Dr Heeschen
received Wed
Dec 4.

ASSOCIATED UNIVERSITIES, INC.
10 Columbus Circle
New York 19, New York

November 26, 1957

MEMO TO: Members, AUI Advisory Committee on Radio Astronomy

FROM: Richard M. Emberson

SUBJECT: Minutes of the October 16, 1957 Meeting

1. Enclosed are minutes of the last Committee meeting. There are two appendices. The first is the statement of policy on the research program at the NRAO. This statement was reviewed in detail by the Committee, and the minutes contain a summary of the comments that were made. The statement is still in Draft, because we will welcome any additional comments or suggestions before a final editing.

2. The second appendix, also in draft form, is a summary of the comments that were made on research programs at other institutions. All the participants are requested to review and, if desired, to extend their comments.

3. If feasible, please send your further suggestions on these appendices to Dr. David S. Heeschen, National Radio Astronomy Observatory, P. O. Box 2, Green Bank, West Virginia, with a copy to me at the New York office. If we have had no word by December 16, we will assume that you have no additional suggestions.

4. We have additional copies of the booklet prepared for the October 17 ceremonies, and will be glad to furnish them on request.

Minutes of the
AUI Advisory Committee on Radio Astronomy
October 16, 1957

1. The Committee met at the Three Hills Hotel, Warm Springs, Virginia, on October 16 to discuss the research programs at the National Radio Astronomy Observatory. A number of astronomers had been invited to participate in the discussions. Those present for all or part of the meeting were:

H.L. Alden	University of Virginia
**L.V. Berkner	Associated Universities, Inc.
**C.C. Chambers	University of Pennsylvania
M.H. Cohen	Cornell University
*A.J. Deutsch	California Institute of Technology
F.K. Edmondson	University of Illinois
**R.M. Emberson	Associated Universities, Inc.
G.B. Field	Princeton University
**J.W. Findlay	National Radio Astronomy Observatory
R. Fleischer	Rensselaer Polytechnic Institute
T. Gold	Harvard University
**L. Goldberg	University of Michigan
*W.E. Gordon	Cornell University
*F.T. Haddock	University of Michigan
T. Hatanaka	Cornell University
**D.S. Heeschen	National Radio Astronomy Observatory
A.E. Lilley	Yale University
C.H. Mayer	Naval Research Laboratory
*E.F. McClain	Naval Research Laboratory
*G.C. McVittie	University of Illinois
*A.B. Meinel	National Astronomical Observatory
T.K. Menon	Harvard University
*D.H. Menzel	Harvard University
F.H. Mitchell	University of Alabama
J.L. Pawsey	CSIRO
C. Payne-Gaposchkin	Harvard University
A.M. Risley	Randolph Macon
R.M. Robertson	Office of Naval Research
C.L. Seeger	Leiden Observatory
**C.K. Seyfert	Vanderbilt University
**O. Struve	University of California
C.H. Townes	Columbia University
H.W. Wells	Department of Terrestrial Magnetism
J.L. Yen	University of Toronto

* Member, AUI Advisory Committee
** AUI Trustee or Staff member

2. Professor Menzel asked Professor Goldberg to act as chairman of the morning session. Dr. Berkner welcomed the group to the meeting and to the ground-breaking ceremonies at Green Bank on the following day. The AUI staff then described the site development and antenna programs for the Observatory.

2.1 The site will consist of approximately 2700 acres. Efforts are being made through local easements, a State zoning act, and Federal action by the FCC and similar agencies, to protect the site from man-made radio interference. A portion of the site is already transferred to the Government and available for use; temporary housing is being provided in remodeled farm buildings; electric power (maximum of 300 KW) is available sufficient for many experimental and observational programs. Persons wishing to bring equipment to the site to take advantage of the low level of interference should communicate directly with Drs. Heeschen or Findlay.

2.2 An 85-foot operational telescope, similar to the one ordered by the University of Michigan from the Blaw-Knox Company, is scheduled for completion at Green Bank by July 15, 1958. This reflector will have a solid surface and will be effective at wavelengths as short as 3 cm. A control building and the necessary electric power installations are scheduled for completion in advance of the telescope. A relatively simple 21-cm receiver is being built by the Airborne Instrument Laboratories and is scheduled for completion by May, 1958. The principal characteristics of the receiver are:

To tune from 1420 mc/s to as low a frequency as possible
IF bandwidth 6 m/sec
Frequency Stability 5 kc/sec

2.3 Proposals on the construction of a 140-foot radio telescope should result in a contract for the instrument by January, 1958. This equatorial telescope will have a solid surface and will be effective at 3 cm wavelengths; under good observing conditions, angular positions good to 10" of arc may be possible.

2.4 In addition to the 21-cm receiver mentioned above, it is hoped that a travelling-wave-tube receiver (for 4-5 cm work) will be ordered this winter. In this connection, Dr. Pawsey noted that the faint source survey program, the 140-foot telescope would have the necessary resolving power at 3 cm if presently available receivers were employed. If TWT receivers are used, even fainter sources will be observed

and it is likely that positional confusion will result unless wavelengths shorter than 3 cm are utilized to improve the resolution of the 140-foot telescope.

3. From the above, the discussion turned to other receivers, including masers. Prof. Townes reported that masers could be built with noise temperatures as low as 30° Abs; that a maser could be tuned over a frequency range from 2500 to 10,000 mc/s by adjustment of the magnetic field and resonant cavity; and that a maser should be particularly rewarding in the study of line spectra. Dr. Berkner suggested that later discussions be arranged on receivers.

4. In response to a question by Dr. Field on provision for low frequency observations, Dr. Wells reported that from his inspection of the site, he believed it offered perhaps the best conditions in the eastern part of the U. S. He pointed out that several areas on the site could accommodate arrays with dimensions of 1 x 2 miles and he predicted that observations could be made at frequencies as low as 10 mc/s when the ionospheric conditions improve with the reduction of solar activity.

5. The discussion next turned to matters of policy concerning the research program at the NRAO, and, in a broader context, the general support of radio astronomy in the United States. Prof. Mc Vittie raised questions concerning the support of the college and university programs that train the astronomers who will work at Green Bank; the consensus was that support for these institutional programs would grow as would the support for the NRAO and that there already is evidence that the NRAO has stimulated programs at other institutions. It was further noted that Government institutions such as the NBS and NRL will send scientists to Green Bank on a temporary basis and, also, when the NRAO is fully operating a greater percentage of students will move into radio astronomy from other fields. The NRAO will, of course, help in the advanced training programs as well as in the research programs and hence the NRAO must be considered as a part of a broader, national program.

6. A draft statement on the research programs, prepared by Dr. Heeschen, was next reviewed, and discussed. (See Appendix "A" to these Minutes) At this point, Prof. Menzel assumed the chair and continued to the end of the conference. Concerning Section I, favorable comment was made on the acceptance of qualified scientists from any place in the world. Prof. Mc Vittie suggested the following sub-paragraph to precede I 1 (a):

> "The proper functioning of the NRAO implies that radio astronomy be supported in universities and other institutions throughout the U.S. for these are the principal sources from which the visiting scientists to the NRAO will be drawn."

It was also noted that the training in radio astronomy at the NRAO would not go so far as formal courses and degrees. In response to a question by Dr. Fleischer, Dr. Berkner commented that students who lacked equipment, but who had completed sufficient course work could come to the NRAO under qualified professional guidance.

7. With reference to I4 (b), the importance of searching for other spectral lines was emphasized by Drs. Gold and Townes. On I4 (c) the point was made that relative and absolute flux, surface brightness, and polarization measurements are needed: In addition to other items mentioned, it was suggested that The NRAO provide both thermal and non-thermal noise standards, for exchange among observatories, perhaps on an international basis, and, in general, that the NRAO must be at the forefront of instrumental development. At this point the discussion departed from the draft; Drs. Deutsch, Findlay, Gold, Lawrence, Pawsey, and Seeger reviewed the need for both relative and absolute standards; absolute standards are particularly important for the synthesis of spectra from many observations at different institutions. It was the consensus that the NRAO would not be in competition with the NBS on the calibration of sources, which should be regarded as cooperative programs.

8. With reference to I 4(a), the consensus was that NRAO must look ahead on antenna programs, on receivers, and on data handling, processing and storage devices. Special arrangements will be worked out by the Director for the installation of arrays, radar, or other equipment of limited rather than general utilization.

9. In response to a question concerning plans for the permanent staff, it was reported that a maximum of about ten scientists might be employed by 1960, of which more than half would be astronomers and the remainder electronic or related specialists.

10. With particular reference to II 5, there was considerable discussion on the need for a receiver system that could scan over a broad frequency band. Concerning III 2, specific visitor requirements were mentioned, such as very precise time signals, well-regulated power supplies for receivers, and a stable high frequency standard.

11. Transportation, housing, and food at the NRAO were discussed as being essential ingredients, even if not a part of the scientific programs.

12. After a luncheon recess, the discussion turned to a review of existing or planned programs at other institutions. These discussions have been summarized by Drs. Heeschen and Findlay and are contained in Appendix B to these minutes. Please note that these comments are in draft form. All participants are being invited to review and revise their comments if deemed necessary. An effort will be made to maintain this program summary on a current basis to assist with planning the work and anticipated instrumental requirements at the NRAO.

13. The conference formally ended at 4:30 PM, but continued informally through the evening and on October 17, at the ground-breaking ceremonies at Green Bank.

Appendix A to the Minutes of the
October 16, 1957 Meeting of the
Radio Astronomy Advisory Committee

DRAFT STATEMENT

The Research Programs of

The National Radio Astronomy Observatory

Prepared by D.S. Heeschen, Head of Staff Research at the NRAO. Approved by the Advisory Committee to the NRAO, D.H. Menzel, Chairman.

I. General Considerations

1. The national nature of the NRAO places certain obligations on it. It is expected to provide the environment, instrumentation and other aides for visiting scientists from all over the United States, and the world, such that through their work the United States may maintain a leading role in radio astronomy. Research at the NRAO, by both staff and visiting scientists, should set a standard of quality for radio astronomy. To accomplish this end several conditions must be met, as follows:

   a) The NRAO must provide equipment and other aid for research by visiting scientists, and contribute to the training of radio astronomers.

   b) The NRAO must continually anticipate the needs of and future developments in radio astronomy, and act promptly and decisively to provide for these needs.

   c) The NRAO should play a leading role in the development of radio astronomy instrumentation -

antennas, receiving systemsm and associated equipment.

d) The NRAO should undertake the difficult, tedious, expensive, but very necessary problems of absolute calibration of equipment, absolute flux measurements, and the development of standard references; in other words, the NRAO should be a source of national standards for radio astronomy.

e) The NRAO must support and complement radio astronomy programs at universities and other institutions. Recognizing that universities are a primary source of scientific progress, and of trained scientists, the NRAO must support in every way it can the development of radio astronomy in universities.

The burden of fulfillment of these obligations lies with the scientific and administrative staff of the NRAO, with the scientific advisors to the NRAO, and with the visiting scientists.

2. The principal instrument of the NRAO will, for some years, be the 140-foot telescope. The resons for this particular choice of instrument are fully described in the Planning Document. It is designed to be a general purpose intrument, but in particular a great deal of time, money, and effort are going toward making it a precise instrument for

high frequency work. It is eseential that one of our main jobs be the utilization of the high precision characteristics of this instrument. The 140-foot will ~~probably~~ be in operation in early 1960.

3. An 85-foot telescope is expected to be in operation by mid-summer of 1958. This too is a general purpose instrument, but especially suited for high frequency work.

4. The above considerations set the pattern for the general development of research at the NRAO during the next few years. If the NRAO is to fulfill its obligations, we must undertake development of the following programs:

   a) 21-cm line research: It has been generally agreed that a considerable portion of the 140-foot observing time would be devoted to 21-cm work, because of its importance to astronomy. The choice of the 140-foot as the first major instrument, and the choice of its characteristics, were based in part on the importance of this area of work.

   b) Cm wave research: The unique suitability and power of the 140-foot (and the 85-foot, also) for cm wave work, and again its interest and importance, make it essential that this general program be developed promptly.

   c) Antenna and receiver calibration, relative and absolute flux and brightness measurements: The

NRAO must provide visiting scientists with equipment - antennas and receivers - whose characteristics are known to the greatest possible degree of accuracy.

d) Development of instrumentation: The equipment available for use with the large antennas of the NRAO should be of the highest possible caliber. Thus, the NRAO must keep abreast of, and implement through its own work, instrumental developments in those areas of interest and use to radio astronomy.

e) Long range instrumentation and planning: Because of the great time lag in the development of major instrumentation, the NRAO should, through its scientific advisors and staff, look now at the general direction of radio astronomy development in coming years, and commence planning for the next stage of development beyond the 140-foot. Only through the constant assessment of the general development of radio astronomy, and through continuous planning and growth, can the NRAO meet its obligations to American radio astronomy, and keep abreast of its changing needs.

5. The above five research and development programs are absolutely essential because of our specific obligations. In addition, we have a general obligation to develop and

support other research programs, and to contribute to the training of students. However, the specific nature of these additional programs should be dictated by the interests of the visiting scientists and the staff, and should not be set in advance.

II. Staff Programs

1. It is not the intended policy of the NRAO to set down an "Observatory Program" which all of the staff members are required to participate in as a team. On the contrary, the members of the staff are expected to carry on their own independent research in their particular fields of interest, within the general broad scope of the observatory policy, as outlined above. However, in addition to their own research, the staff members do share the general obligations of the observatory, namely equipment development, long range planning and development, calibration, and assistance to visitors. Much of this is a natural result of their research activities, and indeed this is the principal reasons for having a permanent research staff at the observatory - to provide the necessary continuity of research, development, assistance to visitors, and other activities.

   The remainder of this section describes the present and contemplated immediate research and development activities of the staff.

2. 21-cm line research. One program within the field of 21-cm research is now being developed for the 85-foot, and for the 140-foot when it is ready. The general field of this program - extra-galactic 21-cm work - is currently of considerable interest, and promises to be a major field of inviestigation for a long time. The receiver being acquired for extra-galactic work can, of course, be used for a variety of other problems, both 21-cm line and 21-cm continuum. This receiver is intended to be the first in a general 21-cm receiver development leading to the versatile and sensitive 21-cm instrumentation needed for the 140-foot telescope.

3. Cm-wave research. No specific work has been started yet in this field, but development of a high frequency program should be started as soon as possible. We should acquire a receiver, probably at X-band, as quickly as we can, so it will be ready when, or shortly after, the 85-foot is in operation. The 85-foot will be an extremely powerful instrument at high frequencies and we should provide instrumentation for it for visiting scientists with high frequency programs. In addition, it is essential that instrumentation be developed for high frequency work on the 140-foot. It may be that the next staff astronomer should be one whose interests are in this field, in order to provide continuity and development, and a basis for visiting scientists programs, as we have in the 21-cm field.

4. Calibration. Gain calibration of the 140-foot and 85-foot telescopes are of prime importance. A necessary part of this is the determination of absolute flux and brightness standards. Because this is a long range program requiring continuity and internal consistency, it is necessarily a job for the observatory staff. Certain phases will undoubtedly require outside assistance, and in all phases the cooperation of visiting scientists, and astronomers at other institutions, is desirable. The staff members are now making specific plans for calibrating the 85-foot. These calibrations will later be used to aid in the calibration of the 140-foot. Calibration of antenna pointing accuracy is also a part of this general program.

5. Receiver development. Two immediate receiver programs are indicated; development of 21-cm equipment, which will be based in part on experience and experimentation with the receiver now being built; and development of a higher frequency receiver. Additional receivers, for other programs, must, of course, be developed. These should be developed as the desires of visiting and staff scientists warrant. How this may come about is described in the section on visitor programs. In addition, there are a number of specific fields of instrumental development which we should follow closely, and assist or take part in as our budget and needs permit. Among these are:

a) general receiver stability problems - the development of gain stable systems.

b) MASERS

c) low temperature front ends and transistorized IF strips

d) Traveling-wave tube amplifiers

e) data processing

Development of radio astronomy instrumentation may be put in two general classes - systems development, and components development. As a general policy, systems development, that is the adaption of techniques and components to meet particular needs, should be done in large part at the observatory. Component development (by components is meant such things as MASERS, IF strips, TWT's, etc. - any unit that forms part of a receiving system) should generally be done through other laboratories, although a certain amount of such development, and particularly testing, must be done at the observatory.

III. Visitor Programs

1. It is necessary that the NRAO plan now to attract and accommodate visiting scientists as soon as observing equipment is available. Certain facilities are already available, in the form of land, test equipment, and some staff assistance. In the fall of 1958 the 85-foot telescope, together with the receivers previously mentioned, will be available for visitor programs.

2. There are several ways in which the receiver requirements for visitor programs can be met, as follows:

   a) The simplest situation, of course, is that in which existing equipment at the observatory can be used. Initially, the existing receivers will be few, and limited in their scope. However, additional receivers will be acquired.

   b) Where practicable, the NRAO may modify existing receivers or acquire new receivers to meet the specific needs of visitors. This is, in fact, the most natural way in which the instrumentation of the NRAO can be developed. It is the intent of the NRAO to acquire, as rapidly as is feasible, as versatile and diverse instrumentation as is possible, and to continually replenish its equipment as techniques improve and requirements change. However, it is generally not feasible, nor is it within the power of the observatory, to accumulate large amounts of general purpose equipment to meet a variety of general, but not specifically defined, requirements. Receiver development and acquisition should be, with some exceptions, based on the specific requirements of people with specific programs. Thus, much of the NRAO receiver developments should come as a result of the specific needs of visiting scientists.

c) The NRAO cannot, of course, provide all the equipment needs of all visitors. In many cases visitors may wish to bring their own equipment with them. The NRAO will be prepared to provide, where needed, power supplies, recorders, test and calibration equipment, frequency standards, and miscellaneous other equipment.

3. The NRAO will have available a number of temporary research appointments of varying length, which it is to be hoped will be filled by scientists on leave from their own institutions, and graduate students working on thesis or other programs under the direction of the staff of their institutions. In addition, the NRAO will have visiting scientists who come to observe for shorter periods, ranging from weeks to months, summer appointments of students, etc. In order that the facilities of the NRAO may be put to most effective use and in order that visitors will be enabled to make most effective use of their stay at the NRAO, careful planning, and coordination, is required. The means to effect this must be set up soon.

4. In writing out a document such as this, there is not meant to be implied any rigidity or fixed limitation in the scope of work carried out at the observatory. The general scope of work that can be undertaken is necessarily

determined in part by available or obtainable instrumentation. However, any scientist with a radio astronomy program that cannot be undertaken at his own institution should be free to discuss with the NRAO how it might be done at the observatory.

Appendix B to the Minutes of the
October 16, 1957 Meeting of the
Radio Astronomy Advisory Committee

Draft* Statement of Plans for Radio Astronomy Studies by Individuals at Other Institutions That Involve or Are Related to the National Radio Astronomy Observatory

1. Following a discussion of the site development and antenna programs for the National Radio Astronomy Observatory, and a review of a proposed policy for the research program at the Observatory, Prof. Menzel asked each conference participant to review informally radio astronomy programs now underway or planned, with particular emphasis on work that might involve the NRAO.

2. Summary of comments:

   Haddock: plans to use the 140-foot for 3 cm studies of the sun and for cm wave studies of H II regions and planetary nebulae. He discussed the possibility of using a 4 horn technique for high resolution. He plans to bring his own equipment.

   Goldberg: is interested in the cm wave emission from Plages. He will perhaps be interested in using the 140-foot at 3 cm.

   Menzel: The Fort Davis Solar Radio program may later be extended in frequency, possibly to 3 cm.

   Gold: His interests are in 21 cm line extra-galactic studies, similar to Heeschen's current work. He will be interested in working on the 140-foot and will probably bring his own equipment. He may desire assistance with the antenna feed. He did not think it likely that he would want to use the 85-foot telescope.

   Menon: is interested in a variety of aspects of galactic hydrogen work. He will want to use the 85-foot telescope and NRAO receiving equipment. His equipment requirements include provision for frequency scanning with a narrow band-width.

   McClain: is interested in 21 cm line absorption problems and extra-galactic red shift measurements. He is also interested in using the 140-foot telescope for pulse radar work. He will provide his own equipment. He indicated that he has a large number of receivers available and that it might be possible for persons to use his equipment, on loan from NRL, on the 140-foot. He is not interested in the 85-foot telescope.

*This statement, in draft form, is being submitted to the persons named herein for review and comment. We will keep the statement at the National Radio Astronomy Observatory with the intention of revising it from time to time to keep it on a current basis.

Mayer: His interests are in cm wave studies of planets, H II regions, planetary nebulae, etc., and in particular in the spectra of planets and in the polarization of sources. He will work on the 140-foot and may be interested in the 85-foot as well.

Wells: brought up the point of using the 140-foot as a means for obtaining precise positions of sources. In this same connection Haddock suggested using the 140-foot with a smaller dish as an interferometer.

Cohen: is interested in polarization of the sun and sources at various wave lengths. He might be interested in working on the 85-foot and certainly on the 140-foot. He would probably need RF front ends for his present receiver, and special antenna feeds.

Gordon: is interested in ionospheric studies and may wish to make simultaneous observations at Green Bank and Ithaca. The question of whether or not the Green Bank facilities would be available for geophysical and other fringe area work was left open for the director to decide.

Struve: The Berkeley Radio project is going ahead with Weaver and Silver. Weaver is interested in 21 cm line work, particularly as regards galactic rotation. He and/or some of his younger people may be interested in using the 85-foot and 140-foot telescope. Silver is interested in upper atmospheric problems. Struve stressed the need for the ability to compare brightnesses at different frequencies and over long intervals of time. He also stressed the possible importance of T. Tauri stars as radio sources.

Mc Vittie: The Illinois program, now in the planning stage, is aiming at obtaining positions and flux densities of sources in the 30 cm to 60 cm wave length range. They are planning a 400' x 600' cylindrical paraboloid.

Townes: may be interested in testing Maser amplifiers on the NRAO antennas. He emphasized the need for cooling these amplifiers to liquid nitrogen temperature, and preferably to liquid helium temperature. He emphasized the probable need for cyrogenic equipment at Green Bank. He is also interested in work at millimeter wave lengths.

Edmondson: Indiana will probably obtain a radio astronomer for their staff and build up a radio astronomy program based on the Green Bank facilities.

Deutsch: is not particularly interested in observing at Green Bank itself. He mentioned the importance of color indices of sources and of the background emission as a function of longitude; and the study of fine structure in the hydrogen line in both angle and frequency.

Hatanaka: is interested in 3 cm wave polarimetry of the sun with the 140-foot telescope.

Fleischer: is interested in observing at Green Bank, both with the 85-foot and the 140-foot telescope. He is probably most interested in 21 cm line work; in particular in the structure of the interstellar medium.

Field: plans to do 21 cm work with the red-shift receiver and the 85-foot. His interest is in intergalactic and extragalactic hydrogen studies. With the 140-foot he is interested in 21 cm studies requiring very high frequency resolution, and in absorption in H II regions.

Lilley: plans to observe with the 85-foot telescope, probably using a receiver he will develop at Yale. He is interested in H I absorption studies of radio stars.

University of Virginia: The University of Virginia wants to develop a program in radio astronomy based on observations with the NRAO equipment. They are now looking for a radio astronomer for their staff.

Lawrence: wants to do low frequency, high resolution interferometry on the sun. There may be too much interference at Boulder. If so, he might be interested in setting up his own 30 megacycle equipment at Green Bank.

Seyfert: Vanderbilt has no radio astronomy plans for the forseeable future.

Yen: At Toronto they are doing absolute calibration and developing thermal noise sources, They have no plans for work at Green Bank.

Meinel: has no specific plans regarding the NRAO. He did, however, suggest the desirability of exchanging resident personnel between the National Optical Observatory and the National Radio Astronomy Observatory

Chambers: The University of Pennsylvania will start a radio astronomy project shortly.They plan to use the NRAO equipment extensively. Since they do not as yet have a radio astronomer, they have no specific plans at the moment.

Seeger: suggested the need for coordination of work on radio observations of occultations of the Crab nebulae. There will be several occultations in the next few years. He feels it is desirable that all large antennas should observe these occultations, that as great a frequency range as possible is covered, and that polarization studies be made.

3. Two general equipment problems were emphasized by the Advisory Committee: These were the need for investigation of the problems of antenna feeds and the need for a temperature and humidity controlled box at the focus of a radio telescope. It was generally agreed that the NRAO should look into both of these problems.