The Australian Centre for Space Engineering Research (ACSER)

The Australian Centre for Space Engineering Research (ACSER) was launched at the University of New South Wales on the 22nd November 2010 by former astronaut Dr. Jan Davis. ACSER aims to provide national leadership for Australian space engineering research by fostering collaborations between researchers, industry and government and to nurture links between our national and international partners to achieve Australia’s space ambitions. ACSER’s purpose is to develop space capabilities relevant to Australia’s needs through research, innovation and education.

ACSER regularly organises forums, workshops and seminars on a range of space-related topics of interest for the wider space community. These events help bring everyone who is working on similar space related research and activity together to encourage future collaborations and strengthen Australia’s place in space.

Off Earth Mining Forum

The prospect of people settling away from Earth has been a topic for dreamers and visionaries for some time. But if it’s ever to happen for real, there needs to be more than starry-eyed optimism. There needs to be a business model, and ways of supporting the colonists.

The business model exists, and it’s one we’ve tried before. When Europe colonised the Americas (from 1492 onwards), it was the gold and other riches that could be extracted from that land which drew the colonists. A similar opportunity exists in space, without the bloodshed of those conquests.

In 2012, the US-based company Planetary Resources was set up as a new venture to mine asteroids for water, rare minerals and other high-value materials. The gold we use on Earth is believed to have come from asteroids and was not on the earth when it was molten, and objects the size of planets have been discovered which are mainly diamond. A rival to Planetary Resources, Deep Space Industries, has also recently been established, looking for platinum.

The first uses for these mining applications would in fact not be to return them to Earth for exploitation, but to aid in other space activities, such as “refuelling” satellites or missions going further afield, such as to Mars.

Of course, there are many barriers to setting up a mining operation in space. Machinery must be designed to work with different types of soils, in zero or low gravity. Automation of that equipment must be such that it needs little intervention from Earth. That automated equipment must be able to position itself without GPS. And it all must work first time, after exhaustive simulation on Earth.

Further, there are the legal issues – who owns those resources? Are existing treaties robust enough? How do you secure your mine? And there are the economics: how well has the geology been studied? Are you mining in the right place? Can a return be guaranteed?

These and many other related issues will be discussed in this first forum of its type in Australia, and possibly the world. The forum will allow the blue (black?) sky researchers to test their ideas with hard-headed miners. The extreme needs of space may well produce useful outcomes for terrestrial mining, particularly in the area of automation.

There is also a logic to its being held in Australia. It allows an industry where Australia is a world leader – mining – to assist in developing an area where Australia is weak – upstream space systems development. Mining is already well-developed in Australia, but improving its productivity has been a subject for recent debate. Australia developing upstream space capability will also be a strong driver to delivering the higher productivity the government seeks.

There are various estimates of when the first off-Earth mine will be established. Some say within a decade. Whenever it is, it is highly likely it will be the next significant step in our colonisation of space.
Organising Committee

Professor Andrew Dempster

Professor Andrew Dempster is Director of the Australian Centre for Space Engineering Research (ACSER) at the University of New South Wales (UNSW). He has a BE and MEngSc from UNSW and a PhD from University of Cambridge in efficient circuits for signal processing arithmetic. He was system engineer and project manager for the first GPS receiver developed in Australia in the late 80s and has been involved in satellite navigation ever since. His current research interests are in satellite navigation receiver design and signal processing, areas where he has six patents, and new location technologies. He is leading the development of space engineering research at ACSER.

Associate Professor Leonhard Bernold

Associate Professor Leonhard Bernold has a Ph.D. in Civil Engineering from Georgia Institute of Technology in Atlanta. In 1986, he was an Assistant Prof at the University of Maryland, he started to work on problems related to Lunar excavation and construction which kept his interest until today. He joined UNSW in 2011, where he has been experimenting with innovative mining technologies for Moon, construction methods to build hollow beams using waterless concrete and studying efficient concepts to store solar thermal energy in the lunar subsurface. Leonhard has published 90 journal articles and over 110 conference papers.

Associate Professor Serkan Saydam

Associate Professor Serkan Saydam is a Mining Engineer with over 20 years of experience in research and mining projects in Turkey, South Africa and Australia. After working as a Research Assistant in Dokuz Eylül University (Turkey) where he completed his research-based Masters Degree and PhD, he spent 4 years in South Africa between 2002 and 2006: 1 year as Post Doctorate Fellow at the School of Mining Engineering at the University of Witwatersrand and 3 years as a Project Manager in a world-leading mining company. In 2006, he joined UNSW’s School of Mining Engineering. He is the originator and the chair of the International Future Mining Conference Series organised in 2008 and 2011.

Keynote Speaker

Mars Curiosity, her successes and challenges
René Fradet
Deputy Director of Engineering & Science Directorate, Jet Propulsion Laboratory, NASA

NASA’s Mars Science Laboratory mission set down a large, mobile laboratory - the rover Curiosity - at Gale Crater, using precision landing technology that makes many of Mars’ most intriguing regions viable destinations for the first time. During the 23 months after landing, Curiosity will analyse dozens of samples drilled from rocks or scooped from the ground as it explores with greater range than any previous Mars rover.

Curiosity carries the most advanced payload of scientific gear ever used on Mars’ surface, a payload more than 10 times as massive as those of earlier Mars rovers. Its assignment: Investigate whether conditions have been favourable for microbial life and for preserving clues in the rocks about possible past life.

This talk will survey the tremendous successes of Curiosity so far, from landing on Mars to photographing, sampling and inspecting her surface. Some of the challenges facing Curiosity in the future include robotically drilling on the surface of Mars. This will be the first time since the Apollo program that humanity has drilled rocks on a non-Earth body, and the first time ever for a robot explorer.

René Fradet is the Deputy Director, Engineering and Science Directorate at NASA’s Jet Propulsion Laboratory (JPL) in Pasadena, California. From 2009 through 2010, René was the Flight System Manager for the Mars Sample Laboratory (MSL) where he was responsible for the overall development of the MSL Flight System. Before assuming his present leadership post at JPL, René was the founder, president and CEO of Alliance Spacesystems, also of Pasadena. René’s company built a wide range of space mechatronic systems, most notably the Robot Arm for Curiosity, as well as the robot arms for the Phoenix lander and the earlier Spirit and Opportunity rovers. Opportunity and its arm are still operational on Mars after almost ten years.

Before founding Alliance, René was at JPL as the Deputy Spacecraft Manager on the New Millennium Program Deep Space One (DS1) Project. Deep Space One travelled far beyond Earth’s orbit, visited both an asteroid and a comet, and was the first spacecraft to use an ion propulsion main engine rather than chemical propulsion for deep space missions.
An Innovative Approach to Space

**Kim Ellis** is an expert in hydrometallurgy, process chemistry and mineral processing. Kim is well placed to speak with authority on mining, mineral processing and business innovation. She has designed and developed both theoretical and practical methods and novel techniques in mineral processing, in particular for pilot plant operations. As part of a large international multidisciplinary team, Kim researched Non-Terrestrial Mining and developed a roadmap for future commercial mining operations in space. Kim’s company, International Earth and Space Technology is currently developing business innovation tools and provides consultancy services.

**Dr. Gordon Roesler** is a visiting researcher at ACSER. His professional focus has been on the engineering of complex systems. At the University of Southern California, he was the principal investigator for two DARPA projects using artificial intelligence techniques for the conceptual design of multi-vehicle systems. From 2002 to 2006, he was a program manager at the U.S. Defence Advanced Research Projects Agency, where he led programs in spacecraft, space surveillance radar, and electromagnetic launch. He conceived and managed a robotic “space tow truck” and oversaw the development of critical technologies being used in NASA and DARPA projects today.

**Donna Lawler** is a commercial satellite lawyer for Optus and a member of the International Institute of Space Lawyers. Over more than a decade in the satellite industry she has had key involvement in the build and launch programmes for six satellites on behalf of Optus and its parent company SingTel. Today she is relied on by Optus for advice on all legal aspects of its satellite business, including securing the use of orbital slots, advising on risk, liability and insurance issues for space-related projects and negotiating satellite capacity contracts with Australian broadcasters, international satellite operators and Government entities, including the NBN. She has published joint papers on Space Law topics internationally and is a presenter on commercial Space Law topics in Australia, Europe and the United States.

**Enabling Technologies**

**Professor Chris Rizos** is the Head of the School of Surveying & Geospatial Engineering at the University of New South Wales, Sydney, Australia. Chris has been researching the technology and applications of GPS since 1985, and established over a decade ago Australia’s premier academic satellite navigation and wireless location technology research group. Chris is President of the International Association of Geodesy (IAG), Co-chair of the Multi-GNSS Asia Steering Committee, and a member of the Executive and Governing Board of the International GNSS Service (IGS). Chris has been conducting research into pseudolite technology for over 13 years, and in that time has assisted with the testing of Locata in a variety of applications.

**Behrokh Khoshnevis** is the Director of the Centre for Rapid Automated Fabrication Technologies (CRAFT) at University of Southern California. He is active in CAD/CAM, robotics and mechatronics related research projects that include the development of novel Solid Free Form, or Rapid Prototyping, processes (Contour Crafting and SIS), automated construction of civil structures and autonomous mobile and modular robots for assembly applications on earth and in space. The automated construction invention, Contour Crafting, was selected in 2006 as one of top 25 best inventions by the National Inventors Hall of Fame and the History Channel’s Modern Marvels program.

**Adrian Boeing** is a senior engineer with the Control and Automation Division of Transmin - award winning innovators in Remote Operation and Automation of heavy duty hydraulic mining and materials handling equipment. Adrian has previously developed advanced driver assistance systems for the automotive industry, and worked on defence and aerospace applications with Raytheon, Thales and the German aerospace agency DLR (Deutschen Zentrums für Luft und Raumfahrt). Adrian completed his PhD in robotics at The University of Western Australia. Adrian takes an active interest in robotics competitions and took part in the DARPA Urban challenge and in the DSTO Multi Autonomous Ground Robotic International Challenge (MAGIC 2010).

**Pieter Prinsloo** qualified as a Process Control Systems Engineer in 1998 from the Pretoria University of Technology. He started his journey in Sandvik Mine Automation in October, 2002 when he was appointed as an Automation System Engineer in the Sandvik Tampere Factory in Finland. In the Department of Automation within Sandvik, Peter has had various roles, which ranged from System and Project Engineer, to Project Manager and Global Automation Product Specialist, to more recently being appointed as the Regional Automation Product Manager for Sandvik APAC. Peter has also been involved in automation forums and consultation within the public and private sectors.

**Dr. Hajime Yano** is Assistant Professor at the Department of Interdisciplinary Space Science, ISAS/JAXA, Japan. He earned his Ph.D. in space science at the University of Kent at Canterbury, U.K., in 1995. His research extends to in-situ measurement and collection and micro-analysis of meteoroids and orbital debris in both earth orbiting satellites and deep space probes, optical and spectroscopic observations of meteors, spacecraft exploration to solar system small bodies, such as asteroids and comets. He was involved in the Hayabusa mission, the world’s first asteroid sample return accomplished in 2010, for 17 years and developed an impact sampling device as well as fetched its return capsule in the Woomera Desert. He was involved in over ten other space experiments and missions in the field of cosmic dust and small body research.
Matthew Dunbabin is a Principal Research Scientist within the CSIRO Autonomous Systems Laboratory. His research interests focus on Field Robotics with a particular emphasis on environmental and mining robots. Matthew joined CSIRO in 2001 to work in the area of Mining Robotics and his research activities have included the development and field application of advanced robotic solutions to the control and performance enhancement of mining machines, specifically shovels and draglines. He was an original researcher on rope shovel automation working on fully autonomous digging and truck loading, and has worked extensively with the dragline automation team on machine control achieving optimal path planning for improved swing performance, precision dumping and automated digging.

Daniel Linton is a third year Aeronautical (Space) Engineering student who currently leads Sydney Lunabotics. Sydney Lunabotics is a team of 16 students from the University of Sydney, they are competing for the first time in NASA's 2013 Lunabotics Lunar Mining Competition. The team at Sydney Lunabotics are challenged with building a lunar mining vehicle capable of overcoming the unique difficulties encountered in mining the moon. Students from the wider community are introduced to the exciting idea of Off-Earth Mining through the outreach programs run by the team.

Resource Utilization

Dr. Philip Metzger is a research physicist and founder of the Granular Materials and Regolith Operations Laboratory at NASA's Kennedy Space Center, which develops space mining and civil engineering technologies and strategies for the Moon, Mars, asteroids, and other bodies, including geotechnical characterization, excavation, site preparation, construction of launch & landing pads and blast mitigation techniques, lightweight composite structures, regolith conveyance for resource extraction, and dust mitigation. He leads the Agency's research into the physics of rocket exhaust interacting with soil for human spaceflight. Dr. Metzger has worked for NASA since 1985, first as part of the Space Shuttle launch team and later with the International Space Station program before moving into exploration technology development.

Robert Mueller is a Senior Technologist for Advanced Projects Development at NASA Kennedy Space Centre (KSC) in the Engineering Directorate and co-founder of the NASA KSC Granular Mechanics & Regolith Operations (GMRO) Lab. Mr. Mueller is the chair of the American Society of Civil Engineers (ASCE) Committee for Regolith Operations, Mobility and Robotics and he is the founder and Head Judge of the annual NASA Lunabotics Mining Competition for Universities. Mr. Mueller has been leading the development of technologies required for Lunar Surface Systems including developing the specifics of Lunar Regolith Excavation and other Surface Support Equipment. He has also worked for NASA at Johnson Space Centre and the Jet Propulsion Lab.

Dr. Kris Zacny is Vice President and Director of Exploration Technology Group at Honeybee Robotics. His expertise includes robotic terrestrial and extraterrestrial drilling and excavation. He worked in South African mines before moving to US where he completed PhD at UC Berkeley in extraterrestrial drilling. He participated in several Arctic, Antarctic, Greenland, Atacama, Mauna Kea, and Mojave drilling expeditions. Dr. Zacny has over 100 publications, has been a Principal Investigator (PI) and a Co-I of over 60 NASA and DoD projects, and has over 15 NASA New Technology Records, and three NASA Group Achievement Awards.

Research with Soil Simulants and Analogues

Laurent Sibille is a lead technology development scientist and a project lead for Team QNA-ESC in the Surface Systems Group and the SwampWorks lean development group at NASA Kennedy Space Centre, Florida (USA). His twenty years of science investigation experience and new technology development for NASA programs have covered many disciplines. He co-founded the current Lunar Simulant Materials program in 2005 and the workshop on Lunar Regolith Simulant Materials that has produced simulant materials standards and evaluation tools since. He is a technical lead project manager on the RESOLVE prototype payload team whose mission is to obtain and analyse core samples of lunar icy regolith.

Christian Andersen is the Test Operations Manager of the Pacific International Space Centre for Exploration Systems (PISCES) and a lecturer in Physics and Mathematics at the University of Hawaii at Hilo. He is the incoming Vice-Chair of the AIAA Space Resources Technical Committee and has been awarded three NASA Group Achievement Awards. Christian holds a B.S. in Physics from San Jose State University and a M.S. in Engineering Records, and three NASA Group Achievement Awards.

Dr. Jon Clarke is a research physicist and founder of the Granular Materials and Regolith Operations Laboratory at NASA's Kennedy Space Center, which develops space mining and civil engineering technologies and strategies for the Moon, Mars, asteroids, and other bodies, including geotechnical characterization, excavation, site preparation, construction of launch & landing pads and blast mitigation techniques, lightweight composite structures, regolith conveyance for resource extraction, and dust mitigation. He leads the Agency's research into the physics of rocket exhaust interacting with soil for human spaceflight. Dr. Metzger has worked for NASA since 1985, first as part of the Space Shuttle launch team and later with the International Space Station program before moving into exploration technology development.

Dr. Zacny has over 100 publications, has been a Principal Investigator (PI) and a Co-I of over 60 NASA and DoD projects, and has over 15 NASA New Technology Records, and three NASA Group Achievement Awards.

Laurent Sibille is a lead technology development scientist and a project lead for Team QNA-ESC in the Surface Systems Group and the SwampWorks lean development group at NASA Kennedy Space Centre, Florida (USA). His twenty years of science investigation experience and new technology development for NASA programs have covered many disciplines. He co-founded the current Lunar Simulant Materials program in 2005 and the workshop on Lunar Regolith Simulant Materials that has produced simulant materials standards and evaluation tools since. He is a technical lead project manager on the RESOLVE prototype payload team whose mission is to obtain and analyse core samples of lunar icy regolith.

Christian Andersen is the Test Operations Manager of the Pacific International Space Centre for Exploration Systems (PISCES) and a lecturer in Physics and Mathematics at the University of Hawaii at Hilo. He is the incoming Vice-Chair of the AIAA Space Resources Technical Committee and has been awarded three NASA Group Achievement Awards. Christian holds a B.S. in Physics from San Jose State University and a M.S. in Engineering Records, and three NASA Group Achievement Awards.

Dr. Jon Clarke is a research physicist and founder of the Granular Materials and Regolith Operations Laboratory at NASA's Kennedy Space Center, which develops space mining and civil engineering technologies and strategies for the Moon, Mars, asteroids, and other bodies, including geotechnical characterization, excavation, site preparation, construction of launch & landing pads and blast mitigation techniques, lightweight composite structures, regolith conveyance for resource extraction, and dust mitigation. He leads the Agency's research into the physics of rocket exhaust interacting with soil for human spaceflight. Dr. Metzger has worked for NASA since 1985, first as part of the Space Shuttle launch team and later with the International Space Station program before moving into exploration technology development.

Dr. Zacny has over 100 publications, has been a Principal Investigator (PI) and a Co-I of over 60 NASA and DoD projects, and has over 15 NASA New Technology Records, and three NASA Group Achievement Awards.

Laurent Sibille is a lead technology development scientist and a project lead for Team QNA-ESC in the Surface Systems Group and the SwampWorks lean development group at NASA Kennedy Space Centre, Florida (USA). His twenty years of science investigation experience and new technology development for NASA programs have covered many disciplines. He co-founded the current Lunar Simulant Materials program in 2005 and the workshop on Lunar Regolith Simulant Materials that has produced simulant materials standards and evaluation tools since. He is a technical lead project manager on the RESOLVE prototype payload team whose mission is to obtain and analyse core samples of lunar icy regolith.

Christian Andersen is the Test Operations Manager of the Pacific International Space Centre for Exploration Systems (PISCES) and a lecturer in Physics and Mathematics at the University of Hawaii at Hilo. He is the incoming Vice-Chair of the AIAA Space Resources Technical Committee and has been awarded three NASA Group Achievement Awards. Christian holds a B.S. in Physics from San Jose State University and a M.S. in Engineering Records, and three NASA Group Achievement Awards.
Simulants and Analogues for Space Mining Research Workshop - Tuesday 19th February 2013

How will we design and test technologies to be used for mining and construction in space? How will engineers be able to create the requisite expertise and knowledge that took thousands of years to develop on Earth?

Since the Apollo missions, sophisticated facilities have been built to simulate extraterrestrial sites in order to train and test astronauts, out-of-this-world tools, equipment, and vehicles. At the same time, the educational contributions of those centres have been invaluable.

At this workshop, six international experts will address problems related to establishing facilities that simulate environments that have so far never been visited by men. The presenters will discuss the creation of soil simulants, subsurface geology and surface analogues that provide adequate fidelity for chemical composition, mineralogy, density, strength, etc. Other challenges to be discussed in the workshop are the consequences of vacuum and (micro) gravity.

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
<th>Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>01:00pm</td>
<td>Welcome</td>
<td>Leonhard Berndol</td>
<td>University of New South Wales</td>
</tr>
<tr>
<td>01:10pm</td>
<td>Smooth and Rough Terrains on Asteroid Surfaces: What We Learned from Hayabusa's Visit to Itokawa</td>
<td>Hajime Yano</td>
<td>ISAS, Japan Aerospace Exploration Agency (JAXA)</td>
</tr>
<tr>
<td>01:40pm</td>
<td>Lunar Simulant Materials, Analogues, and Standards: Needs and Realities in Mission Technologies Development</td>
<td>Laurent Sibille</td>
<td>NASA, Kennedy Space Centre</td>
</tr>
<tr>
<td>02:10pm</td>
<td>Introduction to Extraterrestrial Drilling, Excavation, and Mining</td>
<td>Kris Zacny</td>
<td>Honeybee Robotics</td>
</tr>
<tr>
<td>02:40pm</td>
<td>Break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>03:00pm</td>
<td>Research on Lunar Mining and Construction at UNSW</td>
<td>Leonhard Berndol</td>
<td>University of New South Wales</td>
</tr>
<tr>
<td>03:30pm</td>
<td>Analogue stations for planetary research</td>
<td>Jonathan Clarke</td>
<td>Mars Society Australia</td>
</tr>
<tr>
<td>04:00pm</td>
<td>PISCES: Hawaii as an analog testbed for planetary surface systems</td>
<td>Christian Andersen</td>
<td>Pacific International Space Centre for Exploration Systems</td>
</tr>
<tr>
<td>04:30pm</td>
<td>Workshop Discussion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>05:00pm</td>
<td>Workshop Close</td>
<td>Leonhard Berndol</td>
<td>University of New South Wales</td>
</tr>
</tbody>
</table>

Dr. Jason Held, prior to founding Saber Astronautics, was a US Army Major and Space Support Team leader for USSTRATCOM (formerly Space Command) and deployed globally in support of military space missions. He was a flight software engineer on the Hubble Space Telescope and test engineer for the International Space Station. He was a senior space instructor for USSTRATCOM and an engineer for the Space and Missile Command Battle Lab. At the University of Sydney, he founded the space engineering laboratory, providing leadership for the university small satellite project and Australia’s first premix rocket engine. He is also an active member of AIAA’s Space Logistics Technical Committee.

Dr. Alice Gorman is the Team Leader of Archaeology with Australian Cultural Heritage Management Pty Ltd, an Adelaide-based heritage firm which specialises in managing Indigenous heritage for the mining sector. She is also a lecturer in the Department of Archaeology at Flinders University. She is an internationally recognised expert in the material culture and heritage of space exploration, having pioneered the concept of space as a cultural landscape, and the application of Australia’s Burra Charter cultural significance criteria to space objects and places. Her research focuses on orbital debris, terrestrial launch sites and tracking stations.

Mark Sonter was a visiting scholar at University of Arizona Lunar & Planetary Laboratory in 1995, and wrote a research thesis on ‘The Technical and Economic Feasibility of Mining the Near-Earth Asteroids’. His asteroid mining interests were re-energized a little less than 2 years ago with the formation of the Asteroid Mining Group, to look into the possibility for return to high earth orbit of very small asteroids. AMG's findings were serendipitously validated by the Keck Institute for Space Science Asteroid Retrieval Mission Study published in February last year. Following further business and concept development work, Deep Space Industries Inc was incorporated, and made its public debut on 22nd January 2013. Mark is a founder and the senior mining and metallurgy advisor to DSI.

Roy Sach spent 22 years in the RAAF followed by 20 more as a Department of Defence civilian. He has worked in Russia, France, Britain, Israel, Canada and the US, among other locations. While in the US he served a term as a senior analyst in the Executive Office of the President of the United States (Pres. Clinton) and completed a Senior Executive Fellowship at Harvard University. Roy has undertaken a variety of assignments associated with both commercial and military aspects of satellites, the sensors they carry and their associated ground stations. His final Australian Defence assignment was as Director, Defence Space. He is currently developing his PhD thesis at UNSW (Faculty of Science) where he is investigating aspects of security in the space environment.

Off-Earth Mining In a Larger Context

Bernold Andersen

Christian Clarke

Leonhard Berndol

Hajime Yano

Laurent Sibille

Kris Zacny

Mark Sonter

Simulants and Analogues for Space Mining Research Workshop - Tuesday 19th February 2013

How will we design and test technologies to be used for mining and construction in space? How will engineers be able to create the requisite expertise and knowledge that took thousands of years to develop on Earth?

Since the Apollo missions, sophisticated facilities have been built to simulate extraterrestrial sites in order to train and test astronauts, out-of-this-world tools, equipment, and vehicles. At the same time, the educational contributions of those centres have been invaluable.

At this workshop, six international experts will address problems related to establishing facilities that simulate environments that have so far never been visited by men. The presenters will discuss the creation of soil simulants, subsurface geology and surface analogues that provide adequate fidelity for chemical composition, mineralogy, density, strength, etc. Other challenges to be discussed in the workshop are the consequences of vacuum and (micro) gravity.

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
<th>Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>01:00pm</td>
<td>Welcome</td>
<td>Leonhard Berndol</td>
<td>University of New South Wales</td>
</tr>
<tr>
<td>01:10pm</td>
<td>Smooth and Rough Terrains on Asteroid Surfaces: What We Learned from Hayabusa's Visit to Itokawa</td>
<td>Hajime Yano</td>
<td>ISAS, Japan Aerospace Exploration Agency (JAXA)</td>
</tr>
<tr>
<td>01:40pm</td>
<td>Lunar Simulant Materials, Analogues, and Standards: Needs and Realities in Mission Technologies Development</td>
<td>Laurent Sibille</td>
<td>NASA, Kennedy Space Centre</td>
</tr>
<tr>
<td>02:10pm</td>
<td>Introduction to Extraterrestrial Drilling, Excavation, and Mining</td>
<td>Kris Zacny</td>
<td>Honeybee Robotics</td>
</tr>
<tr>
<td>02:40pm</td>
<td>Break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>03:00pm</td>
<td>Research on Lunar Mining and Construction at UNSW</td>
<td>Leonhard Berndol</td>
<td>University of New South Wales</td>
</tr>
<tr>
<td>03:30pm</td>
<td>Analogue stations for planetary research</td>
<td>Jonathan Clarke</td>
<td>Mars Society Australia</td>
</tr>
<tr>
<td>04:00pm</td>
<td>PISCES: Hawaii as an analog testbed for planetary surface systems</td>
<td>Christian Andersen</td>
<td>Pacific International Space Centre for Exploration Systems</td>
</tr>
<tr>
<td>04:30pm</td>
<td>Workshop Discussion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>05:00pm</td>
<td>Workshop Close</td>
<td>Leonhard Berndol</td>
<td>University of New South Wales</td>
</tr>
</tbody>
</table>
### Wednesday 20th February 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Chair</th>
<th>Speaker</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:30</td>
<td>Forum Welcome and Introduction</td>
<td></td>
<td>Andrew Dempster</td>
<td>ACSR</td>
</tr>
<tr>
<td>09:00</td>
<td>Space Business Innovation</td>
<td></td>
<td>Kim Ellis</td>
<td>Earth Space Technology</td>
</tr>
<tr>
<td>09:30</td>
<td>System Engineering for an Off Earth Mining Capability</td>
<td></td>
<td>Gordon Roesler</td>
<td>University of New South Wales</td>
</tr>
<tr>
<td>10:00</td>
<td>The Moon - a Lawless Outpost?</td>
<td></td>
<td>Donna Lawler</td>
<td>Optus Satellite</td>
</tr>
<tr>
<td>10:30</td>
<td>Morning Tea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Wednesday - Morning Session 1</strong> - An Innovative Approach to Space**</td>
<td>Behrokh Khoshnevis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09:00</td>
<td>Space Business Innovation</td>
<td></td>
<td>Kim Ellis</td>
<td>Earth Space Technology</td>
</tr>
<tr>
<td>09:30</td>
<td>System Engineering for an Off Earth Mining Capability</td>
<td></td>
<td>Gordon Roesler</td>
<td>University of New South Wales</td>
</tr>
<tr>
<td>10:00</td>
<td>The Moon - a Lawless Outpost?</td>
<td></td>
<td>Donna Lawler</td>
<td>Optus Satellite</td>
</tr>
<tr>
<td>10:30</td>
<td>Morning Tea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td><strong>Wednesday - Morning Session 2</strong> - Enabling Technologies**</td>
<td>Gordon Roesler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td>Locata: a Technology Component of Mine Automation</td>
<td>Chris Rizos</td>
<td>UNSW, on behalf of Locata &amp; Leica Geosystems</td>
<td></td>
</tr>
<tr>
<td>11:30</td>
<td>Microgravity Geology: A New Challenge for Human and Robotic Space Exploration</td>
<td>Hajime Yano</td>
<td>ISAS, Japan Aerospace Exploration Agency (JAXA)</td>
<td></td>
</tr>
<tr>
<td>12:00</td>
<td>Virtual Mine (ViMINE) - An innovative Simulation Technique for Novel Mining Systems</td>
<td>Serkan Saydam</td>
<td>University of New South Wales</td>
<td></td>
</tr>
<tr>
<td>12:30</td>
<td>Lunch and Demonstration Tours: ViMINE-Virtual Mine Simulation: iCINEMA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01:30</td>
<td><strong>Wednesday - Afternoon Session 1</strong> - Automation**</td>
<td>Serkan Saydam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>01:30</td>
<td>Mining Machine Automation</td>
<td>Pieter Prinsloo</td>
<td>Sandvik Mining and Construction</td>
<td></td>
</tr>
<tr>
<td>02:00</td>
<td>Lunar and Martian Robotic Construction using In-Situ Resource Utilization</td>
<td>Behrokh Khoshnevis</td>
<td>University of Southern California</td>
<td></td>
</tr>
<tr>
<td>02:30</td>
<td>Remotely Operated Robotic Rock Breaker</td>
<td>Adrian Boeing</td>
<td>Transmin Pty Ltd</td>
<td></td>
</tr>
<tr>
<td>03:00</td>
<td>Off-world Robotic Excavation for Large-Scale Resource Extraction and Habitat Construction</td>
<td>Matthew Dunbabin</td>
<td>Commonwealth Scientific and Industrial Research Organisation (CSIRO)</td>
<td></td>
</tr>
<tr>
<td>03:30</td>
<td>Representing Australia at NASA's Lunabotics Lunar Mining Competition</td>
<td>Daniel Linton</td>
<td>Sydney Lunabotics</td>
<td></td>
</tr>
<tr>
<td>03:45</td>
<td>Afternoon Tea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>04:15</td>
<td>OEMF Working Group Introduction</td>
<td>Andrew Dempster</td>
<td>ACSR</td>
<td></td>
</tr>
<tr>
<td>04:30</td>
<td>Mars Curiosity, her successes and challenges</td>
<td>René Fradet</td>
<td>Jet Propulsion Laboratory</td>
<td></td>
</tr>
</tbody>
</table>

### Thursday 21st February 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Chair</th>
<th>Speaker</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>The Coming Revolution of Industry in Space</td>
<td>Philip Metzger</td>
<td>NASA, KSC - By Video</td>
<td></td>
</tr>
<tr>
<td>09:30</td>
<td>Behavior of Lunar Simulants in Reduced Gravity Flights</td>
<td>Robert Mueller</td>
<td>NASA, KSC - By Video</td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td>Water Extraction System for Moon, Mars, and Asteroids</td>
<td>Kris Zacy</td>
<td>HoneyBe Robotcis</td>
<td></td>
</tr>
<tr>
<td>10:30</td>
<td>Morning Tea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td><strong>Thursday - Morning Session 1</strong> - Resource Utilization**</td>
<td>Leonhard Bernold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td>The Coming Revolution of Industry in Space</td>
<td>Philip Metzger</td>
<td>NASA, KSC - By Video</td>
<td></td>
</tr>
<tr>
<td>11:30</td>
<td>PISCES Lunar Concrete Pilot Project</td>
<td>Christian Andersen</td>
<td>Pacific International Space Center for Exploration Systems</td>
<td></td>
</tr>
<tr>
<td>12:00</td>
<td>What can the Australian Experience Teach us about Exploring and Mining the Moon?</td>
<td>Jonathan Clarke</td>
<td>Australian Centre for Astrobiology</td>
<td></td>
</tr>
<tr>
<td>12:30</td>
<td>An Australian Soil Simulant to Study Lunar Mining and Construction</td>
<td>Leonhard Bernold</td>
<td>University of New South Wales</td>
<td></td>
</tr>
<tr>
<td>01:00</td>
<td>Lunch and Demonstration Tours: ViMINE-Virtual Mine Simulation: iCINEMA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>02:00</td>
<td><strong>Thursday - Afternoon Session 1</strong> - Analytical Frameworks**</td>
<td>Gordon Roesler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>02:00</td>
<td>Reducing Costs of Space Operations Using Predictive Modelling</td>
<td>Jason Held</td>
<td>Saber Astronautics</td>
<td></td>
</tr>
<tr>
<td>02:30</td>
<td>Project Concepts for Near-Term Commercial Asteroid Mining</td>
<td>Mark Sonter</td>
<td>Asteroid Enterprises Pty Ltd</td>
<td></td>
</tr>
<tr>
<td>03:00</td>
<td>Afternoon Tea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>03:30</td>
<td><strong>Thursday - Afternoon Session 2</strong> - Off-Earth Mining In a Larger Context**</td>
<td>Andrew Dempster</td>
<td></td>
<td></td>
</tr>
<tr>
<td>03:30</td>
<td>Fundamentals of Space Security</td>
<td>Roy Sach</td>
<td>University of New South Wales</td>
<td></td>
</tr>
<tr>
<td>04:00</td>
<td>Managing Heritage Values in Lunar and Asteroid Mining: What Are the Issues</td>
<td>Alice Gorman</td>
<td>Australian Cultural Heritage Management Pty Ltd</td>
<td></td>
</tr>
<tr>
<td>04:30</td>
<td>Forum Discussion and Close</td>
<td>Andrew Dempster</td>
<td>ACSR</td>
<td></td>
</tr>
</tbody>
</table>
Social Events

Welcome Reception
Tuesday 19th February 2013, 5.30pm to 7.30pm - Mathews Pavilions, UNSW
Immediately after the Simulants and Analogues for Lunar Mining Research Workshop come and enjoy a drink and canapés and meet all of the forum attendees. Tickets included in all registration packages.

Sydney Harbour Dinner Cruise
Wednesday 20th February 2013, 7.00pm to 10.30pm - The Commissioners’ Steps at the Circular Quay

The Harbour Cruise is the ideal opportunity to catch up with friends – old and new, in a relaxed environment. Enjoy the buffet, drinks, and of course the magnificent views on the world famous, Sydney Harbour. Tickets are included in both Academic/ Individual and Company Two Day Registrations packages. Additional tickets can be purchased at the registration desk for $35 per ticket.

The Harbour cruise will leave from the Commissioners’ Steps at the Circular Quay at 7:30pm, boarding from 7:00pm. Be on time as the boat will not wait for you if you are late!

You can take any of the following buses that stop at Circular Quay:

- **Buses 392, 394, 396, 397, 399, L94**
- **Departure:** UNSW Main Gate on Anzac Pde
- **Arrival:** Young Street, Circular Quay

There are many parking stations in the Circular Quay precinct. The Wilson’s Secure Parking Station (35 Pitt Street) offers special rates for Captain Cook Cruise’s customers.

General Information

Off Earth Mining Forum Website
All the information contained in this brochure and presentations, photos and videos will be made available after the forum on our website: www.acser.unsw.edu.au/oemf

Getting to UNSW by Bus:
It is strongly recommended to catch a bus to UNSW.

- **From Coogee:** Buses 370, M50 run from Coogee and drop off for UNSW on High Street.
- **From City-North:** Buses 392, 394, 396, 397, 399, L94, 302, 303, M10 run from Circular Quay to UNSW main gate on Anzac Pde.
- **From Central:** Buses 393, 395 run from Central to UNSW main gate on Anzac Pde. If you are catching a train into the city, get off at Central and catch one of these buses. Express Buses 890, 891, 892 run from Central and drop off at UNSW on High Street.
- **From Maroubra Junction:** Buses 393, 394, 395, 396, 397, 399, L94, M10 pass through Maroubra Junction to UNSW main gate on Anzac Pde.

UNSW Parking and Vehicular Accessibility:
All day parking is available on the upper floors of the Botany Street Parking Station – enter via gate 11. The cost for metered parking is $3 per hour, all day parking = minimum $6 for 3 hours, and $2.00/hr thereafter up to 12 hours (cash and credit card payment)

Registration Desk Opening Hours
- **Tuesday, 19 February 2013** 11:00am – 7:30pm
- **Wednesday, 20 February 2013** 08:00am – 5:00pm
- **Thursday, 21 February 2013** 08:30am – 5:00pm

Name Badges and Tickets
Your name badge must be worn at all times, as it is your entry to all sessions and inclusive functions. Entry to social events will also not be permitted unless you present the ticket that will be given to you when you register.
## Off Earth Mining Forum Program

<table>
<thead>
<tr>
<th>Event</th>
<th>Time</th>
<th>Date</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>OEMF Registration Desk Opens</td>
<td>11:00am - 07:30pm</td>
<td>Tuesday 19th February</td>
<td>Mathews Pavilions, UNSW</td>
</tr>
<tr>
<td>Simulants and Analogues for Space Mining Research Workshop</td>
<td>01:00pm - 05:00pm</td>
<td>Tuesday 19th February</td>
<td>Civil Engineering 109, UNSW</td>
</tr>
<tr>
<td>Social Function - Welcome Reception</td>
<td>05:30pm - 07:30pm</td>
<td>Tuesday 19th February</td>
<td>Mathews Pavilions, UNSW</td>
</tr>
<tr>
<td>Off Earth Mining Forum - Day 1</td>
<td>08:30am - 05:30pm</td>
<td>Wednesday 20th February</td>
<td>Mathews Theatre B, UNSW</td>
</tr>
<tr>
<td>Social Function - Sydney Harbour Dinner Cruise</td>
<td>07:00pm - 10:30pm</td>
<td>Wednesday 20th February</td>
<td>Circular Quay, Sydney</td>
</tr>
<tr>
<td>Off Earth Mining Forum - Day 2</td>
<td>09:00am - 05:00pm</td>
<td>Thursday 21st February</td>
<td>Mathews Theatre B, UNSW</td>
</tr>
<tr>
<td>Curiosity on Mars - ACSER Distinguished Guest Lecture</td>
<td>06:00pm - 08:00pm</td>
<td>Thursday 21st February</td>
<td>Sir John Clancy Auditorium, UNSW</td>
</tr>
</tbody>
</table>

### Hosted by:

www.acser.unsw.edu.au/oemf

Off Earth Mining Forum, UNSW, Sydney, Australia 19-21 February 2013