Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

August 29, 1977

To: Working Group of the 25-m Telescope

From: M. A. Gordon

Subject: Notes on the UK and SAGMA Millimeter-wave Projects, August 1977
25-m Telescope Memorandum 99

In August of this year I visited Richard Hills and Barry Shenton at Culham Laboratory in Britain, and Jaap Baars and his associates at MPIR in Bonn. This memorandum is a summary of information I gained regarding the status of 15-m UK and the 30-m SAGMA telescopes.

I. The United Kingdom 15-m Telescope

A. Funding.

Last year reverses in the British economy resulted in a government order to reduce science spending by 10%. Because of irrevocable commitments to international projects this reduction meant the virtual elimination of development funds at the lower levels of the British scientific community. The 15-m telescope project came to a halt.

Also, the proposed UK telescope was in direct competition with a proposed French-German-British satellite, the "International X-ray Explorer" (IXE). Space and international science being in vogue, this project posed a substantial threat to the new millimeter-wave telescope.

Now, everything has changed. The spending reduction is over. NASA did not choose the IXE for one of the few rockets available. Presently, the British "Forward Plan" carries the UK millimeter-wave project as endorsed by the scientific community.

Inclusion in the Forward Plan is an important success. Covering the next 5 years, the proposed Forward Plan contains projects selected for funding by the UK scientific community. Once a project has begun, it is difficult to discontinue it, short of a financial crisis occurring within the British economy. In short, the 15-m telescope project looks highly likely; both Hills and Shenton are now confident of funding.

The projected spending levels are given in units of pounds sterling as of 1 January 1977. The UK fiscal year runs from April 1 to March 30. The Forward Plan carries the following budget levels (exclusive of salaries) for the millimeter-wave telescope.

Fiscal Year	1978/79	1979/80	1980/81	1981/82	1982/83
Budget	371K	1356K	1596K	572K	123K

The 1982/83 level is principally operating money.

The administrative chain involved in the funding appropriation is shown in the diagram on page 3.

At this writing, the project has been approved by the Department of Education and Science and hence is carried in the proposed Forward Plan. It now awaits funding by the Treasury.

B. Management.

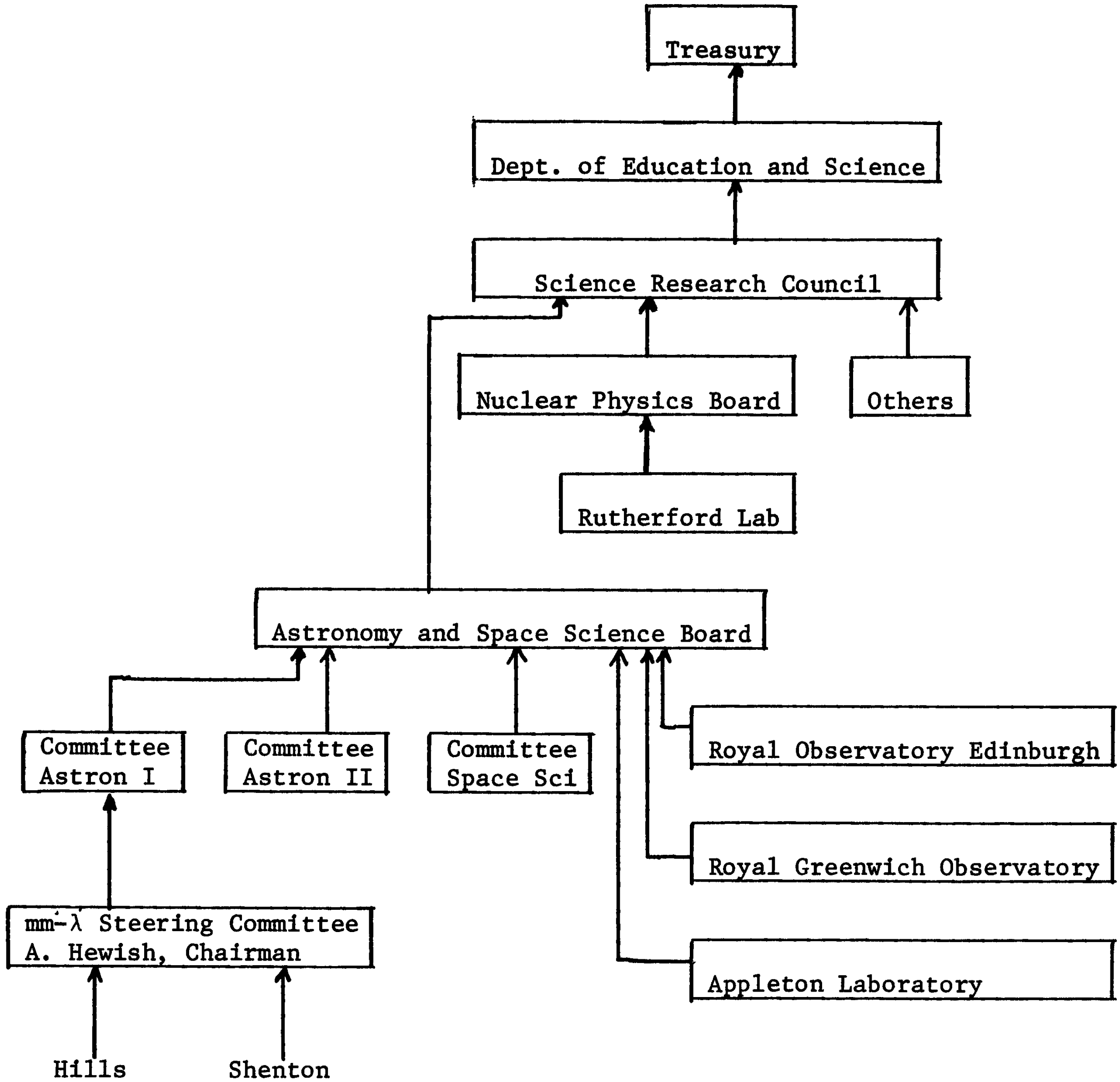
The millimeter-wave project is directed by a interuniversity committee, now chaired by Hewish and formerly chaired by Tom Phillips (now returned to Bell Labs). The committee employs Hills as Project Scientist and Shenton as Project Manager.

Much of the work is carried out at Culham Laboratory. Although Appleton Lab has formal responsibility for developing the project, Shenton and other project employees have worked at Culham Lab (located near Oxford) for many years. They prefer not to move to the more expensive London suburb of Slough, where Appleton Lab is located -- particularly for a project which has an uncertain future. Hills now lives in Cambridge and commutes to Culham when necessary.

Acquisition of this telescope, being unconventional, involves more than straight-forward purchases from industry. Performance must be guaranteed by the designer rather than by the builder. Because nuclear research devices have always involved construction of unconventional apparatus, Rutherford Lab is better-suited than Appleton Lab to supervise the purchase and the erection of the homologous telescope. But Rutherford reports to the Science Research Council by a different route than Appleton, through the Nuclear Science Board rather than through the Astronomy and Space Board. Some arrangements, now unclear, will have to be made for the Nuclear Physics Board to build an instrument to be designed and operated by the Astronomy and Space Board. The obvious step, to create a management office within the SRC, with limited authority over both Boards, is unlikely because it would be an escalation in governmental bureaucracy. Furthermore, whatever the management, it must not be closely allied with any specific university, so as to preserve the national character of this first interuniversity project of British radioastronomy. This important problem must be solved soon.

C. Procurement.

As mentioned above, the unconventional nature of a homologous telescope creates special problems. It is virtually impossible to hold a manufacturer to overall performance specifications which he didn't calculate. The present plan is to break down the project into conventional manufacturing tasks, to set performance specifications



Scheme for funding of radioastronomy in the UK and tolerances for those tasks, and to reserve for the government the responsibility for performance of the integrated system. Again, Rutherford Lab has considerable experience in this kind of procurement, which is the usual way to build nuclear accelerators.

D. Sites.

Here lies another major problem. Most radioastronomers feel Hawaii is too far away, in spite of on-going construction of the UK Infrared Telescope on Mauna Kea. Mainland Spain, which includes sites in the Andalusian cordillera such as SAGMA's Pico Valeta, is still politically difficult for Britain because of the Gilbraltar question. Spanish possessions are possibilities, however. The Northern Hemisphere Observatory, the proposed UK optical observatory, is certain to locate on La Palma, in the Canary Islands off Africa. The reasons are absence of clouds and the fine seeing caused by extraordinarily laminar air-flow. Were the mm-λ telescope to join NHO in the Canary Islands, the mm-wave observatory would be limited to a site of altitude 8000 ft. (The much higher mountain on Tenerife is an active volcano.) While the 27-N latitude would be advantageous to mm-λ astronomy, the 50-μm telescope surface would be overly-precise for an 8000-ft site.

The British may reconsider Mauna Kea. However, were the NRAO to build its mm-λ telescope there, the SRC might hesitate at having 2 similar telescopes on the same mountain. On the other hand, Hills notes the advantage of being able to operate as an interferometer.

E. Surface Plates.

The error budget for the UK telescope allows 25μm for each surface plate. Engineers at Rutherford Laboratory have met this requirement in the following way.

1. Rough machining of aluminum honeycomb using a carpenter's router suspended from a jig.
2. Press the honeycomb to a highly-accurate mold (die).
3. Press aluminum sheet to the same mold.
4. Bond sheet and honeycomb using a cold epoxy and curing the sandwich in the mold.

There are a number of salient points in this process. The crushing of the honeycomb is localized to the edge of the comb structure; there is no residual stress in the honeycomb. By also pressing the sheet to the mold, they eliminate any stress in the plate even after bonding. The epoxy serves only as a light glue; no creeping is expected nor has been detected. (The no-stress aspect of this plate is very different from the German concept, as will be seen.)

The mold consists of a polished cast-iron surface, which has been hand-worked and measured on a Defence Department measuring engine capable of accurate measurements to 5μm.

The final plate can be walked upon, if you wear rubber shoes. A load of 100 psi on selected areas of the plate produced no observable deformation.

Hills notes that the radius of curvature for the NRAO telescope is twice that of the UK telescope. Panels should be even easier to make for the NRAO telescope. He'd sell us 2 plates for $10,000, providing the respective governments would agree.

F. Surface-Measuring Machine.

At Culham there is a laboratory version of the laser distance-measuring device. Unlike the NRAO telescope, but like the MPI telescope, the quadrupod is not an essential structural element. Hence it can be removed for the surface measurement, permitting uninterrupted movement of the laser beam. Tests show the laser system to meet their design goal of 20μm, so far. They have yet to build the rotary part of the beam.

G. Anomalous Atmospheric Absorption.

H. A. Gebbie (Appleton Lab) has reported anomalous absorption of infrared radiation in the atmosphere above that predicted from measured amounts of water vapor and oxygen. These measurements have been made from several mountain sites over the last 10 years or so. No one except Gebbie has confirmed this effect. In fact, one independent group measures no anomalous absorption. So, the SRC is funding Martin and Gillespie of Queen Mary College to build a special device to measure this effect again. Whereas the signal-to-noise ratio of Gebbie's measurements are marginal owing to the sensitivity of his aparatus, the new instrument should have much greater sensitivity. The present plan is to mount Gebbie's instrument side-by-side with the new one of Martin and Gillespie, and to repeat the measurements. In any case, the alleged culprit is a water dimer, which the downslope winds would push away at night.

II. The SAGMA 30-m Telescope

A. Funding.

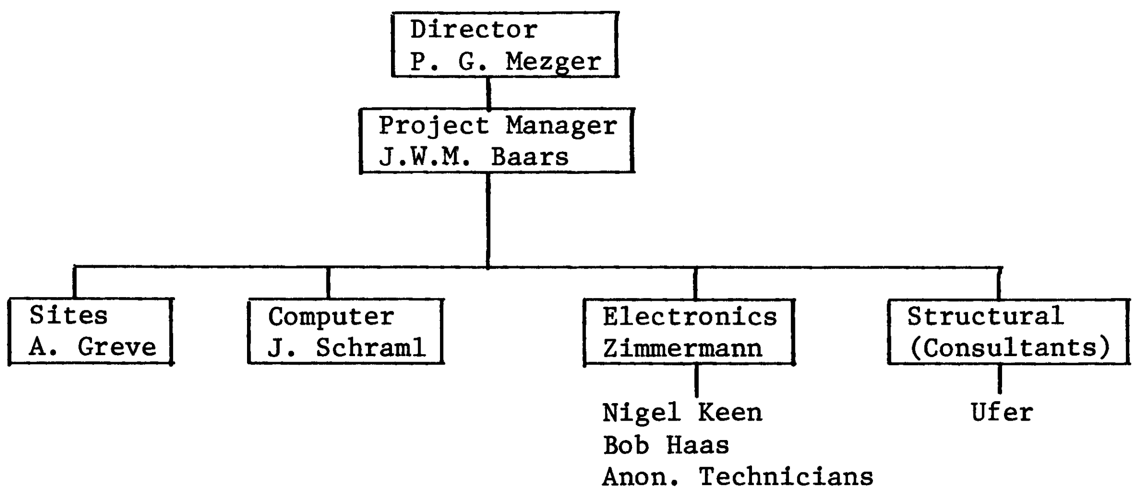
From the German point-of-view, the SAGMA project is a method for the Max Planck Gesellschaft to gain 80 new positions and a millimeter-wave telescope. The entire project requires approximately DM60M for construction of both instruments, DM8M for annual operation. For construction, the German funds are to be provided by the Volkswagen Foundation and the Federal Government, on a matching basis.

Last year, inflation in Germany moved to almost 5% per annum, a frighteningly-high rate for their stability-minded government. The Federal Government reduced its spending, including allocations to the MPG. To accommodate the money reduction, the council of the Gesellschaft chose to defer starts of new projects. Because of the "matching-funds" feature, this decision meant a delay of one year in the MPG millimeter-wave telescope.

The French are also experiencing funding problems, because of limited funds available to INAG, which I understand to be the French equivalent of our NSF.

B. Project Staffing.

The MPG project is headed by Jaap Baars, who works out of the MPI Radioastronomie offices in Endernich. The project office is run, not by MPI Radioastronomie funds, but by MPG funds administered by Mezger. As I understand the organization, it looks something like this:



The structural group, mostly contractors or part-time consultants, consists of the following firms and individuals:

Krupp A. G.
M.A.N.
J. W. Findlay (NRAO)
B. Hooghoudt (self-employed)

Hooghoudt is the engineer who designed the Dwingeloo, Westerbork, and Stockard telescopes. He also has designed optical telescopes. With the possible exception of Baars, MPI has no inhouse design capability.

C. Receivers.

To gain practical experience, they (mainly Haas) have built a cooled-mixer receiver for CO, which will be taken to the Five College telescope in Amherst in October. The arrangement is that MPIR will be given some fraction of telescope time in exchange for use of the receiver. Zimmermann is leaving MPIR for JPL, leaving the receiver group temporarily without a leader. I understand that Tony Gillespie, of Queen Mary College, will be joining the group soon.

D. Telescope Design.

The decision has been taken to build an open-air telescope. In spite of problems arising from this decision, I perceive no weakening of the resolve to forego an enclosure. Even the partial enclosure for the back structure has been abandoned.

The design is homologous, but different from the Effelsberg or NRAO telescopes. Like the UK design, the feed support is not structurally important to their design. To compensate for this structural element, they use a stiff central hub. Design analysis is very much like that of the NRAO; the analysis includes a vertical half-section of the telescope rather than the segment technique used for the Effelsberg dish.

The RF performance goals are not well-fixed. Rather than design a structure to meet a performance goal as NRAO has done, MPG has chosen a 30-m telescope more or less to fit their financial budget. Within this constraint, they are trying to make the telescope as precise as possible. Hooghoudt told me that a performance of 100μm over a substantial part of a day would probably be considered acceptable. Both Mezger and Baars emphasized that predictably good performance over the entire day, as NRAO requires, is not important for their mode of operation. They envision operation similar to the 36-ft telescope in the late 1960's: a do-it-yourself, occasional operation.

The telescope design is massive to survive the occasional violent storms on Pico Valeta. It has 500 Mg above the elevation axis, and 500 Mg below the elevation axis. In addition, the base requires a great deal of reinforced concrete. The estimated price is $8.5M, 1976 units.

The decision not to use an astrodome is based upon 2 factors. It would cost money which they don't have. The climatic conditions at Pico Valeta are perceived to be a natural limit to the science output, which Hooghoudt feels could not be overcome very much by enclosing the telescope within a radome.

E. Site.

I visited Pico Valeta, and later discussed this site with Albert Greve, an astronomer in charge of site evaluations. On first inspection, this site appears to be excellent in terms of (summer) access, proximity to a city, and in atmospheric transparency. It has an altitude of approximately 11,000 ft and a latitude of 37^{o}N. The terrain is very rough, affording no possibility of installing an interferometer such as the French part of the SAGMA organization.

Winter storms are the major obstacle to operation here. Not only can winds be very strong, but the mountain gets a lot of snow. It is a ski resort. In addition, several times each winter it suffers peculiar icing conditions. Super-cooled water clouds move in from the Mediterranean. In 2-3 hours, the 1-cm diameter of a vertical pole grew to 50cm. MPI plans to deal with this problem by applying heat of 350 W/m^2 to the telescope. Even so, it can take several days to reopen access to the peak after one of these storms. These conditions are not expected to be an important problem, because of the casual operation envisaged.

F. Telescope Surface.

This is the major design challenge for the MPG telescope. Because of its open-air design, the telescope has to be massive to withstand wind and icing storms. It is not a fully optimized design, as is the NRAO telescope. Consequently, its error budget for RF performance is much more heavily consumed by the back structure relative to the surface smoothness than for the NRAO design. In short, the surface plates and setting have to be excellent even to achieve an overall surface accuracy of 100μm.

Should they leave the surface unpainted, the sunlight falling on aluminum plates would cause a temperature gain of approximately 15-20C. The telescope would require many hours to relax to equilibrium. If the plates are painted with highly reflective paint, the daytime temperature gain is reduced to 2-3C, but all optically reflective paints tested sofar begin absorbing at 150 GHz and above.

MPIR is approaching this problem in 2 ways. First, they are trying to find better paints. Second, they are searching for plates which are thermally stable.

The plate investigation is being conducted in a systematic way. The ground level of the Stockard telescope contains a test jig. The plate is mounted on this stiff, thermally-insulated jig and measured with a theodelite. Then IR strip lamps above the plate are turned on to simulate solar heating. The plate is then remeasured, and the deflection $\Delta Z-\overline{\Delta Z}$ is determined for the temperature difference ΔT from the front to back of the plate. Hooghoudt gave me the following results, some of which he took from other studies.

Measured and Expected Thermal Characteristics of Surface Plates		
Manufacturer	Plate Construction	Coefficient (µm/C)
Rutherford Lab (SRC)	unstressed Aℓ honeycomb sand.	14
Philco-Ford	machined, cast Aℓ	40-50
ESSCO	stressed Aℓ	30-40*
Dornier (MPG)	stressed Aℓ honeycomb sand.	4-8

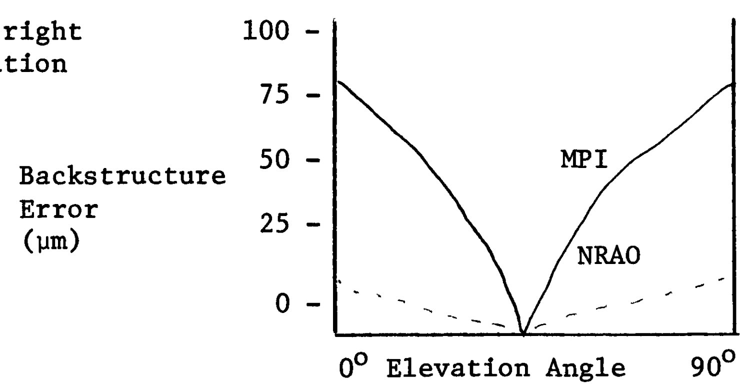
*This number comes from 25-m Memo #36. Memo #86 gives 120 which, to Hooghoudt, intuitively sounds more reasonable. (I'm uncertain as to whether these numbers are strictly comparable, because they do not all derive from the same experimental procedure.)

The honeycomb construction appears to be thermally stable compared to the others. The MPG panel, which is thin and stressed, appears to be excellent. However, unlike the SRC plate, its stressed construction may make it vulnerable to creep of the epoxy bond. Furthermore, it is a flexible panel.

The MPI technique of mounting and adjusting plates is heavily dependent upon subassembly. Hooghoudt wishes to have the factory mount 9 plates upon a stiff backframe (panel). The factory will adjust these panels to the desired accuracy prior to delivery. These plates will be mounted on the telescope as a unit, thereby requiring only adjustment of the large panel to achieve the final surface accuracy.

Because the 30-m design has greater flexure in the backstructure than the NRAO design, Hooghoudt believes that they will not be able to rely on computer predictions for the final surface adjustment. They must measure the surface figure at several elevation angles to choose the correct setting.

The diagram at the right describes the situation qualitatively.



G. Pointing and Telescope Control.

Much of this work has been done by Schraml. His original report is now being translated into English.

They plan to use microprocessors wherever possible, to reduce the load on the central computer. One interesting feature is the use of a digital servo system, whereby the servo response can be changed quickly depending upon the nature of the winds buffeting the telescope. They even envision performing a spectral analysis of telescope motion, analyzing it quickly on-line, then calculating and implementing the appropriate response function for those conditions.

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NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

September 20, 1977

To: Working Group of the 25-m Telescope

From: M. A. Gordon

Subject: Addendum to Memo 99: "Notes on the UK and SAGMA Millimeter-wave Projects"

Jaap Baars has kindly corrected some misimpressions given in my Memo 99. You will want to make the following corrections.

1. Page 5: I inadvertently give the false impression that MPG is interested only in gaining a new telescope. Actually, MPG is highly interested in participating in an international project.

2. Page 6: CNRS, rather than INAG, is similar to our NSF.

3. Page 6: The mm-wave project within MPG also a new Division within MPIR, with Jaap Baars as Division Head. The operations of this Division are funded through the normal MPIR budget. The expenditures specifically relating to the 30-m project are as described in my memo. John Findlay is more of a "Friend of the Project", rather than an official consultant.

4. Page 6: Hooghoudt did <u>not</u> design the Stockert telescope.

5. Page 7: The whole exposed part (except for the surface) of the telescope will be covered with an insulation layer.

6. Page 7: The project will employ 28 people and is seen as more than a "do-it-yourself, occasional operation". But, the observing frequencies will be quickly variable to accommodate changing climatic conditions.

7. Page 8: The icing problem is not expected to be an important problem for operations, because of the large number of people at the telescope, not because of a casual attitude toward operation.

8. Page 8ff: I've misspelled V<u>e</u>leta.