National Committee for Space Science

Decadal Plan

Australian Decadal Plan for Space Science Ground Working Group

Final Report:

Terms of Reference:

Intended to find out:

(i) what interests and capabilities that Australian industry and scientists have in ground-based technology,
(ii) to compare the possible differences between Industry and Science,
(iii) identify how to develop and extend these interests and capabilities for scientific, financial, and national profit.

Activity:

Industry, government and academic groups throughout the country that were expected to have a direct interest in the terms of reference of the GWG were identified and a questionnaire was sent to key people within these groups seeking information and input.

A summary of the responses was provided to the DPSS Steering Committee and circulated widely.

Several suggestions for new scientific instruments/facilities were made and the proponents invited to make submissions to the New Instruments and Missions Working Group.

Outcomes:

The information obtained by the GWG is summarized in the points below and in Appendix I which presents information within the template of the Questionnaire.

Australia’s existing resources in ground-based facilities and related scientific and technical expertise are the basis of either significant programs in space science research or the support of Australian industrial and national defence interests. These provide a solid foundation on which to develop new ground-based space science initiatives for future programs.

It is clear that in the area of solar-terrestrial physics the current suite of instruments and corresponding databases are a major national resource that could be exploited more effectively through the development of major cooperative programs, particularly between defence and non-defence organisations. Therefore the GWG recommends that:

> **A major aim of the Decadal Plan be to develop synergies between defence and non-defence organisations in order to realise the potential of existing assets, both in the form of hardware and databases, to address important scientific problems and defence applications.**

Several new ground-based instruments were proposed and these are listed in Appendix I and item (v) below. The GWG has not attempted to prioritize these as this needs to be done in the much wider overall context that the decadal plan will address.

Specific Points:

(i) The summary of the responses provides a list of relevant Australian ground-based technology (see Appendix II). The list is most likely incomplete as not all questionnaires were returned.

(ii) The following differences between Industry and Science were identified:
  - (a) Industry driven by the need to make a profit whereas science driven by the need to understand
  - (b) Industry wants to deliver high quality products, generally within the constraints of existing knowledge and costs, whereas science aims to extend our knowledge
  - (c) Industry is more concerned with applied science whereas science in academia is more concerned with basic science.

(iii) With regard to developing and extending ground-based interests and capabilities for scientific, financial, and national profit, a variety several suggestions were made and these are listed in the summary of questionnaire responses (Appendix I). These suggestions were very specific to the context of the relevant ground-based capability.

(iv) Australia clearly has substantial ground-based facilities either supporting space science (e.g. satellite and space probe tracking facilities), conducting space science research (e.g. radio, optical and magnetic instruments) or supporting industry and community activities (e.g. geospace monitoring, GPS). In the area of solar-terrestrial physics there are considerable assets that provide direct support, or have the potential to provide direct support, to defence applications such as JORN.

(v) A range of possible plans and projects for the future were suggested (see Appendix I) and several proposals for ground-based facilities have been submitted by individuals to the New Instruments and Missions Working Group. These are:

(a) The 2.4-km Australian Auroral Array
(b) Low-Latitude Digital TIGER Radars
(c) Incoherent Scatter Radar (ISR)
(d) Distributed GPS Arrays for TEC Profiling and Tomography

The GWG recommends that A major aim of the Decadal Plan be to develop synergies between defence and non-defence organisations in order to realise the potential of existing assets, both in the form of hardware and databases, to address

Appendix I. Input Obtained:

1. What are the interests and capabilities that Australian industry and scientists have in ground-based technology?

(i) **Radars:**

Ionospheric Radars: OTHR
Vertical and Oblique Sounders

Science Groups and Contacts: LTU (Dyson),
Newcastle (Menk),
DSTO (Harris).

Industry Groups and Contacts: BAE Systems,
RLM Systems,
IPS (Cole, Wilkinson)

Atmospheric Radars: Boundary Layer Troposphere (BLT) Radar, Stratosphere Troposphere (ST) Radar, Meteor Detection Radar (MDR),
Partial Reflection Radar (usually "MF radar")

Science Groups and Contacts: Adelaide (Reid),
AAD (Morris),

Industry Groups and Contacts: ATRAD Pty Ltd, design and manufacture of radar systems (www.atrad.com.au);
Genesis Software (gsoft.com.au)

(ii) **Ground-reception of satellite data:**

Remote Sensing Data:

Science Groups and Contacts: Geoscience Australia
www.ga.gov.au

Industry Groups and Contacts:

Earth-Stations for Satellite Reception:

Science Groups and Contacts: UTS (Reisenfeld)
U of SA (Parfitt)
CSIRO/COSSA (Held)
CSIRO/Nasa Tidbindilla

Industry Groups and Contacts:

(iii) **Transionospheric Propagation:**

GPS reception facilities: GPS Receivers. –
Gov't Applications and Service networks
University research networks
Every GPS user in Australia

Science Groups and Contacts: QUT (Horvath)
Univ of Adelaide (Gray)
UNSW (Rizos)
CRCSI
DSTO

Industry Groups and Contacts: Members of AGCC (Australian Global Navigation Satellite System Coordination Committee) (see www.agcc.gov.au) (Sinnott)

Scintillation and Total Electron Content

Science Groups and Contacts: DSTO (Harris)

Industry Groups and Contacts:

(iv) **Radio and other wavelength telescopes**:

Mileura Widefield Array - Low Frequency Demonstrator (MWA-LFD:

Industry Groups and Contacts: MWA Low Frequency Demonstrator SHI (Solar-Heliospheric-Ionospheric) Science Collaboration Coordination Committee (Salah).

Industry Groups and Contacts:

(v) **Ground instruments such as magnetometers, optical detectors etc. based in Australia, dependent islands, and Antarctica**:

Atmospheric Lidars: Sodium, Rayleigh

Science Groups and Contacts: Adelaide (Reid),
AAD (Klekociuk)

Industry Groups and Contacts:

Airglow/Auroral Optical Instruments: Fabry-Perot Spectrometers
Czerny-Turner Spectrometers
All-sky cameras
Photmeters

Science Groups and Contacts: Adelaide (Reid),
AAD (Burns),
LTU (Dyson)

Cosmic Ray Detectors
Science Groups and Contacts: Australian Antarctic Division (Duldig)

Industry Groups and Contacts:

Electric Field Mill
Science Groups and Contacts: Australian Antarctic Division (Burns)

Industry Groups and Contacts:

Magnetometers

Science Groups and Contacts: Australian Antarctic Division

Geoscience Australia
www.ga.gov.au)
IPS Radio and Space Services
University of Newcastle

Industry Groups and Contacts:

Riometers

Science Groups and Contacts: Australian Antarctic Division
IPS Radio and Space Services
University of Newcastle

Industry Groups and Contacts:

Variometers

Science Groups and Contacts:

Industry Groups and Contacts: IPS (Cole, Marshall)

2. Do Industry and Science have different needs and expectations? If, so what are they?

Summary

Yes, industry driven by profit, science driven by need to understand.

Yes, clearly. Scientific research into GPS transmissions is mostly using the GPS transmissions as a source of information on ionospheric transmission at L-band. Industry wants fidelity in GPS signal reception so needs to have means to compensate for ionospheric and other contaminating effects on signals. It also needs to augment the raw transmissions with information on the signals' integrity and increased accuracy, down to cms. Both terrestrial and space-based systems provide such augmentation services. Typical of a commercial operation is that of Fugro-Omnistar (has a regional operations center in Perth). High precision through a distributed CORS (Continuously Operating Reference Stations) network is delivered in Victoria and in regions of NSW – thee are currently state-government initiative but are likely to transition to a private operation. The EU is basing their Galileo constellation development on a business case that foresees enormous expansion in location-based services for cars and people: the major consumer issue to be addressed is continuity and integrity of service.

Science often aims at satisfaction at the research level (ie new and usually sophisticated knowledge) while industry can use simple unphysical models to provide customer services. However, industry will always be seeking to improve the simple models provided they are not overloaded with extra costs (eg time, computing power, unmaintainable complexity).

By SCIENCE I imagine you mean Scientific Research, as there are scientists out in industry.
I am sure you already know all this. My observation is that different needs exist driven by funding/profit requirements. Australian Industry does not have enough spare resources to invest time and money into projects that will not see a return or will not lead to a larger market share within a relatively short time. Their bottomline is profit whereas the non-Industry science bottomline is knowledge, with other benefits along the way such as PHD topics/students. DSTO/ISRD deals with Industry regularly, but mostly on a contractual basis and sometimes on a collaborative R&D basis but our drivers are different to most other non-Industry science. DSTO serves the Australian Defence interests but often with a long-term view. Applied science rather than pure?

I would see the split as being more between theoretical and applied research, rather than between industry and science. Many government agencies, for example, are active in the applied areas, as well as industry groups.

Industry (and government agencies servicing industry) is interested in specific applications – e.g. classification of landforms from space derived data sets (such as shuttle radar). University researchers tend to work in more isolated specialized groups. Consequently many are not aware of the problems that governments and industry need answers for, and they are often under resourced and ill equipped to deal with them

Industry (and supporting agencies) is often working in multi-disciplinary teams of which space-derived data (DEM, satellite imagery, position fixing) are but a few tools amongst many that are being applied. University researchers tend to work in more isolated specialized groups.

3. How should industry and science interests and capabilities be developed and extended for scientific, financial, and national profit?

With a significant joint project.

Science contributions to pursuit of national benefit from GNSS (GPS, GLONASS, Galileo and augmentation services) will be most significantly felt in addressing issues of terrestrial effects (eg signal blockage) and specific receiving systems design (eg for indoor reception and other conditions of weak or interference-prone signals). The effects of the ionosphere, which has been the subject of most science interest, are now sufficiently understood for commercial operators to feel comfortable. Firms like Fugro-Omnistar have invested heavily in ionospheric-effects modeling and it is doubtful that scientific research can improve models to a point where the commercial benefit is a significant additional quantum.

Outside Australia, in the EU and US there will be a continuing need to enhance the technology embedded in the GPS and Galileo satellites. The EU will fly passive hydrogen masers as clocks, is moving to a more modern coding scheme than currently used for GPS (and obliging the US to follow suit in GPS system upgrades), and improved satellite orbital parameter reporting will be an ongoing program in the quest for higher accuracy. None of these areas offers a realistic return on investment for Australian involvement, although there is much scope for good science.

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1) Given that radio communication via satellites will continue increasing, and that bandwidth enlargement will require higher frequencies, then satcoms will encounter greater restrictions and interference caused by propagation conditions. The same applies when high resolution positioning and timing satellites are integrated into global infrastructure. There are opportunities for the development of high resolution monitoring, modelling and data exchange for atmospheric and ionised profiles over the Asia-Pacific region.
2) Australia has established monitoring networks of ground-based GPS/TEC, ionospheric vertical and oblique sounders, and magnetometers. The data from these need to be integrated and made available in real-time on-line for scientific purposes. They should also be available in various forms for customized space weather services.
3) There are a number of major satellite downlink facilities available in Australia (eg Fedsat, TERRS, ACRES) and yet the details of their availability, their capabilities, and their supporting equipment are not generally known. Australia would be in a better position for hosting down link sites if a directory of satellite ground stations was available.

   I believe the ground station facility developed for FEDSAT has potential for financial and/or national profit.

DSTO/ISR is very interested in mesosphere-thermosphere-ionosphere coupling at mid- low latitudes, and low-latitude ionospheric dynamics.

There is a critical need to independently validate concepts and methodologies derived from space-based data. In both industry and government there is a tendency to accept spatial data as "true" without field checking. There is also a critical need to determine the best scale for spatial data sets. For example, what is the optimum resolution for radar DEM, optical imagery, etc.

These means better funding, better communication, and better peer review of research results. In the Natural resource Management field, a manger user of space-derived data, it is commonly quoted that 90% of the work outputs are not peer reviewed.

4. What should be priority topics for research and industry/science collaboration in the area of space science?

Space weather studies including solar disturbances, plasma effects on Earth's ionosphere, satellite effects, etc. This can be a good unifying theme, with practical benefits.

As noted above, there is not a persuasive reason for priority in researching the space side of GNSS, in terms of national wealth or benefit. A focus on GNSS applications that are unique to, or at least have a strong correlation with, our circumstances of low population density over much of our landmass invites some priority, in a similar way as does wide-band communications delivery "in the bush". So too, and seemingly paradoxically, do we need to understand the GPS environment, including interference and jamming threats, in urban and industrial areas where business operations are critically dependent on GNSS signals. Australia's circumstance and the way we use GNSS as an infrastructure element are not necessarily identical to those of major industrialized countries and we need our own research base in areas where we do things differently.

1) Mapping of magnetospheric currents in real-time using ground-based and satellite data updates.
2) Ability to monitor ionospheric characteristics over sparsely inhabited regions (eg oceans)
3) Development of realistic indicators of geomagnetic storm characteristics (eg intensity, duration, time of onset)
4) Occultation profiles for atmosphere and ionosphere Regional data centre for STP that can provide real-time data (solar, magnetospheric, ionospheric and possible atmospheric) in forms suitable for immediate use of industry and science.

Better access to spatial data. Some first class data sets, such as SPOT or the 1 second Shuttle DEM are either too expensive or no available in Australia.

There is major emphasis being placed on the use of distributed instrumentation to study large scale structures in the upper atmosphere. Networks of optical imagers, GPS receivers, etc. are being proposed to study the development and propagation of various atmospheric effects. Connection of such distributed instrumentation through high speed data transport to a powerful central processing system can be an important venue for industrial involvement, and could form the basis for educational outreach as well.

5. What plans/projects are needed to develop these topics?

An integrated approach using MWA-LFD and other instruments for solar and solar wind observations, and networks of distributed sensors in Australia, NZ and Antarctica, for ionospheric observations, all linked together into a central processing system.

The use of GPS signals as a probe for ionospheric investigations is well-known and my own view is that it is at a level such that further development of this area of science need not attract priority. It will not deliver significant additional national benefit. Studies on PNT application in both remote Australia and in physically and rf cluttered urban environments warrant moderate priority in order to gain greater national benefit from GNSS technology and build national robustness against the well-known vulnerabilities of the feeble GNSS signal.

Of course GNSS signals are a growing threat to radio astronomy and the move to new modulation schemes and new frequencies will amplify the nuisance. There is scope for further research into smarter ways of reducing the impact of these known signals on radio astronomy. Given the priority, rightly or wrongly, that Australia places on radio astronomy and the fact that he SKA has a good (but not assured) chance of being located on our landmass we would be well-advised to have a sound national research base in GPS-signal interference mitigation.

1) Satellite downlinks for magnetospheric data.
2) ?? TOPEX? SuperDARN data over poles? TEC over oceans?
3) ?? Measurement of magnetic structure of CMEs ? Measurement of transit velocity of CMEs?
4) GPS/Galileo occultation measurements from balloons, aircraft and satellites.
5) Automation of data transmission, analysis and integration with models.

Extension of the TIGER radars would be valuable, but even more so if they could not only LOOK poleward but also Equatorward.

B: Proposed Draft Priority Recommendations:

1. New Research Facilities:

Radars:

(i) Network of Atmospheric Radars
(ii) New OTH Research Radars
a. 2.4 km array looking poleward
b. TIGER radar looking equatorward

2. Ground-reception of satellite data:

No recommendation

3. Transionospheric Propagation:

No recommendation

4. **Radio and other wavelength telescopes**:

Develop Solar-Heliospheric-Ionospheric research using the Mileura Widefield Array - Low Frequency Demonstrator (MWA-LFD:

5. **Ground instruments such as magnetometers, optical detectors etc. based in Australia, dependent islands, and Antarctica**.

Develop virtual networks by connecting the distributed instrumentation already available and to be developed, through high speed data transport to a powerful central processing system.