Report of the CASCA Ground-based Astronomy Committee (GAC): December 2017

Membership and Activities

Jon Willis, University of Victoria (2014-2017, Chair 2017-2018)
John Hutchings, National Research Council (2009-2017)
David Patton, Trent University (2016-2019)
Roland Kothes, National Research Council (2016-2019)
James Di Francesco, National Research Council (2016-2019)
Els Peeters, Western (2016-2019)
Ken Tapping: Radio spectrum management
Ivana Damjanov, Saint Mary's (2017-2020)

Future facilities

TMT

The TMT site issues continue to unfold, with no definite conclusion yet. A construction permit was issued in September, but several appeals now await examination by the Hawaii supreme court. While this may be done relatively quickly, the outcome my not be in time for the nominal April 2018 start date deadline for TMT. A further complication has arisen as the Office of Hawaiian Affairs has sued the University of Hawaii for mismanagement of the mountain. The implications for TMT are not obvious, but more time may be needed to clarify that. The delays have increased the funding shortfall for the project, as well as complicating the potential partnership with the NSF. Given that the Canadian partnership agreement involves provision of specific hardware, this may form the argument for securing the extra funds, but that will have to await the final construction decision.

In the meantime, work has continued well on Canadian design studies, leading to the following milestones:

- IRIS Preliminary Design Review 1 (November 2016) and 2 (September 2017). Final Design Phase is scheduled to start in January 2017.
- NFIRAOS Real-Time Computer Final Design Review (December 2017)
- NFIRAOS Final Design Review scheduled for June 2018

All of these milestones represent a huge amount of detailed design work. The next phase after final design is fabrication and assembly. If the building proceeds next year, this puts us in a good position to deliver, and justify costs associated with the delays.

SKA

SKA international engineering consortia, which consist of some 100 institutions and 500 scientists, engineers and researchers across 20 countries are pushing hard towards the upcoming CDRs. The consortia include the Low and Mid Frequency Aperture Arrays, the Wideband Single Pixel Feed, Central Signal Processor, Dishes, Infrastructures, Signal and Data Transport, and others. The SKA is building on the science and technologies of established premier radio facilities such as the SKA Pathfinder instruments like NenuFAR, LOFAR, GMRT and many others, as well as SKA Precursor telescopes in South Africa (MeerKAT and HERA), and Australia (ASKAP and MWA). Currently under construction, the SKA Global Headquarters located at Jodrell Bank, UK will be the home of the SKA Observatory, the intergovernmental organisation set up to build and operate the Square Kilometre Array. Home to some 135 staff from around the world, it will be tasked with managing the construction and remotely monitoring the operation of the world's largest radio telescope. On 18 October 2017 the last of the 64 MeerKAT dishes was lifted onto its pedestal, a major milestone for Square Kilometre Array South Africa. The next key milestone for MeerKAT will be the integration of 32 antennas using the SKA Reconfigurable Application Board (SKARAB) correlator, which will allow for 32-dish dual polarisation observations. This will place the project well on its way to successfully meet the scheduled deadline of having all 64 antennas integrated by the end March 2018. The Murchison Widefield Array achieved a major milestone in October with the completion of the “Phase II” expansion – the first major upgrade of the MWA since operations commenced in mid-2013. CSIRO’s Australian SKA Pathfinder (ASKAP) telescope released a ground-breaking image of the Small Magellanic Cloud.

LSST

No formal changes in the LSST project have occured since the last GAC report. Construction of the 8.4-m Large Scale Synoptic Telescope on Cerro Pachón continues to progress. The United States plans to integrate the LSST administration with NOAO and Gemini into a new organization (NCOA: the National Center for Optical/Infrared Astronomy). Work continues on the legal agreement between the University of Toronto and Canadian partner institutions that will provide access to LSST for a Canadian Consortium. Since the last GAC report further progress on the legal agreement has been made although a document is yet to be finalised.

MSE

Having completed a number of successful conceptual design reviews of observatory sub-systems through May 2017, the Maunakea Spectroscopic Explorer is currently positioning itself to conduct a preliminary design phase (PDP) during 2018-2020 with the intention of presenting a construction proposal to partners in 2020. A MoU among the current MSE partners to govern the PDP is presently under discussion. Canada’s contributions to the PDP were discussed at a recent meeting between Canadian members of the MSE Science and Management groups and representatives of NRC/HAA - the aim being to plan for meaningful

contributions to the PDP within the reality of limited resources. These contributions may include 1) design and testing of the MSE fibre transmission system, 2) secondment of staff to the MSE project office, 3) development of critical computer software/hardware support of survey scheduling, telescope and spectrograph operations, in addition to data reduction and dissemination, 4) prototyping of the MSE spectrometers and 5) development of the science calibration unit.

CCAT-p

Over the past six months, there has been steady progress on the 6-m Cerro Chajnantor Atacama Telescope (CCAT-p) concept. The telescope itself is in a detailed engineering design phase and instrument teams have been firming up designs and are applying for funding. Meanwhile, science teams have been working to support the instrument funding proposals and refining the planned CCAT-p surveys. *(Thanks to Michel Fich for providing CCAT-p information for this report.)*

NGVLA

NRAO received an award of US$11M in fall 2017 from the US National Science Foundation to fund two years of design studies for the Next Generation Very Large Array (NGVLA) concept. The project is currently working on a reference array design and has contracted General Electric for a preliminary antenna design. Various studies of scientific capabilities are also being funded in the US. Following the successful Canadian Radio Astronomy meeting at McGill University in September 2017, a Canadian NGVLA mailing list, NGVLA-Canada, has been set up to keep our community apprised of NGVLA developments toward the upcoming Astro2020 US Decadal Survey. Please e-mail james.difrancesco@nrc-cnrc.gc.ca to be added to this list. The NGVLA Science Advisory Committee (SAC) is spearheading the creation of an NGVLA Science Book to be completed by 2018. Furthermore, the NGVLA SAC is organizing a conference, “Astrophysical Frontiers in the Next Decade and Beyond: Planets, Galaxies, Black Holes, and the Transient Universe,” to be held in Portland, OR on 26-29 June 2018. Preliminary work has begun on an 18-m design for an NGVLA antenna prototype at DRAO in Penticton, BC.

Current facilities

ALMA

For Cycle 5, the Atacama Large Millimeter/submillimeter Array (ALMA) received a record-breaking 1661 unique proposals, of which 180 had Canadian participation as a PI or a co-I. The number of Canadian PI-led proposals was 39. After proposal review, Canadian PIs were awarded 9.9% of the available North American (NA) time for A- or B-grade projects on the 12-m Array and 51.9% of the NA time for A- or B-grade projects on the ACA. For context, Canada funds 7.25% of the North American ALMA operations. The welcome boost in Canadian participation this Cycle was due to the Large Project “100,000 Molecular Clouds Across the

Main Sequence: GMCs as the Drivers of Galaxy Evolution" for which Erik Rosolowsky (Alberta) is a co-PI. Preparations are underway for Cycle 6. A pre-announcement is expected on December 14, 2017 with the actual Call for Proposals to be released on March 20, 2018. The deadline for Cycle 6 proposals is April 19, 2018. Please check these announcements for new capabilities offered in Cycle 6. In July, Sean Dougherty, Director of the NRC's Dominion Radio Astrophysical Observatory in Penticton, BC, and ALMA Board Member for Canada, was named Director of the ALMA Observatory. Dr. Dougherty will begin his tenure as ALMA Director on February 14, 2018. Current Acting Director Stuart Corder will resume his earlier role as ALMA Deputy Director. As of November 2017, James Di Francesco of NRC has replaced Sean Dougherty on the ALMA Board. Note that NRAO will convene its next iteration of its highly successful Synthesis Imaging Summer School in Socorro, NM on 16-23 May 2018. This School will include lectures on both the Jansky VLA and ALMA, including instruction on the CASA data reduction package used by both facilities. *(Thanks to Gerald Schieven for preparing the Cycle 5 statistics.)*

JCMT

Three of the seven original large programs from the EAO era of operations of the James Clerk Maxwell Telescope (JCMT) have collected all of their data (i.e., SCOPE, MALATANG, and S2COSMOS). In summer 2017, nine large programs were approved consisting of five brand new programs and four extensions to the original seven large programs. Please see http://www.eaobservatory.org/jcmt/science/large-programs/ for details. The observatory continues to operate with 50% of its time devoted to large programs and the other 50% devoted to PI-led programs. The over-subscription rate for PI-led programs is around 3, and is significantly higher for Canada because of our small share. The EAO Board has commissioned a Mid-Term Review committee to provide them with advice as they consider whether to renew operations of JCMT for a second five-year term starting in 2020. The MTR committee submitted its report in October 2017. The committee was asked not to make a recommendation, as this is the purview of the EAO Board. JCMT participated in the Event Horizon Telescope (EHT) observing run in April 2017 and will participate again in April 2018. The next JCMT Users Meeting is scheduled for January 31 and February 1, 2018 on the campus of Seoul National University in South Korea. On February 2, 2018, a JCMT Workshop will be held for new and experienced JCMT users. The Workshop will include presentations covering the observing process from proposals to data reduction and analysis. Canadian participation in the JCMT Users Meeting would be welcome.
(Thanks to Christine Wilson for providing JCMT information for this report.)

Gemini

In 2017B Gemini Telescopes have been involved in some major discoveries, including: 1) the first infrared images (FLAMINGOS-2) and optical spectrum (GS GMOS) detected from a gravitational wave event (a merger of two neutron stars), 2) the characterization of the first asteroid with extra-solar origin (discovered with the Pan-STARRS1 survey telescope) using GN

and GS GMOS in the imaging mode, 3) mass estimates for the earliest supermassive black hole (at z~7.5, 800 million solar masses) based on the GNRIS near-IR spectrum of its host quasar; 4) the discovery of a new class of variable stars (using GS GMOS); and 5) the first detection of a high velocity white dwarf, a remnant of the SN Iax explosion (made with GRACES, GN Remote Access to CFHT's ESPaDOnS spectropolarimeter). The discoveries listed above have been made under the new Gemini Observatory leadership. Dr. Laura Ferrarese (NRC Herzberg) started a one year term as the Interim Director on July 1st 2017. John Blakeslee (NRC Herzberg) has been appointed Gemini Chief Scientist in September 2017. The latest upgrade of the Gemini Telescopes suite of instruments is a new laser for GeMS that was installed and commissioned during 2017B. The Gemini InfraRed Multi-Object Spectrograph (GIRMOS) received CFI funding. GIRMOS combines AO with the multiple IFUs and is expected to become facility instrument at Gemini in 2022. Gemini Observatory top priorities for the development of next facility instruments remain OCTOCAM (an imager and a spectrograph that will simultaneously observe in eight optical and near-infrared filters, currently in the preliminary design stage) and Gemini High-resolution Optical SpecTrograph (GHOST, in the build stage at the NRC-Herzberg with software design by ANU). GHOST commissioning is expected to be done in 2018 on GS. After departure of the IAA-CSIC from the OCTOCAM project, Dr. Alexander van der Horst (George Washington University) was appointed Interim PI for the instrument on December 11. The OCTOCAM is still expected be ready to perform rapid follow-up spectroscopy of LSST transient targets in 2022. Following the Beyond 2021 Strategic Vision document, Gemini STAC recommended a world-class adaptive optics system to be the focus of GN. With the limited funding for instrument development in mind, STAC requested a report on the implications of moving GeMS to GN. GPI relocation study is expected in 2018A. Gemini Observatory is looking for new participants at the 5% to 20% level. Preference is given to participations at the national level. An important process for the future of the Gemini partnership is the so-called “Assessment Point” at the November 2018 Gemini Board Meeting. Partners are expected to report on their intention whether or not to remain in the Partnership post 2021 (and at what level). *(Thanks to Marcin Sawicki for providing some of the information included in the Gemini report.*)

Recommendation:

The GAC encourages CASCA to solicit input from the community in advance of the November 2018 Gemini Board meeting and to coordinate discussions on the future role of Canada within Gemini with both Canadian representatives of the STAC and Board in addition to the LRPIC.

CFHT

CFHT continues to contribute to important discoveries, including these high-impact examples: 1) Observations conducted with the CFHT were critically important for characterizing the first small body with extra-solar origin, discovered using the Pan-STARRS1 survey telescope, as an asteroid rather than a comet and for determination of its orbital parameters; 2) In collaboration with GN, ESPaDOnS/GRACES provided the first spectroscopic signature of a high velocity

white dwarf that survived a SN Iax explosion. Future CFHT instrument, near-infrared spectropolarimeter SPIRou, was shipped from IRAP/OMP to the CFHT in December 2017. A H4RG detector for the instrument is anticipated to be available in the first half of 2018. After acceptance tests are conducted, and when the on-sky capabilities of SPIRou are published on the CFHT web site, a call for Large Programs (LPs) with the instrument will be issued. CFHT teams are looking to improve currently available instruments. SITELLE's first data cube at R=9000 has been released, but the centre-to-edge quality degradation still causes 50% loss in area. The issue is being investigated. MegaCam u and g band throughput may be improved (at the 7/1.5 % level for u/g) using a new BBAR coating of the cryostat window. However, as this would affect the ongoing LP CFIS, the improvement will not be pursued for the time being. LPs from the [2013-2106] cycle - OSSOS, BinaMIcS, MaTYSSE, CFHT-Luau, and HMS - are either completed or are close to completion in terms of observations. The teams working on the programs are continuously publishing results based on these datasets.

CHIME

CHIME is an innovative radio telescope, built at the Dominion Radio Astrophysical Observatory (National Research Council). Its purposes are to a) study the expansion history of the Universe by tracing the distribution of atomic hydrogen over the redshift range z = 0.8 to 2.5, b) search for and study Fast Radio Bursts, c) make accurate and long-term measurements of pulsar timing and to search for new pulsars, and d) study the magnetic field of the Milky Way by mapping the polarized sky. CHIME has been built by a consortium of Canadian universities (UBC, Toronto and McGill). The project involves about 45 people in the Canadian astronomy community. Construction of CHIME was completed earlier this year and culminated in a ceremony on September 7, 2017, in which the Minister of Science, Kirsty Duncan, lifted the last receiver into place and declared the telescope open. Commissioning of all aspects of the telescope is now in full swing. An on-site telescope operator was hired in July 2017. The GPU correlators, the largest ever built for radio astronomy, have operated successfully. The FRB-detection algorithms have detected signals from pulsars. CHIME data are moved onto SciNet for analysis, but data rates are presently limited by the bandwidth into DRAO. It is anticipated that the telescope will move steadily to full operation through 2018.

JVLA

The JVLA, operated by the National Radio Astronomy Observatory, continues to run normally. Currently the JVLA is observing the 17B semester which runs from September 23 2017 to January 29 2018 in B-configuration. The last proposal deadline was August 1 2017 for the 18A semester, which will run from March 2 2018 through September 24 2018. During this time the JVLA will observe in A- and D-configuration. The next proposal deadline is February 1 2018 for the observing period from October 4 2018 through January 7 2019 in C-configuration. The VLA Sky Survey (VLASS) began observing on September 7 2017. VLASS will cover the entire sky visible from the JVLA at a frequency range from 2 to 4 GHz. The observations will be done in

B-configuration providing a resolution of about 2.5 arcsec down to a sensitivity of 69 microJy. All raw visibility data are available immediately from the NRAO archive at: https://science.nrao.edu/facilities/vla/archive/index

DAO

The DAO telescopes continued to be oversubscribed in calendar year 2017. The 1.2-m and McKellar spectrograph received 35 proposals requesting 396 nights for a subscription rate of 109% 63% of the requested nights were for robotic operation. The 1.8-m Plaskett telescope received 28 proposals for 364 nights. Since this telescope was unavailable for about 45 nights because of scheduled dome wheel repair work its subscription rate was a higher 120% despite the lower number of nights requested. The modest number of current users of the 1.8-m telescope (not to mention the ages of the current regular PI's!) is a concern and is the main reason our highest priority with the DAO telescopes is to complete automation of the 1.8-m.

With improvements in telescope tracking (see below), imaging time on the Plaskett telescope is now as popular as spectroscopy with 40% of the available nights used for both observing modes. The remaining 20% was used for spectropolarimetry. More than 14,000 imaging, 675 spectroscopic (this number surprised me but engineering time was scheduled during bright time as much as possible), and almost 1900 spectropolarimetric science observations have been obtained with the 1.8-m telescope so far in 2017. More than 3900 new science spectra have been acquired with the 1.2-m telescope. New and archival DAO datasets are available via the CADC's Advanced Search interface. Processing pipelines are being developed to generate processed spectra and images but to date only a few dozen processed datasets have been transferred to the archive for testing. Quick-look previews are now available through the archive for all DAO spectra and images.

A non-exhaustive use of Google Scholar suggests that the DAO telescopes contributed to 7 refereed publications, and 58 conference papers and circulars published in 2017. The many circulars are generated for solar system and SNe programs being executed on the 1.8-m telescope.

The Plaskett Telescope continues to be the centre piece of public outreach activities at the DAO. Public nights from May through September organized by the Friends of the DAO with the support of RASC-Victoria volunteers, as well as other special events such as the annual series of Vox Humana Chamber Choir performances in the dome attract thousands of visitors. Many special events are anticipated during the Telescope's centenary year of 2018 including a cake-cutting celebration during CASCA 2018.

It has been a challenging year for operation and development support for the DAO telescopes. Our good friend and colleague Les Saddlemyer passed away suddenly early in the year taking much of the detailed knowledge of the telescope systems with him. Dmitry Monin and I are now the only staff members with the knowledge needed for day-to-day instrument changes and operation of the telescopes. Dmitry has spent a good portion of the year gaining familiarity with software and hardware systems that were previously Les's responsibility. Unfortunately Dmitry himself has been on extended medical leave for a month so support of the telescopes has been a continuing

challenge and will continue to be at least until he is able to resume duties in the late winter or early spring.

On the 1.8-m our effort has been focused on hardware improvements that will eventually enable robotic operation of the telescope. This included installation of absolute encoders on both telescope drives (greatly improving tracking) and testing of an innovative collision detection system. The latter is needed to support software limits that are the only current protections in place to prevent the telescope pointing to a location on the sky that could result in collision of the spectrograph with the telescope pier. A considerable amount of time was also spent in the spring and summer investigating problems with a few new dome wheels that were installed earlier in the year. Dmitry's studies, along with those of Dynamic Structures, unfortunately demonstrated that an Ontario engineering firm's design of the new wheel assemblies has fundamental flaws that make them inappropriate for the Plaskett dome. As a result we will not be replacing the remaining wheels but now have a design and plan in place with Dynamic Structures to refurbish the existing wheels and their bearings. Fortunately this refurbishment will cost significantly less than the original plan to replace all of the domes 24 wheels.

1.2-m work has concentrated on replacing dome and telescope hardware so that we can finally upgrade the decades-old telescope control software (TCS) computer and software on the telescope. This has included new absolute encoders on both axes and new dome drive motors. A new TCS computer is ready for the port of software from the 1.8-m TCS now that Dmitry has gained some familiarity with the development environment.

Finally, Dennis Crabtree invited Todd Boroson, the director of the Las Cumbres Observatory (LCO) to the DAO to discuss possible interest in the inclusion of the DAO telescope into the global LCO network. This could in turn give all Canadian astronomers access to the complete LCO network. To be of interest to LCO the automation of the 1.8-m Plaskett telescope needs to be completed and spectrographs on both telescopes would have to be upgraded - perhaps a scaled-down rapid-acquisition 'MOVIES' spectrograph (first proposed for Gemini) for the 1.8m and a standard echelle spectrograph for the 1.2-m. Consideration was given to requesting funds for an NRC Investment Project to pursue this, but it has been decided that this is an idea that should be discussed within the framework of LRP2020. *(Thanks to David Bohlender for contributing this section.)*

DRAO

The Dominion Radio Astrophysical Observatory (DRAO) operates several observing facilities: the Synthesis Telescope (ST), a 7-element aperture synthesis array; the 26-m single-antenna John A. Galt Telescope; the 10.7cm solar radio flux monitor; and nearing completion is a "next-generation" solar radio flux monitor.

The ST is capable of simultaneous observations at 1420MHz and 408MHz. It offers wide-field continuum polarimetry and neutral hydrogen spectroscopy at the former frequency (1' resolution over a 2-degree field), and continuum total intensity only at the latter (3' resolution over a

6-degree field). Telescope time is allocated via a competitive, peer-reviewed process, with deadlines at both equinoxes each year. Both short-term and long-term proposals are undertaken, with past projects ranging from targets of opportunity to surveys aimed at wide sky coverage or deep integrations. Although best-known for its work on Galactic ISM, in particular the Canadian Galactic Plane Survey (CGPS), the ST is also used for targets from solar system to nearby galaxies. Observing time on the ST continues to be fully subscribed, with projects for observers at Canadian universities - including graduate students - and internationally. Plans for upgrades of telescope systems are currently under discussion at DRAO, and an experimental GPU-based correlator is being produced by university collaborators. In the first instance this system will mimic the output of existing correlators, but will have the ability to process larger bandwidths with higher temporal and spectral resolution when commensurate upgrades are made to other parts of the system.

The John A. Galt Telescopes is also open to external users via peer-reviewed proposals, but there are no proposal deadlines for this instrument, and the dominant use is long-term projects. The telescope has been used to observe in various bands from 400MHz to 8GHz, but the majority of experiments focus on neutral hydrogen spectroscopy at 1.4GHz. That said, the Galt telescope is currently fitted with a receiver covering the 400-800MHz band and is dedicated to calibration work related to the CHIME telescope presently under construction on the DRAO site. In parallel, work is underway to upgrade the Galt telescope to use a new cryogenic L-band receiver acquired from EMSS, similar to receivers fitted to the MeerKAT telescope in South Africa. Work on software and firmware for the control system and correlator is nearing completion. Investigations into updating cryogenic components on the telescope and installing an RF-over-fibre system for signal transport are well advanced. Once complete, this upgrade will allow exacting polarization measurements in a survey to learn about cosmic magnetic fields via the Zeeman effect in neutral hydrogen.

Solar radio monitoring is also flourishing at DRAO, with the long-running Solar Radio Flux Monitor experiment - operated in partnership with NRCan - continuing to provide thrice-daily measurements of the 10.7cm (2.8GHz) radio flux to the space environment community (via NRCan's spaceweather.ca site, as well as other methods). Upgrades on non-mechanical components are proceeding well, with one of the two redundant telescopes upgraded with new control computer and software, plus signal-path electronics that are more reliable and maintainable than the aging systems that were in place previously. This has been proven to work well, so similar upgrades will now proceed on the other telescope. The "next-generation" instrument is nearly complete, with just some software work remaining to allow fully automated operation. Uncalibrated measurements at 6 frequencies - 1.4, 1.7, 2.8, 3.3, 5.0, and 8.3GHz - are being made daily, with work on calibration proceeding well. Discussions with the user community may result in future changes and/or additions to the frequencies covered.

Radio Spectrum Management

The main spectrum management issue for Canadian radio astronomy at the moment is that there is no official representative for the interests of Canadian radio astronomy attending national or spectrum management meetings. With international efforts to extend the allocation of frequency bands above 275 GHz and discussion of communications links using THz frequencies, this could be an important issue. Even if potentially affected instruments are international efforts in which Canada is a partner, or even just users, participating in the international effort to address the interests of radio astronomy is really the obligation for any nation that is a participant in international science. As Industry Canada in Ottawa said "If protecting the interests of radio astronomy is important, why aren't you here protecting your interests nationally and internationally". Canadian radio aastronomy requires a representative.

The growing use of unlicensed, low-power radio devices and demand for spectrum space in which to use them pose a new challenge to radio astronomy. There is a line of approach for mitigating individual causes of interference. However, an increase in baseline noise due to numerous low-level interference sources such as WiFi, smart phones, internet of things devices, collision avoidance radars on vehicles is a new problem that as yet sees no solution other than to keep those transmitters away from radio telescope sites. However, there are plans to serve the needs of these devices using airborne or even spaceborne platforms. The regulations for managing these systems are being formulated now. We are one of the most communications-infrastructure dependent nations on Earth. We should be involved in these discussions, making sure our concerns are heard and helping to formulate the solutions.

DRAO has implemented a pilot radio frequency interference monitoring and identification system covering all bands of current and potential interest at the observatory. This has proved useful so the system is being expanded to provide more comprehensive monitoring and also to measure possible increases in baseline noise level. Systems like this are important when deciding on new instruments, particularly if they depend extensively on the ability to make opportunistic observations at frequencies outside bands allocated for radio astronomical use.

Radio spectrum management is an important issue for Canadian national and international radio programs. Ideally an individual or group of individuals with the appropriate mix of scientific and technical skills would be identified within NRC or the Canadian astronomical community. Their role would be to:

(a) Work with the spectrum management part of Industry Canada to help frame national policy and national proposals for taking to international spectrum management meetings (mainly the ITU and CITEL).

(b) Attend as appropriate, as a member of the Canadian national delegation, to these international meetings.

(c) Participate as appropriate in the committees, task groups and working groups formed to execute the work at these international meetings.

(d) Maintain contact with the Canadian community and also with counterparts in other countries.

(e) Participate in other international working groups such as IUCAF, dealing with the spectrum interests of radio astronomers.

(f) Inform Industry Canada on what is happening in radio astronomy.

Recommendation:

The GAC recommends that CASCA advises the NRC of the long-term importance of radio spectrum management to Canada's national and international radio astronomy program with the specific intention of encouraging NRC to allocate appropriate resources (human and financial) to the long-term engagement with national and international radio spectrum management bodies.