engineering. The four specialized Boards are Nuclear Physics, University Science, University Engineering and the ASRB.

The field of the ASR Board is very extensive and comprises first astronomy, both theoretical and observational, whether conducted from instruments on the ground or borne by satellites, rockets or balloons; secondly, space studies, which are mainly concerned with geophysics using instruments carried by similar vehicles; and thirdly, radio research—studies of the propagation of radio waves at all levels of the atmosphere, including the ionosphere, and the influence of solar radiations upon the physical state of this atmosphere. It will be obvious to you that these various types of study overlap somewhat; particularly is this the case when you note that many of the measuring instruments are carried in very expensive vehicles. When the SRC was set up astronomy was still easily distinguished from space studies, and so it was possible for the very detailed examination of proposals for research and for control of the projects arising from them to be conducted through the present two committees, namely APGC (Astronomy Policy and Grants Committee) and SPGC (Space Policy and Grants Committee). This type of clear-cut division is no longer possible, for much work on astronomy is now conducted by space techniques. In addition, the very expensive nature of satellite-borne experiments has a major influence upon the way in which the Board administers its available financial resources. These matters have been studied very carefully by the Council during the past eighteen months, and changes in the arrangements for assessing and selecting scientific projects and for managing their execution have been decided upon so as to be in accord with modern conditions.

Dr. Atkinson will tell how, at the present time, formal decisions are made in the ASRB by committees of independent scientists. He will explain the general background of SRC and about the changes we are proposing to make. You will be well aware that the funds available for the SRC were recently cut, like most other parts of public expenditure, and this makes it all the more important that we spend our money very carefully. The astronomy community is a special one in that it is largely dependent on the SRC for the provision of major equipment and observing facilities, but since these facilities are to be used by many scientists it is necessary that we provide the facilities that the scientists themselves regard as most important and relevant for the future development of their subject. The SRC fully recognizes this, the need to consult the community fully and to involve astronomers and geophysicists in the decision-making process. After Dr. Atkinson has spoken on the organization Dr. Sciama will sketch the scientific background against which the SRC will make decisions about new facilities; he will indicate why the facilities are needed. More details of the future plans of the Board will then be given by Professor Stibbs (Chairman of APGC) and by Professor Elliot (Chairman of SPGC). I shall then open the meeting for questions about the organization and for full discussion and interchange of views about the science programme and the instruments that are seen as necessary for the future.

I now introduce to you Dr. Atkinson, Head of the ASR Division of SRC.

Dr. H. H. Atkinson. Before getting down to the scientific substance of our future plans, I shall try to tell you about two important things: money and organization. How much is spent on astronomy, space and radio by the SRC? How are decisions made? What are the new arrangements to be in the ASR area?

But first, what is the SRC? The Science Research Council was set up in 1965 as part of a complete reorganization of government science. It was formed from the university grants part of the Department of Scientific and Industrial Research, together with a number of Government establishments doing basic research—the Royal Greenwich Observatory, the Royal Observatory Edinburgh and the Radio and Space Research Station (now the Appleton Laboratory)—and also the high-energy physics laboratories, Rutherford and Daresbury. The latter two had been set up not long before, specifically to provide large facilities for university scientists. In addition, the Council took on the management of UK space research, and responsibilities for the European Space Research Organization (ESRO).

The SRC was given a Royal Charter. The Charter begins rather well with the Queen saying, "TO ALL TO WHOM THESE PRESENTS SHALL COME, GREETINGS". According to the Charter the objectives of the SRC are, first, to carry out research and development in science and technology; secondly to encourage and support by any means research and development in science and technology by any other person or body; thirdly to provide and operate equipment or other facilities for common use in research and development in science and technology by universities, technical colleges or other institutions or persons engaged in research; fourthly to make grants for post-graduate instruction in science and technology; and finally to disseminate knowledge concerning science and technology. Within these terms of reference, and within financial limits set by the Government, the SRC is an autonomous body free to determine its scientific policies and research programmes.

From the beginning the SRC's main rôle has been to support university science and engineering. As mentioned by Sir Eric, the paramount importance of this rôle was explicitly stated in 1972 in the White Paper, Framework for Government Research and Development: "the primary purpose (of the SRC) is to sustain standards of education and research in universities".

How does the SRC fit into the Government organization and where does its money come from? The answer to the last point is simple: from the taxpayer. Parliament votes money to DES for the Research Councils. This is called the "Science Budget"; it is distributed by the Secretary of State for Education and Science to the five Research Councils in the light of advice from the Advisory Board for the Research Councils.

The SRC, the Council itself, comprises a Chairman and between 10 and 15 members. The Council is appointed by the Secretary of State. The Council has the overall responsibility for policy and expenditure, and for the SRC's own staff. The accounting officer for SRC expenditure is the Chairman. Under the Council are four Boards, as Sir Eric has said. The one we are concerned with is the ASR Board. This deals with astronomy, geophysics above the Earth's surface, and some radio research. The Board consists of about 14 people, usually all scientists. They are not chosen simply as wise men (or women). Every effort is made to cover a wide range of disciplines and to draw them from a wide range of organizations—educational institutions, research establishments and indeed industry. Because they are responsible for making recommendations about a substantial part of the Council's funds and have delegated financial powers, they are appointed by the Council. At present under the Board there are two main committees, the Astronomy Policy and Grants Committee and the Space Policy and Grants Committee. The APGC is mainly for ground-based astronomy and the SPGC for space-based research. In addition there are laboratory committees and a number of working groups and panels in specific areas. The same criteria for membership apply to these as to the Board. Membership of a particular body is normally for three years. Thus, over a period of time, many members of the scientific community are involved.

The central administration of SRC is at State House in London. The function of the London Office is to provide a secretariat for the committees. The Secretariat is made up of full-time officials through which the Council Chairman as accounting officer ensures that the rules for the expenditure of public money are adhered to. But the scientific policy is decided by the committees of independent scientists.

I shall tell you in a minute about new arrangements under the Board. But first let me say something more about money. The Council expects to get about 84 million pounds in 1974-75, allowing for the recent cuts. Including the ESRO subscription, the fraction of the SRC's funds going to the ASR Board area is about one quarter. In 1974-75 the ASR Board expects to get about £20 million. Of this, just over half will be spent on the planning, construction and operation of major facilities for university and other scientists. These include the proposed Mark Va radio telescope, the Chilbolton radio telescope, a millimetre dish, a 3·8-metre infra-red flux collector, the Isaac Newton telescope, our subscription to the South African Astronomical Observatory and the Anglo-Australian telescope, the proposed Northern Hemisphere Observatory, the satellites UK–5, UK–6, IUE, and EXO, Skylark and other rockets, and balloons. About one quarter goes on

the ESRO subscription; and about one eighth each on minor grants to universities and on the in-house and "national service" work of the three SRC establishments, Appleton Laboratory, Royal Greenwich Observatory, and Royal Observatory Edinburgh.

As Sir Eric has also said, there are to be new organizational arrangements for the ASR area. The present split under the ASR Board is into the APGC and SPGC. This was all right when, a number of years ago, most astronomy was ground-based and most space research was geophysics. But now space is more astronomy than geophysics. So the science is spread between two technique-based committees. Is this the best way of doing things? There was another different problem. How should the planned new facilities, especially the Northern Hemisphere Observatory, be executed? With these points in mind the Council has been recently reviewing all the arrangements in the ASR area. In this the Council has sought to provide, first, means of assessing scientific priorities and determining policy, including manpower policy; and, secondly, means of implementing the policy with strong user association and sound financial control. The Council's conclusions relate first to the committee structure and secondly to the rôle of the Establishments and the management of major facilities.

The ASR Board is to be retained and will cover the same broad area as before. This area has a certain unity, a certain simple charm. In essence it comprises basic research on the entire universe except for *terra firma*. There is of course a fuzzy boundary near the Earth's surface which we share with the Natural Environment Research Council and the Meteorological Office.

The Board cannot do everything itself although it will decide all major policy matters. Under the Board will be three committees. These will be largely science-based as follows: Astronomy I, including radio, X-ray and gamma-ray astronomy, and cosmic rays; Astronomy II, including optical, infra-red and ultra-violet astronomy; and Solar System, including solar physics, lunar and planetary physics, and solar–terrestrial relationships. These are not necessarily the actual names of the committees, which will be settled by the ASR Board. Astronomy has been distributed between two committees to reduce the load on each and to involve more scientists in the decisions. The split is somewhat arbitrary but may be regarded as a division roughly into high-energy events, low-energy events and the solar system. The three Scientific Committees will help the Board to determine its policy for the support of research and to formulate its Forward Look. They will also deal with research grant applications and other proposals for expenditure. Theory will be supported by the appropriate committee.

Regarding the ASR research establishments, the Council sees a threefold rôle, first to support university research particularly in the planning, construction and operation of major facilities; secondly to carry out research on a reasonable scale, preferably in collaboration with universities, and certainly taking account of university programmes; and lastly to carry out other work in the national interest (for example the time and almanac services at the RGO and the radio research at the Appleton Laboratory). Regarding the in-house research of the ASR Establishments, the Council would like it to be funded more like university research, with a block grant to cover salaries and basic costs (like the UGC component for a university) and with competition for marginal extra funds to support particular projects. The Board has been asked to work this out, gradually.

Within this overall policy the Appleton Laboratory will carry prime responsibility for arranging the provision of satellites, rockets and balloons and the coördination of their payloads. During the last two years the Laboratory has, in any case, increasingly been adopting this rôle. The Royal Greenwich Observatory will in the future carry a similar prime executive responsibility for the construction and operation of large national ground-based optical facilities, including the proposed Northern Hemisphere Observatory. This will require a substantial reorganization of the Observatory to enable it to carry out its new function within its present total size. The Royal Observatory Edinburgh is a small establishment. It will remain at about its present size and will continue to make its own valuable contributions to the support of the national astronomy programme as, for example, it has done recently in the field of automation, the northern-hemisphere site survey and the building of the 48-inch Schmidt telescope in Australia. The ROE will continue to complement the RGO by taking on such special tasks as the Board specifically requests of it in furtherance of the national programme, for example, some of the projected instrument development for the proposed NHO.

Finally, I should like to draw together the Council's views about the management of major facilities, which account for the bulk of the Board's resources. The Council expects that the initiative for major facilities will usually come from working scientists, whether in universities or Establishments. Normally, an Establishment will have the executive responsibility for such a major facility, including necessary feasibility studies and, subsequently, for the management or coördination of the design and construction phase, and for operation. This will be under a project manager or project director. However, while this will be the usual position, the management of a facility by a strong university group is not precluded.

The Council recognizes the importance of a strong user participation in each project including through a steering committee reporting to one of the Scientific Committees or to the Board. Such a steering committee will, when appropriate, arrange travel grants and propose advances in instrumentation. Overall, the Council has emphasized the importance of delegation of power and of clear-cut lines of responsibility. Thus, the Council has set the overall framework. At the same time it has recognized that it is for the ASR Board to decide what sub-structure is needed. The Board will now devote itself to this major task, which will involve substantial changes. The committee system will come into operation by 1 October, and the other arrangements will be made as quickly as is practicable.

The Chairman. Although it is something of a marathon for you, we have felt it would be best to press ahead with the description of the work of the Council and to take discussion at the end. I now ask Dr. Sciama to speak in his capacity as a member of the ASR Board.

Dr. D. W. Sciama. It is my task to survey the scientific aspects of the SRC's astronomy programme. In the time available I can touch upon only a few of the important topics. Fortunately my omissions can be rectified in the discussion. The six topics I shall discuss are the atmosphere and ionosphere, the interstellar medium, stellar and galactic evolution, pulsars, radio galaxies and quasars, and black holes.

Research on the solar system and geophysics above the Earth's surface, including radio propagation, are the responsibility of the ASR Board as

well as astronomy outside the solar system. I shall just discuss the atmosphere and ionosphere, leaving the Sun, Moon, planets and the magnetosphere to later speakers.

The atmosphere is important for at least three reasons: its intrinsic interest as a physical system and, more practically, its relationship to the climate, and to communications. The main unsolved scientific problem is to understand the general circulation of the atmosphere. A straightforward theoretical attack on this problem would be too difficult: we need more data. These can be obtained from ground-based observations, for instance using lasers, and from rocket observations. However to obtain adequate coverage at different heights and over long periods of time we need satellite observations such as those of the Oxford–Heriot Watt collaboration using Nimbus satellites. The observations should provide data leading to a self-consistent model relating heat balance, photochemistry, wind structure, sudden warming effects and so on. It is also important to study the atmospheres of the other planets.

The ionosphere is fairly well understood at low latitudes, but not at high latitudes such as in the auroral zones where fast particles play an important rôle. We need to understand the acceleration processes involved, the resulting electromagnetic effects, the influence of solar X-rays and Lyman α, and the interaction between the ionosphere and the neutral atmosphere.

Observations are made from the ground, for instance by using Faraday rotation data, and from rockets and satellites. A particularly powerful tool is to study the scattering of high-frequency radio waves by thermally-induced irregularities in the ionosphere. As with Nimbus, this could determine many parameters at a range of heights continuously for many years, which should enable a self-consistent model to be set up. There is a proposal for a powerful new European facility, EISCAT, to do this; it will be discussed by a later speaker.

The interstellar medium is important for its own sake, for its relationship to the stars and most particularly because it is the site of star formation, and perhaps also of the simpler organic molecules whose further build-up on planets may eventually lead to the development of life. We need to study its composition—involving quantitative determination of its atoms, ions both thermal and relativistic, at least 25 kinds of molecules including organic molecules, and dust—its physical state—density, temperature and magnetic field configuration, heating and cooling processes, turbulent motions, spiral arms, hydrostatics of the disk and halo—and its relationship to stars and especially star formation.

The interstellar medium is a prime example of an astronomical phenomenon that needs a concerted attack by all the different kinds of astronomy. In addition to the well-known optical approach we need to work in the ultra-violet to observe resonance lines of highly-excited interstellar ions, outflow of gas from stars and extinction by dust (for instance the satellite TD–1 and soon the International Ultra-Violet Explorer); and in the infra-red to observe molecules, dust and emission lines related to heating processes, and to observe the sites of star formation. I should mention here the London University and ROE work using balloons and the 1·5-metre flux collector on Tenerife. (A 3-metre flux collector is under consideration.) We also require millimetre observations for discovering organic molecules, and also for studying star formation: lines of different excitation are formed at different depths in

dense clouds. A millimetre dish is under consideration by SRC. X-ray observations reveal absorption by gas and dust, for instance in the work by Leicester and University College London, on the satellite Copernicus: it may be possible to solve the problem of the composition of interstellar dust by a form of X-ray crystallography—by observing dust haloes around X-ray sources and scanning them in wavelength. Various X-ray satellites are in the pipeline—UK–5, UK–6 and ESRO's EXOSAT. A further satellite EXO is under consideration. Cosmic-ray studies give important nuclear information, for example one can study collision products of the primary cosmic-ray flux with the interstellar medium. Its energy dependence looks very informative. Also cosmic rays are dynamically an important component of the interstellar medium. Gamma rays have been recently observed and are probably due to collisions of cosmic rays with the interstellar medium. Radio studies provide much information about interstellar conditions through observations of continuous emission of synchrotron radiation from relativistic electrons moving in interstellar magnetic fields, the 21-centimetre line of neutral hydrogen, the *OH* maser lines and other molecular lines, and the recombination lines of hydrogen, helium and possibly heavier elements. The Mark Va radio telescope which is under consideration for Jodrell Bank would be very effective for this work. Finally, we require theory to synthesize these observations and to provide the ultimate account of all the processes involved. Of course theory is a vital element in all my topics and I need not repeat that each time.

Stellar evolution is a classical subject of optical astronomy. It involves observing stars in different stages of development and also binaries where the evolution of one star is influenced by the proximity of its companion. The early stages link with star formation, and the late stages with supernova explosions, the formation of heavy elements and the transition to highly compact and physically exotic states—white dwarfs, neutron stars and black holes. We are now beginning to see the growth of a new subject, galactic evolution, which is closely linked with the evolution of stars and of the abundances of all the nuclei.

Abundance studies require laboratory work, such as is done at Oxford, to determine atomic parameters, as well as optical and ultra-violet observations of stars and of the interstellar medium, and work on cosmic rays (for instance the Bristol experiment on nuclei heavier than iron on the satellite UK–6) and on meteorites.

To study galactic evolution we must also observe other galaxies, involving work on faint stars or faint lines from the interstellar medium. This needs large telescopes. The SRC is involved with the Radcliffe telescope and the Anglo-Australian telescope and has constructed the 48-inch Schmidt at Siding Spring. A Northern Hemisphere observatory is under consideration. A large space telescope has been proposed by the Americans; it could observe very faint objects and would be particularly useful for studying the evolution of galaxies to understand the Hubble diagram relating red shift to apparent magnitude, which is vital for cosmology. The efficient use of the LST will require more ground-based facilities than we have today.

Pulsars represent one of the greatest discoveries of modern astronomy. It is appropriate here to recall that they were discovered at Cambridge and nearly half the known pulsars have been found by Jodrell Bank who also discovered their linear and circular polarization, their scintillation, and the

steady change in their period. Their main importance is that they contain rotating neutron stars, that is, stars with the mass of the Sun and a radius of only 10 kilometres. In other words they have densities of 10^{15} grams per c.c., as though they were the nuclei of giant atoms. They represent an extreme system for the nuclear and elementary-particle physicist, for the solid-state and plasma physicist, and are even of importance to the general relativist. In addition they link up with the late stages of stellar evolution, with supernova explosions, and as a source of cosmic rays, and can be used as probes for the electron density and magnetic fields in interstellar space.

The basic means of observation is at radio wavelengths, and the Mark Va would be a good instrument for extending our knowledge. The Crab pulsar is also observed at optical, X- and γ-ray wavelengths, and searches should continue for other cases. It is also likely that neutron stars which are not pulsars show up as X-ray sources, for instance HZ Herculis. The idea here is that the neutron star is a member of a binary system which accretes material from its optical companion. The accreted material heats up to X-ray temperatures as it falls onto the neutron star. Future X-ray satellites should clarify this picture and add other examples. The key point is to have good X-ray positions which would lead to unambiguous optical identification. This should be achievable in the future.

Radio galaxies and quasars also represent great discoveries of modern astronomy for at least two reasons. First, they involve explosions in which perhaps as much as one part in a thousand of the total rest-mass of a galaxy is converted into relativistic electrons. How this is done is still a complete mystery. Secondly, the quasars in particular can be observed out to enormous red-shifts, now up to about 3·5. If these red-shifts are due to the expansion of the Universe, as most astronomers believe, then we are seeing out to distances comparable to the radius of the Universe and back to times comparable with the age of the Universe. If the quasars are closer, as some astronomers argue, then their large red-shifts betoken some very exotic physics. Either way they are amongst the most significant objects yet detected in astronomy. The 5-kilometre radio telescope at Cambridge is in a position to map these sources with the very great resolution of one second of arc. Also very accurate radio positions, which will facilitate optical identifications, are now obtainable.

To take full advantage of this power for understanding the structure and the origin of the quasars we need to know their distances. These can only be determined optically via the red-shift. What we need therefore is a large telescope in the Northern Hemisphere which can work down to faint limits and provide us with good optical spectra, which in fact would also give us important information about the composition and the physical processes occurring in the sources in addition to the vital red-shifts. The provision of this telescope is under consideration, as I have already mentioned.

It is also necessary to observe quasars in the ultra-violet, the infra-red and in X-rays, which give characteristically different kinds of important information. Observations of this kind have already been made, but are only in their infancy. The instruments already mentioned as planned or under consideration would be able to extend our knowledge greatly.

Black holes are the ultimate in compact objects; they are highly-evolved stars that have collapsed to their event horizons, emitting neither radiation nor particles and absorbing everything that falls on them. As you all know,

there is a chance that the X-ray source Cygnus X–1 is a black hole, accreting from its optical companion like the neutron star I mentioned a moment ago. Our present understanding of this is based not only on data from an X-ray satellite, but also on radio and especially optical data (some of which have been obtained at the RGO). Future work will require more refined observations at all these wavelengths and also in the ultra-violet and infra-red, though no doubt the X-ray data take pride of place, with special emphasis on variability on a variety of time-scales.

This black hole story is so well known that I shall not repeat the details here. Instead I would like to mention a startling new theoretical result of Stephen Hawking's. According to Hawking a black hole is *not* black if quantum effects are taken into account. Apparently when a star collapses and approaches its event horizon it produces pairs of particles and anti-particles, slowly for a star of solar mass and rapidly for a mini-black-hole which might have survived from the early stages of the Universe. The theory Hawking used involves some approximations, but if it survives more exact analysis astronomers may one day be detecting the ultimate paradox—black hole explosions.

That ends my brief account, Mr. Chairman, and I would like to add just one remark. This country has a proud tradition of leadership in astronomy. Now, in astronomy's greatest period, it is *our* responsibility to ensure that it is maintained.

The Chairman. You will have gathered from Dr. Sciama's remarks that he places a high value on the instruments which the SRC can provide. We are now to hear about those instruments from Professor Stibbs and Professor Elliot who are chairmen respectively of the APGC and SPGC. As you heard from Dr. Atkinson, these two committees are to be replaced by three new committees, but a report such as this can only be given in terms of the existing structure. Our next speaker is Professor Stibbs.

Professor D. W. N. Stibbs. In 1965, with the re-organization of responsibilities for science according to the terms of the Trend Report, all aspects of astronomy and astrophysics were brought together for the first time under the Astronomy Space and Radio Board of the Science Research Council. This included support by way of grants to University departments, the operation of the two Royal Observatories of Greenwich and Edinburgh, and contributions to the two major radio-telescope installations at Manchester and Cambridge. Under the present committee structure, the Astronomy Policy and Grants Committee is responsible for planning the development of ground-based facilities. Future planning for ground-based astronomy in many parts of the subject is dominated by the need to go overseas. There is an obvious need for optical observations to be made in a climate more suitable than that of the United Kingdom, and the same also applies to some other parts of the spectrum. The establishment of overseas facilities necessarily depends upon stable and friendly relationships with the host countries concerned.

Since its formation in 1965, the APGC has been concerned with major facilities in several areas. In optical astronomy these have been the completion and subsequent use of the Isaac Newton Telescope; the construction of the Anglo-Australian Telescope, which is expected to come into operation in 1975 and for which a Director and other senior staff members have recently been appointed; the construction of the 48-inch Schmidt telescope in

Australia; and the creation of the South African Astronomical Observatory in conjunction with their CSIR, using telescopes from the former Cape and Republic Observatories at a new observing station at Sutherland. The 74-inch Radcliffe telescope will shortly be installed there, and it will operate within the terms of the Inter-Agency Agreement.

In radio astronomy two major capital programmes have been carried through—the construction of the five-kilometre aperture-synthesis telescope at Lord's Bridge for Professor Sir Martin Ryle's group, and the Mark Ia modifications of the original 250-foot radio telescope at Jodrell Bank for Professor Sir Bernard Lovell's group.

In infra-red astronomy, the APGC has provided support for Imperial College for the construction and operation of the 60-inch infra-red flux collector at Tenerife. The APGC has also supported the development of the Haverah Park array for work on cosmic rays, and, in addition, certain small experimental installations for the detection of gravitational radiation.

In addition to the provision of major facilities, the APGC has also been responsible for the award of grants to universities for research in optical, radio, infra-red, and theoretical astronomy, and for cosmic-ray and gravitational-radiation research.

Having reviewed the facilities for which the APGC has been responsible during the past nine years, I should now like to refer to the future major facilities with which the APGC is currently concerned. These involve the provision of further major national facilities for optical, infra-red, millimetre-wavelength, and radio astronomy as follows. First, the case for the proposed Northern Hemisphere Observatory is being prepared by a Planning Committee which reports to the APGC. It appears that the research interests of UK astronomers could be met by an observatory with three main telescopes with apertures of 1·5, 2·5 and 4·5 metres, with the largest-aperture telescope probably on an altazimuth mounting. Many possible sites have been considered and Professor Merle Walker of the University of California is acting as a consultant in the assessment of sites. The Royal Observatory, Edinburgh, is responsible to the NHO Planning Committee for site testing, and the site-testing teams are at present at work on Madeira and on Hawaii. It is intended that a formal case for the Observatory will be available for consideration by SRC Committees in the autumn of 1974.

Secondly, the proposed 3·8-metre infra-red flux collector was projected some years ago, in fact in 1968. A costed case had already been considered by the APGC and the ASR Board. Discussions are in hand with the University of Hawaii about the terms for use of a site on Mauna Kea mountain in Hawaii for the flux collector. Thirdly, the Mark Va radio telescope has now been designed by Husband and Company, and tenders for the main components have been sought. An estimate of the cost of construction will be derived from these tenders and the Project Committee will then report to the APGC and the ASR Board.

Furthermore, there is strong scientific interest in millimetre-wavelength astronomy, and the possibility of the construction of a UK facility has been under consideration. At the request of the APGC, the Appleton Laboratory prepared a costed proposal for a 12-metre facility, but the decision to proceed has had to be held up pending a full review of the financial position in the 1974 Forward Look. There is a possibility of collaboration in millimetre astronomy with other European countries, and discussions are continuing

in that direction. Meanwhile, a panel with Professor Hewish as Chairman has been set up to advise the APGC on millimetre-wave astronomy.

At a lower order of costs than any of the foregoing items, the APGC is concerned with developing advanced forms of instrumentation for optical telescopes and has awarded a number of grants in the past for this purpose. It is pleasing to note that one such project, for which Dr. Boksenberg of University College has been responsible, has attracted considerable interest from astronomers in other countries working at extremely low light levels. The APGC has quite recently recommended grants for further development of this image photon-counting system.

I hope it will be clear from this brief survey of the past activities of the APGC, and the future major facilities with which it is currently concerned, that substantial improvements in facilities for ground-based astronomy have already been made, and others are about to be achieved. In addition, plans for future facilities have been actively pursued and proposals for these facilities are in an advanced state of preparation.

The Chairman. I would just interject here that the delay between the definition of a new major project and its approval and funding is necessarily long, since all elements of the costing must be realistically assessed. Otherwise it is easy to reach a situation in which a project has to be abandoned half-completed because the costs far transcend what was foreseen at the inception—a situation painful for all concerned. Space projects are frighteningly expensive; we nevertheless press ahead with them, but we must place a high value on the science before we can consider them worth while. Professor Elliot will now describe the work supported by the SPGC.

Professor H. Elliot. Mr. Chairman, Ladies and Gentlemen, I shall outline that part of the ASR Board programme which comes under the jurisdiction of the Space Policy and Grants Committee which is the sister committee to Professor Stibbs' APGC. This covers astronomy, geophysics external to the surface of the Earth, the interplanetary medium, solar physics, lunar and planetary physics in so far as these are investigated by means of balloons, rockets, satellites and space probes. It is convenient to sub-divide these activities into three groups, the national space programme, the ESRO programme and the collaborative programme with NASA. As a matter of history it should be recalled that UK space science activities were initiated under the auspices of The Royal Society which managed the programme until the formation of the SRC in 1965.

The national programme incorporates the four satellites Ariel I, II, III and IV which have already been launched on American rockets under the NASA international programme and which have been mainly concerned with ionospheric and magnetospheric physics and with some experiments on radio astronomy, solar X-rays and energetic particles. The first of these was launched in 1962 and the next in the series, presently called UK–5, will be launched later this year from the San Marco platform close to the equator. This satellite will be devoted entirely to X-ray astronomy and will carry both survey instruments and instruments which can be pointed at particular sources for lengthy periods. A further satellite in this series, UK–6, is being planned but is not yet fully funded. This spacecraft will carry an experiment for the investigation of the very heavy cosmic-ray nuclei and two X-ray experiments, one a grazing-incidence telescope and the other a large detector to study short-period intensity variations.

A second important part of the national programme is that based on Skylark and Petrel sounding rockets which covers magnetospheric and ionospheric physics and is mainly conducted at high latitudes, as well as X-ray and ultra-violet astronomy. The latter operations are usually based at Woomera and now include stellar-pointing as well as solar-pointing payloads. Finally, we also have a growing high-altitude balloon programme which included some 20 flights last year devoted to cosmic-ray, ultra-violet, infra-red and gamma-ray astronomy. On the subject of high-altitude flights I should also mention the very successful solar-eclipse work carried out last year in Concorde in which the time of totality was extended by a factor of, I think, about nine—and the equally successful work that has been carried out by many groups in the UK on lunar samples brought back on the Apollo missions.

With regard to the future I should say that discussions are at present taking place with our German and Dutch colleagues about a joint project for a large grazing-incidence X-ray telescope to be launched near the end of this decade, and we also expect to make a decision later this year with our European colleagues about EISCAT, the European Incoherent Scatter radar facility for investigation on a continuous basis of the high-latitude ionosphere and magnetosphere.

Turning to the ESRO programme, I should remind you that the rôle of that organization is now changing from a purely scientific function to a mixed science and applications programme in which the applications segment will predominate. We contribute nationally to both sectors, the SRC to the scientific part and DTI to the applications side.

The Organization has successfully launched and operated seven satellites to date, of which the most recent is TD–1 carrying an important UK ultra-violet telescope and spectrograph. The past programme has covered a wide variety of scientific disciplines, covering magnetosphere, ionosphere, solar physics, interplanetary physics, energetic particles and many others besides. The UK has had a very fair share of the payloads launched in the ESRO programme. Future projects which are now approved are a gamma-ray satellite (COS–B) and a magnetospheric satellite in a geostationary orbit (GEOS), and another magnetospheric satellite which comprises one of a group of three to be launched in a joint ESRO/NASA collaboration. Finally there is an X-ray satellite (EXOSAT) which will make use of occultation of X-ray sources by the Moon to provide accurate positions for identification and comparison with optical and radio observations.

The collaborative programme with NASA is one in which UK experimenters, in response to the published NASA flight opportunities, provide experiments for inclusion in NASA spacecraft or collaborate as guest investigators with US scientific groups. Many UK experiments, of which two notable recent examples have been the MSSL grazing-incidence X-ray telescope in the Copernicus satellite and the participation by the Oxford group in the NIMBUS satellites by the remote sensing of atmospheric temperature, have been flown in this way. An extremely important development in this area in the future will be the launch in 1976 of the International Ultra-violet Explorer (IUE) as a joint UK/ESRO/NASA project. This spacecraft will be placed in a geostationary orbit, and one third of the observing time, half of which will be available for UK observers, will be allocated to European astronomers.

This is a very condensed account of the space sector of the SRC's activities

and I would be glad to enlarge on any specific topic during the discussion if required.

Thank you, Mr. Chairman.

The Chairman. There is of course one aspect of this satellite work which should be mentioned, and that is the possibility of rocket failure. After all the time and money which is put into the preparation of the payload, there is always the chance that it will never be in a position to operate.

Now we have a few moments to begin the discussion, and I suggest inviting questions first on Dr. Atkinson's contribution.

A Fellow. I think the creation of Astronomy 1 and 2 is all very well, but will there be an Astronomy 1½ for purposes which are partly in one sphere and partly in the other?

Dr. Atkinson. The duck-billed platypus may not come in any obvious group but it still manages to live and lay eggs!

Professor L. Mestel. Do I understand that, before making application for support for theoretical work, one will have to decide which committee's coverage is closest to the proposed field of work?

Dr. Atkinson. Yes, a decision will have to be made. But that is not for the applicant. He simply applies to the SRC.

Professor W. H. McCrea. I should like to ask Dr. Atkinson whether the SRC proposes that the Committees for the Establishments, in particular the RGO Committee, should continue as heretofore, with effectively the same composition?

Dr. Atkinson. This is one of the questions we have not resolved yet. If we plan any significant changes they will only be made in consultation with The Royal Society and the RAS.

Mr. B. R. Leaton. In view of the Chairman's news that SRC committees are going to be discipline-orientated, and Dr. Atkinson's remarks about the fuzzy area, what will be the SRC's views on disciplines such as the length of the day and geomagnetism where the fuzzy area stretches at least from the centre of the Earth to the magnetopause?

Dr. Atkinson. There will always be a fuzzy area between SRC and NERC. We can only consider specific cases and try to ensure that they do not fall between the two stools. We have two cases in this area at present—proposals for lunar and satellite laser ranging. SRC and NERC are in close touch over them.

A Fellow. In some cases there is a need for quick reaction to a proposal—is there any provision for that?

Professor Elliot. The Concorde eclipse project is perhaps a good example of this. As I remember it, the decision to go ahead and to commit the necessary funds was made in a matter of a few weeks with much of the business being done by telephone.

Professor McCrea. A majority of the active optical astronomers in the UK are, naturally, working at the two Royal Observatories, and so they are employed by the SRC. As compared with astronomers of similar standing who are not employed by the SRC, they are somewhat inhibited in expressing opinions as individuals on matters of scientific policy. The result is that the opinions that receive publicity may not be representative. I hope that in future it will be possible for all these astronomers to speak as individuals.

The Chairman. The heads of the three Establishments are on the Board, so there is no danger of the Establishment voice not being heard! University

astronomers, also, do not want to be deafened by the noise from the Establishments either; we are concerned that we shall draw our advice equally from all sections of the community.

Dr. Atkinson. At present ASR committees include scientists from SRC establishments who are there simply as scientists. They express their own views without inhibition. SRC scientists, as scientists, will play a full rôle in the committees to be set up under the new arrangements.

The Chairman. It is now four o'clock, and I propose that we adjourn for tea until half-past four.

[The meeting did so.]

The Chairman. The rest of the meeting is now available for discussion.

Professor F. G. Smith. Will the SRC continue with the valuable system of inviting The Royal Society and the RAS to nominate assessors to sit on SRC committees?

The Chairman. Yes.

A Fellow. Is it the intention to put millimetre-wave astronomy with radio or infra-red?

Dr. Atkinson. What does the speaker suggest?

The Fellow. Oh dear, oh dear! I can't decide that now!

The Chairman. People seem unnecessarily worried about the divisions between these committees. The divisions are not fixed. Hertz created a grating—he didn't stop to argue as to whether it was optics or not.

The Fellow. But if it's a question of money . . . ? [Laughter.]

The Chairman. You won't lose either way!

Dr. Atkinson. Nor will you get two lots of money!

Dr. H. Rishbeth. Certain subjects border on the interests of SRC and those of other bodies such as NERC. Examples might be external geomagnetism and research in the Antarctic. Will the SRC maintain suitable liaison concerning such subjects?

Dr. Atkinson. There are bound to be problems that fall between two Councils. But don't worry—put in clear-cut proposals and the machinery will deal with them.

Dr. M. V. Penston. One problem may be that of access into the committee system. Dr. Atkinson said one purpose of the SRC was to disseminate information, so can I ask why SRC committee meetings are private? Even if it is impossible to make them public, cannot the membership, agenda and minutes of the various committees be given a broader distribution?

Dr. Atkinson. It is not realistic for any executive organization to conduct its affairs entirely in public. For example, it would clearly be inappropriate to publish details of discussions on specific contracts or on specific grant applications. But we *do* want to disseminate information: our committees are as representative as possible, and we expect there to be informal contact between committee members and other astronomers.

Mr. R. St. J. Walker. We are finding that our expectations about the informal dissemination of information within communities are not well based. We have thought of trying to counteract this by putting out a newsletter several times a year.

Professor D. Lynden-Bell. Such letters should be sent to librarians, not to directors of observatories who are too busy and not so conscientious!

Professor Tayler. Would it not be possible to have, instead of a booklet about the activities of the whole SRC, a regular short newsletter from the

ASR Board? Such a newsletter could go on a notice board and would be much more likely to be widely seen than a booklet which might well disappear into the desk or wastepaper basket of a head of department.

Dr. V. C. Reddish. The SRC may usefully consider publishing reports of its astronomical activities and plans in the Quarterly Journal of the Royal Astronomical Society, as do Observatories and University Departments.

Professor T. R. Kaiser. Like many other people present, I welcome the initiative of the SRC and the RAS in calling this meeting, The mere fact, however, that it is an unusual event does to some extent highlight what I regard as a general lack of communication and consultation between the SRC and its committees on the one hand and the community which they serve on the other. Even this meeting lacks a consultative element in that we are largely being told of decisions already taken. This is not unique to the ASR Board. Only recently another Board of the SRC requested comments from Physics Departments on restructuring of its activities. However, even before these had been received by the Board, I was shown a letter signed by the Chairman of the SRC which implied that decisions with far-reaching consequences for the relevant scientific community had already been made. This brings me to another matter (especially since we have been informed of changes in committee structure): how are these committees constituted? Who appoints the members and especially the Chairmen? The SRC was formed to serve the scientific community, especially the Universities; I believe this community would like to see a more open and representative structure, eliminating any image of a "corridors of power" situation. I am sure this could be achieved without decreasing in any way the efficiency of the Council's activities.

Dr. Atkinson. The heads of all departments were written to twelve months ago about this reorganization, including Professor Kaiser.

Professor Tayler. Am I right in thinking that, under the new arrangements, decisions on major projects will be taken by the ASR Board itself, so that demarcation disputes between the three committees will only be really serious at the minor grant level?

Dr. Atkinson. The Board is in control and it is *advised* by the committees. The Board will take a larger part in making decisions than it has in the past.

Dr. Rishbeth. Will the reorganization make life any more complicated for ordinary scientists? The time of scientists is a valuable resource: does the SRC try to arrange things so as to make the most effective use of it?

Dr. Atkinson. That is the aim.

The Chairman. It is a difficult point. There is no doubt that there will be a substantial increase in the length of time spent by the Board on these matters.

Professor M. Rees. This meeting has helped to disseminate information about the SRC's plans to a wide audience, but it certainly doesn't provide an adequate or appropriate forum for genuine two-way discussion. It might therefore be worthwhile for the RAS to follow up the present meeting by arranging a series of smaller discussions, each dealing with a single topic. Interested members of SRC committees—and perhaps one or two experts from overseas—should be specially invited, and anyone else interested would be free to come along and express his views.

Another way of improving communications between the SRC and the average astronomer would be by putting an RAS "assessor" on all the

"re-structured" astronomical committees (as there now is on the APGC) and encouraging these assessors to consult, and report to, the RAS. The appointment of such assessors would also ensure that there were at least some people on SRC committees who had *not* got there via the machinery about which Professor Kaiser and others seem to feel some disquiet.

The Chairman. Thank you very much for those suggestions.

Professor R. Wilson. The discussion so far has been concerned with the organization of the central SRC committee structure and the manner in which decisions are taken on policy and resource allocations. I wish to comment on another equally important area of organization and management, namely, the use and operation of the major facilities approved by the central procedure. In other words, I am asking the question—how do we do the science? It seems that the answer to this question varies markedly within the different areas supported by the SRC but I wish to confine myself entirely to one area which I consider to be the most pressing and most difficult, namely, national facilities in optical astronomy.

The projected provision of such facilities by the SRC has been outlined by Professor Stibbs and, with the NHO, will present a great opportunity for British optical astronomy. But, to return to my theme, a first-class telescope in a first-class site is not a first-class observatory until you involve first-class astronomers in an organizational framework which allows them to get the best use out of the facility. How is this to be done?

Any answer has to recognize two formidable difficulties. First, the best observing sites are abroad and hence the facilities are remote from the user institutions. Second, operations will be conducted mainly, if not entirely, on a guest-observer basis.

Any solution should meet a number of criteria, for example, a minimum reaction time between the planning and execution of an observational programme; this should be possible since we will be concerned with existing facilities and only administrative and logistical delays need be involved; regular interaction between users so as to ensure cross-fertilization and stimulation; a sufficient degree of continuity to allow forward planning within the user institutions; and the full and effective involvement of the universities.

My own limited contact with the present system indicates that it falls somewhat short of the above requirements, and the purpose of my comments is to appeal for the setting up now of the right organizational pattern for existing and projected facilities. This requires the identification and involvement of the users to the extent, I suggest, of placing scientific control in their hands. This would allow the approximation to an observatory staff (albeit drawn from different institutions) and the achievement of the above criteria including, for example, earmarked allocations to groups against broad programmes, taking account of expertise and manpower. This could be reviewed annually but would be of particular importance to university groups since it would allow both a short reaction time and long-term planning in the allocation of UGC resources. Without this kind of arrangement, I do not think the dual system of support can work for optical astronomy.

The Chairman. This problem has been very much in our minds over the past few years.

Professor Lynden-Bell. I would like to say how glad I am that the Science Research Council has now agreed on the great importance of the large optical telescope in a good site. For too long observers in this country have had

both small telescopes and bad sites. Optical telescopes last a very long time—after 50 years they are still very serviceable if well sited—and the cost of flying people around the world to use them is very cheap compared with rocketing them 200 miles overhead. Thus none of the astronomy that can be done from good sites on Earth should be attempted from space. Furthermore the optical spectrum, although quite narrow in wavelength range, is densely packed with information in its spectral lines. It is not surprising therefore that when a detailed knowledge of the distance or constitution of a cosmic object is required most of the information comes from optical telescopes.

The great strides that have been made here by the radio astronomers have been constantly hampered by lack of optical information on the same objects, and too often the astronomical puzzles thrown up by radio astronomers have not been resolved here but left for those with large astronomical telescopes to produce the satisfying synthesis. Not only radio astronomers but also theorists would gain very directly if our optical astronomers were well equipped. The AAT will be a fine start but it cannot work on the objects of the northern sky that are the prime interest of our radio astronomers. I hope the NHO will be built with all speed.

Dr. J. C. Jackson. Will there be the people to make effective use of all the telescopes we are promised?

Professor J. Ring. The SRC recently made a survey of manpower and observing requirements—Professor Redman is the one to tell us the results.

Professor R. O. Redman. The question was raised some time ago whether there would be enough astronomers available in the UK to use the new facilities being planned or constructed. In consequence SRC sent out a questionnaire last year to all relevant departments, asking for estimated needs for observing time. In analyzing the answers the observing nights requested were matched with the nights which will be available on all telescopes when all projects are completed, and account was taken of the intention when this time comes of discontinuing use of many older and smaller telescopes located in this country. There was no support for the suggestion that there would be a shortfall of optical observers.

Professor Sir Bernard Lovell. No doubt the issue of apparent lack of consultation which Professor Kaiser has raised does worry a number of people. I would therefore like to remark that during my association with SRC I have been impressed by the insistence on the widest possible consultation. Indeed in one or two matters of great delicacy I found that SRC sought the advice of a large number of senior people both in the UK and abroad who might be able to help. So often one finds that complaints from young scientists about lack of consultation and information is really a consequence of failure of communication between the head of a department and his staff, and not a failure of liaison with the heads of departments on the part of SRC.

Professor Kaiser. I still haven't heard an answer to my question as to who appoints the chairmen and members of committees.

Mr. Walker. Proposals are sought from Board members, learned societies, vice-chancellors, and directors of polytechnics. The Council tries to ensure a balance in committee membership. There is a policy of encouraging younger members onto these committees; and there is a three-year rotation in membership which prevents people clinging to power.

The Chairman. I wish there were some power to cling to!

Dr. Atkinson. Committee responsibilities are very widely diffused—there are about 56 people altogether at present on the ASR Board and its various committees.

Professor Lynden-Bell. It would be interesting to know just how many of the 56 have actually observed the sky in the past twelve months.

The Chairman. Well, we've had a good deal of discussion on administrative matters—is there any comment on the scientific presentations?

[Silence.]

The Chairman. There seems to be a marked reluctance to discuss the science!

Professor Rees. Does the SRC have any general policy of trying actively to foster branches of astronomy in which the UK is relatively backward and disadvantaged, rather than merely concentrating resources where successes have already been achieved?

The Chairman. That is up to you—in this you are the SRC.

Professor R. L. F. Boyd. May I remind the Society that space astronomers are already accustomed to operating their observatories from a great distance. Surely the time cannot be far ahead when we will be asking not, what are the travel costs and problems to a distant observatory, but rather, what are the costs and problems of closed-loop remote control and monitoring of the instruments in a distant observatory? We need not suppose that the observatories would be unmanned but merely that astronomers could play their part from a distance.

Mr. E. N. Walker. Mr. Chairman, as no-one else seems to be going to do it I would like to make some comments on the NHO as it is conceived at the present. I have been able to do world-class astronomy over the last two years with only a 12-inch telescope. That is partly because it is in a good site, but much more important was the fact that I was able to use the telescope all night, every night—that is, many telescope man-hours were available.

Now within the time-scale of the NHO, and very probably several years before its completion, the Americans are going to have the Large Space Telescope in operation. This should give them 1/40th arc second resolution with 24 hours per day, 365 days per year usage. I believe that the future needs of British optical observers would be best served by providing them with a multiplicity of relatively small telescopes, making available a large number of telescope man-hours, with, in addition, an orbiting telescope of whatever size could be afforded.

Professor Lovell. I do not think that this assertion that the correct policy for the UK would be to concentrate on an LST type of telescope should go unchallenged. The 120-inch LST as envisaged at present cannot be launched until the 1980s at least. No doubt the freedom from the ultra-violet atmospheric absorption limitations, the attainment of resolving powers which are diffraction-limited and the opportunity of studying fainter objects than can possibly be seen from Earth will lead to major advances in astronomy. However it would be 15 to 20 years before UK astronomers had the slightest chance of buying themselves into any significant share of these specialized observations. Meanwhile, we have no option but to continue to depend on US telescopes and astronomers for the vital observations now needed—for example to consolidate the observations of the UK radio telescopes on radio galaxies and quasars. Many of the solutions to these contemporary problems lie in the range of magnitudes readily accessible to modern large telescopes

on Earth. The SRC has an excellent record in respect of the Anglo-Australian telescope and the 48-inch Schmidt on Siding Spring Mountain. It seems to me a matter of great urgency that these facilities should now be paralleled by initiating the Northern Hemisphere Observatory as quickly as possible.

Professor Redman. Of course most of us would like to use an LST if we could get one, but this country has just not got the financial and technical resources. I do not wish to discourage the enthusiasm of younger men, of which we cannot have too much, but the old men in fact are constantly thinking about these things and perhaps have a livelier sense of what is and is not possible in the economic state of the country. I should remind you too of the American estimate, made two or three years ago, that to use one LST to full advantage about ten 200-inch telescopes should be provided on the ground for complementary research. I cannot agree with the suggestion that we would be wise to spend what money we can get on large numbers of small telescopes. There are millions and millions of objects fainter than seventeenth magnitude which we would like to observe, and if one tries to measure what many astrophysicists want to know about these one soon runs into photon noise. One is compelled to use as large a collecting area as possible.

Professor Elliot. At the present time Dr. Boksenberg and Dr. Burton from this country are participating in the work of the Instrument Definition Team for the LST and we are hopeful that this involvement will grow as the project progresses. Given a significant UK contribution to this project we would hope for a corresponding share of the observing time.

Professor Ring. Although the UK cannot afford an LST of its own, we are involved in the ESRO proposal to build a Spacelab. Infra-red and ultra-violet observers are already planning to mount telescopes in this vehicle—perhaps we should be doing more to exploit its potential advantages at optical wavelenths. A one-metre telescope in orbit for ten days would be a very potent instrument!

Dr. Penston. I believe that astronomy of all wavelengths is one subject, thus the building of the NHO is an important task. There is need for speed, and I think we should select a *good* site and not necessarily the *best* site. It seems to me that Madeira suffers from poor seeing, cloud in winter and a number of other disadvantages, and that a full test of the site will delay the founding of the Observatory. On the other hand we know a good site (Hawaii) and an excellent site (La Palma). I therefore urge that after one more try at La Palma, within a month we decide to go to Hawaii.

Professor Ring. I am surprised to hear Dr. Penston say such un-objective things! He suggests that Hawaii has "good" seeing and Madeira "bad" seeing. I question the evidence for both statements. Prior to the current UK measurements, the assessment of Mauna Kea was based largely on comparisons of planetary photographs which may not correlate well with large-telescope image quality. We need an objective comparison of the two sites to decide their "cost-effectiveness", since even if it turns out that Mauna Kea has better seeing and more useable nights than Madeira, we must be sure that the gain is sufficient to justify the increased capital and running costs of the Pacific site.

In any case, the submission of the NHO proposals cannot be made until

the detailed instrument package is decided upon and this will allow time for an objective comparison of sites.

Mr. B. McInnes. If I may speak on behalf of the Site Testing Project I would disagree with Dr. Penston when he says that Hawaii is known to be an excellent site and that Madeira is known to be a poor site. To be objective we must assess both sites using the same techniques, and this we are doing. As Professor Ring has pointed out, the main assessments of seeing available so far (those which the French used in deciding to site their new large telescope on Mauna Kea) have been based on short exposures on planets with a 24-inch telescope. We are using the Polaris Trail Telescope technique, which is calibrated in terms of the 120-inch telescope at Lick. Our results so far indicate that the seeing is indeed good but perhaps not outstandingly so. As far as Madeira is concerned there is certainly a seasonal effect in the clear-sky conditions, but the month of January this year gave nearly 50 per cent photometric nights, which is anything but poor. The seeing measurements we have made so far indicate that it is not as good as La Palma but certainly not poor. It is not possible to assess the relative merits of these two sites definitely till further work has been done.

Dr. J. V. Jelley. Are the proposed NHO telescopes specialized instruments? I ask this question because the site requirements are somewhat different, are they not, for different applications such as direct photography, spectroscopy or photometry? In other words, have the sites which have been mentioned been tested for qualities other than "seeing"—for instance, overall percentage of cloud-free nights or transparency?

Mr. McInnes. We have a small portable photoelectric photometer which is used to measure stellar extinction and night-sky brightness at the sites we are testing. But perhaps the question is about the NHO telescopes rather than about site testing and Professor Redman should answer it.

Professor Redman. Following a survey of the research requirements of UK astronomers, the present proposals of the NHO Planning Committee are to provide three telescopes, of apertures 1·5, 2·5 and 4·5 metres respectively.

The 1·5-metre telescope is to be a modified Ritchey–Chrétien with an f/8 wide-field focus to be used mostly for survey work for the larger telescopes and for astrometry. It is to be convertible to an f/15 Cassegrain, to be used only over a narrow field, mainly for photo-electric photometry and fast spectroscopy.

The optical design of the 2·5-metre telescope is not entirely settled. It is to be used for direct photography, especially limiting-magnitude work at either an f/3·3 prime focus or an f/8 Cassegrain. Classical optics are likely to be used, with appropriate corrector lenses. There is to be an f/15 Cassegrain focus, mainly for fast and medium spectroscopy, and for photo-electric photometry at all bandwidths. An f/30 coudé focus is to provide for high-resolution spectroscopy and is to accommodate collimators up to 30 centimetres' aperture. Both Cassegrain and coudé foci will be available for other apparatus. The present rapid evolution of photoelectric image devices is being watched closely and the telescope is to be built with their use in mind. The main emphasis of observing programmes is to be on the photography, spectroscopy and photometry of faint extragalactic objects, especially radio sources, and during the bright of the Moon on stellar spectroscopy and possibly infra-red problems.

The 4·5-metre telescope differs from the others in that it is to have an altazimuth mounting, with prime, Cassegrain and Nasmyth foci, and classical

optics. Its research programmes would be generally similar to those of the 2·5-metre, but pressed to fainter or more difficult objects, or purposes requiring a greater light flux.

Professor McCrea. Planetary astronomy has been mentioned once or twice at this meeting, but only in passing. It is a subject in which there is vigorous activity in the UK. The Royal Society organized a study group in the subject in recent years, and its work is now being followed up energetically by further action that will foster this activity. May I express the hope that the importance of the subject will be fully taken into account in the plans about which we have been hearing?

Professor Elliot. There are indications of a change in interest of some of the space research groups in this country from geophysics to planetary studies. In particular I should mention recent proposals for participation in the NASA planetary programme by the groups at Oxford and by MSSL. These are concerned with the neutral atmosphere and the ionosphere of Venus.

Professor Ring. The NHO telescopes can, of course, be used for planetary observations. There are already infra-red planetary observations in progress at Tenerife, and some potential users of the NHO are interested in, for example, high-resolution spectrometry of planetary atmospheres.

Dr. J. R. Shakeshaft. Those of us in universities are very grateful for the new research facilities for astronomy being provided by the SRC on our behalf. We are conscious, however, of strong pressure from the UGC for university staff to spend more and more of their time teaching, and there seems to be a serious danger that the projects we have heard about this afternoon will come to fruition just when we have no time left for research with them. Could Mr. Walker tell us whether the SRC has this problem under consideration and, if so, what steps are being taken to overcome it?

Mr. R. St. J. Walker. We have this problem very much in mind. Circumstances have changed a lot in the last two years. We can only do our best with the resources we have available; we certainly shall do all we can to sustain research.

Dr. D. McNally. I should like to raise two minor points which are of some concern to research students. Would it be possible to publish details of all telescopes which come within the purview of the Large Telescope Users' Panel and the associated "user" equipment? A loose-leaf document which is kept updated would be of considerable value when initial steps are being taken in formulating an observing programme. The second point concerns the waiting period for obtaining time on telescopes abroad. At present a research student who embarks on an observing programme may find, through no fault of his own or of the LTUP, that he does not get his observing time until the beginning of the third year of his studentship. Such an arrangement means that the student must rush the analysis of his data to finish a Ph.D. within the usual three-year period. Could the lead time be reduced to be more nearly that for the INT?

The Chairman. Would you like to comment on that, Dr. Hunter?

Dr. A. Hunter. Unlike some other SRC committees, the LTUP consists largely of youngsters, mostly university people who currently use the telescopes. The Panel recently reduced the lead time on the INT to six months, and it was the university members who resisted further reduction on the ground that they could not rearrange their teaching commitments if

allotted time at shorter notice. The lead time on the overseas telescopes is three months longer than this, at the request of the host Directors, to allow time for the necessary exchanges by correspondence.

Dr. D. A. Allen. It seems to me that there are two places where one can do astronomy—the universities and the Observatories. In the universities, as Dr. Shakeshaft said, much of one's time is taken up in teaching; in the Observatories according to your plan we are expected to devote most of our time to developing equipment and supporting university observers. Is there a place for people, like me, who feel that if they can contribute anything to this subject it is in simple, pure research?

Professor Tayler. I should like to express a view which is not always popular. I think that it is desirable that there should be a small number of (almost) full-time research astronomers. University astronomers have so many calls on their time that the progress of their research is often very much slower than they hope. The best use of SRC money may well involve having some people who do essentially nothing but research. Such people would have to realize that they are privileged and be prepared to work on special projects such as the preparation of a new observatory when required.

Dr. Atkinson. There are of course research fellowships.

Dr. Hunter. At RGO we had until recently ten research fellowships held by astrophysicists. If we are to design the NHO within our existing manpower ceiling, it is inevitable that we must use at least some of these, our only short-term appointments, as they are vacated to take on design engineers and the like. It follows that for some years there will be fewer fellowships available for research astrophysicists.

Professor Lovell. I do not think that the situation in the universities as regards the teaching load per member of staff is significantly different from what it always has been. At least I am sure that the younger members of my present staff do not have a greater teaching load than I had when I began my research career nearly forty years ago. Nevertheless, I think one must be anxious about the future. The current political insistence that the job of the university is to teach undergraduates, the tie of their grants to the number of undergraduates, and the recently published report on post-graduate work, may make it impossible to continue with the rather favourable situation which has so far existed. There are posts, and no doubt there always will be fellowships, which enable the holder to concentrate wholly on research. The complaint that these are of short tenure usually arises from the people who are not good enough to hold them.

The Chairman. Our time is drawing to a close, and it remains for me to thank the RAS for the opportunity of this meeting. I hope you have found it useful; we on SRC have, although you have given us one or two jolts. We evidently have got to do better in making sure that everybody feels he has been consulted, especially in the early stages of a project.

Professor Tayler. I should like to thank you all for coming today. If I can sum up in the form of an end-of-term report my verdict is, "A good start has been made but much more remains to be done". I hope that we shall follow this meeting with other meetings including small ones on specific projects as suggested by Professor Rees. I hope that the ASR Board will produce a newsletter to go on notice boards. I think that it would be particularly useful to hold a discussion meeting when a project is in its earliest planning stages because it becomes increasingly difficult to have really useful meetings once vital decisions have been taken, even if project planning takes many years.