

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

April 16, 1956

Mr Franklin C. Sheppard
Comptroller
National Science Foundation
Washington 25, D.C.

Dear Mr Sheppard:

The purpose of this letter is to provide the information you requested at our meeting in Washington on April 10, 1956. At that time you asked us to supply the following:

1. A reconciliation between the Summary of Financial Requirements for a Radio Astronomy Facility submitted by the Foundation to the Bureau of the Budget in December 1955 and AUI's most recent (March 31, 1956) Capital Cost Estimate for a Radio Astronomy Facility.

This is supplied in Exhibit I.

2. An estimate of the capital cost of a Radio Astronomy Facility (including a 140' radio telescope). You asked that this estimate be based on a ceiling of \$3,500,000, of which \$100,000 is for operating costs.

For this we refer you to Exhibit II.

3. An estimate of the minimum capital cost of a Radio Astronomy Facility which could fairly be regarded as an operative entity.

This is discussed below.

The exhibits should be read in the light of the following general comments.

Exhibit I. The July 18, 1955 estimate was used in the presentation to the Bureau of the Budget, and many of the items in it are derived from estimates made by the engineering firm of Eggers & Higgins in May 1955. Exhibit I sets out in detail the differences between this estimate and that made in March 1956. We wish to emphasize the following points:

(a) The March 31, 1956 estimate is the first one to be based on an actual site for the proposed observatory, namely Green Bank, West Virginia. This has resulted in two large items of increase which by themselves explain most of the \$1,200,000 increase from the earlier figure. In the summary submitted to the Bureau of the Budget, the cost of the land for the observatory was estimated at \$100,000. This estimate was based on the hope that it would be possible to limit actual purchases of land to about 1,000 acres and that the necessary protection from radio noise could be obtained by locating the land purchased in an area where it would be surrounded and thus protected by publicly-owned land; for example, national parks or national forests. As events have turned out, diligent and comprehensive search failed to uncover any such site, and to achieve the necessary protection at Green Bank, purchase of about 6,000 acres is essential for protection and for future growth. AUI holds one-year options on approximately 6,200 acres at a total purchase price of \$502,000. In AUI's judgment, full protection of the Government's investment in this tract can be achieved only by purchasing or restricting the use of an additional 4,000 acres. It will be seen, therefore, that the estimated cost of acquiring a site has increased from the \$100,000 figure submitted to the Bureau of the Budget, to \$800,000, of which \$502,000 is a firm figure. It should be noted that the per acre cost is somewhat below the original estimate of \$100.

The other major difference is the cost of utilities. Here again, it was impossible to make firm estimates until an actual site had been selected, and the estimates contained in AUI's March 31 summary were prepared by Eggers & Higgins, the engineers who have been associated with the project since April 1955. The largest single increase is in the cost of providing electric power, and amounts to \$275,000. Both estimates were based on construction of a diesel driven generating plant adapted to the initial phase of the installation. The later estimate, however, includes a distribution system planned to take care of future development of the site and also provides greater generating capacity. The earlier figure contemplated a more-or-less makeshift distribution system adequate only for the immediate future. Any such system would have to be completely rebuilt as the institution developed and demand for power increased.

(b) The March 1956 figures are the result of a more careful exercise of engineering judgment than was possible in the spring of 1955. Moreover, these later estimates are the product of AUI's conviction that it is improvident to spend money provided by the Government on makeshift structures, utilities, etc., when, by a relatively slight

increase in expenditure, permanent values can be obtained. In the course of our discussion last week, we cited a number of examples. The item of \$15,000 for a generator building is now estimated at \$30,000. Of this larger amount, \$5,000 is for a water cooling tower for the diesel engines, an essential item that had been overlooked. The remainder of the increase results in part from a larger size of building that is deemed necessary for the maintenance of the diesel generators, and in part from shielding devices incorporated in the installation to minimize radio interference.

(c) Finally, it must be remembered that since the estimates submitted to the Bureau of the Budget were prepared, costs of some types of construction have increased in the opinion of Eggers & Higgins by as much as 20%. The result, of course, is that quite apart from the considerations set forth above, the installation contemplated in July 1955 could not be acquired today for \$3,700,000.

Exhibit II. Contrary to the tentative opinion we expressed last week, it is our firm belief that \$3,500,000 is not sufficient to defray the capital cost of a minimal operating installation containing a 140-foot reflector. Exhibit II sets out our best estimate of the cost of a minimum facility of this sort which can be regarded as an operative entity. The notes appended to the figures indicate the extent of the omissions from what is provided for in the March 1956 estimate, and their serious nature needs no further demonstration.

Minimum Facility. Any estimate of the cost of the absolute minimum facility, i.e. without any requirement of a 140' dish or other particular equipment, contains a number of conjectural elements. We have not tried to present a separate estimate, since a total can be derived readily from Exhibit II. The total cost would be \$2,095,000, arrived at as follows:

Exhibit II	\$3,895,000
Deduct cost of 140' dish	<u>2,200,000</u>
	1,695,000
Add cost of 2 60' dishes	<u>400,000</u>
	<u>\$2,095,000</u>

Recommendations:

- (a) In the judgment of AUI, the March 31, 1956 estimate should be adopted, and indeed AUI cannot recommend any important departure from these figures. Unquestionably, some savings can be effected by abandoning any idea of acquiring or controlling the so-called peripheral land, by limiting for the time being the extent of the road and utility distribution systems, and by postponing until FY 1958 or even later some of the purchases of equipment. Nevertheless, in our opinion, the capital cost of what can be regarded as a suitable national facility is bound to exceed \$4,000,000. The reasons for this opinion are set forth above and also in the Exhibits and the notes attached thereto.
- (b) The cost estimate contained in Exhibit II provides, in our judgment, an inadequate facility, but not to the point where it can no longer be regarded as an operative entity.
- (c) Acquisition of what we call the absolute minimum facility would not be, in our judgment, a prudent expenditure of Government funds, given the recommendations contained in the House Committee report.

I hope this letter gives you the information you wanted, and also that we will have a chance for detailed discussion of it on April 19th.

Very truly yours,

R. M. Emberson

NATIONAL RADIO ASTRONOMY OBSERVATORY

EXHIBIT I
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COMPARISON OF COST ESTIMATES FOR FY 1957

	July 18, 1955 <u>Estimates</u>	March 31, 1956 <u>Estimates</u>	March Estimates Over <u>July Estimates</u>
I. <u>Site Development</u>			
Site acquisition	\$ 100,000	\$ 800,000	\$ 700,000 (1)
On-site secondary roads	90,000	190,000	100,000 (2)
Drainage system (Piping, manholes, etc.)	17,000		
Water supply:			
Well	5,000	135,000	58,000 (3)
Pump	7,500		
Pump housing pressure tanks, etc.	12,500		
Fire protection (fire pump and water reservoir)	35,000		
Electric power:			
Two 250 KW diesel generators	94,000		
2,000 ft. of 600 V cable	12,000	418,000	293,000 (4)
Transformer shielding filters, distribution panels, etc.	19,000		
Total, Site Development	<u>\$ 392,000</u>	<u>\$1,543,000</u>	<u>\$1,151,000</u>
II. <u>Buildings and Housing</u>			
Diesel-generator building (15,000 cu. ft.)	\$ 15,000	\$ 30,000	\$ 15,000 (5)
Control building, 140' reflector (12,000 cu. ft.)	15,000	33,000	18,000 (6)
Maintenance building (One wing only - 4,000 sq. ft.)	40,000	68,000	28,000 (7)
Laboratory and administration building (one wing, basement with boiler, 1st and 2nd floors)	300,000	441,000	141,000 (8)
Housing and cafeteria	150,000	20,000	(130,000) (9)
Total, Buildings and Housing	<u>\$ 520,000</u>	<u>\$ 592,000</u>	<u>\$ 72,000</u>
III. <u>Radio Telescope Construction and Equipment</u>			
Excavation, clearing, foundation, etc. for 140' reflector	\$ 400,000	\$ 400,000	\$ -- (10)
Design, construction, and erection of 140' reflector	1,800,000	1,800,000	-- (10)
R. F. components and other electronic equipment	100,000	200,000	100,000 (11)
Other observing equipment	150,000	350,000	200,000 (12)
Total, Construction and Equipment	<u>\$2,450,000</u>	<u>\$2,750,000</u>	<u>\$ 300,000</u>

NATIONAL RADIO ASTRONOMY OBSERVATORY
COMPARISON OF COST ESTIMATES FOR FY 1957

EXHIBIT I
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	<u>July 18, 1955</u> <u>Estimates</u>	<u>March 31, 1956</u> <u>Estimates</u>	<u>March Estimates</u> <u>Over</u> <u>July Estimates</u>
IV. <u>Facility Equipment</u>			
Library	\$ 50,000	\$ 10,000	\$ (40,000) (13)
Shop and repair equipment	100,000	60,000	(40,000) (14)
Electronic test and repair equipment	50,000	65,000	15,000 (15)
Furniture and equipment for offices, cafeteria, guest house, etc.	100,000	50,000	(50,000) (16)
Total Facility Equipment	<u>\$ 300,000</u>	<u>\$ 185,000</u>	<u>\$ (115,000)</u>
Total Capital Costs	\$3,662,000	\$5,070,000	\$1,408,000
V. <u>Salaries, Operation and Maintenance</u>	<u>100,000</u>	<u>100,000</u>	<u>— (17)</u>
Total National Radio Astronomy Observatory	<u>\$3,762,000</u>	<u>\$5,170,000</u>	<u>\$1,408,000</u>

April 16, 1956

NOTES ON EXHIBIT I

I. Site Development

1. Site acquisition: The July 18, 1955 estimate of \$100,000 for acquisition of land was based on the hope that a site could be found surrounded by publicly owned forest land. In that event, 1,000 acres (estimated at \$100 an acre) would be sufficient, in view of the protection provided. The March 31, 1956 estimate of \$800,000 is made up of three figures: \$502,000 for the purchase of 6,206 acres at Green Bank, West Virginia, a price established by actual purchase options; \$250,000 for the purchase of or imposition of restrictions on the use of an additional 4,000 acres, highly desirable from the point of view of noise protection; \$48,000 for legal and other expenses in connection with purchase of the land and for surveys and similar expenses which will be required when the land is first occupied. Eggers & Higgins estimated that topographical surveys will cost \$17,000.

2. On-site secondary roads: The July 18, 1955 figure reflects the greatly reduced acreage then contemplated. The March 31, 1956 figure is based on actual study by Eggers & Higgins of the Green Bank site, and covers the cost of a road system adequate for the future development of the installation. This includes \$22,000 for paved areas (parking, etc.) not provided for in the estimates last July.

3. Drainage system and water supply: The July 18, 1955 estimate of \$77,000 provides a strictly minimal system, with one pump, one well, no on-site distribution system, and no gas. The March 31, 1956 figure of \$135,000, based on actual study by Eggers & Higgins of the Green Bank site, is still minimal in character, but does include gas and distribution to appropriate points on the site.

4. Electric power: The July 18, 1955 estimate of \$125,000 provides a strictly minimal system. The distribution system would cover only the portion of the site required for immediate development and would use buried cables rather than permanent conduits. Power would be supplied by two diesels with a combined capacity of 500 KW. The March 31, 1956 figure (\$418,000) is the result of a study made by Eggers & Higgins at Green Bank. The distribution system, using buried conduits, covers the central laboratory and the 60-foot and 140-foot telescopes, and will be adequate with extensions to other telescopes, for an ultimate maximum load of two to three megawatts. The cost also reflects the increase in acreage in the later estimate, which permits somewhat greater

distances between the individual instruments, thereby reducing natural interferences. The power supply will consist of three 395 KW diesel generators. Additional generating capacity can be acquired as needed. Provision is also made for a telephone system at a cost of \$18,000. This was not included in the July 1955 estimate. An alternative power arrangement became known last week, but detailed cost estimates are not available. The alternative involves the construction of a 66,000 volt line along the Greenbrier River valley to a point northwest of the Green Bank site, where a sub-station would be built to feed a private line, at 12,000 volts, for the National Facility alone. The private line would be buried from a point near the top of the ridge separating the Greenbrier River and the site; the cost would be approximately \$200,000 plus a monthly service charge of about \$3,000. The on-site distribution system would be approximately the same, or \$250,000. Thus, the total would be some \$50,000 greater than the diesel generator system but represents a system that is adequate for an ultimate load of three megawatts or more, requiring merely extensions to later installations.

II. Building and Housing

5. Generator building: The \$15,000 increase from July 18, 1955 to March 31, 1956 represents in part the cost of shielding necessary for noise protection, an additional expenditure amply warranted for long-term purposes, and a water cooling tower, which was omitted in the July estimates. The increase also reflects the general increase in construction costs, estimated by Eggers & Higgins at 20 per cent. If the alternative of commercial power is adopted and if no stand-by power is installed on the site, the total of \$30,000 would be reclaimed.
6. Control building: The July 18, 1955 estimate provides \$15,000 for a single building to serve the 140-foot telescope. The increase to \$25,000 to provide for two control buildings of minimum size designed to permit ready expansion provides for the 60-foot dish and is another example of building permanent value into the site where it can be done at relatively low cost.
7. Maintenance building: The July 18, 1955 cost estimate provided \$40,000 for the construction of one wing of a projected maintenance building. All trucks and other equipment and all surplus supplies of a bulky character (including reflector parts, test jigs, etc.) would have to be stored outdoors or in improvised space in barns and sheds which may be available on the site. Neither a shop nor a separate building for reflector maintenance is provided. The March 31, 1956 estimate

provides for a somewhat larger maintenance building designed to permit ready expansion. A small shop and some minimum provision for maintenance of the reflectors will be possible. As in the other items under this heading, the general increase in construction costs must be borne in mind.

8. Laboratory and administration building: The July 18, 1955 cost estimate provides \$300,000 for a single portion of a laboratory administration building, regarded as the minimum provision for the facility during the early stages of its development. Expansion of the building in subsequent years would be essential. Review of this estimate in the light of conditions at Green Bank and the general increase in construction costs led Eggers & Higgins to the firm opinion that the contemplated structure was inadequate, and to an increase of \$141,000 in the estimated cost. This additional expenditure will permit the construction of a building which can serve as a nucleus for the laboratory and administration building which will ultimately be necessary. The one wing to be built immediately will be a two-story structure with a basement adequate to house heating and other equipment on a scale sufficient to service the complete building. Obviously, it would be improvident to incur expense on makeshift facilities the ultimate replacement of which at increased cost is sure to be necessary.

9. Housing and cafeteria: A saving of \$130,000 has been effected over the July 1955 estimate by making no provision for construction of separate housing and a cafeteria. Some temporary provision for eating facilities can be made in the main building, and by expending about \$20,000 it should be possible to remodel four houses on the Green Bank site to provide living accommodations for the staff during the early stages of the facility. This revision is a further illustration of the changes which inevitably result when an actual instead of a hypothetical site is under consideration.

III. Radio Telescope Construction and Equipment

10. 140-foot reflector: There has been no change in estimated cost. The three designs for the 140-foot telescope have now been received and our present information indicates that the total figure of \$2,200,000 used in July 1955 is sufficient. We must caution you that only when firm bids have been received will there be a truly valid determination of the 140-foot telescope cost,

11. R. F. components and other electronic equipment: Further study has indicated the need for more electronic equipment than was originally contemplated. Furthermore, the

March 31, 1956 estimate provides for three radio telescopes (28-foot, 60-foot, 140-foot), whereas only two (28-foot, 140-foot) were included in the July 1955 figure.

12. Other observing equipment: The increase of \$200,000 in March 1954 represents the cost of the 60-foot radio telescope.

IV. Facility Equipment

13. Library: The July 18, 1955 cost estimate originally provided \$50,000 for setting up a scientific library. This was reduced to \$10,000 in December 1955. The March 1956 cost estimate provides \$10,000 for initial library cost, with further costs to be incurred in future periods.

14. Shop and repair equipment: The July 18, 1955 cost estimate provided \$100,000 for shop and repair equipment. This figure was reduced by \$50,000 in December 1955. The March 31, 1956 cost estimate provides \$60,000 for this purpose. Here again, this sum should suffice for start-up purposes but further purchases will be essential in the near future.

15. Electronic test and repair equipment: The July 18, 1955 cost estimate originally provided \$50,000 for electronic test equipment. This was reduced by \$10,000 in December 1955. In the March 31, 1956 cost estimate \$65,000 is provided for this purpose, a sum sufficient for the initial period of operation, although unquestionably further purchases will be essential in later years.

16. Furniture, etc.: The July 18, 1955 cost estimate originally provided \$100,000 for furniture and office equipment. This was reduced by \$50,000 in December 1955. In the March 31, 1956 cost estimate, the figure of \$50,000 also appears. However, as in the other categories under this heading, this amount is estimated to be sufficient only for the initial period of operation.

NATIONAL RADIO ASTRONOMY OBSERVATORY

EXHIBIT II

COST ESTIMATES FOR FY 1957 -

(MINIMUM FACILITY INCLUDING 140' TELESCOPE)

I. Site Development

Site acquisition	\$ 550,000	(1)
On-site secondary roads	100,000	(2)
Water supply and sewer	130,000	(3)
Electric power	368,000	(4)
Total, Site Development	<u>\$1,148,000</u>	

II. Buildings and Housing

Diesel-generator building	\$ 25,000	(5)
Control building 140' reflector	15,000	(6)
Maintenance building	2,000	(7)
Laboratory and administration building	70,000	(8)
Housing and cafeteria	25,000	(9)
Total, Buildings and Housing	<u>\$ 137,000</u>	

III. Radio Telescope Construction and Equipment

Excavation, clearing, foundations, etc. for 140' reflector	\$ 400,000	(10)
Design, construction and erection of 140' reflector	1,800,000	(11)
R. F. components and other electronic equipment	100,000	(12)
Other observing equipment	75,000	(13)
Total, Construction and Equipment	<u>\$2,375,000</u>	

IV. Facility Equipment

Library	\$ 10,000	(14)
Shop and repair equipment	50,000	(15)
Electronic test and repair equipment	25,000	(16)
Furniture and equipment for offices, cafeteria, guest house, etc.	50,000	(17)
Total, Facility Equipment	<u>\$ 135,000</u>	

V. Salaries, Operations and Maintenance

	\$ 100,000	
Total National Radio Astronomy Observatory	<u>\$3,395,000</u>	

April 16, 1956

NOTES ON EXHIBIT II

I. Site Development

1. Site acquisition: This figure provides only for the purchase of land now actually under option and the incidental expenses necessary in connection therewith. Any provision for acquiring or restricting the use of an additional 4,000 acres of peripheral land has been omitted.

2. On-site secondary roads: This figure provides for only part of the roads which will be necessary when the site is fully developed. Further extension of the road system thus will inevitably be more costly than if the entire system were constructed at one time.

3. Water supply and sewer: The provision for a bottled gas system has been eliminated.

4. Electric power: Provision is made for two instead of three diesel generators, thus effecting a reduction of \$50,000. This is made possible by omitting the 60-foot reflector. If the alternative of commercial power is adopted, the cost reverts to a probable sum of \$450,000.

II. Building and Housing

5. Generator building: This estimate is for a building reduced in size, in accordance with Note 4 above but including a water cooling tower. Again, if the alternative of commercial power is adopted and no stand-by capacity is installed, a diesel generator building will not be needed and the total cost of this item can be set off against the \$450,000 of the preceding item.

6. Control building: Provision is made for one control building for the 140-foot radio telescope since the 60-foot telescope has been eliminated.

7. Maintenance building: The maintenance building has been entirely eliminated and \$2,000 provided for rehabilitation of barns and sheds acquired with the land. These structures can be used as temporary quarters for maintenance operations and also as garage and storage space.

8. Laboratory and administration building: The proposed building is designed to serve ultimately as the maintenance

building, but can be used on a makeshift basis for offices and laboratories by installing temporary partitions, space heaters, etc. In FY 1958, \$450,000 (allowing for a 10% increase in construction costs) will be needed to erect the nucleus of a central building as provided in the March 1956 estimate appearing in Exhibit I.

9. Housing and cafeteria: This provides for the rehabilitation of five houses on the site, four for living quarters and one for a library and cafeteria.

III. Radio telescope construction and equipment

10. Excavation, etc. for 140-foot reflector: \$400,000 remains the best estimate.

11. 140-foot reflector: \$1,800,000 remains the best estimate.

12. R-F components and other electronic equipment: This represents minimum provision of r-f feeds and receivers for a 140-foot and a 28-foot radio telescope. Until more adequate provision can be made, visitors will have to bring some of their own equipment.

13. Other observing equipment: A 28-foot telescope on a temporary mount adjacent to the temporary laboratory building and perhaps an electronic array of moderate size are all that can be acquired. The 60-foot reflector is omitted.

IV. Facility Equipment

14. Library: This represents a minimum start on a library.

15. Shop and repair equipment: In view of the time required for delivery, orders must be placed for equipment of this sort, even though no provision is made for a shop.

16. Electronic test and repair equipment: This contemplates deferring to FY 1958 purchases of most of the electronic test equipment.

17. Furniture, etc.: This is the minimum expenditure necessary, whether for temporary or permanent quarters.

GENERAL

The principal reason the total amount of \$3,895,000 is greater than the budget submitted in July 1955 as reduced in December 1955 is the firm estimate of \$550,000 for land, as compared to the earlier hypothetical estimate of \$100,000