AVN Training Program

History of radio astronomy in South Africa and at HartRAO

Connections to Radar Development during World War II

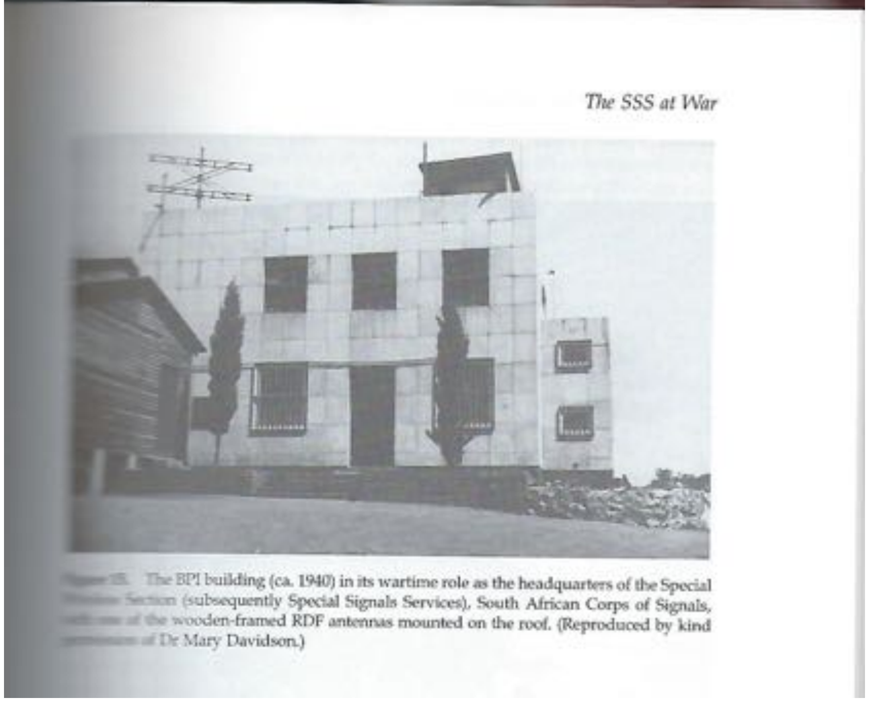
- It is well known that radio astronomy had a development spurt after World War II when scientists and engineers who developed radar returned to Cambridge and Manchester Universities in the UK and to the Radio Physics Laboratory in Sydney, Australia.
- These three groups dominated radio astronomy for a number of years, with the US and the Netherlands and other countries joining in later.

South Africa's role in radar development

- During the war, Britain contacted governments in Canada, Australia, New Zealand and South Africa to inform them about the invention of radar, providing them with details and encouraged them to develop their radar systems for he defence of their own coastlines
- In South Africa this project was led by Dr Basil Schonland, Director of the Bernard Price Institute and a world authority on the study of lightening.

First Radar in South Africa

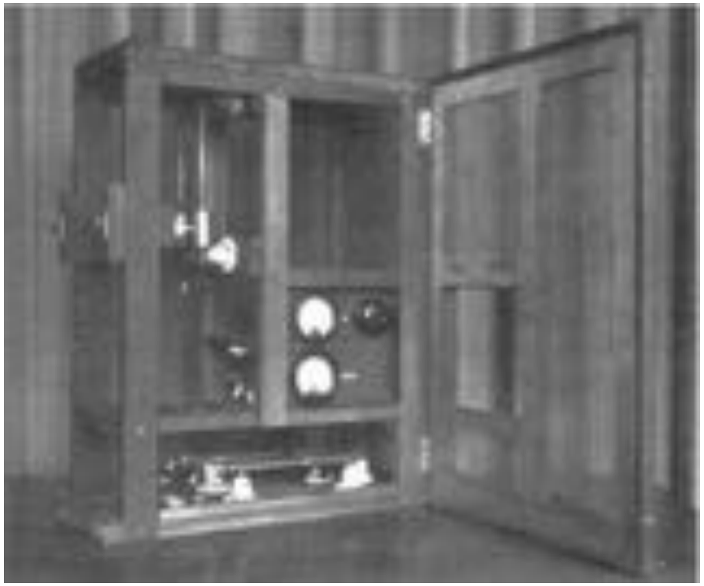
First radar antenna on top of the Bernard Price Institute at the University of the Witwatersrand (c1940)



The SSS at War

[illegible] The BPI building (ca. 1940) in its wartime role as the headquarters of the Special [illegible] Section (subsequently Special Signals Services), South African Corps of Signals, [illegible] wooden-framed RDF antennas mounted on the roof. (Reproduced by kind [illegible] Dr Mary Davidson.)

Early version of South African Radar transmitter



Operational South African Mobile Radar Set

Deployed somewhere in Africa

War-time radar operator

Basil Schonland -
Scientist and Soldier

Basil Schonland was a brilliant South African scientist.

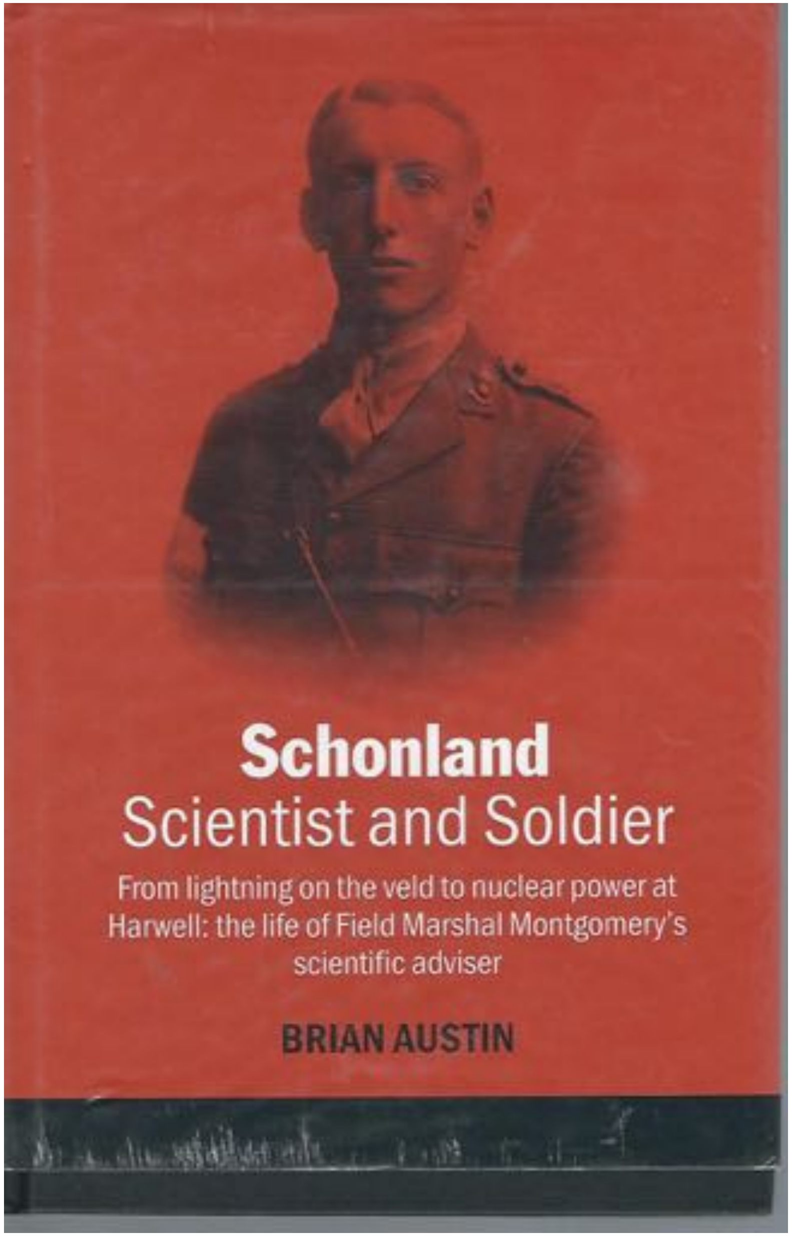
Educated at Rhodes University and Cambridge, he established an international reputation for his studies of the lightening process during 1920s and 1930s

He was appointed to lead the development and deployment of radar sets throughout Africa during Word War II

He became Field Marshal Mongomery's scientific adviser during the War, with rank of Brigadier

After the War General Smuts, PM of South Africa, asked him to establish the SA Council for Scientific and Industrial Research, CSIR, becoming its first President.

Subsequntly, he became Director of the Harwell Nuclear Reactor Research Centre in the UK.



Establishment of the Telecommunication Research Laboratory

- The TRL was one of the first Research Laboratories that Schonland established in the CSIR.
- It was staffed largely by scientists, engineers and technicians who had worked on the development of radar during the war.
- The Director was Frank Hewitt, a war-time protege of Schonland's who later gained his PhD based on radar studies of lightening, following in his mentor's foot steps.

Early policy decision against Radio Astronomy Research in South Africa

- Schonland took and early decision ***not*** to support radio astronomy in South Africa.
- He felt that the UK and Australia had an unassailable lead by then and he knew the calibre of the people involved in those countries.
- He also argued that it would be far too expensive to then start from scratch.

South African radio astronomers abroad – Cambridge and Jodrell Bank

- A number of South Africans went abroad to study radio astronomy, both at Cambridge and Jodrell Bank
- Probably the first was P. A. O’Brien, who studied in the late 1940s and early 1950s at Cambridge.
- He was followed by others among them Bernie Fanaroff who led and directed the successful SA proposal to host the SKA and the MeerKAT Project .
- Others went to Jodrell Bank, among them Raymond Vice , my one time boss and Director of National Institute for Telecommunications Research, the successor to the TRL.

The first paper on radio astronomy by a South African

This is probably the first paper on radio Astronomy by a South African, P.A. O’Brien, working at Cambridge in 1953.

He subsequently returned to South Africa, to the University of Natal and tried to set up a radio interferometer .

But Schonland’s policy of no radio astronomy prevailed.

It wasn’t until 1960/61 that the opportunity to carry out radio astronomy research on a reasonable scale developed., as we shall see.

THE DISTRIBUTION OF RADIATION ACROSS THE SOLAR DISK AT METRE WAVE-LENGTHS

P. A. O'Brien

(Communicated by M. Ryle)

(Received 1953 March 27)

Summary

Measurements of the distribution of radio " brightness " across the solar disk have been made at wave-lengths of 1·4, 3·7 and 7·9 metres, using interferometers of variable aperture. The size of the emitting disk was observed to increase with increasing wave-length, the averaged equivalent temperature being reduced to 10 per cent of its central value at radii of 1·6 R_0, 2·2 R_0 and 2·8 R_0 for the wave-lengths 1·4, 3·7 and 7·9 metres respectively.

At 1·4 metres, using interferometers with axes inclined at various angles to the solar axis of rotation, it was shown that the shape of the Sun was approximately elliptical; the radial distance at which the brightness temperature was reduced to half was about 25 per cent greater at the equator than in the polar direction.

1. *Introduction.*—The earliest attempts to determine the distribution of radio "brightness" across the solar disk were based on eclipse observations at centimetre wave-lengths (**1, 2**), and such observations have now been made over the range 8·7 mm to 1·95 metres (**3, 4, 5, 6, 7, 8**). The results obtained in most of these experiments were not very conclusive, particularly at the longer wave-lengths where the large effective diameter of the Sun makes the observed eclipse curves insensitive to changes in the radial distribution of the emission.

The determination of the distribution by Fourier synthesis, using an interferometer aerial of variable aperture, was suggested by McCready, Pawsey and Payne-Scott (**9**), and this method was first used by Stanier (**10**) at a wave-length of 60 cm, and later by Machin (**11**) at 3·7 metres. In the interpretation of these results it was assumed that the emission was distributed over the solar disk with circular symmetry. The distributions obtained did not agree with those derived theoretically (**12**): at 60 cm the predicted limb-brightening did not occur and at 3·7 metres the amount of radiation from the outer corona was considerably greater than the theoretical values.

The present paper describes further experiments, using interferometers of variable aperture, during the period 1951 July to 1952 July. The method has been extended to wave-lengths of 1·4 and 7·9 metres, and further measurements have also been made at 3·7 metres. At 1·4 metres it has been possible to determine the distribution by a method which does not assume that the source has circular symmetry.

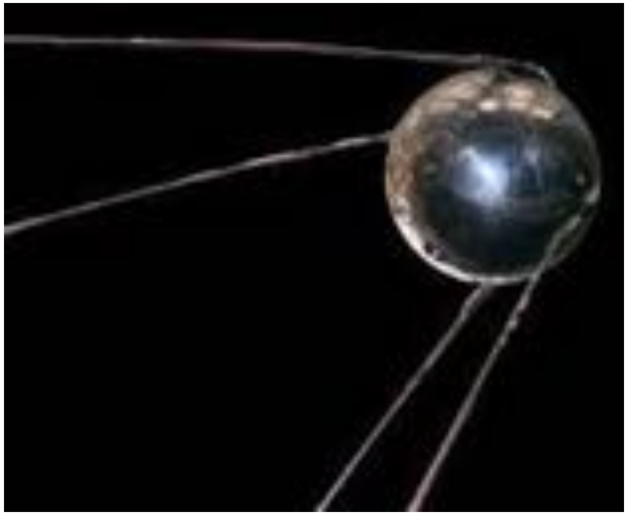
The other big by-product of World War II was Rockets

- Germany developed Rockets during the final stages of World War II and used them to attack Britain.
- After the war, some of the German rocket scientists moved to the US and the American rocket program began.
- This was despite the fact that an American, Robert Goddard, started experimenting with and launching rockets in the early 20th century.

Start of the Space Age: Launch of Sputnik 1

The launch of Sputnik 1 on 04 October, 1957 took the world by surprise and ushered in not only the space age, but also the space race between the US and Russia.

I was a 2nd year university student at the time, and a radio amateur (ham) with a receiver in my bedroom. I listened to Sputnik 1, which transmitted at a frequency of 20 MHz, and found it very exciting.



America had been planning to launch a scientific satellite to explore space above the atmosphere since 1955.

The launch of Sputnik 1 made them accelerate their programmes

NASA minitrack station

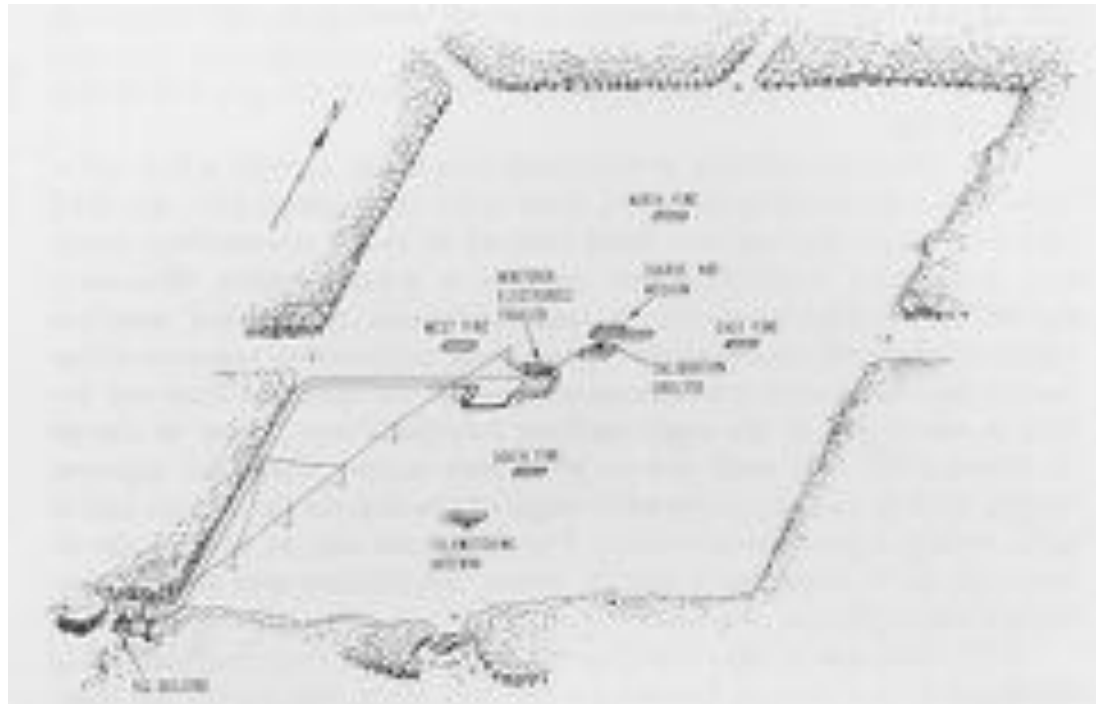
Eventually America succesfully launched an earth satellite which carried a Geiger counter, and discovered the Van Allen radiation belts, named after the experimenter who designed the instrument.

Through the US NAVAL observatory , a world-wide network of stations, called MiniTrack, was built , with one in South Africa, about 5 km to the North of OR Tambo airport.

This consisted of a series of EW and NS interferometers, the first in South Africa.

I worked there in my 3rd year as a vacation student at the end of 1958, and learned that NASA was planning to build a new station with a 26m tracking antenna.

I was already interested in Radio Astronomy and saw this as an opportunity.



Leading up to the construction of the 26m antenna.

The purpose of the new facility would be to track “Deep Space” probes to the Moon and planets, and would be operated by South Africa .

South Africa was a critical location for this station as it would be the first one to track the rocket after it was launched fro Cape Canaveral, and get telemetry information back from the spacecraft.

Three stations were to be built. One in California, one in Australia and the third in South Africa.

These would be able to provide continuous coverage of space probes on their way to the moon and planets.

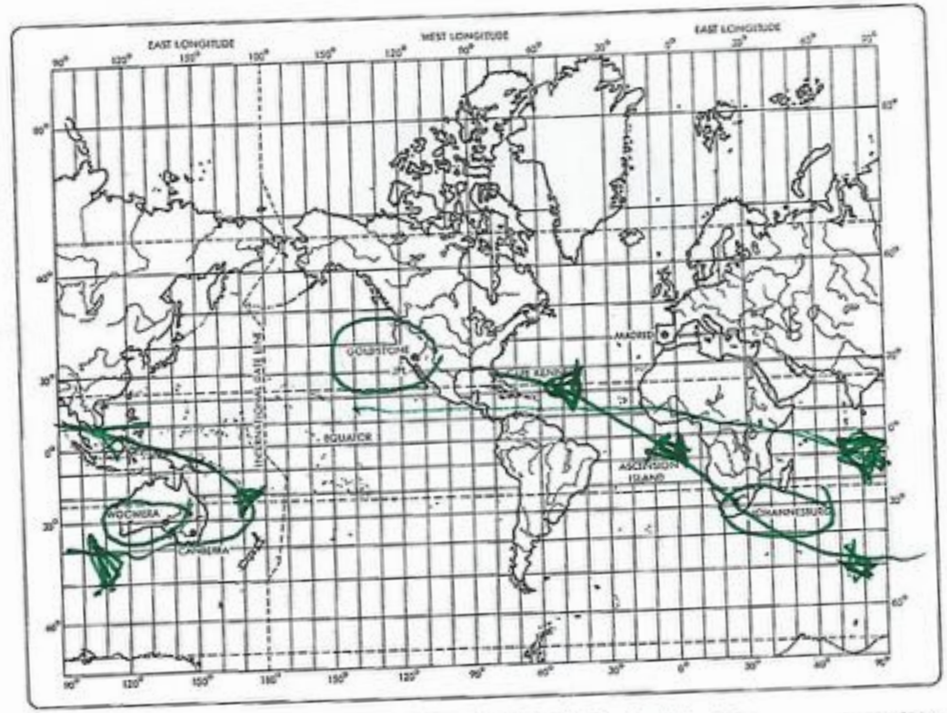


Figure 2-1. World view of the Deep Space Instrumentation Facility, 1961. Although the locations of future sites, near Canberra, Australia, and near Madrid, Spain, are also shown on this diagram, they had not been established at that time.

Construction of the Deep Space Station 51 at Hartebeesstoek 1960-61

At the beginning of 1960, after I graduated, I was offered a job at the Minitrack station.

DR FJ Hewitt, the Director of TRL, by then renamed NITR, was negotiating with NASA for the 26m station to be built.

In his motivation to CSIR and Government to have it built here , he clearly stated that it would be able to be used for radio astronomy, allowing South Africa to make up for lost ground.

I have a copy of a letter by the same DR PA O'Brien to his HoD, detailing a meeting with Hewitt, stating that Hewitt saw this as the only opportunity for South Africa to start research in radio astronomy.

Political obstacles

There were political obstacles, because the US Government were reluctant to build in South Africa and negotiate with the apartheid government.

The importance of the South African location was such that they eventually agreed, a contract was signed, and after a long search the Hartebeesthoek valley was chosen.

The first foundations were poured on Christmas day 1960, such was the pressure to have the station ready by July 1961, ready for the first Ranger spacecraft launch to the moon.

All this while I was on the sidelines waiting to get a chance to get radio astronomy started, with behind the scenes encouragement from my Director, Dr Hewitt.

DSS51 ready for operation in July 1960.

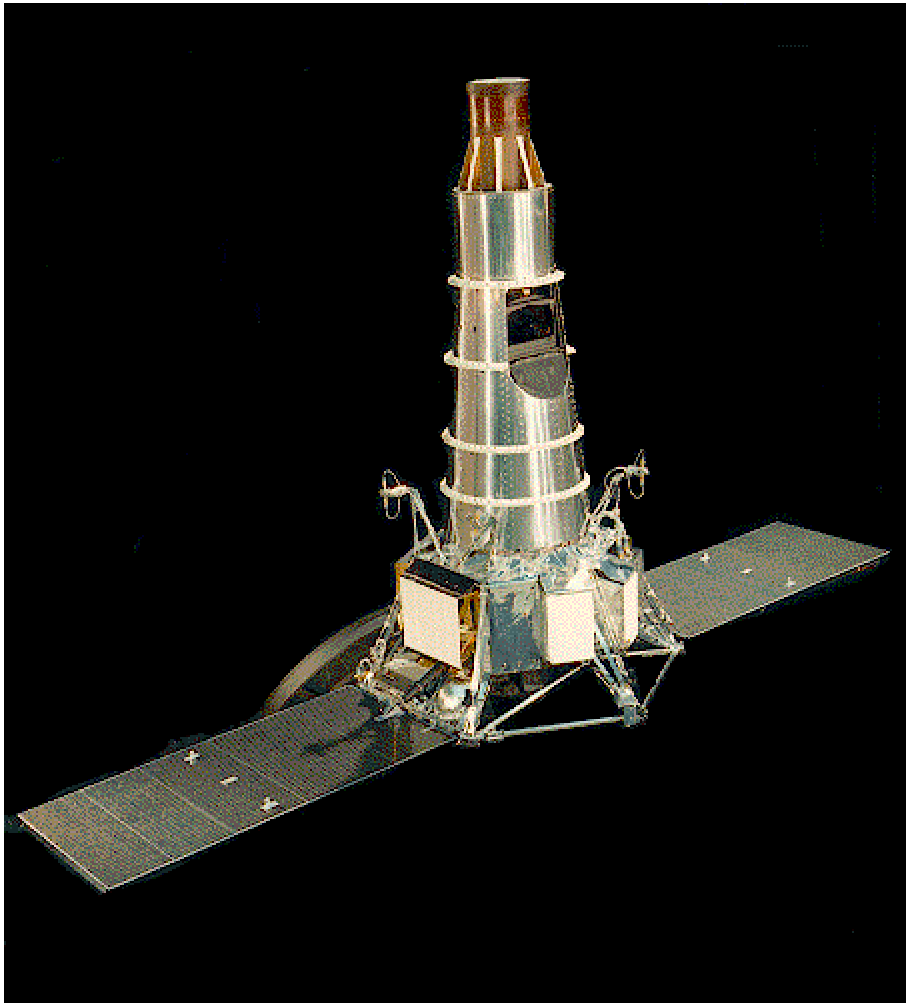
The structural work was completed by Easter 1961, which is when I transferred to Hartebeeshoek . After three months an American team, working with the South African team had installed all equipment and the station was operational.

It was officially opened with much fanfare later in the year, with various dignitaries present.

Although invited, the US government and NASA representatives chose not to attend, as they did not want be associated directly with the SA Government.

The early missions

The first missions were the Ranger spacecraft, which were designed to photograph the moon right up until they crash landed on the moon. The early launches were spectacularly unsuccessful.



Ranger 1: Launched 23 August 1961

Failed to leave earth orbit

Ranger 2:Launched 18 November 1961

Failed to leave earth orbit

Ranger 3:Launched 26 January 1962

Earth contact lost, missed moon by 37000 km.

Ranger 4:Launched 23 April 1962

Sequencer failed, Impacted on Moon

Ranger 5:Launched 26 January 1962

Earth contact lost, missed moon by 725km.

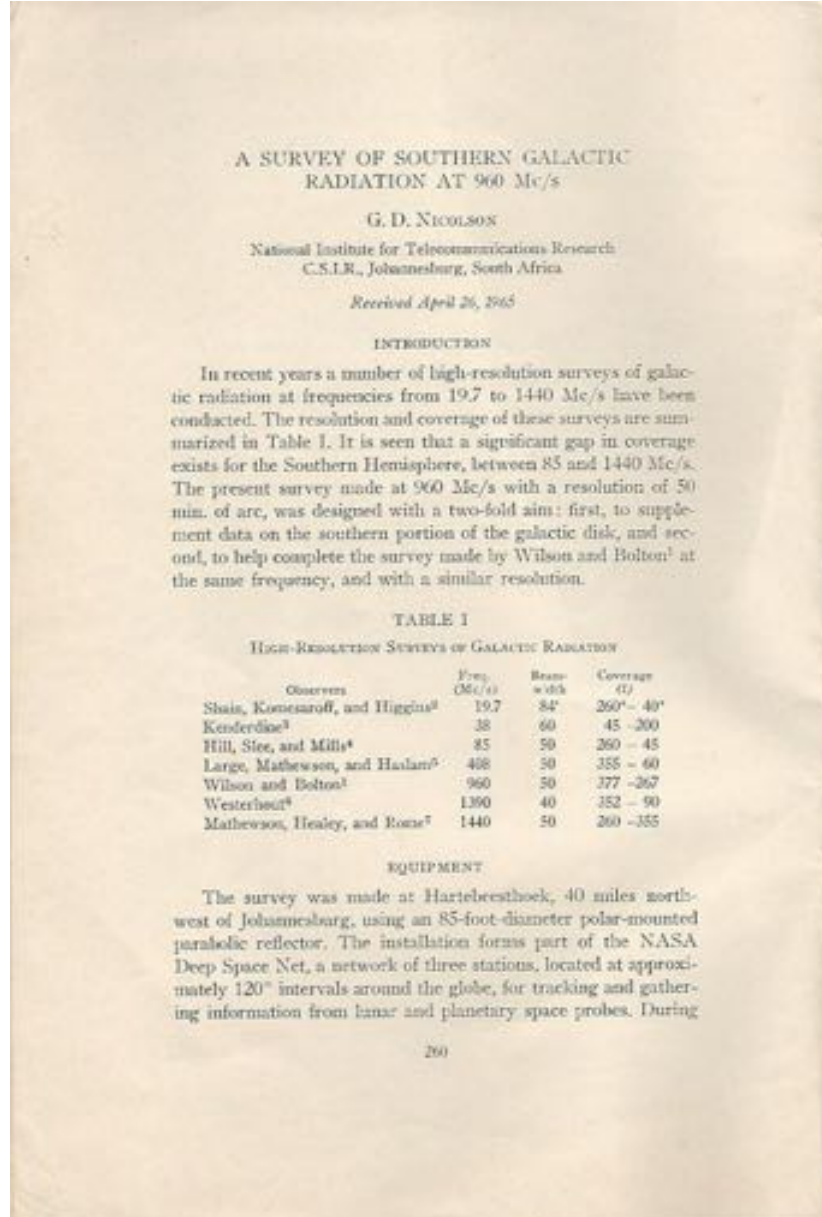
The start of Radio Astronomy

By then JPL, who were responsible for the Moon program realised they had a problem and suspended launches until January 1964, to investigate why there were so many failures.

In 1960 and 1961 I had several meetings with Dr O'Brien to discuss possible projects.

Eventually he suggested a survey of radio emission from the Southern Milky Way, to complement a recent survey in the North. The station receiver operated at the same frequency, so minimal changes were needed.

I had been building the additional components to covert to operation as a radio telescope. I had free access to the telescope, and used the results for my MSc degree, and published the first paper in 1965.



A SURVEY OF SOUTHERN GALACTIC RADIATION AT 960 Mc/s

G. D. Nicolson

National Institute for Telecommunications Research
C.S.I.R., Johannesburg, South Africa

Received April 26, 1965

INTRODUCTION

In recent years a number of high-resolution surveys of galactic radiation at frequencies from 19.7 to 1440 Mc/s have been conducted. The resolution and coverage of these surveys are summarized in Table 1. It is seen that a significant gap in coverage exists for the Southern Hemisphere, between 85 and 1440 Mc/s. The present survey made at 960 Mc/s with a resolution of 50 min. of arc, was designed with a two-fold aim: first, to supplement data on the southern portion of the galactic disk, and second, to help complete the survey made by Wilson and Bolton[1] at the same frequency, and with a similar resolution.

TABLE 1

High-Resolution Surveys of Galactic Radiation

Observers	Freq. (Mc/s)	Beam-width	Coverage (l)
Shain, Komesaroff, and Higgins[2]	19.7	84'	260°- 40°
Kenderdine[3]	38	60	45 - 200
Hill, Slee, and Mills[4]	85	50	260 - 45
Large, Mathewson, and Haslam[5]	408	50	355 - 60
Wilson and Bolton[1]	960	50	377 - 267
Westerhout[6]	1390	40	352 - 90
Mathewson, Healey, and Rome[7]	1440	50	260 - 355

EQUIPMENT

The survey was made at Hartebeesthoek, 40 miles northwest of Johannesburg, using an 85-foot-diameter polar-mounted parabolic reflector. The installation forms part of the NASA Deep Space Net, a network of three stations, located at approximately 120° intervals around the globe, for tracking and gathering information from lunar and planetary space probes. During

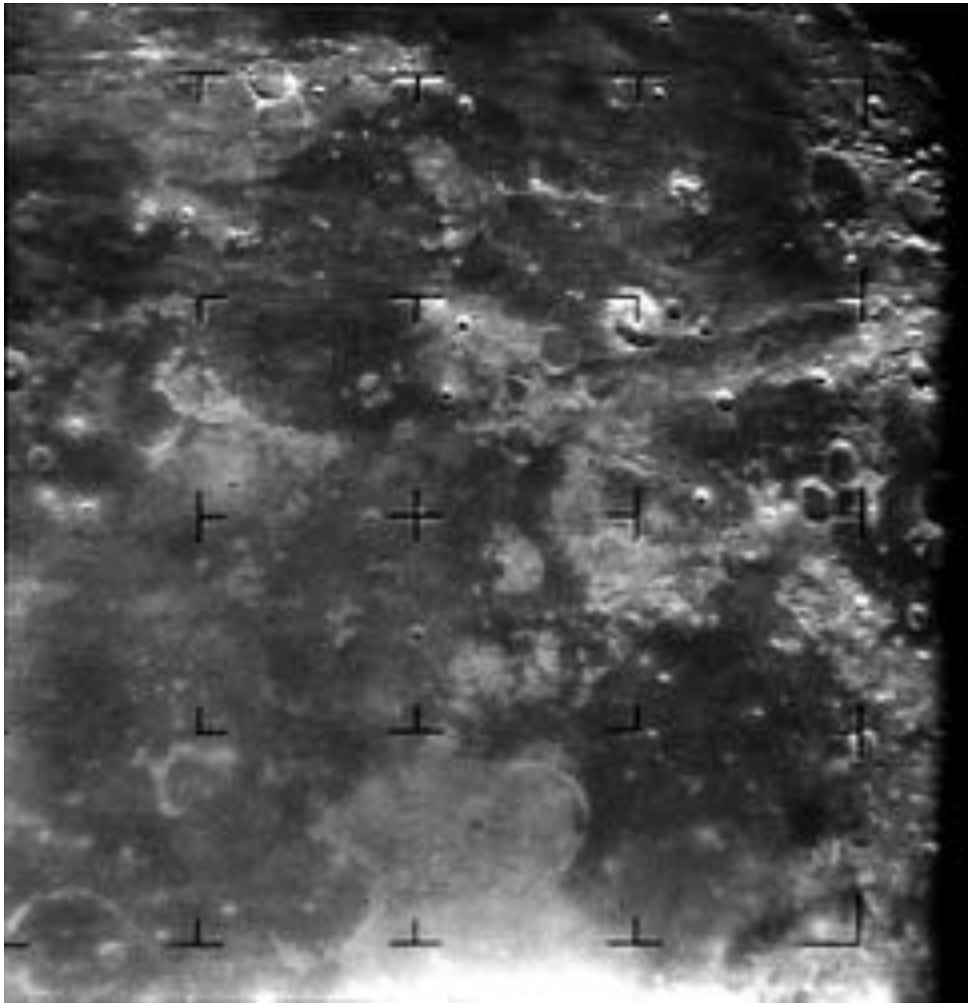
260

Antenna upgraded in 1964 to Cassegrain and new Maser receiver installed.

By 1965 the later Ranger missions were successful, and returned the first high resolution pictures of the moon. Taken by a US spacecraft.

In 1964 the telescope was upgraded to Cassegrain, and a new extremely sensitive receiver installed at the higher frequency of 2300 MHz.

I developed a new radiometer, and started studying variability in quasars and other radio sources beyond the Milky way. I used this work for my PhD, and published a number of papers on this work.



The Start of VLBI in 1970

A group in Australia, led by Dr DS Robertson were among the first in the world to develop VLBI using the NASA deep stations .

By then there were several NASA stations in Australia, several near Canberra, and the original one 1000km away in the Australian desert ideal for starting VLBI. They next used the California DSS14 station.

They used the station computer to record data onto magnetic tape, and once they were successful they invited us to join them and extend the baseline to South Africa.

We had a very successful program for nearly three years, studying objects that I had been observing to measure how they changed with time .

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- By then there were several NASA stations in Australia, several near Canberra, and the original one 1000km away in the Australian desert ideal for starting VLBI. They next used the California DSS14 station, with 64m antennas at each end of the trans-Pacific baseline. This provided exceptional sensitivity at the time.
- They used the station computer to record data onto magnetic tape, and once they were successful they invited us to join them and extend the baseline to South Africa.
- We had a very successful program for nearly three years, studying objects that I had been observing to measure how they changed with time .

NASA withdraws from South Africa.

The political pressures that were building up in the US congress eventually forced NASA to close DSS51. By then they had enough resources elswhere to by without a South African station.

It was a bolt out of the blue. Tracking staff at the station heard it on the 6 AM news service. I read it in the Rand Daily Mail, which quoted DRrHewitt saying that although NASA operations would end we would continue the radio astronomy program.

I was the only radio astronomer and had one electronics technician working with me. We were paid by NITR/CSIR, so our jobs were safe.

Converting from DSS51 to HartRAO

- The last operation as a NASA station was in June 1974.
- JPL/NASA removed most of the equipment but left enough of the older equipment so that we could get going as a basic radio telescope.
- We applied for funds to retain eight of the technical staff to help maintain and upgrade the facility.
- Slowly we grew the research staff from two people to a peak number of ten, and added new receivers.
- We obtained the standard equipment for VLBI and resumed VLBI operations, starting with programs that carried on the earlier work with Deep Space Network.

Key events and discoveries.

- The proposal to covert the station to a Radio Observatory was ambitious:
- We aimed to extend to multiple frequencies
- We would develop equipment and capabilities for Spectroscopy, Pulsar Timing, Continuum Radiometry and VLBI.
- We invited Rhodes University, who had a small program in radio astronomy to join us in using the facility and gave them an allocation of 25% of telescope time.
- Over the years they produced a number of MSc and PhD graduates, and used the telescope to map the entire sky at 2300 MHz.
- In 1977 we recruited Mike Gaylard who became the leader of the spectroscopy program. His early work earned him a PhD.

Key events and discoveries.

- In 1983 we recruited a young German, Axel Nothnagel, to establish a geodetic VLBI program. He completed a PhD based on work done here when he returned to Germany 5 years later, and is now President of the IVS.
- In 1986 we obtained the loan of a Mark III VLBI terminal and Axel led us into the era of precision VLBI. There were successive upgrades to Mark IIIa, Mark IV, Mark V and now Mark 6.
- Claire Flanagan, a Rhodes graduate joined us to develop the pulsar program and discovered important characteristics in pulsar glitch behaviour.
- Ludwig Combrinck started out as a technician and programmer, helping with VLBI operations. He completed degree studies part time, gained an MSc and PhD using GPS techniques, and has been instrumental in building an African network of precision GPS Stations as part of the International GPS Service (IGS) and developing the geodetic program

Key events and discoveries.

- In 2000 we started a contract with NASA to operate a Satellite Laser Ranging (SLR) station.
- We are now one of the few multi-technique geodetic stations in the world, and I believe one of the best –
- 30 years of precision geodetic VLBI measurements
- 20 years of precision GPS
- 15 years of SLR

- As a result of this HartRAO is now the reference datum for the South African mapping service

- The late Mike Gaylard and Gordon MacLeod, who joined our staff as a postdoc in 1991 discovered large numbers of methanol masers at 6.7 GHz. He will tell you more about this in his talks.
- Sharmila Goedhart, a PhD student, discovered periodic behaviour in methanol masers. She will be here later in the program.

Key events and discoveries

- HartRAO has worked with early global VLBI networks since 1979, including a major survey led by Bob Preston at using NASA deep space stations.
- Astronomical VLBI has always been a key component in our activities. We have worked with European VLBI Network (EVN) since 1983 and are now a full member of the EVN.
- We have worked with the Australian Long Baseline (LBA) since its inception.
- HartRAO has also been an important southern hemisphere station for two VLBI space telescopes, the Japanese VSOP mission in the mid 1990s, and the current Russian RadioAstron mission.

- Throughout all of this work we have had exceptional support from our technical team who have had to implement the many upgrades over the years.

- Alet de Witt, who joined HartRAO as a PhD student in VLBI after I retired, has injected fresh enthusiasm into geodetic and astrometric VLBI.
- She and her team have done a great job in organising this AVN training session
- I hope that this training program will be the basis for a successful collaboration with the SKA partner countries, and lead to the development of a powerful African LBI Network!

Thank You!