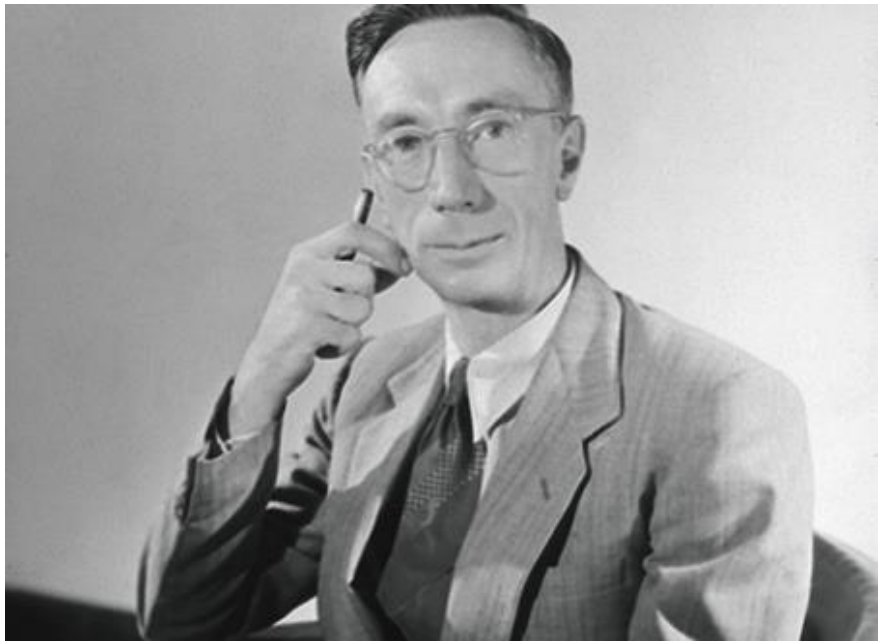
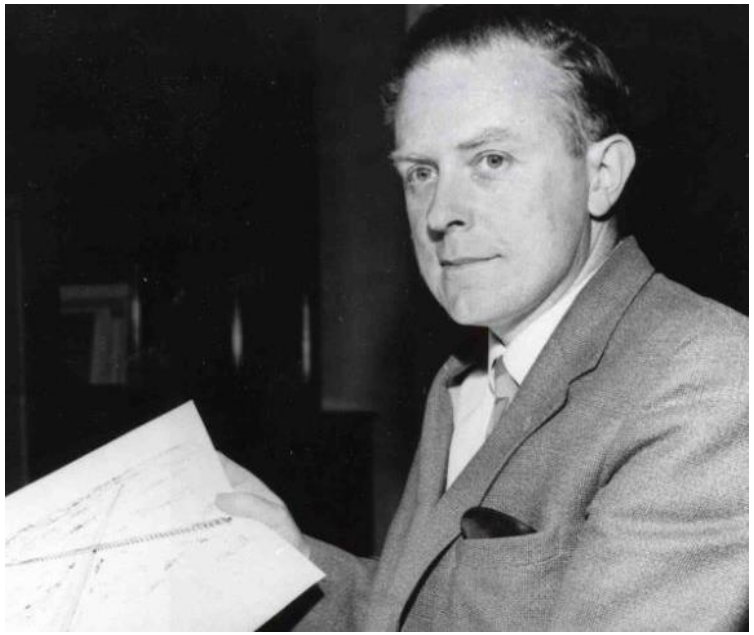
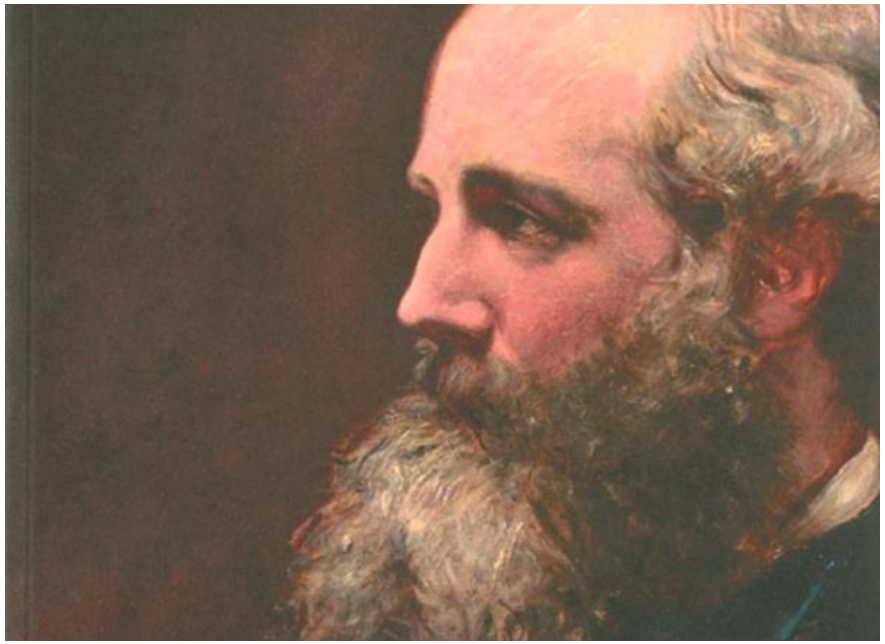




75 Years of Radio Astronomy at CSIRO & Sydney University.

1945-2020.



Pioneers of Radio Research.

Early Radio Research in England.

Cavendish Laboratory,
Cambridge.

31st July 1937.

Dear Madsen,

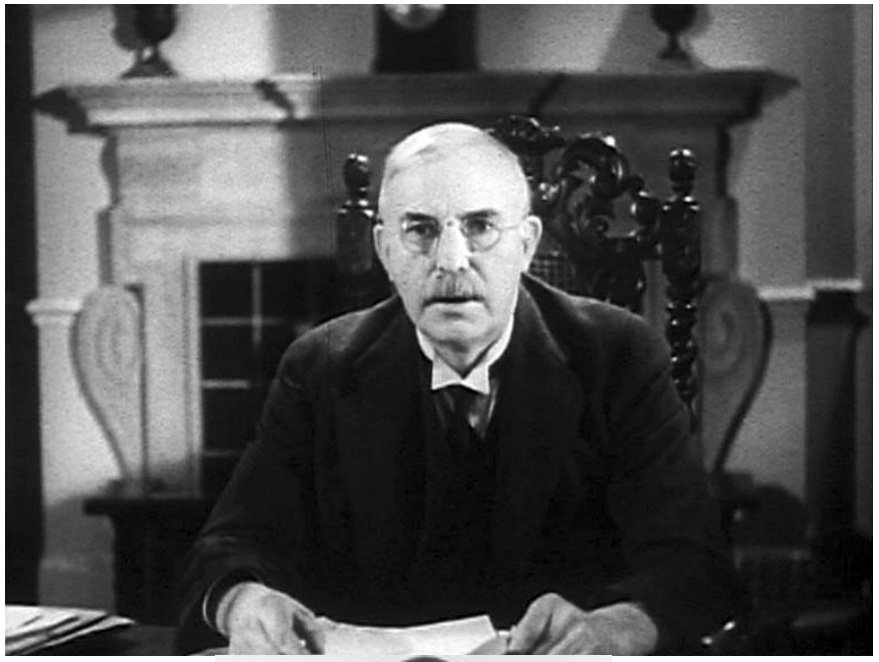
I have just received your letter and the copy of the letter for Nature which is sent in by Martyn and others of your group of workers.

I have heard the subject of their letter mentioned from time to time as a possibility, but it is very interesting to see the excellent relation between the radio observations and the disturbances in the sun. Unfortunately, Appleton is away on holiday for a week or two, so I have not had a chance to show him the letter and discuss the matter with him. He is an expert on the evidence in this type of problem.

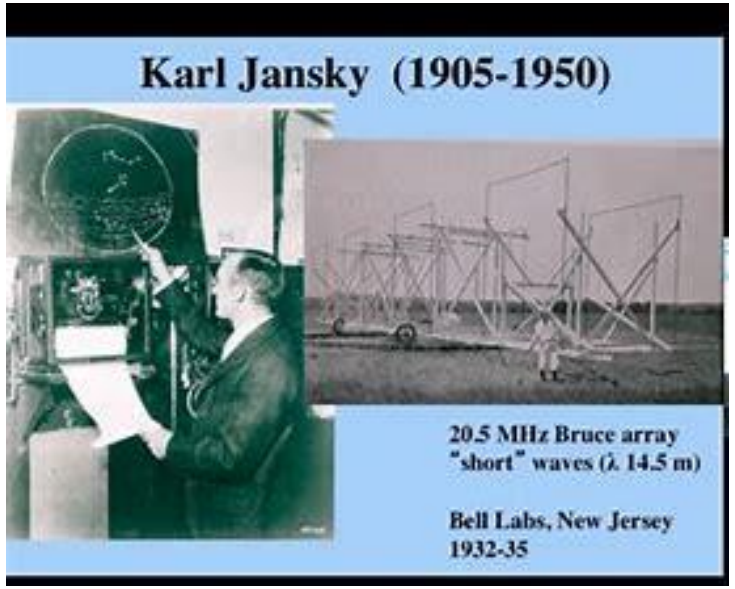
The only trouble I have is that the letter is rather long for Nature, owing to the fact that so many points are introduced and briefly discussed. If I might make a suggestion, I think it would be better in a future letter to concentrate on the main question and to leave out some of the details for subsequent publication in the ordinary way. Gregory tells me that he is deluged with letters, and, while he is anxious to publish as representative a number as possible, there is a limit to his space. However this is a small matter, and I should like to congratulate you all on the success that is attending your radio work. I hope that you will keep closely in touch with the corresponding work in this country. I was wondering whether you are in contact with the latest developments in connection with air defence, but I suspect that you will be, through the Australian authorities. My friend Wimperis is, I believe, visiting New Zealand and Australia shortly in connection with the Air Ministry. I hope you will have an opportunity of meeting him. He is a thoroughly sound fellow and a good friend of mine. We have played many a game of golf together.

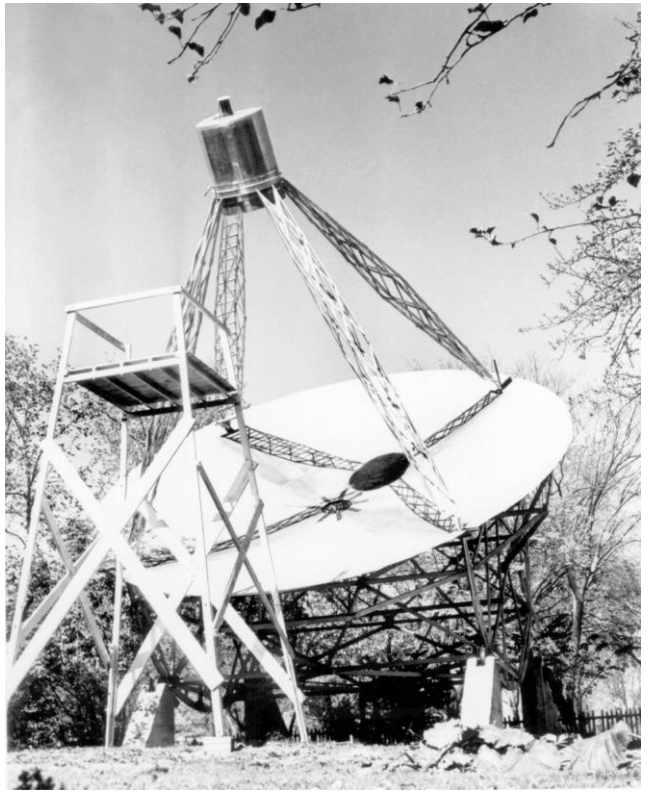
Yours sincerely,

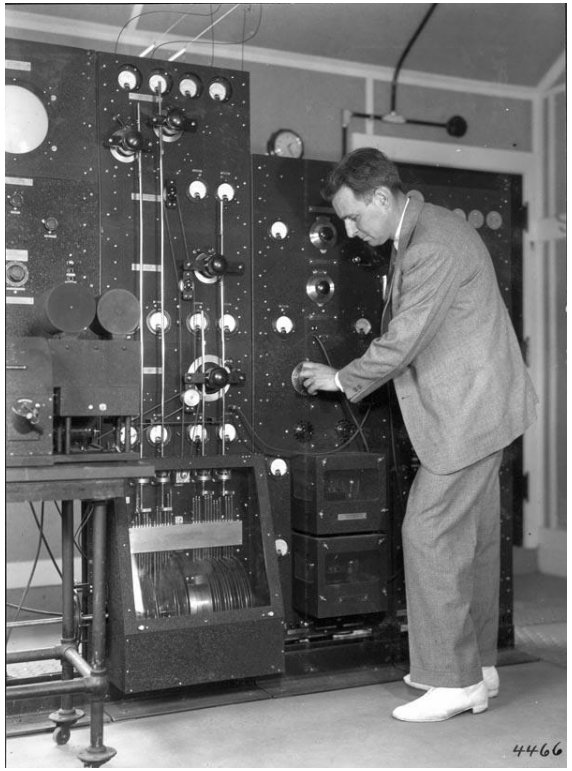
Rutherford



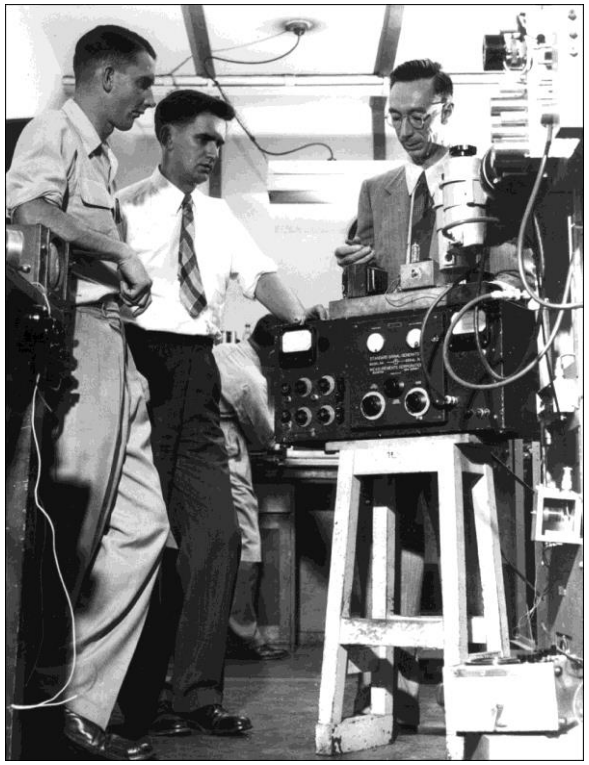
Early Radio Astronomy & Ionospheric Work in America.



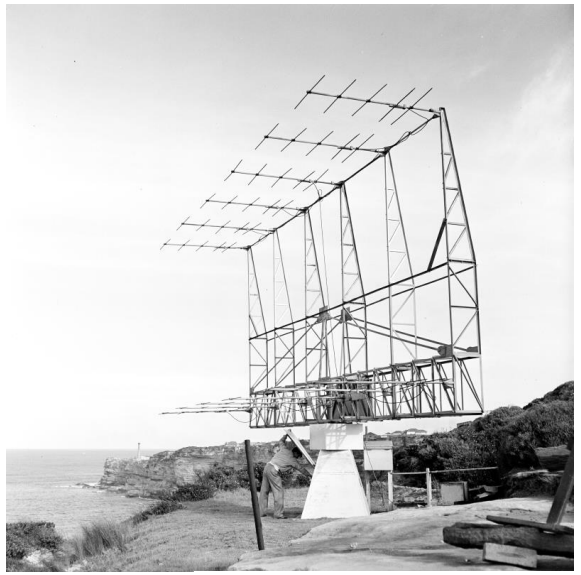


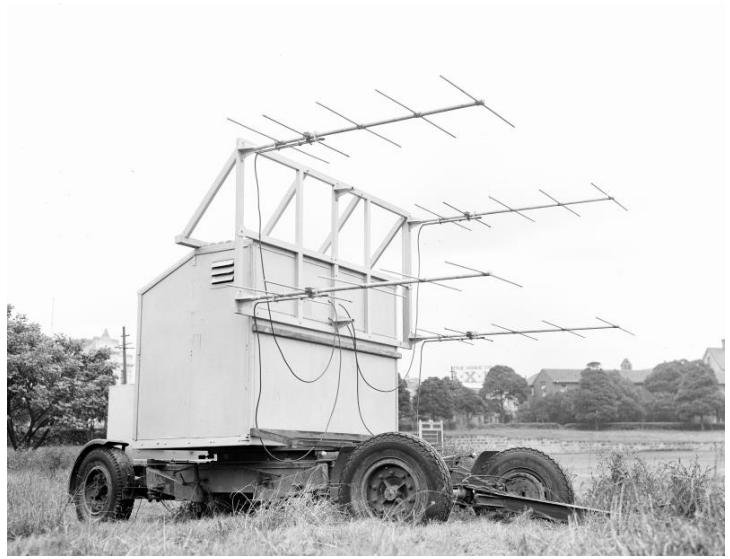


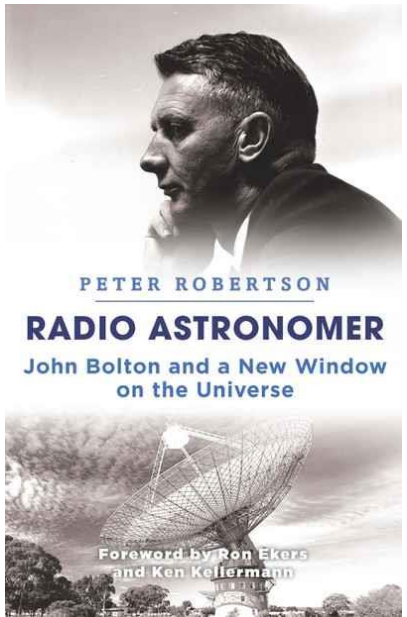
Joe Pawsey at Collaroy 1945. Taffy Bowen.

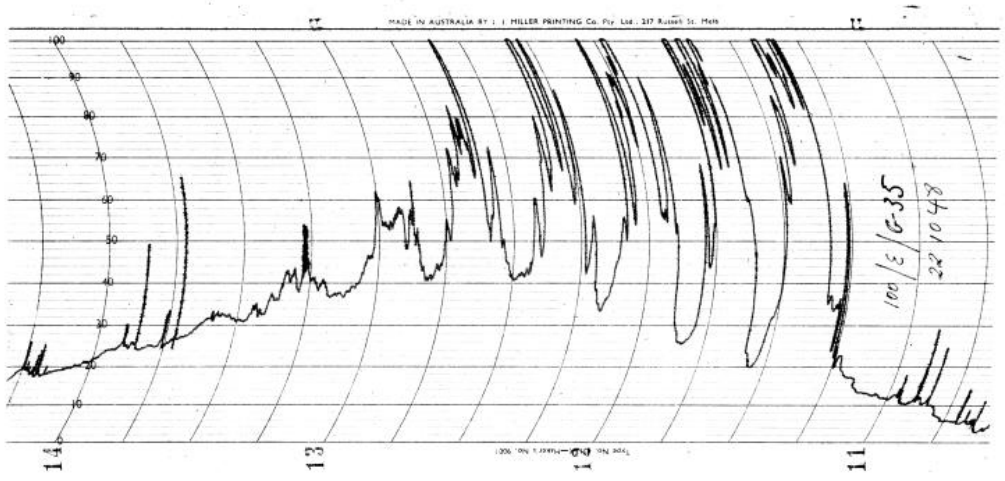


RPL & Dover Heights 1945-1950.

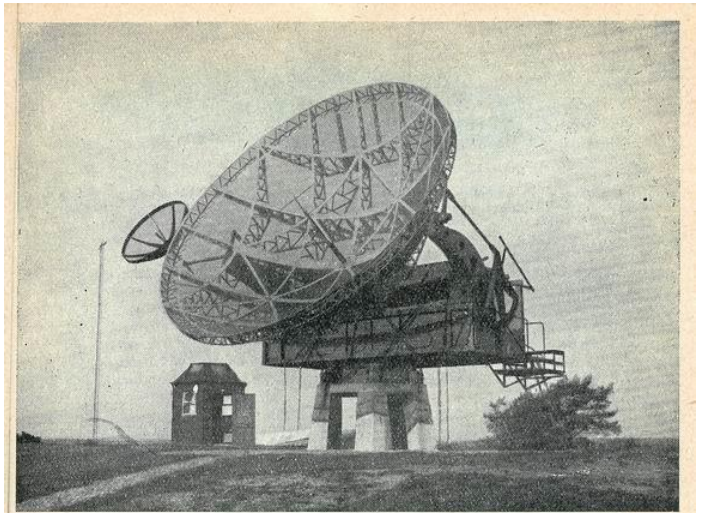


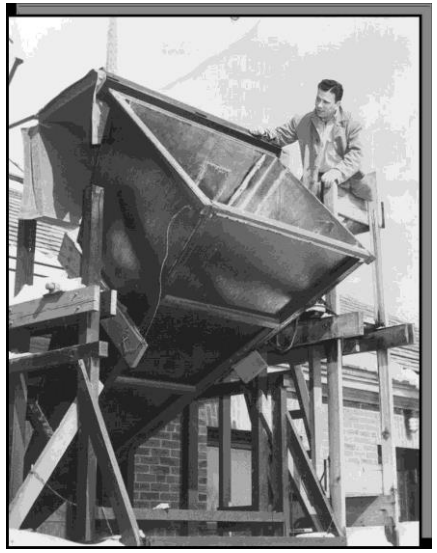


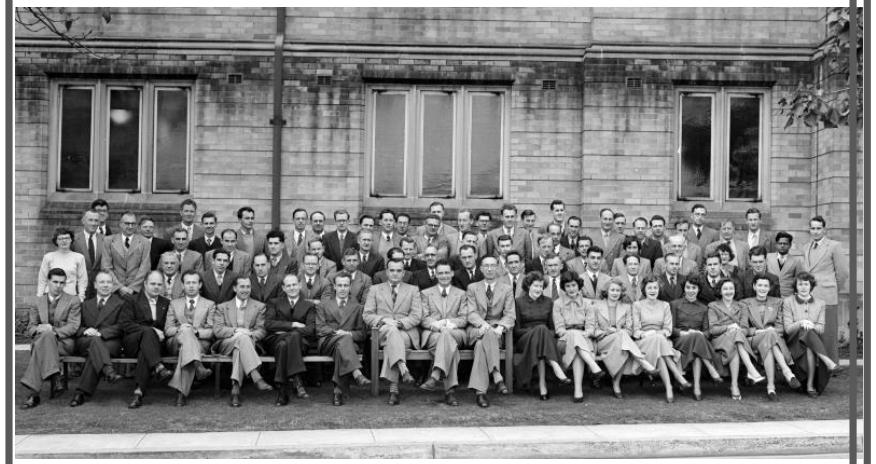




21cm Hydrogen Line & URSI 1952.

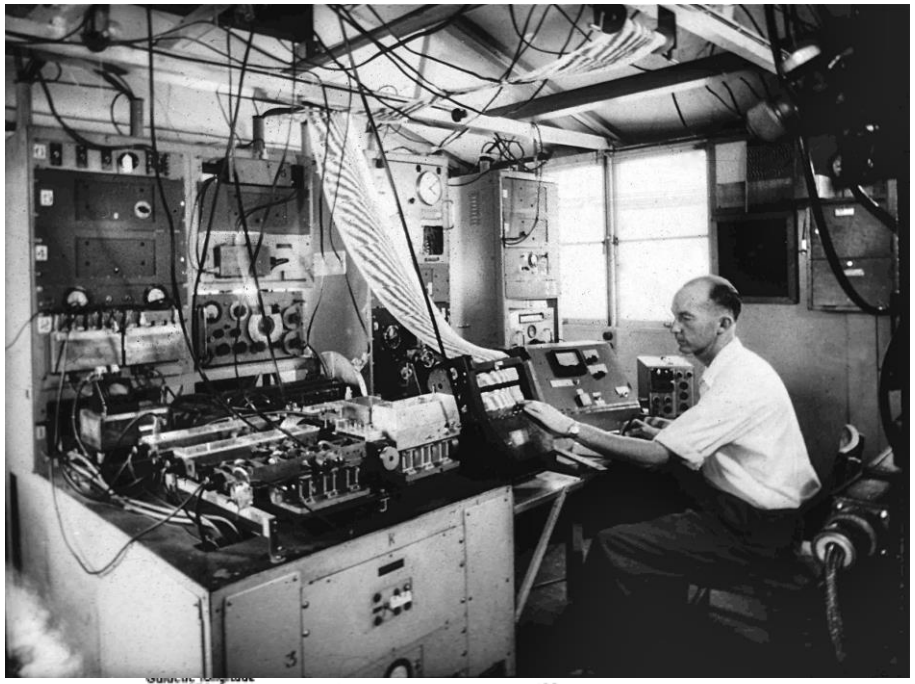


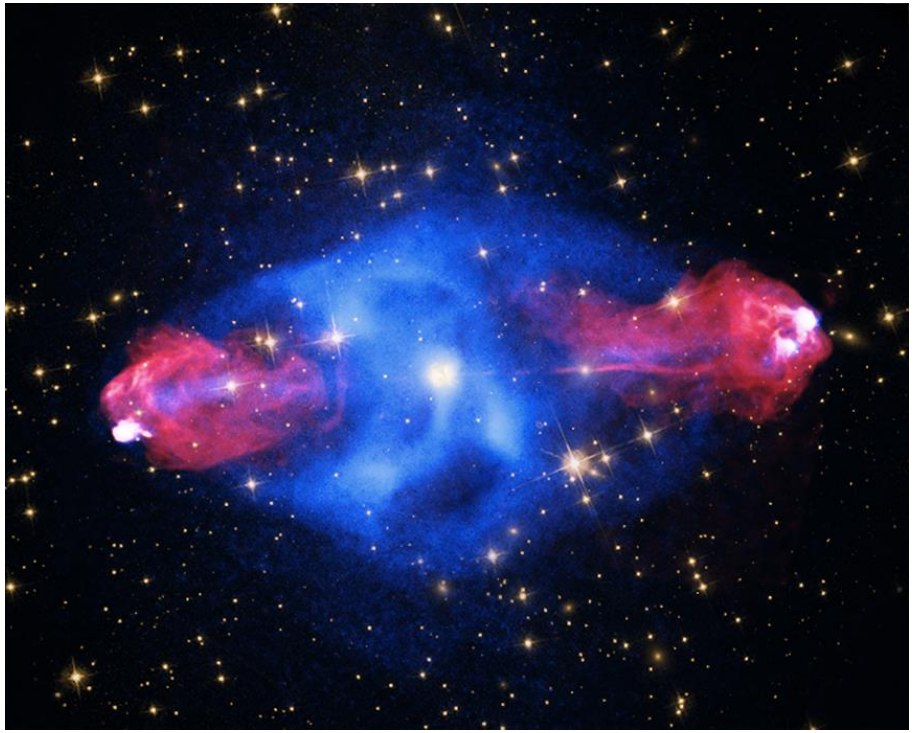


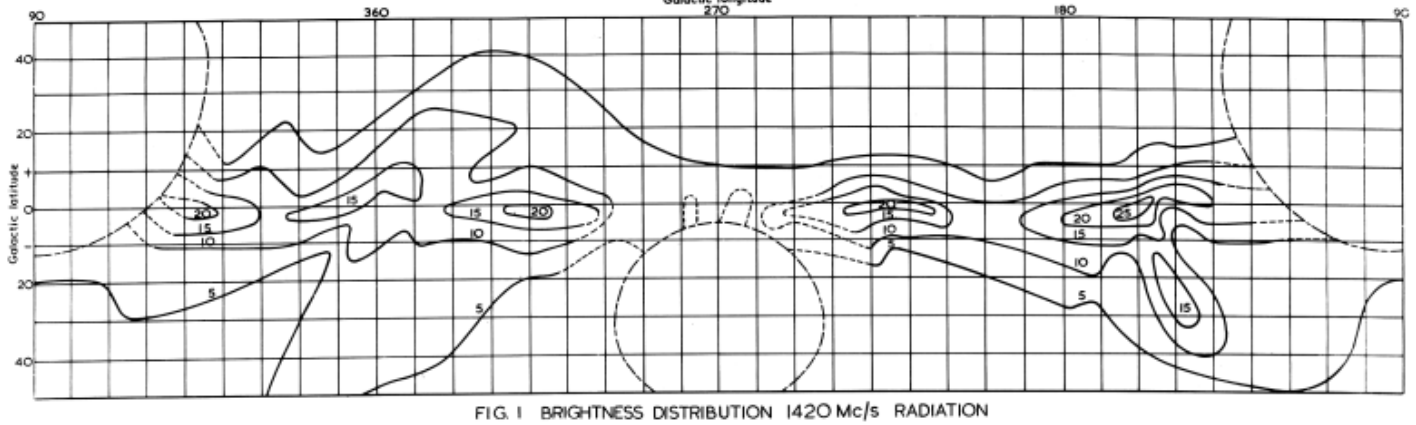


RPL & PottsHill 1952-URSI Organising Committee 1950.

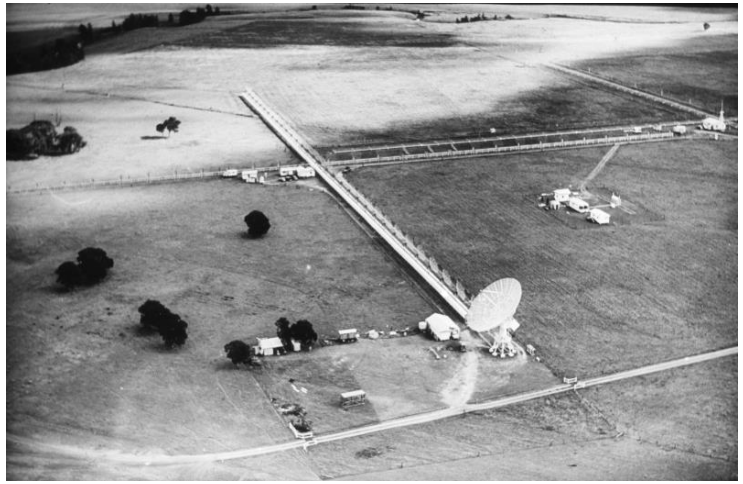
Galactic Hydrogen & Solar Observations.

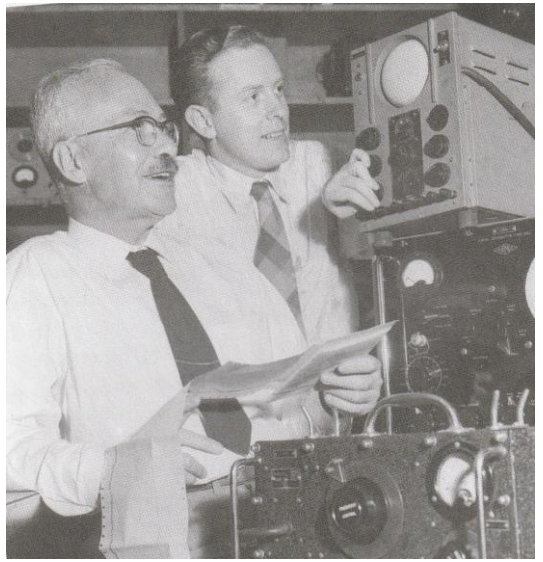


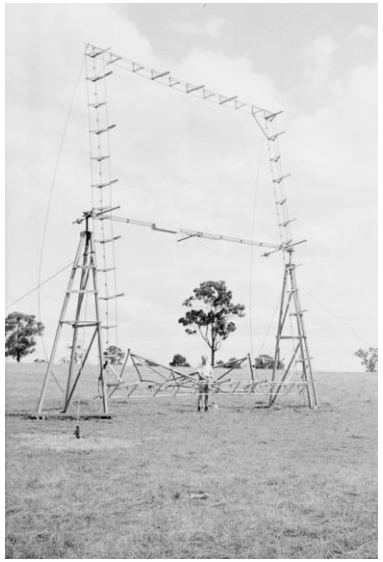




Jodrell Bank & Design for Parkes.

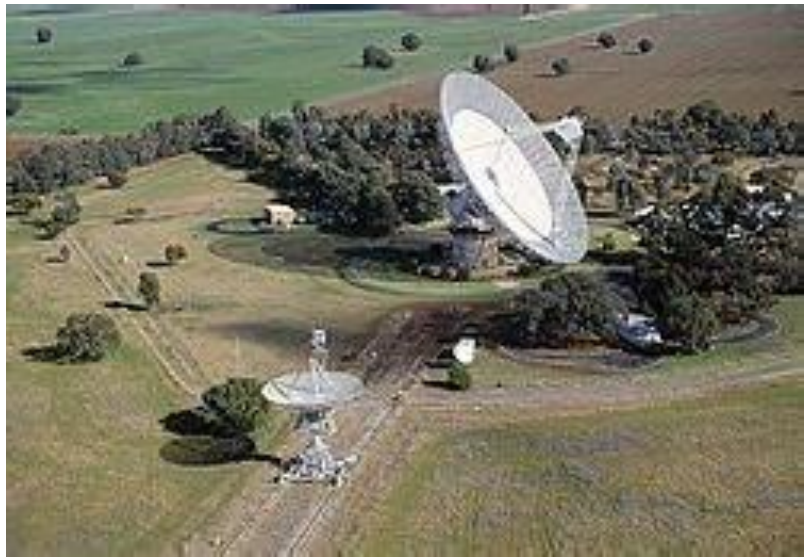




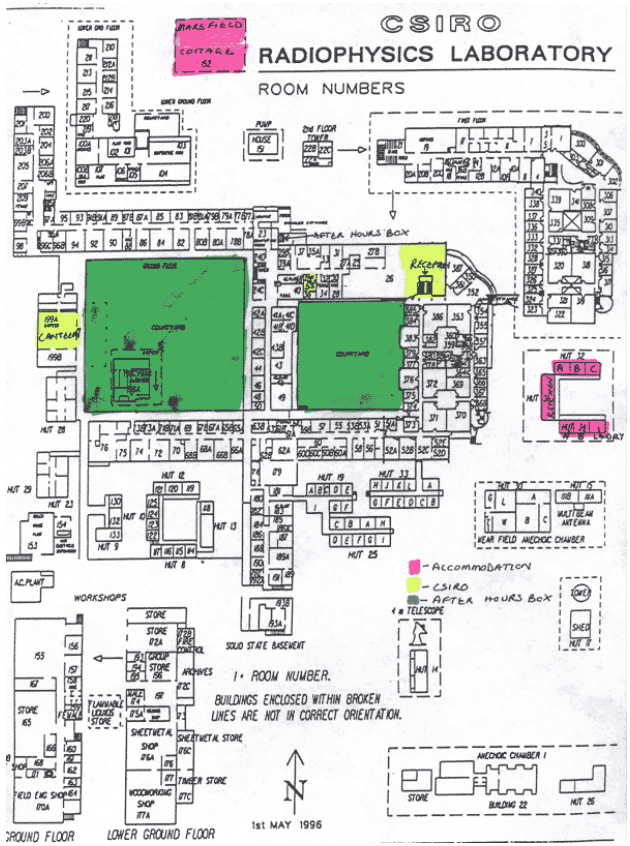


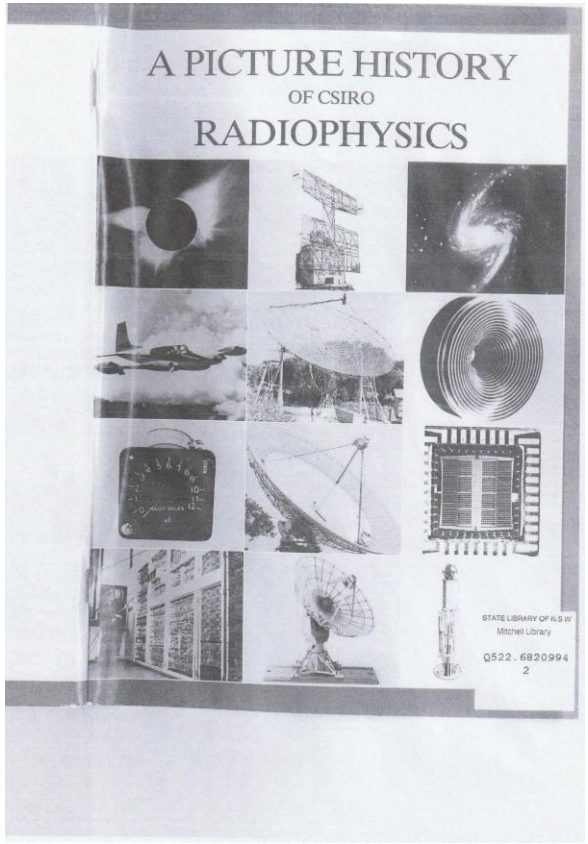
Fleurs & Badgerys Creek.

Parkes Radiotelescope.



Parkes & the Moon Landing: The Dish.





RPL Illustrated History & Marsfield.

Interscan: Paul Wild.

PRIME MINISTER
CANBERRA

16 May 1978

Dear Dr Wild,

I would like to congratulate you and all those in the Division of Radiophysics who contributed to the recent success accorded the INTERSCAN MICROWAVE aircraft landing system developed by CSIRO and the Department of Transport.

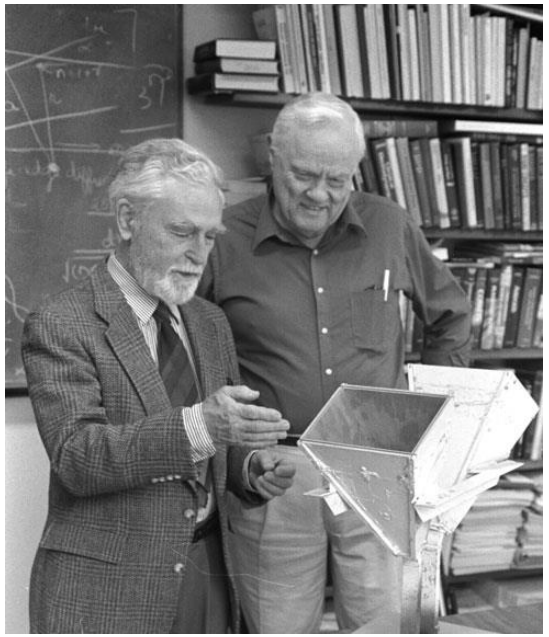
The recent adoption of the INTERSCAN system by the plenary meeting of the International Civil Aviation Organisation All Weather Operations Division, in preference to a strong field of contending technologies, is one of those singular achievements on which CSIRO's world reputation has been built, and is an expression of the high standard of its research activities.

Australia is now in a favourable position to participate in the international development of this system and the Government will be looking closely at its role in these further developments.

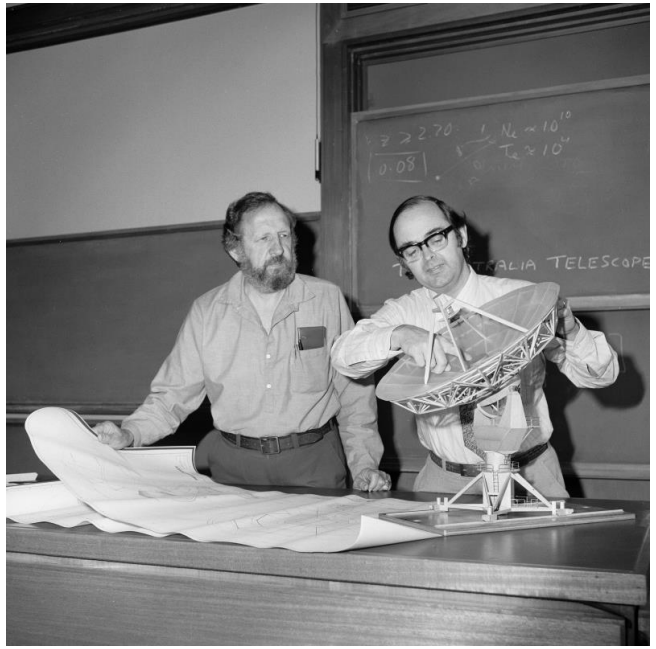
Yours sincerely,

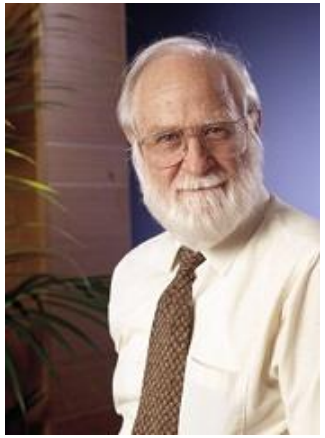
(Malcolm Fraser)

Dr J.P. Wild,
Chief,
CSIRO Division of Radiophysics,
P.O. Box 76,
EPPING N.S.W. 2121

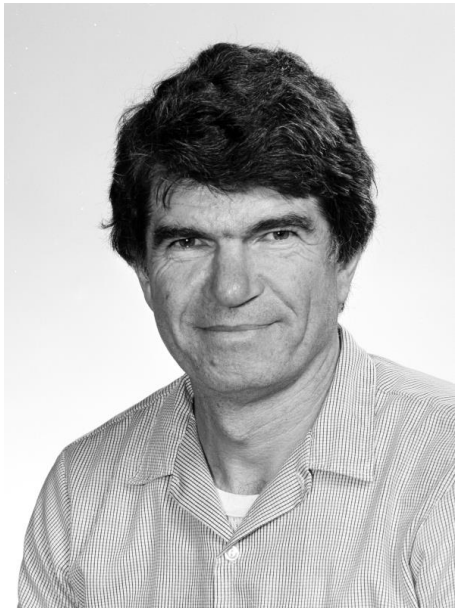


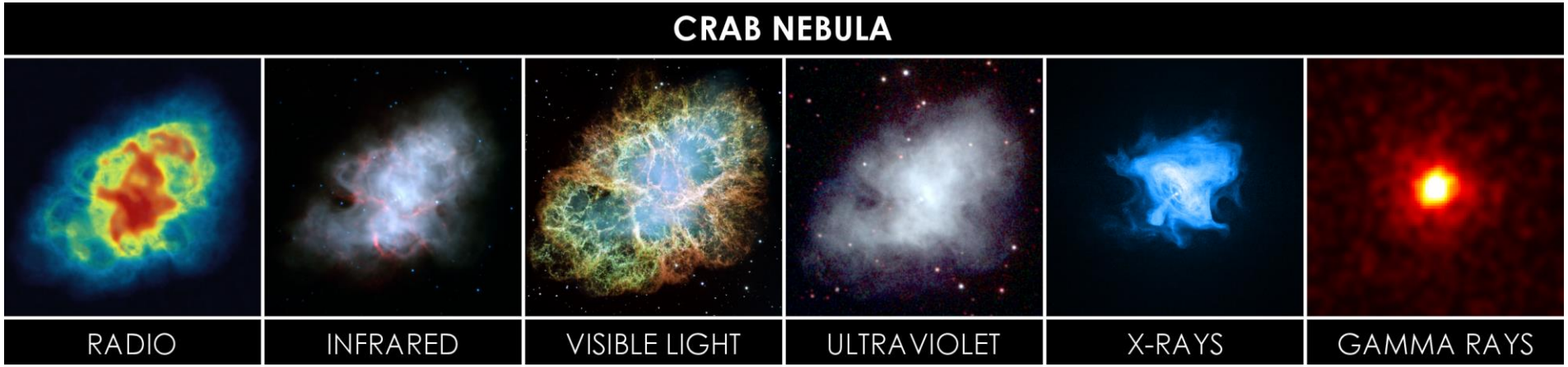
Parkes noteables up to 1996.



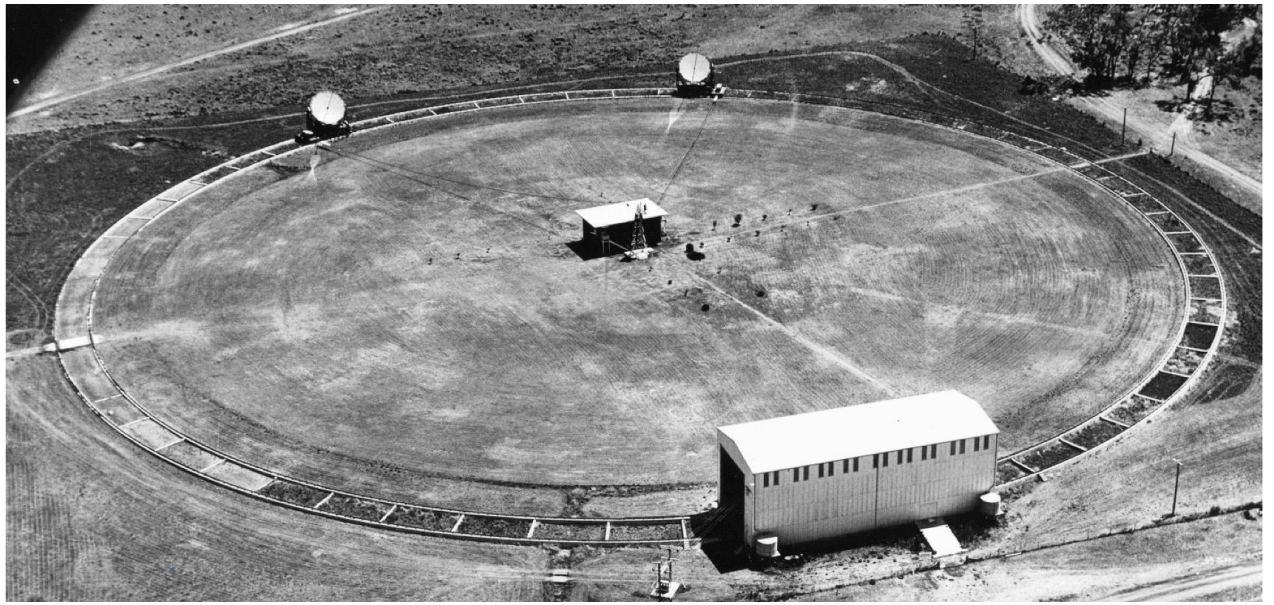


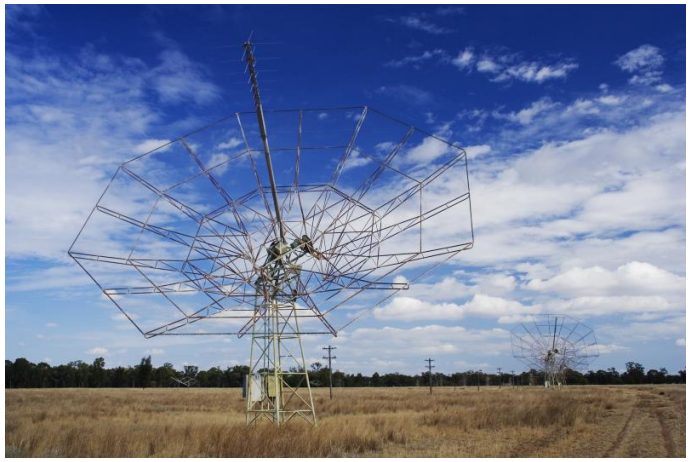
Parkes Specialist Technicians & Crab Nebula

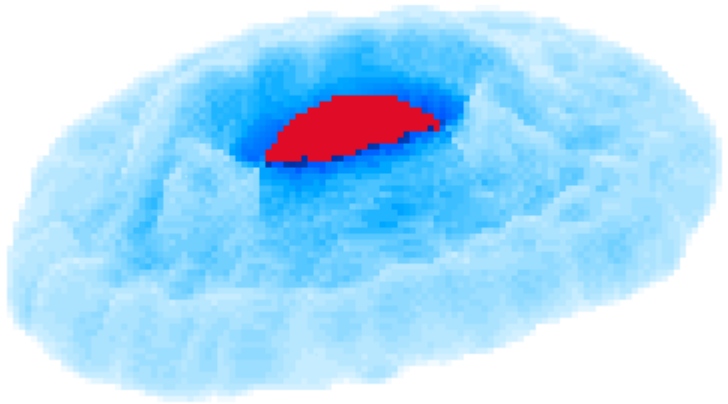


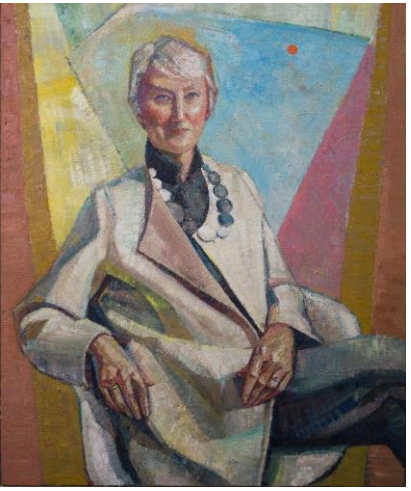


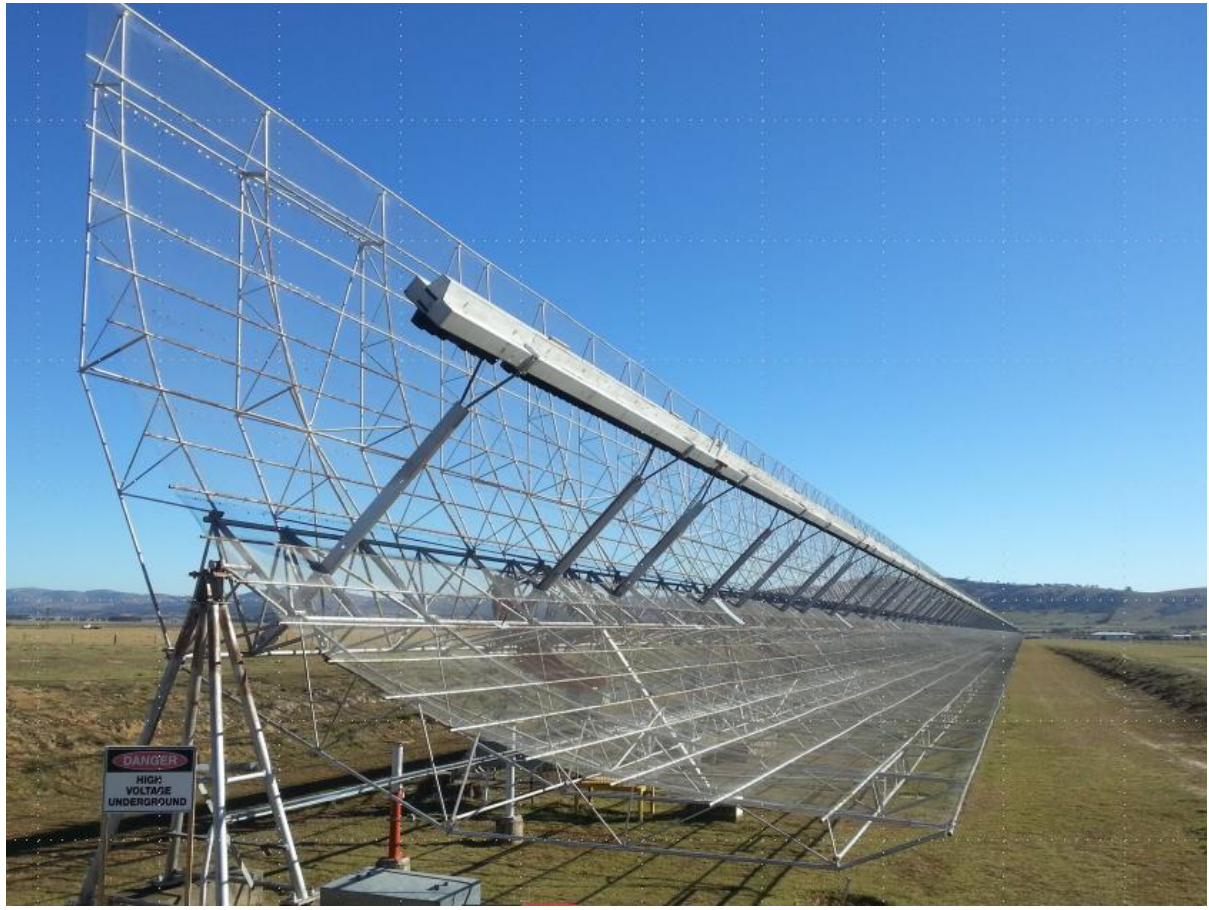
Narrabri Australia Telescope & Sydney University Stellar Interferometer.











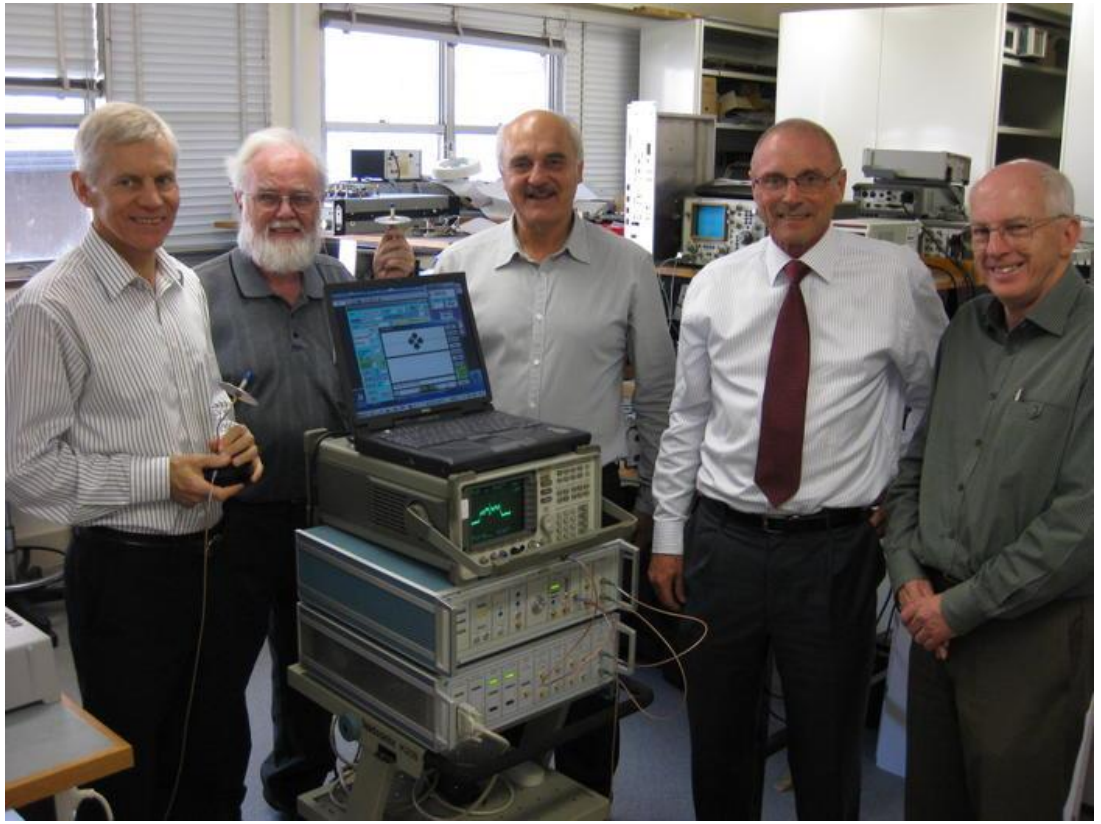
Sydney University Fleurs & Molonglo.

Sidings Springs & Tidbinbilla Deep Space.

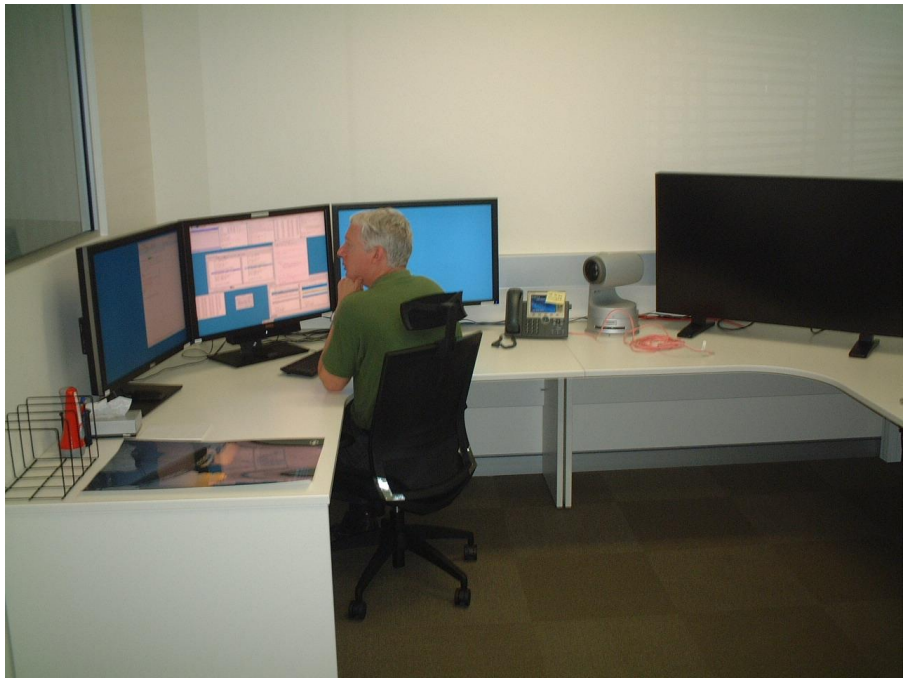
WiFi & Pulsars.

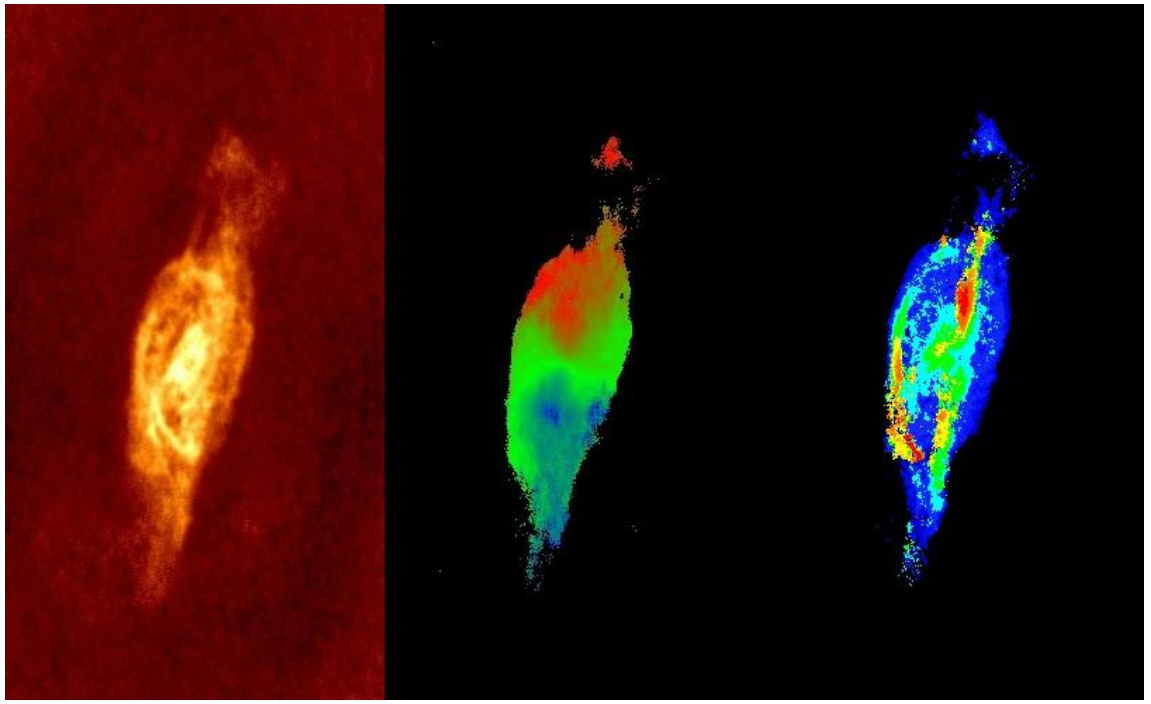
DISCOVERY

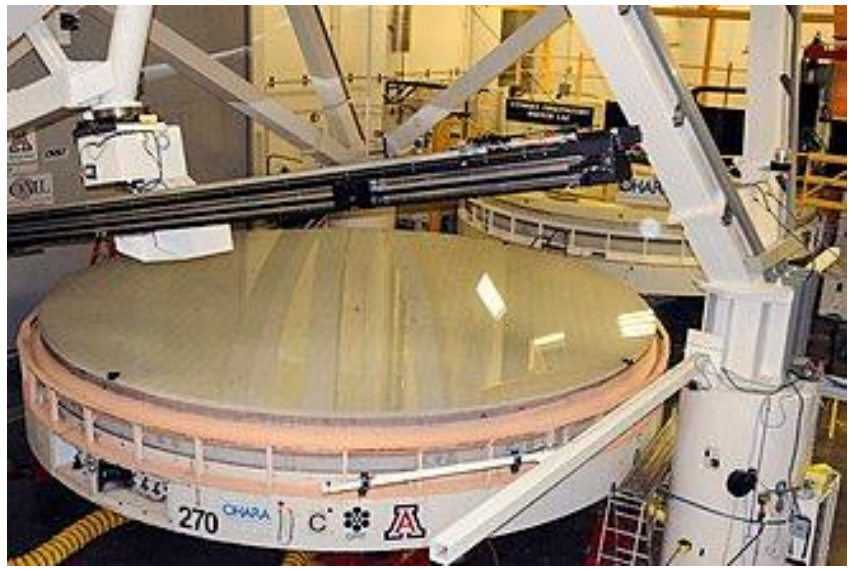
- First one discovered by Cambridge University Researchers Jocelyn Bell and Antony Hewish in 1967
- Detected pulses separated by 1.33 seconds from same position in the sky
- Second pulsar was discovered in the Crab Nebula with a period of 33 milliseconds; confirmed it was a rotating a neutron star
- Around 1600 pulsars found



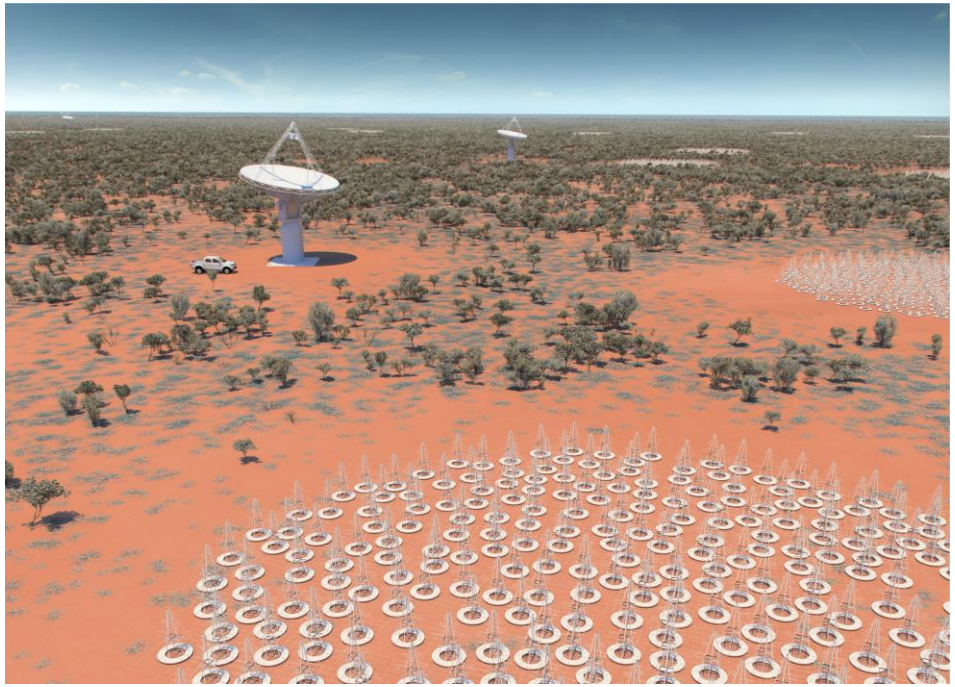
ATNF.





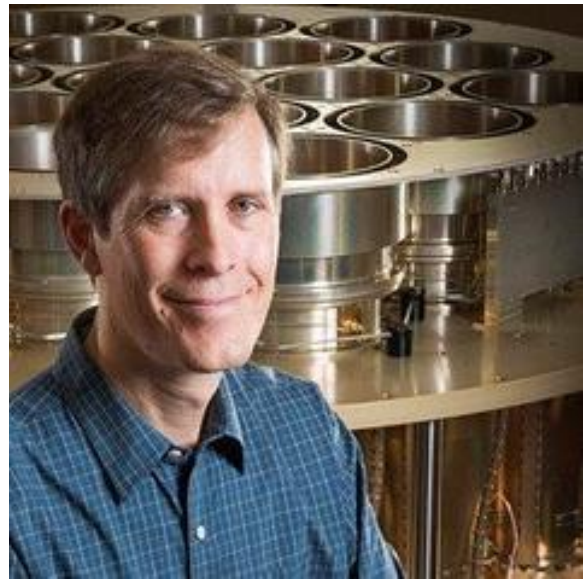


SKA Australia.

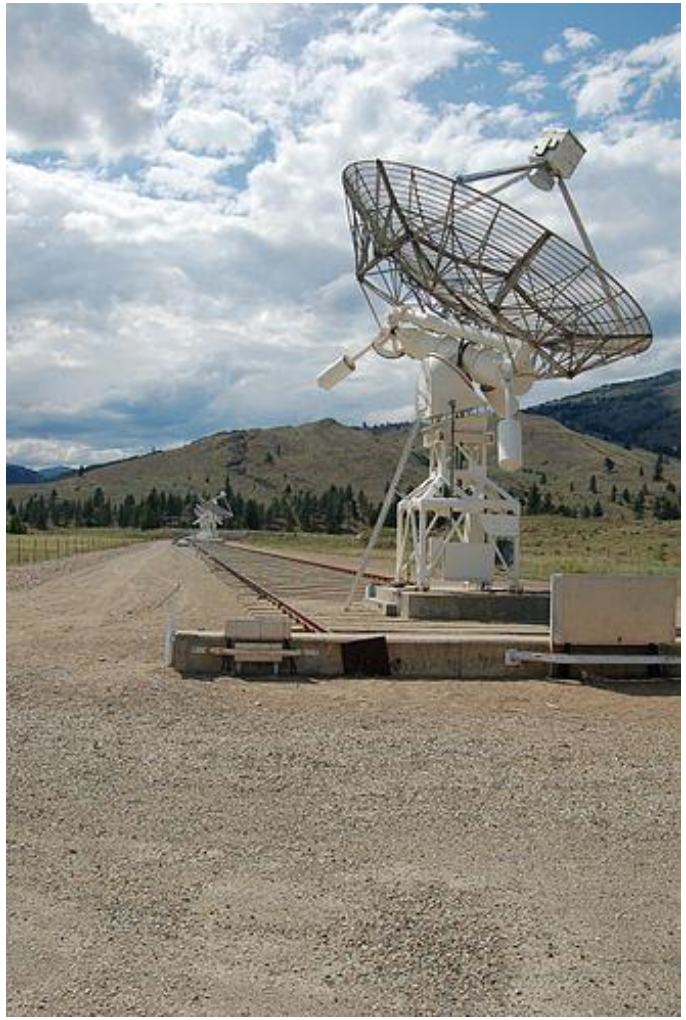


SKA Network & Leaders.

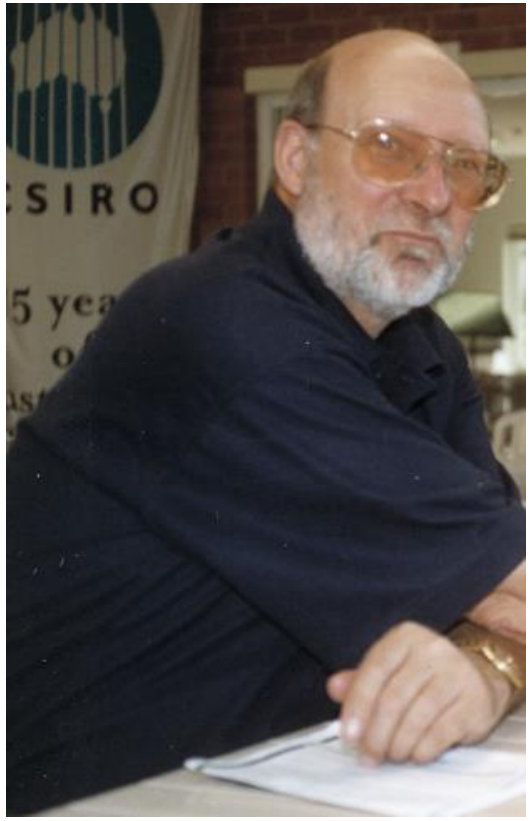
- Douglas Bock SKA Aust.
- Catherine Cesarsky Chair of SKA International in Manchester.
- Richard Schilizzi SKA Intnl & Lewis Ball SKA Aust.
- AARNet fibre optic network for CSIRO & Universities.

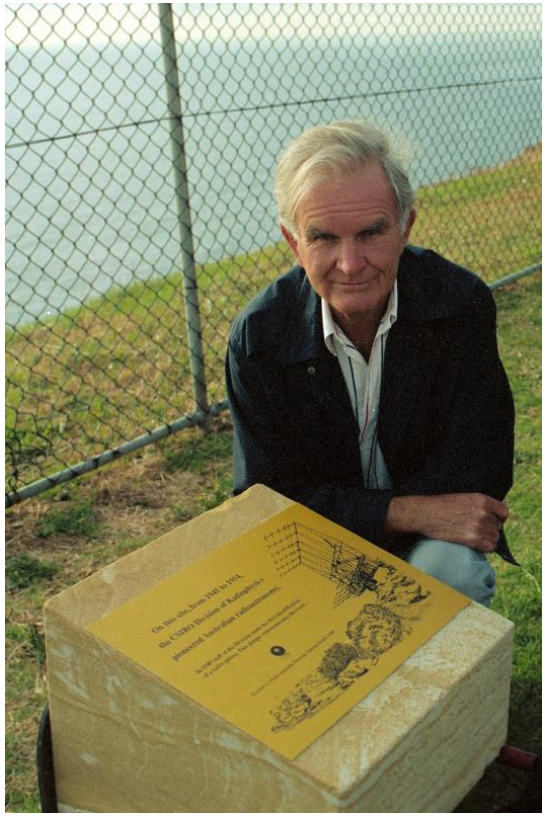


New Zealand & Canada.



RPL & ATNF Communicators.





75 Years of Radio Astronomy at CSIRO & Sydney University.

Prepared by: R.W.Madsen July 2020.

Introduction.

In both Australia & the UK at the end of WW2 radar scientists quickly salvaged what radar & other equipment they could use in the new field of radio astronomy. Radar itself owed its origins to Radio Research & the connection of all 3 areas of scientific research are closely linked. In America after the war, radio astronomy was taken up at Cornell & within 10 years a radio astronomy observatory was established at Owens Valley California in which John Bolton & Gordon Stanley played a significant role.

The Australian Radio Research Board was established by J P V Madsen in 1928 within CSIR & up to WW2 was involved with investigations of the ionosphere, led by JPVM himself based on Sydney University, & investigations of atmospherics & suitable frequencies to be used by radio stations led by Prof. Tom Laby at Melbourne University up to 1939. At the beginning of WW2 Madsen recruited RRB experienced physicists into the newly formed CSIRO-Radiophysics Laboratory located within an expanded National Standards Laboratory in the grounds of Sydney University to work on RDF/Radar & subsequently during the War BSc/BE graduates from Australian Universities were added to the growing number of scientific staff. Notably Taffy Bowen from the UK in 1944 was recruited after experience at MIT on the Tizard Mission dealing with the 10 cm magnetron.

In 1937 Rutherford replied to JPVM concerning publication of RRB work by D F Martyn & others in which he says " it is very interesting to see the excellent relation between the radio observations & the disturbances in the Sun". Joe Pawsey's observations of the Sun at 200 MHz using the Collaroy radar station in October 1945 was very fortunate & it also became apparent how very high the temperature of the Sun was in the corona region. This work marks the commencement of radio astronomy by CSIRO firstly with solar work, Galactic work & then Hydrogen Line.

The role of Sydney University in radio astronomy is linked to CSIRO in a number of ways such as the siting of RPL in the grounds of the University up to 1973, the education to double degree BSc/BE qualification for graduates entering the field & was also the principal site of URSI in 1952. In 1960 when Bernie Mills & Chris Christiansen moved from RPL to Sydney University this marked a more direct role in radio astronomy using the Mills Cross & Chris Cross.

It needs to be mentioned the work of J A Ratcliffe at the Cavendish in Cambridge who trained under Rutherford & did much valuable radio work on the ionosphere & radio astronomy supervising several Australian PhD's such as Joe Pawsey, Ron Bracewell, Brian Robinson & probably Jack Piddington.

Slide 1. 75 Years of Radio Astronomy at CSIRO & Sydney University.

Joseph Lade (Joe) Pawsey, (1908-1962). [Cambridge under Jack Ratcliffe]. In 1946 began observations with the sea interferometer at Dover Heights a technique of his own design. Interferometry became the fundamental principle of many of the world's radio telescopes, including the Australia Telescope operating in the Aperture Synthesis mode, was completed at Narrabri in 1988.

Wilbur Norman (Chris) Christiansen (1913-2007). [BSc, MSc Melbourne University 1934/1935]. Built the first grating array for scanning the Sun at the Potts Hill radio astronomy field station. At

Fleurs he built the Chris Cross Telescope & in 1960 until 1978 was Professor of Electrical Engineering at Sydney University. Chris was with CSIRO Radiophysics 1948-1960. URSI 1952 photo.

J V (Jim) Hindman. Partnered with Chris Christiansen on the confirmation of the 21 cm Hydrogen Line.

Balthaser Van der Pol (1889-1959). Physicist/Mathematician at Philips Research Laboratories in Eindhoven 1921-1948.

Frederick William George (Fred) White (1905-1994). [Cambridge with J A Ratcliffe]. CSIRO Executive in charge of Radiophysics & with vital experience with Radar at RPL 1941-1945.

Sir Edward Victor Appleton (1892-1965). President of URSI & with Radio & RDF/Radar experience from 1926 in the UK at Cambridge, Kings college London & DSIR. Nobel Prize winner for radio work.

Bernard Yarnton (Bernie) Mills (1920-2011). [BE 1942 Sydney University, DSc 1959]. Designer of the Mills Cross 1954 at CSIRO Radiophysics & later at Sydney University School of Physics with the development of the Molonglo Observatory Synthesis Telescope. In 1967 the Molonglo Cross Telescope became operational.

Thomas Howell Laby FRS (1880-1946).[Sydney University & Cambridge]. Professor of Physics Melbourne University. In 1929 joined up with JPVM at the RRB doing the atmospheric work for radio stations but resigned in 1939 when RRB staff went into radar work.

J P V Madsen (1879-1969). 1935 photo from the SMH with Tom Laby probably on the final outcome of radio station frequency work. In 1958 after 30 years as Founding Chairman of the RRB, JPVM was encouraging research into satellite communication following the then recent launch of the Russian Sputnik.

Slide 2. Pioneers of Radio Research.

Michael Faraday FRS (1791-1867). Faraday established that magnetism could affect rays of light & that there was an underlying relationship between the two phenomena.

James Clerk Maxwell (1831-1879). In 1864 Maxwell's classical theory of electromagnetic radiation brought together for the first time electricity, magnetism & light. In 1865 Maxwell demonstrated that electric & magnetic fields travel through space at the speed of light.

Heinrich Hertz (1857-1894). Between 1886 & 1889 Hertz conducted a series of experiments showing that the effects that he was observing were due to Maxwell's predicted electromagnetic waves.

Guglielmo Marconi (1874-1937). Received the Nobel Prize in Physics in 1909 in recognition for his contribution to the development of wireless telegraphy. Marconi's first demonstration of his wireless system to the British Government was in July 1896. In December 1901 he transmitted a signal from Galway in Ireland to St Johns Newfoundland.

Slide 3. Early Radio Research in England.

Ernest Rutherford PRS (1871-1937). Rutherford in NZ in 1895 before going to Cambridge to take up an Exhibition Scholarship was interested in radio work & over 2 years invented a new form of radio receiver but in 1896 discovered that he had been outdone by Marconi. In 1937 he suggested the best method of publishing material in Nature & supporting journals.

Robert Watson Watt FRS (1892-1973). The 1919 wireless station of the Meteorological Office at Aldershot is shown where Watson Watt had the idea of using radio waves to detect thunderstorms & provide a warning to aircraft. In 1928 Watson Watt provided his equipment to the RRB in Australia as part of his idea of having an international network of such observatories.

John Ashworth (Jack) Ratcliffe FRS (1902-1987). [Cambridge]. Prior to WW2 at the Cavendish did work on the investigation of the ionosphere. After WW2 radar work at TRE he joined up with a radiophysics group at the Cavendish including M Ryle & A Hewish. Supervised PhD workers including Australians.

Slide 4. Early RadioAstronomy & Ionospheric work in America.

Karl Guthe Jansky (1905-1950). [Bell Labs 1932-1935]. Jansky's Merry Go Round (100 ft diameter & 20 ft tall) was designed to receive radio waves of 14.6 metres (20.5 Mhz) over several months the results of which he categorized as thunderstorms, distant thunderstorms & faint hiss of unknown origin- he thought it might be the Sun but could not establish this.

Grote Reber (1911-2002). In 1937 Grote built his radio telescope in Wheaton Illinois consisting of a 9 metre parabolic sheet covering a metal dish focused to a receiver 8 metres above the dish which could be tilted but not turned. His first receiver operated at 3300 MHz , the 2nd at 900 MHz & finally a 3rd at 160 MHz in 1938 which was successful. In 1954 Reber moved to Tasmania & carried out work on low frequency emissions for many years.

Lloyd Berkner (1905-1967). Berkner invented a device for measuring the electron density in the ionosphere which has become standard to IPS facilities worldwide. Berkner worked in the 1930's with the Carnegie Institutes Dept. of Terrestial Magnetism in Washington. Berkner installed his equipment at the DMT Watheroo station near Perth in 1939 & then spent 6 months with the RRB in Sydney.

Slide 5. Joe Pawsey at Collaroy 1945. "Taffy Bowen".

Collaroy RS at 200 MHz (1.5 mtrs). On October 3, 1945 earlier radar observations of radio waves being received from a rising sun was confirmed setting Joe Pawsey on to a career in radio astronomy.

John Bolton, Gordon Stanley & Joe Pawsey.: John Bolton (1922-1993) [Cambridge 1940-1942]. Joined CSIRO in 1946 until 1955 & then returned in 1961 to direct the Parkes telescope until 1981 as an astronomer at large. Was involved with the constant interaction between radio astronomy & optical astronomy.

Gordon James Stanley (1921-2001). Joined RPL in 1944 & became expert in design & construction of antennas & receivers. At Dover Heights he worked with John Bolton & Bruce Slee on the detection of emissions from Cygnus.

Edward George "Taffy" Bowen (1911-1991). Joined RPL from the UK in 1944 & from 1946 was Chief of the Radiophysics Division until 1971. Wartime contacts while on the Tizard Mission put him in contact with Vannevar Bush & Alfred Loomis from whom in 1954 he was able to arrange $250 k funds from the Carnegie & Rockefeller foundations towards the cost of what was to become the Parkes telescope.

Robert Hanbury Brown FRS (1916-2002). [At URSI 1952 from UK]. Joined Bernard Lovell's Manchester radio astronomy group in 1949 until 1961. In 1962 he moved to Sydney University &

built his next interferometer- the Narrabri Stellar Intensity Interferometer (NSII) consisting of 2 X 23 ft telescopes. He remained in Aust for 27 years much longer than his expected 2-3 years.

Slide 6. RPL & Dover Heights 1945-1950.

The CSIRO RPL & Standards Laboratory (1940-1970's) at Sydney University. Now known as the Madsen Building.

4 Yagi Antenna. A 200 Mhz located on the blockhouse in February 1947 for solar observations & later discrete sources. Used in conjunction with 2 Yagi array at 60 & 100 MHz & also a single Yagi at 85 MHz.

12 Yagi antenna. Largest & last of sea interferometers. In 1953 produced a catalogue of 104 sources with their positions & properties.

4 Yagi Mobile for NZ July 1948. A 100MHz receiver, recorders, chronometers & weather recording instruments used at Pakiri Hill on the east coast at 3 times the height of Dover Heights & then at PIHA on the west coast.

John Bolton "Radio Astronomer" by Peter Robertson. A very informative work on John Bolton's career . Originally from Sheffield in England as was Paul Wild.

Hole in the ground telescope. Built in 1950 & first used as a 72 ft dish at 160 MHz & then extended to 80 ft to survey the plane of the Milky Way by tilting the feed mast over a range of angles as the Earth turned mapping successive strips of the sky.

1947-1948 Cygnus Observations:. A distinctive Cygnus interference pattern was 1st recorded on June 19, 1947 at 10.00 pm & subsequently.

Slide 7. The 21 cm Hydrogen Line & URSI 1952.

The Dutch Wurzburg at Kootwijk 1951: This 7.5 mtr ex German Wurzburg was used by C A Muller & J H Oort to confirm the Dutch theory of c.1944 that hydrogen radiation would be emitted at 21cm.

URSI 1952 Dinner: F W G White, JPVM, Edward Appleton- President of URSI for many years.

3 Rhombic antennae at Dapto: The spectrograph became operational in August 1952, preceeded by work at Penrith. The equatorially mounted antenna to track the Sun were tuned to 40-75 MHz, 75-140 MHz & 140-240 MHz respectively.

Harold "Doc"Ewen (1922-) 21 cm horn: The experiment at the Harvard Lyman Lab in March 1951 detected the 1st hydrogen emission at 21 cm & confirmed soon after in the Netherlands & Sydney. E M Purcell (1912-1997) worked together with Ewen.

H Line Group at URSI 1952: (L to R):F.Kerr (Aust), P.Wild (Aust), J Hindman (Aust), H.Ewen (USA)., C. Muller (Neth), W. Christiansen (Aust). In July 1951 details of the experiment & the 2 confirmations were published in Nature.

Slide 8. RPL & Potts Hill 1952- Australian URSI Organising Committee 1950: JPVM as Australian President for URSI 1952 heads up the organizing committee (the identity of the Indian chap at the front remains unknown).

RPL Staff 1952: Taffy Bowen heads up the RPL Division photo.

Potts Hill 16 ft X 18 ft Parabola: This antenna was used for the 1st Australian Hydrogen Line observation on July 12, 1951.& also used for many other projects.

Slide 9. Galactic Hydrogen & Solar observations.

Jack Piddington (1910-1997). [Sydney Uni BSc, BE 1932-34, Cambridge PhD 1938]: Very valuable work on AW radar in1941. Collaborated with Harry Minnett working on micro wave astronomy & observations of the Sun & Moon. Worked on theoretical astrophysics, plasma physics, the ionosphere & magnetosphere.

Kevin Sheridan Dapto Solar Observations: Joined CSIRO in 1945 & was chief engineer receiving data in the makeshift Dapto radio spectrograph.

1420 Mc/s Radiation Potts Hill: Isophote map of the galactic distribution of the H-Line radiation between +50 to -50 degrees. The observation was made by Christiansen & Hindman using the 16 ft X 18 ft paraboloid.

CygnusA (NASA): The CygnusA radio galaxy was identified with an optical source in 1951. Several other radio stars were also observed at this time. Apparently there is a super massive black hole at the core.

Slide 10. Jodrell Bank & the Design for Parkes:

SKA HQ at Jodrell Bank: Some 8 key objectives have been defined for the SKA & co-ordination in achieving this with the associated dissemination of data is managed for the 12 member countries at Jodrell Bank.

Barnes Wallis (1887-1979): Wallis recommended a geodetic web type structure for the Parkes antenna – at the time it was done as a private consulting job while he was working for Vickers R & D Dept.

Stockert Radio Telescope in 1956 built by MAN. Germany's 1st telescope for radio astronomy with a 25 mtr dish was inaugurated in 1956 near Bonn. It was built by MAN who went on to build Parkes. No 7.5 mtr Wurzburgs from the War were used for radio astronomy in Germany but the Stockert was designed to meet the 21 cm Hydrogen Line measurements with a pointing accuracy of 1 arcmin. The receiver construction was by Telefunken and the mount was alta-azimuth. A sophisticated co-ordinate converter was required for the astronomical drives. Stockert was designed for 50% radio astronomy work & 50% radar.

Bernard Lovell with his 250 ft radio telescope: The Lovell Telescope was finished in 1957 & is one of the largest steerable telescopes. A Mark II radio telescope of 125 ft was built in 1960-1964.

Slide 11. Fleurs & Badgerys Creek.

Chris Cross & 18 mtr "Kennedy" Dish. In 1957 the Chris Cross was completed at Fleurs. In 1963 CSIRO handed Fleurs equipment & site to the University of Sydney where Chris Christiansen was head of the Elec Eng Dept (1960-1978). The 18 mtr Kennedy was dismantled & moved to Parkes. (At Fleurs Station, Mills Cross was at 85.5 MHz, Chris Cross 140 MHz & Shain Cross 19.7 MHz).

Bernie Mills & Rudolph Minkowski in 1956: Rudolph Minkowski (1895-1976) was a German /American astronomer from Mt Wilson Palomar Observatory who visited RPL in March 1956 in an attempt to clear up a controversy between Sydney & Cambridge astronomers concerning the significance of distant radio sources.

Broadside array at Badgerys Creek for 6 discrete sources: One of 3 arrays built in late 1949.This 3 element interferometer operated at 100 MHz at 2 spacings of 60 mtrs & 270 mtrs. In 1950-1952 it was used to investigate the accurate positions of 6 discrete radio sources viz. CygnusA, CenA, VirgoA, TaurusA, HydraA & FormaxA with errors of 1 to several arcmin.

Chris Cross 1420 MHz: 64 Antenna each 19 ft in diameter arranged in a cross formation with arms 1200 ft in length at Fleurs set up as a crossed grating interferometer.

Slide 12. The Parkes Radio Telescope:

The main antenna; The 210 ft & 60 ft Kennedy dish work as an interferometer. Parkes was very much the brainchild of Taffy Bowen & was completed in 1961. The telescopes at MOPRA (Sidings Springs) & Narrabri Compact Array can be linked to form a Very Long Baseline Interferometer Array. (The Tidbinbilla Communications Dish was increased to 230 ft in 1987 & is larger than Parkes).

The receiving cabin is located at the focus of the parabolic dish supported by 3 struts & is 27 mtrs above the Dish. The cabin contains multiple radio & microwave detectors which can be switched into the focus beam for different science observations. Since 2018 an Ultra Wideband Low Receiver has been installed which can simultaneously receive signals from 700 MHz to 4 Ghz.

The Control Panel & 1960's Date & Time Display :

Parkes & the Moon Landing: The Dish 1969.,

John Bolton is seen at the Control Panel for the Apollo Moon Landing with Taffy Bowen looking on.

Slide 14: RPL Illustrated History & Marsfield.

RPL Illustrated History 1939-1984: Compiled in 1985 by John Deane (1949-2020) who went to be part of the WiFi Team [A second cousin to the author].

RPL at Sydney University: During WW2 office space was quite crowded with the large staff engaged on scientific, engineering & admin. work.

RPL Marsfield. RPL moved from Sydney University to Marsfield in 1968.

Slide 15. Interscan – Paul Wild.

Paul Wild (1923-2008). Paul Wild joined CSIRO /RPL in 1948 & from 1949 for 15 years was involved with solar radiophysics. From 1967 he operated a 3 km diameter radio heliograph at Culgoora & gained a very high international reputation. In 1971 he took over from Taffy Bowen as Chief of RPL (1971-1977) & started to look into applied research opportunities & developed a concept for a microwave landing system at airports. The PM in 1978 (Malcolm Fraser) acknowledges the success of Interscan being selected ahead of international competition at the time. In 1978 Paul Wild becomes Chairman of CSIRO until 1985.

Ron Bracewell (1921-2007) [BSc 1941, BE 1943 Sydney University, PhD Cambridge 1949]: Bracewell joined the RPL for wartime radar work on microwaves under Pawsey & Bowen. In 1946 -49 obtained a PhD at Cambridge under J A Ratcliffe. Back at RPL in 1949-54 worked on very long wave propagation & radio astronomy. In 1955 he joins the Elec Eng Dept at Stanford University & becomes Professor (1974-79) & had a distinguished career including his contribution to medical imaging. He remained active up until his death.. Ron was co-author with Joe Pawsey of a classic book "Radio Astronomy" 1955.

Slide 16. Parkes Noteables up to 1996:

Bob Frater (1937-)[BSc, BE, PhD Sydney University, 1958, 1960]: 1961-1980 Research at Sydney University & PhD on the Molonglo Cross & Assoc. Professor to 1980. Joined RPL in 1981 as Chief of RPL & in 1983 was the visionary leader & designer of the Compact Array at Narrabri (ATCA) which was opened in September 1988. Bob Frater is receiving a momento of the Voyager program.

Harry Minnett (1917-2003). [BSc, BE Sydney University 1940]. Worked with Jack Piddington at microwave frequencies. Responsible for overseeing the design & implementation of the Parkes telescope from 1956. GRT work starts in 1954 & consulted with Barnes Wallis & Freeman Fox with an altazimuth mounting. Was involved with the Interscan design in 1973 & became Chief of RPL in 1978-1981.

Brian Robinson (1930-2004). [BE & BSc Sydney University 1948-50, PhD Cambridge 1954-58]: In 1953 joined RPL at Potts Hill on Hydrogen spiral. His PhD at the Cavendish was under Jack Ratcliffe & in 1958-61 was reappointed to the RPL but spent his time in the Netherlands. In 1962-1992 he returned to RPL as a research scientist & takes on roles such as Deputy Director at Parkes. Brian's amplifier design expertise was acknowledged internationally. He also contributed towards a radio astronomy legacy by having radio astronomy frequency bands clear of man made interference.

Ron Ekers FRS (1941-).[Uni of Adelaide BSc. 1963. PhD 1967 ANU]: John Bolton was the PhD supervisor. In 1980-1987 was Director of the Very Large Array in the USA. Returned to Australia in 1988-2003 as the Foundation Director of CSIRO ATNF. Experience with a very wide range of experiments involving Sun. Moon, planets, stars, galaxies, quasars & cosmic microwave background. Also involved with the evolution of the early Universe & the SKA in WA.

John O'Sullivan (1947-):[BSc, BE , PhD Sydney University 1967, 1969,1974]. In 1977 while working at the Dwingeloo Radio Observatory co-authored a paper titled "Image Sharpness, Fourier Optics & redundant spacing interferometry" presenting techniques for sharpening & improving picture clarity of radio astronomy images. In the early 1990's he led the CSIRO team in developing a reliable & fast Wireless LAN patented in the US in 1996 becoming part of the 802.11a,g,n WiFi standard. John has also worked on the SKA Pathfinder & SKA design.

Slide 17. Parkes Specialist Technicians & Crab Nebula:

Brian Cooper: In 1963 in the Focus Cabin at Parkes working with an antenna for a 11cm parametric receiver.

Robert A (Bob) Batchelor: Over 37 years to 2000 involved with many projects including conversion from vacuum tube to transistors, mm wave receiver, radio astronomy spectral line studies & spent time at NRAO Greenbank. In 1983 involved with Device Fabrication & cooled electronic receivers.

Bruce Mac Thomas (1937-2018): [BE, MSc, PhD Melbourne University-Antenna Design]: Joined RPL at Parkes (1964-1978) on antenna work. 1978-1994 involved with Earth Station antennas for satellite communication & subsequently on industrial Liaison & SKA site evaluation in WA (Mileura site).

Dick Manchester (1942-) [John Bolton PhD student]: Head of the Astrophysics Group at ATNF & a leading authority on pulsars- led a group to confirm pulsars actually observed at Molonglo. By 1978, 10 years after the initial discovery, the Molonglo-Parkes collaboration had discovered 155 new pulsars, more than the number discovered by the rest of the world combined.

Crab Nebula: A Super Nova remnant of a star that violently exploded in 1054 AD as noted from Chinese records.(also observed in Japan Korea & Arabia). Even after 1,000 years the shell of gaseous

material is still rapidly expanding & generating enough energy to make it one of the most powerful radio sources in the sky.

Slide 18. Narrabri Australia Telescope & Sydney University Stellar Interferometer.

Compact Array 1988 Bicentennial Project: Opened in 1988 ATCA (Australia Telescope Compact Array) consists of 6 X 22mtr antennas & is part of the ATNF (Parkes, MOPRA, ATCA & MRO). Located at Narrabri in the Paul Wild Observatory it was designed & built in Australia. John Brooks, an engineer was chosen by Bob Frater in 1983 to lead the project. ATCA has the ability to accurately measure polarization in radio waves for mapping magnetic fields.

Sydney Uni NSII: Hanbury Brown from 1962 built the Narrabri Stellar Intensity Interferometer consisting of 2 X 23 ft telescopes. The large circular track allowed detectors to be separated from 10 to 188 mtrs. It operated from 1963 until 1974 & was used to measure the angular diameter of 32 stars. At Narrabri Sydney Uni Physics Dept have built in the late 1990's a second NSII consisting of 2 telescopes. (John Davis is especially noted for this.)

Radioheliograph remains: The Culgoora Radioheliograph was a 96 element, 3 km diameter radio synthesis telescope for solar radio observations at a frequency of 80 MHz. & also upgraded to 4 frequencies 43.25 MHz, 160 MHz & 327.4 MHz. Each telescope had a diameter of 15 mtrs with a wire mesh surface. Sunspot activities were investigated from 1967-1986.

Jupiter ATCA radio image. The image produced by ATCA represents the massive magnetic field surrounding the planet.

Slide 19. Sydney University Fleurs & Molonglo.

Mills Cross (Bernie Mills). In 1953 an experimental Mills Cross was tested at Potts Hill & in 1954 the dipoles & reflectors for the 455 mtr N-S & E-W arms were able to give high resolution radio reception at 85 MHz at the larger Fleurs site. (The Fleurs site is now the location of the new Sydney airport).

Chris Cross (Chris Christiansen): In 1955 a 5.5 mtr prototype parabola with equatorial mounting was built at the RPL Lab & taken to Potts Hill for testing. In 1957 an array of 32 X 5.8 mtr diameter parabolic dishes was installed & soon after provided observations of solar radio emissions at 1420 MHz. The parabolas gave a narrower angular response than the Mills Cross. In 1963 CSIRO handed the Fleurs equipment & site to Sydney University as Taffy Bowen wanted to concentrate his resources on Parkes. The 18 mtr Kennedy dish was moved to Parkes. The Chris Cross was the worlds first crossed grating interferometer (the Japanese at the same time came up with the same concept but did not progress with it) & Christiansen when at Sydney University proceeded to develop the Chris Cross into the Fleurs Synthesis Telescope by adding 6 stand alone 13.7 mtr parabolic antennas. The FST was closed down in 1988 & the original equipment quickly deteriorated.

Molonglo Cross Telescope & the Molonglo Observatory Synthesis Telescope (MOST). The Molonglo Cross Telescope was built by Bernie Mills & operated by Sydney University Physics Dept & others. It consists of a N-S & E-W arm in a cross shape approximately 1 mile in length. The E-W arm was split into 88 individual elements to form the current MOST. The MOST consists of 2 cylindrical parabaloids 778 mtr X 12 mtr separated by 15 mtrs & aligned E-W operating at 843 MHz. at which frequency a survey of the southern sky was carried out. The observatory has been upgraded to detect FRB & pulsar work. Anne Green at the Astrophysics Dept of Sydney University contributed greatly to the upgrade & SKA prototyping.

Slide 20. Sidings Springs- Tidbinbilla.

Sidings Springs 154 inch telescope (Anglo Australian). In 1974 the Anglo Australian Telescope became operational. The Schmidt telescope (1.24 mtrs) was started around 1973. John Bolton emphasized the need to confirm where possible radio sources with optical observations. The ANU has a 2.3 mtr telescope built in 1984 known as the Advanced Technology Telescope.

Tidbinbilla Deep Space Tracking Station. CSIRO manage & operate one of NASA's 3 tracking stations that provide 2 way radio contact with spacecraft exploring the solar system & beyond.

Slide 21. WiFi & Pulsars.

WiFi: The success of John O'Sullivans team in getting the CSIRO Wi Fi LAN system accepted as the International Standard 802.11 in 1998 was a remarkable achievement based on Fourier experience. The team consists of Dr John O'Sullivan, Dr Terry Percival, Mr Diet Ostrey, Mr Graham Daniels & Mr John Deane.

Pulsars. Pulsars were first discovered at Cambridge in 1967. In 2003 Marta Burgay (from Italy-here shown working at Arecebo) working at Parkes discovered the 1st double pulsar. ie. 2 pulsars orbiting each other.

Slide 22. ATNF.

Remote Control for ATNF.

ATCA Image of Galactic Hydrogen.

ANU Partner in Giant Magellan Telescope -Chile. Following the loss of Mt Stromlo in the 2003 bush fire the ANU is partnering with several other countries led by the US to build an extremely large telescope consisting of 7 X 8.4 mtr primary segments to observe optical & near infrared light.

Slide 23. SKA Australia.

Artist Impression of SKA site at Murchison. The low frequency part of the SKA is being hosted by Australia at the MRO site in WA 800 km north of Perth & will cover an area spanning 65 km consisting of 130,000 antennas. Precursors & Pathfinders are providing vital knowledge in the design of the main telescopes. ASKAP antennas are the familiar dish type & the Murchison Widefield array are located at ground level.

The Pawsey Super Computer Centre in Perth. The amount of data generated by the SKA is in the order of 50% of the rest of the country combined (a staggering amount) & at the Pawsey Computer Centre in Perth a Nimbus Cloud data storage & processing is used. A 320 km fibre optic cable runs from the MRO with data transmission expansion allowed for at 40 Gbps & 100 Gbps per wavelength.

Firmware Coding. Mia Baquiran is shown coding firmware for the SKA in Perth.

Slide 24. SKA Network & Leaders.

Catherine Cesarsky (France): Is the Chair of SKA International with responsibility for co-ordinating the 8 major objectives for the member countries.

Dr Douglas Bock [BSc, BE, PhD Sydney University 1992, 1994, 1998] : Director of CASS & ANTF since 2016 & is Australia's scientific director on the Board of the SKA International Organisation located at the Jodrell Bank HQ, Manchester.

Dr Lewis Ball [BSc & PhD Sydney University -Theoretical Physics 1988]. Had many years of SKA experience at CASS.

Prof. Richard Schilizzi (BSc UNE, PhD Radio Astronomy, 1973 Sydney University). First Director of International SKA for 9 years until 2011.

AARNet fibre optic network.: The SKA data transmission rates anticipated by AARNet are in the order of several Terabits/sec.

Slide 25. New Zealand & Canada.

NZ: The Warkworth Observatory is located near Auckland. The role of New Zealand physicists has been considerable including Elizabeth Alexander's solar work which led to the RPL Collaroy observations in October 1945.

Canada: In British Columbia, Canada has a Synthesis Observatory. The participating countries in SKA besides Australia, South Africa & the UK are Canada, China , Germany, Italy, Sweden & the Netherlands.

Slide 26. RPL & ATNF Communicators. Authors who have contributed to the history of RPL & ANTF over many years are Wayne Orchiston, Bruce Slee, Miller Goss (with Hastings Pawsey) & Helen Sim.