17th April 2008

The Secretary
Senate Standing Committee on Economics
PO Box 6100
Parliament House
Canberra ACT 2600

Dear Secretary Hawkins,

Please find attached the Submission to the Senate Inquiry into Australia's space science and industry sector from the Australian hypersonics network, provided as a Word 97-2004 document.

Yours sincerely,

Russell Boyce.

QuickTime™ and a
decompressor
are needed to see this picture.

Submission by the Australian hypersonics network to the Senate Standing Committee on Economics

The Australian hypersonics network comprises the key institutions conducting hypersonics research in this country. These are: The University of Queensland (UQ); The University of New South Wales at the Australian Defence Force Academy (UNSW@ADFA); The University of Southern Queensland (USQ); The University of Adelaide (UA); and the Defence Science and Technology Organisation (DSTO). The network is university-driven and exists to maintain world-class, fundamental research in hypersonics to underpin developments in both space science and technology and high speed atmospheric and space transport.

Hypersonics is the science and technology of flight at speeds greater than approximately five times the sound barrier, and defines the design and operation of vehicles for access to and return from space, and for entry into other planetary atmospheres. Hypersonics is thus a key enabling technology for space science and industry, and features strongly in the activities of major international space players such as NASA, the European Space Agency (ESA), the respective German, French and Italian aerospace agencies (DLR, ONERA and CIRA), the Japan Aerospace Exploration Agency (JAXA), and others. Hypersonics is also the focus of considerable investment and effort by emerging space-faring nations such as India, China and Brazil.

Australia, mainly through a heritage established and maintained by our universities, but also more recently by the applied work at DSTO, is a world leader in hypersonics research and development. For this reason, we are a key element of the **space technology** part of the first Decadal Plan for Australian Space Science 2008-2017, in which we put forward a medium-term vision for an Australian capability for launching cost-effective small satellites and scientific payloads into low Earth orbit and later re-entering and recovering them. A proposal for ground-based research needed to achieve this aim appears in the Plan. Australian hypersonics is part of the working group, chaired by CSIRO, for Australian participation in the International Space Exploration Coordination Group. We also share the table with USA, Germany, Italy, France and Japan for oversight of the leading forum for advances in the field – the American Institute of Aeronautics & Astronautics **International Spaceplanes and Hypersonic Systems & Technologies** conference series.

This submission summarises the current state of Australian hypersonics, organized in line with the Terms of Reference of the Standing Committee's Inquiry into Australia's Space Science and Industry sector.

Relationship to the Terms of Reference

a) Australia's capabilities in space science, industry and education

(i) Existing Australian activity of world-class standard.

Heritage.

Australian hypersonics has, for over 40 years, been a world-class research strength for our nation. Hypersonics in Australia was started back in the 1960s by Ray Stalker. Stalker drastically increased the maximum velocity limits on the ground-based testing of hypersonic flow by developing the free-piston-driven hypersonic shock tunnel at the Australian National University (ANU) in Canberra. With the T3 tunnel in particular, Stalker and his colleagues Hans Hornung and John Sandeman made significant inroads in the understanding of hypersonic flows with real gas (finite-rate chemistry) effects. These results have proven to be critical to the design and operation of re-entry vehicles such as NASA's Space Shuttle. Eventually Stalker moved to UQ, became interested in scramjet research, developed the T4 shock tunnel for that purpose, and is still involved in the field. Scramjets are airbreathing hypersonic jet engines that are the propulsion technology most likely to enable reduced costs of access to space. More recently, Allan Paull – formerly of UQ, but now Research Leader, Applied Hypersonics Branch, DSTO - has taken the laboratory experiments to the sky with the successful world-beating HyShot flight experiment program, while Richard Morgan – Director, UQ Centre for Hypersonics - has developed the piston-driven expansion tube family that is capable of super-orbital velocities for planetary entry research. Important Australian developments in high speed diagnostic techniques for hypersonic impulse facilities, begun by Sandeman and continued by Frank Houwing and others have also been extremely important to the work here and have spread internationally.

Significant milestones in Australian hypersonics include the development of the free-piston hypersonic shock tunnels (late 60s); the understanding developed from measurements in those tunnels of many aspects of nonequilibrium chemistry re-entry flight physics (70s); development of the free-piston super-orbital expansion tubes (90s); the first demonstration and measurement of net positive installed thrust for a scramjet vehicle in the T4 shock tunnel (1995); and the first demonstration of in-flight pure supersonic combustion with the Mach 7.6 HyShot II scramjet flight experiment at Woomera (2002). For the most part, these achievements have been made through Government-funded research programs such as the Australian Research Council, whose contributions have enabled Australian hypersonics to reach the point of participating in large-scale flight test programs on an equal footing with other nations.

Current demographics.

The demographics of the Australian hypersonics community are as follows. They include the membership of the Australian hypersonics network, as well as relevant industry.

- UQ – this group, known as the UQ Centre for Hypersonics, is spread between the departments of Mechanical Engineering and Physics, and is comprised of 7 academic staff actively involved in the field including the Chair for Space Engineering (and Director of the Centre), the DSTO Chair for Hypersonics, and the Chair for Hypersonic Propulsion; 2 postdoctoral fellows; 36 PhD and Masters students; 2 technical staff.
- UNSW@ADFA - this group is comprised of 8 academic staff in the School of Aerospace, Civil and Mechanical Engineering and the School of Information Technology and Electrical Engineering; 10 (as of mid-2008) PhD students; 2 technical staff.
- USQ – the work here is conducted by 1 academic and 1 PhD student in Mechanical Engineering.
- UA - the work here is conducted by 2 academics in the School of Mechanical Engineering.

- ANU – the work here is conducted by 1 research fellow employed by National ICT Australia (NICTA).
- DSTO – in late 2006, DSTO Weapons Systems Division took on the former UQ HyShot team led by Professor Allan Paull, thus forming the WSD Applied Hypersonics Branch, located at DSTO Brisbane. This branch has recently been transferred to the DSTO Air Vehicles Division, and is led by a Research Leader and consists of 3.5 full time support staff, 9 engineers and scientists with higher degrees, a technician, one full time international visitor, a contractor and various international and national short stay visitors. It also provides facilities to UQ staff and visitors.
- BAE Systems – has supported trial activities at the Woomera Range for over 50 years and is currently the Commercial Support Contractor to the Department of Defence at Woomera. The company provides support to Defence in attracting new trial-related business to the Range, and for example, assisted the UQ hypersonics group with initial HyShot scramjet flights. BAE Systems has a particularly strong interest in supporting Australian hypersonics in conducting ongoing hypersonic programs such as HIFiRE that take advantage of the unique capabilities of Woomera. The company also has the ability to contribute advanced technology towards hypersonic flight payloads.
- AIMTEK – a Queensland engineering company, has invested approximately $500k in supporting the UQ hypersonics program, and has constructed equipment for both the HyShot team, the UNSW@ADFA shock tunnel laboratory, and the launch rail for the UQ-owned launcher at Woomera.
- Teakle Composites – an SME recently formed by Dr Philip Teakle, former CSIRO composites expert, Australian Space Research Institute director, and leader of the Queensland Smart State funded WAGTAIL rocket development project. Dr Teakle performed the carbon fibre winding to construct the nosecone for the Australia/USA HyCAUSE Mach 10 flight experiment in 2007.

Test facilities - laboratories

Our laboratory test facilities and associated diagnostic techniques have been the key to our position of world leadership in hypersonics. As discussed above, the work began at ANU, where 4 facilities were commissioned – the free-piston shock tunnels T1, T2 and T3 and the free-piston shock tube DDT. For several reasons, the ANU hypersonics laboratory closed in early 2007, but not before its two major facilities and laser-based diagnostics equipment were relocated. DDT was relocated to UNSW@ADFA in 2002, has been significantly upgraded, and is now the T-ADFA free-piston shock tunnel. The laser-based diagnostics equipment has also been relocated to UNSW@ADFA where it is operational on T-ADFA. The most significant facility, T3, has been acquired by AIMTEK, relocated to Brisbane, and is awaiting re-commissioning for scramjet test purposes.

In summary, by institution, our facilities are :

UQ : T4 free-piston shock tunnel; X1, X2, X3 super-orbital expansion tubes; T-squared small free-piston shock tunnel; Drummond conventional small shock tunnel; blowdown supersonic windtunnel; laser-based diagnostics systems for planar laser-induced fluorescence and line-of-sight flow visualisation; high speed imaging capabilities; stress wave force balances; and time-of-flight mass spectrometry for measuring species composition. In addition, UQ owns the large rocket launcher at Woomera, formerly owned by JAXA.

UNSW@ADFA : T-ADFA free-piston shock tunnel; T2 free-piston shock tunnel (disassembled); medium size blowdown supersonic windtunnel; medium size rectangular shock tube for shock wave physics research; laser-based diagnostics systems for planar laser-induced fluorescence, tuneable diode laser absorption spectroscopy and coherent anti-Stokes Raman spectroscopy measurements; million-frame-per-second camera and high-quality flow visualization systems; stress wave force balance.

USQ : Two gun tunnels – a pilot facility in operation and a large facility under construction – which can be used for hypersonic aerodynamics including scramjet inlet self-start characteristics.

DSTO : The facilities within DSTO are spread across four sites; DSTO-Brisbane, Fisherman's Bend, Edinburgh and Woomera. DSTO-Brisbane concentrates mainly on taking experimental hypersonic configurations or concepts into flight and performing the flights and post analysis. To do this it has developed the theoretical and technical understandings and the related design tools, as well as an assembly and environmental test laboratory. The majority of these facilities are located at DSTO-Brisbane, however, when required additional capabilities located at the other DSTO sites are used. The other DSTO sites provide significant support to the activities in Brisbane. In particular they provide computational analysis of both fluid dynamic and structural phenomena, material development, trial support which includes seismic sensor development, telemetry development and reception, safety template tool development, vehicle recovery through the use of UAVs as well as light aircraft. DSTO has access to the Woomera Prohibited Area on which resides the largest rocket launcher in the Southern Hemisphere, which is owned by UQ but maintained by the Dept. of Defence. In summary, the basic infrastructure to test and evaluate hypersonic flight is available within the DSTO or can be accessed by DSTO through the Australian Defence Force.

AIMTEK : T3 free-piston shock tunnel.

Test facilities - Woomera Test Facility

The Woomera Test Facility (WTF; see www.woomera.com.au) in South Australia constitutes a unique global resource offering the capability to support hypersonic trials and other demanding programs that cannot be readily undertaken elsewhere in the world (especially where payload recovery is required). The facility is managed as a strategic Defence asset by the RAAF Aerospace Operational Support Group (AOSG). As well as supporting Defence test and evaluation requirements, the WTF is used by Australian and international commercial and research organisations for conducting a wide range of space-related and other advanced trial activities. For example, the Japan Aerospace Exploration Agency (JAXA) is a frequent user of the WTF, and in addition to undertaking past supersonic and hypersonic trials, is currently guiding the Hayabusa spacecraft towards landing of an asteroid sample return capsule at Woomera in mid 2010.

Compelling attributes that render the WTF ideal for supporting hypersonic programs spanning suborbital launch and recovery, orbital recovery and deep space sample return missions include:

- Vast sparsely populated land area of 127,000 km^2 with overlying restricted airspace (largest land-based range in the world comparable to the size of England)
- Ability to safely accommodate long elliptical landing footprints typical of ballistic re-entry from earth orbit or interplanetary space
- Flat terrain facilitating low elevation target tracking and target recovery
- Favourable desert climate allowing year round operations
- Southern hemisphere location (critical for certain programs such as Hayabusa)
- Extensive supporting infrastructure and services at the Woomera Range, Woomera Airfield and Woomera Village
- Supportive approach by the Department of Defence for non-Defence use of the WTF

Given the unique capabilities of Woomera and resulting appeal to overseas research organisations, the WTF represents a key strategic factor in leveraging Australian scientific, technical and industrial participation in pioneering R&D programs. Nowhere is this truer than current and future hypersonic research with wide-ranging applications in national security, next generation space launch vehicles and ultimately hypersonic airliners. The WTF is therefore a powerful complement to the extensive expertise available within Australian hypersonics, and must be used to maximum advantage in securing Australian involvement in international hypersonic programs such as HIFiRE and beyond (including Mars sample return missions currently being planned by ESA and NASA).

Current research activities.

The current research activities in Australian hypersonics can be divided into one of three different categories.

Firstly, hypersonics for atmospheric cruise. Australia, led by DSTO, is currently an equal partner in the Australia/USA HIFiRE program. The American lead is the USAF Research Laboratory. This is an approximately US$50M 10-flight fundamental hypersonics flight experiment program to conduct HyShot-like hypersonic aerodynamics, airbreathing propulsion and control flight experiments at Mach 8. From the Australian point of view, the program represents pushing up the Technology Readiness Level (TRL) of many concepts that have been investigated and demonstrated in our shock tunnels, taking the laboratory experiments to the sky. The flight speed chosen is typical of atmospheric cruise applications, and the mid-range TRL work performed in Australia, underpinned by substantial fundamental research in our universities, represents a stepping stone to hypersonic technologies for the second category - hypersonics for access-to-space.

Current funding in this category includes the UQ/Boeing/QLD-State-Government-Smart-State initiative that funds the UQ HyShot group to contribute 3 flights to the HIFiRE program; ARC DP funding for scramjet drag reduction; and USAF Asian Office of Aerospace Research and Development (AOARD) funding for diode-laser-based flight instrumentation development. ARC DP proposals are currently under evaluation for scramjet inlet self-starting capabilities and for laser-enhanced scramjet ignition.

Secondly, hypersonics for access-to-space. As mentioned above, Australian hypersonics is an important contributor to our national effort in space science, since it represents an enabling technology for getting to and from space. This year, under the umbrella of the Australian Academy of Science, the Australian space science community is releasing its inaugural Decadal Plan for Australian Space Science 2008-2017, and hypersonics features strongly in it. In particular, we are proposing research towards developing a multi-stage rocket/scramjet launch vehicle for placing small scientific payloads in low Earth orbit and then re-entering the atmosphere and recovering those payloads. The “getting there” part of the plan is the topic of a very large ARC DP funding proposal for the next 5 years. This will couple fundamental research into innovative concepts with development of advanced 3D flowpaths, and is in partnership with both JAXA and DLR. The “getting back” part falls into the third category – planetary entry aerothermodynamics.

Thirdly, planetary entry aerothermodynamics. Currently, there is ongoing ARC-funded research in both the forebody flows and the base flows of planetary entry capsules, including measurements of radiative heat flux in our super-orbital expansion tubes. This capability is unique, and of considerable interest and the subject of discussion with agencies such as NASA and ESA. European Commission FP7-funded aerothermodynamics research is also underway here.

Key niche contributions.

Australian hypersonics has many capabilities and areas of research focus that are either unique or world–leading. These enable us to play important niche roles in global access-to-space developments, and with sufficient resources, beyond those presently available to us, would enable greater participation in foreign-owned launch services. Independent launch capability for small satellites and scientific payloads is part of the long term goal of Australian hypersonics, and we have the potential to realize this.

For scramjets, whether it be for atmospheric cruise or access-to-space, some of the greatest technical challenges are: designing self-starting inlets; reducing inlet losses; achieving rapid fuel injection/mixing and rapid ignition to reduce combustor lengths and weights; minimizing skin friction drag; handling the enormous thermal loads; and achieving adequate off-design performance. In Australia, we are performing research in all of those areas and more. For example : developing facilities for inlet self-starting research; research into Rectangular-to-Elliptical-Shape-Transition (REST) engines that have minimal inlet total pressure losses and minimal wetted surface areas while being easy to integrate with vehicles; injection of fuel in the scramjet inlet, allowing mixing to occur upstream of the combustor, followed by shock-induced combustion; the use of the "radical farming" concept to use localized hot flow structures to cause ignition even when the mean flow conditions are too mild for ignition to occur; reduction of combustor skin friction drag by burning fuel in the boundary layer; hot structures research for hypersonics applications; and novel robust multi-disciplinary-design-optimisation research. For planetary entry vehicles, the measurement and prediction of radiative heat flux is a serious issue, and in this area we are developing methods for measuring the radiative component of heat flux in super-orbital flowfields. We are also actively involved in developing diode-laser-based flight instrumentation.

International collaborations.

Australian hypersonics is regarded internationally as a world-leader, and as a result we participate in significant international collaboration. These range from individual bilateral researcher-to-researcher collaborative research to multilateral institution-to-institution programs to very large programs such as the Australia/USA US$50M HIFiRE program. Specific foreign institutions that we work with include : NASA; USAF; Boeing; ESA; DLR; CIRA; QINETIQ; JAXA; as well as universities across North America, Europe, India, China and Japan.

Education.

Hypersonics is exciting and plays a role in inspiring young people to study science and engineering. Hypersonics engineering education in Australia can be divided into three categories – undergraduate and Masters degree coursework; undergraduate final year research projects; and graduate research. Coursework education is provided primarily through the degree programs in Mechanical Engineering and Space Engineering at UQ, and Aeronautical Engineering and Mechanical Engineering at UNSW@ADFA, and consists of 4th year elective courses and their Masters equivalents.

The main thrust of education is however through research training, and Australian hypersonics has produced a large number of higher degree graduates who have found employment in many leading aerospace organisations around the world (including NASA, DLR, JAXA, QinetiQ, GE, Airbus, Aerojet, EADS and a large number of universities), and represent a very powerful influence for including Australian technology in international space programs. Australian hypersonics alumni have also taken important positions domestically – for example, a former CSIRO Chief Scientist, Dr Malcolm Macintosh; several DSTO personnel at Research Leader or Group Leader level; and the current Rector of UNSW@ADFA.

(ii) Areas with little activity but within the country's capability.

As detailed above, Australian hypersonics is active in fundamental university-based research towards technologies for access to and return from space (low range TRLs) and in flight experiments at Woomera towards atmospheric cruise (midrange TRLs). With our network of people and facilities, our country is capable of taking this much much further. Areas of current low or nil activity that are within our capability are :

- Participation in international re-entry flight experiments, utilizing Woomera. This was planned, but did not eventuate due to technical problems, for the German/Japanese/Russian EXPRESS capsule in 1995, and is currently planned for re-entry of the Japanese Hayabusa asteroid-sample-return mission currently in progress. Discussions are underway with ESA (Aerothermodynamics Branch) for Australian participation in three proposed re-entry flight experiments, to be launched from Russian submarines. These are : a microgravity scientific payload recovery capsule demonstration; a multi-capsule flight for which Australia could design, instrument and fly one or more capsules; and a boosted super-orbital velocity radiation flight experiment to re-enact NASA's 1965 Fire-II flight with modern instrumentation. Australian participation can include ground testing, modeling, payload design/ manufacture, and Woomera.
- Participation on international space exploration programs. In particular, the International Space Exploration Coordination Group, of which CSIRO shares the table with 13 foreign space agencies such as NASA and ESA, is seeking a coordinated approach to return to the moon and exploration of Mars and beyond. Controlled spacecraft entry into the Martian or other atmospheres requires hypersonics technologies. Australia has conducted fundamental ground tests of such scenarios. Participation in the development and enactment of actual missions is possible.
- Development, manufacture and flight of hybrid rocket/scramjet vehicles for placing small payloads into Low Earth Orbit. This would extend the TRLs of our fundamental access-to-space research (discussed in the Decadal Plan for Australian Space Science 2008-2017) to mid-range and higher, building on the atmospheric cruise flight experiment program currently underway. The payloads could be space science experiments or they could be small satellite systems that reduce Australian reliance on foreign satellites for Global Positioning System (GPS), national security, and other purposes.
- Space tourism. With our hypersonics R&D capability and the Woomera Test Facility for performing incremental flight experiments, Australia is capable of participating in and capitalizing on the enormous growth worldwide in commercial interest and investment in technologies needed for space tourism – in particular, technologies for the development of reusable and reliable launch vehicles. Successful development of these technologies for this market will dramatically reduce the cost of access to space for commercial, space science and strategic purposes. If this comes to pass, enormous economic, social and strategic benefits will flow. In the meantime, attraction of a share of the global venture capital available for pursuing these developments will also considerably benefit Australia. See below in b(ii) for an expanded argument.

b)

Arguments for and against expanded Australian activity in space science and industry

(i) Risks to Australia's national interest of dependence on foreign-owned/controlled satellites.

Not discussed in this submission.

(ii) Potential benefits for Australia from further development of our space capability.

In terms of our hypersonics capability, further development will have the following potential benefits for Australia : greater participation in international flight programs with agencies such as ESA, NASA, CIRA, JAXA, with corresponding greater access to flight data and know-how; capability for domestic flight programs and missions, thus leading to independence with respect to being able to launch small satellites and scientific payloads to Low Earth Orbit (LEO), including for purposes such as GPS and national security; corresponding cost reductions for our space science community and for commercial sectors such as telecommunications; opportunities for commercial participation in the technology as it matures to higher TRLs; the ability to attract international venture capital for space tourism R&D; greater foreign usage of the Woomera Test Facility for flight programs, which will have both economic benefits to Australia and increased participation in those programs by Australians; and excitement of our young people, leading to greater numbers attracted to studying science and engineering, thus expanding the local high technology workforce.

The long term potential for space tourism is considered in more detail here. Enormous attention and investment is being given worldwide to space commercialization, including space tourism. Of the order of US$1 billion has already been invested in commercial space ventures[1]. Proposed spaceports in Singapore and the United Arab Emirates, totaling almost US$400M, are an indicator that significant venture capital exists to support such ventures[2]. The dream of space tourism, where private citizens can access space for recreational purposes, is rapidly becoming reality – 6 people have already spent approximately US$20M each on flights to the International Space Station, and Richard Branson's Virgin Galactic sub-orbital space tourism flights, based on Burt Rutan's X-Prize-winning Spaceship 1 vehicle, have approximately 250 reservations for US$200k tickets and over 85,000 expressions of interest in taking flights at some stage[3].

The potential market for and success of space tourism **depends on the cost of the ticket**. Market research and analysis by Futron Corporation[4] indicates that sub-orbital flights, starting at US$200k per ticket in 2008 and decreasing to US$50k by 2021, would grow in demand to approximately 15,000 passengers per year by the end of that period, with revenue in 2021 reaching almost US$700M per year. Sub-orbital space tourism has enormous short term potential, and with our domestic capabilities, Australia can participate in this. In fact, Virgin Galactic has expressed specific recent interest in establishing a Spaceport in Australia.

Orbital flights on the other hand, needed to access the International Space Station, or orbiting space hotels being proposed, are much further from reach. Based on current launch vehicle technology (rockets), at $20M per ticket in 2010 and decreasing to $10M in 2021, Futron predict approximately 60 passengers per year by the end of that period and total revenue in 2021 of US$300M. This is insufficient revenue to justify the cost of developing the launch vehicles and infrastructure needed for orbital travel.

However, market research also shows that if the price per ticket can be reduced to something of the order of a 1st class intercontinental airfare, the demand would be of the order of hundreds of

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[1] Mary Evans, "Rocket renaissance : the era of private spaceflight is about to dawn", *The Economist*, May 11, 2006.

[2] RD Launius, DR Jenkins, "Is it finally time for Space Tourism?", *Astropolitcs*, 4:253-280, 2006.

[3] http://www.virgingalactic.com, April 16, 2008.

[4] http://www.futron.com/pdf/resource_center/white_papers/SpaceTourismRevisited.pdf, 2006.

thousands of passengers per year[5]. The development costs of the launch system and infrastructure can then be amortised over many flights, contributing to much of the reduction in cost. The remaining cost reduction must be achieved by successful development of vehicles that are both **reusable** and **reliable**[6]. Reusability means that the very expensive vehicle is not discarded after each flight. Reliability means that the vast cost associated with complex procedures and the teams required to perform them for each flight, for vehicles such as the partially reusable Space Shuttle, is reduced.

Scramjet propulsion offers the potential for both reusability and reliability. Reusability because it is an airbreathing jet engine, and reliability because by not carrying oxygen on board, more mass is available for the vehicle structures and redundant systems that are missing from rockets but are necessary to bring reliability to levels associated with aviation[6]. If the cost of access to space is thus reduced for space tourism, then the cost of access to space for commercial, space science and strategic purposes will also be reduced. If this comes to pass, enormous economic, social and strategic benefits will flow. The point here is that although this is a long term possibility that requires significant technological breakthrough to come to pass, through Australian hypersonics our country is in an excellent position to attract a share of the international venture capital that is available for such efforts. This applies whether or not future launch systems include scramjet propulsion or rely completely on rocket technology. Not only will this help us contribute to the breakthroughs and ultimately reap the rewards that would follow, but it will provide substantial economic benefit in the meantime. The hypersonics work detailed in the Decadal Plan for Australian Space Science 2008-2017, and for which support is requested in that Plan, is focused towards such breakthroughs. Encouragement of commercial support and involvement is also extremely important.

Two further potential benefits from investment in hypersonics technology are worth brief discussion here – access to hypersonic weapons systems for long-range strike; and intercontinental transport. DSTO is now investing heavily in research towards the former, in collaboration with USA, and does so because hypersonic missiles represent a very effective weapons system against which it will be difficult to defend, and because if Australia is not a stakeholder in the development of the technology then we are at risk of being denied access to it. Any strengthening of our hypersonics capability for space-related purposes will also strengthen our strategic developments, with further benefit for our nation. Concerning intercontinental travel, the eventual application of hypersonics technology to this would dramatically reduce international transit times and revolutionise international business dealings. Such impacts, as well as holding a stake in the technology, would also reap considerable benefit for Australia. Again, any strengthening of our hypersonics capability for space-related purposes will flow to this application as well. Investment in our capability is money well spent.

(iii) <u>Needs not being met by Australia's existing space resources or access to foreign resources.</u>

Australia is one of the heaviest users of space per capita. Space-based technologies upon which we are increasingly reliant include satellite systems for research, telecommunications, GPS systems, and national security. We are currently unable to cheaply launch small satellites for such purposes, our costs for access-to-space are high, and we rely completely on foreign launch providers. Australia needs to be a stakeholder in launch provision – by contributing significantly to international reusable launch vehicle technology as a niche player, thus reducing the cost of accessing launch services, and by developing an independent capability for launching small payloads. Both can be achieved by greater government investment and encouragement of

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[5] JP Penn, CA Lindley, "Requirements and Approach for a Space Tourism Launch System", *Acta Astronautica*, 52:49-75, 2003.

[6] RJ Stalker, "Space Transportation – Why is it so Expensive?", Australian Academy of Technological Sciences and Engineering, *Focus* No. 108, Nov/Dec 1999.

commercial investment and participation in Australian hypersonics beyond levels normally associated with university research – in effect, to foster a domestic space sector that designs, builds and flies hardware, underpinned by our existing capabilities. Encouragement of national and international space tourism venture capital could play an important role here.

(iv) Impediments to strengthening and expanding space science and industry in Australia.

Impediments to strengthening and expanding space science and industry in Australia include the current lack of government policy that makes space science and technologies a national priority for research and development, and makes it a priority for international linkage with the key international players, particularly USA (NASA) and Europe (ESA and European national agencies). A further impediment is the lack of an Australian space agency to coordinate and fund technological developments, partner with foreign agencies to facilitate Australian participation in major international technology development, space mission planning, and so on, and to buy indigenous space capability as it is developed.

(v) Goals of any strengthening/expansion of Australia's space capability.

From the point of view of Australian hypersonics, the goals of any strengthening/expansion of our domestic capability would be : the development of prototypes for hybrid rocket/scramjet powered launch vehicles for small scientific or applied payloads; development of Australian re-entry and recovery technologies; flight testing these at Woomera; fostering a domestic industry sector that can participate in the maturation of the technologies and take them to commercialisation.

c) Realistic policy options.

The Australian hypersonics community would encourage the government to : establish a national space agency; create a space policy that addresses Australia's future space-related needs, places priority on space science and technology, places priority on domestic development of the hypersonics technologies needed for cheaper and more independent access to space, and fosters engagement and partnership with foreign agencies; and encourage of domestic and international commercial investment in Australian hypersonics technologies. As part of this, we also encourage the government to adopt the goals and recommendations of the Decadal Plan for Australian Space Science 2008-2017.

Conclusion

Australia is a world leader in hypersonics R&D, for applications such as high speed atmospheric transport, launch vehicle technology for access to space, and technology for return from space. We have the knowledge base, the expertise, the personnel and the facilities necessary to

- be partners and stakeholders in major international space technology developments,
- be able to attract significant foreign investment,
- develop the independent capability for launching and returning to Earth small payloads for space science research or for economic, social and strategic applications, and
- grow an exciting sector that will encourage many more young Australians to study science and engineering

The Australian hypersonics community encourages the Senate Standing Committee to consider and support the arguments and recommendations in this submission.