ASSOCIATED UNIVERSITIES, INC.

350 Fifth Avenue
New York 1, New York

January 21, 1957

MINUTES

Meeting of Special Ad Hoc Committee
140-foot Equatorial Telescope Design

1. The Committee met in the AUI Office, Tuesday, January 15, the following being present:

T. C. Kavanagh Chairman	Praeger & Kavanagh, New York
N. L. Ashton	820 Park Road, Iowa City, Iowa
J. G. Bolton	California Institute of Technology
N. A. Christensen	Cornell University
R. M. Emberson	Associated Universities, Inc.
J. W. Findlay	Associated Universities, Inc.
A. M. Freudenthal	Columbia University
D. S. Heeschen	Associated Universities, Inc.
M. B. Karelitz	Associated Universities, Inc.
E. F. McClain	Naval Research Laboratory
E. J. Poitras	Highland Street, Holliston, Mass.
B. H. Rule	California Institute of Technology
H. E. Tatel	CIW - Dept. of Terrestrial Magnetism

D. H. Menzel, Chairman, AUI Advisory Committee on Radio Astronomy

2. Dr. Kavanagh had just completed his study of the relative costs of telescopes if constructed according to designs prepared by Dr. Feld, Mr. Husband and the D. S. Kennedy Company. Also available were cost estimates by Mr. Silvey (Servomechanisms Laboratory, MIT) on drive and control components, and a letter from Farrand Controls, Inc. with estimates of several systems, all including the Farrand Inductosyn for indicating the angular positions of the telescope, and for converting from equatorial to altazimuth coordinates. A copy of these reports is attached hereto and made a part of these minutes. Dr. Kavanagh cautioned that the structural price estimates did not reflect the actual situation that might develop through the presence or absence of competitive bidding. It was his opinion that if we could develop a strong competitive situation, his estimates were reasonably good. On the other hand, if only one or two firms submit bids to us, his estimates may be too low by 20 per cent or more. He also noted that his estimate would include detailed shop drawings, but did not provide for any expenses of detailed design, nor for other

costs such as legal expenses, insurance, etc. The table on page 2 of his report requires comment because it indicates a considerably higher expense for an equatorial telescope than for an altazimuth design. In this regard, two particular points should be noted: First, Dr. Feld incorporated a lead counterweight in his equatorial design. The choice of lead was dictated by the limited geometry of his design and resulted in a cost of $318,000 for the lead. Secondly, the reflector for Dr. Feld's equatorial design was identical to the reflector of his altazimuth design, except that for the equatorial model an additional massive truss had to be provided across the diameter of the ring girder. It appears that this truss adds $300,000 to the cost of the basic reflector. Assuming that other and cheaper solutions might be found, it will be noted that these two items are responsible for the fact that Dr. Feld's equatorial design is approximately $500,000 higher than the average of the altazimuth designs.

3. The Committee carefully reviewed all factors entering into a decision between an altazimuth telescope and an equatorial telescope. It has long been evident that either design is technically feasible from a structural point of view. It also appears that there are technical solutions for the drive and control problems for either type of instrument. In this regard, however, the altazimuth telescope is at a disadvantage, for most of the astronomical work would require only smooth motion to compensate for the rotation of the earth about its axis. Particularly near the zenith, the altazimuth model demands greater speeds, and therefore, greater power or control capacity of the drive and control mechanisms, than is true for the equatorial telescope. In the matter of complexity, the two systems are similar to the point of input or command, where the altazimuth telescope requires a coordinate converter to change from the desired equatorial coordinates into altitude and azimuth. The coordinate converter would involve an extremely precise mechanism as proposed by Farrand, or a conventional high-speed digital computer. An electronic computer is suspected by many astronomers, both for reliability and high maintenance costs. Dr. Menzel has suggested another apparently simpler digital computer scheme, described in more detail in an attachment to these minutes. An important factor for consideration is the psychological attitude of the astronomers who might be using the telescope. It is certainly true that the vast majority of these scientists would have greater confidence in an equatorial instrument than in the equivalent, but more complex altazimuth design. The final factor considered was the probable cost of constructing the radio telescope. It was the consensus, based on both the pricing studies and preliminary material estimates for the Ashton equatorial design that an equatorial telescope could be had within the budget figure with the same probability as an altazimuth telescope. Accordingly, the Committee concluded and recommended that we table the altazimuth designs and concentrate

our intention on an equatorial design, to be worked out in detail by Prof. Ashton, in accordance with specifications as revised by the Committee at its November 14, 1956 meeting.

4. The Committee considered the specifications for the telescope and made further amendments. It was the consensus that the cost of the telescope could be kept within the budget figure only if a strongly competitive situation could be developed. Inasmuch as the cost of structural materials is a big part of the total, it was obvious that we should seek bids for both aluminum or steel construction. Prof. Ashton pointed out that the design was not identical for the two metals and that parallel designs would add fifty per cent to the cost of the design work and require eight to ten weeks of additional effort. The Committee believed that the additional monetary costs in the design phase would be small compared to the probable savings from competitive bidding. The Committee further recognized that there was a trend of rising prices and labor costs and that a delay of two months might add two per cent to the over-all cost of the telescope. Again, the Committee concluded that this two per cent increase would be absorbed by the savings from competitive bidding. The Committee, therefore, concluded and recommended that we develop parallel designs for the telescope - one for aluminum and one for steel. Mr. Poitras suggested that we might get some preliminary cost estimates from contractors as soon as the design was completed for the aluminum reflector, but the consensus was that the value of this earlier information could be lost through a degradation of the competitive situation we desire to develop. The Committee recommended that all of the aluminum and steel designs be held and sent out simultaneously.

5. The Committee considered the matter of sky coverage in which regard the AUI Advisory Committee had been polled. Compared to complete hemispheric coverage, the limited coverage was defined as that bounded by portions of three great circles, as follows: from the north celestial pole to a point on the horizon 25° north of the east point; from the pole to a point on the horizon 25° north of the west point; and along the horizon from the south point through the east and west points to the above mentioned points 25° north. In addition, motion about the declination axis should permit pointing the telescope 1 degree below the pole. Prof. Ashton estimated that the above limitations would permit him to move the declination axis 12 feet closer to the vertex of the paraboloid, **that would** be possible in a design for complete sky coverage, and that the resulted savings and materials might be as great as $75 - 100,000. This structural change would reduce unbalanced wind torques and thus simplify the drive and control problems. Dr. Tatel proposed the consideration of even more limited sky coverage with the suggestion that this might permit the adoption of some other more economical telescope model. Prof. Ashton indicated that his studies had not revealed any other model

that he would prefer if we asked for a more limited coverage. After detailed and lengthy discussions, the Committee concluded and recommended that the above defined limited sky coverage be adopted.

6. The Committee reviewed the requirements for drive and control about the declination and polar axes and reconfirmed the previous decisions that a 35-foot radius would be adequate for the declination axis and that a 50-foot radius should be provided for motion about the polar axis.

7. Subsequent to the meeting Dr. Tatel wrote to Prof. Ashton. Through the kindness of Dr. Tatel a copy of this letter is attached for the information of the members of the ad hoc Committee.

Attachments:

Report on Relative Costs (Kavanagh, Silvey, Farrand)
Dr. Menzel's Computer Scheme (to be sent later)
Dr. Tatel's Letr to Prof. Ashton dated 1/16/57

Copies to:

AUI Advisory Committee Members
Special ad hoc Committee Members

CARNEGIE INSTITUTION OF WASHINGTON

DEPARTMENT OF TERRESTRIAL MAGNETISM

5241 Broad Branch Road, N. W.
Washington 15, D. C.

January 16, 1957

Dr. N. L. Ashton
Members of Ad Hoc Committee on 140-foot Equatorial Telescope Design

Gentlemen:

After yesterday's meeting it appeared to me that several points which arose were not adequately discussed and I wish to call them to your attention.

Sky Coverage: Previously it had been judged that a coverage in hour angle of ±5 hours was sufficient for the presently contemplated reflector. Yesterday, we discussed the issue once again and the committee decided that ±8 hours was necessary and desirable. This decision was based upon the desire to observe the sun every moment of the year it is above the horizon. While this is a meritorious wish, its realization may be had at a cost. For those who wish to observe the sun, the higher frequencies are necessary in order to obtain maximum resolution. In general the greater hour angle coverage means a structure supported at greater heights. A structure like this is less rigid than a lower structure. If rigidity is sacrificed, then the hour angle and declination over which the reflector may be used at the higher frequency limits becomes more and more restricted. Thus, in gaining wider hour angle coverage, practical coverage is reduced. Bearing this in mind, I would prefer we had stated the limits of hour angle coverage as follows: The hour angle coverage shall be ±6 hours (±90°) and this should be extended up to ±8 hours (±120°) provided an insignificant loss in rigidity results.

Structure: I believe that the structure you described to us has several potential weaknesses which could be easily eliminated to give us a more rigid over-all device. My criticisms are based upon the following hypothesis:

1) A moving structure such as the reflector should be mounted at its strongest point. Separating point of strength from point of mounting results only in reducing structural rigidity.

2) Cantilever supports, such as the declination bearing supports and the polar axis are less rigid than tetrahedral supports. Lessening rigidity of

main support members means an increase in resiliency in one particular degree of freedom. Since the system is closely coupled, energy can be fed into this mode and result in large unwanted vibrations.

3) Gears should be as large as possible, the radii of 50 feet for polar and 35 feet for declination are only minima. Aside from greater accuracy, greater stability in drive results from larger gears, tolerance remaining the same.

4) Pinion supports for declination and hour angle should be mounted on structural members leading directly to the gear axis. If this is not done, flexures in the mount with wind, rotation or thermal stress can change gear clearances.

I respectfully submit that your structure can be strengthened with respect to these points with small changes in design.

1) Mounting of the reflector: A rotation of 45° in the reflector would place declination bearings and declination gear terminations at the reflector strong points. This would enhance the reflector rigidity by incorporating the backing structures into the reflector and increase reflector-mount coupling.

2) Change of bearing supports from cantilever to tetrahedral:

A) Declination: This can be attained by making your polar yoke resemble the CIW mount (for which you have Keller and Loewer's drawings). There is an additional improvement which can be realized in this latter structure. The polar wheel can be made a complete six sided structure. The declination axis is then allowed to rotate about this fixed member between declination bearings. The rigidity of the structure in this plane is enhanced about three times in this way, as loads are always equally shared by the declination bearing supports. In addition, we have found, in a model, that relatively narrow declination bearing supports as you use in your mount at present, are weak in torsion. Carrying a fixed member between the ends of these constrains this degree of freedom.

B) Polar: Again the CIW mount which supports the polar bearings on a tetrahedral support increases the over-all rigidity of the structure. Note that the Keller-Loewer design may be improved by incorporating a fixed member between the upper and lower polar bearings. This is shown in the accompanying print. The polar wheel rotates about this fixed axis. The amount of hour angle coverage with this structure is almost what you wish to make it, the final result will be a delicate balance between rigidity, price, and desirability. The attached print with an hexagonal polar wheel allows for a rotation of ±9 hours (±150°), in principle. I do not recommend this extreme as it means a minimum size of the declination gear and a maximum in counterweight.

3) Large gears: If the CIW type mount is used, the radius of the large gear can be made conveniently equal to the dish radius--say 70 feet. The size of the declination wheel depends upon the hour angle coverage. With maximum practical coverage of ±150°, the declination gear would have a radius of 35 feet. In our 60-foot reflector version, the radius of the polar wheel is 22 feet and the declination gear 15 feet. This gives us ±90° in hour angle. The same proportions on the 140-foot reflector would give gears of radii of 70 feet and 44 feet, respectively. This allows for a minimum in counterweight and a maximum separation of declination support points.

4) Pinion gear mounts: If the changes suggested above are incorporated in your design, pinion gears can be mounted near the apices of tetrahedra whose opposite sides contain the large gear axles. The result is maximum rigidity of pinion-gear assembly. Incidentally, one can also employ a spring-o-matic pinion gear mount. The pinion gear is mounted on a frame on which are opposed rollers with axes parallel to the pinion gears. The rollers ride on the back of the main gear while the pinion rides on the front toothed face of the gear. The whole structure is pivoted on a line tangent to the pinion gear-large gear contact point, but several feet to the side, in the plane of the large gear. Thus, when the main gear is set up, the distance between teeth may be made constant and small changes in radius will not affect tracking. In addition, the pinion gear works at constant mesh with the main gear.

As for time of design involved, the CIW mount is a completely determined structure and the simplest type to calculate. In addition, you already have a copy of Keller and Loewer's calculations which are readily adaptable to the larger mount by a simple scale change. Since you have already worked out the reflector structure and it can be incorporated into the proposed modification, I believe you will lose little time by the change. In addition, you make use of a completely analyzed mount. By the way, the men at Blaw-Knox have checked Loewer's calculations and agree with them.

In conclusion, by slight alterations of your design incorporating certain features of the CIW mount, I believe you will greatly enhance the rigidity of the telescope structure. This should be achieved without any loss in the usefulness of the instrument. In addition, the tripod type mount allows for easier adjustment and inherently greater stability against capsizing in the wind.

Sincerely yours,

Howard Tatel

H. E. Tatel