National Radio Astronomy Observatory
Post Office Box 2
Green Bank, West Virginia

February 11, 1965

LFSP/JWF/3

Dear Colleague:

The Largest Feasible Steerable Paraboloid

I have received a number of comments and replies to my first paper on the design study, and I am circulating these either in full or in abstract in the following documents:

a) Parts of a letter dated January 20, 1965, from Professor F. D. Drake, Cornell University

b) Parts of a letter dated January 21, 1965, from Dr. B. F. Burke, Department of Terrestrial Magnetism, Carnegie Institution of Washington, with a brief note added by me

c) A letter dated January 22, 1965, from Grote Reber

d) A paragraph of a letter dated January 29, 1965, from Mr. T. P. Wright, President of Associated Universities, Inc.

e) A letter and enclosures dated January 28, 1965, from Professor R. N. Bracewell of the Radio Astronomy Institute, Stanford University.

With my best wishes,

Sincerely yours,

John W. Findlay,
Deputy Director

a) Excerpt from a letter from Professor F. D. Drake, Cornell University, dated January 20, 1965:

"My suggestion, which you have heard before, is to consider the analog of the optical mirror cell. I think the presently most plausible form of this would employ an alt-azimuth mount, with the dish supported in many places by pairs of pistons in pneumatic cylinders, the cylinders being nearly at or at right angles. The total force exerted on each piston of a pair would be adjusted so that the resultant force generated by the two pistons is exactly vertical and equal to the weight of the portion of the dish bearing on that particular pair of pistons. As the dish is moved in altitude, the pressures in the two cylinders are varied so as to maintain the resultant force constant in magnitude and direction. This latter task can be done easily in an analog manner by having two master cylinders which feed all the cylinders, the forces in the cylinders being produced by weights on their pistons. These master cylinders move with the mount, and the pressure in their systems will be proportional to the component of the gravitational force of the weights along the axis of the cylinders. Obviously, if the master cylinders are parallel to their slaves, the variation in pressure in each system of cylinders with altitude will be just right.

"Something must take the wind force (also in Bowen's suggestion mentioned in the floating sphere document). I would suggest a wind screen just in front of and behind the dish, and connected by many rods to the same structure which carries the pneumatic cylinder system. The rods would penetrate the dish to reach the screen on the front side of the dish. The wind screen and basic supporting structure will then deflect considerably due to wind and gravity loads, but the dish will not deflect because it is supported with the required forces without self-deflection, and is protected from the wind. The wind screen is a cheap, small radome, carried on the instrument itself.

"The concept can be applied to the equatorial configuration with the addition of a third pneumatic system."

b) Excerpt from a letter from Dr. B. F. Burke, Department of Terrestrial Magnetism, Carnegie Institution of Washington, dated January 21, 1965:

"Thank you for sending along the first draft study on the floating sphere antenna. I have a few comments - mostly negative, but then negative criticisms are always easiest.

"1. Formula 10, page 3, is in error. If the area of section is taken normal to the surface of the sphere as in formula 9, the supporting force must be increased by the cosecant of the angle between the horizontal and the tangent to the sphere. This raises the stress by a factor of almost two which is still within the allowable stress limits for steel. The strain is of the order of 3×10^{-4} however, which is a fairly large elastic deformation.

"2. Dynamic properties of the sphere will certainly be considered in the future. One easy number to calculate is the resonant period of the sphere bobbing in the water. It is easy to see that if the sphere is submerged to the depth ℓ, its resonant period will be $2 \pi A \sqrt{\frac{\ell}{g}}$ which, except for the geometrical factor A, is the same as for a simple pendulum. $A \cong \sqrt{2}$ for the case of a sphere submerged to a small part of its diameter in an infinite bath tub. It is easy to calculate A for other configurations.

"The natural period will certainly be several seconds, an awkward period for a servo system that must compensate for wind pressures varying with similar periods. This point will surely have to be looked into carefully.

"3. Several people, including myself, have championed foam plastic as an unusually stiff material when only self-loads are considered. This morning we measured the ratio of elastic modulus to density, E/ρ, for polystyrene foam and find that it is approximately 60 times worse than steel. Upon reflection, this result is not surprising since one would expect foam steel (steel structures with many members) to be stronger than foam plastic."

Note by JWF:

I agree with BFB's comment 1. My mathematics are wrong. The bobbing action of the sphere I forgot, since it seems reasonable that one would never float all the weight of the sphere, but only about 90%, carrying the rest on wheels and rails for guiding and providing the rotational movements needed.

c) Copy of a letter from Grote Reber, dated January 22, 1965:

"C.S.I.R.O.
Stowell Avenue
Hobart, Tasmania
Australia

"Dear John:

"Thank you for your letter of the 13th and enclosure. I have always been interested in large dish type radio telescopes. They provide important astronomical data plus real engineering challenges. Much of my comments in the past have been critical because I thought both the designs and the methods of approach were poor. However, if the subject is to be taken up again in a rational and unhurried manner, I will try to offer constructive suggestions.

"Mirror Surfaces

"A very good theoretical disertation with experimental confirmation upon the effects of mirror roughness is entitled "Effect of Aperture Distribution Errors on the Radiation Pattern", by John Ruze, Antenna Laboratory Memorandum AFCRC, January 22, 1952. I recommend it as a starting point on mirror design.

"Mirror Support

"General considerations applicable to any design will be found on first three pages of memorandum by me entitled "Large Mirror Design", 12 March 1955, Appendix A-14-1 of AUI report on Steerable Radio Telescopes. These points can be used as a criterion for comparison of widely divergent designs.

"Models

"I strongly urge more time, money and effort be expended on working scale models. Much of the past difficulties have been caused by reliance upon the opinions of consultants with low index of expertness. General considerations relating to models may be found in my comments published in Stenographic Transcript of NASA Conference on Large Aperture Antennas, Washington, D. C., November 6, 1959, pages 117 & 118. Chairman Wallace L. Ikard. On pages 115 & 116 appears some interesting description of design of spars to support focal apparatus.

"Reference LFSP/JWF/2

"Under conclusions should be an item (aa) Windage. This is only hinted at in section (c) item (b) page 4. A simple formula for wind pressure on a flat surface is $P = V^2/300$ pounds per square foot, where V is wind velocity in miles per hour. For long thin cylinders multiply by 2/3 and for spheres by 1/2. Not only will the wind forces be large but highly irregular in direction and magnitude due to gusts. This means large non-uniform horizontal forces must be dealt with. They will be high above the center of support. The idea has been studied somewhat by John M. Boyle, Naval Ordnance Testing Station memorandum TP2183 entitled "A proposal for a very large Antenna for Radio Astronomy, Space Communication and Long Range Radar", 17 February 1959. The design might be attractive on the back of the moon.

"Please keep me on the mailing list. I suggest that this letter be circularized to the whole group.

Best regards

S/ Grote

Grote Reber "

d) Excerpt from a letter from Mr. T. P. Wright, President of AUI, dated January 29, 1965:

"I received your letter of January 13 concerning the LFSP. On rereading this, I believe I have no additional comments to make other than I mentioned to you the other day, namely, that cost estimates be based not only on detailed calculations of the various components added up to give a total, but also a more general estimate based on extrapolation of actual costs which have maintained in the past on telescopes of a somewhat similar type. I found this was very useful in connection with estimating the costs of new types of aircraft which were under development during the past many years. As regards aircraft, it is interesting to note that we found quite consistently that the cost of larger aircraft was less than those of smaller on the unit basis, whether based on airframe weight or on wing area. The actual rule was that the cost of larger units went up as the cube root of the size factor.

"I was much intrigued by your discussion of "the floating spherical antenna." This seems like a very logical concept and one which might very well work out admirably in practice. If this should not prove a feasible scheme, then probably some more usual configuration such as that of the Jodrill Bank telescope will be indicated as desirable. I fear that the arrangement of the 140 ft. telescope at Green Bank is one that has just about reached its maximum in size in that instrument."

e) A letter and enclosures from Professor R. N. Bracewell of the Radio Astronomy Institute, Stanford University, dated January 28, 1965, attached.

RADIO ASTRONOMY INSTITUTE

STANFORD, CALIFORNIA

January 28, 1965

Dr. J. W. Findlay
National Radio Astronomy Observatory
Green Bank, West Virginia

Dear John,

Thank you for sending LFSP/JWF/1 & 2 which represent the beginning of a worthy enterprise.

Here is a suggestion to add to the list of possible LFSP configurations: a number of parallel tiltable parabolic cylinders, each 600 feet long, or longer, mounted so as to be rotatable in azimuth.

Considerations leading to this arrangement are written up in the following references which are attached:

"Future large radio telescopes", Nature vol. 193, pp. 412-416, February 3, 1962. R. N. Bracewell, G. Swarup and C. L. Seeger.

"Proposal leading to future large radio telescopes", Proc. Nat. Acad. Sci., vol. 49, pp. 766-777, June, 1963. R. N. Bracewell.

A feed which has been developed for cylindrical reflectors is described in

"A dual-polarized line source for use at S-band", Microwave Journal, vol. 6, pp. 81-87, January 1963. W. A. Cumming.

In its existing form, this feed allows for linear polarization both horizontally and vertically and for circular polarization in either sense.

If this feed were scaled to 21 cm, it would have a bandwidth of 50 Mc/s, amply covering the protected band 1420-1427 Mc/s.

A cost advantage might result from replacing a cylinder with a line focus by a "scalloped" cylinder with multiple collinear point foci and accepting the extra structural complexity. The point foci would be interconnected as described by Thompson and Krishnan, "Observations of the six most intense radio sources with a 1.0' fan beam" (Ap.J. in press).

Design data and cost estimates on tiltable parabolic cylinders in the smaller sizes were obtained by Rohr Aircraft under Grant GP-440 from the National Science Foundation.

For some astronomical purposes the inability to point at the horizon will be disadvantageous, but for other astronomical purposes the configuration proposed is perfectly satisfactory. Therefore I think it certainly qualifies as a candidate for cost studies alongside other filled-aperture circular-beam radio telescopes.

In addition two particularly advantageous features should be noticed.

(a). The arrangement is well adapted to operation at the wavelength of 10 cm mentioned as a hope in Dr. Westerhout's report, or even less.

(b). In the size range from 600 to 1000 feet no structural barrier is likely to be encountered.

Sincerely yours,

R. N. Bracewell

Encs.

RNB:msn