National Committee for Space Science

Decadal Plan

Final Report, Recommendations, and Supporting Information – 27/11/2006

Space Technology Working Group: Australian Decadal Plan for Space Science

Members:

Iver H. Cairns, Chair, University of Sydney
Rod Boswell, Australian National University [RB below]
Roger Franzen, Auspace Limited [RF]
Alexey Kondyurin, University of Sydney [AK]
Wayne McRae, Gravitec Instruments & University of Western Australia [WM]
Sam Reisenfeld, UTS
Don Sinnott, IEEE [DS]
Salah Sukkarieh, University of Sydney [SS]
Michael Tobar, University of Western Australia [MT]

Others Canvased:

Miriam Baltuck, CSIRO
Grant Griffiths, CSIRO, Industrial Physics
Joe Khachan, University of Sydney (responded)
Phillip Teakle, CSIRO & University of Queensland
Pavel Trivailo, Royal Melbourne Institute of Technology (responded verbally)

Summary

1. Australia has a broad range of interests and desmonstrated expertise in space technology. These range from the design, building and integration of entire spacecraft to the design and building of complete communication packages (hardware and/or software), to individual hardware or software components (ranging from antennas to modems to frequency-stable oscillators to communication/control algorithims to space propulsion systems) to space habitats, and scientific instruments.
2. Australian-designed or -built space technology is on several scientific spacecraft (including Australia's current FedSat, ESA's current Envisat, and ESA's upcoming ACES) while scientific instruments with Australian design input include the SWAVES instrument on NASA's STEREO mission. Australian software and technology for the very successful UAV (Unmanned Aerial Vehicle) program, with both commercial and defence spinoffs, is likely highly relevant to space.
3. Australian space technology is state-of-the-art in several areas, including communications, propulsion systems, and novel instruments. Beyond these areas Australia has the capability to design and build spacecraft, spacecraft components, and scientific instruments to international space standards.
4. Australian Government investment in space is appropriate for reasons of national good (including defence, education, resource management, environment, duty-of-care, and infrastructure protection), national prestige, science, and technology development.
5. One successful strategy is for industrial partners of University inventers (usually funded by Government) to patent the new technology, thereby having a vested interest in developing it. This still requires significant Government support. Moreover, different situations will likely require different approaches to developing, demonstrating, and commercialising technologies.
6. Australian industry is likely to only invest in space missions when there is a very high probability of profit and complete payback within a short (e.g., five-year) period. This likely involves niche markets or ones with limited competition. A ``killer'' application is likely to lead to a foreign takeover and lack of a longterm Australian financial benefit unless provisions prevent this.
7. The Australian commercial sector is presently small and may lack the scale to completely fund large projects (e.g., > $500M). Co-investment with Government or multiple commercial partners is the practical reality.
8. GPS, navigation, satellite communications, some Earth-observation imagery, and related data are likely to become ``commodities''. Duplication by Australian Government or industry of such foreign systems (e.g., the American GPS and European Galileo systems) is not sensible or necessary, but development of commercially attractive Australian technological innovations is plausible in these areas.
9. Access to, and use of, multiple sources of such data is vital to the nation and commercial entities so as to ensure data integrity and continuity, and to reduce strategic dependence. Moreover, the hidden costs (defence, international relations, and financial) of foreign dependence, the likely lack of focus on Australian-specific issues in foreign-controlled observation systems and datasets, and the Government's likely desire to promote competition and reduce the penalty costs from limited competition, provide strong arguments for focused Australian Government and industry initiatives in these areas.

10. Commercial models for ionospheric conditions are available but likely require augmentation for scientific use and forecasting of space weather. Provision of scientific data streams and results of scientific analyses to commercial modelers may provide leverage for joint research and free provision of the commercial models to scientists.
11. Four main areas are identified as attractive for investing in innovative Australian space technology. They either have strong science rationales or can be considered enabling technology for Australian and international space projects. They are all areas where Australian technology is state-of-the-art or is internationally competitive, thereby potentially adding to national prestige and abilities, and that have commercial potential:
    a. Spacecraft electronic systems and communications technology (including communications/control hardware, software and algorithms, frequency-stable oscillators, and antennas);
    b. Spacecraft thruster and propulsion systems for in-space use.
    c. Instruments for Earth observations, including climate, atmosphere, environment, minerals, water, and emergency monitoring.
    d. Novel devices for measuring electric, gravitational, and magnetic fields, with dual scientific and commercial applications, and ideas like swarms of picosatellites and habitat construction where ingenuity and innovation are the key rather than a large supporting infrastructure.

1.a. Recommendations

12. An Australian National Space Center (ANSC) should be established to coordinate, develop, and manage Australia's national program for space science and technology.
13. ANSC should be Australia's top statuatory body for civilian space matters, empowered to sign agreements and contracts on behalf of the Australian Government.
14. ANSC should be Australia's formal point of contact for civilian space matters within the Australian Government (e.g., Defence, DSTO, CSIRO, DEST, and DITR) and with foreign governments, space agencies, and both international and domestic commercial entities.
15. ANSC's research program for space science and technology should address the goals of the present and future Decadal Plans with a balanced mix of research projects that range from pure science to mixed science/technology to demonstrators of technology.
16. ANSC's research program could be divided into a Science Directorate, a Technology Directorate, and a Missions Directorate, each with a base level of funding.
17. ANSC's initial program for technology should have four elements, summarized above in point 8:
    a. Spacecraft electronic systems and communications technology,
    b. Spacecraft thuster and propulsion systems,
    c. Earth observations instruments and systems,
    d. Novel instrument and technology demonstrations.
18. ANSC should support demonstrations of new technologies, as well as new and mature scientific instruments, on both Australian and foreign space missions.

Terms of Reference:

Intended to find out what interests and capabilities that Australian industry and scientists have in space-based technology, to compare these, and then to identify how to develop and extend these interests and capabilities for scientific, financial, and national profit.

Expected outcomes are:

1. Recommendations for priority topics for research and industry/science collaboration;
2. Recommendations for specific plans/projects that develop and extend these interests into instruments, missions, products etc.;
3. Draft text for the Plan to the Steering Committee.

Anticipated subjects include:

- Thrusters and propulsion systems for spacecraft and scientific rockets
- communications technology,
- building of mirrors and habitable structures in space,
- satellite technology, and
- technology for scientific instruments and industrial projects in space.

Projects/missions should be submitted to this WG and also to the New Australian Space Instruments and Missions Working Group (brian.fraser@newcastle.edu.au) for its consideration.

Deadline: This WG is starting work very late. **The deadline for the WG's first report is 7 July**, only 3 weeks away.

Further information on the Decadal Plan for Australian Space Science can be found at www.physics.usyd.edu.au/~ncss .

Provisional Chair: Professor Iver Cairns, University of Sydney. (i.cairns@physics.usyd.edu.au).

Input Requested:

The range of ground-based interests and capabilities relevant to space science are diverse. In order to identify these and information relevant to the development of recommendations by the GWG I am requesting that you provide information on the following by

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

(i) Communications technology:

(DS) I understand that Australia's satellite comms accessible capacity is going to be insufficient within a few years, with known planned commercial and Defence applications. I do not know if a national assessment and trade-off plan has been initiated in government but it ought to be – someone like Andrew Parfitt would be in a better position than am I to comment. When a resource is under pressure one needs to look at both the supply and demand sides: on the supply side, can we access or launch commercial satellites in the time scale required, and on the demand side can the market either manage this through pricing or by national priority-setting (eg, is it more important nationally that Defence communications with major platforms and units in defence of Australia have adequate bandwidth or that *Big Brother* be screened nationally.) The sort of national planning I see as desirable is really about national, as a superset including space, communications and while it is hard to imagine that this has not been undertaken within government it is altogether easy to imagine that not all demand inputs have been considered. Allied with this is highly desirable research into optimizing channel capacity on increasingly scarce satellite links and using increasingly valuable comms spectrum – again Parfitt at UniSA is a major player.

(SR) Satellite Payload Electronics, Onboard processing payloads, including modems, codecs, and data routing, Ka band satellites including rain fade mitigation systems, command and telemetry systems, Earth Station Hardware and Software including fast spatial and frequency tracking capability, modems, codecs including turbo codes, LDPC codes, convolutional codes, and Reed Solomon codes, combined satellite/WiMax systems, low cost earth stations for rural areas.

Science Groups and Contacts: University of South Australia (Parfitt), UTS (Reisenfeld)

(MT) UWA Frequency standards and Metrology research group, and Poseidon Scientific Instruments (PSI) Pty. Ltd. Have capability in stable frequency generation.

These oscillators are in metrology labs world-wide and at the French space Agency (CNES) for the Atomic Clock Ensemble in Space mission.

Description: PSI sells low noise oscillators, UWA makes stable cryogenic oscillators.

Contact: University of Western Australia
Professor Michael Edmund Tobar

ARC Australian Professorial Fellow
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Frequency Standards and Metrology Research Group
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(RF) Auspace Limited has developed a world leading software defined satellite communications modem along with unique waveforms that offer high levels of robustness and protection in stressed environments. This is fundamentally digital signal processing. Auspace also has the system engineering, modeling and analysis capability to develop entire system link budgets and design end to end communications systems, from earth station to satellite comms payload, including the hi-rel integration processes and methods.

Industry Groups and Contacts: Optus (G. Pike)

Defence: **Air Commodore Mark Lax**, Director General Military Strategy, Department of Defence sits over the space area of Defence. At a more accessible level is **Col Michael Collie**, Director Defence Space.

BAES Australia is a significant player in space comms areas of defence industry. The research-focussed person of influence is Dr Lincoln Wood at BAES in Adelaide.

PSI contact is:

Jesse Searls Poseidon Scientific Instruments
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AUSTRALIA

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Fax: +61 8 9335 4650

Auspace Limited

(ii) Spacecraft thrusters:

Description: (1) (RB) Designed, built, and tested a Space Simulation prototype of the Helicon Double Layer Thruster in collaboration with the CRC for Satellite Systems and AUSPACE (pre-2004), ESTEC and Ecole Polytechnique, Paris, (April 2005 and continuing). Development continuing at the ANU and negotiations are in progress with an industrial partner. [ANU]

(2) (RB) Designed, built and successfully tested a new 4-gridded compact thruster with ESA's Advanced Concepts Team & ESTEC[ANU]. Negotiations are continuing with industrial partners and the intention is to pursue this very vigorously with ESA. [ANU]
(3) (JK) Electric propulsion based on new types of discharge that generate, accelerate, and neutralize energetic atoms inside a single hollow cathode [Sydney]

Science Groups and Contacts: ANU (Boswell, Charles, Sutherland), U. Sydney (Khachan)

Industry Groups and Contacts:

(RF) Auspace has assisted Boswell, Charles and Sutherland during the early development of a specialized test configuration for this world leading ANU technology.

(RB/IHC) ESA, ESTEC and other possible industrial partners.

(iii) Scientific rockets:

(SS) **Description: Liquid Fueled Rocket – Student based project which is supported by the ADF.**

Science Groups and Contacts: Salah Sukkarieh (University of Sydney)

(DS) DSTO has a cooperative program in SCRAM jet development and experiments with Uni Qld that may be of some relevance, though not focused on space craft. A suitable DSTO contact would be Dr Warren Harch, Chief of Weapons Systems Division in Adelaide (08 8259 5555).

Science Groups and Contacts: CSIRO (Teakle)

Industry Groups and Contacts:

(iv) Satellite technology, including tethers:

(SS) Description: Small Satellite technology – picosatellites for operations involving many satellites in coordination for remote sensing. Autonomous satellite systems (independent of ground station). Algorithms for data fusion amongst many satellites and cooperative control. (A lot of this technology has been demonstrated on Unmanned Air Vehicles, for applications of remote sensing and tracking). Areas of interest are both on the technology level (building small satellites) and on the algorithm/science level.

Science Groups and Contacts: Salah Sukkarieh (University of Sydney).

(RF) Description: Auspace has a demonstrated track record of designing, building and orbiting spaceborne electro-optic systems. Our specialized integration and

test facilities were used to construct the Fedsat microsatellite. Auspace currently has two electro-optic instruments in orbit and has flown another twice on the Space Shuttle during missions STS-42 and STS-67. We have designed a compact space telescope for the Danish Space Research Agency and have assisted a Japanese consortium to baseline a Hyperspectral instrument design.

Auspace has a CDR standard design for a novel hyperspectral imaging instrument that could be built and flown on a collaborative mission.

(DS) Australia has no independent capability in satellite-based imagery or surveillance. Australia relies on the US alliance to a major extent for defence-relevant imagery but in this area, as well as in less sensitive but nonetheless important areas such as meteorology and civil communications we have no assurance of access, integrity or continuity, These matters were major themes in a recent paper put to government (the SPAG paper) which is now accessible on the web - http://www.asicc.com.au/Documents/Final%20SPAG%20submission%2028%20Nov%2005.pdf

I would recommend some consideration of the merits of a national imaging satellite to serve Australian defence and other interests, in an orbital plane that is more appropriate to us than other visible/IR/radar satellites from which services may currently be secured. Cooperation and cost-sharing with other near-equator nations could be a possibility, but of course well-heeled western-style democracies tend not to inhabit such parts of the globe so like-minded partners may be hard to find. This is not a new proposal and has a long history of rejection so don't expect a warm reception for it.

Description:

Science Groups and Contacts:

Industry Groups and Contacts:

(v) Large-size habitable and industrial structures,antennas and mirrors in space:

Description: (AK) Space industry can not be developed based on technologies that are 50 years old. The modern space station is adequate for limited scientific research, but not for routine production of materials and dev ices. We have now developed a curing process for composite materials in a free space environment. Based on this technology it appears possible to produce large sized frames (e.g., with a 100 m length and 10 m diameter) in Earth orbit. These could be used for factories to produce materials in microgravity (e.g., crystal and drug synthesis) or high vacuum (e.g., electronic components), or to build a space station or a large space ship whose life-support system is based on a greenhouse. Robotic structures like large antennas or mirrors for communications with or observations of Earth and other sources could also be created.

At present no company or space agency in the world can produce such materials and space structures. The University of Sydney appears to be unique in having this technology. With further development and testing. Australia could take the leadership position in a future space industry that produces large structures in space.

Science Groups and Contacts: A. Kondyurin, School of Physics, University of Sydney.

Industry Groups and Contacts:

(vi) Other:

The design, manufacturing, integration and testing of space based systems is a highly specialized area in which Auspace has a successfully demonstrated track record as well as proven facilities and processes. Were a space mission to be conducted in Australia, Auspace has the facilities to perform this work.

Auspace also has a strong working relationship with the Australian Department of Defence in the field of military space applications.

Auspace is the wholly owned subsidiary of Europe's largest space engineering organization, EADS Astrium.

Instruments (WM, Gravitec)
Gravitec Instruments is a research and development company currently based at the University of Western Australia specialising in the development of sensors for mineral surveying in airborne and borehole environments. We're nearing completion of two core technologies that might be of interest to space research. We have a string based magnetic sensor that directly measures the local magnetic gradient tensors (Txz, Tzx, Tyz, Tyz, Txy and Txy) and is completely immune to the local uniform magnetic field. The sensor currently has measurement sensitivity of 0.1nT/m flat response over DC-1Hz. This would improve by 2-3 orders of magnitude when developed for a space based platform offering much higher resolution signal measurements and a wider measurement bandwidth.

We also have a ribbon based gravity gradient sensor that directly measures the gradient tensors (Gxz, Gzx, Gyz, Gzy, Gxy, Gyx) and is capable of 5 Eotvos sensitivity at room temperature. The gravity gradiometer is immune to the local uniform gravitational field and would be capable of significant improvement in sensitivity (again 2-3 orders of magnitude) on a space based platform. Both sensors are cheap to produce, lightweight (ideal for space research), capable of operation at low power, simple in design and robust, and would have better sensitivity than anything currently available.

Possible applications for the sensors include:

· Mineral mapping of asteroids (space probe based), moons and planets (rover based)
· Measurement of changes from uniformity of the Earth's magnetic and gravitational fields and the Moon's gravitational field
· Measurement of magnetic remanence in the Moon
· Solar wind magnetic field measurements

Description:

Science Groups and Contacts:

Industry Groups and Contacts:

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

(SR) Industry has a hardware/software system focus and is driven towards demand pull in commercial, defence, and scientific sections. Science has an end user focus and is a user of space technology for the acquisition of data.

(AK) Industry and Science have absolutely different interests: money and knowledge. But Industry needs knowledge from Science to find new and much more profitable technologies. Science needs money to get new knowledge. These are opposition and crossing.
In sphere of my interests: Industry needs customers of large space structures now, before a start. But market of space technologies for producing of new space materials, Moon mines (for example) or outer Earth human colonies is not formed, it is only in beginning. Therefore, Industry now could not calculate a profit of present activity. Possible profit after 10-20 years is not interesting.

(MT) In my experience one can merge the two by encouraging industry to take out patents, which then become a valuable science output, which may be assessed easily. Also, this enables royalties to be paid to inventing scientists.

(SS) I think so. In many ways (from my limited understanding of the current Australian Space climate) industry requires solutions which require not much science but are heavily focused on technology and development. Aspects for example of picosatellite solutions are not required. Science could do well with cooperative small satellites however because of the cost. Also the science behind making smaller satellites robust and understanding the needs behind when smaller satellites can be used are areas of little knowledge.

(JK) I don't know enough to answer this question

(RF) Yes they do.

Industry is highly unlikely to invest to orbit a scientific instrument for academic gain only. Industry will build the instrument for academia as long as it is paid or will be able to obtain adequate commercial gain form the instruments exploitation.

Science has needs that address academic and scientific progress as well as national good issues. Industry has to be paid to provide and maintain its capability. Industry can invest in systems that have a high probability of commercial payback within a reasonable period of time but ONLY if there is the reality of payback. Communications satellite missions will pay themselves off within the first 5 years of 15 year mission lives, making them very lucrative. There are no entirely commercially funded earth observations missions. All will have some large component of Government anchor revenue augmented by general commercial sales.

The level of investment required for space missions is very high and is rarely within the capability of a single entity. Today many missions have become not only collaborations of commercial organizations but occur at international collaborative levels as well.

(DS) The main difference in expectations between Industry and Science is the requirement for industry to generate income from research investments. If even 50% of the funds invested into research generate technologies of commercial interest in the terrestrial market the generated income will offset the upfront research investment. Science for the sake of science is admirable. But from an industry standpoint there has to be some commercial outcome worth the initial investment.

Yes of course. The comments I provided to the GWG (of which I also seem to have been elected a member!) are provided for reference and bear on the specific issue of GNSS.

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

(SR) There should be an Australian Space Development Agency that would coordinate space research and development activities to fulfill for commercial needs for the use of space and defence needs. The government needs to create strategic research and development funding mechanisms and contracts provide the required seed money to move the industry forward. Specific programs and projects need to be created and linked to the economic and defence welfare of Australia.

(AK) Space is special field for such activity, profitable technologies are in future. The development of pioneer technologies must be supported by long-term government programs with minor industry support. When a new technology is developed and shown at first time, the industry support should be increased immediately. We have to pass only first time with government support.

(MT) Basic science should still be maintained, but with a system to encourage commercialization. This may be done through institutional mechanisms allowing patenting of inventions.

(SS) I am not very familiar with the current political climate regarding space, other than there has not been much support. I have my own experience with Unmanned Air Vehicles which in many ways can draw parallels. Australian interest in UAVs wasn't great 5 years ago however through funding of external (predominately US) sources we were able to not only generate interest in this country but also help support a now early but healthy industry. Sometimes I wonder whether one can do the same; gain funding from sources such as the US Air Force and NASA or ESA, and use the clout to help support interest here.

(JK) New electric thruster technology has the potential to make an impact in all three areas. The major clients for this are mainly ESA and NASA. From a University perspective, this has the potential for greater collaboration with these institutions, which will feed into our Discovery and Linkage grant applications. Thruster development is an ongoing research area and has not reached the maturity required for deep space missions, but is only suitable for satellite applications. It is not clear to me (being a new comer to this area) what financial and national benefits there are.

(RF) Australia is an intelligent and advanced user of space based data services and resources. As such, the industrial and scientific communities are best able to understand what the "next level" of space based instruments and systems should be to further our exploitation of such services. This in turn, means that we are also best able to specify what the new instrument/s should be able to do. Auspace has extensive experience in the requirements definition and system specification process and did precisely this process in concert with the CSIRO some years ago during the ARIES Hyperspectral commercial satellite compaign.

It is economically not sensible nor necessary for Australia to have a complete satellite manufacturing capability, but it is sensible for us to be able to specify and build niche *instrument systems to meet our strategic civilian and military needs. Some of these needs will be national good or scientific only and this means that the nation should be paying for the technology to satisfy the needs. In other cases, the needs can be served by commercially sourced capability, either wholly Australian owned or collaboratively owned via an international consortium.*

The scientific community will need to identify its own strategic priorities for the future. Both to capture the scientific imperative as well as inspirational vision that may help to overcome the pathological apathy resident within the Australian government bureaucracy.

Industry will sort out its own priorities on a commercial basis.

(DS) We have a very economically-dry government that will avoid intervention in markets unless there is a highly critical and politically-visible market failure (or unless we are talking about agrarian socialism). As science is funded largely from government this means that research funds and targeted application outcomes of research are largely disconnected in this country. Those few government schemes (eg from DITR) that attempt to link (partial) government funding with industry-development and research-commercialization are worth connecting with – they emphasise the importance of industry-drive in targeting research. The research-push approach (ie the research spin-off mentality) is seen as very inefficient in achieving industrially-profitable outcomes. It is crucial that the decadal plan recognizes this environment which I would not expect to be much different under an alternative government.

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

(SR) Payload design, earth station design, Ka band and EHF systems, high data rate modems and codecs, integrated space/terrestrial systems, broadcast satellites, defence communication satellites, imaging satellites for surveillance and earth resources.

(AK) Private business has come to space technology with private space carriers and satellite communications. Next step is orbital constructions for space hotels and factories. It needs a technology for space construction materials, which is on the way now in University of Sydney. No one else in the world has great success in such technology today. European Space Agency spends money for development of such technology in France space companies. NASA supports contract for development of inflatable space materials. This is just beginning. We need space oriented company for future realization of the technology and support of scientific stage of development.

(SS) Being biased here as well as limited in knowing what the global perspective is, I would say the use of small satellites (given the expected space budget the Australia could help for) and its use in aspects such as environmental monitoring and surveillance.

(RF) Earth observation for the purpose of environmental monitoring and determination of global warming by way of measuring relevant gaseous species and secondary terrestrial effects must today rate as one of the highest priorities. Opportunities for international collaboration in this endeavour exist widely.

Of highest priority is the establishment of a Federally coordinated "shop front" to aggregate all of Australia's fragmented space activities and to act as a point of reference for international collaboration opportunities.

(DS) I think the only topics in the list below that have legs in terms of being attractive for government funding outside ARC are telecomms and ground-imaging/surveillance, as indicated above. The others are far too diffuse without a clear "what's in it for us" case.

Telecommunications
Medical research
Crystal and thin film growth for optics, ICs, etc.
Mineral surveying of the Moon for future colonization
Mineral surveying of Earth Coorbital Astroids

(WM) Possible applications for the sensors include:

· Mineral mapping of asteroids (space probe based), moons and planets (rover based)
· Measurement of changes from uniformity of the Earth's magnetic and gravitational fields and the Moon's gravitational field
· Measurement of magnetic remanence in the Moon
· Solar wind magnetic field measurements

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

(SR) Federally funded space programs and involving in multi-nationally funded space programs. The creation of a National Space Agency. Efficient interface into the Australian Department of Defence, DSTO, and CSIRO.

(AK) - Polymerisation processes of composite materials in simulated free space environment.

- Polymerisation processes of composite materials in space flight on board of space station, scientific satellites, stratospheric balloon flights.
- Inflatable large space structures for large aperture mirror and antenna (up to some km diameter), large radiation shield, large-size frame of space station for industrial and scientific applications.

(SS) Small satellite technology. Algorithms for data sharing between satellites. Remote sensing using low cost sensor suites.

(JK) A national test facility for electric thrusters is needed. This usually consists of a large vacuum vessel with thruster stands for thrust measurements. The large vessel is needed to simulate a space environment. At present, no Australian University has this facility and it is quite awkward having to dismantle the thruster in order to pack it and ship it overseas to the Netherlands or other nodes of ESA. Such a facility would be relatively inexpensive to establish in Australia.

(RF) Australia needs to establish a national "shop front" as a matter of urgency. It should not be called a "Space Agency" because that concept has attracted rabid opposition from bureaucrats in the past. Something along the lines of the British National Space Center (BNSC) might be a more innocuous model to follow.

Defence, Industry and the Scientific/Academic communities will need to convene as a consultative board into which the "shop front" can be plugged.

A rational national space policy will then need to be established that addresses the national strategies from security, environmental and scientific perspectives.

(WM) Applications of the Gravitec magnetic and gravitational gradient instruments to:

- Mineral mapping of asteroids (space probe based), moons and planets (rover based)
- Measurement of changes from uniformity of the Earth's magnetic and gravitational fields and the Moon's gravitational field
- Measurement of magnetic remanence in the Moon
- Solar wind magnetic field measurements

6. The following persons should be either approached to either join the Space Technology WG or to comment on the proposals:

Name:
Contact Information: