URSI Commission J – Radio Astronomy

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Preface

The organisation and operation of URSI can be seen as a sailing trip around the world by ten boats, each representing one of the ten Commissions of URSI, that gather at three year intervals in a place on earth decided by the central overseers, the Council. At these General Assemblies the captains of the Commission ships meet with the Council to discuss the experiences of the recent period and make plans for the next. The crews of the ten boats set up their individual meetings to present the scientific discoveries of the last three years to their colleagues who could not fit on the ship and travelled to the harbour to hear the news. Occasionally, crews from more than one boat find common interest in holding joint meetings. Also, individual captains may make landfall by invitation at a suitable place for a conference on a special subject of interest.

This procedure has been in place for a hundred years to great satisfaction of the URSI community and with considerable success. It is not unusual to accompany such a centennial with the publication of a book on the history of the organisation. The URSI Centenary Book, of which this chapter is a part, will do just that. But how to write a history of a journey with short highlights every three years and intermediate years of calm? In addition, the highlights, the General Assemblies, tend to be rather similar in structure and there is a danger that the story will become repetitive and rather boring. I have faced this dilemma during the writing of this chapter.

The history of the Commission proper, its terms of reference and organisational and political activity within URSI, demonstrated by its proposals and resolutions, is given the needed attention. The development of the technical means for making radio astronomical observations of increasing breath and depth has been the mainstay of Commission J sessions at the General Assemblies and in specialised Symposia. I have tried to summarise the main aspects of these developments while being aware that it is not an encyclopaedic listing. The astronomical discoveries made possible by the new telescopes have always been part of the program of Commission J sessions. They are treated rather more in passing than in detail in this chapter. A small number of photos, most provided by colleagues, and some personal anecdotal memories are added to give the reader some light relief.

1. Introduction

In the first half of the nineteenth century the experimental work by Oersted, Coulomb and notably Ampère and Faraday demonstrated a close relationship between electric currents and magnetic fields. Faraday's (1791-1867) discovery in 1845 of the rotation of the plane of polarisation of light under the influence of a magnetic field established an intimate relationship between light, considered a wave phenomenon, and electric and magnetic fields. On the basis of this groundwork James Clerk Maxwell (1831-1879) developed the *dynamical theory of the electromagnetic field*, published in 1865. He unified electricity, magnetism and light into the concept of *electromagnetic (EM) waves* travelling though the 'ether' with the speed of light.

The electromagnetic waves originating from Maxwell's equations are not limited to the wavelengths of light. The theory predicts the existence of EM-waves at other wavelengths. Heinrich Hertz (1857-1894) succeeded to demonstrate these *radio waves* in his experiments in Karlsruhe, published in 1888. Hertz's experiments aroused considerable interest in the new field of electromagnetic waves. It led to *wireless telegraphy* and to *radio broadcasting*. These developments used long wavelength (order of meters or longer) radiation transmitted and received by dipole and wire antennas. The term *radio* (from the Latin *radius* - beam) appears in the 1890s as *radio-waves, radio-telegraphy, radio-receiver.* By 1910 *radio* had replaced the term *wireless* in the USA and the European continent, but the latter remained the favoured term in Britain until after the Second World War. The establishment of URSI (*Union international de radiotélégraphie scientifique* in the original document) in 1919 could be considered as the official acceptance of *radio* as the indicator of EM-waves at wavelengths well beyond that of light.

Hertz's demonstration induced several investigations into the possibility of detecting radio waves emitted by the Sun. But all experiments carried out in the USA, England, Germany and France between 1890 and 1901 were unsuccessful due to the low sensitivity of the receiving equipment and the fact that the observations were performed over a period of minimum solar activity. Only the major solar outburst at the maximum of the 11-year solar cycle might have been detectable. With growing commercial interest in long distance radio communication at very long wavelengths, no further efforts in detecting the Sun were undertaken for several decades.

2. The birth of Radio Astronomy

About a decade after the creation of URSI, radio emission at a frequency of 20 MHz was detected, and its origin identified as the central region of our Galaxy, by Karl G. Jansky at the Bell Telephone Laboratories in Holmdel, USA. The first public presentation of his discovery occurred on 27 April 1933 at the USA URSI Meeting in Washington, DC, followed by a paper at the national convention of the IRE in Chicago on 27 June. The impact of this momentous discovery was extremely limited. In a letter to his father Jansky noted "not a word was said about my paper by the handful of old college professors, members of this almost defunct organisation". Astronomers showed no interest in this new source of 'cosmic' radiation. However, an engineer and Ham-radio-amateur, Grote Reber, constructed a 10 m diameter parabolic reflector and mapped a large part of the sky at a wavelength of about 2 m. With some difficulty he managed to get his results published in the Astrophysical Journal in the early 1940s. At the close of WWII physicists and radar engineers started to use their wartime equipment to observe the sky, notably in Australia, Britain and the USA. In the Netherlands, in 1944 Hendrik van de Hulst predicted that a spectral line of atomic hydrogen, the most abundant element in the Universe, at 21 cm wavelength could be detectable. The goal to achieve this became the major driver for the development of radio astronomy in Holland.

The early observations, mostly done at frequencies of a few hundred MHz, produced a small catalogue of individual sources of emission, the celestial positions of which were determined with the use of interferometry to such accuracy that comparison with optical objects was feasible. The identification of the strongest radio sources with supernova remnants (Cassiopeia A and Taurus A) in our Galaxy and extragalactic objects (Cygnus A, Virgo A) convinced the community of optical astronomers that these 'radio engineers' were expanding the realm of astronomy beyond the optical wavelength domain.

3. Radio astronomy enters URSI

At the first URSI meeting after the war in 1946 in Paris President Edward Appleton established a Sub-commission on 'Radio Noise of extraterrestrial Origin'. At the 1948 General Assembly in Stockholm its status was upgraded to a full Commission V (five) – 'Extra-terrestrial Radio Noise'. The name was changed to 'Commission V – Radio Astronomy' at the Zürich General Assembly in 1950.

We should note here that the early radio observations, particularly those of the Sun, had also drawn the interest of the International Astronomical Union, established in 1919, the same year as URSI. At its General Assembly in Zürich in 1948 Commission 40 on Radio Astronomy was established with

20 members, among them a few optical astronomers. The year 1952 was particularly exciting for the small group of radio astronomers. At the General Assemblies of both the IAU in Rome and URSI in Sydney the optical identification of several radio sources was announced and Galactic structure was revealed by the 21-cm hydrogen line observations. It can be stated that these events established radio astronomy as a *bona fide* branch of astronomy that was accepted by the community of optical and theoretical astronomers and astrophysicists.

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Christiansen on the left shows the Pott's Hill radio telescope to high URSI officials Sir Edward Appleton (far right) and, next to him, Professor B. van der Pol, famous Dutch radio scientist, during the URSI General Assembly in Sydney in August 1952. (Courtesy of ATNF Historical Photographic Archive B2842)

At the URSI Assembly in Sydney Commission V was represented with a strong delegation of about 15 radio astronomers from outside Australia, about a third of all foreign participants. In the following years URSI-Commission V published a number of Special Reports with detailed reviews of the state of radio astronomy: Report 1 (1950) on "Solar and galactic radio noise", edited by E. Appleton; Rep. 3 (1954) "Discrete sources of extra-terrestrial radio noise", by J. Bolton; Rep. 4 (1954) "The distribution of radio brightness on the solar disk", by W. Christiansen and Rep. 5 (1954) "Interstellar hydrogen" by J. Oort. Obviously, URSI Commission V was determined to play an active role in the development of technology for and the dissemination of results in the new field of Radio Astronomy.

The existence of 'Radio Astronomy' Commissions in both the IAU (Comm. 40) and URSI (Comm. V) led to considerable discussions within and between the two groups by the mid-fifties. How would the work by radio astronomers be divided over the two Commissions? Should URSI be limited to instrumental, technical aspects and astronomical results be presented and discussed through the IAU? This question was discussed at the high levels of both organisations and the tendency was to answer the question in the affirmative. The great majority of the individual commission members, i.e. the active radio astronomers, did not accept implementation of this idea. Here we should remember that at the time URSI did not offer membership to individual scientists. One could become member of the National Committee in his country and all radio astronomers in these were counted to belong to Commission V – Radio Astronomy of URSI. Most of these had also joined Commission 40 of the IAU. In 1955 the membership of Commission 40 was 49 persons, 32 from the five most active countries (UK, USA, Australia, Canada and the Netherlands). By 1961 these numbers had climbed to 105 total and 70 in the five countries. There was a large overlap between Commission 40 and URSI commission V, so similar numbers apply roughly to the ‘membership’ of Commission V.

2

Australian radio astronomers with foreign guests at the URSI Assembly in Sydney in 1952.
From left to right: First row: W.N. Christiansen, F.G. Smith (England), J.P. Wild, B.Y. Mills, J.L. Steinberg (France), C.F. Smerd, C.A. Slain, R. Hanbury-Brown (England), R. Payne-Scott, A.G. Little, M. Laffineur (France), G.B. Slee, J.G. Bolton. *Second row*: C.S. Higgins, J.P. Hagen (USA), J.V. Hindman (France), H.J. Ewen (USA), F.J. Kerr, C.A. Muller (Netherlands).
Third row: J.H. Piddington, E.R. Hill, L.W. Davies. (Courtesy of ATNF Historical Photographic Archive 2842-43, 8 August 1952)

While the leaders of the IAU and URSI deliberated about division of responsibilities, and URSI published its Reports, mentioned above, both organisations agreed to hold a few Symposia specifically devoted to Radio Astronomy. The first took place at Jodrell Bank in 1955; it was IAU Symposium 4, early in the new series of published IAU Symposia. It was followed by a large and highly successful joint IAU/URSI Symposium in Paris in 1958. During this period URSI and IAU jointly worked on mundane but essential aspects as definition of terms and quantities as well as the naming of the quickly increasing number of radio sources. In 1959 the third Cambridge source survey used the simple source designation 3Cnnn, for third Cambridge catalogue with the number increasing with right ascension. This numbering was the *de facto* system until the Parkes survey with several thousands of sources used the designation e.g. PKS1925+416 for the Parkes Catalogue PKS, right ascension in hours and minutes (19^h25^m) and declination in degrees to one tenth of a degree (+41.6). This system has been widely adopted where the lettering identifies the observatory.

The great majority of radio astronomers in URSI welcomed the connections with IAU Commission 40, but maintained their desire for a structure within URSI that would embody both instrumental aspects and astronomical results. A resolution at the General Assembly in 1960 was passed that confirmed this ‘hybrid’ character of Commission V.

Its terms of reference should be (in a somewhat condensed form):
1. The activities of the Commission shall be concerned with:
(a) Radio sources in space, particularly Sun, solar system, Galaxy, discrete sources in the Universe.
(b) Study of meteors, Sun, moon, planets and other solar system object by radio echo technique (radar).
2. Study and promotion of the development of technical methods in relation to the above. Take strong efforts to protect observations from interference.
3. In connection with (1) the Commission will aim:
(a) to work jointly with other URSI Commissions where common interests exist.
(b) to work jointly with Commission 40 of IAU in convening symposia on Radio Astronomy.
(c) to cooperate with Commission 40 of IAU on the choice of topics for discussion in order to prevent any undesirable overlapping.
4. The Commission shall formulate appropriate recommendations to URSI on any subject in relation to the above for consideration by other URSI Commissions and other international bodies.
(Ref. URSI Proceedings of General Assembly No. 12, pp 175-76 [Brussels, URSI 1960]).

Over the course of time URSI Council or other Commissions have taken issue with this charge without having resulted in a significant change. Its core functions quite satisfactorily despite some adjustments. At the URSI reorganisation in 1975 Commission V was designated Commission J.

From the beginning of its existence Commission V has actively pursued the protection of frequencies for the exclusive use by radio astronomy. The first was, of course, the 21 cm HI-line, for which the frequency band 1400 – 1427 MHz was designated by the International Telecommunications Union in 1959. In 1960 URSI, IAU and COSPAR jointly established IUCAF (Inter Union Committee on the Allocation of Frequencies) to deal with the field of spectrum management on behalf of the passive radio sciences, such as radio astronomy, remote sensing, space research, and meteorological sensing. IUCAF's brief is to study and coordinate the requirements for radio frequency allocations established by the afore-mentioned sciences and to make these requirements known to the national and international bodies responsible for frequency allocations. IUCAF has official standing as a nonvoting organisation at the ITU, the International Telecommunication Union. URSI provides three to four delegates to IUCAF, who are nominated by Commission V. While fighting an uphill battle against the ever encroaching needs of the communication industry, IUCAF has been quite effective in defending existing allocations and implanting awareness of the delicate position the radio astronomer is faced with. Also effective schemes for excision of interference from the observations have helped to co-exist in the crowded radio spectrum with the concurrent drawback of decreasing the weight of our argumentation in defence of the existing allocations to passive use of the spectrum. In Appendix 1 to this chapter the current chairman provides more information on IUCAF.

In the second half of the 1950s several new radio telescopes came into operation, notably the relatively large 15-25 m diameter reflectors in Dwingeloo, Bonn, NRL (Naval Research Laboratory), Harvard, Jodrell Bank (76 m!) and the Cross Antennas and Interferometers in Australia, Cambridge and the USSR. At the Paris Symposium of 1958 a host of new results from these new telescopes was presented. While significant progress in the identification of radio sources with optical objects was presented, it was also clear that larger, more sensitive telescopes, capable of extending the wavelength range into the short centimetre regime, were needed. Also significant progress in the identification of radio sources with optical objects could only be expected from more accurate radio source positions of the order of one arc second.

4. The 'golden years' of radio astronomy and Commission V

The period 1960-1975 has been called the 'golden years' of radio astronomy. Indeed the number of new telescopes of increasing power enabled an enormous increase in production of accurate observations. In the USA several universities obtained antennas of the 25-30 m class. The Caltech interferometer provided accurate positions that helped the identification process significantly. The National Radio Astronomy Observatory was established in 1957 and by 1965 offered open access to its two major telescopes of 300 and 140 feet diameter as well as a three-element variable baseline interferometer. A 64 m dish in Australia became operational in 1961 and the ‘one mile’ synthesis telescope at Cambridge produced the first fully sampled source maps with 23 arc seconds resolution and 1 arc second position precision in 1963. First results from these new telescopes were presented at the 1963 URSI Assembly in Tokyo. The discovery of Quasars should be mentioned here as a beautiful result of close collaboration between radio and optical astronomers.

In 1964 URSI published a book entitled “URSI Golden Jubilee Memorial 1964”. The title speaks for itself. Reviews of activities up to the early 1960s are presented for each of the Commissions. That of Commission V – ‘Radio Astronomie’ – was written by R. Coutrez and R. Agonze, both from the Observatoire Royal de Belgique. It is the only contribution to this book written in the French language. The official languages of URSI are French and English and it is not surprising that these French-speaking authors chose their mother tongue. The review is heavy on the Sun, planets and meteors, but the Galactic and extra-galactic results are mentioned in an optimistic tone for further research, but for one interesting exception. On the subject of discrete sources they write: “the majority of discrete radio sources show however a clear extragalactic character: most of these have not been identified with optical objects and probably never will be in view of their distance”. This was written in 1963; a few years later we knew a lot more.

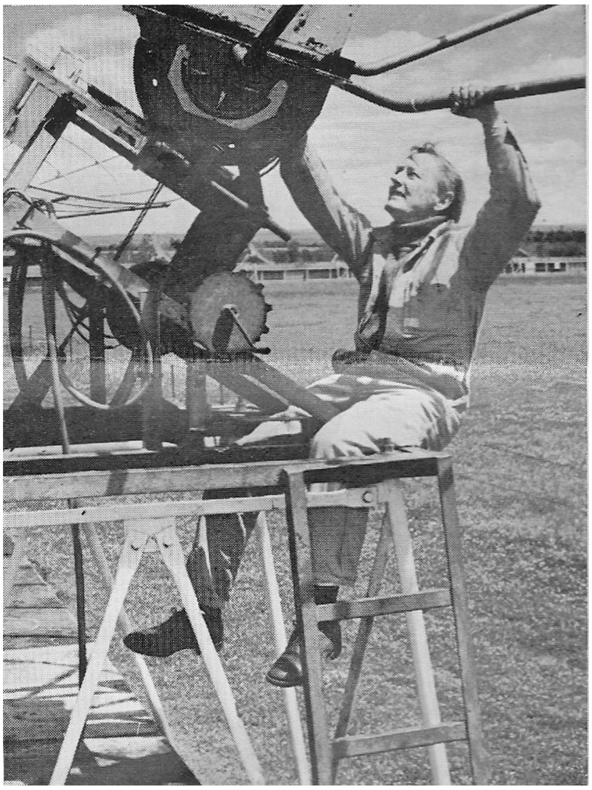
During the General Assembly in Munich in 1966 a large number of recent and future telescopes were presented. The most important ones are listed in Table 1.

Table 1. Major new radio telescopes of the 1960s.

Location	Type	Dim. (m)	Wavel. (cm)	Year - Remark
Parkes, Australia	Paraboloid	64	6	1961
Arecibo, Puerto Rico	Spherical, fixed	305	75	1963, tracking line feed
Nançay, France	Spherical, fixed	300	21	1967, coelostat (‘Kraus’)
Bologna, Italy	Parabolic cylinder	600	75	1967, ‘Northern Cross’
Ooty, India	Parabolic cylinder	530	90	1969, NS, tracking
Algonquin, Canada	Paraboloid	46	3	1966
Green Bank, US	Paraboloid	98	20	1962, transit telescope
Green Bank, US	Paraboloid	43	2	1965
Kitt Peak, US	Paraboloid	11	0.1	1967, mm-waves
Culgoora, Australia	Annular array	3000	375	1967, heliograph 96 parabs
Cambridge, UK	Synthesis array	1500	21, 75	1964, 3 parabs, 18 m
Westerbork, NL	Synthesis array	1600	21, 6	1969, 12 parabs, 25 m

The GA in Munich in 1966 was my first General Assembly. The eldest French delegate, Professor Laffineur read his paper in French, thereby obeying the official state requirement for conference contributions and enabling his younger French colleagues to speak English. I received some good advice from Gart Westerhout: “always take a seat rather up front and somewhat to the side. Ask a question often, stand up and mention your name. You will be well-known after a few conferences”! Actually, I was already favoured company to my American colleagues because I could translate the German menu card in the restaurant. But I was not always sure what would appear on our plates.

The commission V sessions during the General Assemblies in the sixties were crowded with descriptions of these new instruments and the astronomical data. There were a few singular discoveries at Nobel Prize level. The determination of the Cosmic Microwave Background by Arno Penzias and Robert Wilson in 1965 brought them a Nobel in 1978. Jocelyn Bell and Tony Hewish discovered pulsars in 1967. In 1974 a Nobel was bestowed on Martin Ryle and Tony Hewish (but not Jocelyn Bell) for the development of aperture synthesis and the pulsar discovery, respectively. Later radio astronomy related Nobel Prizes went in 1993 to Joseph Taylor and Russell Hulse for the demonstration of gravitational waves emanating from a double pulsar and in 2006 to John Mather and George Smoot for their achievements with the cosmic background explorer COBE.



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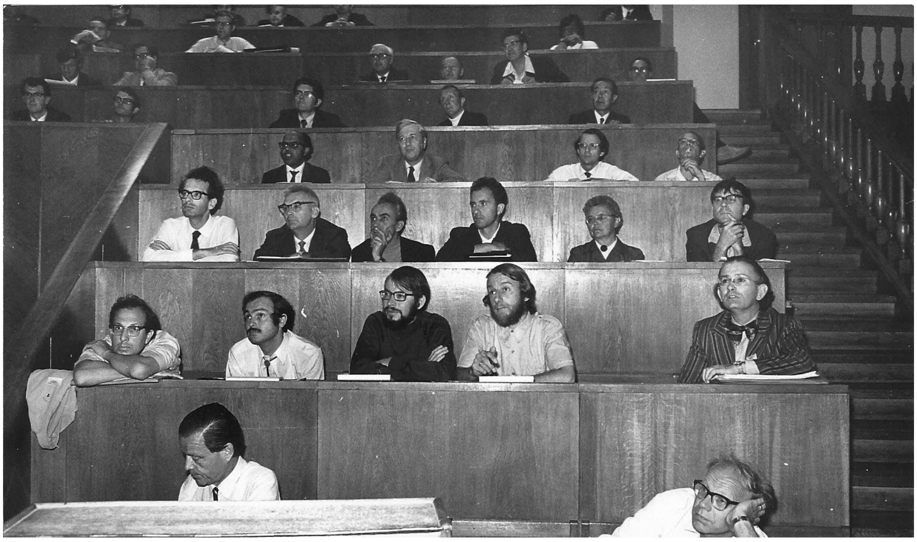
Wilbur (Chris) Christiansen was Chairman of Commission V from 1963-1966 and President of URSI from 1978-1981. Here he is adjusting one of the antennas of the Fleurs Synthesis Telescope (Australia) in 1973. (QV, **6**, no. 4, p.9, 1973)

By the mid-seventies radio astronomy had solidly established itself as an essential component of astronomy. For many radio astronomers the involvement, or at least close contact with the 'technical' aspects, telescope, receiver, data reduction, operation, remained an essential part of their activity. Thus the participation of Commission V in the URSI general assemblies continued to be intense. In addition the Commission increasingly proposed and organised symposia in the area of its concern. Often these were planned and organised in close cooperation with Commission 40 (radio astronomy) of the IAU. Examples of these are the 1966 Noordwijk Symposium on the Galactic System, the 1978 Heidelberg VLBI (very long baseline interferometry) Symposium and the 1980 Grenoble Symposium on Millimetre Technology in Radio astronomy.

In 1972 the GA was held in Warsaw. At the suggestion of our Polish colleagues about a dozen radio astronomers set out to a restaurant, famous for its kitchen and in particular the 'Polish duck'. We were handed a large menu card with many dishes. After unsuccessfully trying to order from the card ("not available") we asked what was available. The answer was duck, only duck! So we ordered duck. When it arrived at our table, it was so lightly cooked that it was barely edible. One remarked: "my duck wanted to fly off my plate" and another retorted, "you should have let it".



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Session during GA in Warsaw 1972, where most can be identified. From bottom, left to right:
1 - John Findlay, F. Graham Smith, 2 - Ken Kellermann, Johann Schraml, Ard Hartsuijker, Jaap Baars, Gart Westerhout, 3 - NN, Stanislaw Gorgolewski (Toruń), Jósef Maslowski (Kraków), NN, Ms Wilhelmina Iwanowska (Director Totuń Obs., Zygmunt Turlo (?) (Toruń), 4 - Govind Swarup, Sam Goldstein, Al Moffet, Kochu Menon, 5 - Lout Sondaar, Kel Wellington, NN, NN, Tanaka, 6 - Jack Welch, NN, Mayo Greenberg (?), NN, George Swenson, 7 - NN, Harry van der Laan, NN

5. Renamed Commission J – Radio Astronomy solidly settled in URSI

The extensive reorganisation of URSI at the General Assembly in Lima in 1975 left the status quo of the Radio Astronomy commission essentially unchanged. From that time onwards the designation became Commission J – Radio Astronomy. Around this time Commission J decided to reserve at least one full day at every GA for short 'Reports of Observatories'. These have been very successful in their democratic and inclusive character; regardless of the observatory's size, each gets his time slot.

5

Picnic during GAS in Lima in 1975 with John Findlay standing right and Ivan Pauliny-Toth on the left in yellow shirt

The arsenal of powerful radio telescopes grew in the early seventies with the Effelsberg 100-m telescope, operating between 2 and 75 cm wavelength, and the Westerbork Synthesis Radio Telescope (WSRT) at 6, 21 and 50 cm. A new 'window' at millimetre wavelengths was opened by the detection of carbon monoxide (CO) in the Galaxy at 2.6 mm with the NRAO 36-ft mm-telescope in 1970. Between 1972 and 1978 Brazil, Finland, Sweden, Spain, Korea and FCRAO Univ. Massachusetts) acquired radome enclosed antennas of 14 m diameter (20 m in Sweden) that could be used at 3 mm, the FCRAO at 1.3 mm.

At the Helsinki General Assembly in 1978 much attention was devoted to aspects of mm-astronomy. The NRAO 36-ft operated at full swing and many new molecules were found. A major emphasis was on presentation and discussion of developments for larger telescopes for short mm-wavelengths (<3 mm) and low-noise receivers. Plans for dedicated mm-telescopes in size between 10 and 45 m, to be located at suitably high sites, were presented by Germany, France, England, Japan and the USA. Further highlights were the successful VLBI observations at cm-wavelengths and plans to extend baselines by antennas located in space.

In the 'business session' it was proposed that there should be time in the overall program for general review papers by each Commission. This has led to the three 'General Lectures' during the GA at dedicated time slots outside the regular Commission meetings. Commission J has been very successful in providing lecturers. A list is given in Appendix 2.
Moreover there was strong support for joint sessions with other commissions. This indeed became a clear part of future General Assemblies. There was also support for separate, URSI sponsored symposia, organised by individual institutes. Commission J organised and sponsored several as mentioned above.

The full operation of the Very Large Array (VLA) in New Mexico in 1980 opened another 'golden decade' for radio astronomy. This synthesis array of 27 antennas, moveable over rail tracks on a 'Y' configuration with 21 km arm length, delivered high quality 'pictures' with arcsecond angular resolution at several wavelengths. Its performance and ongoing improvements were presented at the Washington DC General Assembly in 1981.

The second major development of the decade was the progress in the construction and operation of the large millimetre and submm telescopes that were discussed at Helsinki as mentioned above. This is summarised in Table 2. For completeness four major (sub)millimetre telescopes completed after 2000 are added to the Table.

Table 2. Millimetre wavelength telescopes of the 1980s and 1990s.

Institute	Location	Year	Diam-m	Rms-µm	Protection	Altitude-m
Caltech array of 4 antennas	Owens Valey, California	1979	10.4	60	open	900
NRAO	Kitt Peak, Arizona	1980	12	75	astrodome-open	1940
NRO	Nobeyama, Japan	1982	45	120	open	1350
IRAM	Pico Veleta, Spain	1984	30	70	open	2850
BIMA – array	Hatcreek, California	1985	6	50	open	1280
NRO – array of 5 antennas	Nobeyama, Japan	1985	10	75	open	1350

Caltech - CSO	Mauna Kea, Hawaii	1986	10.4	25	astrodome-open	4140
JIA- JCMT	Mauna Kea, Hawaii	1986	15	30	astrodome skin	4140
Daeduk Astron. Obs.	Korea	1989	13.7	150	radome	
IRAM – array of 3 antennas	Plateau de Bure, France	1989	15	65	open	2550
ESO-OSO, SEST	La Silla, Chile	1990	15	55	open	2400
Purple Mountain Obs.	Nanjing, China	1992	13.7	180	radome	3200
ATNF	Mopra, Australia	1995	20	100	open	860
SMTO MPIfR-Steward Obs.	Mt. Graham, Arizona	1995	10	15	astrodome-open	3200
SMA array of 6 antennas	Mauna Kea, Hawaii	2002	8	20	open	4070
LMT - UMass/INAOE	Cerro la Negra, Mexico	2012/17	50	75	open	4640
ALMA – global poject.	Chajnantor, Chile	2005/13	12	22	open	5000
NOEMA-IRAM 12 element array	Plateau de Bure France	2018/21	15	60	open	2550

The design and construction of these highly accurate reflector antennas was mainly realised by industry under guidance by the Institutes. However the extension of sensitive receivers into this wavelength domain was at the time not of primary industrial interest. Consequently almost every institute aiming at mm-wavelength activity expanded its electronics department with development of appropriate receiver systems. This involved in particular low-noise mixers based on first Schottky diodes and soon SIS-devices and local oscillators of sufficient power. These subjects were extensively reviewed and discussed at the Washington General Assembly and several dedicated symposia were held in the decade, such as the URSI Symposium on Millimetre Technology in Radio Astronomy in Grenoble in 1980 and the URSI International Symposium on 'Millimeter and Submillimeter Wave Radio Astronomy' in Granada, Spain in 1984. The proceedings of the latter symposium present a good review of the status and promise of current observations and future work with the telescopes still under construction or just beginning to produce results. The success of the new mm-telescopes was demonstrated during sessions on the subject during the Assemblies of 1984 in Florence and 1987 in Tel Aviv. Clearly at the shortest wavelengths, where the atmosphere allows earthbound observations from high and dry sites, the sky had much to offer and was intensely observed.

At the two Assemblies just mentioned there was however no lack of new initiatives for more telescopes. In Florence NRAO presented the plan for the Very Long Baseline Array (VLBA) consisting of ten antennas of 25 m diameter to be located on suitable sites from Hawaii in the far west to the Virgin Islands in the Caribbean. The technique of VLBI was constantly being upgraded particularly in the area of bandwidth and data collection and archiving. Studies of “Space VLBI” concepts involving an orbiting radio telescope observing in conjunction with the ground arrays were underway in ESA and NASA and in IKI in the Soviet Union. Richard Schilizzi described the developments in VLBI in one of the General Lectures in 1984.

In the area of mm-astronomy Sweden announced a plan for a 15 m mm-telescope in the southern hemisphere that resulted in SEST (Southern ESO Swedish Telescope) located on the ESO site La Silla in Chile. NRAO reported the refurbishing of its original 36-ft mm-telescope to a slightly larger (12 m) and significantly better antenna. Also NRAO worked on the design of a 25 mm-antenna for operation to 0.8 mm wavelength. CSIRO announced the plan to build a powerful synthesis array in Australia. By the time of the Tel Aviv Assembly, the Australia Telescope was under construction near Narrabri, the site of the original circular radio heliograph built there for solar work by Paul Wild.
In Florence Commission J drafted a letter of strong support for the essential work by IUCAF in the area of frequency protection that was submitted to the URSI Board for support.

More new telescopes were introduced during the General Assembly in Tel Aviv in 1987. A major subject was the potential move of radio astronomy into space with telescopes orbiting the earth. A report was given on the ESA-NASA Space VLBI concept, QUASAT, a large antenna of at least 15 m diameter operating at 1.6, 5 and 22 GHz. NASA made studies of a similar system, called the Large Deployable Reflector, of 10-30 m diameter and aiming at far-infrared wavelengths. Neither of these has been realised. The Japanese proposal VSOP for an 8 m telescope for VLBI at 1.6, 5 and 22 GHz was launched in 1997 and successfully operated for 8 years (the 22 GHz receiver malfunctioned). ESA launched a project for a large space-telescope at far-infrared wavelengths in 1984 named FIRST for Far InfraRed Space Telescope. After a long and tedious technical, organisational and financial development cycle, a 3.5 m diameter mirror with three detectors in the 60-670 µm wavelength range was launched in 2009, named the Herschel Space Telescope. Finally India introduced a major new telescope, the Giant Metre-wave Radio Telescope (GMRT), an array of 30 antennas of 45 m diameter of an original design. It came into operation in 1999.

Commission J again discussed its Terms of Reference in Tel Aviv. It was decided to add ‘space radio astronomy’ and infrared- and optical-interferometry to its fields of interest. As usual a few specialised symposia were suggested, which led to URSI sponsored meetings such as a ‘VLBI Summer School’ in Bologna, Italy in September 1988, a ‘Millimetre Astronomy’ symposium in Hawaii (November 1988), the Symposium on ‘Radio-astronomical Seeing’ in China in May 1989 and the URSI/IAU sponsored meeting on ‘Limits of observational astronomy’ in Sydney in September 1989.

An anecdote on the Tel Aviv Assembly is the extensive interrogation by the border police on departure of Commission J Chairman, Richard Wielebinski. Fostering contact with our colleagues from the Soviet Union he had invited the USSR group of radio astronomers for drinks in his hotel room. This was obviously a highly suspect activity!

The next GA took place in Prague in 1990 after the collapse of the Berlin Wall and the *de facto* ’decommunisation’ of the Eastern European countries. Commission J held productive Business Meetings, where some adjustments to the term of reference were made leading to the following statement:
(a) the activities of the Commission are concerned with observation and interpretation of all radio emissions and reflections from celestial objects.
(b) Emphasis is placed on:
(i) the promotion of technical means for making radio-astronomical observations and data analysis,
(ii) support of activities to protect radio-astronomical observations from harmful interference.

At the 1990 GA in Prague, Richard Schilizzi was elected Commission J vice-chair. However, Council overturned this in favour of a representative from the Soviet Union. Yuri Parijskij became vice-chairman. This was at the time of 'perestroika' and 'glasnost'.

The continuing expansion of VLBI observations, and space VLBI in particular, led to the establishment of an URSI 'Global VLBI Working Group' (GVWG) soon to be a joint WG with the IAU. The objectives of the GVWG were:
i) to develop a concept for an International VLBI network, comprising existing or future national and regional networks;
ii) to promote compatibility of technology in VLBI instrumentation,
iii) to serve as liaison between ground-based observatories and national or international space agencies, for coordination of participation by ground radio telescopes in Space VLBI missions.

6

The Global VLBI Working Group meeting in Onsala, Sweden in May 1993.
Squatting: Hisashi Hirabayashi, Roy Booth (Chair), Anton Zensus, Joel Smith.
Standing, left to right: Peter Dewdney, Fujun Zhang, Robert Preston, Richard Porcas, Junji Inatani, Peter McCulloch, Paul Goldsmith, Chidi Akujor (guest), Valery Altunin, Lucia Padrielli, David Jauncey, Masaki Morimoto, Jim Ulvestad, Dennis Walsh, secretary Margareta Mattsson, Andrzej Kus, secretary Karin Brunzell, Richard Schilizzi, Ron Ekers, Leonid Gurvits, David Meier.

Commission J proposed a number of inter-assembly symposia for sponsorship by URSI and the importance of the work of IUCAF was confirmed. One of the 'founding fathers' of IUCAF since its inception in 1960, John Findlay, retired from IUCAF and was thanked by the Commission for his contributions to the work of IUCAF. It is also worth mentioning that Commission J expressed its 'sympathy' to the intent of a document, tabled by some of its members, entitled "Declaration of Principles concerning Activities following the Detection of Extraterrestrial Intelligence". This declaration is attached to this Chapter more for its historic interest than for its actual use up to the present (Appendix 3).

The science and technology sessions were filled with reports on progress with recently completed instruments, such as the mm-telescopes, announced in Tel Aviv, and the description of new telescopes: a plan for the 'Green Bank Telescope', a 100 m 'clear aperture' dish, certainly a worthy improvement on the collapsed 300-ft telescope; the big upgrade of the Arecibo telescope with point-feeds at several frequencies; the extension of the MERLIN array in England as well as the progress on the GMRT in India. With the VLA in full operation and several arrays at mm-wavelengths in operation there were lively sessions on the issues of data handling, interferometer calibration and imaging processes.

In connection with the GA, URSI sponsored two specialist workshops proposed and organised by the radio astronomy groups at the University of Riga, Latvia and the Special Astrophysical Observatory in Nizhnij Arkhyz, home of the RATAN 600 radio telescope in Russia. About a dozen 'western' GA participants flew from Prague to Riga for a four-day workshop on Reflector Antenna Technologies. With the aid of excellent simultaneous translators, stimulating and pleasant discussions ensued with about 25 scientists and engineers from the USSR, including Latvia, Russia and other Soviet republics. The meeting at RATAN was devoted to 'Holographic testing of large radio telescopes'. It was held in English and included a visit to the 600 m diameter RATAN 'variable profile' antenna system.

During the transfer from airport to hotel in Riga the Latvian secretary turned to us and announced: "Gentlemen, I want you to be aware that you are now in a free country, named Latvia". The trip to Nizhnij went via Moscow and finished with a three-hour drive to the Observatory. It was late at night and since leaving Riga we only had a sweet on the Russian plane. We were told there would be food upon arrival. This turned out to be a stack of large circular loaves of bread and a dozen bottles of apple cider. We finished it all before going to bed.

6. Towards ALMA and SKA

At the GA in Kyoto in 1993 Commission J proposed two Working Groups. The 'Millimeter-Submillimeter Array WG' recognised the need for international collaboration and can be considered as the seed for the creation of ALMA (Atacama Large Millimeter/submillimeter Array). The 'Large Telescope WG' had a goal of defining instrument one to two orders of magnitude more sensitive than any existing or planned facility at centimetre and metre wavelengths and to explore the required international collaboration for such a project. The SKA (Square Kilometre Array) is the result of these considerations. Presentations and discussion of these two major future projects occupied a significant part of the activity of the Commission during this Assembly.

7

An encounter of radio astronomers (from left) Ron Ekers, Richard Schilizzi and Peter Shaver with one of the numerous temples in Kyoto during the URSI GA in 1993. (The lady is unknown.)

A resolution from Commission J urging the ITU (International Telecommunications Union) to avoid spectrum allocation to services that can be realised by 'guided waves' (cable and optical fibre) was accepted by the URSI Council and submitted to the ITU. The extent to which this request has been followed is hard to assess.

During the next General Assembly in Lille, Commission J resolved to continue the Working Groups for the mm array and large telescope. The work and composition of IUCAF was discussed and new members from Commission J were elected. Its chairman Willem Baan presented an extensive report of IUCAF activities over the triennium 1996 to 1999 to the General Assembly in Toronto. It can be found on the URSI website under 'Records of General Assemblies'.

How effective the Working Groups could be, was demonstrated at the Assembly in Toronto in 1999. Progress on the establishment of an international mm array, soon to be named ALMA, was such that Commission J abandoned the working group set up 6 years earlier. Similarly, the prospects for the SKA had also reached a point, where it did not need the support from a separate working group, which consequently also stopped its work. It was decided to continue the activities of the Global VLBI Working Group in view of the increasing number of participating countries and the addition of the Japanese and Russian Space VLBI Telescopes, VCOP-HALCA and RadioAstron, respectively. Further it was proposed to set up a working group to provide support to the OECD Task Force on safeguarding radio astronomy use of the spectrum and a working group to study the effect of halting leap second insertions into UTC.

The 1999-2002 triennium saw great progress in the development of new radio astronomy facilities and the expansion of existing ones. The Giant Metrewave Radio Telescope (GMRT) in India, representing an important step forward in sensitivity at low frequencies, became fully operational. The year 2002 was marked by the operational start of the Green Bank Telescope (GBT), the 105 m diameter 'clear aperture' replacement of the venerable 300-ft that had collapsed in 1988.
Also the international efforts to establish a global large mm- and submm-array culminated in the establishment of ALMA by ESO and NSF, representing Europe and North America (USA and Canada), respectively. 'East Asia' (Japan, Korea and Taiwan) joined as 'associate partner' providing 'enhancements' to the basic instrument. ALMA is located at the 5000 m high Chajnantor plane in the Atacama Desert of Chile. At the time of the official agreement in April 2002 all parties were engaged in instrumental development work, such as prototype antenna evaluation, receiver construction and software development.

In the following triennium VLBI reached a milestone with the detection of fringes at 2 mm wavelength, representing at the time the highest angular resolution in astronomical observations ever made. The stations involved were at Haystack Observatory, Steward Observatory, and the Max-Planck-Institut für Radioastronomie with its new APEX submm telescope in Chile, and IRAM.

In the Netherlands ASTRON engaged in the design and development of LOFAR, an array that is expected to improve the sensitivity and resolution of low frequency radio astronomy by two orders of magnitude. Development of concepts and designs for the Square Kilometre Array continued as an international effort with active groups in Australia, Canada, China, Europe and the United States. The preparations for the SKA advanced sufficiently to issue a request for proposals of sites in 2004. Four viable proposals were subjected to scrutiny in 2006 leaving two, Australia and Southern Africa, on the 'short list'. Eventually, it was decided in 2012 to divide the SKA over both sites: the low frequency telescope to be located in Western Australia and the mid/high frequency telescope in Southern Africa.

Aspects of the technical realisation of these large instruments became a recurring feature of the Commission J presentation and discussion during the General Assemblies up to this day.

During 2006-7 a major discussion point became the proposed URSI White Paper on Solar Power Satellite Systems as URSI's reaction to proposals to build space-borne solar light collectors, transfer the power to microwaves and beam these to receiving antennas on earth. Commission J took the position that all statements in the White Paper and Appendices *advocating* SPS should be removed, and that considerable revision of the remainder of the material was required for this paper to reach the standard expected from URSI. The resulting URSI Council statement at the Chicago GA read: *the URSI White Paper on Solar Power Satellite Systems should be used as a reference to undertake world-wide coordinated studies to investigate the potential of Solar Power Satellites as an alternative energy source, taking into account all relevant scientific aspects, the environmental and societal impact, the impact on other radio services, and the technical and economic feasibility*. The White Paper was issued in June 2007 and can be found on the URSI web pages.

At the GA in Chicago in 2008 Commission J resolved to discontinue the Working Group on the Leap Second because its irrelevance for radio astronomy. The WG on Global VLBI continued with adjusted terms of reference and several new members. The WG concentrated on Space VLBI and seeking contact with more ground-based telescopes in particular in relation to the RadioAstron space telescope mission. In the following years discussions identified the GVWG as struggling to play a role of relevance in the modern world of global VLBI. A conclusion of this discussion was that the GVWG should be disbanded under both URSI and IAU umbrellas. Thus the GVWG was formally closed as an URSI Working Group at the GA in Istanbul in 2011.

The terms of reference for Commission J underwent another small revision at the Chicago meeting to reflect changes in the overall activities of radio astronomical research. The new text was:

Commission J - Radio Astronomy Terms of Reference

- *The activities of the Commission are concerned with observation and interpretation of all radio emissions from the early universe to the present epoch.*
- *Emphasis is placed on:*
  - *The promotion of science-driven techniques for making radio-astronomical observations and data analysis;*
  - *Support of activities to protect radio-astronomical observations from harmful interference.*

Highlights of the Chicago meeting were reports on the progress on construction of the GBT, the extended VLA, ALMA and LOFAR. Future telescopes 'in the pipeline' were described, including the SKA and its Pathfinders in South Africa (MeerKAT) and Australia (ASKAP), and the 500 m diameter FAST fixed bowl in China. Fast fibre-optic connections were enabling the European VLBI Network to operate in a real-time observing mode, called eVLBI.

7. More new, big radio telescopes

The General Assembly in Istanbul in 2011 offered a dense program of progress and results from the large new projects begun in the foregoing years. Emphasis was given to the new telescopes for low frequencies of order of 100 MHz. The status of LOFAR in the Netherlands, GMRT in India, MWA (Murchison Wide field Array) in Western Australia and LWA (long wavelength array) in New Mexico USA was presented and discussed. Many aspects of the plans for the SKA (Square Kilometre Array) were described and discussed from mundane points as power needs and signal transport to critical issues as array configuration, choice of elements (reflector antennas or phased array) and signal processing, calibration and imaging methods.
A second highlight were the reports from ALMA, which was nearing completion. A full overview of ALMA system and performance was presented, including beautiful results obtained with a partial array.
A joint session with Commissions A and G was devoted to 'Pulsar timing and Time transfer'.

The terms of Reference for Commission J were slightly adjusted with respect to the Chicago version to:

The activities of the Commission are concerned with

- *Observation and interpretation cosmic radio emissions from the early universe to the present epoch and*
- *radio reflections from solar system bodies*

Emphasis is placed on:

- *The promotion of science-driven techniques for making radio-astronomical observations and data analysis;*
- *Support of activities to protect radio-astronomical observations from harmful interference*

During the triennium to the GA in Beijing in 2014 substantial progress was made in the completion and upgrade of large telescopes such as MeerKAT, FAST, GMRT, LOFAR with a growing number of stations spread over Europe, and the Russian RadioAstron Space VLBI satellite. These were reported at the Beijing meeting, where also extensive attention was given to the developments around the SKA. Its Director Phil Diamond summarised the SKA Project at one of the General Lectures during the Assembly. ALMA, now fully completed, was also featured extensively along with reports from other (sub) millimetre telescopes APEX, SMA and the space observatory Herschel.

The complexity of the new, large instruments and the enormous data stream they produce require intensive efforts in the area of data handling and analysis. Several sessions were devoted to ‘Correlation, calibration and imaging across all wavelengths’ and ‘Time Domain Radio Astronomy: An Example of Big Data in astronomy’.

During the ‘Business Meetings’ in Beijing there was a lively discussion on the way the General Assemblies were structured. The attractiveness of URSI is strengthened by the potential of cross-fertilization between Commissions. It was found regrettable that there were so few inter-Commission sessions at this particular URSI GA, and all Commissions, including J, were urged to give priority to more coordination between Commissions (inter-Commission sessions).
At the same time the participants argued for shorter papers to accommodate more oral presentations. There should be more flexibility in assigning timeslots during some sessions, in particular for the Commission J standard sessions on “Observatory Reports” and “Latest Results.” It was not immediately clear how all these wishes could be realised within the overall duration of the General Assembly.

While Commission J no longer had any internal Working Groups, it participated in several Intra- and Inter-Union Working Groups:

- URSI Commissions: EFGHJ on ‘RFI Mitigation and Characterization’,
  represented for Comm. J by Willem Baan and Rich Bradley
- Comm. HJ on ‘Computer Simulations in Space Plasmas’, K. Shibata (Japan) for Comm. J
- URSI Inter-Commission ‘Data Committee’, Chair: S. Wijnholds (Comm. J, the Netherlands)
- URSI/IUCAF Inter-Commission Working Group on ‘Radio Science Services’,
  Chair for IUCAF: W. Van Driel (France) (ex officio)
- URSI/IAU Inter-Union Working Group on ‘Historic Radio Astronomy’,
  Chair: R. Wielebinski (Germany) (IAU), R. Schilizzi (UK) (URSI).

A proposal to participate in a recently established Working Group of the IAU for ‘Historic Radio Astronomy’ was welcomed by Commission J and URSI Council, and the WG became an IAU-URSI Working Group. The WG has national reporters in various countries that report to the WG chair on events.

The purpose of the WG 'Historic Radio Astronomy' was reviewed at the Beijing GA along with its three major tasks:
1) assemble a master list of surviving historically-significant radio telescopes and associated instrumentation found worldwide, and document the technical specifications and scientific achievements of these instruments,
2) maintain an on-going bibliography of publications on the history of radio astronomy, and
3) assemble biographies and memoirs of deceased radio astronomers.

At each GA new books and published papers in this area would be listed together with active projects. In addition, the WG planned to organise sessions on Historic Radio Astronomy at URSI and IAU General Assemblies. The NRAO maintains a webpage for the WG (rahist.nrao.edu).

The last General Assembly of URSI in its first century of existence took place in Montreal in 2017. The meeting had a large attendance; almost 1500 papers were submitted and the organisers deemed parallel sessions necessary. Commission J communicated its objection to this to the URSI Council. During the 'Business Session' there was some discussion regarding how to stimulate local URSI meetings in various countries. The concept of workshops affiliated with the URSI meetings was strongly supported.

The program of the Assembly leaned heavily on the success of (sub)millimetre instrumentation, both new telescopes, e.g. ALMA, and upgrades of existing ones. There was a large session on receivers and calibration and another on digital processing of huge data flows. Both subjects are of the greatest importance for the emerging large telescopes, both interferometer arrays and multi-beam phased array feeds (PAF) for single reflectors with their enormous data streams. The APERTIF system on the Westerbork Radio Synthesis Telescope combines PAFs on a 12-element synthesis array. Presentations on the status and outlook of ALMA, the SMA and NOEMA (NOrthern Extended Mm Array) of IRAM promised a bright future. Lars-Åke Nyman gave the tutorial lecture with title 'The Atacama Large Millimeter/submillimeter Array (ALMA)'.

Other subjects that received considerable attention were aspects of the SKA, from design issues to first experiences with MeerKAT, and observations of transient signals (bursts) and pulsars. The first session at an URSI GA on historic radio astronomy focused on the histories of a number of venerable interferometers and arrays. This highlighted the importance of knowledge of history in understanding the present needed for making sensible predictions of the future.

8. Conclusion

To return to the metaphor of the Preface, with the publication of the Centenary Book URSI has collected the summary logbook of each Commission. The one for Commission J has not been written by any of the captains during the 70 years of its existence. I have been for more than 50 years an active and enthusiastic crewmember. Writing this chapter has entailed sometimes-frustrating searches in the archives but always-pleasant recollections in memory. Commission V-J has occasionally been characterised by the 'old guard' URSI officials as a raucous group. We had however one defender among the officials: Chris Christiansen. He told his colleagues in Council: "let the blokes do their thing. They are good at it". I believe that over time the radio astronomers in Commission J have not disappointed him. Commission J is and remains an active participant in URSI.
Recently URSI in a continuous internal discussion about its means and ways has instituted a few significant changes. Since 2017 individual radio scientists are eligible for 'individual membership'. This entails some benefits, such as reduced fees for conferences and publications, but perhaps is more important for its strengthening of the link between the individual and the URSI Organisation. Also URSI has expanded its global reach with the establishment of so-called 'Flagship Meetings', the triennial Regional Radio Science Conferences in the Asian-Pacific and Atlantic regions. Thus,

together with the triennial GA we have now a big URSI meeting every year. This will arguably have a negative influence on the URSI initiated or sponsored specialised Symposia in the years between the General Assemblies, a development that perhaps is regrettable. There is a risk that an annual meeting encompassing whole URSI will lead to overfeeding or a loss of appetite and excitement. It would also appear to have a negative influence on the national URSI meetings that have been advocated repeatedly at Business Meetings during the General Assemblies.
Whatever these developments may bring, it appears quite certain that Commission J will remain a highly active component of URSI that will continue to demonstrate its relevance for URSI and Radio Astronomy through its achievements in a bright future.

Acknowledgement.
In April 2019 I was careless enough to accept a request to write the Commission J chapter for the URSI Centenary Book. At times it was hard going, mainly because archival material was hard to come by. I managed to write this chapter with invaluable help from URSI secretary Inge Heleu and the URSI Document Depository that she is still improving on the web. Knowing that she had nine other authors breathing down her neck, I have been blessed with useful and timely information. My thanks to her are deep. A few of the earlier chairmen of Commission J provided material and other information. I extend my thanks to past-chairmen Richard Schilizzi, Subra Ananthakrishnan and Richard Wielebinski and to Miller Goss, Harvey Liszt and Leonid Gurvits. A lot of information I gathered from my own notes written during the Assemblies. That I still have those is thankfully due to my wife, Marja, who let me keep them despite our move to a smaller domicile.

Appendix 1 – Contribution by the IUCAF Chairman Harvey Liszt

IUCAF - The Scientific Committee for the Allocation of Frequencies for Radio Astronomy and Space Science (http://www.iucaf.org)

Discovery of ubiquitous Galactic emission from the 21-cm line of neutral atomic hydrogen in 1953 at a frequency of 1420.40575 MHz spurred the realization by URSI radio scientists that observations at certain key frequencies would need to be protected in the face of burgeoning commercial and military use of the radio spectrum. Facing the prospect of an impending rearrangement of the radio spectrum at the ITU World Administrative Radio Conference in Geneva in 1959-1960, the Inter Union Committee for the Allocation of Frequencies (IUCAF) was formed from IAU, URSI and COSPAR to make the case for radio astronomy protection.
The history of IUCAF up to 1999 is discussed in the papers by Findlay and Robinson (references below). The passing of the first chairman of IUCAF, J-F Denisse (France), was noted at the opening ceremony of the URSI GA in Montreal in 2017.

IUCAF's activities at the WARC of 1959 and 1963 form the basis of the modern spectrum management scheme that protects all passive radio science: observations of the Earth from space by the Earth exploration satellite service that contributes vitally to weather forecasting and climate studies, and observations of the cosmos by the radio astronomy service and the space research service. Full recognition of purely passive use of radio spectrum, receiving emission solely from the natural world and the wider Universe, required rewriting some of the most basic rules for radio spectrum use (the ITU-R Radio Regulations) and is still a work in progress. The most important innovation accruing from this effort was the creation of internationally-recognized purely passive spectrum bands in which all ITU-R regulated emissions are forbidden, enabling uncontaminated global mapping of terrestrial natural radiation from space. Many nations embody similar spectrum protections in their domestic rules but keeping the passive bands free of harmful RFI is a constant struggle.

Several of the special frequencies identified in the 1950's as needing spectrum protection were related to study of the hydroxyl radical OH that was discovered in interstellar space in 1963. Early generations of various nations' global positioning satellites harmfully interfered with radio astronomy observations of cosmic OH beginning in 1979, and IUCAF led a long struggle to eliminate this interference that was only brought to a successful conclusion in Geneva in 2007. Today, IUCAF is still fighting to keep some of the same OH bands free of interference from a mobile satellite system providing satellite phone service. Spectrum management for radio astronomy is a long game, requiring constant engagement.

With several vacancies, IUCAF is composed of 4 members from each of the adhering scientific Unions, with committee members from the US, France, Sweden, South Africa, Australia, Japan and China. Its finances are managed by URSI and its annual reports appear in the URSI Radio Science Bulletin. Current activities mainly center around IUCAF's longstanding and highly-respected role as a Sector Member of the ITU-R where it leads the international effort to maintain protection of the spectrum bands allocated to radio astronomy. Since 2000, IUCAF has held a series of international spectrum management schools in the US, Italy, Japan and Chile with the next planned for South Africa in 2020.

As URSI celebrates its centenary, IUCAF has just turned 60. This is an especially fraught time for radio astronomy as long-unused spectrum allocations to radar, mobile applications (vehicles and 5G) and satellite broadband internet service are enabled by technological advances well into the mm-wave and sub-mm domains. Spectrum management is more important than ever to the continued success of radio astronomy and URSI should be especially proud of its foresight, its foundational role and its continuing support that have made it all possible.

"Be Kind To Radio Astronomy” (http://www.nrao.edu/~hlizt/RFI/)

References

John Findlay, “I.U.CAF and Frequencies for Radio Astronomy”, in ASP Conference Series Vol. **17** *Light Pollution, Radio Interference and Space Debris*,
also in International Astronomical Union Colloquium No. 112, pp. 194-197, 1991
Brian Robinson, “Frequency Allocation: the First Forty Years”, *Ann. Rev. Astron. Astrophys*. **37**, pp. 65–96, 1999.

Appendix 2 – URSI Award winners and Lecturers, and Chairmen of Commission J

The highest award bestowed by URSI is the **Balthasar van der Pol Gold Medal**. It was awarded to
Martin Ryle in 1963 for development of aperture synthesis,
Paul Wild in 1969 for the development of the Culgora Radio Heliograph,
Jack Welch in 2008 for contributions to millimeter-wavelength interferometry.

The **John Howard Dellinger Gold Medal** was awarded to
Anthony Hewish in 1972, Imke de Pater in 1984, Govind Swarup in 1990,
Alan Rogers in 2008 and Dave Staelin in 2011.
At each GA there are three **General Lectures** selected by Council from suggestions by the ten Commissions. Commission J contributed to these with the following speakers (a few names could not be traced, not even in the URSI secretariat):

1984 - Very-Long Baseline Interferometry - R. Schilizzi
1987 - The Encounters with Comet Halley in March 1986 - ?
1990 - Revealing the Invisible Universe – Ron Ekers

1993 - Radio and Radar Exploration from Spacecraft: Highlights of Magellan at Venus
G. Pettengill
1996 - none from Commission J
1999 - Space-to-Ground Interferometry for Radio Astronomy - H. Hirabayashi
2002 - Microwave background Radiation - J. Carlstrom
2005 - Impacts of Extreme Solar Disturbances on the Earth's Near-Space Environment - S. Basu
2008 - Pulsars, General Relativity and Gravitational Waves - J. Cordes
2011 - The Radio Physics of Meteors: High Resolution Radar Methods Offering New Insights - A. Pellinen-Wannberg
2014 - Square Kilometre Array - P. Diamond
2017 - Exploring Gravity - M. Kramer

Also each Commission presents one **Tutorial Lecture** on its subject during the GA.

1984 - Quasi-Optical Techniques at mm and sub-mm Wavelengths - P Goldsmith
1987 - Radio Astronomy - New Horizons - ?
1990 - Polarization - V. Radhakrishnan
1993 - Charm of Radio Astronomy and its protection - M. Morimoto
1996 - Cosmic Masers - a Useful Tool in Radio Astronomy - J. Moran
1999 - Radio Stars : The High Sensitivity Frontier - ?
2002 - Radio Astronomy on the Move Toward Microarcsecond Accuracy from Geodesy to Cosmology - L. Gurvits and A. Nothnagel
2005 - Low-Frequency Imaging - A. Pramesh Rao
2008 - Phased Arrays in Radio Astronomy - A. van Ardenne
2011 - Exploring the Epoch of Reionization with Low-Frequency Radio Telescopes - A. Parsons
2014 - Enabling Technologies for Modern Radio Astronomy - R. Ekers
2017 - The Atacama Large Millimeter Array (ALMA) - Lars-Åke Nyman

Chairmen (with one lady) of Commission J

1948-53	D.F. Martyn,	Australia
1953-57	M. Laffineur	France
1957-62	A.C.B. Lovell	U.K.
1963-65	WN. Christiansen	Australia
1966-68	E.J. Blum	France
1969-72	C.A. Muller	Netherlands
1972-74	J.L. Locke	Canada
1975-77	G. Westerhout	USA
1978-80	H. Tanaka	Japan
1981-83	V. Radhakrishnan	India
1984-86	R. Wielebinski	Germany
1987-89	R.H. Frater	Australia
1990-92	R. Ekers	USA
1993-95	Y.N. Parijskij	Russia
1996-98	R.S. Booth	Sweden
1999-2002	Jacky N. Hewitt	USA
2003-05	M. Inoue	Japan
2005-08	R.T. Schilizzi	Netherlands
2008-11	S. Ananthakrishnan	India
2011-14	J. Jonas	South Africa
2014-17	W. Baan	Netherlands
2017-20	R. Bradley	USA

Appendix 3

Declaration of Principles concerning Activities following the Detection of Extraterrestrial Intelligence.

"We, the institutions and individuals participating in the search for extraterrestrial intelligence,

Recognizing that the search for extraterrestrial intelligence is an integral part of space exploration and is being undertaken for peaceful purposes and for the common interest of all mankind,

Inspired by the profound significance for mankind of detecting evidence of extraterrestrial intelligence, even though the probability of detection may be low,

Recalling the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, which commits States Parties to that Treaty "to inform the Secretary General of the United Nations as well as the public and the international scientific community, to the greatest feasible and practicable, of the nature, conduct, locations and results" of their space exploration activities (Article XI),

Recognizing that any initial detection may be incomplete or ambiguous and thus require careful examination as well as confirmation, and that it is essential to maintain the highest standards of scientific responsibility and credibility,

Agree to observe the following principles for disseminating information about the detection of extraterrestrial intelligence :

1. Any individual, public or private research institution, or governmental agency that believes it has detected a signal from or other evidence of extraterrestrial intelligence (the discoverer) should seek to verify that the most plausible explanation for the evidence is the existence of extraterrestrial intelligence rather than some other natural phenomenon or anthropogenic phenomenon before making any public announcement. If the evidence cannot be confirmed as indicating the existence of extraterrestrial intelligence, the discoverer may disseminate the information as appropriate to the discovery of any unknown phenomenon.

2. Prior to making a public announcement that evidence of extraterrestrial intelligence has been detected, the discoverer should promptly inform all other observers or research organizations that are parties to this declaration, so that those other parties may seek to confirm the discovery by independent observations at other sites and so that a network can be established to enable continuous monitoring of the signal or phenomenon. Parties to this declaration should not make any public announcement of this information until it is determined whether this information is or is not credible evidence of the existence of extraterrestrial intelligence. The discoverer should inform his/her or its relevant national authorities.

3. After concluding that the discovery appears to be credible evidence of extraterrestrial intelligence, and after informing other parties to this declaration, the discoverer should inform observers throughout the world through the Central Bureau for Astronomical Telegrams of the International Astronomical Union, and should inform the Secretary General of the United Nations in accordance with Article XI of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies. Because of their demonstrated interest in and expertise concerning the question of the existence of extraterrestrial intelligence, the discoverer should simultaneously inform the following international institutions of the discovery and should provide them with all pertinent data and recorded information concerning the evidence : the International Telecommunication Union, the Committee

on Space Research of the International Council of Scientific Unions, the International Astronautical Federation, the International Academy of Astronautics, the International Institute of Space Law, Commission 51 of the International Astronomical Union and Commission J of the International Radio Science Union.

4. A confirmed detection of extraterrestrial intelligence should be disseminated promptly, openly, and widely through scientific channels and public media, observing the procedures in this declaration. The discoverer should have the privilege of making the first public announcement.

5. All data necessary for confirmation of detection should be made available to the international scientific community through publications, meetings, conferences, and other appropriate means.

6. The discovery should be confirmed and monitored and any data bearing on the evidence of extraterrestrial intelligence should be recorded and stored permanently to the greatest extent feasible and practicable, in a form that will make it available for further analysis and interpretation. These recordings should be made available to the international institutions listed above and to members of the scientific community for further objective analysis and interpretation.

7. If the evidence of detection is in the form of electromagnetic signals, the parties to this declaration should seek international agreement to protect the appropriate frequencies by exercising the extraordinary procedures established within the World Administrative Radio Council of the International Telecommunication Union.

8. No response to a signal or other evidence of extraterrestrial intelligence should be sent until appropriate international consultations have taken place. The procedures for such consultations will be the subject of a separate agreement, declaration or arrangement.

9. The SETI Committee of the International Academy of Astronautics, in coordination with Commission 51 of the International Astronomical Union, will conduct a continuing review of procedures for the detection of extraterrestrial intelligence and the subsequent handling of the data. Should credible evidence of extraterrestrial intelligence be discovered, an international committee of scientists and other experts should be established to serve as a focal point for continuing analysis of all observational evidence collected in the aftermath of the discovery, and also to provide advice on the release of information to the public. This committee should be constituted from representatives of each of the international institutions listed above and such other members as the committee may deem necessary. To facilitate the convocation of such as committee at some unknown time in the future, the SETI Committee of the International Academy of Astronautics should initiate and maintain a current list of willing representatives from each of the international institutions listed above, as well as other individuals with relevant skills, and should make that list continuously available through the Secretariat of the International Academy of Astronautics. The International Academy of Astronautics will act as the Depository for this declaration and will annually provide a current list of parties to all the parties to this declaration."

Figure Captions

Note. I have not numbered the figures in the manuscript because they are not referred to in the text. They strictly function as ‘illustration’. Below are the captions in order of appearance of the figure in the text and starting with a running number 1-7.
In the Word file of the manuscript text the approximate position of the figure is indicated by this

running number 1-7.
I suggest to print the captions in size 11 and perhaps in another font.

1. Christiansen on the left shows the Pott's Hill radio telescope to high URSI officials Sir Edward Appleton (far right) and, next to him, Professor B. van der Pol, famous Dutch radio scientist, during the URSI General Assembly in Sydney in August 1952. (Courtesy of ATNF Historical Photographic Archive B2842)

2. Australian radio astronomers with foreign guests at the URSI Assembly in Sydney in 1952. *From left to right: First row*: W.N. Christiansen, F.G. Smith (England), J.P. Wild, B.Y. Mills, J.L. Steinberg (France), C.F. Smerd, C.A. Slain, R. Hanbury-Brown (England), R. Payne-Scott, A.G. Little, M. Laffineur (France), G.B. Slee, J.G. Bolton. *Second row*: C.S. Higgins, J.P. Hagen (USA), J.V. Hindman (France), H.J. Ewen (USA), F.J. Kerr, C.A. Muller (Netherlands). *Third row*: J.H. Piddington, E.R. Hill, L.W. Davies. (Courtesy of ATNF Historical Photographic Archive 2842-43, 8 August 1952)

3. Wilbur (Chris) Christiansen was Chairman of Commission V from 1963-1966 and President of URSI from 1978-1981. Here he is adjusting one of the antennas of the Fleurs Synthesis Telescope (Australia) in 1973. (QV, **6**, no. 4, p.9, 1973)

4. Session during GA in Warsaw 1972; most can be identified. From bottom row up, left to right: 1 - John Findlay, F. Graham Smith, 2 - Ken Kellermann, Johann Schraml, Ard Hartsuijker, Jaap Baars, Gart Westerhout, 3 - NN, Stanislaw Gorgolewski (Toruń), Jósef Maslowski (Kraków), NN, Ms Wilhelmina Iwanowska (Director Totuń Obs., Zygmunt Turlo (?) (Toruń), 4 - Govind Swarup, Sam Goldstein, Al Moffet, Kochu Menon, 5 - Lout Sondaar, Kel Wellington, NN, NN, Tanaka, 6 - Jack Welch, NN, Mayo Greenberg (?), NN, George Swenson, 7 - NN, Harry van der Laan, NN

5. Picnic during GAS in Lima in 1975 with John Findlay standing right and Ivan Pauliny-Toth on the left in yellow shirt

6. The Global VLBI Working Group meeting in Onsala, Sweden in May 1993.
Squatting: Hisashi Hirabayashi, Roy Booth (Chair), Anton Zensus, Joel Smith.
Standing, left to right: Peter Dewdney, Fujun Zhang, Robert Preston, Richard Porcas, Junji Inatani, Peter McCulloch, Paul Goldsmith, Chidi Akujor (guest), Valery Altunin, Lucia Padrielli, David Jauncey, Masaki Morimoto, Jim Ulvestad, Dennis Walsh, secretary Margareta Mattsson, Andrzej Kus, secretary Karin Brunzell, Richard Schilizzi, Ron Ekers, Leonid Gurvits, David Meier.

7. An encounter of radio astronomers (from left) Ron Ekers, Richard Schilizzi and Peter Shaver with one of the many temples in Kyoto during the URSI GA in 1993. (The lady is unknown.)