THE RESEARCH PROGRAMS OF THE NATIONAL RADIO ASTRONOMY OBSERVATORY

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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 aids 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 - antenna's, receiving systems, 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-ft. telescope. The reasons for this particular choice of instrument are fully described in the Planning Document. It is designed to be a general purpose instrument, 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 essential that one of our main jobs be the utilization of the high precision characteristics of this instrument. The 140-ft. will probably be in operation in early 1960.

3. An 85-ft. 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-ft. observing time

would be devoted to 21-cm work, because of its importance to astronomy. The choice of the 140-ft. 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-ft. (and the 85-ft. 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 antenna's 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 its staff, look now at the general direction of radio astronomy development in the coming years, and commence planning for the next stage of development beyond the 140-ft. Only through the constant assessment of the general development of radio astronomy, and through

continuous planning and growth, can the NRAO meet its obligation 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 reason 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-ft., and for the 140-ft. when it is ready. The general field of this program - extragalactic 21-cm work - is currently of considerable interest, and promises to be a major field of investigation for a long time. The receiver being acquired for extragalactic 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-ft. 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-ft. is in operation. The 85-ft. 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-ft. It may be that the second 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-ft. and 85-ft. 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-ft. These calibrations will later be used to aid in the calibration of the 140-ft. 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 need permit. Among these are:

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

   b) MASERS

   c) low temp front ends and transistorized IF's

   d) TWT 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-ft. 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 developments 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 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.