NRAO ONLINE 38

1951-1952: The Quest for a Large Antenna, the Concept of the GIANT RADIO TELESCOPE (GRT) is Born [1]

Introduction:

As we will see, the major impetus for the GRT was the planning for the 250 foot Jodrell Bank telescope (later the Lovell Telescope) which occurred in 1949-1951 with construction from 1952 to 1957[2]. Bowen wrote on 27 August 1952 to an engineering firm in the UK: "Now that the Manchester project is going ahead, local interest has been aroused and there is now a much better possibility that the finance [for the GRT] will be found."[3] Also, Bowen reported to Tizard 15 July 1952[4]: "With the announcement of the Manchester project, local interest, or perhaps local pride, has revived and there is now just a possibility that funds for a similar project can be raised in Australia."

Already in 1948 and 1949, there had been discussions of a large aerial for radio astronomy in Australia. The genesis of the GRT lay in the collaboration with the Royal Australian Air Force (RAAF) and with the early investigations of a large low frequency radar system to detect reflections from the solar corona. The RAAF story has been recounted by Bowen in a number of publications (1981, 1984, and 1989- the latter a copy of the previous year's publication). Unfortunately, most details of these interactions have not been preserved in the RP or NAA archives. Below we point out one exception (from mid-July 1952).

Bowen has provided a succinct summary in *The Early Years of Radio Astronomy*, Sullivan, W. T., III. (1984). Cambridge University Press:

> As in optical astronomy, steerable parabolic antennas are a basic part of the instrumentation for radio astronomy; they played a prominent part in early galactic research, particularly in investigations of line radiation. As in other establishments, there was an urge to increase the aperture of such instruments to the largest possible dimensions.

[1] NRAO ONLINE 38-48 represent background material for Section 7 (Chapters 27-32, also the ESM_27.pdf etc to ESM_32.pdf) of the main book. There is considerable overlap.
[2] The troubled and controversial construction of the Jodrell Bank Telescope has been described by Lovell (1968, *The Story of Jodrell Bank*).
[3] NAA C3830 A1/3/11/1 Part 1 to Nash and Thompson, London
[4] NAA C3830 A1/3/11/3 Part 1

> Among the first options to be explored was a collaborative effort with our friends in the RAAF, with whom we had maintained a post-war connection. As early as 1949, we discussed with them the possibility of building a really large air-warning antenna, with linear dimensions of several hundred feet. Several designs were roughed out and costed, and at one stage there even seemed to be a possibility of going to a horizontal dimension of 500 feet. Our interest in the project was based on the real hope that, if built for defence purposes, we would have the use of the instrument for radio astronomy.

In this chapter we provide details, of the evolution of the GRT in the 1950s; the Parkes telescope became an icon of Australia after the opening on 31 October 1961. The 60th anniversary will be celebrated in 2021 at Parkes with a virtual celebration,

Lunar and Solar Radar – proposal for large stationary aerial

Other efforts occurred in 1948 and 1949, contemporaneous with the 20 MHz observations of lunar echoes starting in early November 1947 and continuing to late November 1948. (Sullivan, chapter 12, "Reaching for the Moon", has provided a summary of the work done by Kerr, Shain and Higgins during this period[5].) In the course of 1948, Frank Kerr produced a RPL memo "Analysis of Proposals for Attempting Radio Echoes from the Sun"[6]. The novel proposal was to build a fixed paraboloid of 200 feet diameter that would be able to observe the sun for periods outside the southern winter (June, July and August) at a fixed frequency of 20 MHz. The dish was to be tilted by 20 deg to the south and 10 degrees to the east and to be co-located at the site of the Shepparton, Victoria, Radio Australia transmitter (located about 600 km southwest of Sydney); this transmitter had been used for the successful lunar radar 20 MHz observations of 1947-48, a bistatic radar with the receiver located at Hornsby, a northern suburb of Sydney. The solar echoes were expected to be a factor of 125 times the 15,000 K brightness of the galactic background at the wavelength of 15 metres; this estimate turned out to be vastly over optimistic. The beamwidth was to be 6.6 degrees, leading to about an hour per day of possible observations of the sun. The cost of the crude structure was only estimated to be £A 2000! (about $A 100,000 to 200,000 in 2019). The system might have been capable of observing the

---

[5] See Kerr, Shain and Higgins, "Moon Echoes and Penetration of the Ionosphere", *Nature*, vol. 163, page 310, 1949 and Kerr and Shain, "Moon Echoes and Transmission through the Ionosphere", *Proc IRE*, vol 39, page 230, 1951.

[6] NAA, KE 12/11, 1948-1951 "Radiophysics Collaboration with Other Bodies Astronomy Work-Discussions with Commonwealth Department". The document is not dated and there is no RPL designation for the Kerr document. Based on the text, the date is likely mid to late 1948. Kerr published a ground-breaking paper in 1951, "On the Possibility of Obtaining Radar Echoes from the Sun and Planets", *Proc IRE*,vol 60, page 660, 1952.

sun and the moon as well as near earth asteroids. Mercury, Venus and Mars would have been un-detectable.

The proposal was described in a letter from Bowen to Cook, the Secretary of the CSIR in Melbourne, on 29 December 1948:

> Coming now… to the one direction in which we might ask for exceptional expenditure for equipment during the financial year 1949/50. I should say right away that this is unlikely to appear in our next estimates and I think the request should be handled at a later date as a supplementary estimate. We have had in mind for some time building an unusually large aerial system, mainly in an attempt to obtain radio echoes from the sun and also to supplement our solar and cosmic noise programme by making further observations of radio frequency waves on the earth from [RPL installations]… I can say that the project would involve the construction of a large aerial structure which would best be handled by an engineering firm to manufacture and erect it to our design. In this way our scientific personnel would not be involved in a large constructional programme. Our ideas on the exact form of the structure are far from complete and it will be some months before we arrive at the answer.

By mid-1949, there was a new report from Kerr about the proposed solar radar aerial- RPL 36. (This report has not been located in our archive searches.) Based on letters from Bowen to White (4 and 7 July 1949), the new proposal achieved the collecting area of the previous 200 foot dish but distributed it among 25 aerials each of 50 metre diameter (165 feet); the total collecting area was thus to be 16 times that of the originally proposed 200 fixed aerial with an enhanced transmitter of 250 kW, compared to 50 kW for the original lunar radar experiment of 1947-8. The cost for this system was estimated to be £A 87,000 (or $4 to $8 million in 2019 dollars)[7]. A major concern was the unknown manpower commitment:

> [Our estimates] do not take into account the fact that a fair number of our more senior research staff would have to be diverted to the project if it is to be a success …The other difficulty I see is the rather small margin which exists between success and failure … [A] conservative estimate of the echo intensity is [only] 10 db [factor of ten] above background noise [the sun and the hot galactic background at 20 MHz].” (This value represented a signal to noise 10 db less than had been predicted in the 1948 proposal, even with a larger collecting area.)

[7] There were also two scaled down schemes with smaller transmitters or smaller number of dishes, essentially a proposal for a prototype radar system.

In two letters from White (Chief Executive Officer of the new CSIRO) from 7 July and 18 July 1949 to Bowen, the mood was pessimistic:

> I certainly think that as things stand at the moment you would not be wise to incur such a large expenditure as this without putting it up to the Executive as a special project. That being the case you would have to be satisfied that you could make a very strong project … The whole thing wants looking at very closely. It obviously has very interesting possibilities, but at the moment I find the expenditure involved rather frightening and I am not quite able to assess the amount of effort on the part of the staff that would have to go into it.

In the end, the solar radar project was never funded by CSIRO. The scientific uncertainty was too great for the large expenditure in capital investment and manpower. Only in 1959 was it possible to detect radar echoes from the sun at 25.6 MHz (Eshleman et al, 1960), followed by detections at 38.2 MHz by James (1964). From the latter experiment, the received solar echo was typically a factor of 100 to 1000 below the background noise.

Interaction with the Commonwealth Observatory – impact on the large aerial projects- 1951

The complex story of the interactions with the Mt Stromlo Observatory in 1951 and the impact this had on the quest for a large reflector at CSIRO is summarised in the main book Chapter 19. Pawsey's role in those discussions of 1951-1952 and the foreshadowing of the growing conflicts between Pawsey and Bowen in the 1950s are treated in some detail. (Chapter 19 section "Resourcing Astronomy in Australia 1951-1952" with participants Oliphant, Woolley, White, Bowen, Pawsey and Madsen.} Likely, this disagreement contributed to the growing antipathy between the two leaders of RP, Bowen and Pawsey, during the 1950s.

The Commonwealth Observatory suggested that they would begin their own programme of radio astronomy. The players in this discussion were Woolley of the Observatory, Oliphant of ANU, and White, Pawsey and Bowen of the CSIRO. The discussions in September-October 1951 between Pawsey and Bowen was acrimonious. Pawsey's vision of the future of collaboration in astronomy lead to strong disagreements with Bowen and White. In May 1952, Mt Stromlo dropped the suggestion of starting a radio astronomy group as Woolley decided to concentrate on the planned 74-inch telescope at Stromlo (inaugurated in November 1955). A major factor was that new staff for radio astronomy was impossible at this era. Close collaboration between Mt Stromlo and RPL had to await the arrival of Bart Bok from Harvard in 1957.

February 1951- Sub Committee on Galactic Work at RP and Plans for the Future

In the course of 1951, there were a number of developments that continued the momentum to plan a large single dish. In early 1951 (18 February 1951), a meeting of the "Sub-committee on galactic work" occurred [8]. Pawsey was chair with attendees Bolton, Mills, Minnett, Piddington and Shain. A few days later, Pawsey wrote a summary of the meeting to Bowen. In the introduction he wrote: "Historically, as you know, we have had the question of a large aerial under consideration for years. Last July (1950), for example, I deferred consideration of Piddington's proposal [for a high frequency antenna] in order to try to reconcile it with the large-aerial low-frequency idea. I now think that they are best taken together."

The minutes of the 12 February 1951 meeting (written by Mills) contained summaries of the work of Shain (18 MHz observations of the galactic background, radio sources and some solar work), Mills (100 MHz source survey), Piddington and Minnett (source surveys at 1200 and 3000 MHz) and Bolton (spectra of radio sources between 30 and 320 MHz). The planning for new research projects contained a fascinating proposal by Bolton: "[He suggested] two large aerials (size about 70 feet[9]) **capable of doing every job better than it has been done in the past** [our emphasis] should be constructed. The aerials would have provision for use as a sea interferometer… and a Michelson interferometer and would be mounted on mobile equatorial axes. They would be designed to have a useful frequency range up to 600 MHz."

Mills countered with criticism: "[these aerials] would not do some jobs better, e.g. accurate position finding and size measurement of the larger sources … and the aerials should otherwise be as small as possible. Frequencies would [need to] be less than 200 MHz with 70-foot aerials and no great accuracy or rigidity would be required in the mounts and no drives would be required." Piddington and Minnett had carried out their first 20 cm observations of a small number of sources using a small 17-foot aerial; for future work a larger aerial of size 50-60 feet would be required and a simple mount with a single E-W axis (i.e. a transit telescope).

A few days later (19 February 1951[10]), Pawsey wrote his summary of the meeting of the radio astronomy sub-committee. He summarised the existing work, listing basic astronomical problems such as (1) "What are the sources of cosmic noise, including radio stars? (2) [Determination] of the space distribution of sources and inference from this concerning such questions as the shape of the galaxy (e.g. the suggestion of a spiral arm)." The major overseas competition was then described: (1) Jodrell Bank, "endeavouring to obtain money for [200 foot plus] movable aerial to point in any direction"; (2) Cambridge, "Has just completed survey of

[8] NAA C3830 A1/1/7.

[9] At a meeting of senior officers of the radio astronomy group six months later on 21 August 1951 (NAA C3830 A1/1/7) Bolton discussed an "80 ft paraboloid ... for metre wavelengths", surprisingly with no mention of interferometry.

[10] Sullivan archive.

discrete sources in northern sky (between Bolton and Mills in resolution). Will probably continue using interferometer [presumably the new 2C aerial]." The most interesting portion of Pawsey's memo was the "Future Programme" for Piddington and Bolton. Piddington suggested a 50-60 foot dish to work at 500 to 2000 MHz with a simple mount which only could move in elevation (transit telescope). According to Pawsey, Bolton had more ambitious plans:

> Better determination of cosmic noise distribution and spectra, and survey of large number of point sources in medium frequency range (100-300 MHz). This requires a large aerial system. There are two lines of approach: (1) Make the aerial so big it can sort out the complex distribution by virtue of its resolution. (2) Use smaller aerials and low cunning [clever but shady methods ?] to increase discrimination by interferometry … The next step is [to increase the number of sources from 50 to 500 sources]. Present thought suggest interferometer using two 80-foot aerials … can be equivalent to a single aerial of about 200 feet … The objective is clearly along the main line of development in radio astronomy ... Make a careful investigation of the best way of realizing equipment to extend cosmic noise radio star survey] and then proceed with construction ... Present ideas are in terms of two 80 foot [fully steerable] parabolas, operating at 100 MHz. I regard this as the major line of development.

Clearly, Pawsey gave Bolton a vote of confidence.

Impact of HI discovery in 1951 and the Role of Pawsey in Building a Larger Telescope

Five months after the discovery of the HI line at 1420 MHz by Ewen and Purcell at Harvard on 25 March 1951, three groups published their results in back-to-back publications in *Nature* on 1 September 1951: Ewen and Purcell "Observation of a Line in the Galactic Radio Spectrum", followed by confirmation publications by Muller and Oort from the Netherlands Foundation for Radio Astronomy at Kootwijk and by Christiansen and Hindman (RPL) with the 16 by 18 foot parabolic reflector at Potts Hill, Sydney[11]. As the impact of the discovery of an observational technique that could be used to determine the 3-D structure of the Milky Way became apparent, Pawsey's role in the planning of the large aerial increased. It was clear to Pawsey that a larger aerial was required to image the plane of the Galaxy using the 21 cm line. In order to achieve an angular resolution of 30 arc min (the diameter of the moon), an antenna with a size

[11] Additional details of Pawsey's role in the detection of the HI line are given in Chapter 20. In particular we discuss the claims made by Bolton and Bowen in later years about the "reluctant" role played by Pawsey in observations of the HI line; in fact Pawsey had tried to stimulate this research before the discovery of the line at Harvard in March 1951.

of about 25 m was required; this instrument would achieve a linear resolution of 30 parsecs at the distance of a nearby spiral arm in the Galaxy at a distance of 3 kpc (kiloparsecs)

The discovery of the 21 cm HI line from the Milky Way by Ewen and Purcell also had a decisive impact on the planning of the new 250 foot antenna at Manchester. The plans were modified in an attempt to make this large aerial useful at 1420 MHz; all future plans for the Australian dish included the possibility for an instrument that had a surface accuracy which would at least provide partial operation at 21 cm. The complex story of three groups trying to detect the HI line at RP (Christiansen, Piddington and Bolton) has been summarised by Wendt, Orchiston and Slee ((2008). WN Christiansen and the initial Australian investigation of the 21cm hydrogen line. *Journal of Astronomical History and Heritage*, *11*, 185-193). The search for the line in Sydney began in earnest after Frank Kerr, then at Harvard on a long term visit, cabled and then wrote Pawsey a few days after the discovery. On 12 April 1951 a meeting was held in Sydney with Pawsey, Higgs, Piddington, Christiansen, Wild and Bolton. From the minutes:

> It was agreed that parallel investigations to check detectability of lines were desirable to obtain independent checks but that, in order to avoid cut-throat competition, the group experimenting in the same field [Christiansen, Piddington and Bolton] should consider themselves, at least on the 1420 MHz line, as a single group and possible publication should be joint. Christiansen and Bolton outlined schemes for attempting to detect the 1420 MHz line with which they were proceeding. They hope to have equipment for tests to start in a week or so. Piddington outlined a different scheme with which he was proceeding.[12]

By 8 May 1951[13], there were only two groups, Christiansen and Piddington. By June 1951, Piddington had also dropped out. There is no record in the RP Propagation Committee minutes as to why Piddington and Bolton had not continued their own efforts.

The RP observations of Christiansen and Hindman (who now joined with Christiansen) started in June and ended in September 1951. Apparently the first detection was in early July 1951. The minutes of the Radio Astronomy meeting held on 4 September 1951 stated that Pawsey had reported:

> Van der Hulst considered the likelihood of observing the line … in December 1945 in a paper written in Dutch, and Reber told me about it in Washington in 1947 [sic was 1948] … Kerr wrote that Ewen had succeeded in detecting the line in March 1951 and Purcell,

[12] NAA, C3830 A1/1/7.
[13] NAA, C3830, B2/2, Part 2.

> in charge of the Harvard work, wrote inviting us to verify the observation. Christiansen and Hindman did this [with a small 16 by 18 foot aerial] on 6th July 1951.

Muller and Oort also had a confirmatory observation of the HI line earlier with a 7.5 m aerial in the Netherlands on 11 May 1951.

Clearly during this period in June –July 1951 (while attempts to detect the HI line were going on at Potts Hill), Pawsey realised that a more sensitive antenna was required for HI surveys of the galaxy at RPL; the first detection of a spectral line at radio wavelengths opened up many new pathways for research in the Milky Way as the opportunity to derive distances in the galaxy was now available.

Pawsey wrote Marcel Minnaert in Utrecht (Netherlands), a member of the board of the Netherlands Foundation for Radio Astronomy- Stichting Radiostrahling van Zon and Melkweg, 13 June 1951[14]:

> We are interested in the possibility of constructing a large parabolic reflector for use in cosmic noise research. We are thinking of a parabola of about 80 feet (25 metres diameter) for use at wavelengths of 1 or 2 metres. There is considerable difficulty in having such a structure designed and constructed in a country such as Australia in which all the engineering facilities are at present badly overstrained. I understand that a similar aerial is being or has been constructed in Holland [the Dwingeloo antenna designed by Ben G. Hooghoudt, opened in 1956] for this purpose and I wondered whether we could get some ... information about the design of the aerial.

Minnaert wrote back to Pawsey with an enthusiastic response on 25 June 1951. He described the construction of the Dwingeloo antenna by Werkspoor, a company in Amsterdam that specialised in the construction of railroad equipment. The advanced design had a diameter of 25 metres and was planned to operate at the newly discovered line of HI at 21 cm. The alt-azimuth telescope had a “pilot” (master equatorial) used for the transformation of the celestial to alt-azimuth coordinates. The Dutch astronomers were interested in initiating a collaborative effort with the Australians in order to share development costs.

---

[14] NAA C3830 A1/3/1(H). At almost the same time, Pawsey wrote Lovell at the University of Manchester to inquire about the progress being made with the construction of a large steerable antenna (said to be 200 feet at this time, later 250 feet). Lovell wrote back on 21 June 1951 suggesting that any possible collaboration be postponed until the funding agency had decided the fate of the large dish project. On 29 June 1951, Pawsey wrote his staff member, Frank Kerr, (working at Harvard University), inquiring about possible large parabolic reflectors planned in the US. Kerr wrote back on 20 August 1951 with a rather negative assessment of the reality of large antenna construction in the US and Canada.

A few weeks later on 20 July 1951, Jan Oort (the Chair of the Netherland Foundation for Radio Astronomy) wrote Pawsey: "I was greatly interested to learn that there is a possibility that you may place an order for a 25-metre paraboloid with the firm of Werkspoor ... I hope that a regular co-operation on certain programmes between your [Radiophysics Laboratory] and our still small group can be established."

In the course of late June through July and early August 1951, the plans at RPL had become even more ambitious. Two aerials were being considered. "Plan A" was for an 80 foot diameter dish that was to be used at wavelengths from 1 to 3 metres, fully steerable in azimuth and elevation. This antenna was to be located at Dover Heights and would be used for galactic background research and sea-cliff interferometry as the radio sources rose on the eastern horizon, as observed from the 80 m cliff site. Lindsay McCready stated that this antenna was to be used exclusively by John Bolton as a sea-interferometer. The other, "Plan B", was a more precise instrument for HI observations at 21 cm that could only observe at transit (i.e. only move in elevation). This instrument was to be located at Potts Hill. In Figure 1 [end of text reference footnote 14], we show a possible design by Carter (March 1951) of a transit (only movable in fixed steps in declination) 60 foot antenna that would have been ideal for 21cm HI research. The cost of material was A£ 3500 for an aerial of 40 to 50 tons, with 10 to 15 tons for the reflector along. In the next months, these plans were described by Pawsey in a series of letters to Werkspoor; the communication was confused due to letters lost in the post. The communications came to end in March 1952 when Pawsey informed Werkspoor[15] that a scaled down Plan B aerial was under construction by the Australians, the transit 36 foot aerial at Potts Hill. Construction began in June 1952, with a completion in early 1953.[16]

1952 – Vision of the GRT, Bowen visits Caltech, Caltech Prospectus of May 1952

---

[15] Interestingly the RPL group had additional contacts with Werkspoor four years later as the Dwingeloo 25 metre radio telescope was being completed in the Netherlands. Pawsey reported to Bowen on 23 September 1954 that he had visited the Werkspoor factory in Amsterdam and discussed the prospects of buying a slightly larger antenna, to be constructed after the Dwingeloo project was completed. The visit was organized by Ben G. Hooghoudt, consulting engineer working for J. H. Oort of the Sterrewacht in Leiden. The RPL group lost interest when they realized that the Dutch design could only be extended to a diameter of about 36 metres. The Dwingeloo antenna was opened in 1956. In the September 1954 letter Pawsey also indicated that the French astronomers under the leadership of J. Steinberg were thinking of buying two of the Werkspoor antennas and putting them on orthogonal rail lines as an "interferometer giving any spacing and direction". Unfortunately this project was never completed.

[16] See above for a reference to the Plan A and Plan B by White (23 February 1951) in the discussion with the Commonwealth Observatory about setting up an independent radio astronomy programme in Canberra.

A key stage in the development of the Australian plans was the interest of the California Institute of Technology, Pasadena, to begin a programme in radio astronomy under the leadership of E.G. Bowen. In November 1951, Bowen spent most of the month in Pasadena, visiting the astronomers following an invitation from Lee A. DuBridge (President of Caltech) and Robert F. Bacher, Head of the Division of Physics, Mathematics and Astronomy. Bowen had known both scientists[17] at the MIT Radiation Laboratory during WWII. On 6 December 1951, Bob Bacher wrote Bowen, regretting that he had missed Bowen on 1 December as he was leaving Caltech to return to Sydney. Clearly a number of informal discussions had occurred with both Bacher and DuBridge about the founding of a Caltech radio astronomy observatory:

> It would be very good if you could work up a broad specification of the kind of aerial which is likely to pay off in radio astronomy, as you suggest. This should be helpful to us in trying to formulate some plans. I hope very much that we can work up some sort of proposal here that you might find attractive. I shall peruse the question during the next year and will let you know how things go. Once again, it was good to have you with us.[18]

At the end of February (21-2-1952), Dubridge wrote with concrete questions and an offer of a position for Bowen to become the inaugural director of the radio astronomy laboratory:

> The idea of creating in conjunction with Mount Wilson and Palomar astronomical observatories and in connection with Caltech, a new laboratory or observatory of radio astronomy, is attracting the enthusiastic interest of many people. All of the members of the Caltech physics and astronomy departments are enthusiastic about the idea as is Dr. [Ira] Bowen[19] and chief astronomers of the observatories. Alfred Loomis[20] and Vannevar Bush, Director of the Carnegie Institution of Washington, were recently in Pasadena and the [Caltech department heads and Ira Bowen] had a long discussion of the possibilities of a radio astronomy laboratory. Both Alfred [Loomis] and Van [Bush] were most enthusiastic and particularly enthusiastic about the idea of your being the director of such a laboratory … I think it is now clear that all of us concerned want to take the opportunity as early as possible of creating in conjunction with the Pasadena observatory center a really forward-looking program of radio astronomy. I am now

[17] DuBridge had been Director of the Radiation Laboratory in Boston, while Bacher had been a division head until 1942 when he moved to the Manhattan Project at Los Alamos, New Mexico.

[18] NAA, C3830, Z1/14/A/I

[19]Ira S. Bowen, director of the Mt Wilson and Palomar Observatories of the Carnegie Institution of Washington.

[20] Loomis, Attorney, investment banker, philanthropist, scientist/physicist, inventor of the LORAN- Long Range Navigation System, and a lifelong patron of scientific research. See *Tuxedo Park, A Wall Street Tycoon and the Secret Palace of Science that Changed the Course of World War II*, by Jennet Conant, Simon and Schuster, 2003.

> writing you to ask if you will help us in preparing a ... proposal for the establishment of a radio astronomy laboratory or observatory. I should be glad to have from you first a brief statement of your thoughts or suggestions for the organization and equipment of such a laboratory. I should then like to ask you if it would be possible for you to prepare a more detailed … prospectus for this enterprise … A prospectus should include a statement of the basic problems which would be investigated in radio astronomy; a statement of the instrumentation which might be needed. The instrumentation might be divided into two parts; first, the group of minimum instruments to be required for the initiation of the laboratory and later the possibly somewhat more ambitious plan for a major large instrument, such as the **200-foot antenna** [our emphasis] which you talked about while you were here [in November 1951]. It would also be desirable to give an estimate of the personnel requirements for such a laboratory, including a minimum starting group and proposal for how the group should go over the first five years … [We] would use your statement, … present the proposal to the Trustees of Caltech and the Carnegie Institution and also to various individuals and foundations … [A]s soon as we see the way clear to initiate the undertaking and have at least some assurance of funds, we would want to present you with an offer to come and be director of the proposed laboratory.[21] In preparing this prospectus I hope you will let your imagination run wild. We might, of course, have to start the laboratory on a modest scale, but we should like to have in mind the possibility that major pieces of equipment, costing possibly several million dollars, might eventually be a part of it. A really bold proposal might have a better chance of finding support than one that is too modest. At the same time it would be desirable to have some idea of what you think would be the minimum program as well as the maximum desirable one.[22]

A few days later (26 February 1952), Bowen replied to Bacher's 6 December 1951 letter with a two-page proposal for a large low frequency aerial and a smaller instrument [rather similar to the Plan A and Plan B proposals of Pawsey but with larger aerials] that would work at the newly discovered HI line at 21 cm.

---

[21] On 7 November 1952, Bowen wrote White a "personal" letter. The goal was to enhance his position within the CSIRO hierarchy. "Following your telephone call the other day, I am writing to tell you what I know about the moves which have taken place tempting me to go back to the US … When I was at Caltech last November [1951] Lee DuBridge made a very attractive verbal offer of a Chair of Physics at Caltech for the purpose of starting up Radio Astronomy in conjunction with Palomar. He indicated this might take a specific form at about the present time." Also he told White that a group in the US was thinking of offering him a position to "properly consolidate the rather chaotic rain and cloud physics work being done in America." NAA, C3830, Z1/7/B Part 1.

[22] *ibid*

> A really significant step would be made therefore if a new aerial could be built with a diameter of 200 feet or greater. Most of the really interesting solar and galactic phenomena occur in the [metre range] and a year ago I would have said the above specification [1 to 10 metres] would be the only one required. [The] discovery of the … emission lines of hydrogen at 1420 MHz alters the picture … and makes it desirable ... to consider an aerial capable of operating down to 20 cm. The main difference ... is that the accuracy of the reflecting surface would have to be greater and the cost would therefore be greater for a given size. [Since the largest aerial used so far had been 30 feet while the Dutch were proposing an 80 foot dish], a significant advance would be made if an aerial of 100 or 150 feet in diameter were built.

Bowen pointed out that for the first time in radio astronomy a general purpose instrument would be constructed with operation around the clock. Thus, multiple receivers would be required for different projects:

> [O]nce it is in operation it could be turning out results 24 hours a day ... [T]o justify the expenditure it would need two, three or four teams working on a shift basis. **Also unlike some of the big machines for physical research, it is most unlikely to be made obsolete by a new idea or a new discovery.** [our emphasis].

The low frequency antenna was to have an alt-azimuth mount with motions of 15 to 20 deg per minute (for example the Very Large Array antennas at NRAO slew 20 deg per min in elevation and 40 deg per min in azimuth), driven by a "polar axis computer which provides automatic tracking ... with a pointing accuracy of 5 to 10 arc min." The surface precision was to plus or minus 2 inches (5 cm). The high frequency instrument ("Large aerial for general radio astronomy research") would work in the wavelength range 20 cm to 10 metres with a diameter greater than 100 feet. The surface precision was to be plus or minus 0.5 inches (1.2 cm). The dish was to be steerable over the entire sky with a pointing precision of 2 to 3 arc min.

On 4 March 1952, Taffy Bowen wrote DuBridge a short letter telling him that: "I will first send a draft of a forward-looking programme in radio astronomy. After having your comments I could then elaborate it into a more complete prospectus." Immediately DuBridge (10 March) replied to Bowen enthusiastically. He told Taffy Bowen of an idea that Ira Bowen had for a simpler large aerial (that was similar to the Bowen proposal of 22 October 1952) which would be a cheaper design. Ira Bowen

> wondered whether a long, narrow cut-away dish would be better... [H]e suggested a cut-away paraboloid maybe 400 feet long and 50 feet wide. This could be mounted in a horizontal direction with the ends supported on wheels on a circular rail for rotation

> about a vertical axis and then could have a simple method for rotation through 180 degrees about a horizontal axis parallel to the long dimension of the dish. Such an antenna ... would be far easier to construct and to manipulate; would involve fewer mechanical problems and ... offer much less wind resistance ... [A]cut-away dish will give you the resolution only in one direction but by looking at the same part of the sky at different times of day, the resolution in both dimensions could be obtained.

Ira Bowen suggested that a factor of two increase in resolution in one dimension could be obtained with the 400 foot aerial compared to the Taffy Bowen proposal (200 feet diameter).

In the interval from early March until Bowen sent the complete "draft programme" on 22 May 1952, Taffy Bowen exchanged letters with Bacher twice; on 18 March Bowen wrote DuBridge. Bowen proposed to Bacher that the solution of the "two antenna problem" (the larger low frequency one plus the smaller higher frequency aerial) was to build a "large dish (say 200-250 feet…), the central 100 feet of which would be good to plus or minus 0.5 inches, the tolerance being relaxed to plus or minus 2 inches towards the edges. The one unit could be used for both purposes. The whole dish would be used for metre wave research and the central portion for the 21 cm HI line … [It would] be quite convenient to build the central portion to close limits, leaving the outer section to wave in the breeze." A week later (18 March 1952), Bowen explained to DuBridge that the Ira Bowen proposal for a one-dimensional antenna had just been completed in Sydney ("we have just finished making a beauty here in Sydney"), the Potts Hill grating interferometer of Christiansen with a size of 800 feet by 6 feet. (With the limited collecting area of this instrument, only the sun could be observed[23].) Taffy Bowen wrote:

> A particularly effective way of using such an aerial would be to have it on the edge of a [sea] cliff some hundreds of feet high, pointed at the horizon and steerable in azimuth. It would then have exceedingly high resolution in two dimensions, in the horizontal plane by virtue of its narrow beam, and in the vertical plane because of the interference effect [due to the sea-cliff interferometer]. Incidentally, such an aerial would not be without interest from a Defence point of view, which is something that is not necessarily so for a large paraboloid.

On 1 April 1952, Bacher wrote to Taffy Bowen, pressuring him to finish the full prospectus. Caltech could not move forward with fund raising until this was available. Bacher was concerned about practical problems such as the site selection: "convenience of operation, trouble with [radio frequency] background, and cost of the installation will undoubtedly depend upon its location. If you could give some additional guidance on this point it would be helpful in

[23]Bowen's claim to DuBridge that it could be used for galactic work was not correct due to the small collecting area.

formulating even very rough plans." Based on discussions with the Pasadena astronomers: "… it does seem clear that a fairly sizeable installation would eventually be necessary to do really first-rate work. It seems to me that we should not start in this field unless we are prepared to back it on such a basis if preparatory investigations are favorable."

On 15 April 1952, Bowen wrote DuBridge apologizing for the delay in preparing the prospectus. (The complete version would arrive a month later.) He did provide a forecast of the manpower for the operations and the total running costs, based on the Australian experience. (He was quite aware of the problems of predicting US costs based on this model.) In order to run the telescope 24 hours a day, Bowen suggested a staff of one director, three scientific staff, three technicians and six assistants (In the modern era we would consider this staffing level far too meagre.) The cost of the aerial was estimated by Bowen to be about US$1 million (1952 dollars) with running costs of $80,000 per year and an allocation of $20,000 per year for new equipment. (The Australian inflation factor is roughly 25 to 50 from circa 1950 to 2014.) Bowen was optimistic that the telescope could be sited in an urban area, if industrial generated RFI was not too high. " ... [I]n only one experiment [the new solar instrument at Dapto near Wollongong] have we found it necessary to go outside the Sydney Metropolitan area … I don't think any serious difficulties would be found in the Los Angeles area." [24]

On 22 May 1952, Bowen sent DuBridge the "Draft Proposal for a Radio Observatory".[25] Bowen was quite apologetic about the delays. "I realize it has many deficiencies and I would be very glad of your criticisms and suggestions. Clearly it needs a much more detailed account of the design and construction of the large telescope, and I am giving this some thought at the present time … The only part which I do not feel confident of developing is that on costs, because I do not know to what extent things have changed since the war years."

The introduction of the 11-page Taffy Bowen report, "A Large Radio Telescope for Radio Astronomy", began:

> The time has been reached in radio astronomy at which the next great advances are likely to come from two specific steps: the close association of radio measurements with good visual observations, and the use of an exceptionally large radio telescope of high

[24] The Owens Valley Radio Observatory (site of the Caltech installation), chosen a few years later by Bolton and Stanley, is at a distance of about 440 km north of Pasadena.

[25] NAA C3830 A1/3/11/1 Part 1 – Technical and Procurement GRT. There is another version, written at about the same time for the CSIRO Executive, especially Fred White (see below), "A Large Radio Telescope for Radio Astronomy". The two documents are quite similar except the "Draft Proposal" (for DuBridge) contains three additional subsections: "Equipment Needs", "Staff" and "Estimated Costs". This second version from NAA C3830 A1/11/3, Part 1. Finance and Policy, GRT.

> sensitivity and resolving power ... Today there is no doubt that radio can make tremendous contributions to the study of astronomy ... The time appears ripe, therefore, to bring radio and visual observations into closer contact. The biggest single advance in the technique of radio astronomy is likely to come from the use of a very large radio telescope ... that is 200 to 250 ft in diameter.

Following the summary of “solar noise” and “cosmic noise”, a short description of the newly discovered hydrogen line, as well as radar research, followed. The proposed observations of the HI line implied that the central part of the new antenna would have a higher surface accuracy; in this case the higher frequency HI line at 1.4 GHz (21cm) could be observed with optimal sensitivity. Bowen had already described his estimate of the staff required, running costs and the expected capital expenditure in the letter of 15 April.[26]

After the May 1952 document from Bowen had been sent to DuBridge at Caltech, a number of letters were exchanged.

On 11 June 1952, DuBridge responded[27] thanking Bowen for the prospectus, which was under review. He had read about the 250 foot radio telescope plans (mistakenly thinking they originated from Birmingham), asking Bowen if these UK plans would lead to a modification of the Caltech plans. Two days later, Bacher wrote to Taffy Bowen; he would discuss the prospectus with Ira Bowen. Bacher thought the idea to build the radio observatory close to the existing large optical telescopes was “sound”.

On 20 June 1952, Bowen wrote to DuBridge with details of his own assessment of the Manchester proposal:

> The announcement of the grant to Manchester University for a giant telescope came as a surprise in one or two respects. I knew about the proposal, and the interest in the project has in fact, gone along in parallel with our own for a year or two. I was given the impression in England last summer, however, that the Government were [sic] unlikely to support it, so that the news about the grant came as something of a surprise … One final point. At Manchester they will not have the benefit of a close association with good visual observations or, for that matter, with other astronomers. And, [due to the bad

---

[26] *Ibid*. Bowen also used this document in discussions with colleagues in Australia. A month later (6 June 1952), he wrote Fred White: “I might add that I have fairly clear ideas about what such an aerial should look like and the programme of work which might be carried out with it. I drew up something along these lines, more or less for my own amusement ...You may be interested to see the rough copy.” (Bowen was somewhat disingenuous; he did not mention the provenance of the document, an earlier proposal for a Caltech Observatory.)

[27] NAA, C3830, Z1/14/A/I.

> weather in the UK], they are unlikely to get it. An important point in a proposal from Caltech would be the close association between the radio and visual observations.

Bowen pointed out (20 June 1952) his own ideas "on the use of a **giant radio telescope**" [our emphasis, perhaps this is the invention of the new term, GRT] differed substantially from the Manchester proposal. This UK group "has put greatest emphasis on radar-type observations of the sun and planets and a determination of the astronomical constant … [But] the sensitivity of radar-type equipment on the sun and the planets will be marginal. Unless they have something exceedingly cunning up their sleeve, I doubt whether it will be possible [to determine the astronomical constant]."[28] Bowen was convinced that the major scientific return would be from "extra-terrestrial noise" at frequencies above 300 MHz. In particular, "some portion of the aerial should be usable at 1420MHz" for the HI line.

On 11 July 1952, an important new theme appeared in Bowen's letter to DuBridge. Australia might be able to afford a GRT on its own. He implied that it was less likely that he would be interested in leaving Australia to start a new radio astronomy programme in California. Bowen wrote:

> I think you know that in Australia we have always been keen on making a giant radio telescope. We did, in fact, prepare a case for one three or four years ago [the 1948 proposal], but unfortunately, the finance was not forthcoming and the scheme lapsed. The project was such a huge one that there was grave difficulty justifying it in a country of limited industrial development such as Australia.
>
> With the announcement of the Manchester project, however, local interest, or local pride, has been stimulated to such an extent that some financial support might after all be obtained. Whether it is obtained is still a matter of conjecture, and would depend very much on the kind of case put up from this Laboratory. The stake we already have in radio astronomy is such that I would be failing in my duty if I did not back this possibility to the utmost. Would you mind … if I kept a foot in both camps and pushed both the Australian project and the one you have in mind? This need not interfere with any plans which might eventuate in the future. For example, if I left here after a year or two, there would still be quite a number of people to carry the project through.[29]

[28] Bowen suggested that radar astronomy would only become a major field in a few years when a 1000 foot antenna with a transmitted power of 1 megawatt would be possible. This instrument was similar to the Arecibo Telescope of Cornell University which was to open in 1963.

[29] At this point in the letter, Bowen suggested a collaborative, complementary effort with the possible construction of two large radio telescopes, one in California and the other in Australia to cover both hemispheres.

> Although I may have written about this with some enthusiasm, I think a cold assessment ... indicates that the chances of getting one in Australia are still small. It would be unfair of me, however, not to back even a remote chance.

Taffy Bowen then discussed the Australian financial outlook. He thought it likely that the government would only finance the project if it were to find a portion of the funds from other sources. He would approach the Nuffield Foundation in the UK who planned to make a substantial grant to the Manchester project. "When I was last in Washington (in 1951), Van Bush mentioned that there were some Carnegie funds intended for use in [British] Commonwealth countries which had been accumulating for a number of years … I wonder if you would regard this as interfering in any way with what you have in mind. I will wait to get your reply before actually getting in touch with [Bush]."[30]

DuBridge wrote back on 6 August 1952 "... [I was] quite interested to learn that there is a possibility of a giant radio telescope in Australia ... I should think you would certainly want to pursue this possibility to the limit and I do not see the possibility of a conflict between a project which you might set up there and any that might develop in this country [USA]. In fact, if Australia can develop such a project it would seem to be a stimulation to American sources to provide funds to do so at least as well. With all the information you have now provided us, Bob [Bacher] and I are actively exploring the possibilities of getting something going and we will keep you informed."[31]

Bowen followed with a letter on 30 August with a short description of the new HI 21 cm line results coming out of the RPL research at Potts Hill. He used the example of the spiral arm structure in Cygnus being derived by Christiansen and Hindman to emphasise the point that a large radio astronomy aerial must have an accurate central portion in order to observe at 21 cm. "All this means that some portion at least of a giant telescope must work at 1420 Mc/s." Bowen followed with a description of the possibility of building a conventional antenna (1) out of structural steel (a conventional elevation-azimuth mount) which would be similar to the Manchester design or (2) light alloys. For the latter design, Bowen suggested a novel concept consisting of a "swash" plate in which the dish was both supported and driven on hydraulic rams. Bowen then described the coordinate transformation from equatorial to alt-azimuth being carried out by a "small model on a polar axis mount"- a master equatorial. Bowen concluded the letter to DuBridge: "Since size is important and there is no point in making a

---

[30] The source of possible funding was the British Dominions and Colonies Fund of the Carnegie Corporation of New York (Bowen assumed this existed from the years before 1940 and had funds largely unspent). Bowen had heard about this possible source from Vannevar Bush during an earlier visit to the US in 1951.

[31] NAA C3830 A1/3/11/3 Part 1.

telescope smaller than that at Manchester, there may be some point in adopting a new unit of size, namely 100 yards (or perhaps 100 metres)."[32]

URSI 1952 Sydney – Impact on the planning of the GRT

The year 1952 was a crucial year in the planning of the GRT; numerous activities occurred that shaped the course of events leading to the completion of the Parkes telescope. The URSI General Assembly of August 1952 was an opportunity to showcase the achievements of RPL in the post war era. With the arrival of famous overseas guests, Australian scientists saw an opportunity to launch a new project. On 4 June 1952, Fred White wrote Bowen[33] with a description of a conversation with David Martyn. Appleton, the Nobel Laureate and President of URSI (planning to visit Australia for some time during August for the URSI conference and to give lectures throughout Australia), had written Martyn to suggest "he [Appleton] may be able to stimulate an interest in the Government [of Australia] here providing money for a large radio telescope". Appleton had earlier played a role in facilitating the finance of the Jodrell Bank telescope. White was worried that the approach might be too early; he suggested to Bowen that he decide whether RPL would be interested in the large antenna. "Will you please discuss it with Pawsey and let me know what you feel about it? ... Once we have made up our minds I think I could then write to Appleton and you could follow it up." Bowen wrote back immediately (6 June 1952) with an enthusiastic response.[34]

> I have not yet had a chance of discussing the question of a big aerial with Pawsey but I am quite certain ... that this is something Radiophysics should go for in a big way. We have now practically passed the initial phase of Radio Astronomy in which some wonderful physical results could be obtained with elementary equipment. The next important results are most likely to come from the big increase in sensitivity and in resolving power possible with a large aerial. The only reason that I personally have not pressed hard in this direction so far is that, much to my regret, Joe [Pawsey] has not show [sic] much enthusiasm for it and , secondly, I doubted whether a Commonwealth Government- even one as generous as ours- would be willing to produce a quarter of a million pounds in one hit. If the Government could be persuaded to support the project ... I would be flat out for it.[35]

[32] *ibid*
[33] NAA C3830 A1/3/11/3 Part 1
[34] *ibid*
[35] As we show in subsequent texts (NRAO ONLINE 39-47), Pawsey did in fact play a major role in the negotiations for funding and detailed astronomical planning for the GRT in the years 1952 to 1961.

As we have seen above, Bowen also used the opportunity to tell White (on 6 June 1952), about his own plans for a large aerial. He then explained to White the differences in this proposal compared to the Manchester (Lovell) plan, i.e. the emphasis on 1420 MHZ HI and less emphasis on solar and planetary radar. "The Manchester aerial will not operate very well at 1 metre and not at all on 1420 MHz. This, I think, is a serious mistake."

White wrote back on 11 June 1952 stating that Australian Government support could not be found in the 1952/53 budget; also he was not hopeful that such a large sum could be proposed for the following year. White had a number of concrete questions for Bowen about total cost and whether the costs could be spread out over many years. Also he asked Bowen whether either the Australian Department of Defence or a private foundation (e.g. Nuffield or Carnegie) could share in the funding. "Is there any possibility of your making some saving in other directions- say by dropping some of our present radio-astronomical work?"

Bowen replied to White on 17 June 1952[36] that the expected cost for the giant telescope would be in the range £250,000 to 500,000 with a time scale for design and construction of two to three years. As we shall see, these estimates turned out to be far too optmistic. Bowen wrote:

> I am no longer as hopeful of getting defence support for an aerial of this kind as I was a year or so ago. The main reason for this is that, as our ideas have gotten bigger and bigger, the technical requirements for an aerial for defence research as compared with one for radio astronomy have tended to diverge. The emphasis in radio astronomy is on a dish of circular [geometry]; for radar research, on a cylindrical reflector very long in one dimension. In the last few years the ideal radar aerial has got [sic] longer and narrower and therefore further away from what we would really like in radio astronomy. The converse argument is in fact the stronger one. If we were building a long cyclindrical aerial for defence research there is no doubt it could be quite useful for radio astronomy. If we were building one of circular section for radio astronomy, we would not honestly claim it would be very useful for defence research.[37]
>
> If we went for the giant telescope I don't think we could possibly save on another part of our programme. The cost of a big aerial should be regarded as a special item of

[36] *Ibid*

[37] NAA C3830, Z1/7/B Part 1. A month later (17 July 1952), White wrote Bowen with a report of a meeting between himself and Clunies Ross of the CSIRO with the Royal Australian Air Force Chief of the Air Staff (CAS), Air Vice-Marshall F.R.W. Scherger (1904-1984, who had been in command of the RAAF during the Japanese raids in early 1942). The CAS had "come to thank us for allowing you to give so much help to the RAAF… While thanking us he was careful to explain that it would be impossible for the RAAF to help [CSIRO] financially with [a possible GRT] ... [T]here was no point in trying this, at least at present ... I told [the CAS] ... that any really secret project would be difficult for us to handle in RP and with this he agreed."

> capital expenditure over and above our normal budget. The running budget costs, however, might come somewhere within our present budget. A good deal of our present radio astronomy could be done far better with the big aerial and we would transfer a number of activities to it. In that way our annual expenditure would remain roughly the same.

Bowen then described the British Dominions and Colonies Fund possibility to White. He asked White for permission to inquire again with a letter to Van Bush.

White wasted no time in contacting Appleton, who was already on his way by ship to Australia for the URSI General Assembly from the UK. On 27 June 1952 he wrote Appleton in care of the ship *SS Strathmore* as it stopped in Aden on the way to Sydney.[38] White wrote: "... you may be able to stimulate interest in Australia to have a large radio telescope ... We have been discussing this project here for some time and Bowen and Pawsey have very definite ideas as to the research programme that they would carry out if they were able to get a radio telescope of large dimensions". White then asked Appleton to apply some high level pressure on the Australian government:

> The presence of so many eminent radio scientists in Australia at the forthcoming URSI meeting will undoubtedly emphasise that Australian radio science is of a very high standard and there will be no doubt opportunities for you, as President of URSI to make this amply clear to our Prime Minister [Menzies] and to the Minister-in-Charge of CSIRO [Casey]. With that backing I would feel very hopeful that if we had, say, half of the amount necessary for the radio telescope from other sources, the Government might find the remainder.

Details of possible encounters that Appleton had with government ministers are not known, but Appleton did mention the large radio telescope at his opening Presidential address at the URSI General Assembly on 11 August 1952 at the University of Sydney:

> In the case of radio-astronomy, I feel that the whole authority of our Union should now be stressing, to Governments and to Research Foundations, the need for financial support for appropriate equipment ... It seems to me now that the radio-astronomer's turn for substantial subventions for building bigger and getter radiotelescopes ... [He then described the ongoing construction of the 250 foot radio telescope at the University of Manchester by Lovell.] I will only add these few remarks, concerning the construction of this powerful radio-astronomical tool in the Northern Hemisphere, that those of us who follow the subject, either as workers or interested onlookers, would

[38] NAA C3830 A1/3/11/3 Part 1

> much like to see, in due course, a similar instrument at the disposal of your radio astronomers here in the Southern Hemisphere.[39]

Pawsey's report on a 100-metre telescope, August 1952

Within a month after the URSI conference ended on 21 August 1952[40], Pawsey wrote a report "Notes on Applications in Radio Astronomy for a 100-Metre Diameter Telescope". He wrote:

> Radio Astronomy covers the study of the radio waves emitted by the sun, moon and cosmic sources and the use of the radar method to obtain echoes from bodies such as the moon. The use of a great, e.g. 250 feet or 100 metres diameter, aerial would provide a resolution in two dimensions five or ten times greater than the best previously available and a power sensitivity, for small sources, 25 or 100 times greater. This should lead to a better understanding of many phenomena of which we now have partial knowledge, but it also opens up the **possibility of new discoveries**. (our emphasis) We cannot make plans concerning the latter, but such possibilities should be borne in mind while we examine the way in which a large aerial would open up the study of known phenomena. The features of a very large radio telescope are: (1) it permits a detailed study of the brightness distribution over an emitting region, provided the beam width is substantially smaller than the angular extent of the region; (2) it gives great energy gathering power and correspondingly great detection sensitivity for sources of angular size less than the beam width. A number of current problems of radio astronomy have been pursued, using interference methods, to a point where little further advance is possible without the use of a very much larger aerial than has previously been available. These include (1) the survey of discrete sources of cosmic noise (radio stars) over the sky; (2) the study of discrete sources of large angular size; (3) the examination of the detailed distribution of radio brightness over the sky; (4) the use of radar methods to obtain echoes from the sun or planets. [41]

---

[39] URSI, *Proceedings of the General Assembly* 11-21 August 1952, Sydney. Vol 9, Administrative Proceedings, page 15.

[40] As described by Goss and McGee ((2009). *"Under the radar: the first woman in radio astronomy: Ruby Payne-Scott."* Vol. 363. Springer Science & Business Media.) Pawsey was ill during much of the URSI General Assembly, only able to attend the first few days of the conference. He did recover at the end of the Congress and was able to host Appleton at the tour to the new Dapto solar site the days after the end of the URSI congress on 21 August 1952. (John Murray, private communication)

[41] Pawsey pointed out that in order to obtain an image of the sun with a beam width 1/10 of the solar size (i.e. 3 arc min) would require an aerial of an implausible size, 200 metres at 20 cm.

> There are at present about 100 known sources [discrete sources of cosmic noise, "radio stars"[42]]. These are based mainly on measurements at 3 and 4 metres with interferometers employing aerials of about 100 square metres area. The number are limited by two factors: (1) lack of power; (2) lack of resolution. The power increases greatly at longer wavelengths but lack of resolution, with current aerial sizes, limits the number recognizable. At shorter wavelength the resolution is adequate but the sensitivity is the limiting factor. It seems that the only hope of a substantial increase in the number of detectable radio stars is in using larger aerials which give simultaneously greater resolution and greater sensitivity to point sources. A large number of sources are small enough to gain in this way.

He suggested that the optimum wavelength for radio star (discrete sources) observations would be 2 metres (150 MHz) where the number of sources detected would be about 10,000 compared to the 100 discrete sources known in 1952. This increase would allow the determination of reliable statistical properties about the source population, e.g. number counts. Source optical identifications could also be made for a large number of objects. Again Pawsey emphasised the use of the new aerial for 21 cm HI investigations of the Galaxy; the current HI surveys had been made with small aerials of only five to ten metres. "It is of obvious interest to get as fine detail as may be practicable for the 1420 MHz radiation and to compare it with similar details in the distribution of continuous radiation." An additional programme would be the determination of source spectra in the range 100 to 1000 MHz. Finally Pawsey wrote "the 100-metre diameter should make radar echoes from the sun and Venus just detectable with available powers".[43]

Contact with Van Bush

During mid to late 1952, Bowen was in frequent correspondence with a number of colleagues in the US and the UK about the funding prospects of the proposed new telescope. Much of the discussion concerned the possible access of funding from the British and Colonies Fund of the Carnegie Corporation of New York. Bowen wrote to Vannevar Bush[44] on 22 August 1952 with a

---

[42] Surprisingly, Pawsey still used the term "radio stars" in 1951.

[43] Two appendices were included: numerical data with angular resolution at different wavelengths for a 100-metre aerial and angular sizes of various components of solar emission and cosmic sources, including the galactic background.

[44] Bush (1890-1974), famous American engineer, inventor and science administrator. He was director of the Office of Scientific Research and Development during WWII. His book *Science, The Endless Frontier. A Report to the President on a Program for Postwar Scientific Research* of July 1945 served as a basis for the formation of the National Science Foundation in 1950. Bush knew Bowen at the Radiation Laboratory of MIT during the war. As Jerome Wiesner has written (1979): "No American has had greater

reply on 3 September 1952[45], with many details explaining the need for a new large antenna. The basic motivation was, Bowen:

> We have been engaged on the study of Radio Astronomy in Australia for a number of years and like to think that we have made some progress in the field. Several years ago I suggested the construction of a giant telescope in Australia but failed to make progress for lack of funds. Now that the Manchester project has been announced local interest has been aroused and there is a chance that some part of the funds at least may be forthcoming in this country.

Bush wrote back on 3 September 1952 with a tempered response. He was convinced that "radio astronomy has an extraordinary future, nor do I doubt that it is going to be an exciting field in which participation will be highly stimulating ... I have been unable to see my way through this matter as yet ... I remain in a bit of confusion ... but it is not easy [for me] to see what form the actual construction should take to best advantage ... I will try to get a grasp of the matter as soon as I can". Clearly Bowen was concerned by this doubt and tried to settle some of uncertain points in a long letter to Bush on 23 October 1952. He presented a succinct history of radio astronomy starting with Jansky in the 1930s who achieved an imperfect view of the radio sky with beam widths of some 10s of degrees. He then provided a detailed (but muddled) history of early interferometry which had been carried out using small elements with large primary beam sizes. Bowen wrote: "All this adds up to the fact that the interferometer has now been exploited to the utmost. It will not be of much use for the discovery of new [radio] stars or the extension of our knowledge beyond the present frontiers ..." Bowen did not appreciate that a major step forward, which would be occur in the next decades, would be the use of modest size (18 to 25 metre) paraboloids for interferometry.[46] Bowen continued with a number of arguments in favour of the large single dish antenna using points taken from the Pawsey document from August 1952 about the utility of a 100-m aerial. Bowen urged Bush to contact Tizard and Appleton to obtain additional supporting points of view; Appleton had just been in Australia for the URSI congress and was aware of the radio astronomy environment in Sydney.

Sir Henry Tizard- contact mid-1952

---

influence in the growth of science and technology than Vannevar Bush, and the twentieth century may yet not produce his equal."

[45] NAA, C3830, A1/3/11/3 , Part 1. The letter to Bowen was "Dear Taffy".

[46]Bolton had proposed this in February 1951.

Bowen also had an exchange of letters with Sir Henry Tizard, formerly of the Ministry of Defence in the UK and a prominent scientist in the history of radar in the UK in the 1930-1950 era. Bowen's letter of 15 July 1952 began[47], "I am afraid that when I don't know which way to turn I have got into the habit of writing to you for help ... [I]n our less reticent moments we like to think that we have made a substantial contribution to this new science [radio astronomy]. Some years ago we became very enthusiastic about building a GRT but, unfortunately, finance was not forthcoming and the project lapsed … With the announcement of the Manchester project, local interest, or perhaps local pride, has revived and there is now just a possibility that funds for a similar project can be raised in Australia." The success of the project was dependent on the quality of the case for the GRT as well as "the possibility of obtaining some part of the finance elsewhere". With a cost of about half a million pounds, "I am writing you to ask if you know of any philanthropic bodies who might be approached …" He asked about the Nuffield Foundation, who was contributing to the Manchester project. Bowen also told Tizard that he had heard from Bush about the Carnegie funds which had "been accumulating for a number of years ..." Bush had asked for a report "of good research uses to which [these funds] might be applied".

Tizard wrote back on 11 August 1952 (a short handwritten-letter, "Dear Bowen"): "I should like to see you with a large radio telescope. It is important to get observatories going in both hemispheres. But I am not very hopeful that the Nuffield Foundation will be able to fund the money, however sympathetic they may be." On 20 August, he wrote a longer letter to Bowen with more details. As he had told Bowen earlier, the best bet was the British Dominions and Colonies Fund of the Carnegie Corporation of New York. "The income is nearly $500,000 per year. Last year the expenditure was over $100,000. They still have a balance of unspent funds from 1942-1946 … I think that the Carnegie people would be very sympathetic to your proposal. But that they would be unlikely to fund all the money." He suggested to Bowen that he should find part of the funds in Australia. "So my advice is: apply to the Carnegie Corporation: use my name in support if you think it will help. Let me know their reply."

M.L. Oliphant- contact 1952

Two letters from Mark Oliphant (Director of the Research School of Physical Sciences and Engineering at the Australian National University) were written to Bowen in 1952 (12 June and 15 August) with a reply from Bowen on 3 July 1952.[48] These letters foreshadow an issue that

[47] *ibid*

[48] These letters followed the correspondence between Pawsey and Oliphant of 10 September 1951 about the possible collaboration of ANU and RPL (see chapter 19 in the main book).

was to face the Australian astronomers in later years: would the newly planned GRT be a *national* facility or just a part of a CSIRO division? With the inauguration of the Australia Telescope National Facility in 1988, a national observatory was finally created.

In June 1952 Oliphant was visiting the UK (he had returned to join the new ANU in 1950) with a visit to Jodrell Bank. He was impressed and hoped that a southern equivalent could be constructed:

> As you know, I was hopeful that your proposal [after 1948] for a similar mirror in Australia would be sympathetically considered, but I now understand that the project has been shelved. Because of the importance of the southern sky and the desirability that an Australian achievement should be developed to the full, I feel that this is a tragic decision and I am wondering whether I could not do something to help have it revived. An undertaking of this kind is too revolutionary and too expensive to receive proper consideration as an item in the budget of a Division of CSIRO, however well received it may be. Under prevailing conditions it can succeed only as a <u>national</u> [original underlined] undertaking and as a matter of <u>national</u> prestige. I was wondering whether a properly documented proposal could be prepared ... at the times of ANZAS and URSI conferences [later in 1952] and a proper campaign initiated to fund an Australian equivalent of Jodrell Bank [at Manchester].[49]

Oliphant had been given a copy of the Manchester proposal, believing that the Australian dish could be "done more simply and less expensively and would like to discuss it all with you on my return [to Australia]." He suggested setting up an informal committee of 8-10 prominent Australian scientists and "have them press for the scheme. It may take a little time, but [we] may be successful, while it is important to have everything ready for action when the economic climate changes."

Bowen was pleased to get this message. On 3 July 1952, he did not respond to the issue of a national facility but clearly welcomed the support: "I was delighted to get your letter of 12 June indicating your interest in a giant aerial for Australia. I was always very disappointed that we were unable to go ahead with our early plans, but there are already signs of a change in attitude here now that they are going ahead with one in the UK."

Bowen was quite pleased with the suggested discussions of the new project taking place during the August URSI General Assembly. "I believe that Appleton is also anxious to help in this direction and is likely to bring pressure on appropriate quarters [the government] when he is out here." Bowen pointed out that the plans for the Australian large antenna were to be

---

[49] ibid

different than for Jodrell Bank with less emphasis on radar astronomy and more on solar and cosmic noise research. In Oliphant's reply on 15 August 1952 (he was not able to attend the URSI General Assembly), he stressed "that if we build a radio telescope in [Australia], it should be done as a national job and not just as a normal part of the work of your Division of CSIRO. It is necessary to think in terms of a continued programme which might far outlast the interest of those of your team who are at present skimming the cream in this field".

Carnegie Corporation- October to December 1952

By October 1952, Bowen and Pawsey were discouraged by the negative signs that had come from the Carnegie Corporation of New York concerning funding prospects. In the 3 September 1952 letter, Bush had warned the Australians that the interests of the Carnegie Corporation of New York were slanted to the fields of social sciences rather than the physical sciences.

> This has been a very natural emphasis, since the heavy emphasis of government subsidy for matters in the physical sciences has rendered the opportunities of the foundations in this field somewhat less attractive, although in particular instances none the less important. Also the Corporation [in New York] has not in recent years been inclined to make large grants for major pieces of equipment, particularly in the field of physical sciences ... their present emphasis lies elsewhere.

On 3 November 1952, Bowen wrote Dr Charles Dollard, President of the Carnegie Corporation of New York[50]:

> I believe that some weeks ago Dr Bush may have written you telling of our interest in building a giant radio telescope [GRT] in Australia … So far the greater part of radio astronomy has been carried out with relatively simple equipment. This ... is the best procedure in a new and growing science. The stage has definitely been reached ... at which these simple techniques have been fully exploited and the next big advances only likely to come from a considerable increase in the sensitivity of the aerials … and a great improvement in their resolution. Both of these can be obtained from an increase of the size of the receiving aerial.

Bowen then described the size of the proposed aerial (200 to 300 feet) with a cost of about a million dollars with a running cost of about £A 20,000 per year. "I am quite sure that the [government] would provide the running costs … and perhaps make a contribution to the capital cost. There is grave doubt … [that they] would provide the full cost of the project."

[50]NAA, C3840, A1/3/11/3 Part 1

Bowen then mentioned that he was aware of the British Dominions and Colonies Fund, “but I am a little uncertain of the exact purpose for which this is intended. I am writing to ask if there is any possibility of its being devoted to a project of this kind. I have not attempted to make a case at this stage, rather to point out the great scientific advances that might emerge from the use of such an aerial. This I would gladly undertake if you think a good purpose would be served by doing so.”

It is likely that Bowen had anticipated the negative answer that did arrive a few months later (2 December 1952) from Whitney Shepardson, the Director of the British Dominions and Colonies Fund of the Carnegie Corporation of New York: “ ... [W]e have come to the conclusion that the project is too far away from the Corporation’s current program for us to entertain it.” (This was the only communication between the Carnegie Corporation and CSIRO since the Bowen letter of 3 November.) Clearly the rejection was a major disappointment for CSIRO. As we will see, the RP colleagues did not give up.

Bowen (1981) has written that in late 1952:

> The goodwill continued, but the money there was not [sic]. This was a pretty depressing point in our history, as we saw a promising avenue for development closing up in front of our eyes. Discussions followed with Fred White and Clunies Ross on the possibility of proceeding on our own. Very early in the piece it became obvious that in the context of 1952 there was no way in which CSIRO was likely to get a large capital sum for such a project ... Some way had to be found of squeezing it out of the existing Radiophysics budget.

Bowen’s “rolling barrel” design, a large aerial

Already in October, Bowen had anticipated that the Carnegie Corporation of New York would reject their proposal. On 22 October 1952 Bowen wrote a two page letter to Fred White describing a new antenna design that would allow the Sydney group to remain competitive with the Manchester group (Bowen 1981):

> There are one or two objections to our going for an altitude-azimuth design like the Manchester one. The first is that we could not possibly complete it before them and there is the danger that we might lag several years behind. The second is that their dimension of 250 feet is scarcely large enough for some purposes and it is desirable that

at least one dimension of the aerial should be much bigger. Finally, we would have to be assured of the whole cost of the aerial before we could make a start.[51]

In the 22 October 1952 letter to White, Bowen sketched out a "rolling barrel" cylindrical paraboloid (Figure 2) that was to have a final length of 1000 feet with a width of 200 feet. There were to be up to 5 sections each of 200 feet (each module had a weight of about 20 tons) along an East-West line. The projected cost was only £A 25,000 per module. The major cost saving was the fact that the reflector was close to the ground with essentially no mount. A line feed was required and the steering was to be plus or minus 60 deg in elevation. Also the aerial could be built in series (one 200-ft module after the other) over a multi-year period, using single year budget allocations over a five year period to complete the project. Each addition would provide a useable radio telescope. Bowen wrote on 22 October 1952: "It should not take more than a year to get the first section running. The Manchester aerial is going to take three years to erect [in fact the project took much longer]. This means we could start a galactic survey a year or two before Manchester got going, and probably complete it before they had power in their aerial."[52]

Surprisingly, little detailed work was done on planning for this project even though it was discussed during two meetings of the "Large Radio Telescope" committee in October and November 1952.[53] Bowen (1981) summarised the end of the "rolling barrel" project: "It would not have taken us long to realize the advantages of spreading these segments over a longer base-line.[54] Sad to relate, although everyone was keen about it, the answer was NO, for lack of sufficient [funds]. So this proposal failed to materialise and once again our hopes for the development of Australian radio astronomy were at a low ebb."

---

[51] NAA C3830 A1/3/11/1 Part 1 . Bowen did not discuss the problems of this asymmetrical antenna with an elongated beam shape of 5 to 1; two dimensional observations of the complex galactic plane would have been hindered by the large declination beam width with this transit instrument.
[52] *ibid*

[53] During the 16 October meeting, Bowen's scheme was discussed with no conclusions. During the 10 November 1952 meeting, Carter discussed the 200 foot by 200 foot basic structure. The estimated cost was £20,000. McAlister reported on the feasibility of a smaller 50 foot aerial (estimated cost £ 2000) of the "rolling barrel" type; this was seen as a prototype for the larger 200 foot design. The prototype was to be used as a sea-cliff interferometer by Bolton at Dover Heights. Apparently, nothing came of this plan.
[54] Bolton (1982) has summarised three projects that he and Gordon Stanley had considered at the end of 1952 to continue their research at Dover Heights: (1) a second "hole in the ground" antenna to form an interferometer at 400 MHz; (2) "… two rolling barrels – parabolic cylinders inside circular cylinders -- to form an interferometer;" (the Bowen proposal); and (3) the "tennis-court" sea-cliff interferometer at 300 MHz (see below; the published frequency in the publication of 1982- 400 MHz- is incorrect).

In spite of this discouraging outcome in late 1952, a great deal of progress had been achieved. The ground work for the GRT was laid; most importantly a solid channel of communication had been achieved with the Carnegie Corporation. This patience was to pay off in May, 1954.

Committee meetings of the GRT planning committee in 1952

At least three meetings of the "Large Radio Telescope" committee were held in 1952 after the URSI conference in Sydney[55] with Bowen, Pawsey, Carter, McAlister and McCready in attendance.

Topics discussed at the 23 September 1952 meeting were the form of the 250 foot diameter aerial, with an accurate central 100 foot surface. The form of the mount was discussed with the consensus that an alt-azimuth mount would be built. An interesting discussion was led by Keith McAlister, "reflecting screen adjustable and automatically corrected" which permitted the use of a less rigid framework which could be distorted due to gravity loading. This is an early discussion of a "rubber mirror" or a deformable surface that would be corrected in real time. This topic was discussed in more detail in the next meeting on 20 October 1952. "Investigations show that there is no 'deformable' structure which carries safe stresses in its member." Carter led a discussion on a conventional alt-azimuth type with a diameter of 250 feet. Pawsey discussed an Arecibo type dish which "requires a valley and the erection of a reflecting surface by means of wires, poles etc. The shape of the surface to achieve the required [gain] with adequate steerability, say plus and minus 40 deg, needs considerable investigation. In abeyance at present." Considerable discussion on the feed arrangement (for the conventional steerable aerial) was held, all prime focus schemes. Different heights of the feed above the surface were discussed for a tower that could carry a focal package that weighed only 50 pounds. Also the "rolling barrel" proposal of Bowen was discussed, the long 1000 foot cylinder with a width of 200 feet.

It is noteworthy that at the time of the third 1952 session on 10 November, the committee was joined by John Bolton; for this meeting the name was changed from "Large Radio Telescope" to "Giant Radio Telescope"- the GRT.[56] The major discussion topic was the "rolling barrel" design, with the suggestion that a small 50 foot module could function as a sea-cliff interferometer aerial at Dover Heights.

---

[55] C3830 A1/3/11/2, from W. T. Sullivan archive. The more formal "Radio Telescope Planning Committee" was formed in May 1954. These more formal meetings were held in the years 1954-1955 with at least 14 meetings from May 1954 to November 1955. A successor committee, the Technical Advisory Committee, mainly consisting of outside experts, began work in July 1955, with eight meetings up to June 1959.

[56] The GRT terminology became the common designation in the last months of 1952; this was used up to the time of the inauguration of the Parkes telescope in late October 1961

“The tennis court” 300 MHz sea-cliff interferometer project of Bolton- end 1952

Bolton did plan a new instrument for Dover Heights in November 1952; instead of a 50 foot module he suggested a new larger, higher frequency sea-cliff interferometer for Dover-Heights. [57]

Apparently the origin of this idea for a Kraus type radio telescope was a letter from Bowen (10 June 1951) from the UK. He had visited a Royal Air Force (RAF) site in the UK at Martlesham Heath (north of Harwich). Bowen wrote (from Martlesham Heath) to Pawsey[58]:

> I wonder if we have been missing out on a simple form of big aerial for radio astronomy which would be very cheap and easy to erect. It has been suggested to me that an experimental parabola is being used [by the RAF] for blind landing [of aircraft trials]. It is a simple cylindrical parabola 80 feet across and 20 feet high. The reflecting material consists of a series of horizontal wires about 8 inches apart fixed by staples to posts driven vertically in the ground. The whole thing cost a few pounds, took a day or two to erect and gave an excellent polar diagram. For radio astronomy, it would be quite easy to erect such an aerial on a cliff site like Dover, with an aperture of say 500 feet. The beam width would be extremely narrow in horizontal plane [due to the large dimension] and could be steered over a wide angle by moving the feed in the focal plane. It would have the usual lobe pattern in the vertical plane [sea-cliff interferometer fringes] and the whole thing would, of course, be used as an interferometer. I don’t know how this fits in with your present ideas on big aerials. But clearly it could be done for a small amount of money and in a short time. It would not have the disadvantages of Lovell’s present fixed aerial and might be an exceedingly useful step before we embark on a really big paraboloid. I would be very glad to have your comments and those of Bolton, who I hope is well on the way to recovery.

At the end of 1952, Bolton and Stanley wrote “A New Aerial for Source Survey Work”, based on the Bowen idea. Details of this proposal can be inferred from Bolton’s 1982 retrospective publication “Radio Astronomy at Dover Heights”, the National Archives of Australia and from two interviews with W.T. Sullivan in 13 August 1976 and 15 March 1978. (The extensive

---

[57] On 19 November 1952, McCready wrote Bowen a memo : “Large Radio Telescope”. Apparently, he and Carter were working on a design of the Bowen rolling barrel, However, no details have been found in the archives. “Bolton has agreed to accept an 80 foot aerial with the feed inside the aperture plane. This means that the 80 foot model Dover aerial will be a model of the 200 foot [one of the five modules] job.”

[58] NAA, C3830, A1/3/1 (H). The 1951 Bowen letter as well as details of the undated Bolton and Stanley proposal from late 1952: “A New Aerial for Source Survey Work”. The authorship of a number of handwritten pages can be inferred by the well-known handwriting of Bolton, Stanley and Pawsey. Bowen letter also in C3830, Z1/9/1951 Part 1.

proposal was found in the NAA[59]; in the interview with Sullivan, Bowen asserted that there was no written record.) The proposal was not discussed in the three meetings of the large radio telescope committee in late 1952. Bolton ((1982). "Radio astronomy at Dover Heights." *Proceedings of the Astronomical Society of Australia*, vol. 4, pp. 349-358):

> … [M]y own choice was to build a large sea interferometer [at Dover Heights] for use at 400 [sic, actually 300] MHz. This would have consisted of a cylindrical paraboloid 20 [sic, actually 24] feet high and 200 feet long with a focal length of about 150 feet fed by a vertical stack of dipoles [made up of 10, 24 feet high sections ("bays"), each of length 10 feet]. The construction of the mirror would have been similar to the fence around a tennis court and would have been built for each 40 deg of azimuth; the 40 deg interval covered by moving the dipole stack [for small angular displacements]. The primary beamwidth would have been 1 deg in azimuth and the interference fringes 15 arc min apart. [The vertical beam would have been 4 deg.] Unfortunately it was not to be financed- the Mills Cross had won the day.[60]

The extensive proposal from the NAA has provided details of the astronomical motivation as well as numerous suggestions for the method of construction and costs. The discussion of source confusion shows that the authors had carefully balanced the sensitivity (gain) of the array with resolution; confusion in radio astronomy was clearly understood by this group.

> It is proposed to construct a new aerial to further the study of the distribution of the discrete sources of galactic noise. Past studies [by Bolton et al and especially Mills, 1952, "The Distribution of the Discrete Sources of Cosmic Radio Radiation"] have revealed the existence of a concentration of the brighter sources to the galactic plane [Mills' Class I sources]. Much greater numbers are required to investigate secondary features of the distribution- such possibilities as clusters following the clustering of extragalactic nebula. Present systems at 100 MHz suffer from an excess of sensitivity over resolving power with the result that many of the sources that can be detected cannot be discerned in the general confusion. Given a certain aerial area there are two things that can be done to overcome this situation; firstly to arrange the aerial in such a way that

[59] NAA C3830 A1/3/1 (H) with no date, inferred to be late 1952.

[60] In the 13 August 1976 interview, Bolton described to Sullivan the reason the "tennis court" interferometer was not built. "We had done tests to show the system would work, but at the same time Bernie Mills came up with the idea of the [Mills] Cross. Taffy Bowen was backing me and Stanley and Pawsey was backing Mills. Pawsey was the head of the radio astronomy group and so we lost out and so [my] next work was in Cloud Physics." Bolton has asserted to Sullivan that this decision by Pawsey was the reason he left radio astronomy in 1953. Starting in mid-1953, Bolton worked in the RP Cloud Physics group for one and a half years; in January 1955 he moved to Caltech. He founded the Owens Valley Radio Observatory'; Bolton remained at Caltech until December 1960.

> the resolving power becomes greater than is indicated by the physical area or the gain (Mills case) or to operate at a higher frequency. There is for a given sized aerial an optimum frequency of operation where the number of sources that can be detected [sensitivity] is the same as the number that can be discerned [resolution].
>
> The beam will be directed by swinging the feed over restricted angles and moving the reflector [**that is reconstructing the main cylindrical paraboloid for a declination change of 10 deg by moving each of the 20 bays-** our emphasis**]** for larger angles. It will be constructed in sections to permit ease of movement [thus a movable "tennis court"] The present cleared area at Dover will permit observations over declinations 40 deg to -10 deg from sites north of the main hut and from -10 deg to -40 deg south of the main hut …

Bolton and Stanley calculated the number of expected sources based on a minimum detected source flux density at 300 MHz of two Jy compared to 50 Jy with the older 100 MHz instrument at Dover Heights. At 300 MHz the total number of possible detected sources would be larger than 750 (based on the source counts at 100 MHz and an assumed spectral index). The number of sources that could be discerned (the area of the celestial sphere divided by the number of aerial beamwidths) was 3000; thus the number of beams per source would be about 4, far smaller than the currently accepted value of about 30.

Bolton and Stanley also calculated that the expected positional accuracy of the new instrument would be 10 to 15 arc min, an improvement over existing surveys. The limits of angular sizes would be about 10 arc min as well. The proposal ended with a list of two areas in which the 300 MHz survey would complement the planned Mills 80 MHz survey that was to be carried out at Fleurs with the Mills Cross: (1) spectra of some hundred discrete sources and (2) an overlap between the Mills survey and the northern hemisphere.

The materials and construction of the reflector consisted of two sections: a list of materials, handwritten by Gordon Stanley such as 1.5 inch water piping tubes (with screwed joints), 2 inch chicken wire and 300 pound concrete blocks (used as anchors for each bay). The construction costs consisted of bulldozing of the site and welding the A frames. John Bolton provided a page of detailed calculations of the method of construction for the movable bays with a special design for the movable concrete blocks. Notes on the documents are written in Bolton's characteristic neat handwriting. "The deflection at the top of the bays … in an 80 mile per hour wind should be less than 2 inches." The Stanley document stated that the "total cost of aerial, site levelling, tower erection shall not exceed £ 1000."

The most fascinating document found in the National Archives collection is the first page on the collection of documents concerning the Bolton-Stanley proposal of late 1952. This page is shown in Fig 3. The handwriting on the sketch is Pawsey's, likely his perception of the layout of the proposed 300 MHz aerial at Dover Heights. The two comments at the bottom are: "Is this Bowen's idea?" and "Difficulty (1) distance of Point A from cliff". (The focal length was 150 feet.) In fact this proposal is an updated version of the Bowen 1951 suggestion. Point A should not be too far from the cliff as this would seriously limit the declination range of the proposed aerial; the reflections from the sea would be blocked by the cliff for some orientations. Based on this evidence, we can infer that Pawsey had severe doubts about a new large scale sea-cliff interferometer, even at 300 MHz.

The inflexibility of this instrument with observations only possible over a short period each day remained a major limitation. The creation of an all sky survey of radio sources with the "tennis court" sea-cliff interferometer would have been a challenging prospect. The reorientation of the reflector would have been a major handicap. After these initial plans, the project died as the new Mills Cross project at Potts Hill and then Fleurs began.

Below fig 1

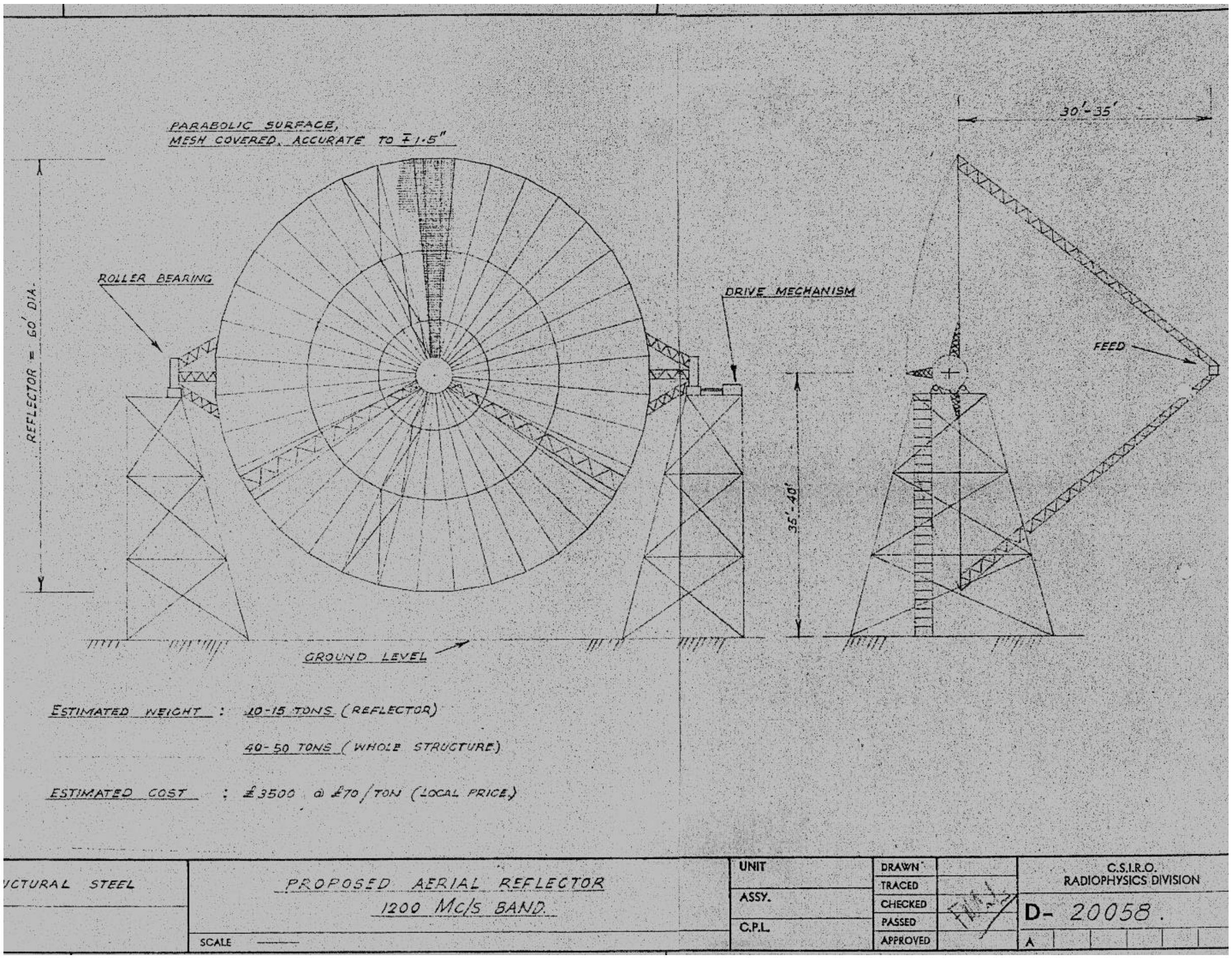

Fig 1 Caption Carter's March 1951 design of a transit dish of 60 feet in diameter (only movable in fixed steps in declination) that would have been ideal for 21cm HI research. The cost of material was A£ 3500 for an aerial of 40 to 50 tons, with 10 to 15 tons for the reflector. The dish was not constructed.

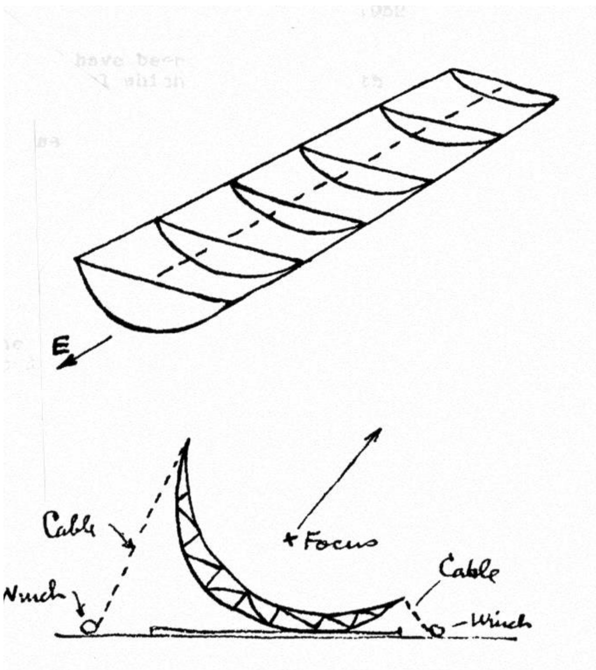

Fig 2. Bowen anticipated in October 1952 that the Carnegie Corporation of New York would reject the proposal for financial support for the GRT. He proposed to White (NAA C3830 A1/3/11/1 Part 1) that a low-cost cylindrical paraboloid of 1000 feet might be a back-up solution. The simple instrument (a sketch drawn by Bowen) was close to the ground with essentially no mount. It would be constructed in 200-foot instalments. In the end this was never built; the Carnegie Corporation of New York did allocate a grant of US$250,000 (NRAO ONLINE 40) for the GRT in mid-1954.   The figure first appeared in a letter from Bowen to White on 22 October 1952. (original RP Archive CSIRO Marsfield, A1/3/1h). The figure also was published by Bowen in 1981: "History of Australian Astronomy, The Pre-History of the Parkes 64-m Telescope" in *Proceedings of the Australian Society of Australia*, vol. 4(2), p 267.

Below fig 3

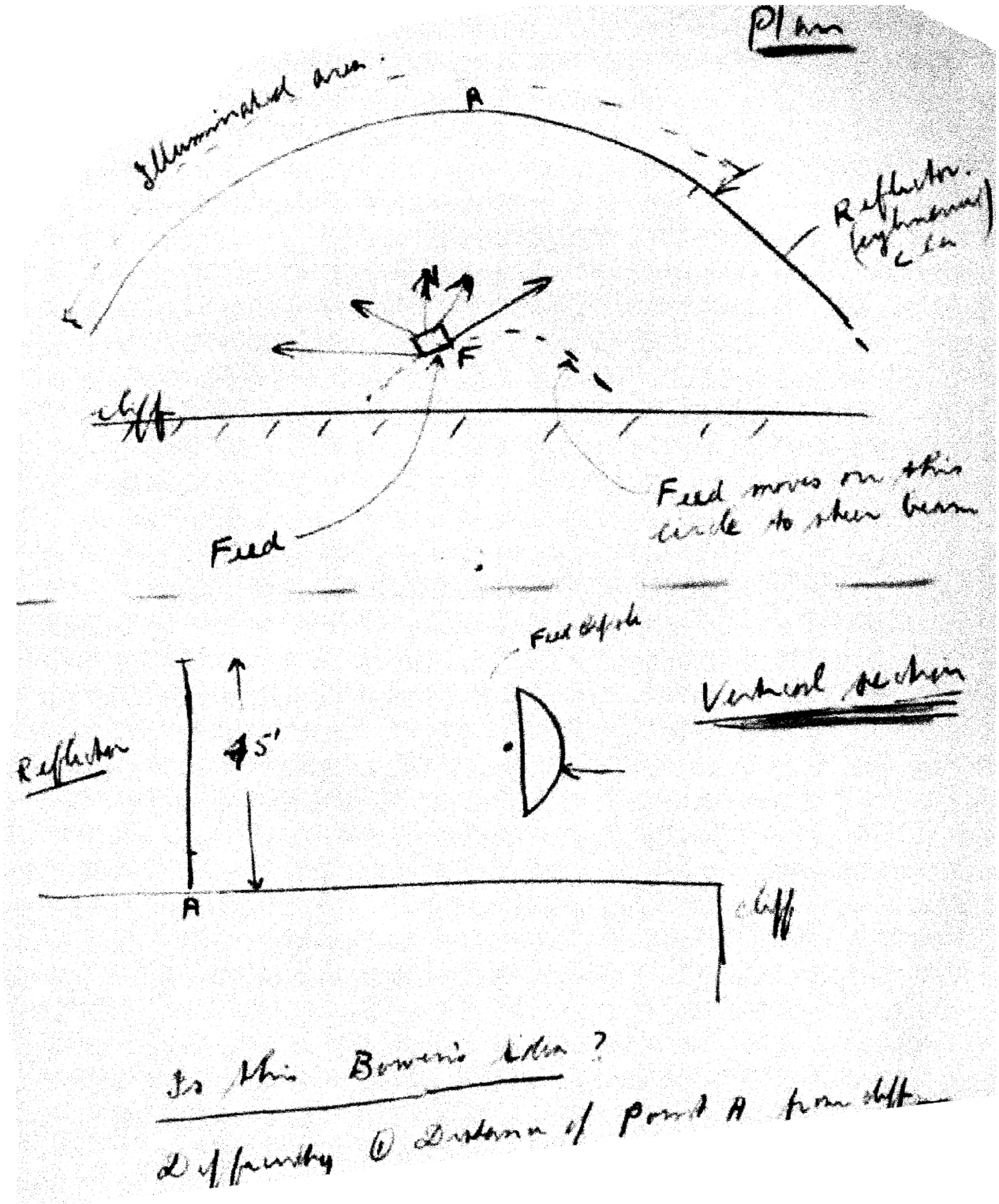

Fig 3 “The tennis court” 300 MHz sea-cliff interferometer project of Bolton in late 1952. A sketch drawn by John Bolton in late 1952 of a proposed 300 foot sea cliff interferometer for Potts Hill [NAA C3830 A1/3/1 (H)]. The handwriting is from Pawsey “Is this Bolton’s idea?” and “Difficulty (1) Distance of Point A from cliff”. Pawsey had severe doubts about the proposal which was never built.