



15TH AUSTRALIAN SPACE RESEARCH CONFERENCE

September 29 - October 1, 2015

(INCORPORATING THE 3RD AUSTRALIAN WORKSHOP ON SPACE SITUATIONAL AWARENESS)



Australian Academy of Science



NATIONAL SPACE SOCIETY
OF AUSTRALIA LTD



UNSW
THE UNIVERSITY OF NEW SOUTH WALES

CANBERRA



Mars Society Australia





Welcome to the 15th Australian Space Research Conference

and to the University of New South Wales, Canberra! This will be the ninth ASSC jointly sponsored and organised by the National Committee for Space and Radio Science (NCSRS) and the National Space Society of Australia (NSSA). The ASRC is intended to be the primary annual meeting for Australian research relating to space science. It welcomes space scientists, engineers, educators, and workers in Industry and Government.

The 15th ASRC has over 120 accepted abstracts across Australian space research, academia, education, industry, and government.

We would like to thank the University of New South Wales (Canberra) for hosting the event, led by Russell Boyce, and Lockheed Martin for their sponsorship. Special thanks also go to the Australian Space Mars Society Australia (MSA) for its support.

We look forward to an excellent meeting!

Iver Cairns
Co-Chair ASSC 2015
University of Sydney

Wayne Short
Co-Chair ASSC 2015
President, NSSA



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The National Space Society of Australia is the coming together of like-minded space enthusiasts who share a vision for the future in which there is an ambitious and vigorous space program leading to eventual space

settlement.

To this end the National Space Society (worldwide) promotes interest in space exploration, research, development and habitation through events such as science and business conferences, speaking to the press, public outreach events, speaking engagements with community groups and schools, and other pro-active events. We do this to stimulate advancement and development of space and related applications and technologies and by bringing together people from government, industry and all walks of life for the free exchange of information.

As a non-profit organisation, the National Space Society of Australia draws its strength from an enthusiastic membership who contributes their time and effort to assist the Society in pursuit of its goals.

For more information, and to become a member:

www.nssa.com.au

Ad Astra!
Wayne Short
NSSA President 2015



The National Committee for Space and Radio Science (NCSRS) is chartered by the Australian Academy of Science to foster space science, to link Australian space scientists together and to their international colleagues, and to advise the Academy's Council on policy for science in general and space and radio science in particular. The NCSRS was formed in 2012 by combining the former National Committee for Space Science (NCSS) and the National Committee for Radio Science (NCRS). The NCSRS web page can be reached at

<https://www.science.org.au/committee/space-and-radio-science>

NCSRS believes that ASRC meetings provide a natural venue to link Australian space scientists and foster the associated science, two of its core goals. As well as ASRC, NCSRS is also sponsoring the VSSEC – NASA Australian Space Prize.

This is the fifth ASRC meeting following launch of the first Decadal Plan for Australian Space Science. NCSRS encourages people to work together to accomplish the Plan's vision: "Build Australia a long term, productive presence in Space via world-leading innovative space science and technology, strong education and outreach, and international collaborations."

2015 ASRC Program Committee

Jeremy Bailey (UNSW Australia)

Russell Boyce (UNSW Australia, Canberra)

Iver Cairns (Co-Chair, University of Sydney)

Graziella Caprarelli (Co-Chair, University of South Australia)

Jonathan Clarke (Mars Society of Australia)

Andrew Dempster (UNSW Australia)

Alice Gorman (Finders University)

Duane Hamacher (UNSW Australia)

Trevor Harris (Defence Science and Technology Group, Department
of Defence)

Isabelle Kingsley (POWERHOUSE Museum)

Flavia Tata Nardini (Launchbox Australia)

Carol Oliver (UNSW Australia)

Tim Parsons (Delta V SpaceHub)

Chris Rizos (UNSW Australia)

Richard Samuel (Australian Space Research Institute)

Chris Rizos (UNSW Australia)

Murray Sciffer (University of Newcastle)

Kefei Zhang (RMIT University)

2015 ASRC Organising Committee

Russell Boyce
UNSW Australia (Canberra)
Chair, local organising committee

Cheryl Brown
Australian Centre for Space Engineering Research, UNSW Australia
Conference Secretariat

Iver Cairns
University of Sydney
Co-Chair ASRC 2015
Co-Chair, ASRC Program Committee

Graziella Caprarelli
University of South Australia
Co-Chair, ASRC Program Committee

Aditya Chopra
Australian National University

Jonathan Clarke
Mars Society Australia

Alice Gorman
Flinders University

Jonathan Horner
University of Southern Queensland

Philippe Lorrain
UNSW Australia (Canberra)

Wayne Short
Co Chair ASSC 2015
President, NSSA

Program Overview

| TIME | TUESDAY | WEDNESDAY | THURSDAY | TIME |
|-------|-----------------------------------|--|---|---------------|
| 8:00 | Registration | Registration | Registration | 8:00 |
| 8:30 | | Plenaries | | 8:30 |
| 9:00 | Opening / Plenaries | | Plenaries | 9:00 |
| 10:00 | | Mars Symposium | | 10:00 |
| 10:30 | | Satellite Platforms | | 10:30 |
| 11:00 | Break | SSA Workshop (1) | Break | 11:00 |
| 11:15 | | | | 11:15 |
| 11:30 | | Break | | 11:30 |
| 12:00 | | | | 12:00 |
| | National Context | Mars Symposium (con't'd) | Space and Atmospheric Physics | |
| | | Satellite Platforms (cont'd) | Earth Astro-Biology | |
| | | Space Projects | | |
| 12:30 | | SSA Workshop (1) (cont'd) | | |
| | | | Lunch (12:20) | Lunch (12:45) |
| | | | | |
| 13:00 | Lunch / Poster Session 1 | Lunch (13:15) | Poster Session 2 | 13:00 |
| 13:30 | | Lunch | | 13:30 |
| 14:00 | | Plenary Talk | Education | 14:00 |
| 14:30 | Space and Atmospheric Physics | Remote Sensing | Planets | |
| 15:00 | Archaeo-astronomy/ Indigenous Sky | Satellite Subsystems | | 14:30 |
| | Break | | | 15:00 |
| 16:00 | Break | (16:10) Break | Space Engineering | |
| 16:30 | Small Objects SS / Meteorites | (16:15) Break | Break | 16:00 |
| 17:15 | GNSS | Decadal Plan Mid-Term Review Town Hall Meeting | | 16:30 |
| 18:00 | Cocktail Reception | | Closing remarks / Prize Giving Ceremony | 17:15 |
| 19:00 | | | | 18:00 |
| 19:30 | | Gala Dinner | Mars Society Dave Cooper Public Talk | 19:00 |
| 20:30 | Close | | | 19:30 |
| 22:00 | | Close | Close | 20:30 |
| | | | | 22:00 |

Venue Details

The entrance at UNSW Canberra to use for conference delegates is via Northcott Drive. The conference venue on the campus is the Lecture Theatre North (building 32) complex. The theatres on the top floor of this building will be used for the conference. The northern car park on Kapyong road is the closest car park for visitors with vehicles onsite.

Stream 1 and other Plenary sessions will be held in Lecture Theatre 7.

Stream 2 sessions will be held in Lecture Theatre 6.

Stream 3 sessions will be held in Seminar Room 7.

The Space Situational Awareness Workshop will be held in Seminar Room 6.

Teas and lunches will be served in the foyer outside the lecture theatres.

Poster will be served in the foyer outside the lecture theatres.

The area outside Seminar Room 7 will be used for the conference secretariat.

Gala Dinner

Wednesday September 30

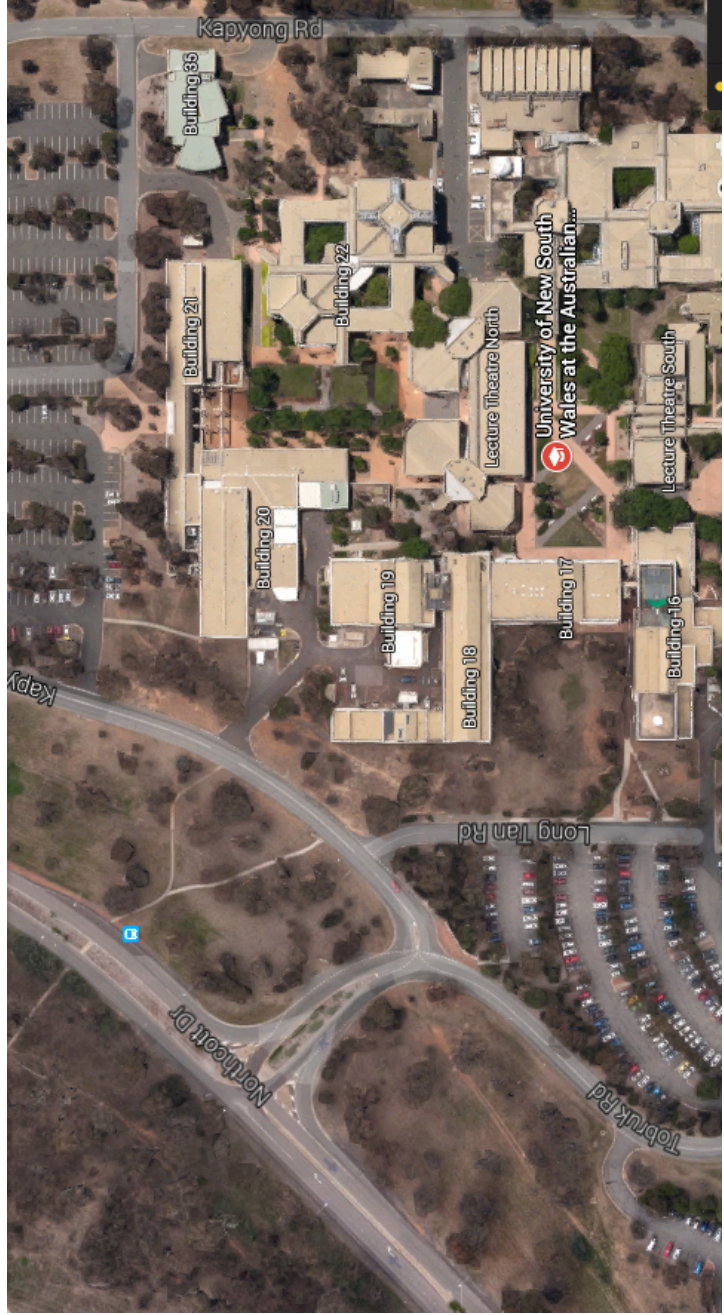
7:15 pm for a 7:30pm start

Dress: Smart casual

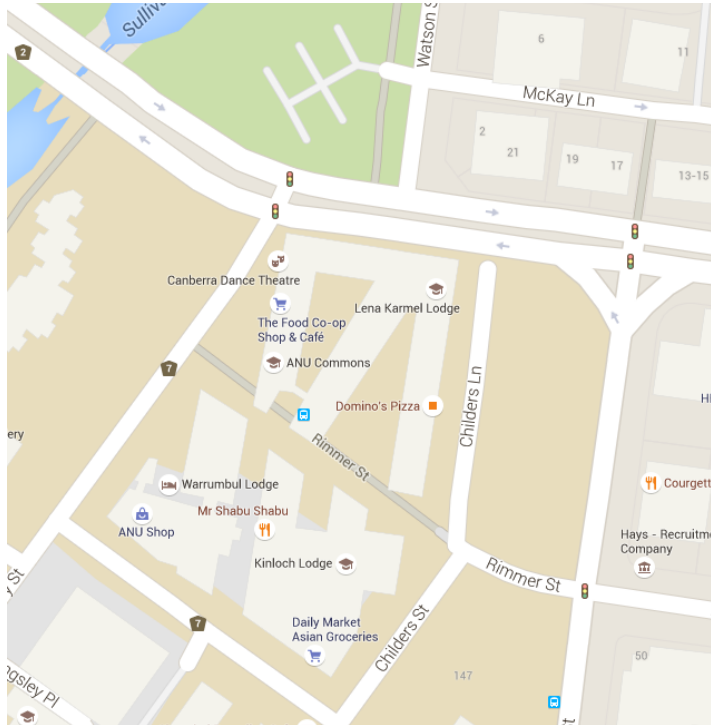
Location: ANU Commons function centre
Rimmer St , Acton

(parking is available in the Childers lane car park – adjacent to building – cost of \$8 for 3 hours)

**Location of conference facilities - Lecture Theatre North at
UNSW Australia (Canberra)**



**Location of Conference Gala Dinner –
ANU Commons function centre
Rimmer St, ACTON**



Detailed Program

Tuesday - Stream 1 (*Lecture Theatre 7*)

| Time | Speakers Name | Title |
|--------------------|------------------------|--|
| 7:30-9:00 | Registration | |
| 9:00-9:05 | I. Cairns, W. Short | Welcome to ASRC |
| 9:05-9:10 | S Tyo | Welcome to UNSW Canberra |
| 9:10-9:30 | B. Schmidt | Opening address |
| | | Plenary Session I |
| 9:30-10:00 | Ed Kruzins | Options for Australian Payloads and Cubesats with NASA |
| 10:00-10:30 | Grant Hausler | GNSS Activities in Australia - Strengthening Capability and Resilience |
| 10:30-11:00 | Iver Cairns | Solving the 'Type II Solar Radio Burst Problem' and Predicting Space Weather |
| 11:00-11:15 | Tea | |
| | | National Context |
| 11:15-11:25 | TBA | CSIRO-CASS |
| 11:25-11:35 | Craig Smith | CRC-EOS |
| 11:35-11:45 | TBA | Dept Industry perspective |
| 11:45-11:55 | TBA | DFAT perspective |
| 11:55-12:05 | Nick Stacy | DST perspective |
| 12:05-12:15 | Kerrie Dougherty | International Space University – SHS3P |
| 12:15-12:25 | TBA | SIAA |
| 12:25-12:35 | Brett Biddington | IAC 2017 |
| 12:35-13:00 | Russell Boyce | National perspective and COSPAR |
| 13:00-14:00 | Lunch / Posters | |
| | | Space and Atmospheric Physics 1 |
| 14:00-14:20 | Daniel Meehan | Ionospheric Research in Defence |

| | | |
|--------------------|------------------|--|
| 14:20-14:35 | Manuel Cervera | TID wavelength control of disturbance features in VI and QVI ionograms |
| 14:35-14:50 | Vickal Kumar | On the prediction of foF2 using 10.7 cm solar flux and Kp index |
| 14:50-15:05 | Ronald Maj | Quasi-thermal noise spectroscopy and dust detection in Earth's ionosphere |
| 15:05-15:20 | Anne Unewisse | High Frequency and 630 nm Airglow Observations of Travelling Ionospheric Disturbances over Adelaide, Australia |
| 15:20-15:35 | Julie Currie | SuperDARN Backscatter During Intense Geomagnetic Storms |
| 15:35-15:50 | Lenard Pederick | Modelling the Interference Environment in the HF Band |
| 15:50-16:05 | Lewis Freeland | The symmetry of halo Coronal Mass Ejections as a quantitative predictor for severe space weather at Earth. |
| 16:00-16:30 | Tea | |
| | | Space and Atmospheric Physics 2 |
| 16:30-16:45 | Bruce Ward | ELOISE – Towards an enhanced understanding of ionospheric variability and its impact on radio wave propagation |
| 16:45-17:00 | David Netherway | On Power Received via Oblique HF Ionospheric Propagation |
| 17:00-17:15 | Samira Tasnim | A Generalized Theory for the Evolution of Angular Momentum and Azimuthal Magnetic Fields in the Ecliptic Heliosphere |
| 17:15-17:30 | Andrew Heitmann | Preliminary observations of ionospheric disturbances using 2D angle-of-arrival estimation on oblique incidence soundings |
| 17:30-17:45 | Aramesh Seif | Characterizing Daytime GHz Scintillation at Equatorial Regions Using GNSS Radio Occultation Measurements |
| 17:45-18:00 | Trevor Harris | The DSTO Ionospheric Sounder Replacement for JORN |
| 18:00-19:15 | Cocktails | To held in the Officers Mess (building 6) |

Tuesday - Stream 2 (Lecture Theatre 6)

| Time | Speakers Name | Title |
|--------------------|------------------------|---|
| | | Remote Sensing |
| 14:05-14:30 | Jack Scott | SBAS for Australia and New Zealand |
| 14:30-14:45 | Ruken Alac Barut | Investigation of the Izmit Earthquake with Interferometric SAR, Global Navigation Satellite System (GNSS) Positioning and Geophysical Seismic Modelling |
| 14:45-15:00 | Zheyuan Du | Stripmap and ScanSAR Combined Earthquake Modelling Strategy |
| 15:00-15:15 | Lavender Qingxiang Liu | Damage Detection for 25 April 2015 Nepal Earthquake with Satellite Synthetic Aperture Radar Intensity and Coherence results |
| 15:15-15:30 | Kefei Zhang | Towards an advanced near real-time tropospheric water vapour platform using the Australian NPI for weather forecasting |
| 15:30-15:45 | | |
| 16:00-16:30 | Tea | GNSS |
| 16:30-16:45 | Chris Rizos | A Real-time Precise Navigation System for UAV Applications |
| 16:45-17:00 | Stavros Melachroinos | Developing an Australian GNSS analysis capability for augmented Precise Point Positioning |
| 17:00-17:15 | James Bultitude | Attitude Determination and Control System for UNSW's QB50 Cubesat |
| 17:15-17:30 | Eamonn Glennon | Qualifying the Kea GPS Receiver for UNSW's EC0 CubeSat |
| 17:30-17:45 | Nicholas Robinson | Optimal Path Planning for a SLAM-based Navigation System for Small UAVs |

Tuesday - Stream 3 (Seminar Room 7)

| Time | Speakers Name | Title |
|--------------------|----------------------|---|
| | | Archeo-Astronomy/Indigenous Sky |
| 14:05-14:30 | Alice Gorman | Is it wrong to wish on space hardware?" Exploring emotional attachments to spacecraft. |
| 14:30-14:45 | Duane Hamacher | An Introduction to Sydney Aboriginal Astronomy |
| 14:45-15:00 | Robert Fuller | Stellarium Skycultures as an aid to K-6 Science Syllabus Cross-cultural Understanding of Indigenous Astronomy |
| 15:00-15:15 | Carla Guedes | Meteor Traditions of the Torres Strait Islanders and other Melanesian Cultures |
| 15:15-15:30 | Trevor Leaman | Animals in Australian Aboriginal Astronomical Traditions |
| 15:30-15:45 | Brooke Porteus | Astronomical and Seasonal knowledge within Torres Strait Islander Art |
| 16:00-16:30 | Tea | |
| | | Small Objects SS/Meteorites |
| 16:30-16:45 | Trevor Ireland | Hayabusa Mission Update |
| 16:45-17:00 | George Georgevits | Detection of Kuiper Belt Objects by Stellar Occultation |
| 17:00-17:15 | Luke Daly | Early solar system events revealed by analysis of tiny nuggets. |
| 17:15-17:30 | Robert Howie | Deploy Your Own Desert Fireball Network Observatory |
| 17:30-17:45 | Ellie Sansom | The Expansion of the Desert Fireball Network |
| 17:15-18:00 | Piers Koefoed | U-Pb dating of the oldest known planetary meteorite: The achondrite Asuka 881934. |

Wednesday – Stream 1 (*Lecture Theatre 7*)

| Time | Speakers Name | Title |
|--------------------|----------------------|---|
| 8:00-9:00 | Registration | |
| | | Plenary Session IIA |
| 9:00-9:30 | Russell Boyce | Near-Earth Space Physics: the science to underpin Space Situational Awareness |
| 9:30-10:00 | Naomi Mathers | The Advanced Instrumentation and Technology Centre (AITC): A National Facility Supporting Astronomy and Space Activities in Australia |
| | | Mars Symposium |
| 10:10-10:30 | Eriita Jones | Shallow transient liquid water on Mars and its implications for life: Lessons from the Phoenix Lander and Curiosity Rover |
| 10:30-10:45 | Jon Clarke | Photovoltaic Power System Design for a Mars Analogue Research Station |
| 10:45-11:00 | Siddarth Pandey | Spaceward Bound India 2016: Taking Astrobiology to the Roof of the World |
| 11:00-11:30 | Tea | |
| 11:30-11:45 | Steve Hobbs | A Comparative Analysis of Terrestrial and Martian Gullies: Evidence for Erosion by Complex, Multi-Agent Processes |
| 11:45-12:00 | Eriita Jones | The Thermophysical Properties of Impact Crater Ejecta and Floor Materials on Mars |
| | | Space Projects |
| 12:05-12:20 | Graziella Caprarelli | Mars Australian Remote Virtual Experiment Laboratory (MARVEL) |
| 12:20-12:35 | Carol Oliver | An innovative approach to astrobiology education in the online environment |
| 12:35-12:50 | Jay Ridgewell | Getting cash for communication |
| 12:50-13:00 | Session chairs | (Moderated) Open discussion on Mars and space projects |
| 13:05-14:00 | Lunch | |

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|--------------------|---------------------|--|
| 14:00-14:30 | Ross Taylor | Plenary Session IIB Why can't a planet be more like a star |
| 14:30-14:55 | Brian O'Brien | Moon From Antarctic Auroras to Nanodust on the Moon, 60 Years of Glorious Entertainments in Space Science: A Tribute to Professor Harry Messel |
| 14:55-15:10 | Robert Pidgeon | Dating late thermal events on the Moon from the annealing of radiation damage in zircon |
| 15:10-15:25 | Lucy Forman | Looking for a Needle in a Haystack: The Search for Extralunar Fragments in Apollo 14 Soils |
| 15:25-15:40 | Thomas Haber | Constraining the bombardment history of Moon with a set of Apollo 16 impact melts rocks. |
| 15:40-15:55 | Craig O'Neill | The role of core-differentiation in ejection of a Moon-forming disk |
| 15:55-16:10 | Siqi Zhang | Thermal evolution of the Moon modelled by core-mantle coupling |
| 16:10-16:30 | Tea | Decadal Plan mid-term review Town Hall Meeting |
| 16:30-16:45 | R. Boyce & K.Oliver | Preparing for the mid-term Decadal Plan review – result of survey from space science community |
| 16:45-18:00 | | Discussion following presentation |
| 19:00-22:00 | Gala Dinner | ANU Commons function centre, ACTON |

Wednesday – Stream 2 (Lecture Theatre 6)

| Time | Speakers Name | Title |
|--------------------|--------------------|---|
| | | Satellite Platforms |
| 10:05-10:25 | Dhiren Kataria | Nanosatellites for in-situ studies of the Earth's ionosphere and thermosphere – exploiting the QB50 mission opportunity for Space Weather science |
| 10:25-10:40 | Dhiren Kataria | Enhanced performance low resource in-situ sensors for space missions |
| 10:40-10:55 | David Lingard | Australian Participation in the Biarri Cubesat Missions |
| 11:00-11:30 | Tea | |
| 11:30-11:45 | Sam Reisenfeld | The Communication System of the Australian Space Eye: Ultra-faint Astronomy Imaging from Space |
| 11:45-12:00 | Sana Qaisar | Systems Engineering Essentials for Small Satellite Missions |
| 12:00-12:15 | Anthony Horton | Australian Space Eye: Ultra-faint astronomical imaging from a CubeSat |
| | | Space Industry |
| 12:20-12:35 | Matthew Richardson | If you build it, will they come? An Analysis of Price and Demand in the Launch Industry. |
| 12:35-12:55 | Timothy Broadbent | Solving the Mission Operations Problem |
| 13:00-14:00 | Lunch | |
| 14:00-14:30 | | Plenary Session IIB (stream 1) |
| | | Satellite Subsystems |
| 14:30-14:45 | Stephen Bathgate | A plasma thruster using a magnetic nozzle with a HIPIMS plasma source. |
| 14:45-15:00 | Courtney Bright | Stereolithographic 3D Printed Nozzles for Cold Gas Propulsion Experiments |
| 15:00-15:15 | Patrick Neumann | Pulsed Cathodic Arc Spacecraft Propulsion Systems |
| 15:15-15:30 | Christine Charles | Plasma propulsion as a vehicle for science in space and in the laboratory |

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| 15:30-15:45 | Joon Wayn Cheong | Effect of Self-shadowing and Attitude on Cubesat Solar Power Generation: A Case Study on UNSW EC0 QB50 Cubesat |
| 15:45-16:00 | Jason Held | Parabolic flight testing results for DragEN Electrodynamic Tether Deployer |
| 16:00-16:10 | Sebastian Oberst | Sensitivity to micro-vibrations: damping of thin curved flexible space structures |
| 16:15-16:30 | Tea | |

Wednesday – Stream 3 (Seminar Room 6)

| Time | Speakers Name | Title |
|--------------------|---------------------|---|
| | | Space Situational Awareness Workshop 1 |
| 10:00-10:15 | Hadrien Devillepoix | Desert Fireball Network |
| 10:15-10:30 | Andrew Lambert | Progress in passive optical tracking using the Falcon Telescope Network |
| 10:30-10:45 | Tyler Hobson | Dynamic steering for autonomous low confidence reacquisition |
| 10:45-11:00 | Stuart Anderson | Radar scattering properties of satellite wakes and their utility for space situational awareness |
| 10:55-11:30 | Tea | |
| 11:30-11:45 | William Crowe | Opportunistic flyby characterisation of Earth passing asteroids |
| 11:45-12:00 | William Crowe | Cooperative estimation of asteroid mass |
| 12:00-12:15 | Melrose Brown | Buccaneer risk mitigation mission |
| 12:15-12:30 | T J Chin | Robust Space Object Detection |
| 12:30-12:45 | Brett Carter | 2015 St Patrick's Day superstorm. Effects in the near-Earth space environment and impacts on technologies |
| 12:45-13:00 | Christopher Capon | Development of a coupled PIC-DSMC method for the study of objects in a charged space environment |
| 13:15-14:00 | Lunch | |
| 14:00-14:30 | | Plenary Session IIB (see stream 1) Space Situational Awareness Workshop 2 |
| 14:30-14:45 | Ba-Ngu Vo | Advanced statistical approaches to SSA |
| 14:45-15:00 | Roy Sach | A controversy-in-waiting for Australian science? |
| 15:00-15:15 | Darren May | An update on Defence's SSA activities |
| 15:15-15:30 | Mark Rutten | SSA Research in DST Group |
| 15:30-15:45 | Moriba Jah | Perspective on current US SSA research |
| 15:45-16:00 | Andrew Ash | Perspective on current UK SSA research |
| 16:00-16:30 | Tea | |

Thursday – Stream 1 (Lecture Theatre 7)

| Time | Speakers Name | Title |
|--------------------|-------------------------------------|--|
| 8:00-9:00 | Registration | |
| | | Plenary Session III |
| 9:00-9:30 | Fred Menk | Magnetoseismology: Ground-based remote sensing of Earth's magnetosphere |
| 9:30-10:00 | Martin Van Kranendonk | Early Earth and the making of Mankind: Astrobiology in our own backyard |
| 10:00-10:30 | Gail Higginbottom | Origins of Standing Stone Astronomy in Britain |
| 10:30-11:00 | Tea | |
| | | Space and Atmospheric Physics |
| 11:00-11:15 | Joachim Schmidt | Demonstration of a Viable Quantitative Theory for Interplanetary Type II Radio Bursts |
| 11:15-11:30 | Bo Li | Mapping magnetic field lines between the Sun and Earth |
| 11:30-11:45 | Brett Carter | On the vulnerability of the equatorial region to geomagnetically induced currents |
| 11:45-12:00 | Rhea Barnett | Relationship between field-aligned and geomagnetic induced currents |
| 12:00-12:15 | Daniel Kucharski | The interaction between the Earth's magnetic field and the spinning satellites |
| 12:30-13:30 | Lunch / Poster Session 2 | |
| | | Space Engineering |
| 13:30-13:45 | Christopher Miller / Yilser Kabaran | A review of steering with Rocker Bogie chassis design |
| 13:45-14:00 | Siddarth Pandey | Computational study of the effect of Mars surface atmosphere induced thermal convection within horizontal gap enclosures on surface heat transfer characteristics within a Mars rover. |

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| 14:00-14:15 | Nicole Blinco | Photovoltaic Power System Design for a Mars Analogue Research Station |
| 14:15-14:30 | Martin Cupak | Desert Fireball network: Handling of the multi terabyte data |
| 14:30-14:45 | Alexey Kondyurin | Large size space construction for space exploitation |
| 14:45-15:00 | Michael Phillips / Brian Luc | Development of a low-cost Software-Defined-Radio based student groundstation |
| 15:00-15:15 | Harrison Steel | Development and testing of a Complete, Sub-\$1000 2U CubeSat Prototype |
| 15:15-15:30 | James Waldie | Initial Operational Assessment of the Gravity Loading Countermeasure Skinsuit on the International Space Station |
| 15:30-15:45 | Michael Smart | A Reusable Launch System for Small Satellites |
| 15:45-16:00 | Ingo Jahn | Aerodynamics and Control Optimal Design for Hypersonic Vehicles |
| 16:00-16:30 | Tea | |
| 16:30-17:00 | | Prizing giving ceremony |
| 17:00-17:15 | Closing Remarks | |

Thursday – Stream 2 (Lecture Theatre 6)

| Time | Speakers Name | Title |
|--------------------|-------------------------------|---|
| 11:00-11:20 | Vickie Bennett | Earth – Astrobiology Planetary samples from the Early Earth: New revelations from the oldest terrestrial rocks |
| 11:20-11:35 | Tharika Liyanage | Searching for the (hydrocarbon) skeleton key: Using biomarkers to find evidence of the first animals |
| 11:35-11:50 | Aditya Chopra | Is Habitability Constrained by Biology? The Case for a Gaian Bottleneck |
| 11:50-12:05 | Haiyang Wang | Elemental Devolatilization Patterns of Material in the Solar System |
| 12:05-12:20 | Jonathon Wasiliev | Viscosity Formulations and the effect of uncertain parameters |
| 12:30-13:30 | Lunch / Poster Session | |
| 13:40-14:00 | Frank Mills | Planets Post-Venus Express: An Overview of Current Issues in Understanding the Composition and Chemistry of Venus' Mesosphere |
| 14:00-14:15 | Jonti Horner | The Structure of the 'Asteroid-belt' Analogue Around HR8799 |
| 14:15-14:30 | Daniel Cotton | Carrying a Torch for Dust in Binary Star Systems |
| 14:30-14:45 | Lucyna Kedziora-Chudczer | Observations of H3+ Molecular Emissions in Jupiter's Aurora |
| 14:45-15:00 | Courtney Bright | Venus Atmospheric Pathfinder Research Vehicle: A Mission Concept Study |
| 16:00-16:30 | Tea | |

Thursday – Stream 3 (Seminar Room 7)

| Time | Speakers Name | Title |
|--------------------|-------------------------------|--|
| 11:00-11:15 | Kerrie Dougherty | Historical/Medical/Social Space-related Research and Innovation in the Australian Defence Scientific Service |
| 11:15-11:30 | Jeff Ayton | Antarctica- A Space Analogue - Australian Human Biology and Medicine Research |
| 11:30-11:45 | Rowena Christiansen | Update of the Australian Resuscitation Council Cold Injuries Guideline – Results of a Literature Review |
| 11:45-12:00 | Jacob Hacker | Legal and Political Implications of Future On-Orbit Servicing Missions |
| 12:00-12:15 | Gabriela Hobbs | HOT TOPIC: Off-Earth mining The Case for Mining Asteroids |
| 12:15-12:30 | Andrew Dempster | Off-Earth mining forum 2015 |
| 12:30-12:45 | Andrew Dempster | Q & A session on the forum |
| 12:45-13:30 | Lunch / Poster Session | |
| 13:30-13:45 | Troy McCann | Education The University of Melbourne Space Program - Launching Melbourne into the final frontier |
| 13:45-14:00 | Li Lily Qiao | Experience gained from Satellite Design Projects |
| 14:00-14:15 | James Gilmour | A Space Academy to inspire the next generation of Space Engineers |
| 14:15-14:30 | Annalea Beattie | NASA Spaceward Bound New Zealand 2015: Advancing Astrobiology Curriculum Via Teacher-Scientist Collaboration in the Taupo Volcanic Zone. |
| 16:00-16:30 | Tea | |

Plenary Speakers



Professor Russell Boyce

University NSW (Canberra)

"Near-Earth Space Physics : the science to underpin Space Situational Awareness"

Professor Russell Boyce holds the position of Chair for Space Engineering at UNSW Canberra, bringing 25 years' experience (including leading the \$14M international SCRAMSPACE project) in studying the interaction between high speed vehicles and their environment in the field of hypersonics and scramjets, to the interaction between satellites / space debris and their near-Earth environment.

He is the Chairman of the Australian Academy of Science's National Committee for Space and Radio Science, and is a member of the Executive Council of the Space Industry Association of Australia.



Professor Iver H. Cairns

University of Sydney

"Solving the 'Type II Solar Radio Burst Problem' and Predicting Space Weather"

Professor Iver Cairns received his B.Sc. (Hons) and PhD from the University of Sydney (Australia) in 1983 and 1987, respectively. He worked at the University of Iowa (1986-1998), starting as a postdoctoral fellow and becoming a Research Scientist and Adjunct Associate Professor. In 1998 he was awarded a 5-year ARC Senior Research Fellowship, one of only 20 awarded. In 2004 he was awarded an Australian Professorial Fellowship and in 2009 was appointed Professor in Space Physics at University of Sydney.

Iver's primary interests are in the theory, simulation, and observation of plasma waves, radio emissions, shocks, and space weather produced in the solar corona, solar wind, planetary

magnetospheres, Earth's ionosphere, outer heliosphere, and local interstellar medium. He is a Co-Investigator on NASA's STEREO spacecraft and several upcoming NASA rocket projects, and a longtime leader of the Solar, Heliospheric, and Ionospheric Group for the Murchison Widefield Array (MWA) in Western Australia.

As Chair of the Australian Academy of Science's National Committee for Space Science, Iver led the development of the first Decadal Plan for Australian Space Science (launched 2010) and with Wayne Short and NSSA the ASSC and ASRC conferences. He holds or has held leadership positions in the Asia Oceania Geosciences Society [AOGS], the international Committee on Space Research (COSPAR), and the International Association for Geomagnetism and Aeronomy [IAGA].

Iver is working on the i-INSPIRE spacecraft project and an associated payload project, as well as Sydney SpaceNet, the University of Sydney's network for space research (focused on Earth observations from space) and outreach to space industry and government. SpaceNet is a co-founder of delta-V (see www.deltavspacehub.com), a startup accelerator intended to develop Space Industry 2.0 for Australia, with UNSW's Australian Centre for Space Engineering Research, Saber Astronautics, and Launchbox Australia.



Dr Grant Haulser
Geoscience Australia

*"GNSS Activities in Australia -
Strengthening Capability and Resilience"*

Grant Hausler is Coordinator for the National Positioning Infrastructure (NPI) at Geoscience Australia (GA). He is a member of the Australian Government PNT Working Group, the National Positioning Infrastructure Advisory Board, the Attorney General's Space Community of Interest, and the International GNSS Society Advisory Committee.

Grant holds a Bachelor of Geomatic Engineering and PhD from the University of Melbourne along with a Graduate Certificate in Commercialisation from Melbourne Business School. Grant's research contributed to the Cooperative Research Centre for

Spatial Information Positioning Program and included international research experience at the University of Nottingham. Grant has previous experience as an engineering surveyor in both London and Australia working for a variety of rural and metropolitan surveying companies.



Dr Gail Higginbottom

Australian National University, University of Adelaide

"Origins of Standing Stone Astronomy in Britain"

Gail is a Landscape Archaeologist who investigates why people create things, including cultural landscapes. In particular, she studies the connection people have to Nature through time and look at ways to improve, acquire or construct methodological applications to do so.

Major scientific investigations include the application and development of geographical information systems as well as the application of astronomy and statistics used in astrophysics. Specifically she researches why people erect monuments and what this can tell us about peoples' cosmological belief systems. She has worked as a Cultural Heritage Manager and am now a Fellow of the *Society of Antiquaries of Scotland*, and a Visiting Research Fellow of The Australian National University, School of Archaeology & Anthropology, and the University of Adelaide, School of Chemistry & Physics.



Dr Ed Kruzins

CSIRO Director NASA Operations and Canberra Deep Space Communication Complex

"Options for Australian Payloads and Cubesats with NASA"

Ed Kruzins commenced as the CSIRO

Director of the Canberra Deep Space Communications Complex (CDSCC) on 1 May 2012 and has been responsible for tracking obligations to the fleet of 40 international space missions operating across the Solar System on behalf of NASA & CSIRO under the auspices of US/AS Bilateral Space Tracking Treaty.

Most recently as the Director General of Capability Science (DGCS-DSTO) to the Australian Department of Defence (DoD), Ed was science advisor to the Chief of Capability Development on major capital equipment acquisitions under the Defence Capability Plan. He was a permanent member of the Defence Options Review Committee and Capability Development Boards.

As previous Engineering Manager of CDSCC Tidbinbilla in Canberra, his tenure provided 24/7 ground station capability for key space missions including the Cassini, Huygens Titan encounters, the Mars & Lunar Recon Orbiter, Mars Rover, Deep Impact and the Voyager spacecraft, now the deepest space object made by man. Earlier employment with DSTO included joint authorship of Defences first Network Centric Warfare Roadmap and he was TTCP National leader for Space Based Surveillance.

Ed began his working career in the UK with BAE/Matra/Marconi Space Systems where he provided systems and design engineering for European commercial and military satellite subsystems, including Olympus 1, Inmarsat 2, Telecom 2 and Skynet 4. With the European Union as sponsor, his team provided the very first study work on the European Galileo navigation constellation.

Ed obtained his PhD degree at Southampton University UK, in Aerospace Engineering and obtained his science degree with honours at the University of Sydney in Astrophysics.



Dr Naomi Mathers

Australian National University

"The Advanced Instrumentation and Technology Centre (AITC): A National Facility Supporting Astronomy and Space Activities in Australia"

Dr Naomi Mathers has a technical background in Aerospace Engineering with experience in research, industry, education and policy development. She is currently applying these skills as Industry Liaison

Engineer at the ANU Advanced Instrumentation and Technology Centre.

Dr Mathers was a member of the Australian Government Space Industry Innovation Council from 2010 to 2013. For the past eleven years she has represented Australia at the Asia Pacific Regional Space Agency Forum where she worked with her Asia-Pacific colleagues to establish the Kibo-ABC, a program that facilitates access to the ISS for countries in the Asia-Pacific. Between 2009 and 2012 she represented Australia on the International Space Education Board, facilitating collaboration with the education directorates of the world's major space agencies including NASA, ESA, JAXA, CSA, KARI, CNES and SANSA.

Dr Mathers has been an active member of the International Astronautical Federation, since 2005, including as Vice-Chair of the Space Education and Outreach Committee and Education Symposium Coordinator since 2012. In 2016 and 2017 she will help shape the technical program of the International Astronautical Congress as the International Program Committee (IPC) Co-Chair. In 2014 Dr Mathers was awarded two Women in Industry awards for Industry Advocacy and Excellence in Engineering.



Professor Fredrick Menk

University of Newcastle

"Magnetoseismology: Ground-based remote sensing of Earth's magnetosphere"

Frederick Menk obtained his PhD in space physics in 1984, and has since authored or coauthored over 140 research papers in this field and medical physics. His research interests focus on propagation of ultra-low frequency plasma waves through the magnetosphere and ionosphere, related instrumentation, and improving radiation treatment of cancers. He has chaired the International Association of Geomagnetism and Aeronomy working group on ULF waves, served on many international and national committees and review panels, convened several international symposia, and was project manager for the NewMag magnetometer payload on the FedSat spacecraft. He also has an extensive teaching record, has mentored over 30 PhD students and has also held significant administrative responsibilities including Deputy Dean of the Faculty of Science & IT at the University of Newcastle, where he is currently Professor of Physics and Head of the School of Mathematical and Physical Sciences.



Professor Ross Taylor

Australian National University

"Why can't a planet be more like a star"

Ross Taylor born in New Zealand and has a Ph. D. at Indiana University. He worked at the Universities of Oxford and Cape Town before moving in 1961 to the Research School of Earth Sciences at the ANU.

He has worked on the composition and evolution of the Moon, the continental crust, tektites and impact glasses, island arc rocks and many other topics involving trace element geochemistry. Ross Taylor was a member of the Preliminary Examination Team at NASA JSC, Houston, Texas and carried out the first analysis of the first lunar sample returned to Earth. He has published 240 papers and ten books.

He has been awarded the Goldschmidt Medal of the Geochemical Society, the Leonard Medal of the Meteoritical Society, the Bucher Medal and the Bucher Medal of the American Geophysical Union.

Asteroid 5670 is named Rosstaylor.

He is a Foreign Member of the National Academy of Sciences of the United States of America and a Fellow of the Australian Academy of Science, He is a Companion of the Order of Australia (AC)



Martin van Kranendonk

University of New South Wales –
Australian Centre for Astrobiology

*"Early Earth and the making of Mankind:
Astrobiology in our own backyard"*

Martin was born and trained in Canada, receiving his PhD in 1992 from Queens University in Kingston, Ontario. After working at the Geological Survey of Canada from 1992-1994, Martin moved to Australia as an ARC post-doctoral fellow at

the University of Newcastle, where he commenced research on the Pilbara. He joined the Geological Survey of Western Australia in 1997, where he worked for 15 years until the start of 2012, when he accepted a position as Professor of Geology at the University of New South Wales, in Sydney, Australia, where he is currently employed and is the Director of the Australian Centre for Astrobiology. His main interests are Archean tectonics and the geological setting of early life on Earth, and he is widely published in these fields. Martin is the Chair of the Precambrian Subcommission of the International Commission on Stratigraphy, an associate editor of the journals *Precambrian Research*, *Geology*, *Astrobiology*, and *Episodes*, co-leader of IGCP 599 "Changing Early Earth", and Core member of the International Precambrian Research Centre of China. He has appeared on numerous television and radio documentaries on early Earth, and has been involved in educational outreach programs for school children and the general public.

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Investigation of the Izmit Earthquake with Interferometric SAR, Global Navigation Satellite System (GNSS) Positioning and Geophysical Seismic Modelling

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In 1999, Izmit Earthquake struck Istanbul and the surrounding area in Northwest Turkey. It was one of the most devastating earthquakes of the twentieth century, significantly impacting on 20 million inhabitants and nearly half of the country's industry. Such earthquakes in the Izmit are likely to affect the Istanbul area in the future.

A combination of Interferometric Synthetic Aperture Radar (InSAR), Global Navigation Satellite System (GNSS) and geophysical modelling techniques has improved the detection of deformation around the fault zone. InSAR is an effective method for measuring displacement due to seismic events in areas where it is impossible to conduct ground surveying or to deploy GNSS reference stations.

This paper describes the measurement of the Izmit Fault deformation using InSAR and GNSS data. The source characteristics of the earthquake are determined by geophysical seismic modelling of the observed data. The physical principles behind the InSAR and GNSS methods will be compared with seismic modelling to assess the accuracy of each method for the fault area under study.

Radar scattering properties of satellite wakes and their utility for space situational awareness

Stuart Anderson

University of Adelaide

The hypersonic motion of satellites and other space objects through the earth's ionosphere results in a wide variety of gas dynamic and plasma phenomena. Many of these processes have been studied because of their relevance to space-ground communications, in situ sensor performance, orbital decay and ballistic missile early warning systems.

In the context of space situational awareness, signatures which persist and which can be correlated with object shape and function are of particular interest, particularly when other sensible object characteristics are weak or easily manipulated. One candidate for consideration here is the radar signature of the object wake, the region of plasma inhomogeneity around the object and extending to a substantial distance behind it.

Although the near-body plasma may attain significant electron densities, nominally observable at microwave frequencies, at length scales of tens or hundreds of metres behind the object, the wake may be detectable only at far lower frequencies, specifically in the HF band. Thus we are motivated to explore the prospective use of HF skywave 'over-the-horizon' radars as candidate sensors for a rudimentary form of space object classification via the scattering characteristics of the wake.

Modern HF skywave radars, aided by advances in low-noise waveform generation and signal reception, achieve extremely high sensitivity and accurate phase measurement. A simple back-of-envelope calculation reveals that the RCS required for line-of-sight detection by a modern HF skywave radar might be as low as -40 dBsm. It would seem not implausible that satellite wake echoes could exceed this threshold by a margin sufficient to enable discrimination of discrete features of their space-time structure and hence afford a classification capability.

In this paper we describe a model for the plasma wake of an object travelling through the ionosphere, derive expressions for its HF scattering characteristics, and draw some preliminary conclusions about the utility of this sensing modality.

A perspective on current UK SSA Research

Andrew Ash

Defence Science and Technology Laboratory, UK

This presentation provides an update on activities within DSTL to provide R&D support to the UK MOD in the area of SSA; in particular it will cover the work that has been ongoing to support the MOD response to the 2014 UK National Space and Security Policy (NSSP) to examine enhanced indigenous SSA capabilities. An overview will be provided of the newly formed DSTL Space Programme, the top-level drivers from an SSA perspective and how the technical work is structured. A series of updates on the major activities within the project will then be detailed including the outcome from the recent ATV-5 event, ongoing work to examine observation of high value targets around the GEO belt and other technical highlights. Finally, the ongoing activities with AUS and potential opportunities for further collaboration within the international community will be discussed.

Astrobiology and life sciences, Human Biology and Medicine

Dr Jeff Ayton

Australian Antarctic Division - Chief Medical Officer, Leader Human Biology and Medicine Research 2002-present | Australian Delegate SCAR Life Sciences Standing Scientific Group | Scientific Committee Antarctic Research(SCAR) Council of Managers of National Antarctic Programs(COMNAP) Joint Expert Group Human Biology and Medicine Chief Officer | Past President Australian College of Rural and Remote Medicine | Adjunct Associate Professor, School of Public Health, James Cook University | Chair ACRRM National Telehealth Advisory Committee | Member Aerospace Medicine

Antarctica is an isolated, confined and extreme environment. Antarctica has been described and utilised as a space analogue. Australia has conducted expeditions to Antarctica for more than a century and the Australian Antarctic Division (AAD) has maintained a permanent presence in Australia's Antarctic Territory since 1948, with three continental and one sub-Antarctic stations.

Since the early 1990s the AAD Polar Medicine Unit has had an operational and research agreement with NASA Headquarters (Washington DC), to conduct significant scientific studies and bilateral collaboration aimed at informing the space communities on human risks to space travel, and in particular, long term exploratory missions and the medical support that may be required.

Australia's Antarctic stations have total isolation periods for up to 9 months and comprise of small groups of highly screened support and scientific personnel who are reliant on hi-fidelity technical systems to ensure safety survival over winter in the extreme environment. Studies have been undertaken across a wide range of fields, such as: immunology, psychology and behavioural health, photobiology, virology, bone metabolism and epidemiology. These studies have provided a sound evidence base for operational medicine and medical policy development and response including medical, dental and psychological screening, telemedicine support, and the scope of practice and training that could be required for medical support personnel in the extreme conditions of space.

This presentation will highlight a little known involvement in Australian Space Research and a significant collaboration with NASA-Antarctic Human Biology and Medicine research. Past and current work will be described highlighting opportunity for future collaborations.

Relationship between field-aligned and geomagnetic induced currents

Rhea Barnett, Colin Waters

University of Newcastle

The impact of solar flares and coronal mass ejections (CMEs) on near-Earth space cause large geomagnetic field disturbances. In the auroral zones, enhanced field-aligned currents (FACs) flow along geomagnetic field lines in space and dump excess energy via enhanced ionospheric currents. These generate ground currents known as geomagnetic induced currents (GICs) with associated electric fields in the ground. High voltage transformer neutral connections provide paths of low resistance for GIC flow, with possible core saturation leading to permanent damage or complete failure of transformers.

Developing a high resolution spatial map of the geoelectric field has presented a significant challenge in GIC research. A study completed by Marshall et al. (2011) derived a GIC index describing the geoelectric field using ground magnetometer data. However, it is limited to magnetometer location. FACs are readily imaged using the magnetometer data from the Iridium satellite constellation. By comparing derived GIC index values determined using Northern Hemisphere ground magnetometer data with the FACs, the spatial and temporal evolution of the GIC index was found to follow the FACs. A correlation between the integrated GIC index (GICint) and FACs was seen with an R-squared value of 0.95. A first approximation was made to quantify this relationship, finding $GIC_{int} \approx 0.07FAC$. Therefore, it should be possible to improve both the spatial and temporal resolution of GIC mapping using FACs derived from Iridium data.

A plasma thruster using a magnetic nozzle with a HIPIMS plasma source.

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David McKenzie

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We demonstrate a simple plasma thruster that uses a magnetic nozzle to collimate and accelerate copper ions produced by a high power impulse magnetron sputtering discharge (HIPIMS) in argon. Ion currents produced by a HIPIMS discharge were measured with a 20mm diameter disc shaped Langmuir probe as a function of the magnetic field strength of a solenoid that formed a magnetic nozzle that had its axis aligned with the centre of the HIPIMS target. Measurements of ion current were made with the probe at ground potential and at other voltages. The ion current increased in proportion with the magnetic nozzle current. Measurements of ion energies were made with a simple retarding field energy analyser (RFEA) that consisted of a grid placed in the aperture of an enclosure that surrounded the Langmuir probe. Ion energy was determined by varying the potential applied to the grid and the probe. The flux of ions and neutrals was determined by the deposition rate on a substrate.

NASA Spaceward Bound New Zealand 2015: Advancing Astrobiology Curriculum Via Teacher-Scientist Collaboration in the Taupo Volcanic Zone.

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and the participants of Spaceward Bound New Zealand

Spaceward Bound is a NASA education outreach that, with partner organizations, brings together scientists and teachers in the field, using scientific research to mentor teachers and students and questioning how life evolved over billions of years on Earth, what life is like or what it might be like on other planets in regions that have features analogous to those planets like Mars.

In January 2015, fifty scientists, educators and students from NASA and partners from JPL, Mars Society Australia, Mars Society New Zealand, Auckland University of Technology, and GNS Science, took part in a week-long field trip in the dynamic heart of the Taupo volcanic region. Following the New Zealand Science curriculum, research themes on the expedition linked to 1) Extreme Life Science, 2) Planetary Science, 3) Planning to live on Mars, 4) Planetary Protection, 5) Technology, Rockets and Robots and 6) Art and Culture as a means of communicating Astrobiology.

Across a range of settings and fieldtrips, NZSB combined biology and geology to focus on microbial adaptation in extremely high temperature geothermal springs. An investigation of alkali-chloride systems, thermophile communities and micro-stromatolites was conducted, considering how modern textures of microbial structures, (mats, balls, other periphyton materials) and silica -rich sinter deposits (eg. flat plates, cones, spherical concretions) correlated with a range of physical conditions within the geothermal pools. Scientists and students explored how and which materials might be preserved over geologic time, serving as biomarkers of ancient climates and environments. Rovers and drones equipped with cameras, remote sensing systems, and sampling apparatus were deployed in geologically interesting

settings and sinter and microbial samples were collected for later analysis.

The deliverables from New Zealand Spaceward Bound are being refined post- expedition. This presentation will include a discussion of the field trips, the science and engineering involved, and its relation to Mars analogues and astrobiology.

Planetary samples from the Early Earth: New revelations from the oldest terrestrial rocks

Vickie C. Bennett

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The geochemical signatures preserved in Earth's oldest rocks (3.6 to 4.0 billion years old) provide the most direct information on early terrestrial formation and differentiation processes and on the composition and size of early chemical reservoirs including atmosphere, hydrosphere, crust and mantle.

Ancient rocks today comprise only about 1 millionth of the Earth's surface, reflecting the small volume that has survived >3.5 billion years of crustal reworking and recycling. Nearly all ancient samples are found as small fragments within gneiss complexes scattered across Greenland, southern Africa, Antarctica, Australia, Canada, China and Eastern Europe. Working on early terrestrial rocks provides a special set of challenges as almost all have been metamorphosed in later tectonic events under high pressures and temperatures that resulted in transformation of the original mineral assemblages and deformation of the original structures. Recognising and "seeing through" these later tectonic events is necessary to accurately interpret chemical characteristics of rock record. Where are these ancient rocks and how do we recognize them in the field?

Despite these challenges, the last 10 years has seen an unprecedented growth in the understanding of the earliest history of the Earth through the combination of new discoveries of ancient rocks and applications of new isotopic approaches to reveal both the timing and processes of early events. Of particular note are enhanced capabilities for precise isotopic measurements, which enabled the detection of small "extinct" nuclide anomalies preserved in some ancient terrestrial rocks, arising from the ^{182}Hf - ^{182}W (half-life=8.9 myr) and ^{146}Sm - ^{142}Nd (half life= 103 myr) decay schemes. Variations in ^{182}W and ^{142}Nd isotopic compositions, as compared with modern rocks, can only arise from chemical events occurring in the first 0-400 myr of Earth history, that is whilst the parent isotopes (^{182}Hf and ^{146}Sm) were still actively decaying.

In this talk I will review the current knowledge of the existence of the >3.6 Ga rock record and highlight recent findings from this record that are providing new insights into the extent of early crustal volumes and the timing and processes of early Earth evolution.

Near-Earth Space Physics : the science to underpin Space Situational Awareness

Russell Boyce

UNSW Canberra

The global economy, including Australia, depends deeply on space-derived data. Space congestion is rising rapidly. Alongside improved tracking, high-accuracy prediction of near-Earth satellite/space environment interactions and dynamics is critical to mitigating the risk of service disruption or denial from space weather or collisions. Development of networked, game-changing miniature satellites – a growing opportunity for Australia – also depends on such predictions. There are large and urgent gaps in the science that underpins them. This science – accurate rapid prediction of the dynamic behaviour of the near-Earth space environment and its effects on the behaviour of artificial space objects and of the artificial space population as a whole (including both operational satellites and space debris) – is the science of Space Situational Awareness. It represents a unifying theme for much of Australian space research.

Preparing for the mid-term Decadal Plan review – results of a survey of views from the space science community

Russell Boyce, Carol Oliver

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It is time for a mid-term review of the space science research community's Decadal Plan 2010-2019. In preparation for that review the Australian Academy of Science's Committee on Space Research conducted a survey among members of the space science research community to poll views on the progress of the Decadal Plan. We report on the results of the census as a first step to doing the following: 1. Re-examine the main goals and priorities of the Decadal Plan in light of any significant changes since it was published; 2. Review and, if necessary, revise the recommendations; 3. Review the implementation of the Plan or revised recommendations; and 4. Assess the scope and status of the Australian radio science sector, and review synergies with the space science sector.

Venus Atmospheric Pathfinder Research Vehicle: A Mission Concept Study

Courtney Bright, Rounak Manoharan, Siddharth Pandey,
Hilbert van Pelt, Jai Vennik

UNSW Canberra

Earth and Venus, both similar in size, mass and bulk composition, have shared a lot in terms of their origin and evolution over time. It has been recognised by the international community that studying Venus will provide a better understanding of Earth's past evolution and its future. The number of missions to the planet to date has been constrained by large development times and high costs, the technical complexity of successfully orbiting the planet notwithstanding.

This paper will present a mission concept study which attempts at providing a solution to the aforementioned limitations. Here a low cost microsatellite mission to Venus for in-situ atmospheric measurements is discussed. This paper presents the mission in 2 stages: architecture of a microsatellite to journey from Earth to a Venus orbit; and, the payload instrumentation (and scientific justification) used for performing in-situ atmospheric measurements. The challenges of the mission will be presented: Earth to Venus transfer trajectory for a microsatellite, repeated atmospheric sampling of Venus upper atmosphere, thermal and radiative protection of the satellite, as well as lightweight and low power hardware and communications for operating over long distances and flight durations.

In addition to describing these challenges, the authors shall present a distributed approach to tackle these problems at a subsystem level. The aim of the design is to form a basis for multiple future missions, allowing essential data to be gathered in advance of larger missions. Finally, it is the aim for such a project to enable participation and collaboration of universities and smaller organisations in interplanetary missions. Future work and limiting factors for the work shall also be discussed.

Stereolithographic 3D Printed Nozzles for Cold Gas Propulsion Experiments

Courtney Bright, Sean Tuttle, Andrew Neely

UNSW Canberra

A biaxial thrust stand is under development at UNSW Canberra for fluidic thrust vectoring cold gas propulsion experiments. Fluidic thrust vectoring involves asymmetric injection of a secondary fluid into a supersonic nozzle to deflect the thrust through an oblique shock wave and momentum of the secondary fluid. The thrust stand consists of two parallel 1/4" stainless steel tubes to supply main and secondary high-pressure nitrogen gas to a stereolithographic (SL) 3D printed nozzle. The tubes are welded into a rigid baseplate, allowing the tubes to act as a cantilever when a force is applied to the nozzle. Acceleration of the cantilever end is measured in two directions with a tri-axial accelerometer to infer axial and transverse thrust.

SL 3D printing works by directing a laser across a tray of liquid photo-polymer resin, causing successive thin layers to solidify. This permits fast and inexpensive nozzle geometry changes for parametric studies, and the 25-micron layer thickness provides a smooth surface finish with minimal post-print finishing. However, investigation is required into the repeatability of the prints and the uniformity of the geometry. A profilometer is used to map the surface of the nozzle contour for comparison with the input geometry for various print orientations. The pull-out strength of the bond between the stainless steel gas supply tubes and the 3D printed material also needs to be determined for safe operation of the thrust stand when the system is pressurised. Two bonding methods are investigated: two part epoxy and liquid SL resin, which is cured in an ultra-violet chamber. Tensile tests are carried out to determine the required depth of tubing within the 3D print for safe operation at expected gas supply pressures (up to 30 bar). Preliminary outgassing tests of the cured SL resin will also be presented.

Solving the Mission Operations Problem

Tim Broadbent, Dr Jason Held

Saber Astronautics

One of the major barrier to accessing space, especially for low to medium budget missions, is mission operations. Saber Astronautics is a space technology company dedicated to developing space technologies which includes addressing both the costs and complexities of operating one or more satellites once in orbit. Saber conducts lean research and development to rapidly develop solutions targeted to our customers current and future needs. The two aspects of reducing operational complexity are the quantity and presentation of spacecraft telemetry and other data, and improving spacecraft automation processes.

Saber has developed its own Responsive Space Operations Centre to both simplify the mission operations interface, and to predict and diagnose satellite health issues before malfunctions occur. The backend software - the Predictive Interactive Groundstation Interface (a.k.a. PIGI) - is now being developed for mission operators to run their own missions themselves with a low-cost software package and minimal training required. The software is currently being trialed at various academic institutions across Australia for mission simulation and planning.

Buccaneer Risk Mitigation Mission

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The Buccaneer Risk Mitigation Mission is the first of two CubeSat flights conducted within the collaborative partnership between UNSW Canberra and DST. Scheduled to launch in December 2016, the Buccaneer Risk Mitigation Mission will flight test several key technologies and on-orbit operations for the digital high frequency receiver and antenna for the Buccaneer Main Mission that will perform calibration experiments with the Jindalee Operational Radar Network (JORN). The flight will additionally provide a platform to conduct photometric experiments with the UNSW Canberra node of the Falcon Telescope Network and provide data for the validation of astrodynamic simulations. The presentation will provide an overview of the progress to date of the space vehicle design and manufacture; payload; experimental aims and objectives; software development; UNSW Canberra ground station and details of the planned environmental stress screening campaign.

Attitude Determination and Control System for UNSW's QB50 Cubesat

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*Australian Centre for Space Engineering Research
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An Attitude Determination and Control System (ADCS) has been implemented to provide de-tumbling and pointing capabilities for the University of New South Wales EC0 CubeSat as part of the QB50 project. This ADCS implementation is based upon a realistic MATLAB - STK simulation model developed at UNSW. The 2U CubeSat utilises a sun and an earth sensor, 3 axis gyroscope and 3 axis magnetometer to provide attitude determination through an extended Kalman filter. Based on the calculated attitude, the attitude control algorithm then actuates a set of varying pulse width modulated (PWM) outputs to the 3 axis Magnetorquer to manoeuvre the Cubesat.

This paper details the software development and hardware integration and testing of this system for a 2016 launch opportunity. The findings cover the functionality of the system, as well as a discussion of the low-cost testing methods selected for subsystem verification and validation.

Solving the "Type II Solar Radio Burst Problem" and Predicting Space Weather

Iver H. Cairns

School of Physics, University of Sydney

For over 60 years type II solar radio bursts have defied detailed quantitative explanation, despite their promise for predicting space weather at Earth and their status as the archetype for coherent radio emission stimulated by shocks. Type II bursts are widely accepted to be radio emission produced at the electron plasma frequency and/or twice that frequency upstream from shock waves (usually driven by coronal mass ejections [CMEs]) moving through the corona and solar wind. At the University of Sydney we have developed quantitative analytic descriptions for the required plasma physics. We have also constructed a state-of-the-art theoretical / simulational model for a specific type II burst by combining the radio emission theory with a 3D MHD simulation of the CME-driven shock moving through a realistic, data-driven, 3D model for the corona and solar wind. Impressive quantitative agreement is demonstrated here between the predicted and observed properties of both coronal and interplanetary type II bursts. These suggest that we are very close to "solving the type II problem" and being able to use our simulations of type IIs for space weather prediction.

Development of a coupled PIC-DSMC method for the study of objects in a charged space environment

Christopher Capon

UNSW Canberra

Earth's local space environment can be described as a low-temperature, partially ionised, tenuous plasma. Understanding the interaction of near-Earth objects with the local space environment is becoming increasingly important in a variety of fields. The affect that the coupled interaction between charged objects and the local space environment has on aerodynamic forces may help explain orbit perturbations during solar weather events. To investigate these charged aerodynamics, a coupled Particle-in-Cell (PIC) - Direct Simulation Monte Carlo (DSMC) code, "pdFoam", is under development at the University of New South Wales Canberra in conjunction with the University of Strathclyde. Development, initial validation studies and future applications of pdFoam, will be presented here.

Mars Australian Remote Virtual Experiment Laboratory (MARVEL)

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The Mars Australian Remote Virtual Experiment Laboratory (MARVEL) project is a virtual laboratory for processing, computational analysis, and interpretation of digital data from publicly available NASA and ESA missions to Mars. To date the project involves researchers from 5 core organisations: the University of South Australia (UniSA), Amazon (AWS), the Italian National Institute for Astrophysics (INAF), the CINECA consortium of Italy, and the University of Modena and Reggio Emilia (UNIMORE). Work on the system architecture for the project commenced in the first half of 2015, with plans to deploy the virtual laboratory by the end of 2015, and to conduct proof-of-concept testing in the following 12-18 months. Testing will be conducted by two groups of users: (1) power users, comprising researchers from all 5 core organisations; (2) end-users, represented by selected planetary scientists, educators and school students.

The primary goal of the project is to facilitate scientific collaboration among researchers in the five core organisations. The secondary goal of the project is to enable and encourage scientific collaboration with the broad planetary research community. The tertiary goal of the project is to engage educators and students interested in planetary research, and to facilitate distribution and exchange of data and modules for curriculum content in science, technology, engineering and mathematics (STEM) disciplines.

In this proof-of-concept implementation phase, MARVEL is wholly supported by AWS infrastructure, and by the researchers in the five core organisations involved in establishing the system architecture, the data, and the processing tools. Selected end-users will be able to access the laboratory gratis. Upon successful

completion of the testing phase, funding and resources for long-term deployment and expansion of the virtual laboratory will need to be found.

This presentation outlines the scope and scale of MARVEL, and highlights the progress to date.

The 2015 St. Patrick's Day superstorm: Effects in the near-Earth space environment and impacts on technologies

Brett Carter^{1,2}, Endawoke Yizengaw¹, Chin Lin¹, Rezy Pradipta¹, Robert Norman², Tzupang Tseng³, James Bennett⁴, Rebecca Bishop⁵, Matthew Francis⁶, Michael Terkildsen⁶, Keith Groves¹, Ronald Caton⁷ and Kefei Zhang²

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The recent superstorm on March 17, 2015 was the most intense storm of the current solar cycle. The Kp index reached 8- and the Dst index reached a minimum of -223 nT. Large geomagnetic storms caused by disturbances in the solar wind are known to cause various phenomena in the near-Earth space environment that adversely affect a wide variety of ground- and space-based technologies. In this contribution, we will examine three of these phenomena: (1) Geomagnetically Induced Currents (GICs) in the equatorial region that can possibly damage power grids; (2) the occurrence of Equatorial Plasma Bubbles (EPBs) that impact Global Navigation Satellite System applications; and (3) large-scale thermospheric temperature and density increases that elevate satellite drag at low-Earth orbit altitudes.

It is demonstrated that increased GIC levels occurred at the magnetic equator in the South-east Asian region during this storm, and that the equatorial electrojet current system is responsible for locally amplifying the geomagnetic fluctuations. Space- and ground-based observations show that the growth of post-sunset EPBs was suppressed around the world for the duration of the storm. This suppression is understood to be due to the equatorward wind surge from the high-latitude regions during the storm. As they reach the equatorial region, this wind surge translates into a decrease in the eastward zonal wind that contributes towards the strength of the post-sunset upward plasma drift. These effects create less-favourable conditions for EPB growth after sunset, which translates into reduced scintillation

activity at Gigahertz frequencies. Finally, satellite orbit predictions for satellites between 400 and 800 km altitude are shown to be influenced during the St. Patrick's Day superstorm. The ramifications of the reduced orbit prediction accuracy will be discussed in the context of the space debris problem and the orbital collision avoidance mechanisms that rely on these predictions.

On the vulnerability of the equatorial region to geomagnetically induced currents

Brett Carter^{1,2}, Endawoke Yizengaw¹, Rezy Pradipta¹, Alexa Halford³, Robert Norman² and Kefei Zhang²

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Geomagnetically induced currents (GICs) are one of the most serious examples of space weather impacts on human technology. The adverse influence of GICs on high-latitude power grid infrastructure during extreme geomagnetic storms has been well documented. GICs are typically largest in the high-latitude region where the magnetic fluctuations from space-based current systems are amplified by the auroral electrojets. However, the equatorial region that is home to the less intense equatorial electrojet has been largely overlooked. In this study, we examine GICs at the magnetic equator that have been caused by interplanetary shocks. It is demonstrated that the equatorial electrojet acts as a local amplifier of magnetic field fluctuations from space, in a similar manner to the auroral electrojets. This magnetic field fluctuation amplification gives rise to increased GIC levels beneath the electrojet regions compared to the surrounding mid-latitude regions. Importantly, this amplification occurs for interplanetary shocks during both quiet and disturbed periods. As such, these results indicate that damaging GIC levels are possible at the equator during completely quiet geomagnetic periods. This finding has profound implications for the vulnerability of infrastructure at the magnetic equator that may not have been originally designed to cope with space weather effects.

TID wavelength control of disturbance features in VI and QVI ionograms

Manuel Cervera, Harris

Defence Science and Technology Group (Cervera, Harris)

The University of Adelaide (Cervera - Adjunct)

Travelling ionospheric disturbances have been long known to affect HF radio waves propagating through them with additional features (e.g cusps and loops) being manifest on vertically incident (VI) and quasi-vertically (QVI) soundings of the ionosphere. In a previous paper we used gravity wave theory to generate synthetic ionospheric disturbances. 3D magneto-ionic Hamiltonian raytracing was then employed to model the effect that these ionospheric disturbances have on QVI ionograms. These modelling results were compared with ionograms recorded near Adelaide and the characteristics of the observed disturbances were successfully modelled. In this paper we present the results of modelling TIDs over a range of wavelengths and compare with observation. We focus on how the wavelength of the TIDs control the characteristics of the disturbance features observed in the ionograms.

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from the conference**

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from the conference**

Plasma propulsion as a vehicle for science in space and in the laboratory

Christine Charles and Rod Boswell

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The Space Plasma, Power and Propulsion Laboratory (SP3) at ANU has been conducting work on both basic and applied plasma physics (space science, materials science and space propulsion) for the past three decades. It has developed unique expertise in wave-plasma interactions, plasma instabilities, cross-field diffusion, high-beta plasmas and more recently momentum imparted from plasma expansion and plasma detachment from magnetic fields.

Science in space is based on a good control and understanding of non-linear plasma physics in the laboratory. SP3's development of a suite of plasma thruster concepts and prototypes (the HDLT also called the Australian Plasma Thruster, the Pocket Rocket thruster) provides two major opportunities not previously possible in Australia:

1-"Indirect experiments" relating laboratory and space are now possible in the new national space simulation facility WOMBAT XL which SP3 developed to test the thrusters in collaboration with the astronomers at Mount Stromlo and industry partner AIRBUS. To date this was traditionally carried out with small size plasma systems which could not truly reproduce the conditions of space but which have been applied to charge particle acceleration in the Earth's aurora and the unexplained solar corona acceleration. Intermediate and actively-controlled experiments not requiring space events and data from expensive conventional satellites (which Australia does not have) can now be carried out in WOMBAT XL.

2-"Direct experiments" in space using SP3's plasma thruster concepts and prototypes (the HDLT also called the Australian Plasma Thruster, the Pocket Rocket thruster) scaled for the Cubesat platform to study for the first time basic plasma behavior in space, interaction between the ejected plasma plume and the Earth magnetic field and turbulence in space.

3- Industry sector: SP3 has a long history of successful collaborations with international partners (NASA, ESA, AIRBUS,

LOCKHEED MARTIN) and its thruster technology can be scaled to suit Nano satellites (Cubesats), small satellites (such as TECHDEMOSAT 1), larger telecommunications satellites (placement on graveyard orbits) and high power vehicles for future access to deep space.

Effect of Self-shadowing and Attitude on Cubesat Solar Power Generation:

A Case Study on UNSW EC0 QB50 Cubesat

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*Australian Center for Space Engineering Research
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UNSW's QB50 Cubesat harnesses solar power via three body-mounted and two deployable Photovoltaic panels. For a given mission, the amount of solar energy that can be generated can be optimised if non-mission-critical configurations such as the solar panel deployment angle and the satellite's attitude can be varied. Taking the orbit-averaged generated power as the function to maximise, a comprehensive set of CAD-based in-orbit simulations can then produce the optimal configuration for a mission. The simulation has been developed in MatLab and incorporates 3D ray tracing algorithms to account for the shadowing effects of the deployed solar panels on the body-mounted solar panels. Taking into account the self-shadowing effect, a parametric study was then conducted to solve for the power output of the CubeSat at all orientations in 3D space.

Incorporating the various power efficiencies of the satellite load and Electrical Power Systems (EPS) module, the computed solar energy generated is then used to accurately predict the power margins of the system at a variety of operational modes and spacecraft attitudes. This analysis thus provides a useful guide to ensure that the design of our mission is operating within sufficient energy margins.

Taking the UNSW Cubesat mission as a case study, this analysis has shown that the effects of self-shadowing can reduce up to 30% of instantaneous output power, and thus is an important factor to be considered. By optimising the satellite roll and panel deployment angle, the satellite is able to maintain a positive power margin, as opposed to a negative power margin as observed in other non-optimised configurations.

Robust Space Object Detection

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² *Inovor Technologies*

³ *Defence Science and Technology Group*

Space Situational Awareness (SSA) is an area of interest to both the civilian and defence agencies in Australia [Defence White Paper 2013 and Australia's Satellite Utilization Policy]. Having a low cost platform from which to conduct space monitoring tasks would support the ground based assets in existence or planned in Australia. A space based imager has advantages over ground based systems such as more observation opportunities of space objects, no atmospheric disturbances, no cloud cover restrictions. The key is to develop technology that is small enough to be implemented on a lower cost space based platform.

This paper presents the configuration design for a nano-satellite based SSA system and the results from our object detection image processing algorithm. The detection is based on the geometry underpinning a moving imaging system in space. Given two images with overlapping views, objects in near orbit will exhibit noticeable parallax across the images, whereas background objects (i.e., stars) will exhibit zero parallax due to being infinitely far away. Leveraging on this fundamental constraint, we have developed an algorithm based on branch-and-bound optimisation to detect man-made objects in space images. Unlike many heuristic algorithms used in processing space images, branch-and-bound optimisation guarantees optimal results, which improves the system's robustness. We present detection results on real-life data, which underline the potential of our system to detect small targets in a highly cluttered field of background stars. The results show successful detection using two different observation modes, star field tracking of fixed attitude tracking. In each case the algorithm is shown to be able to detect all known satellites in the image sequence. We also present runtime information, which supports the feasibility of our algorithm on a low-power space-based platform.

Is Habitability Constrained by Biology? The Case for a Gaian Bottleneck

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National University*

The prerequisites and ingredients for life seem to be abundantly available in the universe. However, the universe does not seem to be teeming with life (the Fermi Paradox). The most common explanation for this is a low probability for the emergence of life (an emergence bottleneck), notionally due to the intricacies of the molecular recipe. Here we present an alternative Gaian bottleneck explanation: if life emerges on a planet, it only rarely evolves quickly enough to regulate greenhouse gases and albedo, necessary conditions to maintain surface temperatures compatible with liquid water and habitability. Such a Gaian bottleneck suggests that (i) extinction is the cosmic default for most life that has ever emerged on the surfaces of wet rocky planets in the universe, and (ii) rocky planets need to be inhabited, to remain habitable. In the Gaian bottleneck model, the maintenance of planetary habitability is a property more associated with an unusually rapid evolution of biological regulation of surface volatiles, than with the luminosity and distance to the host star.

The habitability of a rocky planet is strongly influenced by the volatile content of its atmosphere which controls both the albedo and greenhouse warming. Because of the strength, rapidity and universality of abiotic positive feedbacks, the rapid evolution of the atmosphere can lead to temperatures too hot for life (runaway greenhouse) and loss of water (runaway loss of hydrogen), precluding long term planetary habitability. We argue that even if abiogenesis is common on rocky planets, runaway greenhouse effects and volatile loss could be the largest obstacle to life's persistence on initially wet rocky planets throughout the universe.

Update of the Australian Resuscitation Council Cold Injuries Guideline – Results of a Literature Review

Rowena Christiansen

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Department of Medical Education, The University of Melbourne
Ormond College, The University of Melbourne
Chair, Medical Advisory Committee, Australian Ski Patrol
Association
Board Member, World Association for Disaster and Emergency
Medicine*

Best practice management of cold injuries is relevant for space exploration training in Earth's extreme environments as well as the hostile environment of space itself and extra-terrestrial exploration targets such as the Moon and Mars.

A literature review is currently being undertaken as part of the process of updating the Australian Resuscitation Council guidelines on the management of cold injuries, including hypothermia, frostbite and frostnip. The results of the literature review will be presented, together with the recommendations for updating the management guidelines.

The performance of field science in a simulated space suit: stromatolite identification by geologists and non geologists

Jonathan Clarke, Waldie, M. Cooper, S. George, S. Houlahan, G. Murphy, K. Silburn, D. Sprigg and M. Sprigg

Mars Society Australia/Australian Centre for Astrobiology

Understanding the constraints of field work while in a space suit is critical when considering the capabilities and limits of crewed exploration on the surface of the Moon, Mars and other accessible Solar System bodies. Mars Society Australia has studied the effect of simulated space suits on field work over several years, most recently during the Arkaroola Mars Robot Challenge Expedition in 2014. A simulated space suit on loan from the Victorian Space Science Education Centre was used. The scenario was the investigation of a potentially fossiliferous carbonate outcrop on Mars identified by satellite imagery and investigated by a sortie from a landing site several tens of km distant. Geologically-briefed engineers and specialized geologists would spend a limited amount of time assessing whether or not the outcrop contained mesoscopic signs of life in the form of stromatolites, which are columnar or domal structures mostly formed by the growth of generally shallow water and usually photosynthetic microbial communities. Seven volunteers, three geologists and four non-geologists, examined an outcrop of Neoproterozoic Trezona Formation dolomitic limestone and identified features they considered as possible and probable stromatolites over a period of 20 minutes. Each identification was assessed by the experiment lead. False positive identifications were also recorded, and whether they thought the exposures were in cross section or in plan view. All participants correctly identified stromatolitic features, despite the suits, glare from low angles, and time pressures. Overall there were 167 observations, of these 50.9% were identified as probable stromatolites and 38.3% as possible stromatolites, all of these identifications judged to be correct. A further 7.8% of observations were assessed as false positives (something was identified as a possible or possible stromatolite when it was mostly likely not) and 3% as false negatives (a genuine stromatolite was dismissed as not being stromatolitic). On an actual mission samples collected on the basis of these observations would contain diverse evidences for fossil microbial life.

65° South - The mischarted Flight of Yuri Gagarin

Peter Connery

Australian Dental Association

"Once you eliminate the impossible, whatever remains, no matter how improbable, must be the truth."

Arthur Conan Doyle

"Coincidence is God's way of remaining anonymous."

Albert Einstein

12 April 1961, during his historic mission, Gagarin commented

"...I am over America..."???

Many authors believe that he was lost.

But consider this; Gagarin was a trained Cosmonaut and qualified Fighter Pilot. Do you really believe that he didn't know where he was?

The Bay of Pigs Invasion (not the Cuban Missile Crisis!) closely followed the launch of Vostok1.

In documents from George Washington University, Kennedy's attitude to Cuba changed markedly on 12 April 1961. THE SAME DAY!

There are many inconsistencies in the published histories of both events. Maps of the 65° Orbital Angulation flightpath show a north-easterly launch. However launch 65° south-easterly, and Gagarin would have passed parallel to the eastern seaboard of the U.S.A., about 220Km from Washington, 100Km from New York and 40Km from Cape Canaveral.

Coincidence?

At 30,000km, a 0.1° change in launch angle deviates the flightpath by 52Km. Judicious analysis of the launch video indicates a south-easterly flightpath.

The accepted history of the flight contains statements that have been added by author/s:

"06:37UT Vostok1 continued on its journey as the Sun set over the North Pacific. Gagarin crossed into night, north-west of the Hawaiian Islands."

"06:49UT Gagarin reported he was on the night side of the Earth."

These events are 12 minutes apart! 5,400Km at 450Km/min, Perth to Auckland!

Only one of these is accurate when plotted against the Darkness Terminator.

Critical analysis of ONLY the statements made by Gagarin on the tape-recorder, confirm it, and place him "....over America...."

Assessment of Vostok's physical dimensions shows an interesting connection:-

Vostok1 Weighed 4725Kg.

Little Boy (Hiroshima A-bomb) weighed 4,400Kg.

Fat Man (Nagasaki) 4,633Kg.

Why launch such a heavy satellite?

Carrying a Torch for Dust in Binary Star Systems

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The circumstellar disks of young stars are believed to be planet-forming regions. Scattered light imaging of proto-planetary disks reveals a rich variety of structures including spirals, gaps and clumps. At present, self-consistent modelling of both imaging and multi-wavelength photometry provide the best interpretation of the location and size distribution of disks dust.

In this work we present, by way of example, a polarimetry method for probing the circular symmetry of dust in circum-binary disks. Using multi-epoch multi-waveband polarimetry, the intensity and phase angle of polarisation from the system can be used to trace out the illumination of the disk by the secondary, and thus probe the dust properties, including size distribution.

Epsilon Sagittarii is an unusual star system. It is a binary system that is also believed to host a dust disk. The primary has a spectral type of B9.5III and is ~ 3.5 times the mass of its 0.95 Solar mass companion. The secondary orbits at 106 AU from the primary, whilst the debris disk is 155 AU distant. As the secondary orbits the primary, it will race ahead of the disk, illuminating each section in succession as if a torch shining upon it.

Recently we observed Epsilon Sagittarii with HIPPI (the HIgh Precision Polarimetric Instrument). Here we present calculations and preliminary data to investigate HIPPI's ability to probe the effect.

Opportunistic flyby characterisation of Earth passing asteroids

William Crowe, Nathan Kinkaid, John Olsen, John Page

UNSW Simulation and Virtual Engineering (SAVE) Laboratory

Many Potentially Hazardous Asteroids (PHAs) will fly through the Earth-Moon system several times before possible impact. Furthermore, asteroids that pass through the Earth-Moon system are most likely to be discovered only a few weeks before they fly past. Recent development of small spacecraft, especially cubesats, shows promise in their use for space missions. Without leaving Earth orbit, opportunistic near-intercepts of PHAs could provide improved and more regular characterisation of these asteroids than observations from Earth-based facilities. They could also be launched at short notice when a new PHA is discovered. A mission is proposed where a mothership will release several cubesat-sized spacecraft to intercept PHAs as they fly past closely past the Earth. This research investigates the technology that is in development and already available that could be used for these missions, as well as design considerations for the missions themselves.

Cooperative estimation of asteroid mass

William Crowe, Nathan Kinkaid, John Olsen, John Page

*School of Mechanical and Manufacturing Engineering,
UNSW Australia*

and

Australian Centre for Space Engineering Research

Past missions to asteroids have used a single spacecraft in a closed orbit to estimate mass and mass distribution. Spacecraft swarms have the capability to reduce the time required to characterise these properties. A method of determining asteroid mass through use of a multiple-input Bayesian Filter is presented, along with simulations illustrating the approach. A discussion outlines the issues found in combining swarm data to build a full picture of the characterised asteroid.

Desert Fireball network: Handling of the multi terabyte data

M. Cupak[1], P. A. Bland[1], M. C. Towner[1], R. M. Howie[1], J. P. Paxman[1], E. K. Sansom[1], H. Devillepoix[1], G. K. Benedix[1], S. J. Tingay[1], M. J. Galloway[2] and T. Jansen-Sturgeon[3]

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The Desert Fireball Network (DFN) is a continent-wide astronomical observatory system, designed to capture meteors in order to allow triangulation and eventually recovery of fresh fallen meteorites with associated orbits.

As of today, the network consists of 31 individual cameras, 13 in Western Australia and 18 in South Australia. Each camera is built around a COTS 36MP full-format DSLR, continually taking exposures every 30 seconds throughout the night. Most of the cameras record also video, although the majority of the video files are deleted and only those time-overlapping with detected meteor events are kept. Altogether, even considering that the cameras interrupt operation in case of cloudy weather, the average daily volume of data per camera is ~55GB, resulting in nearly 600GB of data p.a.

Although from the point of view of the primary purpose of the network - searching for meteorites - only about 1% of this data volume is needed, it was decided to keep all this data stored for later processing and scientific analysis. The motivation is not only internal to be able to re-run the meteor detection, but also to make the unique dataset available for other purposes, e.g. astronomy or spacecraft tracking.

The volume of data is too big to transfer it from cameras to the data store over an internet connection, therefore the camera system design includes exchangeable drives that are replaced every six months, and full drives transported to Perth. Data from these drives are then ingested into LiveArc database hosted by Pawsey supercomputing centre. As part of the ingestion, the data is pre-processed and metadata is generated for later searching. The database allows a variety of queries based around time/location/system etc. We describe the design of the metadata and archive architecture, which allows a variety of use-cases related to planetary science, astronomy, and other to-be-decided areas of study

SuperDARN Backscatter During Intense Geomagnetic Storms

Julie Currie, Prof. Colin Waters, Prof. Fred Menk, Dr. Murray Sciffer

University of Newcastle

The Super Dual Auroral Radar Network (SuperDARN) is a network of over 35, HF (8-12 MHz) over-the-horizon radar installations used to study ionosphere dynamics. The literature often mentions that SuperDARN radars experience a loss of backscatter during geomagnetic storm events. This was one of the reasons for the introduction of StormDARN, a collection of SuperDARN radars located at mid-low latitudes to enable studies of ionosphere dynamics during geomagnetic storm times.

The occurrence of HF radar backscatter during 18 intense geomagnetic storms was examined using a superposed epoch analysis. The analysis was applied to both the Bruny Island (Tasmania), mid latitude radar and the high latitude Kodiak (Alaska) radar. The amount of received backscatter was examined as a function of range gate and geomagnetic storm phase. A loss of backscatter at range gates beyond 15 was consistent with the loss of backscatter noted previously in the literature for SuperDARN radars. We also found an increase in backscatter at close range that occurred at the onset of the main phase. The decay and recovery times of HF radar backscatter occurrence were calculated for the normalised storm time base. This allows prediction of backscatter fadeout and occurrence return for any given geomagnetic storm.

Early solar system events revealed by analysis of tiny nuggets.

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Carbonaceous chondrite meteorites contain micrometre sized alloys of platinum group elements known as refractory metal nuggets (RMNs). RMNs are thought to be the first solids to condense from the solar nebula. We are using high resolution techniques such as transmission Kikuchi diffraction (TKD), transmission electron microscopy (TEM), and atom probe, that can provide chemical and crystallographic data at an atomic-nanometre scale. These techniques are revealing nanometre scale textures never previously observed that provide clues to the conditions at the time of RMN formation, when the sun first started to shine.

The first observed texture is annealing twins, which indicate that this particular RMN must have been reheated post-formation to temperatures >500 °C. Evidence for reheating events has previously been identified in some meteorites, but it is the first time such evidence of reheating has been found in inclusions this small.

Several isolated RMNs are also found to have identical crystal orientations to each other. These grains were unrelated to their host sulphide but once had a crystallographic relationship to other minerals in the sample. Sulphides are a secondary alteration feature, indicating that crystallographic relationships can be preserved during secondary alteration.

An entirely new mineral phase was discovered forming as a pseudomorph of the original RMN. In addition, this RMN also has a shared crystal axis with the host phase, which is a potential indicator that the host phase nucleated around the RMN. The new mineral also exhibits apparent super cooling textures, suggesting

that the time frame for these secondary heating events must involve very rapid cooling.

In conclusion, these high resolution techniques provides in situ data and analysis revealing nanometre scale structures that indicate how these grains formed and have been subsequently altered, providing a window into the dynamic environment at the very dawn of the solar system.

Off Earth Mining

Andrew Dempster

*Australian Centre for Space Engineering Research (ACSER),
UNSW Australia*

With the launch in 2015 of Planetary Resources' Arkyd 3 Reflight spacecraft, commercial exploitation of space resources is officially "off the ground". This talk will summarise the current state of off-earth mining, and where research is being applied across many disciplines.

A satellite survey with the Desert Fireball Network

Hadrien Devillepoix

Desert Fireball Network, Curtin University

We present here the benefits of having an all-sky optical survey for satellite tracking. The Desert Fireball Network uses low-cost consumer camera technology to triangulate meteors entering the atmosphere, and already covers 1/3rd of the Australian continent. An upgrade to those systems, the Desert Transient Factory, is being built to cover the same area, but for transient astronomy targets. This new system has better resolution and sensitivity (magnitude 13), which enables it to see a significant portion of satellites and debris population as a byproduct. The DTF is designed in a way to easily rule out non deep-space phenomena by having two distant cameras looking at the same patch of sky. The rejected events include sensor and atmospheric artifacts, but also objects in Earth's orbit, which are instantly triangulated. Building a satellite orbital database from scratch requires a lot of telescope time, and a significant ground coverage, especially for Low Earth Orbit satellites. Instant triangulation is a huge advantage thanks to the strong astrometric constraints it yields. All of this data is already saved and archived for DFN and DTF science operations. Extracting the satellite data is merely a data processing effort.

Photovoltaic Power System Design for a Mars Analogue Research Station

Keira Doherty¹, Yao Xiong Loo¹, Nicole Blinco¹, Liam Waldron¹, and Jonathon Clarke²

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² *Mars Society of Australia*

The Mars-Oz project is one of the Mars Society of Australia's (MSA) key projects. It centres on the design of a Mars Analogue Research Station (MARS) that is planned to be built in South Australia. This station will provide crews with the opportunity to live and conduct a wide range of research under similar constraints that they would on Mars. Education, training and outreach activities will also be supported. Preliminary investigations have determined that a daily average of 52 kWh of energy would be needed for the MARS to be fully operational when occupied during winter. MSA identified that a solar renewable energy system would ensure that the station would be self-sustaining and not have to rely on the electrical grid. We found that photovoltaic (PV) technology would be most appropriate for this system since the other alternative – solar thermal – typically has a larger operational scale and higher costs. The PV system will comprise 128 polycrystalline silicon solar cells configured as 32 strings of 4 panels, mounted with groups of 8 on a single non-tracking mounting unit. 34 valve-regulated lead acid batteries will be placed in the cargo module where crew members will spend little of their time. These will store excess energy generated by the panels and provide power to the MARS when the panels are not able to meet the power demand. The power conditioning system will comprise of 32 charge controllers, 4 inverters, over 70 circuit breakers, and a battery controller. A backup diesel generator and junction boxes should also be incorporated into the system to improve its performance and effectiveness. Feasibility of the design's operation can be used to further refine actual Mars station design and for applications to other off-grid facilities on Earth.

Space-related Research and Innovation in the Australian Defence Scientific Service

Kerrie Dougherty

PhD student, UNSW

In 1949, the Australian Government established the Australian Defence Scientific Service (ADSS), in order to consolidate and expand the nation's defence-related research and development efforts in association with the British weapons research to be carried out at the Woomera Rocket Range. This new agency incorporated the Long Range Weapons Establishment, which managed the Woomera Range, and the Defence Research Laboratories: they were later combined to form the Weapons Research Establishment (WRE). Although 'space activities' were not even considered when the ADSS was formed, over the following three decades it would carry out research and innovation that contributed to Australia's modest space activities between 1957-1979.

This paper will present examples of the research and innovation carried out under the auspices of the ADSS that either contributed to Australia's early space activities, or could have formed the basis of a more extensive national space program, had the Australian Government decided to establish such a program.

Atmospheric Correction over Ordos region based on Differential Interferometry And Persistent Scatterer Interferometry

Zheyuan Du, Linlin Ge, Xiaojing Li and Alex Hay-Man Ng

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Earth surface displacement can lead to ground hazards, namely changes of river flow path and collapses of private and public infrastructures, such as roads, buildings, schools water supply and sewage system. In recent two decades, Differential Synthetic Aperture Radar Interferometry (hereafter DInSAR) was widely applied to monitor such events with great success. However, its result can be significantly degraded due to atmospheric propagation artifacts, which is mainly consist of tropospheric stratification and tropospheric turbulence components. Therefore, time-series SAR interferometry (TS-InSAR) and more advanced Distriubted Scatterer (DS) based TS-InSAR (DS-TS-InSAR) were proposed to mitigate tropospheric turbulence delay. In this paper, tropospheric stratification delay is estimated by exploring Global Atmospheric Models (GAMs), and the verification step is conducted over Qinghai, Sichuan and Ordos. The preliminary outcome demonstrats the reduction of atmospheric effect is about 21%. This is competitive to the result generated from MODIS or MERIS. In addition, since the conventional DS selection method for DS-TS-InSAR is purely based on statistical analysis, there is no doubt that some biases may degrade the accuracy. In this paper, we aim to design and validate a time series InSAR technique based on constrained DSs (CDS-TS-InSAR) in order to increase the density and measured accuracy of DSs. Iterative Self-Organizing Data Analysis (ISODATA) Technique, Lidar DEM will be exploited to mitigate these biases together.

Looking for a Needle in a Haystack: The Search for Extralunar Fragments in Apollo 14 Soils

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The lunar surface holds many secrets and clues to past processes that have shaped and altered it over the course of its history. A lack of tectonic activity, limited solar weathering and lack of water erosion allow for much material to be preserved from the point of formation or time of impact. The Moon has endured considerable impacts over the last 4 Gyr as is demonstrated by its crater-dominated surface. Although impact size, angle and velocity are variable, impact events of low speed are highly likely to have left impact debris on the surface.

Geochemical studies completed in 1972 revealed a chemical anomaly in the majority of the Apollo mission lunar soils, which was attributed to the presence of extralunar material. Specifically, the Apollo 14 soil, 14163, was found to have 2.4 %wt of non-lunar material present. The aim of this study is to identify the extralunar fragments in soil 14163, and characterise them according to their meteorite class using elemental signatures.

X-Ray Fluorescence (XRF) Synchrotron images were collected for a range of meteorites and Apollo 14 lunar soils at the Australian Synchrotron facility in Melbourne, which show 23 element spatial distribution maps at high resolution (2 $\mu\text{m}/\text{pixel}$) for each sample. This data was used to train a neural network, a machine-learning tool allowing for automated recognition of trained meteorite classes and components. Element maps are subdivided into separate meteoritic components within each class, and the neural network learns each elemental signature. The composition of each grain of lunar soil can then be tested, and if extralunar components are detected, the programme will indicate the meteoritic component and class it most closely resembles.

Understanding the source of impactors on the lunar surface will allow us to identify any variation in impactor composition and impact influx over lunar history.

The symmetry of halo Coronal Mass Ejections as a quantitative predictor for severe space weather at Earth.

Lewis Freeland, Michael Terkildsen

Bureau of Meteorology - Space Weather Services

The Bureau of Meteorology's Space Weather Service operates an alert service for severe space weather events. The service relies on a statistical model which ingests observations of M and X class solar flares at or shortly after the time of the flare to predict the occurrence and severity of terrestrial impacts with a lead time of 1 to 4 days. This model has been operational since 2012 and caters to the needs of critical infrastructure groups in the Australian region.

A project is underway to improve this forecast model by including observations of coronal mass ejections (CMEs) associated with the triggering flares. This work will increase the accuracy of the model predictions and lower the rate of false positives. In particular, we focus on the degree of symmetry of a CME by analysing its earthward direction parameter extracted from SOHO coronagraph images. The direction parameter has been shown to be a good predictor for the geoeffectiveness of a CME.

This paper reports improvements in our ability to predict the occurrence of severe space weather events at Earth through a detailed analysis of CME characteristics.

Stellarium Skycultures as an aid to K-6 Science Syllabus Cross-cultural Understanding of Indigenous Astronomy

Robert S. Fuller

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Stellarium is a popular and free personal computer-based planetarium program. One component is called Skycultures, and is a means of showing artwork representing cultural objects in the sky, such as the common artistic depictions of the Zodiacal constellations that align with the Ecliptic, some examples being Scorpio (the scorpion) and Gemini (the twins). In Stellarium, artwork can be developed and placed anywhere in the night sky, and used to depict the cultural night sky objects of any culture where these are known. In the course of a project studying the astronomy of the Kamilaroi and Euahlayi Australian Aboriginal peoples of north central and northwest New South Wales, these cultural objects were recorded and studied. As a part of the project, the knowledge reported in academic journals was returned to the respective communities in the form of a Giving Back package, and as a school teaching resource for years K-6 where the BOSTES Science Syllabus called for cross-cultural understanding of Indigenous Astronomy. In this case, one component was the development of a Stellarium Kamilaroi and Euahlayi Astronomy Skyculture package to aid teaching the accompanying resource material. This article describes the process of creating Stellarium Skycultures for school resources, and the evaluation of the resources in the Kamilaroi and Euahlayi communities.

Detection of Kuiper Belt Objects by Stellar Occultation

George Georgevits

UNSW Australia

Stellar occultations provide the only means of detecting small, distant solar system objects that are too faint to be seen by direct observation. Despite numerous occultation based searches, our knowledge of the Kuiper Belt and beyond remains very limited for objects of less than ~ 50 km radius. Population statistics for small objects residing at the outer reaches of the solar system are required to improve our knowledge of the solar system as a whole, to confirm theories about small object formation processes, and to derive an estimate for the total residual mass of the solar system.

For this occultation survey, we used the 1.2 m UK Schmidt Telescope (UKST) in conjunction with the 6dF spectrograph (6dF). The 6dF was operated in a new, specially devised "through mode" to achieve the required fast acquisition rate.

Our occultation survey is by far the largest survey capable of detecting sub-kilometre radius objects conducted to date. It is concentrated specifically on the ecliptic, with a significant portion of the acquired data set coming from a region that includes Neptune's L5 (lagging) Lagrangian point. It contains $\sim 6,700$ star hours of data, sufficient to provide a meaningful restriction on the upper limit of the small Kuiper Belt Object (KBO) population. It is sensitive to detection KBO's down to ~ 500 m radius, representing a two orders of magnitude improvement over what can be achieved by direct observation.

Our survey has not detected any KBO's of radius ~ 500 m or greater. From this data we will derive the implied upper limit for the population density for such objects within $\pm 2\sigma$ of the ecliptic, including within the Neptune L5 Lagrangian region, plus an upper limit for the total residual mass of the solar system.

A Space Academy to inspire the next generation of Space Engineers

Adam Gilmour

Gilmour Space Corporation

Our presentation will focus on the education content of our space academy including the combination of space simulators and theory. Our theory content is delivered in a hands on practical way with frequent experiments and a question asking delivery style. We have worked with professors from the Singapore University of Technology and Design and the US Air force academy in Colorado to develop the experiments and delivery mechanism. We believe our museum and academy will be an effective lever to accelerate the focus and interest on space in Australia, and this has to be done with education.

Qualifying the Kea GPS Receiver for UNSW's EC0 CubeSat

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The Kea V41SB GPS receiver is an evolution of the Namuru V32R3A receiver developed for Defence Science and Technology as part of the Biarri program by UNSW and General Dynamics of New Zealand. The Kea Receiver will be used on UNSWs EC0 (QB50).

In this paper we describe the results of the qualification tests performed for integration into the EC0. These include the thermal, vibration, mechanical and electrical integration tests, as well as GPS functional tests relating to the GPS payload. Examples of the latter include validating time-to-first-fix, accuracy in low earth orbit, carrier phase performance and timing accuracy.

We also provide test results relating to use of the receiver in high dynamic environments, such as those experienced in launch.

"Is it wrong to wish on space hardware?" Exploring emotional attachments to spacecraft

Alice Gorman

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In popular imagination, space hardware is cold, mechanical, and remote: an evocation of the high technology of the Space Age. Yet at the same time, many people form emotional attachments to both real and fictional spacecraft. In recent years this has been fostered by the use of social media to engage the public with individual spacecraft and missions. Characterising the nature of this attachment is part of the process of assessing social value, as well as a step in effective heritage management of space places and objects. This session will take participants through a visualisation exercise in order to understand more about the cultural values of spacecraft, and hence their heritage significance.

Meteor Traditions of the Torres Strait Islanders and other Melanesian Cultures

Carla Guedes and Duane Hamacher

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Sky knowledge is a counterpoint of the Melanesian Torres Strait Islander cultures of Australia. Among these traditions, meteors play a special role, appearing in dance machines, story, art, and music. This study examines the role of meteors and meteoritic phenomena in Islander traditions using the methods and theoretical frameworks of cultural astronomy. We also explore accounts of witnessed meteorite falls, the importance of meteorites and other natural features attributed to “falling stars”. These traditions are compared to other Melanesian cultures, as well as global Indigenous cultures, showing a common thread throughout the world. This project is part of the Meteor Beliefs Project, initiated by the International Meteor Organization.

Constraining the bombardment history of Moon with a set of Apollo 16 impact melts rocks.

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Basin-scale impact events played a crucial role in the lunar bombardment history, and are the key to the question whether there was a "Lunar Cataclysm" – a sudden increase in the impactor flux around 3.9 Ga. Crystalline impact melt rocks from the Apollo 16 (A16) landing site were potentially sourced by basin-scale impacts, and can therefore hold vital information about the Moon and Earth's bombardment history.

For a set of thirty-five A16 crystalline impact melts we aim to better constrain: (A) the number of sourcing impact events; (B) the chemical and isotopic signatures of the source regions; and (C) the processes involved in the formation of those samples. To achieve this, we combined the analyses of the major and trace element chemistry and the whole-rock ⁸⁷Rb-⁸⁷Sr and ¹⁴⁷Sm-¹⁴³Nd isotopic systems with the ⁴⁰Ar/³⁹Ar dating of the samples.

(A) With our ⁴⁰Ar/³⁹Ar data we can resolve at least four different events in the timespan associated with the potential "Lunar Cataclysm", at 3815 ± 19 Ma (n=2), 3865 ± 17 Ma (n=1), 3891 ± 10 Ma (n=4) and 3952 ± 25 Ma (n=1). Furthermore we found a younger event at 3633 ± 42 Ma (n=1).

(B) The 3815 Ma and 3952 Ma events are recorded by samples with bulk crustal chemical and isotopic signatures. This suggests an origin of those samples from the lunar feldspathic highlands. The other three events seem to have excavated more evolved materials from the Procellarum KREEP terrain.

(C) Chemical and isotopic variations seem to be in first order an effect of mixing during the impact melt emplacement into the local lithology. However, the diversity of samples representing the 3891 Ma event suggests more complex igneous melt body processes – either in the target lithology prior to the impact, or afterwards within the impact melt body itself.

Legal and Political Implications of Future On-Orbit Servicing Missions

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Recent technological advances and proposed future missions in the field of On-Orbit Servicing (OOS) of satellites and other space infrastructure have significantly increased the need for a stringent legal and political framework for the industry on an international level. In particular, the threat of a critical density of space debris in Low Earth Orbit (LEO) has brought urgency to the development of technologies to remove or manipulate decommissioned or malfunctioning objects in orbit. To identify benefits of OOS and Active Debris Removal (ADR), as well as to assess the intricacies of international relations between space-faring nations, a working group was formed during the Space Generation Congress 2014 in Toronto, Canada. The working group examined the political implications of the development of an international OOS legislation through the process of a simulated regulatory hearing.

This paper summarises the current state of the OOS industry and planned future missions, as well as their primary and secondary stakeholders and possible concerns. To gain a more accurate perspective of the latter, a simulated hearing for OOS licensing was conducted. Based on the results of the discussions therein, probable challenges and the benefits of domestic and international regulation were highlighted. A review of these challenges and benefits resulted in several recommendations from the authors, outlining methods to ensure the practicality of OOS and ADR and to encourage the licensing and regulation of such activities.

The recommendations include the international regulation of OOS and ADR activities that should be considered by the United Nations; the licensing of OOS missions by government agencies; and the need for governmental support to create sustained demand for these services. Particular emphasis is laid on measures to prevent the weaponisation of space, as these were found to be critical for the initiation of international collaboration.

An Introduction to Sydney Aboriginal Astronomy

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Sydney has a long tradition of astronomical research from both an Aboriginal and colonial perspective - employing more professional astronomers than any other city or region in Australia. But the study of the stars goes back well beyond the colonisation of Australia, when James Cook visited the eastern shores after observing the transit of

Venus in Tahiti in 1770. For tens of thousands of years, Aboriginal people have been observing the skies and incorporating their collective celestial knowledge into their cultures and lives. Despite near decimation upon arrival of the First Fleet in 1788, Aboriginal oral traditions have survived to modern times, including some that describe astronomical knowledge. This preliminary study utilises archival documents, archaeological studies, language studies, and oral traditions provided by Aboriginal elders and custodians to reconstruct the astronomies of different Aboriginal groups in the Sydney region (stretching from Newcastle to the north, to Nowra in the south, and the western edge of the Blue Mountain). The study reveals the ways in which the sun, moon, and stars informed social structure, ceremony, sacred law, seasonal change, animal behaviour, and food sources. It also reveals links to complex and far researching Dreaming tracks and song-lines that cross-cross the country. This is the basis of at least two PhD theses exploring Astronomical knowledge in and around Sydney.

The DSTO Ionospheric Sounder Replacement for JORN

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The Jindalee Over-the-horizon Radar Network (JORN) is an integral part of Australia's national defence capability. In order for JORN to perform its duties a real-time model of the ionosphere is generated. The primary source of data for this model is a set of 13 vertical- incidence sounders (VIS) scattered around the Australian coast and inland locations. These sounders are a mix of Lowell DPS-4 and DPS-1. Both of these sounders, the DPS-1 in particular, are near the end of their maintainable life. As part of the ongoing sustainment program for JORN the VIS network is being upgraded and a VIS replacement was sought. Over the last few years the High-Frequency Radar Branch (HFRB) of DSTO has been developing its own sounders based on its successful radar hardware technology. The DSTO ionospheric VIS configuration known as PRIME (Portable Remote Ionospheric Monitoring Equipment) will be described in this paper. Of considerable importance to a successful VIS is the auto-scaling software, which takes the ionogram images and produces a single-valued function-of-frequency trace, and from that produces a set of ionospheric parameters that represent the overhead ionosphere. HFRB has developed its own auto-scaling software, which has been tested under a large variety of ionospheric conditions. Recently, PRIME has been run at a JORN VIS site collocated with the existing Lowell DPS-1. This side-by-side testing was to ascertain the fit-for-purpose level of the PRIME. The performance of DSTO's PRIME under a multitude of challenging ionospheric conditions and the results of the side-by-side comparison will be presented.

Preliminary observations of ionospheric disturbances using 2D angle-of-arrival estimation on oblique incidence soundings

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Medium-scale ionospheric disturbances, including travelling ionospheric disturbances (TIDs), are a major contributor to the spatial and temporal variability routinely observed in the mid-latitude ionosphere. These disturbances, on the scales of hundreds of kilometres and tens of minutes, can potentially affect sky-wave over-the-horizon radar operations at HF by reducing the detectability and registration accuracy of targets.

The recent installation of two 19-element oblique incidence sounder (OIS) receiving arrays in Laverton, WA and Coondambo, SA aims to improve our understanding of how the manifestation of mid-latitude disturbances in OIS ionograms (e.g. kinks, focusing and spread in the traces) relates to realistic electron density disturbance models and observations by other instruments, including sky-wave radar. A 2D angle-of-arrival (AoA) technique is used to extract bearing and elevation estimates for each ionogram, and one-way channel scattering functions at key propagation frequencies complement the ionograms with measurements of Doppler.

Preliminary results collected as part of the ELOISE experimental campaign will be presented, showing the off-angle returns and perturbed Doppler spectra characteristic of disturbances and dynamic behaviour in the ionosphere. Modern direct-digital hardware means that high fidelity AoA ionograms can be received and processed with a fast revisit rate (3.75 minutes) on up to 8 paths simultaneously, greatly increasing the sampling density of existing sounder networks in space and time.

With the two OIS receiving systems operating on near orthogonal paths, and a dense network of vertical incidence sounders sited around the mid-points, the expectation is that the ELOISE data set will allow the structure and sources of medium-scale disturbances to be better understood and modelled in future real-time ionospheric models.

Parabolic flight testing results for DragEN Electrodynamic Tether Deployer

Jason Held, Daniel Bunker, Tim Broadbent

Saber Astronautics

The DragEN (Deployable for Recovery through Atmospheric Gravity ENtry) is a very simple, highly redundant tether deployer used for responsible de-orbit of picosatellites at the end of their mission life. With a de-orbit time of ~ 15 days, DragEN is a flexible, elegant solution compared to conventional de-orbiting systems currently on the market. Current drawn from the tether's interaction with the space environment can provide an extra source of electric power if the tether is configured as an active system with emission cathodes.

A key challenge with space tether devices is ensuring the tether can unroll cleanly and without snags or other defects. DragEN has successfully completed a parabolic flight campaign with NASA Flight Opportunities Program (NASA FOP). Six flights and over 80 microgravity parabolas were conducted which characterised behaviour over deploy/release, rollout, and braking of the tether. Results proved DragEN to be a highly stable solution validated to TRL-6, and is ready for its maiden flight which is manifested in 2016. This presentation will overview results of the flight campaign and discuss preparations for flight.

Origins of Standing Stone Astronomy in Britain

Gail Higginbottom

Australian National University

Significantly, a series of astronomical associations have been empirically verified for many Bronze Age monuments that were erected between 1400-900 BC in western Scotland (Higginbottom et al. 2015, 2001, 2000). Further, two series of complex landscape patternings associated with these monuments and their orientations have been identified (Higginbottom et al. 2015, in preparation). However, when and where these patterns were first associated with standing-stone structures was unknown. Through innovative statistics and software I will show that visible astronomical-landscape variables found at Bronze Age sites on the inner isles and mainland of western Scotland were actually first established nearly two millennia earlier, with the erection of the first 'great circles' in Scotland: Callanish on the Isle of Lewis and Stenness on the Isle of Orkney, mooted to be the first standing stone sites created in Britain.

The Case for Mining Asteroids

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Human rights and space exploration, space ethics and space law in particular, are major long-term key steps for human development. Asteroids provide a viable medium term step for extra-terrestrial mining – key to providing material requirements for a burgeoning space race. Ethicists need to urgently analyse and separate human auto indulgence from painful standards of ‘love for outerspace’ which advocate against mining based on moral values. The need to shift to other environments in space, such as asteroids, to obtain a clear or improved understanding on how ethicists and legal professionals can contribute to environmental space decision-making will help resolve the complex issues of mining in an unknown territory.

The different ethical perceptions of establishing mining projects on Earth, especially in Antarctica and in the Arctic, demonstrate that asteroid mining is not about competition, nor about clashes between governments and non-government companies for the outer space mining profits. The multinational cooperation in developing and operating the International Space Station (I.S.S.) - another touchstone of evolutionary ethical value-approach –also proves that ethical standards have been already set for specialists of various areas of science and of different countries to interact positively. We all have much to learn about mutual cooperation which is an essential step for a pro-exploration culture. Educating the public that without resource mining, colonisation of outer space is impossible, is an important step.

A Comparative Analysis of Terrestrial and Martian Gullies: Evidence for Erosion by Complex, Multi-Agent Processes

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The discovery of Martian gullies in 2000 caused considerable excitement within the planetary science community. The similarity of these Martian gullies to terrestrial counterparts, and their superposition on young features, such as dunes, suggested that liquid water, previously thought not to be stable on Mars today, has acted as an erosive process in Mars' recent past. We used a GIS to exploit multiple datasets, including High Resolution Imaging Science Experiment (HiRISE) derived DEM and imagery, and other remotely sensed data to study and characterise gullies within the Noachis Terra Highlands. We compared these to three field surveyed gully sites located in semi arid, temperate and periglacial regions in Australia and New Zealand.

Comparison of these gully systems highlighted the importance of liquid water in gully formation and evolution on both Mars and Earth, as well as the additional influence of non-fluvial erosion mechanisms. All studied gullies presented evidence of formation by liquid water, as well as the action of subsequent erosion events, probably driven by changes in the local climate. We suggest that local geomorphological conditions, such as regolith composition, structural setting and, in the case of many of the terrestrial gullies, influence of vegetation, significantly control gully evolution. In the case of Mars gullies fluvial erosion was likely initiated by high slopes, loosely consolidated material and degradation of ice rich material. Additionally, erosion at many studied sites appeared to be periodic and varied with magnitude. Our study indicates that global assumptions may not work at the local scale and that local environmental conditions must be taken into account before any meaningful analysis of gullies can be carried out.

Astrobiology With Mars'Obot: Identifying Microbial Life Forms Using Ground Based Remote Sensing

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The astounding success of the NASA Curiosity rover reaffirms the ongoing value of using wheeled robotic missions to explore Mars. The Mars'O Bot project proposes to develop affordable rover platforms suitable for undertaking scientific exploration in terrestrial environments analogous to Mars. We conducted science trials of a small Sojourner size rover, "Junior", in the Rotorua Hot Springs region, New Zealand, between 16 and 18 January, 2015. Extremophiles inhabiting thermal environments, such as those found in Rotorua, are among the earliest forms of life and are adapted to living in areas hostile to common life forms. Evidence of past thermal environments have been found in different areas of Mars (eg., gypsum deposits in Gusev Crater). Thus our robotic operations in the hot springs environment in NZ allows us to determine whether these types of environments can be characterised using unmanned methods and to assist in providing a baseline for what an early Martian environment might have been like.

We trialled Junior at two hot spring sites, Waimangu Volcanic Valley and a floodplain of Parariki Stream, characterising them by a custom made four band multispectral camera, a non-contact thermometer and a visible light spectrometer. We found that chlorophyll-based extremophiles were very easily distinguished by the multispectral camera, returning strong signatures of vegetation, even when the microbial life form was embedded within rocky material or sinter deposits. We also obtained useful data on operating robots in such extreme environments. Lessons learned from this investigation will then be used to inform and educate decision makers in future robotic missions.

A4 Rover Proposal: A Small Planetary Science Rover for Geologic and Astrobiology Investigations for Mars Surface Exploration

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Although mobile Mars missions have ranged in size from 10-900 kg, no nano-rover (2 kg) class vehicle has ever landed on the Red Planet. Such a small vehicle weighs significantly less and uses little volume compared with larger missions, while recent advances in microtechnology would facilitate useful scientific returns. Additionally the small size of a nano rover would make it an ideal secondary payload with its own independent mission in a similar manner to Cubesat missions.

The A4 rover is intended to test and characterise skid-steer mobility and science data collection for a nanorover class vehicle in three Mars analogue environments in Australia and India. The environments will be chosen based on what may be expected on Mars: ice-rich sediment, sands and loose stones. These data will be used to refine mobility and locomotion designs for the A4 Rover and contribute to the design of a space-qualified rover.

The project is aimed at combining the hardware assembly and environment testing capabilities at UNSW Canberra and the Australian Centre of Astrobiology with collaborating the Mars surface exploration group at NASA Ames Research Center, and the NASA Spaceward Bound program participating institutions. Detailed astrobio/geo research objectives are formed in collaboration with these agencies. The research plan aims to assemble two rover prototypes consisting of a terrestrial version and a later version with space qualified components. A research matrix is created to test efficiency and performance of hardware components (instruments, batteries, solar panels, wheels, receiver and transmitters). Physical outcrops are defined and characterized for rover trials in Canberra, MDRS and Ladakh. The planned tests planned are set to answer specific questions towards whether such a rover design is successful against agreed research criteria.

Initial Orbit Determination using Minimal Imagery and Constrained Trajectories

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A number of international agencies maintain catalogues of the man-made resident space objects (RSOs) to anticipate and avoid destructive collisions involving important space assets such as manned missions and active satellites. A primary means for gathering this information is by regularly making direct observations of the tens-of-thousands of currently detectable RSOs. But operational constraints sometimes prevent accurate and timely reacquisition of all known RSOs, which can cause them to become lost to an agency's tracking system. Furthermore, when comprehensive acquisition of new objects does not occur, these objects, in addition to the lost RSOs, result in uncorrelated detections when next observed. Due to the rising number of space-missions and the introduction of newer, more capable space-sensors, the number of uncorrelated targets is at an all-time high. The process of differentiating uncorrelated detections caused by once-acquired now-lost RSOs from newly detected RSOs is a difficult and often labour intensive task. Current methods for overcoming this challenge focus on advancements in orbit propagation and object characterisation to improve prediction accuracy and target identification.

We propose a complementary approach that incorporates increased awareness of error and failed observations into the RSO tracking solution. Our methodology employs a technique called dynamic steering, which enables a sensor to autonomously plan each observation in real time, using a sensor steering solution that is informed by all prior attempts at observing the target. A vital element to this strategy is the incorporation of negative information – such as when an RSO is targeted for observation but it is not observed – to achieve a limited search capability. This capability permits a relaxation of the traditional constraints imposed upon the collation of sensor targeting information. To explore how these relaxed constraints may be exploited, we have investigated the application of this capability to the problem of reacquiring uncorrelated targets, using as few as one or two images.

The practical implementation of a single experimental sensor is described and the results of recent field measurements and

simulations are offered. Using a constrained admissible region (CAR), an appropriate state distribution is generated to initialise dynamic steering. The system is subsequently capable of reacquiring an RSO months after it was briefly observed and in spite of the apparent lack of tracking information. It is believed that such a system will offer a means of enhancing surveillance for Space Situational Awareness (SSA) via a reduction in the number of uncorrelated targets in orbit about the Earth.

The Influence of Jupiter and Mars on Earth's orbital evolution

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In the coming years, it is likely that the first potentially Earth-like planets will be discovered orbiting other stars. Once found, the characterisation of those planets will play a vital role in determining which will be chosen as the first targets for the search for life beyond the solar system. We must thus be able to gauge the relative importance of the various factors proposed to influence potential planetary habitability, in order to best focus that search. One of the plethora of factors to be considered in that process is the climatic variability of the exo-Earths in question. In our solar system, the Earth's long-term climate is driven by several factors, including the modifying influence of life on our atmosphere, and the temporal evolution of solar luminosity. The gravitational influence of the other planets in our solar system adds an extra complication, driving the Milankovitch cycles that are thought to have caused the on-going series of glacial and interglacial periods that have dominated Earth's climate for the past few million years.

Here we present the results of two suites of integrations that together examine the influence that the architecture of our solar system has on the Earth's Milankovitch cycles. We consider separately the influence of the planets Jupiter and Mars, both of whom contribute to the forcing of Earth's orbital evolution on timescales of tens of thousands and hundreds of thousands of years. Our results illustrate how small changes to the architecture of a given planetary system can result in marked changes in the potential habitability of the planets therein, and are an important first step in developing a means by which the nature of climate variability on planets beyond our Solar system can be characterised.

The Structure of the 'Asteroid-belt' Analogue Around HR8799

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The planetary system discovered orbiting the star HR8799 is, in many ways, one of the closest analogues found to date of our own Solar system – albeit both significantly younger and on a larger scale. The system features four giant planets, directly imaged over the past decade, organised in an architecture strikingly similar to that exhibited by our own giant planets. In addition, observations of the HR8799 system at infrared wavelengths have revealed the presence of two debris disks. The first, exterior to the orbit of HR8799 b (the outermost planet in the system), is analogous to the Solar system's Edgeworth-Kuiper belt, and was directly imaged by the Spitzer Space Telescope. The second debris disk lies interior to the orbit of HR8799 e (the innermost planet found to date), and is analogous to the Solar system's asteroid belt.

Whilst the extent of HR8799 outer debris disk has been relatively constrained by the direct images obtained by the Herschel and Spitzer Space Telescopes, the innermost disk is known purely as a result of the excess radiation observed at infrared wavelengths from HR8799 itself. Since the disk is far closer to its host star, it cannot yet be directly resolved, and we must instead rely on indirect methods to determine its structure and radial extent.

Here we present the results of a detailed dynamical investigation of the HR8799's inner debris disk. We have followed the dynamical evolution of a million massless test particles, distributed interior to the orbit of HR8799 e, which has allowed us to map the likely extent and structure of this Asteroid belt analogue. As is the case in our Solar system, we find that the disk likely exhibits a large amount of internal structure – extra-solar "Kirkwood Gaps". Our results further reveal that objects in the theoretical 'habitable zone' of HR8799 would be dynamically stable on timescales comparable to the system's age, leaving open the possibility that the system may one day be found to be an even better analogue for our own Solar system than is currently thought!

The Kilodegree Extremely Little Telescope (KELT): Searching for Transiting Exoplanets in the Northern and Southern Sky

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The Kilodegree Extremely Little Telescope (KELT) is a ground-based program designed to search for transiting exoplanets orbiting relatively bright stars. To achieve this, the KELT Science Team operates two planet search facilities: KELT-North, at Winer Observatory, Arizona; and KELT-South, at the South African Astronomical Observatory. The telescopes used at these observatories have particularly wide fields of view, allowing the KELT surveys to study the largest possible number of potential exoplanet host stars.

The great benefit of targeting bright stars with an exoplanet transit survey is that any planets found can then be followed up using other astronomical facilities, allowing their accurate characterisation. This typically involves two steps. The first is confirmation follow-up, where the existence of a planet is verified using other facilities, and typically takes place before the existence of the planet is widely publicised.

Once this is achieved, the true benefit of the host star being bright comes into play – with a bright host, a plethora of additional characterisation observations are possible. These enable us to study the physical nature of the planet in more detail, as well as helping us to better understand its orbit and past history.

To this end, the KELT Science Team are working with a large number of other ground-based facilities, including the Mt. Kent Observatory at the University of Southern Queensland, to achieve rapid follow-up of any candidate planets. This widely distributed approach is already yielding great results, with several planet discoveries already published and confirmed.

In this poster we present a broad overview of the KELT survey and follow-up work, and highlight some of the most exciting results obtained to date. KELT is a shining example of the value of international collaboration for the rapid detection and dissemination of exoplanet discovery results.

2001 QR322 – an update on Neptune’s first unstable Trojan companion

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The Neptune Trojans are the most recent addition to the panoply of Solar system body populations. The orbit of the first discovered member, 2001 QR322, was investigated shortly after its discovery, based on early observations of the object, and it was found to be dynamically stable on timescales comparable to the age of the Solar system.

As more observations accrued of the object, the best orbital solution available changed, and in 2010 we examined the dynamical stability of the new orbit for the object. In that work, we found that 2001 QR322 lay on the boundary between a highly dynamically stable part of Neptune’s Trojan cloud, and a much less stable region. Overall, we found that our population of ‘clones’ of 2001 QR322 decayed over time, with a dynamical half-life of ~ 553 Myr. Our study highlighted the need for further observations of the object to be carried to refine its orbit, in order to attempt to disentangle the truth of its dynamical stability.

Here we provide an update, five years on from our initial study. We have carried out fresh dynamical simulations of the evolution of a swarm of 351,135 test particles, centered on a new best-fit solution for the objects orbit. The swarm of clones was spread across a range of orbital element space spanning $\pm 3\sigma$ around the best-fit solution, and represents a twenty-fold increase on the number of test particles considered in our earlier work.

Despite the improved precision with which the orbit of 2001 QR322 is now known as a result of an increased observational arc, our results remain the same. The object is still tentatively balanced on the brink between areas of dramatically different orbital stability – and it seems likely that significant further observations will be required in order to fully disentangle its true nature.

Despite the continued uncertainty on the true instability of this object, our results reinforce our earlier conclusions that the

Neptune Trojans likely represent a parent population for the Solar System's Centaurs. These objects, in turn, are well established as being the proximate parent population of the Jupiter-family comets, the source of a significant component of the Earth's ongoing impact flux. As a result, the Neptune Trojans may well have contributed to the Earth's past impact history, playing a role in both the hydration of our planet and occasional collisional mass extinctions.

Australian Space Eye: Ultra-faint astronomical imaging from a CubeSat

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The Australian Space Eye is a proposed astronomical space telescope based on a 6U CubeSat platform. The aims of the project are to demonstrate Australian capability to execute CubeSat missions, develop the specific capabilities required for astronomical research with CubeSats (e.g. high pointing stability), demonstrate the low surface brightness imaging performance of a small space telescope and exploit that performance to undertake measurements of the extra-galactic background light anisotropies and image low surface brightness structures around nearby galaxies. The satellite will be based on the Tyvak Endeavour CubeSat platform with a 90 mm aperture low surface brightness optimised refracting telescope as payload. The baseline payload design will enable deep broadband imaging in the astronomical i and z bands (approximately 700 to 1050 nm) with a field of view of 1.67 x 1.25 degrees and spatial sampling of 3 arcseconds per pixel. The main technical challenge for astronomical research from CubeSats is achieving the instrument pointing stability required to enable the long exposures needed for faint targets. We plan to combine low jitter reaction wheels with precision star tracking in the telescope focal plane and piezo-electric image sensor shift image stabilisation. A consortium of 9 Australian universities, the Australian Astronomical Observatory, Cal Poly and Tyvak are

currently seeking funding for the project through the ARC LIEF grant scheme with a decision expected in November 2015. If funded we plan to launch in 2018 for a nominally 2 year mission.

Deploy Your Own Desert Fireball Network Observatory

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The Desert Fireball Network (DFN) currently consists of 32 stations located in The Australian Outback covering over one million square kilometres deployed in less than two years. This rapid deployment was enabled by the small and cost effective fireball observatory presented at the Australian Space Research Conference in 2014. We have designed an even smaller and more inexpensive fireball observatory that other researchers and interested amateurs can easily deploy in a couple of hours in order to become part of the DFN or to deploy their own partner network.

The new observatory still contains a full-frame DSLR, all-sky lens, embedded PC, hard drive, and GPS synchronised LC shutter for fireball timing but is designed for mains powered sites that can be attended more regularly (twice per year). The cost of the observatory, minus the camera, is comparable to an entry level full-frame DSLR, and it can be installed by one or two people in a couple of hours.

We are constructing 50 of the new low cost observatories to be distributed to domestic and international collaborators. We will present a brief overview of the new systems, details on the techniques enabling further size and cost reductions and information for prospective collaborators.

Preliminary Design of an Asteroid Flyby Mission using CubeSat Technology

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The first step involved in asteroid mining is to prospect target asteroids so as to determine their composition and value. This paper examines the preliminary design of a low cost asteroid prospecting mission constructed using CubeSat parts. This probe will piggyback onto a geostationary transfer orbit (GTO) launch and thereafter conduct a flyby of an asteroid passing through the Earth-Moon system. During the flyby, the probe will make observations of the asteroid using visual and spectroscopic instruments and beam back data afterwards. Aspects of the probe's design are examined, particularly trajectory design, payload design and communications system design. A greater understanding of the challenges facing use of CubeSat technology for space exploration is thus achieved.

Hayabusa Mission Update

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The Hayabusa Mission of Japan Aerospace Exploration Agency (JAXA) returned particles from asteroid 25143 Itokawa to Earth in June 2010 (see Okada et al. 2014; Earth Planets Space Vol. 67). As of 2015, some 1500 particles have been documented and characterised. Sizes range down from ca. 400 μm . Many of the particles are silicate-dominated and are entirely consistent with their derivation from a chondrite body with dominant minerals olivine, pyroxene, plagioclase and troilite (FeS). Oxygen isotope compositions are also coincident with LL chondrite (Yurimoto et al. 2011; Science 333, 1116). Noble gas isotopic compositions indicate that asteroid Itokawa is very young, less than 8 Myr, based on the abundance of the cosmogenic isotope ^{21}Ne (Nagao et al. 2011; Science 333, 1128). The Hayabusa sample recovery has potentially benefitted from taking an accidental surface sample because it is this material that is not represented in meteorites.

Riding on the success of Hayabusa to asteroid Itokawa, JAXA proposed Hayabusa II to go to a C-type asteroid, (162173) 1999JU3. The rapid turnaround meant that most of the technology associated with Hayabusa was incorporated into Hayabusa II. However some new technology is included as well. A semiautonomous lander called MASCOT includes infrared and visible spectrometers, magnetometer, radiometer, and a viewing system capable of microscopic observation. A Small Carry-on Impactor will cause an impact crater that will then be sampled by Hayabusa II; during detonation Hayabusa II will retreat to the backside of the asteroid. Hayabusa II also includes Minerva remote observation landers that will be deployed during touchdown or touchdown rehearsals. Hayabusa II will be capable of a maximum of three sampling touchdowns, although this could be affected by the MASCOT and Minerva drop offs. Hayabusa II lifted off in December 2014 with an expected arrival in July 2018.

Analysis of daily variations from simultaneous Swarm constellation magnetic data and Intermagnet data

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The European Space Agency (ESA) Swarm constellation currently in orbit consists of three low-Earth orbit satellites: Swarm A and Swarm B at 460 km altitude, with orbital inclination 87.4 degrees; and Swarm C at 539 km with orbital inclination 88.0 degrees.

The system includes electric field instruments as well as vector magnetometers and scalar total intensity measurements.

Our interest is the modeling and analysis of the daily variations of the magnetic field above and below the ionosphere using vector and scalar magnetic data from the Swarm satellites combined with ground-based data from the Intermagnet network of magnetic observatories throughout the world.

In both satellite and surface magnetic data we will determine the daily variation fields of internal and external origin . Magnetic field variations above the ionosphere will be modeled to include any non-potential fields, possibly field-aligned currents between the Sq daily variation current system foci.

Perspective on current US SSA research

Moriba Jah

Air Force Research Laboratory, USA & UNSW Canberra

Dr. Moriba Jah is the lead for the Air Force Research Laboratory's (AFRL) Advanced Sciences and Technology Research Institute for Astronautics (ASTRIA) and Mission Lead for Space Situational Awareness at AFRL's Space Vehicles Directorate. He received his B.S. in Aerospace Engineering from Embry-Riddle Aeronautical University, Prescott, Arizona, and his M.S. and Ph.D. in Aerospace Engineering Sciences from the University of Colorado at Boulder specializing in astrodynamics and statistical orbit determination.

Before joining AFRL in 2007, he was a spacecraft navigator for NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, serving on Mars Global Surveyor, Mars Odyssey, Mars Express (joint mission with ESA), Mars Exploration Rovers, Hayabusa (joint mission with JAXA), and the Mars Reconnaissance Orbiter. Dr. Jah is the Chair of the American Astronautical Society's (AAS) Space Surveillance Technical Committee and Chair-Elect of the AIAA Astrodynamics Technical Committee. He is a member of the Astrodynamics Technical Committee of the International Astronautical Federation (IAF) and a permanent member of the Space Debris Technical Committee of the International Academy of Astronautics (IAA). Dr. Jah is a Fellow of AAS and the Royal Astronomical Society (RAS), as well as an AIAA Associate Fellow, IEEE Senior Member, Associate Editor of the IEEE Transactions on Aerospace and Electronics Systems, IEEE Aerospace and Electronic Systems Magazine, and Elsevier Information Fusion Journal.

Dr. Jah is a world-recognized subject matter expert in astrodynamics-based Space Situational Awareness sciences and technologies.

Aerodynamics and Control Optimal Design for Hypersonic Vehicles

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Recent progress in hypersonics flight (HiFIRE, NASA Hyper-X, HyShot) has renewed the possibility of controlled flight at speed greater than Mach 5. Nevertheless the design and demonstration of hypersonic flight vehicles that can follow a prescribed trajectory is in its infancy. To achieve both efficient and controlled flight a close integration of the aerodynamic design, which yields performance efficiency, actuator design to give control authority, and control system design is required.

This paper outlines a multi-disciplinary methodology to deliver an efficient and controllable hypersonic flight vehicle. It consists of aerodynamics experiments to characterise unsteady aerodynamics and fluid-control interactions, numerical research to inform vehicle and actuator aerodynamics, and optimal control system design.

Preliminary results, including data from experimental tests characterising dynamic interactions between hypersonic flow and an actuator representative geometry will be presented.

The Thermophysical Properties of Impact Crater Ejecta and Floor Materials on Mars

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Impact cratering is a fundamental geologic process throughout the solar system. Over 350,000 impact craters have been mapped on the surface of Mars, making them one of the dominant surface morphologies on the planet. Craters offer unique opportunities to study the composition of the Martian subsurface, because they expose hidden lithologies and provide accessible samples of subsurface materials through their ejecta. Furthermore, the mechanics of impact produces heat, enabling the generation and release of liquid water, driving hydrothermal circulation, directing liquid flows through the fracturing of target rocks, and thus affecting the formation of new habitable environments. We analyse the thermophysical properties of ~5000 Martian impact craters larger than 30 km in diameter, using a global map of surface materials at the ~3 km scale. We report and analyse the range of grain-size of materials in the ejecta, floors and central peaks and pits of the studied craters, and interpret their spatial distribution. The results of our study lead to further understanding of subsurface material variations and their volatile content throughout Martian history. More generally, this study constrains the shallow subsurface habitability associated with impacts.

Shallow transient liquid water on Mars and its implications for life: Lessons from the Phoenix Lander and Curiosity Rover

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The surface of Mars today is predominately cold and dry. Average temperatures are typically below zero degrees Celsius, and partial pressures of water vapour are generally 1/3000th those at sea-level on Earth. Hence any liquid water exposed to the atmosphere will vaporise or freeze on timescales of hours to days. These conditions have likely persisted for much of the last 10 million years while Mars had low obliquity ($< 30^\circ$) similar to its current state, and perhaps longer. Despite this, the shallow subsurface regolith of Mars may not be completely inhospitable to life. Given our current state of knowledge of life on Earth, three pre-requisites are necessary for an environment to be 'habitable' and therefore capable of supporting terrestrial-like life: energy, biogenic elements, and liquid water. Using evidence from the Phoenix Lander (2008) and the Mars Science Laboratory (2012-current), the occurrence of these three factors and habitable conditions in the shallow Martian regolith will be discussed.

Enhanced performance low resource in-situ sensors for space missions

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The Mullard Space Science Laboratory (MSSL) has strong heritage with plasma instrumentation delivering capable instruments for a range of missions including for magnetospheric missions (Cluster, Double Star), planetary environments (Cassini, Mars 96) and cometary studies (Giotto). These activities are backed up with a strong instrument development programme and state of the art test and calibration facilities. A particular focus of the current development activities is instrument miniaturisation using novel instrument geometries and micro-fabrication techniques. A brief description of the sensors follows.

Building on the laboratory's heritage with top-hat type analysers, the Improved Plasma Analyser (IPA) has been developed with the addition of an electrostatic deflector plate system to scan the field of view to cover $\pm 45^\circ$ and a variable geometric factor system to vary the instrument geometric factor by up to an order of magnitude, providing significantly enhanced performance over conventional top-hat systems. The analyser provides the baseline design for the Electron Analyser System (EAS) of the Solar Wind Analyser (SWA) package on Solar Orbiter, currently scheduled to be launched in October 2018.

To realise highly integrated and miniaturised sensor systems, a number of analyser geometries and fabrication techniques are being studied. Based on results from these, the Charged Particle Spectrometer (ChaPS), has been developed and launched on the UK's TechDemoSat mission. ChaPS provides an in-flight demonstration of a novel analyser geometry combining low energy electron and ion analyser. The instrument design is tailored for a number of different goals, measurement of electrons in the Earth's auroral regions, cold ($< 60\text{eV}$) ions in low Earth orbit and spacecraft charging, with sensor performance and operational modes optimised for each of the goals.

The Hot Plasma Environment Monitor (HoPE-M) is a low resource particle detection system being developed under ESA contract for satellites in Geostationary Orbits. HoPE-M will combine an electrostatic analyser with an energetic particle detection system to provide in-situ measurements of the low to medium energy plasma for space weather monitoring. The electrostatic analyser is

a combined electron-ion analyser based on ChaPS and is designed to measure their energy distribution functions. A breadboard system is currently being tested and the complete instrument to include the detector and the sensor electronics is estimated to weigh less than 650 gms and draw 1 W.

This paper will present an overview of the development programme, details of some of the missions and the corresponding sensors under development for them, the current status of the developments and a roadmap of the programme vision. Preliminary in-flight results from ChaPS will also be presented and discussed.

Nanosatellites for in-situ studies of the Earth's ionosphere and thermosphere – exploiting the QB50 mission opportunity for Space Weather science

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With the rapid development of miniaturised platform and payload technologies, nano-satellites, in particular in the CubeSat form factor, provide an attractive low cost platform for in-situ monitoring of the Earth's upper atmosphere. Funded under the space call of the European Union's 7th Framework Programme, the QB50 mission will launch up to 50 CubeSats to an altitude of ~ 380 km and the satellites will then be allowed to undergo a decaying orbit until they burn up at around 90km. Sensors have been chosen to make in-situ measurements of plasma and neutral atmosphere parameters in this altitude region where few measurements have been made before. This paper will present a brief overview of the QB50 mission and the sensors that are being developed and discuss the opportunity that the mission presents for space weather science.

The Ion and Neutral Mass Spectrometer (INMS), one of the three sensors forming the Science Unit on the QB50 mission - the other two being the multi-Needle Langmuir Probe and the Flux Probe Experiment - combines the cold ion detection capabilities of electrostatic analyzers with a novel ionizer to deliver neutral particle detection capability. The sensor geometry has been designed to address the QB50 science requirements, sampling low mass ionised and neutral particles in the spacecraft ram direction with the instrument resolutions optimised for resolving the major constituents in the lower thermosphere. Performance characteristics of the INMS, both from simulations and from preliminary results of laboratory characterisation tests, will be presented. A prototype-flight model of the sensor has been launched on a precursor flight and is currently undergoing commissioning. The status of the flight instrument will be discussed

Carrington-L5: The Next Generation Space Weather Operational Mission

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Airbus Defence and Space have carried out a study to investigate the possibilities for an operational L5 space weather mission, in collaboration with RAL, the UK Met Office, UCL and Imperial College London. The study looked at the user requirements for an operational mission, a model instrument payload, and a mission/spacecraft concept. A particular focus is cost effectiveness and timeliness of the data, suitable for operational forecasting needs. The study focussed on a mission at L5, assuming that a US mission to L1 will already occur, on the basis that L5 offers the greatest benefit for SWE predictions. The baseline payload has been selected to address all MOSWOC/SWPC priorities using UK/US instruments, consisting of: a heliospheric imager, coronagraph, EUV imager, magnetograph, magnetometer, solar wind analyser and radiation monitor. The platform is based on extensive re-use from Airbus' past missions to minimize the cost and a Falcon-9 launcher has been selected on the same basis. A schedule analysis shows that the earliest launch could occur in 2020, assuming Phase A KO in 2015. The study team have selected the name "Carrington" for the mission, reflecting the UK's proud history in this domain.

Observations of H₃⁺ Molecular Emissions in Jupiter's Aurora

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In the powerful magnetosphere of Jupiter, energetic solar wind particles collide with the constituents of the planetary atmosphere. This generates an auroral display in the upper regions of the atmosphere due to collisional excitation of hydrogen species. In addition, interactions involving Jupiter's magnetosphere and its moons, Io and Ganymede, also contribute ionised particles. These move in a magnetised plasma around the planet, creating visible spots of aurora emission called 'footprints'.

We will give an overview of observed auroral emission features arising from H₃⁺, the simplest triatomic molecule first detected in infrared spectra by Trafton et al. in 1989. We will present our observations as near-infrared, high (R~18000) and medium (R~4000) resolution spectra of Jupiter's polar regions, produced with the GNRIS instrument at the North Gemini telescope. In these, we identified 18 emission lines related to the H₃⁺ molecule, corresponding to a 2v₂ overtone band. We will show how these observations are used to measure the temperature and column density of H₃⁺ particles in the northern and southern aurora. Finally we will discuss how these measurements help us understand physical conditions in the upper atmosphere of the planet.

U-Pb dating of the oldest known planetary meteorite: The achondrite Asuka 881394.

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Determining how our Solar System formed is an important step towards understanding our origins. Key to this is sequencing the events which transformed a cloud of interstellar gas into the Solar System we see today. Currently, the U-Pb system is the only absolute isotopic chronometer able to produce the resolution needed for high precision dating of the early Solar System. Additionally, only well preserved and ancient achondrites provide the material which records early planetary formation processes.

Asuka 881394 is a unique basaltic achondrite composed of mostly calcic plagioclase and pyroxene. Differences in Mn-Cr systematics, stable Cr isotopic anomalies and oxygen isotope data indicate Asuka 881394 was formed on a separate body to all other achondrites. The current reported Pb-Pb age for Asuka 881394 (4566.51 ± 0.21 Ma) makes it the oldest achondrite studied so far. However there is a ~ 1 Ma age discrepancy between the Pb-Pb age and the age recorded by other chronometer systems (Al-Mg, Mn-Cr). Here we re-examine the U-Pb systematics of Asuka 881394 using an approach designed to evaluate the uncertainties and better understand the age discrepancies.

Analysis was conducted on five mineral fractions (two plagioclase, one pyroxene, one tridymite (silica) and one whole rock, with each undergoing five acid leaching steps before complete dissolution. A Pb-Pb isochron using both data from the old study and our new more precise data yields an age of 4566.75 ± 0.31 Ma, MSWD = 2.6. This new age is ~ 0.25 Ma older than the previously determined Pb-Pb age, confirming that Asuka 881394 is the oldest known achondrite, and that the discrepancies between the time intervals measured with different isotopic chronometers are caused by natural processes rather than analytical artifacts.

Large size space construction for space exploitation

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Space exploitation is impossible without large space structures. We need to make sufficient large volume of pressurized protecting frames for crew, passengers, space processing equipment, & etc. We have to be unlimited in space.

Now the size and mass of space constructions are limited by possibility of a launch vehicle. It limits our future in exploitation of space by humans and in development of space industry.

Large-size space construction can be made with using of the curing technology of the fibers-filled composites and a reactionable matrix applied directly in free space. For curing the fabric impregnated with a liquid matrix (prepreg) is prepared in terrestrial conditions and shipped in a container to orbit. In due time the prepreg is unfolded by inflating. After polymerization reaction, the durable construction can be fitted out with air, apparatus and life support systems.

Our experimental studies of the curing processes in the simulated free space environment showed that the curing of composite in free space is possible. The large-size space construction can be developed.

A project of space station, Moon base, Mars base, mining station, interplanet space ship, telecommunication station, space observatory, space factory, antenna dish, radiation shield, solar sail is proposed and overviewed.

The study was supported by Humboldt Foundation, ESA (contract 17083/03/NL/SFe), NASA program of the stratospheric balloons and RFBR grants (05-08-18277, 12-08-00970 and 14-08-96011).

Options for Australian Payloads and Cubesats with NASA

Dr Ed Kruzins

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Communication Complex*

The National Astronautics and Space Administration's (NASA) robotic exploration of the Earth and Solar System has an enviable track record. Most recently NASA has strongly engaged with the technology and adaptability of cubesats as augmentations, companions and standalone missions in its suite of space activities. This has driven changes in the way NASA could approach its exploration program and how it will support them through its network of ground stations. NASA-JPL's Deep Space Network (DSN) for example will seek to adapt to the coming age of cubesat activities and to consider the challenges that tracking cubesats side by side with large robotic missions, may have. At the same time Australia has shown an increased vigour to embrace cubesat technology and through this perhaps springboard into payloads that could one day fly on board large NASA robotic missions. While the invitations have come from NASA to partner in future Solar System exploration, Australia is yet to find its niche and resources within these opportunities. This presentation will discuss opportunities that Australian Institutions might have with NASA and how the age of cubesats might shape options.

The interaction between the Earth's magnetic field and the spinning satellites

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The geodetic satellites are designed as spherical, fully passive objects and are launched with an initial spin, which helps to stabilize attitude of the spacecraft. The spin dynamics of the metallic satellites is changing under the influence of the forces and torques caused by the Earth's gravitational and magnetic fields, and the solar irradiation. The eddy currents, generated by the external magnetic field in the spinning metallic body, are the main reason for the exponential loss of the spacecraft's rotational energy.

We have analyzed the Satellite Laser Ranging data of the spacecrafts placed on different altitudes: Ajisai, Etalon-1, Etalon-2, LAGEOS-1, LAGEOS-2, LARES, Larets, Stella, and obtained their spin rates history. The spin trends indicate that the de-spin process depends on the altitude of a satellite (strength of the Earth's magnetic field). The spin period of the Low Earth Orbiting satellites doubles every 38.3 days (Larets) and 166.8 days (Stella), while the higher satellites present 2.2 years (LAGEOS-1) and 1.6 years (LAGEOS-2). The High Earth Orbiting satellites show very slow decrease of the rotational energy - it takes 167.8 years for the spin period of Etalon-1 to double, and 72 years for Etalon-2. Ajisai and LARES are placed on a similar altitude (close to 1500 km), but lose rotational energy with much different rates due to their specific magnetic properties. Applying the theoretical model to the observed spin trends allowed finding the inertial orientation (and its change over time) of the geodetic satellites.

The knowledge about the spin parameters of the geodetic satellites allows for the investigation and improvement of the physical models of the perturbing forces and torques which are of magnetic, gravitational and non-gravitational nature. Knowing the spacecraft 's inertial attitude can help to model the non-gravitational perturbations of its orbital motion and obtain more accurate orbital solution.

On the prediction of foF2 using 10.7 cm solar flux and Kp index

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High Frequency (HF) radio communication systems are widely used by defence and emergency services because they are robust against natural and manmade disasters. Compact, mobile digital HF transceivers with Internet Protocol (IP) capability have come to the market. For many years, the Space Weather Service (formerly the Ionospheric Prediction Service) has predicted Best Useable Frequencies (BUFs) using the ionospheric T index. The T index is an effective sunspot number estimated by linearizing the relationship between sunspot number and the critical frequency of the F2 layer of the ionosphere (foF2), independently for every location on the Earth. The foF2 parameter depends on the solar and geomagnetic activity, season, time of day and location. Predicting the effects of geomagnetic activity on foF2 is especially challenging. This study investigates the prediction of foF2 using the 10.7 cm solar flux and Kp index, rather than the T index. This study uses foF2 observations from a global network of over 160 ionosondes that operated between 1960 and 2014. This is a larger database than used originally to estimate foF2 maps for T=0 and 100. We will compare the prediction of foF2 using the 10.7 cm solar flux and Kp index with predictions made using the IRI model and the established T index prediction system. This foundation study is part of our ongoing effort to improve the accuracy of the BUF prediction system.

Development and Testing Platform for the UNSW ECO Cubesat

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Australian Centre for Space Engineering Research, UNSW Australia

UNSW-ECO is a double cubesat developed at the Australian Centre for Space Engineering Research (ACSER) at UNSW as part of the European funded QB50 project. The program is due to launch 50 satellites into low Earth orbit at the end of 2016 to perform atmospheric, technology development and fundamental science experiments.

The UNSW team developing the satellite is large, academically diverse and distributed over several sites, currently comprising 9 undergraduate students, 5

postgrads, 3 researchers and 7 academics. The nature of such a team poses a challenge when collaboratively developing on a single hardware model for software development and testing on the Onboard Computer (OBC) and core systems. The development environment for UNSW-ECO caters for these requirements by selectively exposing the required software interfaces to allow seamless handovers between developers without stressing fragile connection points on the hardware and to also allow for development to be done remotely. A custom interface box was also developed to facilitate charging, external powering, debugging and switching (e.g. RBF pins). The OBC software architecture is modular to minimise the impacts of any one module on others. A distributed version control system, is adopted to manage collaborative changes to the source code. This system blends well with the Agile software development methodology which is implemented via the adoption of Atlassian tools. This paper will comment on the effectiveness of this approach, lessons learned and suggestions for future university based satellite developments.

Progress in Passive Optical Tracking Using the Falcon Telescope Network

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The Falcon Telescope Network (FTN) uses optical telescopes to observe resident space objects (RSO) under passive illumination. One node of the network resides at UNSW Canberra, and has for the past year been tracking RSO for the purposes of tomographically reconstructing large RSO such as the ISS from multiple observations, and tracking CubeSat sized objects in LEO to refine techniques in support of proposed Australian orbital missions. Together with spectral classification of RSO using astrometry and photometry, and STEM outreach, these activities have been directing the operation of the FTN. We detail progress in these areas, and future directions of the FTN that will impact Australian endeavours.

Animals in Australian Aboriginal Astronomical Traditions

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Ethnographic records of Aboriginal astronomical traditions suggest a tangible link between animal behaviour and the positions of their celestial counterparts in the sky, particularly at dusk and dawn. For example, the acronychal rising of the celestial emu in the autumn, traced out by the dark spaces in the Milky Way from Crux to Sagittarius, informs the Kamilaroi Aboriginal people of New South Wales when emus are laying their eggs, which is an important food source. In Dharawal traditions of Sydney, the annual northerly migrations of the orca correspond to the heliacal rising of the Pleiades, with the return journey south from their breeding grounds matching closely to its acronychal setting. Similar examples abound. Many early records of Aboriginal astronomical knowledge are incomplete. This project develops a quantitative methodology to estimate the connection between stellar positions and the behaviour of their terrestrial animal counterparts. We use the Aboriginal astronomical traditions of the Great Victoria Desert region of South Australia as a test case. This will be the basis for a much larger study across many other Aboriginal language groups in the near future.

Mapping magnetic field lines between the Sun and Earth

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An approach is developed for mapping large-scale magnetic field lines between the Sun and Earth near the solar equatorial plane, using near-Earth observations and a solar wind model with nonzero azimuthal magnetic field at the source surface. Unlike Parker's solar wind model, which is intrinsically limited to $\phi_B = (90^\circ\text{--}180^\circ, 270^\circ\text{--}360^\circ)$ and so unable to predict field configurations for other ϕ_B values frequently observed in the solar wind, our approach can account for all the observed ϕ_B values, where ϕ_B is the in-ecliptic angle for the magnetic field in Geocentric Solar Ecliptic coordinates. Predicted maps show that near both minimal and maximal solar activity the field lines are typically open, and that loops with both ends either connected to or disconnected from the Sun are relatively rare. The open field lines, nonetheless, often do not closely follow the Parker spiral, being less or more tightly wound or strongly azimuthally or radially oriented, or having inversions. The time-varying classes (e.g., bidirectional electrons) of suprathermal electron pitch angle distributions at 1 AU are predicted from the configurations of mapped field lines and compared with Wind observations for two solar rotations, one each near solar minimum and solar maximum. Predictions by our approach are shown to agree quantitatively ($\sim 90\%$) with the observations and to outperform (by $\sim 20\%$) the predictions by Parker's model. The magnetic mapping developed here should be important for understanding the connectivity to Earth of suprathermal particles of solar origin, e.g., solar energetic particles and beam electrons in type III solar radio bursts.

Australian Participation in the Biarri Cubesat Missions

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Biarri is a collaborative cubesat mission involving Defence R&D agencies from the United States, United Kingdom, Canada, Australia and New Zealand. A risk mitigation mission will launch in 2016 involving a single cubesat, and the main mission will likely launch in 2017 and will involve a formation of three cubesats. Australia has contributed the Namuru GPS unit to be part of the payload for the Biarri cubesats. Namuru was developed by the Australian Centre for Space Engineering Research (ACSER) at the University of NSW and General Dynamics Corporation (New Zealand). In addition, Australia is contributing a ground station being developed by Defence at Edinburgh (South Australia) to support Biarri. The various nations involved in the collaborative mission have proposed experiments for the cubesats. This presentation will focus on experiments proposed by Australia, specifically Defence Science and Technology (DST) in the Department of Defence, ACSER and University of NSW Canberra. These experiments will validate the performance of the Namuru GPS units on-orbit and demonstrate novel applications for Namuru, involve a differential drag experiment to learn more about the drag and lift forces on the Biarri cubesats, and employ the Biarri cubesats as test targets for Australia's ground-based systems for tracking space objects.

Damage Detection for 25 April 2015 Nepal Earthquake with Satellite Synthetic Aperture Radar Intensity and Coherence results

Qingxiang Liu, Linlin Ge, Chun Tung Chou and Xiaojiang Li

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The 25 April 2015 Nepal Earthquake has brought heavy human crisis for the local people, including large numbers of fatalities and a great amount of financial loss. For the quick response of the natural disasters including earthquake, satellite Synthetic Aperture Radar (SAR) as a remote sensing technique has the ability of acquiring usable data independent of the cloudy weather and daylight and has been proved to be useful in damage response in many cases such as the 12 May 2008 Ms8.0 Wenchuan Earthquake. In this paper, three original Advanced Land Observing Satellite - 2 (ALOS-2) PALSAR images with the same frame, path and looking angle are used, two of which were acquired before the earthquake on 4 October 2014 and 21 February 2015 respectively and one after the earthquake on 2 May 2015. The intensity difference result and coherence result are generated with different processing and optimisation methods to detect the damages over Kathmandu city area. Results of the coherence method and intensity difference method will be analysed and compared. Besides, the preliminary verification of the results are conducted by the comparison of high-resolution Worldview-2 and Worldview-3 images before and after the earthquake. It proves that both methods are useful while they have their own advantages and disadvantages; a combination of both results can be more reliable to identify damaged cities over the urban area.

Searching for the (hydrocarbon) skeleton key: Using biomarkers to find evidence of the first animals

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Australian National University

The mid-Neoproterozoic Era (800 – 700 Ma) was a markedly active time in Earth's history, with the occurrence of globally synchronous glaciations, significant tectonic activity and major leaps in the evolution of complex cellular life. Predictions from molecular clocks indicate that the radiation of animals occurred around 700 Ma. Very little is known, however, about the precise evolutionary state and biodiversity of complex cellular life or the environmental conditions preceding this dramatic diversification. Molecular fossils (or biomarkers) are hydrocarbon skeletons derived from bio-organic molecules produced by organisms during their lifetime. Biomarkers preserve critical biological, ecological and environmental information, which can be used to clarify the complex interplay between climatic, tectonic and biological processes occurring in the Neoproterozoic Era.

Two samples from the Chuar Group (aged 800-742 Ma) that were analysed for biomarkers revealed an unusual distribution of biomarkers (Summons et al. 1988), but it is still unclear whether the signal was the result of a local ecosystem or a representation of the global eukaryotic diversity. We have acquired uncharacterised rock samples from the Visingsö Group in Sweden, which are similar in age but from a distant paleo-geographic location to the Chuar Group. The intended outcome of the project is a clean record of the biodiversity of cellular life at one locality, which will contribute to a larger international, collaborative investigation into the global state of diversity of complex, multicellular life. This will lead to the formulation of new research directions into the relationship between the advent of animals and Earth's biogeochemical cycle.

Quasi-thermal noise spectroscopy and dust detection in Earth's ionosphere

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University of Physics

Thermal electrons and ions excite thermal levels of Langmuir and other waves in a plasma, which are sometimes called thermal or quasi-thermal noise (QTN). Measuring the QTN allows the electron density and temperature to be determined, as well as other plasma quantities. This technique has been used to measure the plasma properties of the solar wind and various planetary magnetospheres.

We propose using QTN spectroscopy on a cubesat in Earth's ionosphere and inner magnetosphere to measure the plasma properties and improve understanding of space weather and the Earth's space environment. We show how the small size of the craft and antenna are ideal for ionospheric conditions and how measurements via this method allow the possibility of determining the spatiotemporal evolution of the plasma quantities, detecting dust and other space debris, and identifying the effects of space weather. Further, a continuously orbiting craft allows for a continuous stream of data points around the Earth. This data is therefore much more frequent and covers a much greater range than any other methods currently used to measure the ionosphere. This could lead to improved ionospheric models, especially empirically based models such as the International Reference Ionosphere (IRI).

The Advanced Instrumentation and Technology Centre (AITC): A National Facility Supporting Astronomy and Space Activities in Australia

Naomi Mathers

AITC, ANU

The Advanced Instrumentation and Technology Centre (AITC) was established as a national facility to support the development of the next generation of instruments for astronomy and space science. The specialist environments, advanced processes, precision manufacturing, and rigorous test requirements, which are essential to meet the needs of the astronomical community, also make the AITC a world-class facility for the assembly, integration and test of space-based instruments and small satellites.

The impact of such a facility is already being demonstrated. Since it was established in 2006, the AITC has enabled projects to the value of \$117.8 million including export contracts to the value of \$18.4 million. This includes supporting the design of instruments for the Giant Magellan Telescope, partnering with research organisations in Australia and overseas to build instruments for major observatories, collaborating on five Australian Research Program projects, partnering with industry on commercial contracts and being a core partner in the Space Environment Research Centre (SERC), which is headquartered at the AITC.

The AITC has already supported the test and evaluation of the Australian Plasma Thruster and tested mechanisms for the GMT Integral Field Spectrometer. The AITC is currently preparing to test the three Australian QB50 satellites and the DSTO Buccaneer satellite. Looking to the future, the ANU has partnered with six other Australian Universities, the Australian Astronomical Observatory (AAO) and Cal Poly, on a proposal for the Australian Space Eye, a 6U CubeSat to conduct ultra-faint astronomy imaging from space. This presentation will provide an overview of the AITC's activities and explore how this facility is an enabler for astronomy, space and geospatial activities in Australia.

Geodynamics of Venusian-type planets

Samuel Matthews

Craig O'Neill

Macquarie University

CCFS (Core to Crust Fluid Systems)

Knowledge of the Venusian interior with regards to subsurface layering, mantle dynamics and physical properties is somewhat limited. It has been suggested that the coupling between the lithosphere and the mantle on Venus is different to that of Earth, based on admittance values. Spherical harmonic studies of both the Earth and Venus with regards to the topography, gravity and geoid were performed using SHTOOLS. Very strong admittance values are observed at low spherical harmonic degrees on Venus, contrasting to the corresponding admittance values for Earth. The absence of a low viscosity zone (asthenosphere) beneath the lithosphere on Venus is drawn from these results. This knowledge was carried into numerical simulations performed with CitcomS where variations of viscosity, Rayleigh Number and internal heating were modelled until the desired parameters were determined. A rather viscous mantle with a relatively low Rayleigh Number and slightly raised internal heating meets the desired parameters regarding Venusian lid stress, lid thickness and convective regime. With the determination of these parameters, full global models were performed and the mantle dynamics of Venus were observed. A simulation was performed of a super-Venusian planet with parameters derived in this study. This simulation shows that a planet with these parameters would likely remain in a stagnant-lid regime.

An Update on Defence's SSA Activities

GPCAPT Darren May

Director Defence Space Coordinating Office

The 2009 and 2013 Defence White Papers identified Space Situational Awareness (SSA) as a capability priority, and assured access to space as a national security imperative. Currently, the Australian Defence Force (ADF's) SSA capability is in an embryonic stage with early developments being realised through the acquisition of SSA sensors rather than a holistic SSA capability. Australia has entered into an SSA partnership with the United States (US) and is developing a nascent SSA capability via a US owned and Australian operated C-Band radar and Space Surveillance Telescope. An indigenous SSA capability is also being pursued through an arrangement between Defence and Electro Optics Systems (EOS). However, the acquisition of these SSA sensors, which will all contribute to the US controlled Space Surveillance Network (SSN), presents both an opportunity and a challenge for the ADF. To reduce Australia's reliance upon the US for assured access to space, while also managing our fair share of the international SSA burden, the ADF requires the ability to acquire, process and distribute SSA data in a coordinated, efficient and effective manner that simultaneously caters to the needs of Australian warfighters, civilian satellite operators, and the US Department of Defense (DoD).

The University of Melbourne Space Program - Launching Melbourne into the final frontier

Troy McCann, Prof. Stan Skafidas, Robert Mearns, Anton Tarasenko, Martin Lawrence, *The University of Melbourne*

Currently, communications systems take up a significant proportion of both mass and power budgets in deep space spacecraft, increasing their size, and consequently energy requirements and propulsion system complexity. In the near future, as both space exploration and other space based industries develop, long-range communication will be required. Specialised whole earth orbiting satellite networks for providing communication between Earth and deep space assets will enable better more reliable communication.

The University of Melbourne Space Program is a student run program with the ambitious long-term vision of developing an intra-solar system communications network for both space based industry and scientific research. In order to achieve this, the UMSP is currently prototyping a cubesat based platform.

Unlike larger satellites, cubesats are uniquely suited for our long-term vision; their small size facilitates the rapid and inexpensive prototyping which can then be integrated into earth wide aperture mesh networks.

Mesh networks relaying data between orbiting cubesats, will permit the creation of advanced large aperture receive stations bigger than ambitious projects like the square kilometre array.

Utilising these small satellites, however, introduces many challenges in miniaturising and integrating pointing, power, low integration time, and high-gain dish technologies into such a small form-factor. Although the program is in its infancy, our first cubesat aims to address some of these challenges.

Thermal (mid-) infrared laboratory studies of materials found in meteorites

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and Les Kinsley

Research School of Earth Science, Australian National University

Missions to other planetary bodies are expensive and difficult, but geochemical characterisation of surface planetary materials can be achieved through remote techniques such as thermal (mid-) infrared (IR) spectroscopy. It is commonly assumed that meteorites - fragments of asteroids and other planetary bodies that have been transported to the Earth's surface - are representative of asteroids. Thus, laboratory spectra of meteorites provide a crucial link to asteroids.

To relate the spectral signatures of meteorites to asteroids, we need to measure asteroid-related materials under appropriate conditions. For example, we need laboratory measurements of meteorites at temperatures appropriate for asteroids. We also need measurements of all of the possible materials in asteroids including rock, and components that might be lost in transit such as organic compounds and ices. To investigate these variables, direct spectral measurements are needed at a range of temperatures.

In this study, we measured the mid-IR spectra of meteorites, organic compounds, dry ice (solid CO₂) and mixtures consisting of: meteorite:dry ice, basalt:dry ice, sodium methanesulfonate:dry ice, and meteorite:organic compounds. We chose to examine organic compounds based on those common in the Tagish Lake meteorite, with particular care to avoid those compounds that could be contamination. Both reflectance and transmission spectra of pure organic compounds compare well with literature spectra at room temperature. We are in the process of obtaining reflectance spectra at temperatures as low as -150 °C under vacuum for pure organic materials, Tagish Lake meteorite and the mixtures listed above. Our study will detail the effect of changing temperature on mid-IR spectra of organic compounds, meteorites and mixtures at low temperatures relevant to asteroids.

Ionospheric Research in Defence

Dr Dan Meehan

*Defence Science and Technology, Department of Defence,
Australia*

High-Frequency Radar is a Major Science and Technology Capability (MSTC) for Australia's Department of Defence. This MSTC is managed by High-Frequency Radar Branch within the Defence Science and Technology Group, formerly DSTO. HF propagation aspects are underpinned by knowledge of the ionosphere derived from years of synoptic data collection, computer modelling/simulation, and sophisticated experimentation. Of great importance are the many years of real-world application and use of the results of real-time ionospheric measurements coupled with simulation, especially in relation to Over-The-Horizon Radar (OTHR). Ionospheric research is an important part of the Branch's R&D with the primary goals being to improve the coordinate registration and the frequency management of Australia's OTHRs. Pursuing these goals has benefits for other HF activities such as communications and HF emitter geolocation. This talk will focus on current ionospheric research activities in the Branch.

Developing an Australian GNSS analysis capability for augmented Precise Point Positioning.

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Australia's Satellite Utilisation Policy provides a vision for Australia's use of space and space-related technologies including providing strategies to enable Australia to meet its national priorities through space and to ensure Australia meets its future space-related education and innovation needs. The Policy emphasises the importance of space based navigation and timing as components of Australia's smart infrastructure and social, economic and national security.

Annexed to the Policy is the National Positioning Infrastructure (NPI) Plan. This Plan proposes improved governance of the national positioning infrastructure, additional investment in ground infrastructure to deliver accurate and reliable positioning information to users across Australia and the development of a sovereign capability for GNSS product generation and integrity monitoring through an indigenous Analysis Centre Software (ACS).

The objective of the ACS project is the development of a multi-GNSS, multi-frequency network processing platform. It shall deliver as output the numerical estimation and quality description of the network parameters for all available GNSS satellites and CORS network stations receivers that the users require to position themselves in a Precise Point Positioning mode in real-time (PPP-RTK).

This presentation focuses on the development activity of the ACS and the research challenges of PPP-RTK.

Magnetoseismology: Ground-based remote sensing of Earth's magnetosphere

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The Earth's magnetosphere forms a vast and dynamic plasma physics laboratory, home to space weather and satellite technology that is essential to modern society and commerce. The outer boundary of the magnetosphere interfaces with the solar wind, while the ionosphere and atmosphere form the lower boundary. Magnetospheric regions and processes map to the ground along geomagnetic field lines, producing signatures in a variety of ground-based instruments. Arrays of magnetometers thus provide information on the equatorial mass density distribution. Other ground-based remote sensing tools utilize the dispersion and Doppler shift of VLF radio signals, HF radar observations of varying electric fields in the ionosphere, and refractive shifts in GPS and radio astronomy signals. The observed spatial and temporal variations in magnetospheric density provide input to data assimilative models. This presentation outlines the essential techniques and presents illustrative examples.

A review of steering with Rocker Bogie chassis design

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BLUEsat Space Projects, UNSW Australia

*Australian Centre for Space Engineering Research
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The BLUEtongue rover was built in 2015, utilising a rocker bogie coupled with skid steering for orientation and terrain traversal. Rocker bogies are a passive suspension which offer high stability and clearance for minimal complexity, and are widely used as the de facto suspension for rover designs. Skid steering is a simple turning method in which reorientation is achieved by counter-rotation of the left and right wheels. When coupled, these two system can ideally provide high rover mobility for a low cost. However, as was discovered on the BLUEtongue rover, the demands of a rigid frame for the operation of skid steering prove problematic due to the nature of rocker bogie suspension designs. As a result, attempts to rotate the rover produced flexure in the frame alone. To address these issues, three solutions have been sought. The first, and most simple of these, is a fixed bracing between the rocker and bogie. This linkage has been tested and restores turning functionality at the cost of free rotation in the bogie. Second is quite similar to the fixed bracing, but utilises remote locking, allowing for both turning and free rotation of the bogie when either is more relevant. The third of these is the implementation of a swerve drive, which allows all wheels to rotate independently, again restoring turning without limiting the bogie's free rotation.

Post-Venus Express: An Overview of Current Issues in Understanding the Composition and Chemistry of Venus' Mesosphere

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Several dozen spacecraft missions, Earth-based observations, laboratory research, and numerical modelling have identified the major constituents and chemical processes in Venus' atmosphere (e.g., von Zahn et al 1983, Esposito et al 1997, Mills et al 2007). The most recent spacecraft, the European Space Agency's Venus Express (VEx), ceased operation at the end of 2014 after eight years. VEx and Earth-based observations over the past 10 years have provided the first detailed view of geographic, local time, and temporal variations in the abundances of several important chemical species (Marcq et al 2015). Nevertheless, numerous important questions remain unanswered and many new questions have arisen (Mills et al 2007, Mills and Allen 2007, Marcq et al 2015, Vandaele et al 2015).

A major focus for recent work has been sulphur chemistry in Venus' mesosphere. VEx/SPICAV and HST observations suggest there are significant variations with time in SO₂ transport upward through the cloud layers (Marcq et al 2013, Jessup et al 2015), and 3-d tropospheric simulations show episodic behaviour consistent with this (Stolzenbach et al 2015, Vandaele et al 2015). HST observations also provided the first evidence that SO₂ cloud top abundances depend on local solar time and that there is another chemically active reservoir of sulphur, besides SO and SO₂, at the cloud tops (Jessup et al 2015). At higher altitudes, VEx/SOIR, VEx/SPICAV, and JCMT observations agree that an as yet unidentified reservoir of sulphur interacts on relatively rapid

timescales with SO and SO₂ producing an SO₂ inversion layer, but the different observations don't agree on the magnitude of the inversion and no model has offered a satisfactory explanation for it (Sandor et al 2012, Vandaele et al 2015).

This talk will present an overview of current knowledge and issues in understanding the composition and chemistry of Venus' mesosphere.

Potential Impacts of Heterogeneous Chemistry on Venus' Mesosphere

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Atmospheric chemistry on Venus comprises three large-scale chemical cycles: the carbon dioxide, sulphur oxidation, and polysulphur cycles (e.g., Mills et al 2007). The first maintains the chemical stability of the atmosphere's primary constituent; the second produces the global sulphuric acid cloud layers; the third may be responsible for producing polysulfur, a leading candidate for the unidentified ultraviolet absorber (von Zahn et al 1983, Esposito et al 1997, Mills et al 2007). Venusian atmospheric chemistry also can be viewed as comprising reactions within and amongst chemical families, such as HO_x, ClO_x, NO_x, SO_x, O_x, chlorosulphanes, polysulfur, and chlorine nitrates. The gas-phase chemistry for most of these families and their roles in the large-scale chemical cycles have been explored to varying extents in numerical models developed over the past thirty years (Krasnopolsky 1981, Yung and DeMore 1982, Mills 1998, Mills and Allen 2007, Krasnopolsky 2012, Zhang et al 2012).

A prominent characteristic of Venus' atmosphere is the global, sulphuric acid cloud layers (Travis 1975). In addition, there are haze layers that extend above and below the main cloud layers (Knollenberg et al 1980). Venus Express observations suggest the upper haze layer may be around 25-km thick and extend through most of the mesosphere and thermosphere (Wilquet et al 2009). The cloud and haze particles are reservoirs that can, depending on total mass, buffer the gas-phase abundances of some species, particularly H₂SO₄, H₂O, SO₃, and SO₂. Modelling of the upper mesosphere SO₂ inversion layer has focused on this buffering (Zhang et al 2010, Zhang et al 2012).

Little attention has been given in past numerical modelling studies to the potential impacts of heterogeneous chemistry occurring on or in the cloud and haze particles. This presentation will describe results from preliminary assessments, focusing on the carbon dioxide and sulphur oxidation cycles.

On Power Received via Oblique HF Ionospheric Propagation

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The ionosphere is variable over a wide range of temporal and spatial scales. Networks of ionospheric sounders periodically and spatially provide information on available high frequency (HF) propagation paths through the ionosphere and enable ionospheric parameters to be estimated. For example, parameters derived from vertical incidence sounders (VIS) are used to produce the Real-Time Ionospheric Model (RTIM) currently used in the Jindalee Over-The-Horizon Radar Network (JORN). In the future, parameters derived from a dense network of oblique incidence sounders (OIS) will also be incorporated into the RTIM.

Statistical analysis of sporadic E (Es) propagation over a month of soundings (selecting fully saturated Es to emulate a near perfect spherical reflector) has been used in part to validate that essential components of the power modelling are valid (such as the modelled antenna patterns, focussing effects and system gain).

In this paper, ionospheric parameters (from either the RTIM or OIS estimates at path mid-points) have been used to estimate the power received on OIS paths using various ray tracing techniques (analytic and numerical) and compared with measurement.

Histograms for data collected on 3 paths for 3 days in August, 2014 gave median differences between models and measurement of less than 2 dB with standard deviations around 6dB.

These results indicated that the dominant factors have been accounted for, enabling further investigation of, for example, absorption models, ground forward scatter and partial reflection from, and transmission through, Es layers.

Pulsed Cathodic Arc Spacecraft Propulsion Systems

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Orbital transfer and stationkeeping manoeuvres require reliable thrusters to guarantee payload delivery and orbit maintenance. In recent years electrical propulsion systems such as Hall Effect thrusters (HETs) and gridded ion thrusters (GITs) have been replacing chemical thrusters due to their higher specific impulse and technological maturity. HETS and GITs use pressurised gas as reaction mass, and thus require tanks, pipes, valves and regulators to operate. Pulsed Cathodic Arc Thrusters (PCATs) use solid conductive cathodes as their reaction mass, and so would use less mass budget for operation as well as increase reliability. This work presents experimental tests of an PCAT testbed, in which thrust and mass flux rates are measured in order to determine the specific impulse, jet power efficiency and thrust-to-power ratios of numerous fuels under varied conditions.

The role of core-differentiation in ejection of a Moon-forming disk

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MQ Planetary Research Centre

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The isotopic similarity between the Earth and the Moon is difficult to accommodate in the canonical giant impact model for lunar formation, in which a high proportion of the impactor is incorporated into the Moon-forming disk. To resolve this issue, more recent models have explored head-on impacts between bodies of equal size (1), or smaller impacts impinging on a rapidly spinning proto-Earth (2). Both scenarios are consistent with disk accretion models, but require substantial angular momentum loss post lunar formation. This rapid rotation resulted in an extremely oblate proto-Earth that may have been unstable for extremely rapid rotation periods (~ 2 hr).

Here, we use smooth-particle hydrodynamics models to explore the possibility that increasing spin-rates caused by the redistribution of mass due to core formation in the proto-Earth, may have increased the radius of the central bulge causing mass ejection and the formation of a circumplanetary disk beyond 2.9 RE, from which the Moon formed. This scenario explains the isotopic similarity of the Moon and the Earth, the water content of the Moon, and the angular momentum of the Earth-Moon system, without the need to appeal to special ad-hoc classes of impacts. The mass of the Moon and the size of the lunar core calculated from these models are consistent with observations.

Sensitivity to micro-vibrations: damping of thin curved flexible space structures

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Owing to a change in the Australian government's paradigm to increase the nations' presence in space, Australian universities and government organisations schedule affordable, routine in-space missions using nano-satellites with off-the-shelf payloads combined with special-purpose scientific instrumentation.

However, due to small characteristic lengths in nano-satellites, thin flexible mechanisms such as deployable sun sails or antennas get proportionally larger. Together with higher mass and packaging restrictions, the stability behaviour of these fragile structures poses a significant problem for the spacecraft's overall stability and attitude control owing to both changing environmental loads and internal micro-vibrational disturbances.

Here, the vibration modes of a deployable tape spring HF antenna are investigated and characterised by means of a sensitivity study. Especially torsional modes appear very sensitive to small load changes and imperfections in the material. Using a global variance-based sensitivity study it is shown that reducing thickness and density imperfections can control certain buckling modes. Various laminates in the form of uni- and bi-directional nylon and glass-fibre re-enforced scotch tapes as well as Kapton tape are experimentally tested, applied to either the full or the partial antenna. Partially laminating the antenna structure with a double layer of bi-directional glass-fibre re-enforced Scotch and Kapton tape provides highest stability and good damping properties, especially for torsional modes without compromising packaging and weight too much.

From Antarctic Auroras to Nanodust on the Moon, 60 Years of Glorious Entertainments in Space Science: A Tribute to Professor Harry Messel

Prof. Brian J. O'Brien FTSE

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Professor Harry Messel uniquely transformed Australian science research and education in his pursuit of excellence. Here I offer a tribute to Harry with two personal storylines of space research discoveries.

The first is about exploration of the magnetosphere by me and two former students in the 1960s, continuing by those students now world leaders into the 21st century, one of them exploring the heliosphere. The second is a more solitary quest for knowledge about movements of dust on the Moon, from 1966 to date. Four times my 1966 invention, the 270 g Apollo Dust Detector Experiment was deployed on the Moon, by Apollo 11, 12, 14 and 15. With 3 solar cells and 3 thermometers, my instruments have to date made over a dozen discoveries, and remain the only quantitative measurements of dust movements on the Moon. The Apollo astronauts found that dust was the most significant environmental hazard on the Moon. Dust led to numerous failures of experiments, as well as causing overheating and mechanical problems to equipment. Furthermore, in spite of official scepticism that running dust-detection experiments was at all necessary, at a time when very fine dust was regarded largely as a nuisance by geologists participating in Apollo science, it became recognised after Apollo that dust is in fact a repository of extraterrestrial knowledge.

In this presentation I briefly highlight some of the most significant results emerging from these studies, up to the latest discovery being that sunrise-driven dust storms remediated and smoothed the landing site disturbed by Apollo 12 astronauts and equipment. I also speculate on how these recent results could decrease community concerns about mining on the Moon, while alerting future lunar rovers (eg., the winning projects in the Google LunarX Medal Contest) of an unexpected dust hazard which might cause mechanical problems after they survive the extreme cold of their first lunar night.

An innovative approach to astrobiology education in the online environment

Carol Oliver, Martin Van Kranendonk and Tara Djokic

Australian Centre for Astrobiology, School of Biological, Earth and Environmental Sciences, UNSW Australia

Astrobiology: Life in the Universe is a third-year elective course at the University of New South Wales. In semester 2 of 2015 the course moved from face-to-face to the online environment, which immediately doubled student numbers from 35 to 75. We employed a range of learning strategies based on five years of experience in a first year astrobiology online course, and on the literature on aspects of online learning that – when closely examined – reveal that translating the face to face experience directly into the online environment does not work. We discuss the construction and delivery of the course and its implications for other space-related university courses.

Computational study of the effect of Mars surface atmosphere induced thermal convection within horizontal gap enclosures on surface heat transfer characteristics within a Mars rover.

Siddharth Pandey, Sean Tuttle, John Young

University of New South Wales, Canberra, Australia

As opposed to general spacecraft thermal insulation such as Kapton and MLI, Mars surface spacecraft require rigid and convection isolation to accommodate the Martian atmospheric entry, descent, landing, wind and dust loads. Traditional thermal insulation options for Mars surface spacecraft have involved low mass density and low thermal conductivity solutions such as thermoplastics and foam material. The last successful rover mission to Mars, NASA's Mars Science Laboratory, utilises the Mars surface atmosphere with average pressure of 6mbar and low thermal conductivity, (96% CO₂ with average $k_{CO_2_mars} = 0.01$ W/m-K). This reduces the overall system mass and volume required by conventional insulants, which is a tremendous advantage for an interplanetary mission in bringing down cost and development time. Therefore, bulky solid thermal insulation is replaced by designing gas gaps to vent in ambient atmosphere and surround warm electronic enclosures. Convection can set in if the gas gaps are designed too wide and therefore an optimal gap design is required to be carried out for the surface that requires thermal insulation. This paper looks at modelling the density induced thermal convection cells within a basic horizontal gas gap, the theoretical formulation of which is well known and can be validated against our numerical model. A set of horizontal gas gaps is studied and the effects of the onset and propagation

of thermal convection is standardized for Mars surface atmospheric and gravity conditions. The work also takes into account the thermal modelling conducted by other spacecraft thermal teams. The experimental work plan is presented and the objectives to validate the earlier computational work is discussed. This is the first sub-campaign by us of multiple such planned towards increasing our understanding of how thermal convection can play a role on the surface heat transfer characteristic parameters within several gap configurations, orientations and non-uniformly heated surfaces.

Spaceward Bound India 2016: Taking Astrobiology to the Roof of the World

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Space exploration and space science education transcend geographical and cultural boundaries. As a species we work together at the frontiers of exploration and educating and enlightening students and general public across the globe.

The Spaceward Bound Program started out of NASA Ames Research Center as an educational field experience where astrobiologists would conduct research experiments and scientific observations alongside students and science educators, and engage in scientific discussions. The program has been conducted in the US, Namibia, Australia, New Zealand, and the Americas, and we are now looking into bringing it to India. India's space ambitions and recent success with its Mars Orbiter Mission caught the attention of people around the world, and enthused the Indian youth.

The Spaceward Bound India 2016 expedition will be coordinated jointly by Indian researchers and their counterparts in NASA Centres and astrobiological researchers in Australia and New Zealand. This paper describes the astrobiological relevance of Ladakh in Northern India and the various transects planned for the expedition. Along with the various science objectives of the expedition, an outline of the planned experiments and educational activities to engage participating students will be given. Important deliverables from the study will be made available to the review team, to gauge the effectiveness of the project and identify areas for further work.

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Modelling the Interference Environment in the HF Band

Lenard Pederick, Manuel Cervera

Defence Science and Technology Organisation

The performance of systems using HF (high frequency) radio waves, such as over-the-horizon radars (OTHR), can be strongly affected by external interferers at great distances (thousands of km) from the system's receiver. However, the propagation of interference has complex behaviour and is known to vary with location, time, season, sunspot number and radio frequency. Understanding how the level of interference varies with all of these factors is important for the design of new systems such as next-generation OTHR. By combining databases of known transmitters, ray-tracing propagation and a model ionosphere, a model of the behaviour of interference at HF has been developed. This talk will outline the principles, techniques and current progress on the model.

Development of a low-cost Software-Defined-Radio based student groundstation

Michael Phillips, Brian Luc, Stuart Bartlett, Thomas Dixon and Elias Aboutanios

BLUEsat Group, UNSW Australia

Austalian Centre for Space Engineering Research (ACSER)

The falling cost of CubeSat nanosatellite missions has made educational satellites increasingly common. All missions require a groundstation to provide command uplink and data downlink. Traditional small, educational groundstation architectures have made use of a amateur packet radio techniques, with an audio transceiver coupled to a terminal node controller. However, in recent years, advances in software-defined radio have made it possible to replace an analogue transceiver and TNC with an SDR module. This provides substantially improved flexibility, allowing the use of a wide array of frequencies, modulation, and encoding schemes on a single set of hardware. As a result of this trend from hardware to software defined radio, educational institutions find themselves with legacy equipment remaining from previous groundstation setups or simply inherited from other groups, and using them in conjunction with a modern groundstation design presents interesting challenges. Developing custom 'bridgeware' consisting of both hardware and software solutions, the BLUEsat team has succesfully employed aged control infrastructure into a modern SDR groundstation. Given tight budget constraints facing students wishing to build a ground station, minimising costs as a function of ground station design plays a direct role in the efficacy of cost-conscious groups being able to produce and reproduce ground stations suitable for nanosatellite communications. The switching circuit for the routing of high frequency RF signals on UHF and VHF amateur bands can be designed to both maximise interoperability between bands and minimise switching complexity.

Dating late thermal events on the Moon from the annealing of radiation damage in zircon

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Isotopic dating techniques have played a major role in advancing our understanding of the origin and the evolution of the Moon. Most valuable has been the U-Pb dating of zircon and phosphates that occur in many lunar breccias and soils. The zircon U-Pb ages date the formation of the zircon host rock as a primary or impact generated melt. The U-Pb ages of phosphates are generally younger and record resetting of the U-Pb systems during a thermal pulse of $> 450\text{-}500^{\circ}\text{C}$ generated by a major impact.

In this contribution we describe the application of radiation damage accumulated in zircon as a new dating technique. Energy from tU and Th decay series progressively breaks down the zircon lattice and the accumulating radiation damage can be monitored by Raman spectroscopy. However, zircon radiation damage can be annealed at a temperature of $\sim 230 \pm 25^{\circ}\text{C}$. The time of any annealing can be estimated by comparing the observed radiation damage and a-dose with that of un-annealed zircon.

We report radiation damage age results for zircons from three lunar breccias. Multiple measurements on one grain from breccia 72215 indicate that the last low temperature annealing coincided with the late heavy bombardment. However, a set of zircon grains from Apollo 14 breccia 14311 recorded a younger age, suggesting a low temperature thermal pulse associated with mare volcanism. Multiple analyses on a third grain from breccia 76295 gave conflicting results suggesting that this grain experienced complex partial annealing. Zircon radiation damage ages described here provide a new means of investigating the late, low temperature thermal history of the Moon, and provide a unique method for comparing the late thermal histories of breccia samples from the same or different Apollo landing sites.

Astronomical and Seasonal knowledge within Torres Strait Islander Art

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This paper explores the representation of astronomical and seasonal knowledge in past and present Torres Strait Islander art, specifically relating to shark constellations. Islander art collected for online and within the published literature is examined for information relating to the connection between Torres Strait Islander astronomical knowledge and seasonal calendars that are used in the daily, cultural and ceremonial lives of Islanders. Islander astronomical and seasonal knowledge specifically relating to shark constellations have been interpreted by Islander artists and used to educate future generations the relevance of traditional Islander knowledge through artistic representation that has been influenced by Melanesian and traditional artistic forms and motifs.

Systems Engineering Essentials for Small Satellite Missions

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UNSW Canberra

The rate of launches for satellites under 50kg mass is continuously growing with over 160 launches recorded in the year 2014. The increasing number of stakeholders in the government, commercial, science and education sectors is contributing to this growth. All such missions, however, differ inherently from the traditional large satellites in aspects such as satellite technology, development, testing infrastructure, launch and ground station.

In reaction to this rapid growth, there is a growing realisation within the small satellite community that there is need for the following specific initiatives. Firstly, developing a qualification-framework for small satellite missions, i.e. what (not necessarily the mass and size of spacecraft) makes a satellite mission small? Secondly, shifting the traditional Systems Engineering (SE) philosophy towards “lean thinking” approaches so the small satellite missions do not miss the proven SE advantage while acknowledging the need to tailor this down to the smaller scale. This later concern requires developing new compliance standards for warranting success of missions, as far as possible. Examples of the efforts for desired standardization, currently in progress at ISO, include ISO/CD/17770 (CubeSat), ISO/CD/19683 (Testing) and ISO/TC20/SC14 (Small Satellite Definition).

The main purpose of this paper is to highlight the significance of un-conventional approaches to SE required for small satellite missions. First, we discuss the “common-sense” approach to SE for small satellite missions, generally likely to be followed due to relatively-limited mission scope, time and budget constraints. We identify some gaps between this and the formal SE approaches, which need to be addressed, in the areas such as requirements engineering, design, verification testing and workforce. Some considerations for developing new strategies which address the identified gaps and push towards “maximum” SE rigour, under the particular conditions of small satellite missions, are then presented. This can potentially contribute to the standardisation efforts.

Experience gained from Satellite Design Projects

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The Australian Centre for Space Engineering Research at UNSW Australia has undertaken two space mission design projects since 2010. The Synthetic Aperture Radar (SAR) formation satellite mission, also known as the Garada project, (phase 0/1), was initiated at the end of 2010, while the QB50 CubeSat mission has been ongoing since 2011. This paper presents the key management lessons identified by the staff and students involved in the two aforementioned projects. This paper will first provide an introduction to the two space projects, including the management challenges confronted, and will then introduce the unique characteristics of a university-run space project, exploring both strengths and weaknesses. The experiences gained are presented from three different perspectives: team, task and component control, with discussion focussing on the control of cost, schedule and scope. In addition to lessons learned, some recommendations are offered for future projects.

A thermochemical comparison of metal transport, speciation and condensation in a lunar volcanic gas and a terrestrial volcanic gas

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A range of lunar volcanic glass samples from Apollo 17 and Apollo 15 contain glass beads with coatings rich in S, F, Cl combined with metals such as Zn, Cu, Ni, Ga, Fe and Pb [1] [2]. These coatings are likely to have been deposited by a gas phase on glass/molten beads during fire fountain eruptions [1] [3]. Using a computed lunar volcanic gas composition [5], we calculate the equilibrium speciation and condensation of metallic sublimates and salts during decompression from 1000 to 10⁻⁹ bar and cooling from 1500 to 500°C. These data allow comparison of lunar and terrestrial volcanic gas mixtures (Erta Ale, Ethiopia) [4] and their sublimates. Metals occur as sulfides, chlorides, oxides, fluorides and pure metals (M₀), both in the gas as well as the sublimates.

Owing to its low oxygen fugacity (IW-2), oxide species are of little importance in the lunar volcanic gas in contrast with more oxidised terrestrial gas (QFM: if the QFM buffer, then no O required, unless it is above or below the oxidation value, i.e., QFM ± any value that applies. Please, check). In both gas models M₀ species are dominant relative to more complex molecules at low pressures and high temperatures. In the lunar gas the M₀ species are more important along with Cu, Ni and Pb sulfide gases, whereas in the terrestrial gas the chlorides are more stable and sulfides are rare, except for Pb. The sublimates are mainly sulfides and M₀ species in both systems. These model results agree well with observed sulfides on lunar glass beads [1] [2].

[1] Meyer et al. (1975) Proc. Lunar Sci. Conf. 6th, 1673-1699. [2] Butler & Meyer (1976) Proc. Lunar Sci. Conf. 5th, 1561-1581. [3] Rutherford & Papale (2009) Geology 37, 219-222. [5] De Moor et al. (2013) Geochim. Geophys. 14, 4076-4108. [4] Renggli et al. (2015) Goldschmidt Conference.

The Communication System of the Australian Space Eye: Ultra-faint Astronomy Imaging from Space

Sam Reisenfeld

Macquarie University

There are numerous occasions when scientific observations from low earth orbit produce extremely valuable scientific data.

In particular, low earth orbit offers considerable advantages for astronomical observations relative to ground based telescope observations. Space-based observations are not distorted by a transmission path through the earth's atmosphere. Because of atmospheric filtering, astronomical observations on the earth are limited to wavelengths in the range of 3000 Å in the ultraviolet to about 240,000 Å in the infrared. Light with wavelengths longer than 7,600 Å is greatly modified due to molecular absorption in the atmosphere. Ground based astronomical observations suffer from astronomical seeing, which is blurring and twinkling of astronomical objects such as stars due to turbulent mixing in the earth's atmosphere causing variation in the optical refractive index.

To overcome the effects of atmospheric distortion, a new, proposed Australian satellite, named Space Eye, is intended to fly an astronomical observation instrument in low earth orbit. The astronomy payload of this satellite, consisting of a sensitive telescope, an image sensor, and electronics, will record deep space images observed with light wavelengths longer than 7000 Å. Atmospheric distortion of the image will be avoided at the satellite in an 800 km orbit because the observed light does not pass through the earth's atmosphere. The Space Eye payload will measure very low intensity light with specific angles of arrival from deep space sources. The power spectral density of the images recorded in two dimensional spatial coordinates will be used to measure anisotropies from extragalactic background light. This is a powerful technique to measure the properties of interesting astronomical light sources that are too faint to be detected directly, such as primordial galaxies and black holes in pre-ionization epoch and lower redshift intra-halo stars that are not gravitationally bound to a galaxy.

Existing CubeSat small satellite technology provides a low-cost approach to the design and development of the Space Eye Satellite. CubeSat spacecraft have been widely used as platforms for cost effective scientific observations from space. There has been a current trend in cost reduction in spacecraft design by

reductions in the size of satellites. With advances in the electronic technology, reductions in electronic size, mass, and power consumption are possible, with increasing functional capability. The CubeSat satellite platform utilizes these electronic advances to provide the capability of a cost effective satellite designed for low earth orbit scientific observations.

Each astronomical image recorded by the Space Eye Satellite will have a 10 minute exposure time. Using long time exposure imaging, very low light intensity astronomical objects may be studied and important scientific data may be obtained.

The downlink data transmission requirements of the astronomical images from the Space Eye Satellite are presented in this paper. A preliminary design of the communication system, including both satellite and earth station elements, is described. A performance analysis of the communication system is provided to verify that the design fulfills the downlink data transmission requirements. The Space Eye communication system utilizes commercial off the shelf (COTS) hardware and, therefore, is a cost effective approach to the acquisition of the astronomical image data.

If you build it, will they come?

An Analysis of Price and Demand in the Launch Industry

Matthew Richardson

Nova Systems

Lowering space launch costs is widely seen as crucial to the long-term development of the space industry. However, many proposals for reducing these costs make use of an often unspoken underlying assumption: that reducing launch costs will stimulate demand. Such a significant assumption warrants investigation, in order to test its validity. To this end, a census of all commercial LEO and GEO launch activities from 1997 to 2014 has been completed. Average annual unit launch costs (in USD/kg) and total annual demand (measured as total payload mass delivered to orbit) have been determined for all commercial launch systems over this period. This data was used in a non-linear regression analysis to establish a model for the relationship between launch costs and demand. The model is used to estimate how much of the variance in demand is attributable to cost, and to establish Price Elasticity of Demand (a measure of the behaviour of demand relative to price) for the space launch industry. The model is also assessed as a general tool for use in space economics analysis and research. The results indicate that price is a significant variable in the demand function, with the model accounting for almost 70% of the variance in demand. Furthermore, the model indicates that demand is highly elastic relative to price. However, while the model fits the existing data well, it would be unviable for extrapolation outside the existing data set. Nonetheless, these results indicate that there is a strong relationship between launch costs and demand. Therefore, efforts to reduce launch costs should stimulate demand, and the aforementioned assumption is valid.

Getting cash for communication

Jay Ridgewell, Emma Donnelly

Curtin University, SSERVI Australia

Grant writing is all about delivering research bang for the bucks, but what about getting cash for communication? Dynamic demonstrations, messy activities, public lectures, citizen science, Instagram – it's all good fun, but when are you going to have the time to do all that?!

Community engagement is necessary to raise the profile of science, technology, engineering and maths (STEM) amongst the general public and policy makers. Communication of research is becoming an integral part of grant requirements. Communication research outcomes are sought after by funders; by your organisations' leaders, public relations and marketing teams; and by schools and the greater community. While some scientists are the cover-boys and -girls of their field; organising events, keeping up with social media and giving talks can take a lot of time and may not always be your highest priority.

In this session Jay will touch on a variety of outreach and engagement methods and put forward a template for deciding how you can engage with the community, share your science, still have time for your research and maybe win a few grants because of it too!

A Real-time Precise Navigation System for UAV Applications

Chris Rizos, Yong Li, Wei Jiang

School of Civil and Environmental Engineering, UNSW

Unmanned Aerial Vehicle (UAV) technology is useful for many tasks in science and engineering, ranging from aerial surveillance, environmental monitoring, mapping, search and rescue, and others. All require the position of the UAV (and its sensors) to be determined to the appropriate level of accuracy, and a navigation capability to support its operation.

High accuracy real-time positioning of UAVs, based typically on low-cost onboard navigation devices is a critical task. In order to achieve accurate real-time navigation, the real-time kinematic (RTK) GNSS technique is adopted in this work. RTK is a relative positioning technique that uses carrier phase measurements made by a pair (or more) GNSS receivers: one on the UAV itself, and the other one (or more) set up on the ground, at a reference station of known coordinates. Unlike conventional UAV-RTK systems that transmit the raw measurement data from the UAV GNSS receiver to the ground, where the RTK solution is computed on a computer, the RTK system described in this paper is implemented on the UAV, and the precise positioning can be used for UAV navigation and control.

The UAV-RTK navigation components are included on a low-cost navigation and control board – called NAVCON. NAVCON is a “smart” board, equipped with a range of sensors and computing capabilities, such as a GPS receiver, MEMS-based accelerometer and gyroscope, magnetometer, barometer, DSP and a rich set of peripheral interfaces. It has a low power consumption, and has a small physical size (8.5cm by 5.5cm). Details of the NAVCON architecture and configuration will be presented in this paper.

RTK positioning results were derived for experiments under various configurations, and an analysis of performance will be presented. The UAV-RTK implementation is vital for many swarm (or multiple) UAV applications which require very strict control of relative navigation and positioning of multiple UAV.

Optimal Path Planning for a SLAM-based Navigation System for Small UAVs

Nicholas Robinson

The University of Sydney

Visual flight as a means for navigation has been used by pilots for many years as it facilitates the notion of 'see and avoid' in terms of avoiding other traffic. As the research in the area of unmanned aerial vehicles (UAVs) continues to grow, more often than not these UAVs rely on Global Navigation Satellite Systems (GNSS) for navigation purposes rather than visual flight methods. This has many issues in built-up environments where GNSS can be unreliable, inaccurate or even bogus (in the case of a military situation). This issue has given rise to the method of Simultaneous Localisation and Mapping (SLAM), which uses visual references (from a camera or multiple cameras) to identify features and localise in real-time without any a priori knowledge of the environment. As the same features are repeatedly observed, the position error reduces. Central to a SLAM-based navigation system, is an optimal path planning system which optimally decides which areas to visit in order to obtain a better position estimate and also to enlarge the map. This system will gradually push the UAV closer to its goal. Work has been conducted in to the development of an improved potential field path planning system in order to solve the problem more efficiently to facilitate navigation in real-time using SLAM. This system has been successfully implemented on low-cost hardware (the Parrot AR Drone), to prove that the algorithm is robust. Future uses of the path planning system could be in satellite trajectory planning and on-orbit servicing.

SSA Research in DST Group

Mark Rutten and Neil Gordon

Defence Science and Technology Group

DST Group has recently established a new Strategic Research Initiative (SRI) for Space, which will encapsulate and extend DST Group's current space-related research in the areas of small satellite missions, niche sensing technologies and SSA. This presentation summarises both the current work and the goals of the SRI that are relevant to SSA. The motivation for DST Group's research in SSA is in ensuring Defence's access to space systems. Australia's investment in SSA is seeing the installation of a c-band radar and the DARPA space surveillance telescope in WA, which are dedicated sensors for the US Space Surveillance Network (SSN), along with support infrastructure and personnel for operations. DST Group is supporting this investment by research into new methods for the construction and maintenance of a catalogue of objects in orbit and exploiting niche sensing technologies, such as the MWA radio telescope and the Desert Fireball Network. This research is supported and validated through experiments, using an optical SSA system constructed at DST Group Edinburgh and in collaboration with University partners. DST Group has international defence R&D partners with a mutual interest in SSA, which has provided opportunities for wider, multi-national collaborative experiments. This presentation will describe the DST Group program and outline possible avenues for collaboration.

Outer Space: Debris and Deceit?

Roy Sach

Sach Initiatives

This session will highlight possible inaccuracies in published data quantifying and describing orbiting anthropogenic debris.

The technology available to detect and measure items of orbiting debris has improved since the space age began. If charts showing progressive increases in orbiting anthropogenic debris over several decades include raw data obtained from technologies that were less sensitive than the contemporary capabilities, the claimed increase, or rate of increase, in orbiting debris has probably been exaggerated. It would be due in part to technological enhancements. Conversely, if contemporary observations have been extrapolated to adjust the historical data, details of this process and associated methodology are not commonly visible for peer review.

Contemporary definitions and categorisations of debris do not address debris launched intentionally into outer space. Inclusion of this component changes the debris trend line and associated statistics. There is also evidence that published estimates of assessed, as contrasted with catalogued, debris have been influenced by national political agendas.

Debris data is commonly presented to emphasise the cross sections or other physical dimensions of objects in orbit rather than considering their mass or density. Relative velocity is seldom mentioned. Consequently, the data tends to provide a basis for calculating the probability of collisions between orbiting debris and operational spacecraft, rather than considering the likelihood of catastrophic damage being caused by such events. Many collisions may occur at low relative velocities, or involve debris with low mass characteristics, and therefore could cause little or no harm.

These issues should motivate individuals to further investigate discrepancies in debris-related data. They also should assist organisations with responsibility for allocating science funding to evaluate submissions seeking their support for research related to orbiting anthropogenic debris.

The Expansion of the Desert Fireball Network

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The Desert Fireball Network (DFN) is dedicated to the observation of fireballs with the aim of characterising incoming material, defining orbits and ultimately recovering fallen meteorites. The DFN is the only such network in the Southern Hemisphere and the barren terrain of southern Australia is well suited to recovering meteorites. Four Autonomous Desert Fireball Observatories (ADFOs) set up during the trial period used film cameras and recovered 2 meteorites with orbits (Bland et al. 2009, Towner et al. 2011). The establishment of a digital network has been ongoing since 2012 and over the last year, the number of ADFOs deployed has more than doubled and currently totals 32 cameras. This amounts to a current observation area of 1.7 million km², the largest fireball camera network ever built.

Each month 57.6 TB of data are acquired, requiring an automated pipeline for data reduction. Significant resources over the last year have been allocated to the development of this pipeline. The established approach for detecting fireball events has been significantly improved to reduce the high percentage of false positives flagged. An automatic method to determine points and times along the fireball path has been created, as well as a high precision calibration of the cameras to allow the conversion of these points from pixel coordinates to altitude and azimuth. Triangulation calculations have also been improved to allow more than two ADFO datasets to be considered when determining fireball trajectories. In 2015, the DFN has observed over 100 multi-station fireballs greater than 2 seconds long over the Western Australian Wheatbelt, Nullarbor Plain and South Australia.

With this success we are taking the network overseas. The development of our kit cameras has caught the interest of fellow researchers in the US, UK and Morocco who will use them to establish complementary networks outside Australia.

Petrography, Chemistry and Chronology of Refractory Inclusions in NWA 4502

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In cosmochemistry the age of Calcium-Aluminum-rich Inclusions (CAIs) in chondrites is considered the beginning of the formation of the Solar System. The age of CAIs is determined by high-precision U-Pb isotope dating [1, 2], although the influence of secondary processing experienced by the host meteorites (parent-body metamorphism and aqueous alteration, impacts, and terrestrial weathering) on the U-Pb isotopic system is not well understood. Since no known meteorite is completely free from secondary processes, one way to get reliable ages of CAIs is to compare the dates of CAIs from various CV chondrites that were influenced by different secondary processes to various degrees.

The CV chondrite NWA 4502 is the second largest CV chondrite so far after Allende, and contains abundant CAIs, suitable for comprehensive geochemical and isotopic study [3]. At a mineralogical level, this meteorite is less affected by secondary alteration than Allende and many other CV chondrites [4]. This makes NWA 4502 a promising candidate for establishing CAI chronology and understanding the effects of secondary processes on the isotopic systems in CAIs.

We present the petrology, mineralogy, element and isotopic (oxygen, uranium, Al-Mg and Rb-Sr) compositions and U-Pb ages of five coarse-grained CAIs from NWA 4502. Even though the studied NWA 4502 CAIs show a low level of secondary hydrothermal alteration, thermal and shock metamorphism that affected CAIs in other CV chondrites, and complexities discovered in some of the isotope systems (Al-Mg and Rb-Sr), indicate significant imprint of terrestrial weathering. Acid leached residues of NWA 4502 CAI fractions yield a U-Pb age and initial $^{87}\text{Sr}/^{86}\text{Sr}$ and $^{26}\text{Al}/^{27}\text{Al}$ consistent with those reported for Allende and Efremovka CAIs, in spite of the differences in secondary processes between these chondrites.

[1] doi:10.1016/j.epsl.2010.10.015;

[2] doi:10.1126/science.1226919;

[3] Meteoritical Bulletin, No. 101, MAPS 47; [4] LPSC 44, 1036.

Demonstration of a Viable Quantitative Theory for Interplanetary Type II Radio Bursts

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Between 29 November and 1 December 2013 the two widely separated spacecraft STEREO A and B observed a long lasting, intermittent, type II radio burst for the extended frequency range ~ 4 MHz to ~ 30 kHz, including an intensification when the shock wave of the associated coronal mass ejection (CME) reached STEREO A. We demonstrate for the first time our ability to quantitatively and accurately simulate the fundamental (F) and harmonic (H) emission of type II bursts from the higher corona (near 11 solar radii) to 1 AU. Our modeling requires the combination of data-driven three-dimensional magneto hydrodynamic simulations for the CME and plasma background, carried out with the BATS-R-US code, with an analytic quantitative kinetic model for both F and H radio emission, including the electron reflection at the shock, growth of Langmuir waves and radio waves, and the radiation's propagation to an arbitrary observer. The intensities and frequencies of the observed radio emissions vary hugely by factors $\sim 10^6$ and $\sim 10^3$, respectively; the theoretical predictions are impressively accurate, being typically in error by less than a factor of 10 and 20 %, for both STEREO A and B. We also obtain accurate predictions for the timing and characteristics of the shock and local radio onsets at STEREO A, the lack of such onsets at STEREO B, and the z-component of the magnetic field at STEREO A ahead of the shock and in the sheath. Very strong support is provided by these multiple agreements for the theory, the efficacy of the BATS-R-US code, and the vision of using type IIs and associated data-theory iterations to predict whether a CME will impact Earth's magnetosphere and drive space weather events.

SBAS for Australia and New Zealand

Jack Scott

The Space Based Augmentation System (SBAS) is providing substantial productivity gains in the US and Europe through the wide area provision of improved accuracy, availability and integrity of GPS signals. SBAS is an ICAO standard which ensures interoperability as the global take up of SBAS blossoms. A joint project between Australia and New Zealand would make a significant contribution to the global SBAS footprint as a major Southern hemispheric coverage area. SBAS would provide the positioning, navigation and timing (PNT) infrastructure which would bring productivity enhancements especially to the regional areas for aviation, agriculture, maritime, roads and rail. SBAS, as a global standard, has been incorporated into the billions location based devices which would enable all Australians and New Zealanders with the power of augmented positioning bringing productivity efficiencies into their daily lives.

Characterizing Daytime GHz Scintillation at Equatorial Regions Using GNSS Radio Occultation Measurements

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Ionospheric scintillation of radio waves can behave differently at different locations with a strong diurnal dependence; particularly in the equatorial regions. Ionospheric scintillations at gigahertz (GHz) frequencies have been observed during both daytime and nighttime. It is believed that daytime scintillation is associated with blanketing sporadic E (Esb), whereas nighttime scintillation is attributed to F layer irregularities. Scintillation events associated with Esb during daytime are of our primary interest. Recent studies show that in the ionosphere, electron density profiles from Global Navigation Satellite System (GNSS) Radio Occultation (RO) provide valuable information to help better understand the physics of the ionosphere. In particular, GNSS RO observations of GHz scintillation in the proximity of the E-layer have been interpreted as being caused by sporadic E.

In this paper the characteristics of daytime scintillations at 1.5 GHz recorded simultaneously from two stations (i) Universiti Kebangsaan Malaysia (UKM) (2.55°N, 101.461°E; dip latitude 5.78°S), and (ii) Langkawi (6.19°N, 99.51°E; dip latitude 1.90°S) during November and December 2010 are analyzed. The characteristics of daytime GHz scintillation and its relationship with E region irregularities at equatorial regions are investigated. Ground-based scintillation and Total Electron Content (TEC) data recorded by the GSV4004 receivers were utilized in combination with the amplitude scintillation measurements in terms of GPS C/A code SNR fluctuations during a ground-based GPS and space-borne GNSS RO experiment at the two equatorial stations. Scintillation activity was found to be more prominent at UKM. Moreover, strong scintillation with the S4 index exceeding 0.6 has only been observed at UKM, while at Langkawi the scintillation intensity (S4 index) did not exceed 0.3. Signal-to-noise measurements obtained from GNSS RO indicate that daytime scintillations are very likely caused by Esb. Our further research will be concentrated on an in-depth investigation of day-time irregularities in equatorial regions using both ground and space-borne GNSS technologies.

A Reusable Launch System for Small Satellites

Prof. Michael K. Smart, Mr Dawid Preller, Mr Adriaan Schutte

University of Queensland

The global economic environment combined with the rapid pace of technology advancement is placing importance on reducing the cost and increasing the responsiveness of access to space systems. Based on decades of practical experience with rocket-only launch vehicles, current technology is operated close to theoretical limits and only marginal further efficiency improvement is achievable. In order to further improve the efficiency of access-to-space vehicles, new propulsion systems will be required. Airbreathing engines, and scramjets in particular, are considered the most promising alternative. Scramjets have an advantage over rocket propulsion in terms of a significantly higher specific impulse; other benefits of airbreathing propulsion for access-to-space are increased launch flexibility, such as shorter time to rendezvous with a target spacecraft, and increased launch window duration and number of opportunities. This project investigates the use of a three-stage rocket-scramjet-rocket system for transporting payloads of approximately 500 kg to a Sun Synchronous Orbit. It is believed that this mission profile meets the requirements of many missions, such as responsive surveillance of man-made and natural disasters and several earth science missions.

Development and testing of a Complete, Sub-\$1000 2U CubeSat Prototype

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The LEONIDAS (Low Earth Orbit Network Imaging and Data Acquisition Satellite) satellite project stemmed from the coursework of 12 undergraduate students of Mechanical, Mechatronic and Aerospace Engineering at the University of Sydney. It was designed and built from the ground-up by the student team to comply (as near as possible) with the 2U CubeSat and QB50 mission standards. One primary purpose of LEONIDAS is its capability as a selfie (self-imaging) satellite: An external screen and boom-mounted camera allows students from around the world to have their picture (displayed on the screen) to be taken in orbit with the earth as the background, a function which serves to generate interest among teenagers and young adults in astronomy and space technologies. Additional purposes include the satellite's usage as an open-source programming test-bed for students, allowing their commands to be uploaded to the satellite, and its status as a technology demonstrator for the capability of 3D printed structural members and components to withstand the stresses of the launch and space environments.

In this paper we discuss the development of this project, placing special focus on analysis of the rapid prototyping techniques which were employed to expedite the process and minimise costs. These techniques included 3D printing, which has been the subject of much recent research in the international space community due to its ability to provide cheap, light, and customizable components for use in CubeSat missions.

We also present results and lessons-learned from the 2015 Intercollegiate Rocket Engineering Competition (IREC) held this July in Green River, Utah, at which we launched our CubeSat in a two-stage sounding rocket in partnership with the Missouri University of Science and Technology.

A Generalized Theory for the Evolution of Angular Momentum and Azimuthal Magnetic Fields in the Ecliptic Heliosphere

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An analytic, self-consistent, theoretical model for the solar wind is developed that generalizes previous models to include all of the following: conservation of angular momentum, frozen-in magnetic fields, both radial (r) and azimuthal (ϕ) components of the magnetic field (B_r and B_ϕ) and velocity (u_r and v_ϕ) from the source surface to 1 AU, and the detailed tracing back of observations at 1 AU to the solar source surface and all intervening (r, ϕ). The new model applies near the solar equatorial plane, assumes constant radial wind speed at each heliolongitude, and enforces corotation at the source surface.

It is shown that the new theoretical model can be reduced to the previous models in the appropriate limits. We apply the model to two solar rotations of Wind spacecraft data, one near solar minimum (1-27 August 2010) and one near solar maximum (1-27 July 2002).

The model constrains the Alfvénic critical radius r_a to typically be less than fifteen solar radii, in agreement with some recent observations.

Values of $v_\phi(r, \phi)$ are predicted from the model, being always in the sense of corotation but varying in magnitude with r and ϕ . Reasonable and self-consistent results are found for $B_r(r, \phi)$, $B_\phi(r, \phi)$, $v_\phi(r, \phi)$ and $n(r, \phi)$ from the source surface r_s to 1 AU. Both the azimuthal and radial magnetic fields on the source surface vary with time by more than an order of magnitude and usually $|B_r(r_s, \phi_s)| \geq |B_\phi(r_s, \phi_s)|$. Typically, though not always, magnetic contributions to the total angular momentum are small. Interestingly, however, the azimuthal flow velocities observed at 1 AU are not always in the corotation direction and usually have much larger magnitudes than predicted by the model. Conservation of angular momentum alone cannot explain these azimuthal velocities. Issues regarding the model's applicability appear to be due to the assumptions of corotation and constant wind speed breaking down below the Alfvén critical radius.

Why Can't a Planet be more like a Star

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Stars are largely formed from hydrogen and helium (with traces of other elements). Differences among classes of stars are mostly based on their mass, with their behavior being described by the Hertzsprung-Russell (HR) diagram, that reflects the nuclear reactions taking place in these simple gas mixtures. In contrast planets, developed from material left over from accretion around stellar disks, are diverse both in mass and composition.

The planets of our solar system are all distinct from one another for mass, density, composition, rotation rates and obliquity, which makes it impossible to lump them into a simple classification scheme, as the furore over the status of dwarf-planet Pluto shows. Consequently, there is no planetary equivalent of the H-R diagram.

The extraordinary variety of extra-solar planetary systems, as revealed by the Kepler Mission, is perhaps one reason that the origin of the solar system is one of the oldest unresolved problems in science. The problems of studying planets can be illustrated by the long history of attempts to study the history of the Earth, geology being a late-comer among the sciences. Even when nature managed to assemble two planets similar in mass, such as Earth and Venus, we find that they have evolved in completely different ways.

In this talk I will discuss the contrasting geological evolution of these 'twin planets'. I will also address relevant aspects of human evolution, deep time and the possibility of intelligent life developing elsewhere.

Initial Results From The Desert Fireball Camera Network: Meteorites On The Ground

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The Desert Fireball Network (DFN) currently consists of 32 stations located in the Australian Outback covering over one million square kilometres, deployed over the last two years. Recent focus has been on developing the tools and software to detect and analyse the observations made, following on from hardware construction.

The deployed camera systems autonomously detect fireball events in the night-time imagery, and report coordinates to a central server. The server then triangulates the results, and estimates fall position, emailing the operator with any interesting observations. To date, several large fireballs have been recorded and triangulated, most notably two events greater than 10 seconds long, seen by multiple cameras which have almost certainly resulted in meteorite falls.

We will present a brief overview of these events, and an overview of the data processing algorithms and pipeline used to automatically detect them and reduce the number of false alarms reported.

High Frequency and 630 nm Airglow Observations of Travelling Ionospheric Disturbances over Adelaide, Australia

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Defence Science and Technology Group

A Travelling Ionospheric Disturbance (TID) over Adelaide, Australia was observed simultaneously in 630.0 nm airglow and 2 – 20 MHz HF sounder data by the Defence Science and Technology Organisation (DSTO) on the 27th of January 2014. A comparison between the two measurements shows a strong inverse correlation between h'F2 virtual height measurements and airglow intensity. The measurements indicate the initial TID splits into multiple TIDs before reforming. TID wavelength, velocity and period parameters calculated from both airglow and HF measurements and are found to be in agreement.

Early Earth and the making of Mankind: Astrobiology in our own backyard

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Earth has evolved over its 4.5 billion year (Gyr) history from a hot, molten, sterile ball of magma to a cooler planet with large tectonic plates, a global hydrosphere, oxygenated atmosphere, and a thriving, complex biosphere. This transformation has been punctuated not only by extinction-generating meteorite impacts but, at least since 3.2 Ga, by the supercontinent cycle. Recent analysis of subduction proxies shows that the supercontinent cycle had a major effect on rates of crust production and, by extrapolation, volcanic degassing. In turn, these changes affected the composition of the hydrosphere and atmosphere, as well as the biosphere, pointing to a planetary driver of evolutionary change through the Precambrian.

In this presentation I review Precambrian Earth history and show how our planet evolved through a repeated triad of stages, linked to the supercontinent cycle: i) pulses of rapid crust formation and intense volcanic degassing linked to supercontinent assembly; ii) periods of banded iron-formation deposition under reduced oxygenation; iii) ice ages, including the famous "Snowball Earth" event, accompanied by a rise of atmospheric oxygen and evolutionary diversification.

These events eventually led to the rise on our planet of complex life forms, including our species, thus contributing to what has become a very different place from early Earth. There is therefore a deep connection between early Earth and astrobiology, allowing us to study this field literally from our own backyard.

Stochastic Geometry for Space Situational Awareness (SSA)

Ba-Ngu Vo

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Currently, there is no principled methodology for modelling the population of space objects, as a whole, that accounts for uncertainty in the states of these objects as well as the numbers. Stochastic geometric modelling provides the necessary notion of uncertainty for the collection of orbital space objects that is fundamental to SSA, as well as elegant mathematical tools that are ideal for key SSA functionalities. Random finite set (RFS) is the most natural and elegant model for the collection of orbital space objects, since it captures the uncertainty in the number of objects, their states and interactions. Stochastic geometric constructs such as intensity function, void probabilities, Palm distribution etc., enable simple and elegant formulations/solutions to many key SSA tasks that are very complex to formulate using other techniques. In addition these constructs are useful as a visualisation tool as they provide a physically informative summary to a human operator.

Initial Operational Assessment of the Gravity Loading Countermeasure Skinsuit on the International Space Station

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⁵

Despite the use of several countermeasures, significant physical changes and physiological deconditioning due to microgravity still occur in astronauts on International Space Station (ISS) long-duration missions of more than 6 months. As such, new and innovative countermeasures are required to maintain astronaut health on future (and possibly much longer) missions to ISS and beyond. It is likely that loading regimes that mimic those encountered on Earth will provide some degree of prophylaxis during microgravity exposure. Conceived in Australia in 1999, a skinsuit that induces loading on the body to mimic standing on Earth has been developed by the European Space Agency, MIT, Kings College, Dianese and RMIT. The form-fitting elastic fibre mesh of the Gravity Loading Countermeasure Suit (GLCS) allows axial loading to increase gradually from the shoulders to the feet, thereby accurately reproducing the regime normally imparted by body weight due to gravity. It can also be used to harness the crewmember to exercise devices to produce Earth-like impact loads. As a light, comfortable, non-powered and easy-to-use multi-purpose countermeasure, the suit can be used to provide as much as 1-g on orbit, or to supplement loading up to 1-g when worn in partial gravity, such as on the surface of the moon or Mars. The GLCS has been refined and validated through ground and parabolic flight trials, and will be operationally assessed in early September 2015 during a flight to the ISS by Danish astronaut Andreas Mogensen. Specifically, this assessment will examine the ability of

the GLCS to attenuate the increase in stature that occurs in microgravity, which is thought to be associated with in-flight back pain and changes in spinal length and spinal structure morphology. This paper will summarise the development of the suit, and early findings of the ISS assessment from the European Astronaut Centre.

Elemental Devolatilization Patterns of Material in the Solar System

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Bulk chemical compositions of a terrestrial exoplanets are crucial for assessing habitability, but they are not measurable remotely. To estimate the bulk chemical composition of a planet one needs to quantify the chemical relationship between the planet and its host star. Using the best available bulk chemical compositions of the Sun, CI chondrites, and the Earth, we quantified the depletion of volatiles in the Earth and CI chondrites, in combination with the 50% condensation temperatures. The relative elemental abundances of refractory elements are identical to those in the Sun. Moderately volatile elements show intermediate levels of depletion in the Earth, while the most volatile elements are depleted in the Earth and CI chondrites by different levels. The transition between depleted and non-depleted elements occurs at a certain condensation temperature for the Earth and CI chondrites respectively: $T_c(\text{Earth}) = 1430 \pm 45 \text{ K}$ and $T_c(\text{CI}) = 565 \pm 35 \text{ K}$. This difference is probably due to the different thermal and photoevaporation histories of materials at $\sim 1 \text{ AU}$ and $\sim 3 \text{ AU}$ in the solar system. On this basis, compared with the patterns of depletion of volatiles (i.e., devolatilization) in the Earth and CI chondrites, volatiles on Mars are expected to be less depleted than the Earth (more than CI chondrites) and $T_c(\text{Mars})$ should be within the range of 565 - 1430 K. Conversely, Venus should have smaller abundances of volatiles and a higher T_c . Devolatilization is a universal process and is essentially correlated with the effective temperature of a planet in a star system. So a universal effective-temperature-dependent devolatilization pattern is expected for terrestrial planets around Sun-like stars.

ELOISE – Towards an enhanced understanding of ionospheric variability and its impact on radio wave propagation

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Defence Science and Technology Organisation

Over The Horizon Radar (OTHR) systems rely on HF radio-wave propagation to detect and geo-locate targets of interest and must adapt to the variations in propagation which result from variability in the structure of the ionosphere. The ability to measure and model the ionosphere for the purposes of real-time propagation management continues to evolve due to both advances in technology and improved understanding of the underlying geophysical phenomena.

The composition of the ionosphere is driven by a wide range of external and internal forces and the interplay between these forces results in variations in electron density with a wide range of spatial and temporal scales. Because the different kinds of variations are potentially happening simultaneously they can be difficult to separate. Furthermore, they have different signatures on different measurement systems.

The JORN OTHR's incorporate a real time ionospheric model which is driven by data from a network of vertical incidence sounders. An enhanced capability which incorporates data from a network of oblique incidence sounders is under test. The general broad scale day to day and hour to hour variations (solar, thermosphere and internal causes) are largely captured by the model. The current research focus is on improving the ability to measure and model medium scale disturbances in the ionosphere with sufficient accuracy to provide an operationally useful enhancement in geolocation accuracy.

The ELOISE campaigns will observe and characterise mid-latitude ionospheric disturbances using a range of measurement systems. The objective is to establish which processes are or can be adequately modelled for real time application in OTHR and to assess whether additional measurements (eg angle of arrival) might assist in understanding. The first of the ELOISE campaigns will be conducted in weeks leading up to the conference although subsets of the equipment have been under test for some months. This paper will describe the rationale for ELOISE together with an overview of the systems being deployed. Subsequent papers will deal with early results from several of these systems.

Viscosity Formulations in ASPECT: the effect of uncertain parameters

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The development of detailed models of the interior of the Earth and other terrestrial planets is frequently hampered by poorly constrained compositional parameters, namely Activation Energy and Volume, which are necessary to define Arrhenius viscosity. This results in the values of said parameters varying considerably to suit the needs of individual investigations. A computational exploration of the effects of Activation Energy and Volume on the Earth's mantle was thus conducted, with a view to developing a robust and versatile method for obtaining a first-degree approximation for the parameter values, and provide some context for future studies.

A wide range of plausible mantle configurations was examined in both one and two dimensions, in the latter case by utilising the modelling program ASPECT to generate a series of simple Earth-like planets which were allowed to evolve until a steady state was achieved. A comprehensive statistical analysis was performed, allowing for suitable parameter values to be more effectively constrained for numerous given viscosity formulations. Activation Energy was seen to exhibit considerable influence over the bulk magnitude of interior viscosity values, while Activation Volume heavily impacted the viscosity contrast between the upper and lower mantle. This behaviour stems from the parameters controlling the temperature and pressure dependency of viscosity within the calculation. Results were found to be highly dependant on the minimum and maximum values imposed on the viscosity, reinforcing the need for a fuller understanding of the formulation.

A notable impact on stress profiles, and hence tectonic regime, was also observed. As such similar calculations were also performed on directly scaled Super-Earths, with the intention of providing some insight into scenarios conducive to particular tectonic regimes in planets outside our solar system.

Towards an advanced near real-time tropospheric water vapour platform using the Australian NPI for weather forecasting

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It is well known that the GNSS signals are refracted and delayed during the signal propagation path. This delayed signal carries significant signature about the state of the troposphere and can be used to determine precipitable water vapor (PWV) contents in the atmosphere. Recently, the advances in GNSS technologies have suggested that the footprint of the signal captured can be very valuable for both climate and weather forecasting especially nowcasting and severe weather services.

RMIT University together with its collaborators is developing a near real-time PWV monitoring platform for the State of Victoria, Australia. This research is funded through the Natural Disaster Resilience Grant (NDRG) scheme and the overarching goal of the project is to develop a state of the art PWV monitoring platform covering the State of Victoria using the ground-based Continuously Operating Reference Stations (CORS) network together with space-borne and meteorological atmospheric measurement systems. The strategy for the determination of near real-time (NRT) PWV/total zenith delay (ZTD) will be investigated in relation to its use in NWP/weather forecasting, in particular severe weather forecasting and nowcasting.

The paper first introduces the NRDG project and our recent significant effort in using the ground-based system for both weather and climate research. The CORS networks used include GPSnet, ARGN and some selected IGS stations in Australia. Quality assessment is conducted to compare two primary GNSS data processing scenarios: Precise Point Positioning and differential techniques in terms of bias and standard deviations with respect to IGS troposphere products, radiosonde and other meteorological measurements.

The hourly troposphere estimates are investigated and the best scenario will be presented. Our preliminary results suggest that the accuracy of the NRT ZTD/PWV products by using our optimised strategy can meet the needs of Australian NWP. This will be tested using the Australian Community Climate and Earth-System Simulator (ACCESS) numerical weather prediction model.

Thermal evolution of the Moon modelled by core-mantle coupling

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There is a clear dichotomy between the nearside and farside hemispheres of the Moon, and recent findings from GRAIL gravity gradiometry show- a large quasi-rectangular pattern in the Procellarum KREEP Terrane (PKT), which is likely to have been created by a degree-one plume, possibly in response to a magma-ocean overturn. However the thermal evolution of the Moon is not well constrained.

From a modelling perspective, production of a degree-one feature after the overturn is challenging, due to its small size, small core, and low gravity. Recent modelling studies have only been able to produce degree-one plumes with very low activation energies, or a pre-defined KREEP layer under the PKT region. On the other hand, the Moon is likely to have a long lasting gravity field, even though it only has a relatively small core. Previous evolutionary models have failed to produce a long lasting core dynamo, even including energy sources from freezing of the core. Mechanical stirring has been postulated as an additional source for driving a longer lasting Moon dynamo. This mechanism has never been incorporated in mantle dynamic models before.

Here we carry out dynamic mantle simulations of the Moon, coupled with a parameterized core evolution. We explore different rheological parameters and initial conditions to constrain the thermal evolution and magnetic history of the Moon.

A Method for Improving Two-line Element Outlier Detection Based on a Consistency Check

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As the most complete source of orbital element information available to the public, the NORAD two-line element sets (TLEs) are used in a wide variety of orbit propagation tasks. Unfortunately, there is no error information provided for TLEs and therefore no measure of the data quality. Due to orbit manoeuvres, errors introduced during the TLE generation and unmodeled perturbations, there are inevitable outliers in the TLEs, which have a large deteriorative impact on orbit determination and propagation. Most of the current methods identify outliers using the three-sigma rule or a Mahalanobis distance-based detection method. However, in these methods the different perturbation characteristics of space objects in different altitudes are not taken into account. This study presents an improved method for detecting outliers in the TLEs based on a consistency check on pairwise differential residuals of adjacent TLEs. A filter based on the principle of locally weighted regression is applied on the pairwise differential residuals to investigate their underlying structure. The detection threshold is then determined by the variance of the filtered residuals in the moving window.

Satellites from different altitudes with known manoeuvre histories were selected to assess the effectiveness of this improved method. Our results show that this method can achieve reliable detection of the manoeuvre events. The difference between the characteristics of TLE outliers of satellites and debris objects is also analysed to facilitate the application of the satellite-based method to debris to identify erroneous TLEs. Finally, a set of criteria for TLE outlier detection are proposed based on the different characteristics of space objects according to their altitudes. It is expected that this improved method will contribute to more robust orbit propagation and conjunction analysis using TLEs.