

ASSOCIATED UNIVERSITIES, INC.
350 Fifth Avenue
New York 1, New York

April 20, 1956

MINUTES

AUI Radio Astronomy Advisory Committee Meeting
March 26-27, 1956

1. The Advisory Committee for the Radio Astronomy Project met at the AUI Office, 350 Fifth Avenue, New York, N. Y. at 9:30 a.m. on March 26, 1956. The Chairman of the Committee, Dr. Bart J. Bok, presided. The following persons were present:

L. V. Berkner	AUI
J. G. Bolton	Cal-Tech (Advisory Committee)
C. C. Chambers (1)	AUI Trustee from the Univ. of Pennsylvania
A. J. Deutsch	Mt. Wilson-Palomar (Adv. Comm.)
C. F. Dunbar	AUI
R. M. Emberson	AUI
H. I. Ewen	Harvard College Observatory (Adv. Comm.)
F. K. Edmondson	Univ. of Indiana (visitor)
N. H. Frank (3)	AUI Trustee from MIT
Jacob Feld (2)	AUI Consultant
Leo Goldberg	Univ. of Michigan (Adv. Comm.)
W. E. Gordon	Cornell Univ. (Adv. Comm.)
F. T. Haddock	Univ. of Michigan (Adv. Comm.)
D. S. Heeschen	Harvard Coll. Observatory (AUI Consultant)
H. S. Hogg	National Science Foundation
M. B. Karelitz	AUI
E. F. McClain	Naval Research Laboratory (Adv. Comm.)
A. B. Meinel	National Optical Observatory (Adv. Comm.)
M. A. Tuve (2, 3)	Carnegie Inst. of Washington (Adv. Comm.)
J. B. Wiesner (3)	MIT (Adv. Comm.)
P. D. Wild	CSIRO, Sydney, Australia (visitor)

2. Dr. Bok said the purpose of the meeting was to receive a progress report from AUI and then to offer advice based on the facts. He emphasized the importance of not losing the momentum which has been gained in attaining the goal of the Project namely, the establishment of a National Radio Astronomy Facility. The members of the Committee must function not merely as advisors, but also must aggressively support the effort to achieve the desired result.

He then called the attention of the Committee to the agenda dated March 12, 1956, copies of which had already been circulated. Items 2, 3, and 4 entitled, respectively, "The 140-Foot Radio Telescope Program", "Site Selection", and "Program

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- (1) Not present on Monday.
 - (2) Not present on Monday evening.
 - (3) Not present on Tuesday.

for Electronic and RF Components" were the most important. Items 5 and 6 were inevitably affected by conclusions reached on the three main topics, and discussion of them would necessarily be a part of the discussion of the other three substantive topics.

3. Dr. Bok then asked Dr. Emberson to introduce the discussion on the 140-foot radio telescope program. The Committee was reminded of the decisions reached at the meeting in March 1955. The consensus at that time was that emphasis should be placed on pieces of equipment which individual institutions could not afford to either build or operate. The most important instruments were felt to be large parabolic reflectors, and the consensus was that an instrument of intermediate size (a diameter of substantially over 100 feet) should be undertaken as soon as possible. Pursuant to these decisions, an effort was made to obtain firm proposals for the design and fabrication of a 140-foot dish, based on performance specifications. None of these proposals, which were considered at a meeting of the Committee in July 1955, provided suitable basis for a contract. It was concluded, therefore, to have a design or designs prepared in which AUI had confidence, and then to seek bids for fabrication and erection.

Following the receipt of the second grant from the National Science Foundation, AUI entered into three contracts for a preliminary design of a 140-foot telescope: one by D. S. Kennedy & Co., to be an extrapolation of 60-foot and 84-foot telescopes already built or under construction; one by Husband & Co., to take advantage of experience gained with the British 250-foot telescope, and one by Dr. Feld, to gain experience with design problems anticipated with larger telescopes, such as a 600-foot reflector. These designs were to be based on new specifications, somewhat tighter than those proposed in the spring. Deflection of the reflector was to be held to a $\frac{1}{4}$ -inch, in an effort to obtain an instrument which would be accurate enough for three-centimeter work. Ten seconds of arc for drive and control was also specified. A separate contract for a study on drive and control problems was let to the MIT Servomechanisms Laboratory.

4. The Committee at its December 13-14 meeting in Washington had recommended a study of the feasibility of an equatorial mount for the 140' telescope. The possibility, if such a mount were used, of diminishing the sky coverage and possibly relaxing some of the other specifications was brought up at that time. The general attitude of the engineers consulted since then is that the additional cost of the structural parts of an equatorial mount will outweigh any cost saving which might be achieved in the drive and control mechanism. These estimates had been referred to the National Science Foundation on February 7, 1956.

5. Dr. Emberson described the arrangements he has made to have all three designs (Feld, Husband and Kennedy) reviewed by outside engineers. Sub-groups of three each were to study structural characteristics of each design. Other consultants will study particularly the radio frequency and drive and control characteristics. They will be asked to express their professional opinion of the likelihood that construction in accordance with each of the designs would result in a radio telescope having the desired performance. The same groups will be asked to review actual bids when they are received.

6. At the request of the Chairman, Dr. Feld then gave a brief account of his design. In general, it follows the study he prepared for a 600-foot reflector, but some new ideas on adjustments have been developed. During observation, one side of the reflector will always be kept above. This results in a considerable design saving and makes it easier to adjust the paraboloid surface. As to cost, Dr. Feld estimated \$700,000 for the basic structure and \$700,000 for machined parts. These figures include estimates of the cost of motors and gears to drive the telescope, but do not include the control mechanism, design of which was excluded from Dr. Feld's study. The surface is a free paraboloid supported only at the edges. The RF feed at the focus is supported by a central mass; the focus can be reached by tipping the reflector upside down. The structural load is carried by the central bearing. Only wind loads are carried by railroad type tracks running on circular tracks.

7. The Chairman then asked Mr. Karelitz to review the Husband and Kennedy designs. The Husband design was independently conceived, but strongly suggests the Grote Reber model. It is heavier in structure than either the Feld or Kennedy designs, rigidity being sought through great thickness. The reflector is mounted on a huge horizontal cylinder that rolls on top of a cross-bridge as used in the Feld design. Only about 10% of the total load rests on the central bearing; the remainder is carried by the trucks running on circular rails. The method of adjustment of the surface is not flexible, once the adjusting shims have been set and welded in place. At the time of the meeting, Mr. Husband had not sent details on his drive and control system, but he expressed confidence in his ability to produce one based on his work with the 250' telescope for the University of Manchester.

8. The Kennedy design differs markedly from the other two. The basic material is aluminum. The reflector surface is made up of 72 panels riveted to adjustable members which, in turn, are attached to a tubular structure. A steel or concrete vertical cylinder, about 80 feet high and a third as thick, supports a

turret that floats on oil pad bearings. One end of the turret extends beyond the cylinder, and there the reflector is mounted with a suitable elevation axis. The RF feed is supported by a quadripod. There appears to be a difference of opinion among experts as to whether a central mast or a quadripod has better RF characteristics.

Mr. Karelitz prepared a table showing relative weights and other features of the three designs:

**Preliminary Tabulation of
Weights, Moments, and Drive Power Requirements**

Item	Feld	Husband	Kennedy
Reflector weight (tons)	219	130	50
Elevation axis load (tons)	333	735	100
Total weight (tons)	520	1385	500
Structural steel* (tons)	410	1125	--
Machined parts (tons)	110	260	--
Moment of Inertia (lb-ft ²)			
Elevation	9.5x10 ⁸	36.4x10 ⁸	2x10 ⁸
Azimuth	30	71.7	6
Horsepower (hp)			
Elevation - fast	2-60	4-40	1-25
- slow	2-7.5	geared 120:1	
Azimuth - fast	2-30	4-40	2-25
- slow	2-3	geared 120:1	

*Aluminum for the Kennedy design.

Some very preliminary cost estimates were given, as follows:

Feld design - \$1,400,000, including \$100,00 for electrical equipment

Husband design - \$1,300,000 for erected steel

Kennedy design - \$2,350,000, including \$350,000 for a drive and control mechanism

The Feld and Husband estimates would have to be increased by about \$500,000 to cover the cost of a drive and control mechanism. Mr. Karelitz pointed out that the Husband design involved more than twice as many tons of metal as the other designs, which presumably would show up in a cost figure when bids are taken also, it was his opinion that the Husband design would have the most turning friction and hence would be the most difficult to control precisely.

9. Dr. Emberson described the progress being made on studies of a drive and control mechanism. Great precision will be needed to adjust to ten seconds of arc, and it seems unlikely that a true servo device feeding back from the signal of a radio star, can be designed. Hence it appears that what Dr. Tuve has proposed for an equatorial mount will also be used in the alt-azimuth mounts; programmed directions will be given to the drive motors, and from that point on, dependence is made on the rigidity of the mount. If corrections are made for differential temperature or wind effects, these will be introduced through a system independent of the basic drive and control system. The report from the MIT Servomechanisms Laboratory is expected before the end of April.

10. Dr. Bok then brought up the question of an equatorial mount. The National Science Foundation Advisory Panel on Radio Astronomy met on January 16-17, at which time the opinions expressed at the December meeting of the AUI Committee were known. The Panel recommended that AUI study the feasibility of an equatorial mount; this recommendation was not communicated to AUI by the National Science Foundation.

Dr. Emberson said that all three design engineers agree that an equatorial mount is feasible, but also consider that it would be more expensive if the same specifications were used. To obtain three designs, as had been done for the alt-azimuth configuration, he estimated \$30,000 would be required. This matter had been passed on to the National Science Foundation.

Dr. Berkner said the designs using an alt-azimuth mount seem to have gone smoothly, and that AUI would be able to present to the Foundation three workable designs for a 140-foot telescope. He considers that the specifications should not be relaxed, and expressed the opinion that to achieve any substantial saving, considerable relaxation would be necessary. The equatorial mount needs more study, and the 60-foot telescope at Harvard will supply the first practical experience. The particular advantage of the alt-azimuth mount is that it provides experience which is bound to be valuable in designing bigger telescopes. He expressed the hope that the Committee would recommend proceeding with the alt-azimuth design, although he sees no objection to continuing to study the feasibility of an equatorial one.

Dr. Tuve expressed the opinion that a true servo mechanism to provide corrections for deflection resulting from wind gusts could not be devised. Dr. Deutsch emphasized the point that the same would be true for an equatorial mount. A position indicator can be used, Dr. Tuve continued, but it then will be necessary to take what you can get. He doubted that a servo could be designed for such massive equipment that would respond smoothly in periods as short as one second. He expressed the views that

the cost of equatorial and alt-azimuth structures would not be very different, and the drive would be much simpler for an equatorial mount.

11. Dr. Tuve then returned to the question of the desirability of relaxing the overall specifications. The National Science Foundation Advisory Panel thinks that the design should be adapted to work at seven to eight centimeters rather than three centimeters, and sees no particular value in having a telescope capable of operating at less than ten centimeters. He displayed a small model of an equatorial mount developed at the Department of Terrestrial Magnetism, CIW. However, he pointed out that if to achieve the necessary reflector tolerances a Feld-type ring mount is necessary, the DTM design could not easily accommodate such a reflector structure. Attachment A-11-1 is a recent letter by Dr. Tuve discussing these matters, and attachment A-11-2 is the reply thereto.

Dr. Bolton said equatorial mounts would be used for the two telescopes being designed for Cal-Tech, and the tolerances would not be small enough for work below 21 centimeters. High pointing accuracy will not be needed, since the two dishes will be used as an interferometer pair. The reflectors, as presently designed, will weigh 30,000 pounds, with a total weight of 120,000 pounds for the entire telescope.

The advisability of relaxing AUI's specifications was discussed at length. Dr. Bok emphasized that as accurate a reflector as possible is what is wanted and that in his opinion it would be unfortunate to relax the specifications now. He opposed any idea of using a sum of money as the limiting factor and building the largest telescope that could be built for this sum without any particular regard to tolerances. If an equatorial study is to be made, he considered it should be based on the same specifications used in designing the alt-azimuth mounts.

Dr. Tuve seriously questioned whether the extra cost necessary to get down to three centimeters was warranted. He advocated determining what observations were desired, and then building with that objective in mind. Dr. Berkner emphasized that as a practical matter the AUI specifications called for a five (5) centimeter rather than a three (3) centimeter design, and opposed any relaxation to ten (10) centimeters; the possible money saving resulting from such a small increase in tolerances would be almost insignificant.

The Committee then adjourned for lunch.

12. Upon reconvening after lunch, Dr. Emberson read to the Committee a letter dated March 22, 1956 from Dr. Raymond J. Seeger of the National Science Foundation, addressed to Dr. Berkner. A copy is

attached hereto, as Appendix A-12. Noting the direction that an equatorial design be undertaken, Dr. Berkner urged that since AUI apparently had one or more workable designs for a 140-foot dish, it be authorized to proceed on the basis of one of those designs rather than delay further the establishment of the National Radio Astronomy Facility. In the discussion which followed this recommendation, it became apparent that to obtain a preliminary design based on an equatorial mount would require somewhere between four and six months. Dr. Bok suggested that since construction funds will certainly not be available until July 1, 1956, it would be desirable to undertake a study of an equatorial mount. Dr. Tuve emphasized that the National Science Foundation needs assurance on two points. First, it wishes to be confident that the alt-azimuth design will work satisfactorily. For this, completion of the servomechanism study is essential. Second, it must be sure that an opportunity for a really substantial saving in cost is not being overlooked. In his judgment, and unless the price margin is very great, it should not be the determining reason for selecting the type of mount. Dr. Bok suggested and it was the consensus that AUI should proceed with its plans for evaluating the alt-azimuth designs which it has obtained, but at the same time undertake a study of an equatorial mount, with a view to obtaining a single design.

Dr. Berkner then stated his understanding to be as follows: AUI will proceed as planned with the evaluation of the three designs it has obtained, and advise the National Science Foundation of the result. It will also use funds in the amount of \$10,000 previously allocated for studies of large dishes to obtain a preliminary design of an equatorial mount. If it becomes apparent while this design is being prepared that the alt-azimuth designs should be abandoned, it will advise the National Science Foundation promptly. The equatorial study and design will be based on the same specifications used for the alt-azimuth designs, but the design engineer will be asked to give rough estimates of the effect on the cost of relaxing tolerances in certain particulars. This statement represented the consensus of the Committee.

13. Dr. Bok then announced that the Committee would proceed to Item 3 on the agenda. Dr. Emberson reminded the Committee that at the December meeting three sites were considered, and the following order of preference was established: Green Bank, Deerfield and Massanutten. Through Arthur D. Little, Inc., an unexpected opportunity of establishing contact with the Governor of West Virginia arose, and AUI has moved forward aggressively with plans for the Green Bank site. An agent was employed to obtain options to purchase land, and he has succeeded in acquiring options covering 6200 acres for a total purchase price of \$502,000. AUI's original estimate for the cost of the land was \$500,000, but owing to budgetary requirements, this was reduced to \$100,000 in July 1955.

Dr. Berkner expressed the opinion that at least 2,000 acres more should be acquired to provide complete protection. Dr. Emberson continued that in the opinion of AUI's agent, it is now impossible to acquire further options at reasonable prices, but owners of a good deal of the property in the perimeter area have indicated a willingness to sign some sort of agreement restricting the use of their property in return for some appropriate sum. In Dr. Berkner's judgment, the National Science Foundation should set aside \$800,000 for site acquisition. Dr. Bok reminded the Committee that the options were good only until March 1957.

Dr. Emberson then presented some provisional estimates prepared by Eggers & Higgins for the Green Bank site development. A copy is attached to this record, as Appendix A-13. The problem of commercial power is serious because of the overloading of existing power lines. To meet all the requirements of the facility, actual and potential, it will be necessary to bring in a new line from Elkins, West Virginia, which would cost about \$1,000,000. The installation of this line would have the further disadvantage of making the area more attractive for industrial development. The alternative to commercial power is the installation of a diesel generator system, which would require an initial investment of \$400,000. Eggers & Higgins considered there should be three generators at the outset, one of which would be for standby purposes.

The Committee reviewed Eggers & Higgins' estimates, and it was the firm consensus that too much economy of construction funds had been sought in placing the diesel generator in the basement of the laboratory and that the generators should be in a separate building.

14. Dr. Emberson then described the measures taken to achieve protection against radio noise. Three avenues of approach are being followed:
 1. Purchase of land and obtaining of restrictive covenants;
 2. Zoning. AUI's general counsel, Milbank, Tweed, Hope & Hadley, with the cooperation of the Attorney General of West Virginia, are preparing a statute to provide zoning protection. However, this proposal raises serious constitutional questions;
 3. Federal regulation. Mr. William A. Porter, representing AUI, is in contact with the Federal Communications Commission (FCC) and the Interdepartmental Radio Advisory Committee (IRAC) to

achieve protection against both commercial and Governmental installations. The jurisdiction of FCC in the field of radio astronomy is by no means clear, and depends on what is included in the word "communications". It is proposed that zones of avoidance be established to protect a few of the most important radio astronomy installations, in addition to the program on which Dr. Hagen has been working to obtain allocations of frequencies.

15. Dr. Emberson requested the help of the Committee in planning the additional radio noise measurements at the site requested at the December meeting. He reported that he had not been able to locate any portable equipment that was more sensitive than that used previously. The desirability of making further noise measurements was then discussed. Dr. Tuve suggested that for the protection of the National Science Foundation, it might be well to make some measurements with hydrogen line equipment before actually purchasing the land. On the other hand, he pointed out that Green Bank had been selected because, of the sites under consideration, it appeared to be the least vulnerable to future interference, and probably these basic facts are sufficient warrant for proceeding with the purchase of land.

Dr. Berkner said that AUI would endeavor to make some additional measurements before actually going ahead with the purchase of property, but the matter of expense and delay would have to be considered.

After discussion, on motion duly made by Dr. Deutsch and seconded, all members present voting, the Committee unanimously

VOTED: That in the opinion of the Advisory Committee, the radio noise measurements and other studies made to date are sufficient to warrant the selection of Green Bank as the site for the National Radio Astronomy Facility, and the Committee hereby recommends that the National Science Foundation acquire, or authorize acquisition, of title to that site at the earliest possible date.

Attached hereto is a budget for the first phase of the facility. According to the most recent estimates, with the budget submitted to NSF in July 1955, shown for purposes of comparison, the most recent estimate calls for a total of \$4,785,000, including \$2,200,000 for a 140' dish.

16. Dr. Bok said that the National Science Foundation had asked the Bureau of the Budget for \$3,500,000 to cover construction costs for the first phase, and including \$100,000 for the operating expenses of the first year. The latest estimates indicate that \$4,785,000 will be needed for this purpose. The question is, what course should be followed?

Dr. Frank pointed out that delay in and of itself was almost certain to result in increased costs, and asked what the time schedule was. Dr. Emberson said that the schedule developed at the December 1955 meeting called for completion of the 140-foot dish by December 31, 1957.

Dr. Berkner emphasized that acquisition of the land was essential because of the expiration of the options in March 1957. \$1,285,000 seems to be the minimum required for site development, apart from scientific equipment. Items of \$300,000 for equipment and \$200,000 for smaller dishes cannot be reduced substantially. It will be incumbent on the NSF, therefore, to make some critical decisions as soon as Congress has acted finally.

Dr. Hogg expressed the opinion that under no circumstances would the National Science Foundation be able to increase the budget for the facility by the amount in question (over \$1,200,000). The entire NSF budget, apart from facilities, is \$36,000,000 in the Bill passed by the House, of which \$8,000,000 is earmarked for education. The request submitted by the President was for \$41,000,000.

Dr. Frank suggested that an attempt be made to determine what could be done for \$3,500,000. The consensus was that it would be unwise to purchase only a limited amount of land, say 1,200 acres. Dr. Berkner suggested postponing the 140-foot dish, and thus reduce the total estimate to \$2,585,000. This would make it possible to have an operating facility and to proceed with detailed design of the reflector. Dr. Emberson suggested that the first-year operating costs of \$99,000, together with the cost of the detailed design of the 140-foot dish, might be met by the NSF from its regular budget.

Subsequent to the meeting Dr. Berkner arranged a meeting with Dr. Waterman and other representatives of the National Science Foundation. His letter, given here as Appendix A-16, was the basis of the discussion on budgets.

Monday Evening, March 26, 1956

17. The Committee met informally at the Harvard Club, 27 West 44 Street, New York, N. Y. about 8:30 p.m. on March 26, 1956 as the guests of AUI.

Following the dinner, Dr. Berkner said that he would like to discuss the organization of the proposed National Radio Astronomy Facility. This has two aspects. The first is the contractual mechanism to be employed, which is primarily the concern of the NSF and AUI and will be the subject of careful consideration when AUI's report is presented to the NSF. The second aspect, namely, the organization of the National Radio Astronomy Facility, is a matter of concern to the Advisory Committee, and Dr. Berkner said he would like to present his own ideas as a basis for discussion. These are set forth in the numbered paragraphs below:

1. Governing Body

The institution will be operated by a corporate entity of some sort. The governing body of this corporation should be a Board of Trustees or Directors, representing both administrative and scientific skills. The responsibilities of the Board are to select the top staff, determine broad research objectives, insure research performance of the highest type based on programs in the public interest, and develop satisfactory personnel and operating policies.

2. Executive Head

The corporation should have a full-time President, who will be its principal executive officer and who will be responsible for carrying out the policies established by the Trustees.

3. Operating Organization

The operating organization should be headed by a Director who must be a truly distinguished scientist. He will be responsible for all aspects of the work, scientific and administrative. Under the Director there should be three operating departments; namely, Research, Engineering and Maintenance, and Administrative, each headed by an experienced and competent individual. The head of the Research Department (the Director of Research) should also be Deputy or Associate Director of the institution. He will devote most of his time to research, but will assist the Director with external relations. The Director will be expected to devote some time to research, but his major responsibilities will be in other areas. The Chief Engineer will be responsible for the maintenance of the scientific equipment and will undoubtedly be active in developing new equipment. The administrative head, or Business Manager, will be responsible for all business aspects, including ordinary maintenance of grounds and buildings.

Dr. Berkner's ideas were discussed extensively by the Committee. It was agreed that the functions described by Dr. Berkner were necessary ones, but there was some question whether they could not be distributed among a smaller number of people. For example,

it was suggested that the positions of Director and Director of Research could be combined in one man, on the grounds, at least in part, that it would be very difficult to find two topnotch scientists to fill these positions. Furthermore, some thought that, for an organization with a total staff of only about 75 people, the number of top positions was excessive.

Dr. Deutsch suggested starting off with a Director and a Business Manager, and instructing the Director to appoint the necessary personnel to fulfill all necessary functions, in accordance with an organization plan developed by him and approved by the Trustees. Dr. Wiesner emphasized the undesirability of freezing an organization plan before the Director was selected.

Dr. Bok pointed out the analogy to a university, in which the Director is similar to the President, and the Director of Research to the Dean of the Graduate School. These two men must have between them the skills of a physicist, an electronic engineer, and an astronomer.

Dr. Berkner pointed out the burden of the directing function, which would leave the Director with comparatively little time for research. A large amount of research will be done by visitors, and one of the Director's principal tasks will be to make arrangements for visitors to work and to develop a time schedule.

Dr. Berkner expressed the opinion that there would be work for four people at the top levels, but the division of work among them will have to depend on the individuals. When a Director is appointed, the required functions can be explained to him, and he can be given wide discretion in the selection of people to carry them out. The important point is to make clear to the Foundation that these functions exist and require high level personnel.

Dr. Bok proposed that the organization outlined by Dr. Berkner be submitted to the Foundation as a sample, but always with the proviso that there must be flexibility in the division of labor.

According to Dr. Berkner's ideas, the organization should present a budget annually to the NSF and receive money in broad categories to be used in carrying out programs which have been generally approved by the NSF. The NSF is beginning to assume responsibility for separate activities and therefore is bound to be interested in the sort of organization selected to carry them out.

Dr. Emberson pointed out that every scientific member of the staff would have a responsibility for the entire program, and probably should devote about 50 per cent of his time to facilitating the work of visiting scientists. The permanent research staff will probably consist of about 12 people.

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Tuesday, March 27, 1956

18. The Committee met again at 9:00 a.m. on March 27, 1956 at the AUI office. The discussion of protection against radio noise, which was discussed at the meeting on March 26, was concluded. Dr. Emberson said the position of the National Science Foundation was that it would support the general principle of protection by setting up zones of avoidance, but could not support specific application of this principle to Green Bank until a definite decision had been made. However, it is of great importance that AUI make a firm recommendation, so that Mr. Porter may be in a position to make a strong submission to the FCC and IRAC.

19. The Committee then turned to discussion of the planning document. Dr. Berkner suggested that a subcommittee of the Advisory Committee be appointed to review the document after it is put in final form. The present draft requires a good deal of editing to insure internal consistency. Dr. Emberson expressed the opinion that such a committee need not meet, but could instead send in individual comments.

Dr. Goldberg pointed out that the fundamental criticisms of AUI's proposals are issues between the National Science Foundation and AUI. For example, one objection that has been raised is that there are no radio astronomers on AUI's Board of Trustees.

Dr. Berkner said that this criticism was a fair one, although he did not agree with it. In his opinion, the National Science Foundation should appoint an Advisory Committee on Radio Astronomy after the establishment of the facility has been agreed upon. The purpose of this committee would be to review the operation of the facility and evaluate the contractor's performance. In choosing an operating contractor, the important point is competence in managing a research institution. AUI is not prepared to make any change in its basic organization, but would be prepared to add two radio astronomers to the Board of Trustees, if this would satisfy the objections which have been raised. Increasing the number of sponsoring institutions would not be desirable or serve any useful purpose. As it now stands, AUI is an independent organization, with the experience and prestige needed for the selection and support of competent personnel. The Brookhaven experience has demonstrated AUI's ability to deal competently and impartially with academic institutions, whether or not they happen to be sponsors. However, if the radio astronomers as a community are not satisfied with AUI as an operator of the new facility, AUI is quite prepared to assist in setting up some other kind of organization. Dr. Berkner emphasized that AUI would not undertake the operating job if there were any substantial dissenting element among the radio astronomers.

He suggested that for the selection of an operating contractor, the following three tests should be applied: (1) competence to operate, (2) ability to maintain high academic standards, and (3) ability to make provision for national representation through a Visiting Committee, as well as at the NSF level.

Dr. Emberson said there had also been some criticism of AUI's method of operation. It has been asserted that AUI is too lavish. Drs. Goldberg and Deutsch agreed that this criticism did not come from informed sources and also was dying down. Dr. Meinel expressed the opinion that the worries on this point are mostly of a personal nature, resulting from the fact that budgets in astronomy are traditionally low.

Dr. Berkner pointed out that we are living in an expanding world and one of the responsibilities of the scientific community is to meet the problems this condition creates.

At the conclusion of the discussion on the planning document, Dr. Bok appointed a subcommittee composed of Messrs. Goldberg, McClain and himself, the function of which would be to review the document in detail and submit comments to Dr. Emberson at the earliest possible date.

20. Dr. Emberson then asked advice on how best to mount a 60-foot telescope, in view of the suggestion at the December meeting of the Committee that the 60-foot instrument be employed as an interferometer with the 140-foot telescope. The relative desirability of moving on a road or on tracks was discussed. Dr. Feld pointed out that laying tracks would be considerably cheaper than building the necessary road. It was the consensus that the ultimate decision on this point should be reserved for the operator of the facility.
21. Mr. Haddock, as Chairman of an ad hoc committee composed of Messrs. Bok, Ewen, McClain and himself, made a report on a program for electronic and rf components. He submitted a list* calling for an expenditure of \$520,000. Dr. Emberson asked whether AUI should recommend a program to the National Science

*The Committee was not prepared to recommend the specific items as listed, but suggested that the list was valuable as an indication of the kinds of components required and their probable cost. The list follows: Antenna feeds, VSWR 1.05, 65-75% efficiency, illumination 15 db down at edge of paraboloid, 2:1 frequency coverage - \$15,000; Precision 20-foot horn for calibration purposes, - \$6,000. Waveguide, co-axial, etc. lines - \$35,000; receivers - \$150,000. display units, 8 Leeds & Northrop and 10 Esterline Angus paper tape recorders, Du Mont precision oscilloscope, cameras, wire or tape sound recorders - \$35,000; calibration equipment, 20-foot horn, helium and argon gas discharge tubes, etc. - \$8,000. power supplies, 10-Sorenson, 6 Novation, 1-Kay Lab and 6 less precise supplies - \$16,000. test equipment - \$100,000; inventory of electronic parts - \$20,000; machine shop & supplies - \$120,000; shielded test room - \$2,000 optical equipment, cameras, transits, dark-room & drafting equipment - \$10,000; calculators - \$3,000.

Foundation and start purchase of equipment in the fall. Dr. Ewen urged that the ordering of equipment on any substantial scale should be postponed until the Director had been appointed. It is necessary to determine whether research and development in equipment is to be done on the site or turned over to outside contractors. A program such as outlined by Mr. Haddock suggests that research and development will be done on the site, and if this is the decision, the problem of finding competent electronic engineers will arise. On the other hand, if the goal is to have reliable equipment at the site and leave development to others, the effort should be to select rugged equipment which can be easily maintained, and for which diagrams and manuals are available. The equipment should not be too elaborate for ordinary use. Dr. Chambers supported Dr. Ewen's argument, and pointed out that the expenditure proposed was out of proportion to the small staff now provided for in the operating budget.

Dr. Emberson then pointed out that testing equipment should be available as soon as the telescope is completed, and asked the judgment of the committee on when orders should be placed. Dr. Bok named an ad hoc committee composed of Messrs. Haddock, Heeschen and Ewen to advise on preliminary equipment of this sort.

It was the consensus that procurement of equipment would be one of the first tasks of the new director and that preliminary purchases of basic equipment should be kept to a minimum. The Committee considered that the initial expenditure would be heavy and would continue annually at a diminishing rate.

22. Mr. Haddock expressed himself as greatly disturbed at the suggestion of relaxing tolerances on the 140-foot dish. He argued that to relax to a point where the dish would be useful only at 21 centimeters would be a major blunder. In his judgment, tolerances should be held to 10 centimeters and preferably to 3 centimeters. In support of his argument, he pointed out that even with the 50-foot dish at NRL new sources are being discussed, and this clearly indicates the many possibilities that a big precise dish presents.
23. Dr. Berkner then suggested that the National Radio Astronomy Facility be called the Karl G. Jansky Radio Astronomy Observatory. After discussion, on motion duly made and seconded, all members of the Committee present voting, it was unanimously

VOTED: That the Committee hereby recommends to the National Science Foundation that the National Radio Astronomy Facility be called the Karl G. Jansky Radio Astronomy Observatory, in honor of the discoverer of radio astronomy.

NATIONAL SCIENCE FOUNDATION
Washington 25, D. C.C
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March 22, 1956

Dr. L. V. Berkner
President
Associated Universities, Inc.
New York 1, New York

Dear Lloyd:

It has been some weeks since the first chapters of the AUI planning document were received at the Foundation. We all are grateful to you for the opportunity of reviewing the various copies which Dr. Emberson sent us. Dr. Waterman wishes to discuss various aspects of the proposed management with you in the near future. The report on Phase I, the Feasibility Study, of course, is necessary "to provide the information needed to make the decisions to proceed." (Enclosure A)

First of all, as you know, the material you have sent us does not cover all the points completely in view of recent desired modifications with respect to the design itself. The progress on the design has indicated that the original specifications for the 140-foot instrument should preferably be relaxed. As of this date we would like to have you consider certain modifications (Enclosure B) and include them in the first phase of your report. This means that we now wish to get a basic engineering design and preliminary cost estimate from at least one contractor like Kennedy on an equatorial mount of specifications which that contractor feels are attainable without highly exaggerated efforts and costs. The "program device" indicated in the AUI specifications, to enable the dish to follow the sun, moon, planets, or other objects which do not travel in the sky at the steady rate of the "fixed stars" should definitely be omitted from such a design quotation and estimated later, perhaps, as a separate item. We wish Dr. Emberson to go forward with an equatorial design study after consultation with members of your Steering Committee, such as Drs. Tuve, Bok and Hagen.

Concern has been expressed that the MIT Servo Laboratory is not able to submit a servo-mechanism design for an altazimuth mount in accord with the specifications. Therefore, we would like to be informed as to the group which will carry out the servo drive and computer problem, the actual specifications, and the technical characteristics (time constants, damping, power, flutter and self-oscillation characteristics, and other matters) of the controls which are to accompany the favored altazimuth designs.

Dr. L. V. Berkner

- 2 -

March 22, 1956

In view of the many unforeseen factors which have arisen recently in connection with the Green Bank site, such as cost of land, difficulty of radio zoning, oil and gas options, etc., what is your present estimate as to the time that a final recommendation on site can be made and the feasibility report completed?

Cordially,

Raymond J. Seeger
Assistant Director (Acting)

Enclosures**

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** See Appendix A-11-1 (letter from M. A. Tuve) for identical enclosures.

ASSOCIATED UNIVERSITIES, INC.
350 Fifth Avenue
New York 1, New York

March 30, 1956

Dr. Alan T. Waterman, Director
National Science Foundation
1520 H Street, N. W.
Washington 25, D. C.

Dear Dr. Waterman:

The studies conducted by Associated Universities, Inc. under the grants of the National Science Foundation and looking to the establishment of a national radio astronomy facility have reached a point where, in our judgment, major decisions can and should be made. The work under these studies consists of three major parts:

1. Studies of steerable paraboloids and associated electronic equipment;
2. Selection of a site;
3. Planning an operating organization.

The studies are being summarized in a planning document which will consist of 9 chapters. Rough drafts of all but three of these have already been transmitted informally to the Foundation. Of the three remaining chapters, one will discuss the instrumentation program, the principal item being the 140' radio telescope discussed below. Another chapter will describe the development plan for the site. The New York firm of Eggers & Higgins are working on this problem and have furnished us with cost estimates in advance of their final report. The third chapter will contain a history of the work done by AUI under the two grants from the Foundation.

Pending discussions with the Foundation and in accordance with your express request, we have not yet put any part of the planning document in final form. In the meantime, from members of our Advisory Committee and others, I have received comments that I hope to discuss with you and to incorporate in the final draft. Moreover, it is our intention that when the several subjects encompassed by the planning document incorporate the results of our discussion, the whole document will be appropriately edited before final publication. In our judgment, a document of this kind, satisfactory with NSF and AUI, should be useful as a guidepost in the establishment of the observatory.

LARGE REFLECTOR: The three independent design studies of the 140' reflector, initiation of which the Advisory Committee approved at its meeting in July 1955, were undertaken in November 1955, when funds became available, and have not been completed. These designs are undergoing a careful review by an ad hoc group of consulting engineers in order that we may be in a position to assure the Foundation before bids are invited that one or more of the designs are indeed adequate. Invitations for bids could be issued by the contractor designated to operate the facility as soon as decisions concerning the operating contract for the Facility have been made and a contractor chosen, but in our judgment, issuance should be postponed until that time. Meanwhile, in accordance with Dr. Seeger's letter of March 22, 1956, we are diverting the sum of \$10,000 originally planned for studies of large reflectors (600' and possibly other sizes in excess of 140') to an

March 30, 1956

immediate study of a polar type mount for the 140' reflector. We hope that this study can be completed in less than four months. This time schedule is such that feasibility and preliminary cost estimates of the equatorial mount will be available prior to the need for award of the contract to the alt-azimuth design. Thus flexibility in the final decision as to the form of mount is retained.

THE SITE: With respect to a site, the studies have now reached a point where the AUI Advisory Committee on Radio Astronomy believes that no further tests are needed and that the Green Bank site should be acquired as soon as funds are available. Furthermore, in our negotiations with the Federal Communications Commission and the Interdepartmental Radio Advisory Committee for protection against radio interference, it is highly desirable that a decision on a specific site be made at an early date.

AUI now has about 6,000 acres under one-year options. We have learned from our agent in the area that the holder of one-year oil and gas leases on part of the property in question has indicated his willingness to relinquish his interest if our purchase options are exercised. The acquisition of an additional 4,700 acres would have been desirable for complete protection of the site. However, the option program was not extended to this acreage for several reasons. In the first place, as the option program proceeded, land prices steadily rose and have now reached levels that we consider unreasonable. In the second place, the land involved is needed only to protect and control against radio interference on both sides of the road passing through the valley. In the third place, most of the owners of the peripheral land not under option have signified their willingness for an appropriate consideration, to agree formally to restrict the use of their property to activities that produce negligible radiation interference. All in all, we consider ourselves safe in asserting that enough land can be acquired or controlled to assure a satisfactory site at Green Bank. As soon as a decision on acquisition of this site is reached, we propose to discuss with the NSF detailed acquisition procedures.

We will continue the engineering studies of the site, including core borings, over the next few months in order that exact locations for the foundations for the telescopes can be determined. Our engineers assure us that they anticipate no difficulty in finding at Green Bank a suitable substructure for foundations. In their judgment, any subsurface defects that may be found will not extend more than a few hundred feet, though of course it may be necessary to give up initially planned locations in order to secure the best foundation conditions. We expect to have this work completed by August, and we firmly believe that this detailed engineering work should in no way delay the acquisition of the site. The Advisory Committee concurs completely in this latter opinion.

ORGANIZATION: The work on the proposed organization has been largely outlined in the rough drafts of the planning document. It is now appropriate that discussions be opened with the Foundation looking to the selection of, if necessary, creation of the necessary management body responsible to the Foundation, in order that the establishment of the observatory may proceed as rapidly as possible. I hope to discuss this with you in the near future.

I am enclosing herewith figures showing our most recent estimate of capital costs for FY 1957 and FY 1958. We are able to make these estimates with considerable

March 30, 1956

confidence in the light of our engineering studies on the 140-foot telescope design and on acquisition and development of the specific site at Green Bank. You will note that the total of \$6,400,000 for the two years is comparable to the original figures of \$6,649,000 presented in our letter of May 6, 1955. The budget figures for capital construction for 1957 will permit minimal utilization of the facilities for actual research, while the figures for 1958 will permit full development of the research potentialities of the instruments provided. These figures do not include construction of large instruments beyond the 140' telescope. The members of the Advisory Committee and I fully realize that the sum required considerably exceeds the corresponding budget item for the National Radio Astronomy Facility submitted to the Congress by the President. It seems highly desirable, therefore, that we confer at an early date on the measures to be taken to make sure an operating facility can be set up during the forthcoming fiscal year.

The operating funds of \$100,000 for 1957 included in our submission of July 16, 1955 appears suitable. For FY 1958, we believe that the operating budget of \$212,000 should be increased to \$250,000 to ensure utilization of the facility toward full capacity at the optimum rate.

We are satisfied from our studies that it is now possible to proceed in accordance with the ideas set forth above, and so I hope, therefore, that these ideas can be considered in the very near future and the necessary decisions promptly made.

Sincerely yours,

L. V. Berkner
President

Note: The fiscal tables originally attached to this letter have been deleted and are replaced by the appended letter to Mr. Franklin C. Sheppard dated April 24, 1956.