OECD MEGASCIENCE FORUM

Final Report of the

WORKING GROUP ON RADIO ASTRONOMY

November 1998

The Working Group on Radio Astronomy has surveyed current and future priorities worldwide in the field. At least two types of megascience facilities are being planned: large (sub)millimetre arrays and a new large facility dedicated to the centimetre-decimetre wavelength range. Essential for both these types of instruments will be a capability of observing over a wide range of frequencies in order to complement planned and existing optical telescopes. Specific areas where action by governments is required to allow the field to continue to develop and flourish have been identified.

The main Conclusions of this Working Group are:

- Down-link signals from planned communications and remote sensing satellites in low Earth orbits are a serious new threat to Radio Astronomy. The future of the field may be in jeopardy unless action is taken to ensure that radio astronomers continue to have access to the radio spectrum.
- Planned new (sub)mm and cm-m radio telescopes are essential complements to existing and planned 8-10 meter optical/near-infrared telescopes, as well as to the projected successor to the Hubble Space Telescope, the Next Generation Space Telescope.
- The costs involved in building these new radio facilities are so high that there are compelling economic as well as scientific reasons for international collaboration. The Working Group strongly endorses efforts to achieve co-operation between the several different groups planning large (sub)mm arrays.
- Efforts to promote early co-operation in the development of what is being called the Square Kilometer Radio Telescope, to operate at cm-m wavelengths, are noted and applauded.
- This Working Group notes that a wide variety of mechanisms exist for the planning of major facilities but that no immediately appropriate international organization is at hand for promoting the next generation of large radio telescopes. It recommends that attention be given to coordinating planning efforts in order to facilitate international collaborative efforts.

Contents

Introduction

1. The Working Group on Radio Astronomy was established by the Megascience Forum in January 1997. Its goal was to strengthen inter-governmental contacts among officials responsible for advance planning of investments in Radio Astronomy for the period of the next 10-20 years. The following aims were set out:

   - Exchange information about national and regional priorities and plans.
   - Consider future requirements for large facilities from a global perspective.
   - Explore opportunities for international co-operation in order to save money and time, and to maximise scientific productivity and other benefits for participating countries.
   - Identify obstacles to co-operation and take steps to remove them.
   - Initiate specific international activities and consultations.
   - Develop recommendations for actions by governmental or non-governmental bodies, with specific findings and recommendations for Ministers, if appropriate.
   - To consider follow-on actions beyond the expiration of the WG mandate.

2. The meetings of the Working Group were attended by 35 delegates from 17 different countries. The delegations were predominantly made up of a representative from a government funding-agency and a government designated scientist. The following countries participated in this Working Group.

Australia	Germany	Spain
Belgium	Italy	Sweden
Canada	Japan	United Kingdom
China	Mexico	United States
Finland	Netherlands	European Union
France	Poland	

3.

4. The Working Group has met on three occasions: in Paris (June and December 1997) and Washington DC (June 1998). It also co-sponsored a meeting of radio observatory directors and radio spectrum management experts during the August 1997 General Assembly of the International Astronomical Union in Kyoto.

5. This Final Report of the WG has been prepared specifically for use by science policy makers and focuses on issues that deserve their attention. It is structured as follows: Section II provides the Rationale for investing the Radio Astronomy. Section III summarises the Next Generation of Large Facilities being discussed, and section IV explores the Scope for International Co-operation leading to their realisation. Section V identifies A Major new Threat to the study of radio signals from the distant Universe, arising from constellations of telecommunications satellites in low Earth orbits. Finally, a summary of the WG's findings and conclusions is given in Section VI.

6. Additional background information is provided in a series of annexes. The background and essential elements of the threat from telecommunications satellites are provided in Annex 1. A summary of current priorities in Radio Astronomy and of decision making procedures in the participating countries are given as Annex 2. Annex 3 is a copy of a declaration by radio observatory directors resulting from the discussions in Kyoto in August 1997 concerning the spectrum interference issue. A formal approach to the delegations of the OECD Megascience Forum on the same matter is provided in Annex 4. In Annexes 5 and 6 are reprinted articles that served as useful background to the Working Group's deliberations.

7.

8. Rationale

9. Astronomy is experiencing a Golden Age, when fundamental questions about the structure, history and fate of the Universe are being answered empirically. Thanks to technological breakthroughs in recent decades, one of the oldest of sciences is revealing our physical Universe in ways never before imagined. Public awareness and interest in the field is intense, and the governments of developed countries have been making major investments in space- and ground-based facilities for exploring the Cosmos.

10. Historically, astronomy has played an important role in the development of fundamental physics and the quest for understanding the origins and evolution of life. These connections to other fields of science remain strong. In recent years, new sub-fields of research have even arisen from these connections: gravity wave and neutrino physics, which have built on astronomical observation to define the very nature of these exotic phenomena; observational cosmology, that aims to understand the physics involved in the Big Bang creation event as well as to observe directly the evolution of the Cosmos thereafter; study of the extinction histories of species on Earth, in which astronomical causes for the major extinction events have been brought to light; and even the systematic search for civilisations elsewhere in the Galaxy.

11. To maintain the momentum of discovery, a series of major new telescopes, operating over a wide range in wavelength, is scheduled for completion over the next 10-15 years. These new facilities promise to provide the required boost in sensitivity to answer many questions that have puzzled scientists for decades. Perhaps the most fundamental questions concern the eventual fate of our Universe (How did the Universe begin? Will it go on forever?) and how the planets, stars and galaxies that we see around us today were formed.

12. The Universe beyond our Solar System can only be studied using "remote sensing" techniques, whereby electromagnetic signals emitted by distant objects, such as stars and galaxies, are captured by telescopes and subsequently analysed. The extraordinarily large distances to even the closest stars and galaxies mean that astronomical signals are very faint by the time they reach the Earth, overwhelmingly so in comparison with any man-made signal.

13. By always looking to perform challenging and innovative observations on such faint signals, astronomy has historically been a critical driver of technological development. The synergetic coupling of astronomy and technology is expected to continue if the next generation of telescopes is built and the journey of discovery continues.

14. Since the signals received at their telescopes are the only source of information for astronomers, terrestrial contamination of these signals is a very serious concern. Light pollution from cities has forced optical astronomers to move to remote high-altitude sites. The growth of satellite and cellular telecommunications now threatens to seriously impede access by radio astronomers to the distant Universe – unless adequate steps are taken soon. In fact, the danger is much greater for Radio Astronomy than it is for optical astronomy because of the planned global coverage of telecommunications networks. Large numbers of low Earth orbiting (LEO) satellites will soon mean that no place on Earth will be immune to these very strong, rapidly moving, man-made signals from the sky.

15. Radio astronomers study signals having wavelengths in the millimetre to metre range, and the technologies they employ differ profoundly from those used at shorter wavelengths (e.g. in the optical and infrared parts of the spectrum). Most of the world's large radio astronomy facilities grew out of technologies developed during the Second World War, and were built twenty to forty years ago. These facilities are in their middle age, and many are undergoing, or have planned, extensive upgrades, to extend their usefulness by a decade or so. For these reasons, a new generation of bigger, more powerful radio telescopes will need to be designed, funded and built during the coming decade.

16. Historically, radio telescopes have been important discovery instruments, especially as regards the very distant Universe. Celestial radio sources are often intrinsically very luminous, so they can be seen to great distances, and space is remarkably transparent to radio waves – in contrast to ultraviolet and optical wavelengths, which are easily absorbed by intervening gas and dust. In addition, the 21-centimetre line of neutral Hydrogen is a unique tracer of the most abundant element in the Universe. Observations using the 21-cm line are likely to feature heavily on the agenda of astronomy in the next 20 years. The new large radio facilities will permit studies of the first objects that formed in the very early Universe, will give insight into how and when the intergalactic medium became (re)ionized, will allow observation of the development of structure in the distribution of galaxies on the very largest scales, and will provide unique insights into the formation of stars, both in very distant galaxies and in our own neighbourhood.

17. Many of these exciting discoveries will have their greatest impact when complemented by studies at other wavelengths. Astrophysical understanding is in practice maximised by continued improvements in sensitivity over the entire spectrum. Development of new facilities in Radio Astronomy should therefore also be seen as an essential complement to other new facilities, be they in the infrared, optical, ultraviolet, x-ray or gamma-ray part of the spectrum. The largest advance in sensitivity in another waveband will likely involve NASA/ESA's Next Generation Space Telescope, which is planned for launch within ten years. Adequate interpretation of the data from that instrument will require complementary advances in sensitivity at radio wavelengths such as are being discussed in the radio astronomical community.

18. At cm and m wavelengths, signals from distant objects pass unimpeded through the Earth's atmosphere, regardless of weather conditions. Historically, therefore, radio astronomical facilities have been located in the organising country and have been financed on a national basis. However, the great cost of the major new facilities which are currently planned means that a failure to move beyond purely national organisational vehicles to construct these instruments is likely to hinder the future realisation of the field's scientific potential.

19. Although generally nationally based and financed, radio astronomical facilities have traditionally pursued a policy of open and gratis access, based on quality and urgency of proposed observations, and without regard for institutional or national origin of the proposing scientist. The exceptions to this tradition have involved instruments to explore the sky at mm and shorter wavelengths, which *are* sensitive to climate and which are best located at high altitude, predominantly dry sites. A few instruments of this type, therefore, have been developed through international co-operative arrangements that provide for operation in third countries having optimum weather conditions. Similarly to inter-governmental arrangements in other fields of science, these facilities have been less open, reserving only a small fraction of the available observing time for gratis use by scientists from financially non-participating countries.

20. The increased scale and expenditure required for the next generation of radio telescopes, both at mm and at cm-m wavelengths, and the limited number of such very large facilities likely to be built, make a compelling case for multilateral co-operation. For this to be achieved the necessary organisational vehicle must be created or an existing organisation in another field must be adapted.

21.

Next Generation of Large Facilities

18. In all fields of astronomy, significant improvements in sensitivity are being made to allow astronomers to address the key scientific questions of our time. In the optical and near infrared, this has led to the construction of 8-10m telescopes on the ground. A number have already been completed – at least 10 more large optical telescopes are being constructed. Plans are being developed for a 6-8m space telescope, NASA/ESA's Next Generation Space Telescope.

19. At (sub)millimetre wavelengths a strong case has been made for a mm-wave interferometer with a total collecting area of between 5,000 and 10,000 m^2. The American, European and Japanese astronomical communities have independently decided that technology is ripe for the construction of a large mm-array telescope. Discussions between the various groups have been taking place about the possibility of merging two of the three projects, and a decision to co-operate may been taken shortly.

20. These millimetre arrays promise to afford astronomers unique windows on the formation of planets, stars, galaxies, and the Universe itself. They will reveal for the first time physical phenomena at the edges of the supermassive black holes in the cores of active galaxies, will elucidate the process of collapse of interstellar dust and gas clouds that are forming new stars, and will permit astronomers to search for planets around thousands of nearby stars.

21. Discussions have also begun in many countries concerning a new facility optimised for cm-m wavelengths, that would reveal the content, structure and evolution of the physical Universe as seen at these wavelengths and would complement the planned optical and (sub-)mm telescopes. Based on scientific arguments, an increase in sensitivity over current telescopes by a factor of one hundred is considered desirable.

22. Because receiver technology is currently so good that improved electronics cannot contribute substantially to this improved sensitivity, the required increase can *only* be achieved by constructing a larger telescope. A total collecting area of the order of one square kilometre is indicated, and the various initiatives that are under study can

collectively be referred to as the Square Kilometre Radio Telescope. The size of such an instrument clearly marks it as a megascience facility.

23. The scope of the science to be addressed with the Square Kilometre Radio Telescope is exceedingly broad, ranging from observations of comets and asteroids, through the detailed study of the formation physics and evolution of stars and galaxies, to revealing the earliest epochs of the Universe, before the first stars and galaxies formed.

24. Informal discussions between the groups involved in developing ideas for the Square Kilometre Radio Telescope have been taking place since 1993, when the Large Telescope Working Group (LTWG) was set up under the auspices of the International Union for Radio Science (URSI). The LTWG promotes international discussions between astronomers and is responsible for a compilation of the scientific objectives of the instrument. In March 1996, the directors of eight institutes in six countries signed a Memorandum of Agreement to co-operate in the development of technologies for the next generation radio telescope. A consortium of institutes has been formed to co-ordinate and optimise the research and development activities.

25. The development and construction of both the millimetre arrays and the proposed Square Kilometre Radio Telescope will have a considerable impact on technology in each of the participating countries. There is substantial scope for high-tech industrial involvement in many fields – such as semi-conductor technology, high-speed computing and construction using lightweight new materials.

26.

Scope for International Co-operation

26. The historical development of Radio Astronomy facilities has been almost exclusively the preserve of individual institutes or of national research councils. This has led to the current situation in which some 40 radio telescopes are in everyday use throughout the world. A large number of astronomers are now familiar with the techniques involved in Radio Astronomy. Contact and co-operation at institute level is generally good internationally.

27. A special case in point is the technique called Very Long Baseline Interferometry (VLBI). During VLBI observations, radio telescopes simultaneously observe the same position on the sky and record the signals on magnetic tape; these signals are then later combined off-line to provide the highest spatial resolution of any available imaging technique in astronomy. Co-ordination of VLBI observations is done by a variety of different consortia of institutes and universities – the European VLBI Network (including the Joint Institute for VLBI in Europe), the US National Radio Astronomy Observatory, the Australia-Pacific Telescope, the Southern Hemisphere VLBI Experiment, and the Co-ordinated Millimetre VLBI Array. In addition, VLBI observations are sometimes based on ad-hoc agreements between individual observatories. These networks of radio telescopes observe in concert several times each year and generate continuing close contacts both at the scientific and organisational levels between radio observatories. The grass-roots nature of the organisation of VLBI is unusual in international co-operations, and is based on the expectation of continued financing at adequate levels of national programmes by governments.

28. This Working Group has prepared a summary of the planning cycles and priorities for large-scale facilities in Radio Astronomy. See Annex 2. It is clear from that document

that a lack of synchronisation of funding cycles, together with a mix of national and megascience priorities poses difficulties in generating the momentum required to realise some of the ambitious scientific goals set by the radio astronomy community. The long period (over a decade) between identification of the scientific need and the first serious discussions of international co-operation in the case of the proposed large millimetre telescopes serves as a good example of this point.

29. Plans for three different mm-wave interferometers (in the USA, Europe and Japan) are now in different but advanced stages of development; the US project has actually begun. All three projects have chosen the same high altitude site in Northern Chile. Talks have started to come to agreement about collaboration or even a full merger of the European and US projects, although there are complexities posed by detailed differences between the instrumental concepts and the timescale on which funding may become available in the different countries. The Working Group strongly supports the efforts that are being made to define a common project that will lead to a single instrument capable of achieving more than either community originally planned.

30. Developments towards the Square Kilometre Radio Telescope are at a very early stage and therefore were more amenable to consideration by this Working Group. This has had an international dimension from the outset. In 1996, the directors of eight institutes from six countries signed a Memorandum of Agreement, to “co-operate in a technology study program for a Future Very Large Radio Telescope”. An assessment of progress will be made in the year 2000/2001. At that time, decisions are planned concerning the technical concept and the subsequent organisational structure for the project. At present, construction of one or more prototype instruments is foreseen, to be completed around 2004-2005, followed by a decision on the final configuration(s), location(s) and operation.

31. In addition to these centralised large facilities, the VLBI networks noted above are discussing ways to increase sensitivity and angular resolution in the future. Primary goals are to allow study of small scale structures at the edge of the observable Universe and to permit detection of planetary systems around other stars that will escape detection by other techniques. The temporary incorporation of the large millimetre and cm-m telescopes discussed above in VLBI networks is one way to improve sensitivity, and the space radio telescope projects under consideration in the US, Japan and Russia would lead to improved angular resolution. The Working Group notes the past success of VLBI as a scientific endeavour and endorses continued support for this inherently international discipline.

32.

A Major Threat to the Future of Radio Astronomy

32. The radio spectrum is shared by many different interest groups, most of which make both passive (receive) and active (transmit) use of the bandwidth allocated to them. The allocations are agreed at meetings of the International Telecommunications Union (ITU). Radio Frequency Interference (RFI) occurs when signals emitted by an active user lead to a loss of information by another user, each operating within his allocated piece of the spectrum. As the demand for frequency space has increased, RFI has started to occur more often. Radio Astronomy is more susceptible than most other users, because of the extreme sensitivity of radio telescopes; however, astronomers cause no interference to other spectrum users, since they only make passive use of the spectrum (that is, they only “listen”). In recent years, commercial users have also started to suffer from interference.

Considering the huge investments that are made in the telecommunications industry, very good reasons exist why telecom operators may also want to see stricter regulations. Decisions that will define the regulatory climate around the year 2010 are being formulated now.

33. For at least the past 30 years, radio astronomers have participated actively in the spectrum allocation process, both nationally and internationally. The radio frequency allocations in use today were originally defined in a period when the sensitivities of radio telescopes were low compared to what they are now, and were defined to permit study especially of the nearby Universe. That is, special protection was given to those parts of the radio spectrum close to the laboratory wavelengths of the most important spectral lines used by radio astronomers (for example the hydrogen line at a wavelength of 21 cm). In addition, a number of conveniently spaced bands were reserved for continuum measurements. Thus the limited bands of frequencies allocated to Radio Astronomy were appropriate both technologically and scientifically. This legacy has reserved about 2% of the radio spectrum for the exclusive use of Radio Astronomy.

34. However, the Universe is transparent at radio wavelengths out to such great distances that we can actually detect objects whose radio signals were emitted a exceedingly long time ago. In principle it is even possible to reveal the entire history of the Universe by observing galaxies at increasingly large distances. The sensitivities needed to achieve this aim are only a factor of one hundred greater than have been achieved with today's radio telescopes. This is one of the main arguments why a collecting area of a square kilometre is considered desirable for a next generation telescope that operates at cm-m wavelengths.

35. Expansion of the Universe requires that looking out to great distances be accompanied by changes in observing frequency. As a result, as radio telescope capabilities have improved, astronomers increasingly need to observe over large ranges in frequency, not just the narrow bands currently allocated. The proposed millimetre arrays and the Square Kilometre Radio Telescope will be unable to achieve their full scientific potentials unless a solution is found for the interference caused by other spectrum users. Moreover, the major investments that need to be made in order to construct these telescopes will only be worthwhile if future levels of interference can be controlled.

36. The urgency of the situation was stressed last year at the triennial meeting of the International Astronomical Union in Kyoto (Japan) when, under co-sponsorship of this Working Group, 36 directors of the world's radio observatories signed a declaration expressing their concerns about the issue of spectrum management. They also agreed to intensify their efforts of informing policy makers of their concerns, and to increase the level of co-ordination between the world's radio observatories. See Annex 3.

37. Commercial pressure on the frequency space available for new applications is intense and the time scale for phasing out older applications is long because of the large base of installed, expensive and hard-to-replace hardware still in use. However, a combination of proper re-use of the spectrum, combined with innovative technologies (high performance filters; time-, space- and frequency multiplexing; mixed space- and ground-based networks) together with imaginative regional policies, should allow these problems to be addressed successfully.

38. This Working Group has taken the initiative by proposing that representatives of the telecommunications industry, spectrum regulators and directors of radio observatories be invited to an *ad hoc* meeting to discuss what the situation should be like in ten years time. It is hoped that this is to be the first step in setting in motion a process that could provide

a long term framework for generating proposals to the ITU for international consideration and decision.

39.

40. Summary of findings and recommendations

41. Radio Astronomy can provide unique contributions to our knowledge of the content, structure, and evolution of the Universe. To fulfil this promise, serious plans are being made to develop a new generation of observing facilities. This Working Group has examined the issues confronting the radio astronomy community, and makes the following endorsements and recommendations.

42.

a) **Protecting scientific use of the radio spectrum**.

Finding:
Radio astronomy provides unique scientific insights into the history and structure of the Universe, including information on the formation and evolution of planets, stars and galaxies. Many OECD countries, having already made substantial investments in the field, are considering large-scale international partnerships for a new generation of extremely sensitive radio telescopes that are expected to produce major discoveries about the origin of the Universe and many other topics. To fully utilize these new facilities, radio astronomers must have access to large portions of the electromagnetic radio spectrum. Unfortunately, such access is threatened by increasing levels of interference from space-to-Earth transmissions by telecommunications satellites. Unless effective ways of sharing the spectrum can be found soon, the exploration of the Universe (and other fundamental scientific research that can only be made at radio frequencies) will be severely compromised.

Recommendation:
The radio spectrum is a valuable public resource that is managed by national Administrations. Governments should exercise this authority to promote the continued expansion of global telecommunications and, at the same time, to protect scientists' ability to study the Universe. To this end, governments should sponsor and promote a constructive dialogue involving the scientific community, the telecommunications industry, science funding agencies, national regulatory bodies, and the International Telecommunication Union. The goal of this activity should be to develop technological and regulatory solutions that ensure the continued access of scientists to portions of the radio spectrum at existing observatories, and that enable the limited number of new observatories to access most of the radio spectrum for significant periods of time, with minimum impact on the telecommunications industry.

b) **Improving co-ordination of spectrum management activities**.

Finding:
Use of the radio spectrum for commercial telecommunications purposes is expanding rapidly and in practice the radio spectrum is approaching full utilisation. Future trends include globalisation of telecommunications services and strong pressure for the re-allocation of portions of spectrum for new applications. In addition to the specific threat of telecom satellite down-links noted above, it may be anticipated that proposals will be made regularly by commercial operators to re-allocate the frequencies currently reserved for Radio

Astronomy as well as to develop systems that inadvertently interfere with radio astronomical observations. The Working Group believes it is imperative that radio astronomers maintain their involvement in local and regional radio spectrum management decision making processes, and expand these activities to include regions of the world where improved co-ordination might be effective. The Working Group has identified the Central and South American and the Asia-Pacific regions as areas for which additional co-ordination aimed at monitoring and protecting use of the wavelength bands allocated for use by Radio Astronomy could be especially effective.

Recommendation:
The Working Groups endorses the initiative recently undertaken to improve co-ordination in the Americas by expanding participation in the US national Committee On Radio Frequencies (CORF) to include astronomers from other North, Central and South American countries. The Working Group encourages similar efforts in the Asia-Pacific region to form an international committee for monitoring regional regulatory developments and for co-ordinating spectrum management activities in the interests of Radio Astronomy.

Governments are asked to encourage and where necessary actively to support initiatives such as these by radio astronomers to improve the level of participation in and the international co-ordination of activities relating to regulation and to management of the use of the radio spectrum.

c) Balancing national and international investments.

Finding:
Each national astronomy community balances its national and international investments to reflect national priorities, tempered by economic constraints. While there is no unique or optimal mix of national and international investments in Radio Astronomy, each is required for a healthy scientific programme. Innovation is often effectively stimulated in the university environment and at local observing facilities, but only if adequate funding for speculative R&D is available. The effective training of young talent requires hands-on experience that is best acquired at local and national facilities, even when the ultimate research frontiers are found at large international instruments. Access to the latter is extremely competitive and hence limited. The Working Group concluded that maximal scientific benefit to a community from its investments in international facilities accrues when a strong national community is maintained and is nurtured across generations. Systematic attention to achieving a balanced investment programme that includes both national and international components is desirable but does not always occur in practice.

Recommendation:
The Working Group recognises that international co-operation has long enriched astronomy in general. In Radio Astronomy, international VLBI observations currently play a significant role in the field, and the Working Group believes that such efforts should be maintained. The Working Group also specifically applauds recent efforts to internationalise both the millimetre array and Square Kilometre Radio Telescope projects and strongly encourages the continuation of such efforts.

40. Strong national programmes are seen to enhance and maximise productivity of international facilities. The Working Group urges both its scientific colleagues and the national agencies responsible for financing the field to ensure that an appropriate balance be struck between national and international investments, such that synergy is achieved and the next generation of scientists in the field is effectively trained.

41.

d) Planning for international co-operation.

Finding:
A wide range of national planning mechanisms for astronomical investment exists. Some, like the periodic decadal studies in the US, are highly structured, involve the entire national astronomical community and result in a careful delineation of national priorities. Other countries maintain less elaborate mechanisms, which nevertheless serve the needs of their national communities well. The Working Group noted, however, that there is a natural tendency in practice to focus on the national situation and the possibilities for realisation of projects through national channels. This has led in recent cases to consideration of international co-operation rather late in the planning process. While there is no unique or ideal planning mechanism suitable for all nations participating in the Working Group, it seems clear that early consideration of international interest and of developing the necessary organisational vehicles would often be beneficial to large projects.

Recommendation:
Where formal, structured planning mechanisms exist, they should be encouraged to serve as springboards for generating international collaborations. The Working Group recommends that all national planning mechanisms begin to incorporate assessments of international interest in future large instruments. This will permit the national communities to be fully informed as to the potential for international co-operation, and will allow for the broadest possible planning context in each country.

40.

e) Scientific access to radio astronomical facilities.

Finding:
Traditionally, radio astronomical facilities have maintained a policy of open and gratis access to researchers regardless of home institution. All that is required is a competitive scientific proposal. Recent bi- and tri-lateral international agreements to develop and operate radio telescopes working at millimetre wavelengths have departed from this tradition, but do reserve a fraction of available observing time for external proposals and provide this time without requiring financial re-imbursement. This Working Group, the membership of which includes several observatory directors, is unanimously of the view that the scientific effectiveness of research facilities in Radio Astronomy is maximised by a policy of open and gratis access based solely on the quality and urgency of submitted proposals.

Recommendation:
The Working Group urges funding agencies in the strongest terms to ensure that the operational modalities of future large radio telescope facilities include the possibility for access by researchers regardless of their home institution or their ability to contribute financially.

40.

41.

References.

40.	Protecting the Future of Radio Astronomy	Annex 1
	Summary of National Planning Cycles and Current Priorities	Annex 2