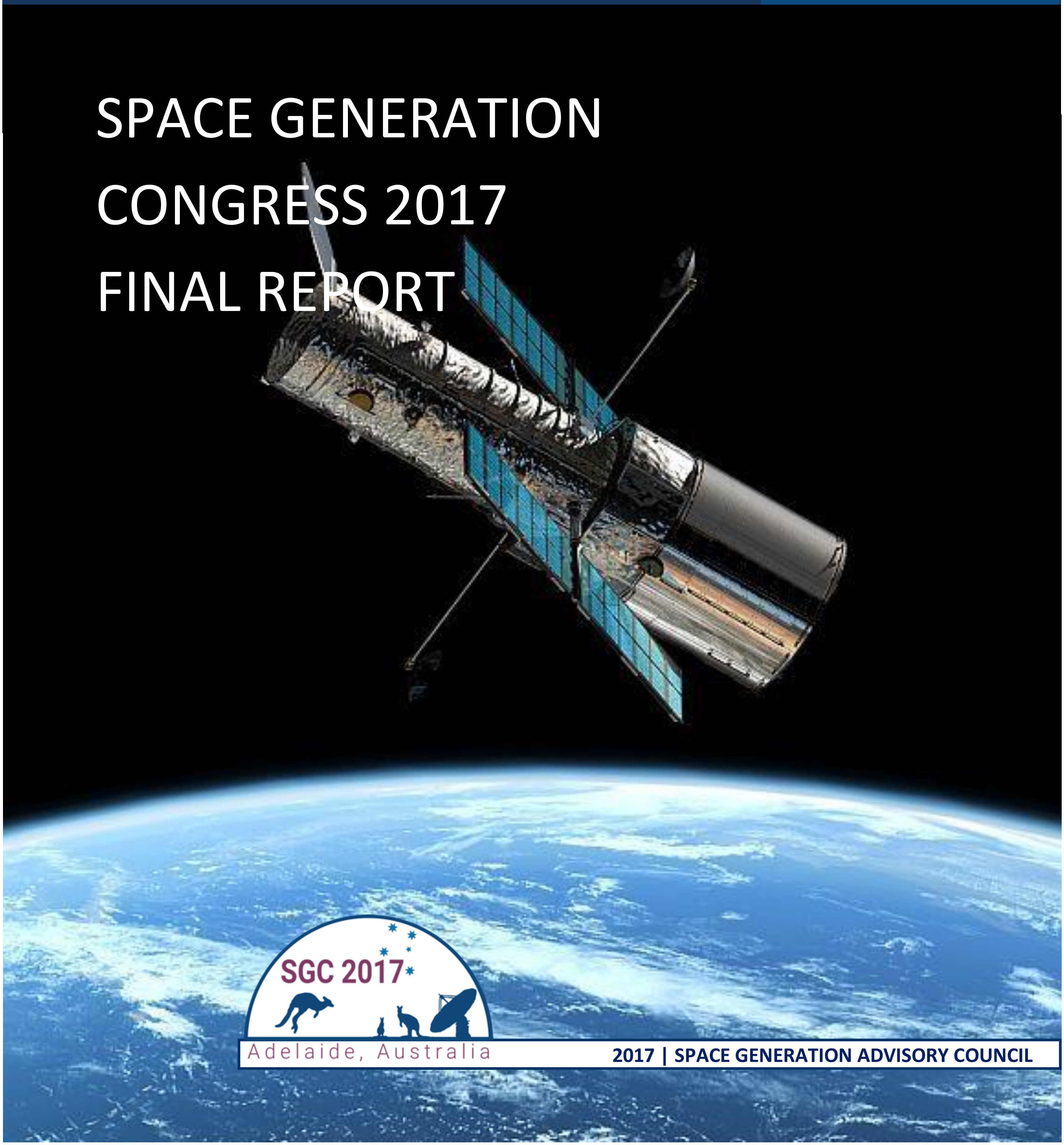
SPACE GENERATION CONGRESS

ADELAIDE 2017

SPACE GENERATION ADVISORY COUNCIL

IN SUPPORT OF THE UNITED NATIONS PROGRAMME ON SPACE APPLICATIONS

SPACE GENERATION CONGRESS 2017 FINAL REPORT



SGC 2017

Adelaide, Australia

2017 | SPACE GENERATION ADVISORY COUNCIL

In support of the United Nations Programme on Space Applications

c/o European Space Policy Institute (ESPI) Schwarzenbergplatz 6 Vienna A-1030 AUSTRIA

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A.C. CHARANIA **KEN DAVIDIAN** **JULIO APREA**

AJEET HANSRA

JIM BURKE

THE SGAC WOULD LIKE TO THANK ALL OF OUR SPONSORS AND SUPPORTERS FOR THEIR CONTRIBUTIONS TO THE 16TH SPACE GENERATION CONGRESS!

LETTER FROM THE SGC CHAIRS

Dear SGC Delegates,

Welcome to Adelaide! We are very excited to meet you all at SGC 2017. We received a large number of high quality applications this year. To ensure a high quality event, the number of participants was limited to 150 but we are happy to see a mix of former and new participants being selected for the event. The SGC team has done a fantastic job putting together a programme to inform and inspire you. Take this opportunity to learn from each other, discuss the issues presented to you, and come up with new ideas that could change the world. We encourage you to be frank and fearless while you are here; SGC is an opportunity for you to challenge yourself, your peers, and what is accepted! We know that you will have a lot of fun along the way.

In the next few days, you will be discussing pressing global issues that the space industry currently faces with peers from all over the world. Make sure that you embrace the differences among you, in terms of technical and cultural background, to look at these problems from different perspectives. You will not necessarily solve these challenges, but you might point others in the right direction. Yet SGAC is not just about discussion. Make sure to use this platform to meet young and experienced space leaders from all over the globe, and perhaps brainstorm opportunities for collaboration beyond the next three days! By Saturday, we expect you to share some recommendations on what should come next. Remember, SGC is not the end! Your work and input in this conference will lead to recommendations that are presented by SGAC at the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS). Additionally, many of our working group members continue refining what they discussed here, sharing their perspectives through publications and presentations around the world. This is your chance to be heard by the space community; make it count!

We wish you a wonderful time in Adelaide and hope you get as energised as we do by all the exchange of ideas and enthusiasm that takes place. Work hard, but remember to enjoy yourselves as well!

Ad astra,

Ali Nasseri
SGAC Chair

Alexander Gibson
SGAC Co-Chair

LETTER FROM SGC ORGANISING TEAM

Dear SGC 2017 Delegates,

On behalf of the SGAC Office and Space Generation Congress 2017 Organising Team, we are pleased to welcome you to the 16th SGC in Adelaide, Australia! The annual SGC brings together delegates and colleagues from government, industry, academia, policy-makers, and entrepreneurs to debate and discuss issues affecting our fast-growing sector.

Through SGC, SGAC aims to inspire the present and future workforce, provide a platform for networking and allow you the opportunity to have your opinions and ideas heard on an international platform. The discussions and recommendations from the three days at SGC will be presented at the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) sub-committee meeting in February 2018.

We would like to acknowledge the hard work and dedication of the SGC 2017 Organising Team who have put in endless hours of volunteer time to the development and planning an engaging SGC 2017 programme. We would also like to thank the many SGC 2017 sponsors who enable us to deliver this great event, allowing tomorrow's space sector leaders to grow their network and interact with senior professionals in the industry.

We wish you a productive and enjoyable time at the 16th Space Generation Congress!

Cheers,

Minoo Rathnasabapathy

SGAC Executive Director

Arnau Pons

SGC 2017 Congress Manager

SGC 2017 CONGRESS OVERVIEW

The Space Generation Congress (SGC) is an annual event which brings together 150 of the top young minds from around the world to focus on key space topics. A truly unique event, SGC offers the next generation of space leaders an opportunity to critically engage on pressing topics facing the international space community, all while building strong networks with their international peers and senior industry leaders alike.

Aims of the Space Generation Congress

First, to strengthen the international network of the Space Generation Advisory Council. Delegates have a chance to interact and engage with the incoming generation of space professionals from around the world. From the perspective of the Space Generation Advisory Council, it enables us to consolidate our international links in order to best represent the voice of the next space generation.

Second, to examine and consider key questions that are facing the space sector and international community at large as well as to provide input to international stakeholders from the next generation of space professionals.

Third, to allow future space sector leaders to network among their peers by working together. Delegates also have the opportunity to interact with today's space leaders by way of the Space Generation Congress' high-level speakers.

2016 Space Generation Congress Delegation in Guadalajara, Mexico

16th SPACE GENERATION CONGRESS SCHEDULE

Adelaide, Australia ~ 21-23 September 2017

Wednesday, 20 September						
09:00 – 12:00	**Moderators Workshop** (5.57 – Ingkarni Wardli)					
15:00 – 19:00	**SGC Delegate Registration** (Atrium - Ingkarni Wardli)					
19:00	**Departure to Optional Dinner** (Atrium - Ingkarni Wardli)					
19:30 – 22:00	**Optional Dinner** (Cooper's Alehouse)					
Thursday, 21 September						
07:30 – 08:00	**Doors Open** (Plenary – Horace Lamb Lecture Theatre**)**					
08:00 – 08:30	**SGAC 2017 Welcome** (Plenary – Horace Lamb Lecture Theatre)					
08:30 – 08:50	**Invited Speakers** (Plenary – Horace Lamb Lecture Theatre)					
08:50 – 09:10	**Coffee Break** (Atrium - Ingkarni Wardli)					
09:10 – 12:00	Working Group 1: **Space Exploration** B18 – Ingkarni Wardli	Working Group 2: **Space Policy** B17 – Ingkarni Wardli	Working Group 3: **Space Law** 5.57 – Ingkarni Wardli	Working Group 4: **Space Innovation** 2060 – Barr Smith South	Working Group 5: **Space Transportation** 2051 – Barr Smith South	Working Group 6: **Space Technologies** 2052 – Barr Smith South

12:00 – 13:30	Working Group 1 Lunch Break 12:00 – 12:45 Atrium - Ingkarni Wardli	Working Group 2 Lunch Break 12:00 – 12:45 Atrium - Ingkarni Wardli	Working Group 3 Lunch Break 12:00 – 12:45 Atrium - Ingkarni Wardli	Working Group 4 Lunch Break 12:45 – 13:30 Atrium - Ingkarni Wardli	Working Group 5 Lunch Break 12:45 – 13:30 Atrium - Ingkarni Wardli	Working Group 6 Lunch Break 12:45 – 13:30 Atrium - Ingkarni Wardli
13:30 – 15:00	Working Group 1: **Space Exploration** B18 – Ingkarni Wardli	Working Group 2: **Space Policy** B17 – Ingkarni Wardli	Working Group 3: **Space Law** 5.57 – Ingkarni Wardli	Working Group 4: **Space Innovation** 2060 – Barr Smith South	Working Group 5: **Space Transportation** 2051 – Barr Smith South	Working Group 6: **Space Technologies** 2052 – Barr Smith South
15:00 – 15:15	**SGC Official Picture**					
15:15 – 15:30	**Coffee Break** (Atrium - Ingkarni Wardli)					
15:30 – 16:40	Working Group 1: **Space Exploration** B18 – Ingkarni Wardli	Working Group 2: **Space Policy** B17 – Ingkarni Wardli	Working Group 3: **Space Law** 5.57 – Ingkarni Wardli	Working Group 4: **Space Innovation** 2060 – Barr Smith South	Working Group 5: **Space Transportation** 2051 – Barr Smith South	Working Group 6: **Space Technologies** 2052 – Barr Smith South
16:40 – 17:40	**Scholarship Winners Presentations** (Plenary – Horace Lamb Lecture Theatre)					

17:40 – 18:00	**Invited Speakers** (Plenary – Horace Lamb Lecture Theatre)					
19:00 – 22:00	**SGC International Cultural Night** (Adelaide Zoo – Sir Thomas Elder Rotunda venue)					
Friday, 22 September						
07:30 – 08:00	**Doors Open**					
08:00 – 08:30	**SGC Day 2 Welcome** (Plenary – Horace Lamb Lecture Theatre)					
08:30 – 10:00	Working Group 1: **Space Exploration** B18 – Ingkarni Wardli	Working Group 2: **Space Policy** B17 – Ingkarni Wardli	Working Group 3: **Space Law** 5.57 – Ingkarni Wardli	Working Group 4: **Space Innovation** 2060 – Barr Smith South	Working Group 5: **Space Transportation** 2051 – Barr Smith South	Working Group 6: **Space Technologies** 2052 – Barr Smith South
10:00 – 10:20	**Coffee Break** (Atrium - Ingkarni Wardli)					
10:20 – 12:30	Working Group 1: **Space Exploration** B18 – Ingkarni Wardli	Working Group 2: **Space Policy** B17 – Ingkarni Wardli	Working Group 3: **Space Law** 5.57 – Ingkarni Wardli	Working Group 4: **Space Innovation** 2060 – Barr Smith South	Working Group 5: **Space Transportation** 2051 – Barr Smith South	Working Group 6: **Space Technologies** 2052 – Barr Smith South

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13:30 – 15:10	Working Group 1: **Space Exploration** B18 – Ingkarni Wardli	Working Group 2: **Space Policy** B17 – Ingkarni Wardli	Working Group 3: **Space Law** 5.57 – Ingkarni Wardli	Working Group 4: **Space Innovation** 2060 – Barr Smith South	Working Group 5: **Space Transportation** 2051 – Barr Smith South	Working Group 6: **Space Technologies** 2052 – Barr Smith South
15:10 – 15:30	**Coffee Break** (Atrium - Ingkarni Wardli)					
15:30 – 16:30	**Invited Speakers** (Plenary – Horace Lamb Lecture Theatre)					
17:00 – 18:00	**SGAC Government House Reception** – Invitation Only					
19:00 – 22:00	**Space Night** (National Wine Centre of Australia)					
Saturday, 23 September						
08:00 – 08:30	**Doors Open**					
08:30 – 08:40	**SGC Day 3 Welcome** (Plenary – Horace Lamb Lecture Theatre)					

08:40 – 09:00	**Invited Speaker**					
09:00 – 10:40	Working Group 1: **Space Exploration** B18 – Ingkarni Wardli	Working Group 2: **Space Policy** B17 – Ingkarni Wardli	Working Group 3: **Space Law** 5.57 – Ingkarni Wardli	Working Group 4: **Space Innovation** 2060 – Barr Smith South	Working Group 5: **Space Transportation** 2051 – Barr Smith South	Working Group 6: **Space Technologies** 2052 – Barr Smith South
10:40 – 11:00	**Coffee Break** (Atrium - Ingkarni Wardli)					
11:00 – 12:00	**Invited Speakers** (Plenary – Horace Lamb Lecture Theatre)					
12:00 – 13:00	Working Group 1 Lunch Break 12:00 – 12:30 Atrium - Ingkarni Wardli	Working Group 2 Lunch Break 12:30 – 13:00 Atrium - Ingkarni Wardli	Working Group 3 Lunch Break 12:00 – 12:30 Atrium - Ingkarni Wardli	Working Group 4 Lunch Break 12:30 – 13:00 Atrium - Ingkarni Wardli	Working Group 5 Lunch Break 12:00 – 12:30 Atrium - Ingkarni Wardli	Working Group 6 Lunch Break 12:30 – 13:00 Atrium - Ingkarni Wardli
13:00 – 14:40	Working Group 1: **Space Exploration** B18 – Ingkarni Wardli	Working Group 2: **Space Policy** B17 – Ingkarni Wardli	Working Group 3: **Space Law** 5.57 – Ingkarni Wardli	Working Group 4: **Space Innovation** 2060 – Barr Smith South	Working Group 5: **Space Transportation** 2051 – Barr Smith South	Working Group 6: **Space Technologies** 2052 – Barr Smith South

14:40 – 15:00	**Coffee Break** (Atrium - Ingkarni Wardli)
15:00 – 17:30	**Working Group Final Presentations** (Plenary – Horace Lamb Lecture Theatre)
17:30 – 17:45	**Closing Remarks** (Plenary – Horace Lamb Lecture Theatre)
19:30 – 22:00	**SGC Annual Closing Dinner** (Adelaide Town Hall)

SGC 2017 CONGRESS SPEAKERS

Ms. Simonetta Di Pippo
Director, United Nations Office for Outer Space Affairs (UNOOSA)

Mr. Michael Davis
Chair/Ex Officio Chair, Space Industry Association of Australia / IAC 2017 LOC

Mr. William H. Gerstenmaier
Associate Administrator for Human Exploration and Operations, NASA

Lena De Winne
Chief Executive Officer, Asgardia

W. Michael Hawes, DSc
Vice President & Orion Programme Manager, Lockheed Martin Space Systems Company

Sarah Rietmüller
Trainee Event Coordination, Center of Applied Space Technology and Microgravity (ZARM) / IAC 2018 LOC

Birgit Kinkeldey
Head of Corporate Communication, Center of Applied Space Technology and Microgravity (ZARM) / IAC 2018 LOC

Mr. Jason Crusan
Director of Advanced Exploration Systems Division, NASA

Mr. Jose Ocasio-Christian
Chief Executive Officer, Caelus Partners

Dr. David Kendall
Chair, Committee on the Peaceful Uses of Outer Space United Nations

Piero Messina

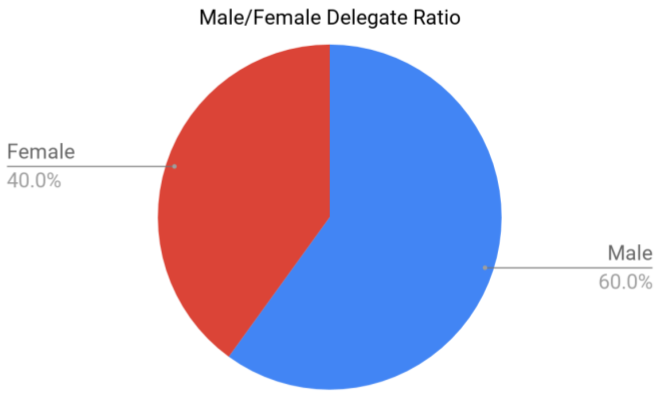
Strategy Department, European Space Agency

Mr. Clay Mowry
Vice President - Global Sales, Marketing & Customer Experience, Blue Origin

Dr. Stephen A. Townes
Chief Technologist of the Interplanetary Network Directorate at JPL, NASA

CONGRESS STATISTICS

This year has been a remarkable year for SGAC, as we celebrated our landmark 16th Space Generation Congress. Highlights of the 16th Space Generation Congress include:



150 Delegates
43 Nationalities
90 scholarships and awards

~20% increase in scholarship opportunities were made available for SGC 2017 compared to SGC2016

The 16th Space Generation Congress had 6 Working Group topics supported by:

- NASA Advanced Exploration Systems
- NASA Space Communications and Navigation
- Defence Science and Technology Group Australian Department of Defence
- Secure World Foundation
- European Space Agency
- BlueOrigin

This year's SGC Closing Dinner was also a chance for us to highlight the unwavering support of our partners for SGAC and the next generation, attended by over 350 space professionals from industry,academia and government. We are honored to welcome several Heads of Agency and His Excellency,Administrator of the Commonwealth (Acting Governor General), The Honourable Hieu Van Le AC and Mrs Le to the dinner.

SCHOLARSHIP WINNERS

Scholarship	First Name	Last Name
Space Generation Leadership Award	Olga	Stelmakh
Space Generation Leadership Award	Shreya	Santra
Space Generation Leadership Award	Maryanne	Muriuki
Space Generation Leadership Award	Marta	Lebron Gaset
Space Generation Leadership Award	Carmen Victoria	Felix Chaidez
$pace is Business Competition	Graham	Johnson
Move an Asteroid Competition	Rita	Neves
Move an Asteroid Competition	Kristin	Shahady
International Space Education Board	Alexander Luke	Miller
International Space Education Board	Zaid	Rana
International Space Education Board	Ermanno	Napolitano
International Space Education Board	Elise	Harrington
International Space Education Board	Roxanne	Fournier
International Space Education Board	Victoria	Van Dyk
International Space Education Board	Samuel	Laprise
International Space Education Board	Kathryn	Robison
International Space Education Board	Mathew	Miller
International Space Education Board	Sungmin	Lee
International Space Education Board	Sukmin	Choi
International Space Education Board	Ho-Sub	Song
International Space Education Board	Sungmoon	Choi
International Space Education Board	Junho	Lee
Emerging Space Leaders	Alexander	Linossier
Emerging Space Leaders	Narayan Prasad	Nagendra
Emerging Space Leaders	Maria Alexandra	Lora Veizaga
Emerging Space Leaders	Annelie	Vermeulen
Emerging Space Leaders	Abinish Kumar	Dutta
Emerging Space Leaders	Ahmad	Shaqeer
Emerging Space Leaders	Doris	Grosse
Emerging Space Leaders	Lisa	Peacocke
Emerging Space Leaders	Wei-Yu Louis	Feng
Emerging Space Leaders	Marco	Gómez Jenkins

Emerging Space Leaders	Matjaz	Vidmar
Emerging Space Leaders	Merve	Erdem
Emerging Space Leaders	Pablo	Melendres Claros
Emerging Space Leaders	Sarah	Wittig
NASA AES Scholarship	Ryan	Joyce
NASA SCAN Scholarship	Christian	Gilbertson
NASA SCAN Scholarship	Matthew	Lyn
Future Space Leaders Grant Program	Deepak	Atyam
Future Space Leaders Grant Program	Sirisha	Bandla
Future Space Leaders Grant Program	John	Conafay
Future Space Leaders Grant Program	Joshua W.	Ehrlich
Future Space Leaders Grant Program	McClain	Goggin
Future Space Leaders Grant Program	Peter	Schulte
Future Space Leaders Grant Program	Anna	Thomas
Young ESA - SGAC Diversity Scholarship	Didunolowa	Abiodun Obilanade
ILEWG Scholarship - Young Lunar Explorer (Paper)	Johanna	Pardo
ILEWG Scholarship - Young Lunar Explorer (Essay)	Mark	Fittock
DLR Standout Student Scholarship	Joshua	Kiefer
DLR Standout Student Scholarship	Daniel	Wischert
ASI Grant	Kaveh	Razzaghi
ASI Grant	Livia	Savioli
ASI Grant	Erind	Verurari
ASI Grant	Alberto	Fedele
ASI Grant	Lorenzo	Bucci
ASI Grant	Andrea	Colagrossi
ASI Grant	Adam	McSweeney
ASI Grant Supervisor	Maria	Messina
Space Generation Congress 2018 Logo Competition	Caroline	Juang
AYAA Scholarship	Brittany	Chambers
AYAA Scholarship	Oliver	Paxton
AYAA Scholarship	Philipp	Dahm
AYAA Scholarship	Steven	Apirana
AYAA Scholarship	Evelina	Onopriyenko
AYAA Scholarship	Caitlyn	Georgeson
AYAA Scholarship	Filip	Drazovic
AYAA Scholarship	Meika	Liveris
OHB Competition	Manfred	Ehresmann
OHB Competition	Enrique	Garcia Bourne
Australian Space Generation Innovators Award (first place)	Timothy	Fist

Australian Space Generation Innovators Award (runner up: 1/2)	Viha	Parekh
Australian Space Generation Innovators Award (runner up: 2/2)	Karl	Domjahn
Embry-Riddle Scholarship	Olivia	Kirk
University of Adelaide Scholarship	Hamish	McPhee
University of Adelaide Scholarship	Jack	Hooper
University of Adelaide Scholarship	Nathaniel	Shearer
University of Adelaide Scholarship	Brandon	Blake
University of Adelaide Scholarship	Madison	Simmonds
Russian Scholarship	Ksenia	Lisitcyna
Space Generation Congress 2017 Logo Competition	Marc	Fittock
Embry-Riddle Scholarship	Jaclyn	Wiley

WORKING GROUP

WORKING GROUP 1: SPACE EXPLORATION

EXECUTIVE SUMMARY

Continuing the “Proving Ground Enabling Human Exploration” theme from Space Generation Congress (SGC) 2016, the Exploration Working Group of SGC 2017 was asked to investigate how cislunar infrastructure could influence and enable commercial and international partnerships in addition to new scientific research. There were two main objectives: the first was to identify compelling activities that could involve commercial and international partners and how those partners could benefit from planned cislunar infrastructure. The second objective was to determine what scientific research may be enabled by the unique environment of cislunar space.

The Exploration Working Group came up with three primary recommendations as a result of investigating these topics. The first is a recommendation to establish a framework for partnership governance with a goal to enable access to as many entities as feasible. The second is to ensure that the international and commercial communities are involved in the cislunar infrastructure development process from the beginning. The third recommendation is to provide a number of services from the cislunar spacecraft that can support multiple commercial and scientific interests. Appropriate planning in the design process to accommodate partnerships is the only way to ensure these cislunar developments are utilised to their maximum potential.

To improve on the collaboration that has sustained the International Space Station, the working group suggests establishing a multinational and multi-organizational partnership governance board. By making an internationally coordinated effort to explore deep space, costs could be spread among many partners while providing those partners with access to capabilities they may not have on their own. This model would help to reduce the amount of resources any one nation must contribute to sustain this exploration and attract a number of different investors, including commercial, academic, and non-governmental organizations. A relationship that ultimately shares costs while providing increased access and capabilities would be mutually beneficial to all partners involved, as well as potentially enabling to beyond-LEO exploration.

The Exploration Working Group envisions the Deep Space Gateway (DSG) as a platform that could provide multiple services for the partners involved in its creation and operations as well as customers who are interested in the operational environment. The delegates propose four main categories of services the Gateway could provide which include Transportation, Maintenance and Manufacturing, Communications, and Working Volume.

With the provided services mentioned above and the ability to offer hosted payload volume and power allocations, the DSG could then be leveraged for a number of different technology

demonstrations and research opportunities. The group suggests prioritizing high energy, low dose rate radiation research to reduce the uncertainty around the effects of deep space radiation on the human body. The group would also like to see prioritization of research on environmental control and life support systems that can handle transition to and from quiescent and crewed operational states and address microbial growth, detection, and mitigation strategies.

There are many opportunities on the DSG and/or other cislunar spacecraft capable of supporting crew to provide, accommodate, and request services that can engage international and commercial partners as well as stimulate the growth of the global space industry. A partnership governance model should seek to incentivize inclusion of developing and emerging entities in flight projects. The governing board would have the potential to reduce the barrier to entry for smaller nations, institutions, and companies. It would also be able to request space-based services or capabilities to be contributed by various partners. Over time, including a wide variety of partners will increase the supply of space based services and hardware, increase the number of competitors for contracts and flight projects, and ultimately reduce the cost of spaceflight. The Deep Space Gateway also provides unique opportunities to conduct science which are not possible in Low Earth Orbit and will enable the future of human space exploration. The group recommends making the most of this opportunity by leveraging the Deep Space Gateway as a focal point of this effort.

WORKING GROUP PARTICIPANTS

NAME	ROLE	NATIONALITY
Jason Crusan	Keynote Speaker	USA
Marshall Smith	Subject-Matter Expert	USA
Nicole Herrmann	Moderator	USA
Joao Lousada	Moderator	Portugal
Ryan Joyce	Rapporteur	USA
Carmen Victoria Felix Chaidez	Rapporteur	Mexico
Lisa Peacocke	Delegate	New Zealand
Ghanim Alotaibi	Delegate	Kuwait
Stacha Petrovic	Delegate	Netherlands

Evelina Onopriyenko	Delegate	Australia
Joshua Ehrlich	Delegate	USA
Samu Eshima	Delegate	Japan
Tobias Niederwieser	Delegate	Austria
Susanne Peters	Delegate	German
Hosub Song	Delegate	Republic of Korea
Peter Schulte	Delegate	USA
Kathryn Robison	Delegate	USA
Kenneth Lui	Delegate	Hong Kong
Jan Lukačevič	Delegate	Czech Republic
Siddharth Pandey	Delegate	Indian
Julie Mottin	Delegate	French
Madison Simmonds	Delegate	Australia
Marco Gómez Jenkins	Delegate	Costa Rica
Brandon Blake	Delegate	Australia
Didunoluwa Obilanade	Delegate	UK
Lorenzo Bucci	Delegate	Italy
Danielle Richey	Delegate	USA
Bernadette Maisel	Delegate	Chile
Eleanor Morgan	Delegate	USA
Andrea Colagrossi	Delegate	Italy
Maria Alexandra Lora Veizaga	Delegate	Bolivia
Pablo Melendres Claros	Delegate	Bolivia

Abinish Kumar Dutta	Delegate	Nepal

Demographics

The Space Generation Congress 2017 Exploration Working Group convened in Adelaide, Australia and 30 young professionals and students from 24 different countries gathered together to brainstorm how cislunar infrastructure might be utilised for the benefit of all involved. The working group also had strong representation of both genders including 12 female participants. This diverse representation shown in Figure 1 ensured the working group had a broad variety of ideas, values, and opinions to inform the final recommendations. The diverse collaboration proved to be an asset, producing ideas and recommendations that would not have been possible without the contributions of all involved. As a result, the working group believes further human endeavors in space would benefit greatly from similar collaboration.

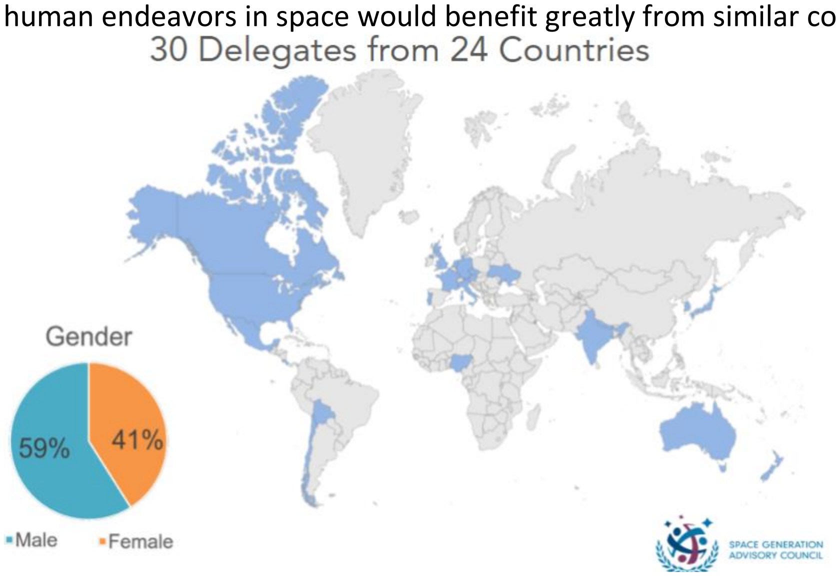


Figure 1: Working Group Composition: Gender and Country Representation

Sponsorship and Background Material

The working group was sponsored to conduct this study by the National Aeronautics and Space Administration's (NASA) Advanced Exploration Systems (AES) Division which is leading the proposed concept of the Deep Space Gateway (DSG). Support material to inform the discussion was provided through NASA's 'Exploration Objectives'[1], 'Deep Space Habitation Strategy'[2], and 'Strategic Knowledge Gaps'[3], and the International Space Exploration Coordination Group's 'Scientific Opportunities Enabled by Human Exploration Beyond Low-Earth Orbit'[4] and 'Exploring and Using Lunar Polar Volatiles'[5] website.

INTRODUCTION

Continuing the 'Proving Ground Enabling Human Exploration' theme from Space Generation Congress (SGC) 2016, the Exploration Working Group of SGC 2017 was asked to investigate how cislunar infrastructure could influence and enable commercial and international partnerships in addition to new scientific research. There were two main objectives: the first was to identify compelling activities that could involve commercial and international partners and how those partners could benefit from planned cislunar infrastructure. The second objective was to determine what scientific research may be enabled by the unique environment of cislunar space.

The Exploration Working Group came up with three primary recommendations as a result of investigating these topics. The first is a recommendation to establish a framework for partnership governance with a goal to enable access to as many entities as feasible. The second recommendation is to ensure that the international and commercial communities are involved in the cislunar infrastructure development process from the beginning. The third recommendation is to provide a number of services from the cislunar spacecraft that can support multiple commercial and scientific interests. Appropriate planning in the design process to accommodate partnerships is the only way to ensure these cislunar developments are utilised to their maximum potential.

Utilisation of Planned Cislunar Infrastructure

The discussion was primarily focused around NASA's Deep Space Gateway concept, shown in Figure 2, a limited new investment and crew-tended outpost in cislunar space. The Gateway is planned to serve as a stepping stone and proving ground for the demonstration of new technologies and operations that cannot be tested on the International Space Station (ISS) and will enable further human space exploration.

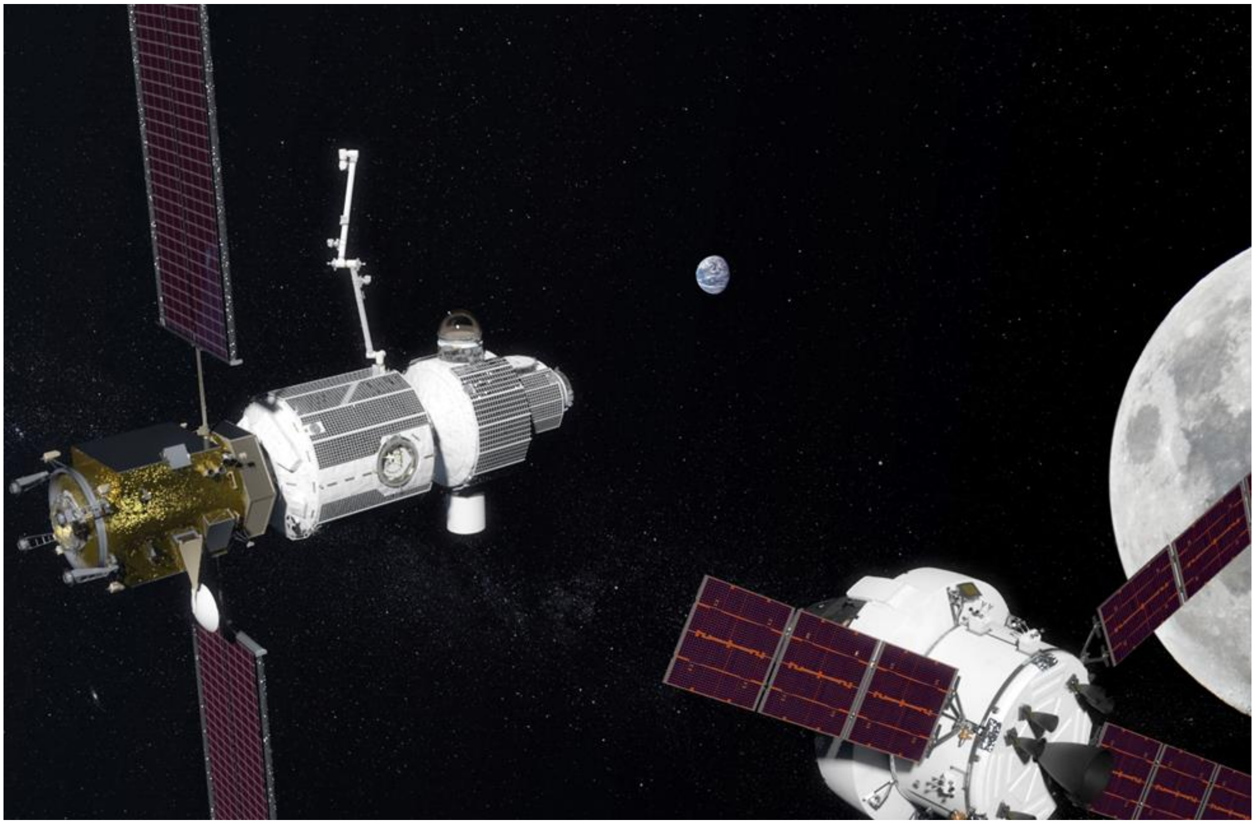


Figure 2: NASA's Proposed Deep Space Gateway in Cislunar Space with Orion Approaching (Image Credit: NASA)

Approach

The working group split into two teams, one focused on scientific research opportunities in cislunar space and the other focused on potential commercial applications of the cislunar infrastructure. Each team then split into two subgroups to brainstorm before combining their results into one list of recommendations per team. Afterwards, the two teams presented their suggestions to the group and modified them based on the group's input.

INCREASING INTERNATIONAL COLLABORATION

As multiple space agencies and private entities develop plans for human exploration of deep space, the working group believes an integrated international effort would ensure the most effective use of humanity's deep space assets. Long term, sustainable human space exploration is a challenging endeavour that no single nation has proven willing to fund on their own. To date, the only sustained human exploration effort has been the International Space Station, which has only been successful due to the cooperation and collaboration among the many different nations that support it.

Because sustained human exploration is such a challenge, and the ISS has proven a successful model of such exploration, a similar model should be followed when conducting even more challenging endeavours beyond Low Earth Orbit (LEO). By making an internationally coordinated effort to explore deep space, costs could be spread among many partners while providing those partners with access to capabilities they may not have on their own. This model would help to reduce the amount of resources any one nation must contribute to sustain this exploration and attract a number of different investors. A relationship that ultimately shares costs while providing increased access and capabilities would be mutually beneficial to all partners involved, as well as potentially enabling to beyond LEO exploration.

PARTNERSHIP GOVERNANCE MODEL

To improve on the collaboration that has sustained the ISS, the working group suggests establishing a multinational partnership governance board. The working group recommends that the board be headed by NASA, as NASA is currently planned to be the primary contributor and majority investor in the Deep Space Gateway, the primary platform toward which these recommendations are directed.

The board's primary function would be to select valuable ideas from all contributors, then encourage and enable new nations and entities to access space environments they may not otherwise have the means to access. The working group suggests the board do this by establishing the following categories of partners based on participants' involvement and capability to access space: "Established", "Emerging", and "Developing". Entities that fall under the "Established" category would be those nations, companies, or institutions that have routine access to space, via their own launch vehicles or purchased launches, and are capable of building their own spacecraft. These would include space agencies from major space-faring nations and large aerospace corporations. Entities that fall under the "Emerging" classification would be those nations, companies, or institutions that have some, non-routine access to space and/or can build space-qualified instrumentation or hardware but do not meet the "Established" criteria. This could include nations or companies that have launched a small number of satellites. Entities that fall under the "Developing" category would be those countries, companies, or institutions that are interested in space exploration and attempting to develop the capability to build their own launch vehicles, space-qualified instrumentation, and/or hardware but do not satisfy the "Emerging" criteria. Some examples could include nations with no space infrastructure, start-up companies, and universities.

When funds, payload volume, and power allocations are available, the board would create a request for proposals and then evaluate the received proposals. Entities that match the "Established" or "Emerging" categorisation whose proposals were accepted would then have to include "Developing" entities on some percentage of their approved projects. This process would help newer entities continue to develop and become closer to qualifying for the "Emerging" categorization. Then, as more entities are brought from the "Developing" category into the "Emerging" and "Established" categories, the currently steep entry-barrier to space access will decrease. The working group believes this would increase demand for and supply of space-based services, stimulating the space-based economy and continuing its growth and development.

SERVICE AND SUPPORT HUB

The Exploration Working Group envisions the Deep Space Gateway as a platform that could provide multiple services for the partners involved in its creation and operations as well as customers who are interested in the operational environment. The delegates propose four main categories of services the Gateway could provide and then the services which fall under each category. The service categories include Transportation, Maintenance and Manufacturing, Communications, and Working Volume.

In addition to focusing on the services the Gateway could provide, the working group also discussed the time phasing of these services and utilisation possibilities for the DSG. The group determined that there are a number of potential near and long term opportunities. In the early stages of DSG utilisation, the working group found opportunities to provide capabilities on the DSG that are synergistic with increased international and commercial partnerships in addition to the recommended partnership governance model.

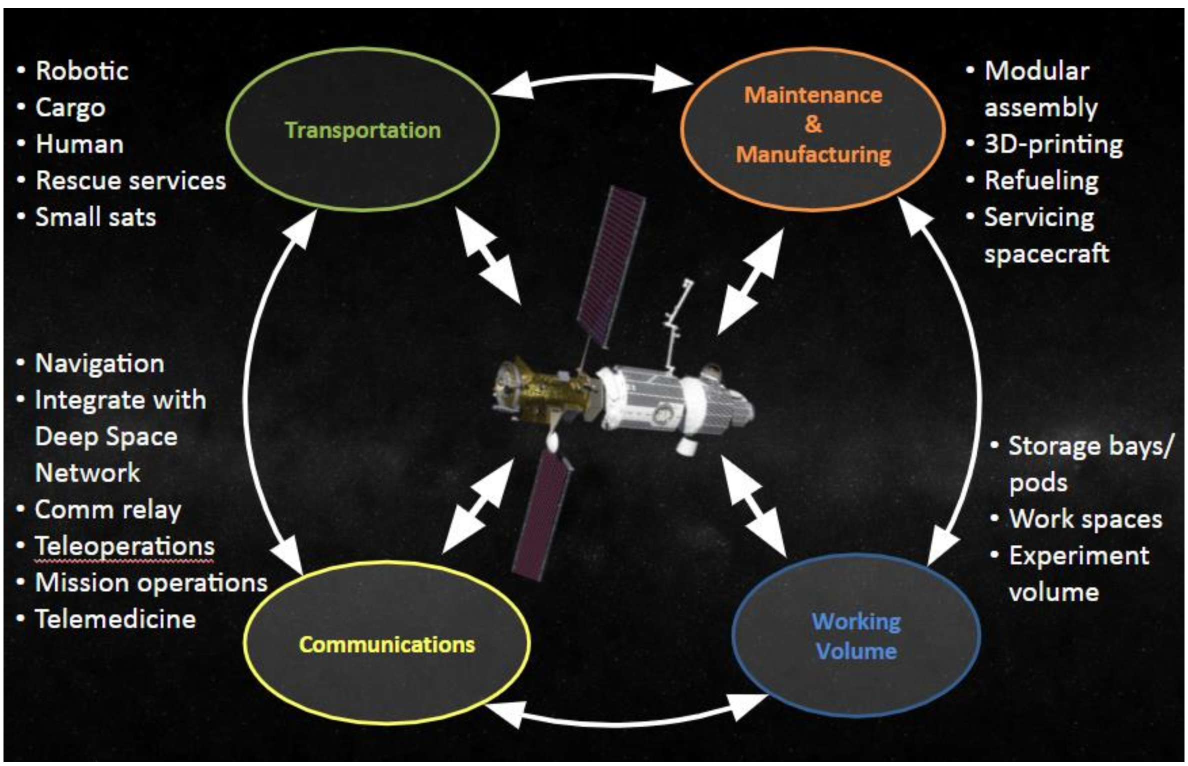


Figure 3: Deep Space Gateway Suggested Capabilities (Background Image Credit: NASA)

INITIAL UTILISATION OF DSG VIA THE PARTNERSHIP GOVERNANCE MODEL

Anticipated within the first 5-10 years of the Gateway's operational life, the group envisions the Gateway providing transportation services via CubeSat deployment and as a potential docking/holding and refueling location for a cargo delivery service supporting lunar surface exploration. The group also sees the Gateway as a potential location for maintenance and manufacturing development through 3D printing, modular assemblies and hardware servicing. The Gateway could also serve as a communications relay to the Deep Space Network, potentially allowing lunar surface assets or small CubeSats to carry smaller communications systems that link with the Gateway instead of all the way back to Earth. Finally, the Gateway could provide onboard volume and power allocations for hosted experiments. Examples of unique experiments that could be supported by the Gateway are those that require high-quality microgravity but also occasional crew support and those that take advantage of the cislunar environment.

If the Gateway is planned to provide or accommodate any of these services, the partnership governance board can immediately be put to use by procuring the services from either commercial or international partners. By competing proposals to provide these services, the operators may be able to save money or spread costs while encouraging development of new entities' capabilities. This may involve trading services with other governmental agencies or purchasing services via contracts with commercial companies. The service provider would be responsible for operating their service and paying its operational costs, thus reducing the financial burden on any one entity. By reducing or spreading the costs among multiple entities and increasing the total number of potential suppliers, the global human space exploration effort will take a more sustainable approach that is likely to grow and last.

IN-SPACE TRANSPORTATION AND SURFACE ACCESS

The ability to deploy CubeSats from the Gateway opens up different lunar studies that could potentially be supported by smaller nations, universities, or start-up companies. These "Developing" entities would, in turn, start the transition into "Emerging" entities positively impacting the space industry. Similar opportunities exist for cargo lander services to enable robotic lunar surface exploration in the near-term. Such missions could send rovers to scout for frozen water deposits and test out harvesting and processing procedures to eventually lead to larger scale in-situ resource utilisation and propellant production facilities. This in turn could lead to economic returns through the sale of propellant and other resources near the Moon, increasing the autonomy of crews in space and decreasing the need for resupply from Earth. This could also pave the way for the Gateway to act as a waypoint for crew to stop, gather supplies, outfit or refurbish their vehicle before proceeding to an ultimate destination. Such missions could then go to Mars, the lunar surface, or a Near-Earth Asteroid.

MAINTENANCE AND MANUFACTURING

Additive manufacturing capabilities on the DSG would enable spare parts to be printed from raw materials. This has the potential to reduce the total number and mass of spare parts brought on deep space missions by increasing the commonality of those spare parts. This could also enable the DSG to provide repair services for satellites that lose functionality in cislunar space. Eventually, this could lead to commercial companies manufacturing more complex and lightweight parts in space, taking advantage of reduced structure mass since the parts don't have to go through the stressful conditions of launch from Earth's surface. The working group acknowledges that as the space industry grows, in-space manufacturing capabilities will allow for higher performance transportation vehicles and satellites by reducing dry mass as well as allowing for more cost effective repairs of existing systems.

COMMUNICATIONS

The DSG's location in cislunar space, possibly in a near-rectilinear halo orbit, comes with some unique advantages as a communications relay. Having a satellite in a polar orbit around the Moon opens potential exploration opportunities on the far side of the Moon where communications with Earth are normally not possible. A polar orbiting satellite, however, has multiple opportunities for line of sight with surface assets exploring the far side of the Moon. This could enable both robotic and crewed exploration missions to locations that cannot currently receive radio transmissions easily. Similar communications services could be provided to CubeSats exploring cislunar space, or rovers on the surface, which could potentially carry smaller communications systems or receive and transmit at higher bandwidths by communicating with the Gateway as a relay between the asset and the Deep Space Network.

TECHNOLOGY DEVELOPMENT AND SCIENTIFIC RESEARCH

With the provided services mentioned above, and the ability to offer hosted payload volume and power allocations, the DSG could then be leveraged for a number of different technology demonstrations and research opportunities, in addition to reducing risk and increasing technology readiness levels of new hardware required for future deep space missions. One of the key technologies the group identified that should be assessed on the DSG is Environmental Control and Life Support Systems (ECLSS), including operations in uncrewed states. The DSG is one of the few locations where an ECLSS system can be monitored in crewed and uncrewed modes, providing a great environment to test vital microbial growth detection and mitigation technologies, which are key challenges associated with leaving a spacecraft in orbit while crew visit a planetary surface. It would also allow testing and research on bioregenerative life support systems and the impact of galactic cosmic radiation on their ability to perform their environmental control functions in deep space.

The group also suggests utilising the high-energy radiation environment of cislunar space to conduct significant radiation and biomedical research that will provide vital knowledge before committing crews to long duration missions beyond Earth's magnetic field. The current low energy, high dose rate human radiation exposure data that space agencies use to predict the effects of space radiation are not entirely analogous to the high energy, low dose rate seen in deep space. The group suggests that long term radiation experimentation in cislunar space be conducted to reduce the uncertainty around the human effects of long term galactic cosmic ray exposure. This would allow more informed decisions to be made about the space radiation environment's impact on crew for long duration missions. Conducting the recommended research and testing new, enabling technologies in cislunar space should ultimately feed forward to future deep space missions and continue humanity on the path to living sustainably in space.

FUTURE UTILISATION OF THE GATEWAY

Beyond ten years in the future, the group envisions the Gateway as a prototype manufacturing facility of the future; testing small-scale processes that can ultimately develop into the large scale production required by in-space manufacturing facilities. Because pressure shells have proven to last longer than their expected lifetimes even in micrometeoroid and orbital environments, the process could begin with repurposing expended modules that have served their purpose by stripping old electronics and outfitting the interior and exterior to match customer needs. Then, as technology and capabilities mature, these modules could develop into larger scale production facilities. Even if the DSG is only capable of beginning that process in this timeframe, with the beginning stages of these capabilities, the group highlights the Gateway's value as a waypoint and location to provide supplies and/or modules for outbound missions and refurbish vehicles between destinations.

After the initial deployment and operational stages of the DSG, the group also sees it playing a role in the development of systems that begin to enable Earth independence. Cislunar space is one of the closest locations to Earth where the deep space environment can be accessed. As a result, it provides a unique environment to test a change in operational methodology, starting with a remotely operated spacecraft, moving towards partial automation that can execute stored commands but not maintain vehicle health completely unmonitored, and finally an autonomous system that can maintain vehicle health without outside command or monitoring. The group also sees food production and regenerative ECLSS systems as an important part of the progression toward Earth independence.

CONCLUSION

There are many opportunities on the DSG and/or other cislunar spacecraft capable of supporting crew to provide, accommodate, and request services that can engage international and commercial partners as well as stimulate the growth of the global space industry. A partnership governance model that seeks to incentivize inclusion of developing and emerging entities in flight projects and can also request space-based services or capabilities, has the potential to reduce the barrier to entry for smaller nations, institutions, and companies. Over time, doing this will increase the supply of space-based services and hardware, increase the number of competitors for contracts and flight projects, and ultimately reduce the cost of spaceflight. Reduced costs should also increase demand, growing the space industry as more business opportunities become economically feasible and cost effective. If the market were already saturated, it is possible reduced costs would not increase demand but many launch providers already have manifests that go years into the future suggesting the market is unlikely to be saturated.

The DSG also offers a unique environment to conduct research and technology demonstrations to reduce risks associated with deep space missions. Conducting high energy, low dose rate radiation research also has the potential to reduce the uncertainty around the impacts of space radiation on the human body. A temporarily crewed system is also ideal for testing out ECLSS systems that can handle quiescent-to-active and active-to-quiescent transitions, a key technology for maintaining a spacecraft in orbit while crew visit a planetary surface. Through collaborative development and research, the space industry has a chance to lower the barrier of entry to space and increase the sustainability of human space exploration. The group recommends making the most of this opportunity by leveraging the Deep Space Gateway as a focal point of this effort.

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WORKING GROUP 2: SPACE DIPLOMACY

EXECUTIVE SUMMARY

The combination of increased access to outer space and expected rise in demand for vital resources on Earth and in space has increased awareness concerning the importance of the access and availability of resources. Interest has particularly grown in resources that are off-Earth, leading to the recent burgeoning of commercial ventures and state-driven projects dedicated to exploring the viability of space resource utilisation. Current commercial ventures including iSpace, Deep Space Industries, Moon Express, and Planetary Resources, are all pursuing space resource utilisation at a rate that current international policy cannot match.

To date, activities in outer space have been largely regulated under five international treaties, four of which are widely ratified by most major spacefaring nations and, to varying degrees, adopted into national law. Of these however, the “magna carta” of space law is really the Outer Space Treaty of 1967 which outlines the basic laws and principles governing all space activities. The Outer Space Treaty was drafted half a century ago, before space resource expropriation was a realistic commercial venture, and its guidance on this topic is rather vague. While, the treaty is clear on the point that neither nation-states nor the private entities under their jurisdiction can claim sovereignty over celestial bodies, the ambiguity around whether nations/companies can assert property rights over resources extracted from an asteroid or celestial body such as the Moon has remained an open question.

This legal ambiguity at an international policy level has become problematic in recent years as the business case around space resource extraction has strengthened. With current asteroid valuations ranging between $195 billion to $10,000 quadrillion, and technology seemingly not far behind making these ventures achievable, a growing nascent industry has begun placing pressure on both national and international policymakers. As a result, in 2015 the U.S. Congress sought to resolve this dilemma by explicitly giving American companies ownership rights to whatever they extract but stopped short of giving them rights to own the asteroid itself.

Then in 2017 Luxembourg followed suit. In addition to extending property rights for asteroid miners, Luxembourg’s new law sets up a framework for authorising and supervising these miners, including provisions on corporate governance. Many companies are now looking to benefit from these laws which could also mean gaining a possible share in the $200 million made available for related Research and Development (R&D) investment. Currently, the only condition that must be met by these companies is the requirement to have a Luxembourg office. While these laws are somewhat controversial, they have boosted a nascent industry that had been inhibited by uncertainty.

RECOMMENDATIONS

1. Drafting of guidelines, including built-in risk controls and minimum standards for operations and commercial ventures, coordinated with the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) operations guidelines.
2. Private entities should demonstrate to their respective State, through a regulatory and licensing scheme, that they meet required guidelines.
3. Clarification between "non-appropriation" and "freedom of use" is to be developed by a UN working group, which considers the acquisition and ownership of space resources.
4. Privileged access granted to scientific activities alongside industrial activities.
5. Setting up a UN working group to investigate the establishment of an international regulatory body for space resources.

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The Space Diplomacy Working Group (on Space Resources Governance) would like to kindly thank our
sponsor, the Secure World Foundation.

We wish to encourage the responsible use of outer space resources.

INTRODUCTION

The combination of increased access to outer space and expected rise in demand for vital resources on Earth and in space has increased awareness concerning the importance of the access and availability of resources. Interest has particularly grown in resources that are off-Earth, leading to the recent burgeoning of commercial ventures and state-driven projects dedicated to exploring the viability of space resource utilisation. Current commercial ventures including iSpace, Deep Space Industries, Moon Express, and Planetary Resources, are all pursuing space resource utilisation at a rate that current international policy cannot match.

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This legal ambiguity at an international policy level has become problematic in recent years as the business case around space resource extraction has strengthened. With current asteroid valuations ranging between $195 billion to $10,000 quadrillion, and technology seemingly not far behind making these ventures achievable, a growing nascent industry has begun placing pressure on both national and international policymakers. As a result, in 2015 the U.S. Congress sought to resolve this dilemma by explicitly giving American companies ownership rights to whatever resources they extract but stopped short of giving them rights to own the asteroid itself.

Then in 2017 Luxembourg followed suit. In addition to extending property rights for asteroid miners, Luxembourg’s new law set up a framework for authorising and supervising these miners, including provisions on corporate governance. Many companies are now looking to benefit from these laws which could also mean gaining a possible share in the $200 million made available for related Research and Development (R&D) investment. Currently, the only condition that must be met by these companies is the requirement to have a Luxembourg office. While these laws are somewhat controversial, they have boosted a nascent industry that had previously been inhibited by uncertainty.

It should perhaps be noted here that the legality of space resource extraction, despite the emergence of these national laws, is still being debated at an international level and could be deemed illegal in those countries that oppose it. There are currently two camps: those who side with the United States and Luxembourg, and those who wish to establish an international regime that regulates miners and what they can mine in outer space. Currently, two of the most vocal opponents to Luxembourg’s law are Russia and Brazil. The current status quo of emerging divergent national laws and lack of a guiding policy framework is worrying. Similar to the Seas and the Antarctic, which required international regulation in order to ensure sustainability and access for all, space is also a global commons.

In response to the increasing importance of using space resources, the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) Legal Subcommittee has included considerations on the topic as an agenda item. Moreover, the Hague Space Resources Governance Working Group (SRGWG) was set up in December 2014 to address the lack of a governance framework [3]. There is near consensus among stakeholders that the governance framework should ensure that space resources are gathered and utilised in a peaceful and sustainable manner and that legal certainty for investors, explorers, and miners is imperative for achieving these goals. This working group assessed space resources and produces recommendations to address these challenges.

Working Group Focus Questions:

Focus: What factors should the international community consider in formulating policy responses to the
issues under the four building blocks?

Desired outcome: Identification of sub-topics and issues under each of the four building blocks. This might include identification and definition of key terms, formulation of suggested policy approaches, identification of gaps in knowledge of business and/or technology plans, and a description of models of activity and/or benefit.

Focus: What are the pathways towards discussion, implementation, and adoption of proposals to improve space resources governance? What are specific steps that the UN, international organisations, and national governments can take in implementing proposed space resources governance models and what are the potential obstacles to overcome?

Desired outcome: Suggested mechanisms by which the policy/legal and scientific/industry communities might improve information sharing on the topics represented by the building blocks. Suggested forums for consideration of any proposals for space resources governance, be they that of the SRGWG or otherwise.

Focus: What is the role of the younger generation in ensuring long term sustainable management of space resources?

Desired outcome: Delegates will broaden their personal knowledge of the topic. They will be able to articulate ways in which their roles in the space sector relate to space policy and governance topics in addition to the challenges associated with the on-going commercialisation of space.

CURRENT REGULATORY FRAMEWORK

- Outer Space Treaty [4]
- U.S. Commercial Space Launch Competitiveness Act 2015 [1]
- Luxembourg Law on the Exploration and Use of Space Resources 2017 [2]
- The Hague Resources Governance Working Group: Draft Building Blocks for the Development of an International Framework on Space Resource Activities 2017 [5]
- UN COPUOS Guidelines on the Long-Term Sustainability of Outer Space Activities (in progress) [6]

- Relevant State-made laws pertaining to organisations within that State

To achieve the goal of responsible and sustainable use of space resources, a trade-off between a strictly and loosely formulated regulatory frameworks needs to be made. The following overview details the advantages, disadvantages, applicable industry maturity level, and example reference frameworks for both strict and loose policies.

Strictly Defined Regulatory Framework

Advantages:

- Provides legal certainty

Disadvantages:

- Can be stifling to innovation
- Difficult to gain alignment

Application:

- Regulation of mature industry

Examples:

- ITU Regulations
- Convention on the High Seas

Loosely Defined Regulatory Framework

Advantages:

- Allows for interpretation and evolution

Disadvantages:

- Regulation discrepancy between States
- Encourages disagreements in interpretation.
  → Potential for conflicts between states

Application:

- Early stages of industry

Example:

- Outer Space Treaty

Industry Challenges

Too strict of an international regulatory framework can generate legal barriers to industry growth. Too loose of an international regulatory framework can create an environment that limits innovation through fear of backlash from the international community. This uncertainty also allows individual States to develop divergent regulatory frameworks that could cause both philosophical and practical issues many years later. A delicate balance between strictly and loosely defined frameworks must be struck to allow for growth and innovation in the nascent space resource utilisation industry.

DISCUSSIONS

Within the scope of the Working Group, key points have been discussed and detailed below:

Accountability and Transparency

The question that has to be addressed is: Who is held accountable for ensuring the sustainable and responsible exploitation of space resources, and who bears responsibility for the associated risks of related activities?

According to the Outer Space Treaty, “States shall be responsible for national space activities whether carried out by governmental or non-governmental entities” [4]. However, the current framework does not allow states to determine how the actions they permit to be carried out by “non-governmental entities” will be received by the international community. This creates a situation where states must either choose to be bold and create potentially controversial legislation in the name of promoting industry, or choose to be safe and limit or prohibit industry. Therefore assurances from the international community are needed and will only be agreeable to many different states if there is a high level of transparency into the motivation, mission, and methods of the entities looking to extract and use space resources. Not only will these assurances reduce the burden of accountability on the states themselves, but it will also encourage them to develop regulations which promote the responsible use of outer space resources.

People tend to invest more in organisations with greater transparency because they are inherently less risky. This trend then encourages increased transparency throughout the market and leads to a mechanism for enforced accountability and a safer environment.

Clarity and Certainty vs. Ambiguity

A key question discussed by the Working Group was, “Should the key legal terms that can be interpreted differently be defined or maintain the status quo?”

The WG agreed that a look should be given to regulations of resource exploitation found in other areas of law such as the law of the High Seas [7], the Antarctic regime [8], and the regulation of genetic resources [9]. The WG came to a conclusion that drafting flexible guidelines will allow the industry to follow its natural development path to ensure legal certainty, without restricting innovation.

Ownership

Clarifying legal aspects of ownership is critical in enabling space mining activities. One of the fundamental questions raised in regards to the legality of space resource utilization concerns the ownership of space resources. Answering such a question is not an easy task and implies not only an extended analysis of the current principles of international space law but also refers to soft law as a support for the rapidly increasing commercial activities in outer space. In line with the technological progress, the commercial concept of space resource activities has developed stronger support at the international level and private companies now ask for a consensus under international law.

The principle of non-appropriation given by Article II of the Outer Space Treaty [4] extends to States, but whether States can authorise companies to appropriate needs to be agreed upon by an international body.

However, clarity is required on which entities, if any, are able to authorise the possession, use, and disposal of space resources. It is critical to draw a distinction between the two methods of acquiring ownership: 1) through the *Claiming* of resources or 2) through the *Assignment* of resources.

An international regulatory body must determine a procedure for recognising property rights that could achieve international agreement. Such a procedure needs to be developed and formulated.

The recognition of property rights hinges upon the responsible and sustainable operations of any entity using space resources. While creating criteria of ownership for extra planetary mining endeavours seems preemptive, the WG recognises the special need for a means of revoking claims to property rights by private actors. These actors endanger both mankind and its common heritage, such as free and safe access to space.

The WG therefore asks the UN COPUOS to develop and formulate a set of guidelines, that when broken, revokes the legal mandate of any organisation operating in space. In doing so, the further economic use of extracted resources by that entity consequently becomes illegal.

Therefore, the WG recommends that the legal recognition of ownership shall not be based on technical criteria for which actors *should* claim extra-planetary resources, but rather on actors that *should not*. This should not to be based on the state of the material being extracted, but rather on whether the extraction is executed in a responsible manner.

Since ownership is a complex legal issue, associated rights and obligations must be considered. The WG recognises that while the current definition of ownership is sufficient for planetary interests, the right to freely access recognised property (without obstruction), for the purpose of unloading and offloading assets in space, is not addressed. These limitations in current definitions should be taken into account when a legal definition for ownership of resources is formulated. A subsequent extension from ownership rights is vital for enabling the growth of an industry.

Furthermore, the WG recognises the issues protecting intellectual property in space, due to the need to affirm the peaceful intentions of any space endeavour.

Ultimately, the obligations of any actor wishing to exercise ownership of extra-planetary resources must reflect on the fragility of the Earth's ecosystem and minimise the operational risk to the planet. However, this WG welcomes the possible expansion of obligations upon private actors in space that nations find agreeable.

The WG has agreed that there is a need to initiate the foundation of a registry system to recognise property rights on extracted space resources as well as access rights to sources of space.

Innovation (policy driven)

Actors within the market have a necessity to be certain that their competitors are playing with a similar set of rules and are equally accountable to those rules. In order for this to happen, there is a need to consider creating different incentives and encouraging actors to follow guidelines as positive reinforcement is mainly now guided by risk mitigation and prestige.

The WG is in favour of encouraging activities of private entities to utilise outer space resources. States are inherently responsible for the acts of these private entities, registered therein. Therefore, States are likely to enact policies which discourage risky activities such as asteroid mining. The WG aims to propose recommendations which reduce the legal, financial and political risk to individual States from private actors partaking in space resource-based activities and therefore enable States to encourage such activities.

Market

In regards to space mining, the WG predicts a rapid growth in technology. Therefore, there is a need to justify why regulation is important. This can be accomplished by showcasing the various benefits of such technology which will thus help encourage the private sector to pursue space resource exploitation.

RECOMMENDATIONS

The discussions of the 2017 Space Generation Congress' Space Resources Governance Working Group concluded with the following five recommendations:

Recommendation 1 ("Legal Framework"):

Drafting of guidelines, including built-in risk controls and minimum standards for operations and commercial ventures, coordinated with UN COPUOS operations guidelines.

The major difficulty in establishing regulation of space resources and any future industry or technologies is the nascent stage of the current industry. It is yet unclear which technologies will be used, by whom, to collect, distribute, or sell which resources. Non-binding guidelines will offer States and commercial players within these States some assurance and legal security without restricting innovation or specifying a direction that the industry must follow. This balance will enable states to encourage the development of space resources management systems, markets, and technologies.

While the exact nature of space resource operations is uncertain, guidelines can provide methods of risk management and operational standards to which companies must adhere in order to meet the requirements of existing space legislation and treaties, such as the Outer Space Treaty. The goal is to establish standards for operations that may occur, thereby preventing diminished access to space resources, harm to people, the environment, or resources. These standards would also ensure that commercial or other ventures incorporate the necessary procedures and equipment in their systems from the beginning. This is intended to preempt potential incidents and be proactive rather than reactive as has been seen in extremely damaging terrestrial resource incidents such as the Deepwater Horizon oil spill in the Gulf of Mexico [10].

Non-binding guidelines could be adopted by States, which would then apply to actors within their jurisdiction through local regulatory frameworks. These guidelines could be maintained by an existing organisation in the short term until, in the long term, a governing body can be appointed, as given by the example of the International Monetary Fund [11] or created as was done with the International Telecommunication Union [12]. The discussion of using UN COPUOS, a technical committee, or another body to draft and maintain guidelines remains open. The purpose of these guidelines will be to reduce risk to states by transferring it to actors, thereby encouraging states to adopt progressive policies with regards to the use of outer space resources.

Recommendation 2 (“Access and Licensing Framework”):

Private entities should demonstrate to their respective State, through a regulatory and licensing scheme, that they meet required guidelines

The Outer Space Treaty currently places legal liability for space activities on the responsible State, which also includes all commercial or private activities from that State. In order to shift some responsibility for the actions of space resource companies or organisations away from the State and onto the players themselves, States should adopt a licensing framework specifying conditions that must be met and maintained by space resource organisations in order to undertake space resource activities. This provides States with legal recourse to pursue organisations that breach the space resource guidelines and the conditions of their license. Similar schemes are already used in terrestrial industries.

In the future, as the industry and technologies become more developed, the license conditions should include technical specifications. For the time being however, the conditions should focus on *how* the activities are conducted, rather than *what* the activities are. Following the laws adopted by Luxembourg [2], license applications should demonstrate that an organisation meets requirement for:

- Financial soundness and longevity (including clean-up or restoration at the end of a project)
- Insurance coverage
- Technical capability and/or experience
- Sound risk management practices
- Specification of legally responsible persons

This would include regulations on insurance and operational capability along with risk and financial soundness.

Recommendation 3 ("Clarification on Ownership"):

Clarification between "non-appropriation" and "freedom of use" is to be developed by a UN working group which considers the acquisition and ownership of space resources

Current space treaties prevent appropriation of space resource and protect the freedom of use of space for all nations. These terms are not specifically defined and are open to interpretation. As space resources may be bought and sold in the future, there must be a clear definition of what constitutes ownership of resources, and the conditions under which it is granted. This will encourage space resource shareholders to continue taking part in the industry and inform their decisions regarding business models, market structures, and technologies. In order to establish this definition, or at least provide some guidance until the nature of the industry becomes clearer in the future, a UN working group should be established. This working group will revise its guidelines or definitions as the industry and technologies develop over time.

Recommendation 4 ("Scientific Access Rights"):

Privileged access granted to scientific activities alongside of industrial activities;

"Space resources" does not only include physical resources; space and celestial bodies also provide a wealth of knowledge and scientific investigations that are just as important. It is expected that industrial and/or commercial activities may outpace or expand past scientific investigations, or they may take place in regions previously not scientifically investigated. Commercial ventures should not prohibit the collection of scientific data. This can be managed in a number of different ways:

- Allocating “national park” areas for scientific investigation, untouched by other activities
- Allowing scientific investigations to be conducted before commencement of commercial activities
- Conducting parallel scientific investigations and commercial activities
- Commercial ventures conducting scientific investigations themselves and providing the outcomes to the scientific community.

Data of scientific value gathered during the activity shall be provided to the scientific community, respecting the requirement to share benefits.

Recommendation 5 (“International Organisations”):

Set up a UN working group to investigate the establishment of an international regulatory body for space resources.

As operators from different States will likely come into contact or competition in space, an international regulatory body is required to coordinate between States and other shareholders. This is a practice that has been implemented effectively in a number of other international industries; for example, the International Telecommunication Union (ITU) coordinates the allocation of the radiofrequency spectrum between States and other users to avoid conflict and interference during operations.

Investigations must be conducted as to whether a completely new organisation is required or if the responsibilities should be allocated to an existing body with experience in resource management. A future space resource industry may have a large economic impact on Earth’s society and markets, in which case an organization such as the International Monetary Fund (IMF) may be a suitable governing body. If the majority of coordination for space resources relates to allocation of regions and resource access, then a new body similar to the ITU may need to be established.

The WG recognises that the establishment of an international regulatory body for the governance of outer space resources may be impractical until the industry and technologies mature. Initially, an existing organisation, such as the UN COPUOS, should maintain the guidelines and oversee international coordination. This would also ensure the space resource guidelines meet the requirements of existing or future treaties and agreements. Once the demand for coordination exceeds the capabilities of the existing body, a new governing organisation can be found or established.

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WORKING GROUP 3: SPACE LAW

EXECUTIVE SUMMARY

The *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, commonly known as the Outer Space Treaty (OST), is the cornerstone of international law governing the activities in, and the uses of, outer space. The foundations for the treaty were laid by the United Nations General Assembly (UNGA) Resolutions prompted by the launch of Sputnik by the Soviet Union in 1957 and the ensuing global tensions that arose in relation to the potential ways in which outer space may be exploited if left unregulated.

As of this year, the OST has been ratified by 105 States and is generally considered to have been very successful in guiding and shaping the ways that outer space has been used over the past 50 years. However, over recent years there have been revolutionary developments in the way space is exploited and the nature of the players involved in space activities. This has created a pressing need for the OST to be adapted to continue to preserve the benefits of outer space for future generations. To this end, the Space Law Working Group asks:

"How can the Outer Space Treaty be adapted for the next generation to enjoy the benefits of space over the next 50 years?"

The working group has addresses this question in relation to: (i) military uses of space; (ii) commercialisation and democratisation of space; and (iii) space debris.

Working Group Sub-topic 1: Military Uses of Space

This sub-group made the following recommendations in relation to military uses of space:

- Draft a supplementary protocol to the OST related to improving transparency and confidence-building measures (**TCBMs**) for outer space activities – this protocol will mandate the establishment of an intergovernmental body, similar to the International Civil Aviation Organisation (**ICAO**), to address disputes related to space activities in order to prevent space conflict from arising
- Draft a supplementary protocol to explicitly extend the Law of Armed Conflict (as reflected in Additional Protocol 1 of the Geneva Convention)[10] to outer space and specifically address the key principles of International Humanitarian Law in the context of outer space so as to effectively regulate possible military conduct in outer space.

Working Group Sub-topic 2: Commercialisation and Democratisation

This sub-group made the following recommendations in relation to commercialisation and democratisation:

- Draft a supplementary protocol to the OST related to commercialisation and democratisation of outer space in respect of space resources (Art I), appropriation by nationals of States (Art II), recognising equality of certain commercial rights (Art III), no restriction on the basis of nationality (Art IV) and reaffirming international law (Art V)
- Adopting these articles will allow for the undertaking of commercial activities without diminishing the principles provided in the OST.

Working Group Sub-topic 3: Space Debris

This sub-group made the following recommendations in relation to space debris:

- Draft a supplementary protocol to the OST related to space debris that provides for definitions of terms that have previously been contested (Art I), imposes an obligation to track on launching states (Art II) and allocates responsibility in event of debris being created (Art III)
- Adopting these articles can for the basis of a new regime that prevents and addresses issues arising from space debris as it is created.

WORKING GROUP PARTICIPANTS

Figure 1: Delegates of the Space Transportation Working Group

NAME	POSITION	NATIONALITY
Duncan Blake	SME, IALPG	Australia
Roger Franzen	SME, Shoal	Australia
Crystal Forrester	SME, DSTG	Australia
Tyson Lange	Moderator	Australia
Monique Hollick	Rapporteur	Australia
Kristin Shahady	Rapporteur	USA
Matthew Miller	Delegate	USA
Joel Dennerley	Delegate	Australia
Desislava Gancheva	Delegate	Australia

Imogen Rea	Delegate	Australia
Merve Erdem	Delegate	Turkey
Wei-Yu Louis Feng	Delegate	Taiwan
Matthew Driedger	Delegate	Canada
Mia Brown	Delegate	USA
Caitlyn Georgeson	Delegate	Australia
Andrew Butler	Delegate	Australia
Oliver Paxton	Delegate	Australia
Mark Novakovic	Delegate	Australia
Zaid Rana	Delegate	Canada
Victoria Van Dyk	Delegate	Canada
Alexander Gibson	Delegate	USA

Sponsored by Shoal, Australian Department of Defence Science and Technology Group (DSTG) and the International Aerospace & Law Policy Group (IALPG).

INTRODUCTION

The *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, commonly known as the Outer Space Treaty (OST), is the cornerstone of international law governing the activities in, and the uses of, outer space. The foundations for the treaty were laid by the United Nations General Assembly (UNGA) Resolutions prompted by the launch of Sputnik by the Soviet Union in 1957 and the ensuing global tensions that arose in relation to the potential ways which outer space may be exploited if left unregulated. The treaty was ratified in 1967 by all major space-faring nations of the era and reflects the competing interests of the United States and Soviet Union at this time, as well as a mutual desire to avoid a nuclear war fought in or from space. The OST is a framework convention and provided the basis for an additional four treaties which together comprise the international space regulation framework: the *Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (1968)*, the *Convention on International Liability for Damage Caused by Space Objects (1972)*, the *Convention on Registration of Space Objects Launched into Outer Space (1976)* (Registration

Convention), and the *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (1984)*. The underlying principles of the OST pervade each of these treaties, namely, the freedom of exploration and use of space, the use of space for peaceful purposes, space as the province of humanity, the use and exploration of space for the benefit of all States, the non-appropriation of outer space, and the responsibility of States for the space activities of their nationals [1].

Today, the OST has been ratified by 105 States and is generally considered to have been very successful in guiding and shaping the ways that outer space has been used over the past 50 years [2]. Space is yet to be used as a theatre for war and no nuclear weapons or weapons of mass destruction have been placed into space, despite the 1960s Space Race taking place against the backdrop of the Cold War. However, over recent years there have been revolutionary developments in the way space is exploited and the nature of the players involved in space activities. This has created a pressing need for the OST to be adapted to continue to preserve the benefits of outer space for future generations. For example, while the use and exploration of space was once exclusively a government activity, it is increasingly accessible to private entities, universities, and even individuals. While near-Earth space was once an uncongested, seemingly infinite resource, today it is teeming with thousands of space objects on the verge of producing a runaway cascade of collisions. While anti-satellite missiles and directed-energy weapons were once technologies of science-fiction, they are now a reality and have been tested in space with remarkable accuracy. To this end, the Space Law Working Group asks:

"How can the Outer Space Treaty be adapted for the next generation to enjoy the benefits of space over the next 50 years?"

with particular regard given to: (i) military uses of space; (ii) commercialisation and democratisation of space; and, (iii) space debris.

WORKING GROUP APPROACH

The Working Group was initially briefed on the objectives of the sessions and the context for the issue by the Moderator. The group was then given time to individually brainstorm questions related to any of the three sub-topics, which were consolidated to a mutually exclusive set of questions in each sub-topic and used as guidance by the Subject Matter Experts (SMEs) in their presentations. Following their presentations, the SMEs kindly made themselves available for further consultation and to assist with the deliberations of the Working Group for the majority of the Congress. The delegates allocated themselves to three subgroup, each focusing on one of the three sub-topics. To take advantage of the benefits of the full Working Group, time was allocated at the end of each day to regroup as a full cohort to summarise and collaborate on the proceedings of the sub-group sessions. The first sub-group session was dedicated to identifying the key challenges surrounding the topic and prioritising the areas to be addressed, as well as those that were deemed out of scope. The sessions of the second day of the Congress were focused on brainstorming, prioritising and expanding upon potential solutions to the prioritised set of challenges. The sessions on the third day were focused on narrowing down the final recommendations and future steps, and developing and delivering a presentation for the Congress. In addition to the SMEs, the Working Group was fortunate enough to have expert guidance and feedback from David Kendall, the current Chair of the United Nations Committee On the Peaceful Use of Outer Space (UN COPUOUS), and Gilles Duchet, from Spectrum Space Security Inc., during portions of the Working Group sessions.

MILITARY USES OF OUTER SPACE

Context

Article IV of the Outer Space Treaty [1] is the core provision of international law pertaining to the militarisation of space. The Article prohibits parties to the Treaty from placing nuclear weapons and other “weapons of mass destruction” into outer space, and reiterates the use of the Moon and other celestial bodies to be exclusively for peaceful purposes. It also forbids the establishment of military sites, military manoeuvres, and weapons testing on celestial bodies.

Major points of contention regarding the OST in the context of space militarisation are that:

- It does not explicitly prohibit weapons in general from being used in space
- Since customary international law has evolved to accept the exploitation of space for military applications. Some examples are:
    - Command, Control, Communication, Computers Intelligence, Surveillance and Reconnaissance applications
    - Global Positioning System (GPS)
    - Earth Observation satellites
- It is too broad in that it does not distinguish sufficiently the types of military activities that are and are not permitted.

With respect to the latter, it can be argued that non-aggressive military activities in space do not violate the “peaceful purposes” principle of the Treaty and that a valid interpretation is to prohibit aggressive actions and weaponisation only. Regardless of the fact that space is already used for military objectives, achieving a blanket ban on space militarisation is infeasible in practice due to the fact that many space technologies and spacecraft are dual-use (having both military and civilian objectives and payloads) and can be repurposed. For example, lasers are being developed for next generation communication technologies, but they can also be used as directed energy weapons. Also, many satellites by virtue of their velocities (on the order of kilometres per second) could be repurposed as kinetic weapons. To complicate the matter further, it is nearly impossible to verify the *intended* use of a satellite or space technology.

Kinetic space weapons have already been developed and demonstrated by major State actors in space. In 2007, China used an Earth-to-space Anti-Satellite (ASAT) missile to destroy one of its defunct satellites in low-Earth Orbit. Shortly after, in 2008, the United States used similar technology to intercept a space object to prevent toxic hydrazine (a fuel source in some satellites) from reaching the Earth's surface. Russia is also reported to have ASAT capabilities, and although they have not yet been used in respect of space objects, Russia has demonstrated high precision manoeuvrability technology which may be applied to kinetic weaponry [3]. The US has responded to the threat of satellite destruction, both intentional and unintentional, by developing the Geostationary Space Situational Awareness Program (GSSAP), which involves satellites capable of monitoring and rendezvous operations in the geostationary orbit. An extremely damaging by-product of kinetic space weapons or actions, is the exorbitant amount of space debris that they can create. For example, the 2007 Chinese ASAT test produced thousands of new pieces of space debris, many of which will persist in space for hundreds of years [4].

There have been several notable attempts to legally regulate the military uses of space over the past two decades. Although each document has faced challenges in obtaining unanimous acceptance by the major space-faring nations, they propose various commendable and (in many cases) well-accepted ideas from which inspiration has been drawn by the Working Group. The United Nations General Assembly has passed an annual resolution for many years, known as 'Prevention of an Arms Race in Outer Space' (PAROS). It has not been comprehensively supported (notably, the US has typically declined to support the resolution), although it has received widespread support, owing perhaps to the insubstantial and aspirational nature of the resolution and its less-than-treaty status as a non-binding instrument.

Nevertheless, the annual PAROS resolutions did provide impetus for two drafts of the Prevention of the Placement of Weapons in Outer Space Treaty (PPWT) [5], the latest of which was proposed in 2014 by Russia and China, and gained the support of a significant number of States. Several nations, including the US, have refused to enter into negotiations on the draft Treaty, continuing the stalemate in regulating space weapons. Critics of the PPWT cite the lack of verifiability of the provisions, the absence of reference to ASATs, and the poor definition of a weapon as the major shortcomings of the Treaty.

The draft International Code of Conduct (ICoC) [6] originated as a European Space Agency initiative. It attempts to establish transparency and confidence-building measures for activities in space, to prohibit the creation of long-term space debris, and actions which would result in the destruction or collisions between space objects. Major disapproval of draft the ICoC arose from all three current space superpowers – the Russia, China and the US, primarily due to the lack of consultation and input from them throughout the development of the document. The US supported a later version of the draft ICoC, once the European Union relinquished control of the process to develop the draft, handing it over to the US. Nevertheless, Russia and China advocated for any further action in respect of ICoC to be undertaken in the context of the Conference on Disarmament, a UN body that has not been able to settle anything substantive for many years due to the requirement for consensus even on procedural issues.

The Report of the Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities produced in 2013 [7] provides recommendations related to improving interactions, dissemination, and clarification of activities in outer space, but implementation of the contents of the report remain purely voluntary.

Key Challenges

Early in the sub-group's convention, it was established that efforts would be best-placed, in terms of likelihood of adoption, in attempting to supplement the OST rather than amending it. In light of the history and current context of the military uses of space and its legal status, the sub-group identified the primary challenges in supplementing the OST to be:

- Prohibiting weapons or a subset of weapons in space
- Creating a legal regime to regulate dual-use technologies without stifling innovation and commercialisation in the space industry
- Explicitly applying International Humanitarian Law (IHL) to outer space
- Providing provisions to mitigate the consequences of armed conflict in the event that it arises
- Outlining a proactive dispute resolution mechanism for activities in outer space
- Mechanisms to promote transparency and verification methods
- Creating an supplementary protocol (or similar device) acceptable to space-faring powers

The issue of prohibiting weapons (or a subset of weapons) in space, has been an object of contention for several years, most notably in the debates surrounding the PPWT. As mentioned above, a key roadblock to their prohibition is the dual-use nature and re-purposability of many space technologies and space objects, the difficulties associated with providing an appropriate definition of a weapon, and means for verification of intended use. Furthermore, historical precedents suggest that prohibiting methods and means alone are often insufficient to prevent aggressive action, since ways around the definition of these methods or means are often achieved. With this in mind, the group prioritised the key challenges to those which relate to regulating the *conduct* of military activities in space, improved and objective means of transparency and verification with regards to space objects and space activities, and promoting dispute resolution mechanisms.

Recommendations

The first of two key recommendations from the sub-group is a supplementary protocol to the OST related to improving transparency and confidence-building measures (TCBMs) for outer space activities. The importance of promoting TCBMs has been referenced by UNGA Resolutions and the Report of the Group of Governmental Experts, and is also evidenced by their prominence in the aerospace and maritime industries. Noting the increasing prevalence of clandestine activity in space, and the challenge in incentivising open communication and disclosure between different actors in space, the supplementary protocol should be focused on the development and implementation of objective and data-driven verification means, such as global access to Space Situational Awareness (SSA) information. In addition, the sub-group recommends that the protocol mandates the establishment of an intergovernmental body, similar in nature to the International Civil Aviation Organisation (ICAO) Council in the aviation industry, to handle disputes related to space activities in order to prevent space conflict from arising.

The second key recommendation of the sub-group is for a supplementary protocol to explicitly extend the Law of Armed Conflict (as reflected in Additional Protocol 1 of the Geneva Convention) [10] to outer space. The sub-group believes that by regulating the *conduct* of military behaviour, rather than its means and methods, the supplementary protocol is more likely to advance further than previous attempts at regulating the military uses of space because it circumvents the issues around defining a weapon, or classifying prohibited/permitted technologies, including dual-use technologies. By avoiding these issues, it is also believed that such a protocol will have greater regulatory control in the future as technologies continue to advance, without compromising regulation of the *consequences* of space activities. Key elements of the Law of Armed Conflict that the sub-group has identified as critically important are the principles of distinction, proportionality and precaution. These principles must be extended in the supplementary protocol to increase their applicability to space. With regards to the principle of proportionality, the nature of space and space technology is such that injury or damage caused by particular actions can be indirect and difficult to quantify, and can also be more wide-reaching and long-term than many actions in conventional theatres of warfare. For example, destroying the functionality of a communications satellite may not directly cause injury or loss of life; however, the degradation of a service upon which modern civilisation relies may directly reduce the quality of life of large numbers of civilians and may result in injury or loss of life. Furthermore, the consequences of a particular action depend strongly on the nature of the space object targeted, as well as the robustness of a State’s space infrastructure. The principle of distinction in space is complicated by the prevalence of dual-use satellites, which inhibit the distinction between military and civilian targets. A supplementary protocol must therefore specifically address these key principles of IHL in the context of outer space so as to effectively regulate military conduct in outer space.

COMMERCIALISATION AND DEMOCRATISATION OF OUTER SPACE

Introduction

The Outer Space Treaty establishes that all nations should have free access to space and stresses that exploration should be a peaceful endeavour that is “for the benefit and in the interests of all countries." As a caveat, the OST instituted in Article II that "Outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means." This article was inspired by the territorial grabs that plagued Antarctica in the early 1900's resulting in the Antarctic Treaty.

Article II in the OST has multiple interpretations by various States of this statement. To prepare for the upcoming mining industry in space, the United States provided one interpretation. US Congress passed the US Commercial Space Launch Competitiveness Act in 2015 which ensures US based companies will get the rights to anything they collect in space. Luxembourg followed suit in July of 2017 by passing the Luxembourg Law on the Exploration and Use of Space Resources of 2017. This law secures the right of private operators in the space industry to resources that have been extracted in space and assures they have the rights to said extracted resources.

Due to these multiple interpretations of Article II of the OST, the future increase of human activity in space, and increased commercial activities including resource extraction in space, protocols and amendments with strict wording limiting biased interpretations are imperative.

Other collaborative efforts that were referenced for this discussion were the Svalbard Treaty, UN Convention on the Law of the Sea, and the International Telecommunications Union.

Scope

The aim of the Commercialisation and Democratisation subgroup was to write supporting text on:

- Defining property rights in space and allocate responsibility to a governing party for property rights
- Decreasing ambiguity in Article II
- Human rights throughout space activities
- Defining the future space marketplace

Methodology

To accomplish the goals of the Commercialisation sub group, resolving the ambiguity of Article II was the first issue addressed. The US Commercial Space Launch Competitiveness Act was a source for a solution while considering the rights of countries with a limited space presence that intend on having a larger presence in the near future. Laws for human safety and activity were then reviewed beginning with defining an astronaut or spaceflight civilian. Article III assisted with establishing international law in space. The following protocols and commentary were the result:

> ***Draft Supplementary Protocol to Article II of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies***
>
> *Article I - Space Resources*
> *All nationals of a States Party engaged in commercial recovery of a resource shall be entitled to any space resource obtained, including to possess, own, transport, use, and sell the space resource, subject to appropriate national jurisdiction and control.*

Using the US Commercial Space Launch Competitiveness Act and the Luxembourg Law on the Exploration and Use of Space Resources, this article establishes that citizens of Outer Space Treaty signing states are entitled to any space resource obtained and/or extracted. These resources, however, will be subject to the party's jurisdiction and import/export control. With the use of a licensing regulatory board under the oversight of the UN, this article will be controlled and keep states incentivized to follow this agreement.

> *Article II - National Appropriation*
> *These rights of all nationals of States Party to possess, own, transport, use and sell space resources does not constitute national appropriation under Article II of the Outer Space Treaty.*

To protect equitable sharing of resources and reaffirm Article II of the OST, this article does not constitute national appropriation. This article does not state the term "use", only "appropriate" to maintain equal share of space and allow for some extrapolation with respect to individual states.

> *Article III - Liberties in Space*
> *The nationals of States Party shall have equal liberty of access and entry to outer space and they may carry on there without impediment all industrial, mining and commercial operations on a footing of absolute equality subject to national jurisdiction and control.*

Using the UN Convention on the Law of the Sea, equal individual liberty of access and entry to outer space without impediment is granted within this article. This will grant commercial companies the rights they need to be able to mine space objects and celestial bodies.

> *Article IV - Free Space Market*
> *The ability of nationals of all States Party to possess, own, transport, use and sell space resources, shall be implemented on a basis of equality, with no restriction permissible on the basis of nationality ensuring that such activities are carried out for the benefit and in the interests of all countries.*

This article institutes a free market place in space with no restrictions on the basis of nationality. UN licensing board will enable this article and can guarantee to protect objects in space for countries that are not yet able to carry out such activities.

> *Article V - Reaffirming International Law*
> *This protocol shall be applied in accordance with all provisions of the Outer Space Treaty and all other obligations of international law.*

Reaffirming rights established in Article III of the OST, this article states the protection of the rights of humans that will travel to space and bodies in space by obliging to international law. This ensures reasonable efforts will be taken to ensure the safety of human life. Legality of risky human operations will be determined by the space party as long as it remains within international law.

Conclusion

Protocols establishing and defining human rights and property rights in space are needed for the upcoming space economy. In order to make sure it is freely able to operate, state parties will be able to acquire and sell space resources with the approval and acquisition of a license by the United Nations. All nations will have the ability to participate in commercial activities and the free space market. Human rights are also protected under pre-established international law, however reaffirmed before human activity is increased over the next century.

SPACE DEBRIS

Introduction

Space debris is not addressed explicitly within current international law requiring international agreements addressing this issue. International space laws have been created under the support of the UN Committee on the Peaceful Uses of Outer Space. Space debris is addressed in the following treaties:

- The OST
- The Registration Convention
- The Inter-Agency Space Debris Coordination Committee Space Debris Mitigation Guidelines, October 15, 2002.

The OST addresses international responsibility and liability by a state for damage caused by objects that the party launched into space. The Registration Convention mandates that all launching states notify the UN of any objects they launch including orbital parameters to determine this liability. The Space Debris Mitigation Guidelines are recommendations for Member States to voluntarily take measures to ensure limited space debris as well as safe practices and procedures. To prevent trans-boundary harm, humanity is obligated to design and enforce policy beyond the Outer Space Treaty and additional guidelines.

Scope

The aim of the Space Debris subgroup was to write supporting text on:

- Referring to mitigation to increase the binding degree to be included in an international treaty as protocol
- Regulating the phase prior to a serious collision event
- Establishing responsibility for space debris, what that responsibility entails, and whether there should be consequences for irresponsible actions
- Defining space debris

Methodology

To accomplish the goal scoped for the Space Debris sub-working group, different terms such as "launching state," "space object," "orbital elements," "life cycle," and "fragmentation event" were defined. This allowed for more specific protocols to be written about space debris. Then, the group established requirements to track and monitor objects in space in order to declare responsibility for launching states and their uncontrolled debris. Tracking and prevention of future space debris cataclysmic collision events was determined to be more necessary than the mitigation of current space debris. The following articles were written:

Draft Supplementary Protocol to the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies relating to Space Debris

Article I - Definitions

For the purposes of this Protocol

(a) The term "Launching State" means:
(i) A State which launches or procures the launching of a space object;
(ii) A State from whose territory or facility a space object is launched;

(b) The term "space object" includes component parts of a space object as well as its launch vehicle and parts thereof;

(c) The term "orbital elements" includes basic orbital parameters, including:
(i) Nodal period;
(ii) Inclination;

(iii) Apogee;
(iv) Perigee.

(d) The term "life cycle" includes all events from launch until such time that the space object returns to the surface of the Earth, or it can be proved by the launching State to no longer pose a threat to other space operations, capabilities or space objects;

(e) The term "conjunction event" means a space object(s) striking or colliding with another space object(s) either accidentally or intentionally;

(f) The term "fragmentation event" means any event where component parts of a space object, fragment or disconnect from the space object permanently, and are uncontrollable.

<u>Article II - Requirements to Track</u>

(a) The launching State shall track and monitor for their entire life cycle, all space objects that it registers pursuant to Article II.1 of the Convention on Registration of Objects Launched into Outer Space.

(b) The orbital elements of all space objects being tracked under Article II.1 of this Protocol shall be transmitted to other States Parties to the Protocol or the Secretary-General of the United Nations as frequently as practicable.

(c) In the course of tracking and monitoring a space object, if a launching State becomes aware of the possibility that any event as outlined in Article III of this Protocol may occur, it shall immediately inform the other States Parties to the Protocol or the Secretary-General of the United Nations.

(d) The requirement to track and monitor space objects incumbent on launching States can be transferred to another single State Party to the Protocol or jointly with other States, including cases where they are carried on within the framework of international intergovernmental organisations. Where such events occurs, the launching State shall immediately inform the other States Parties to the Protocol or the Secretary-General of the United Nations.

<u>Article III - Responsibilities of the Launching States</u>

In all cases where a conjunction event occurs involving the launching State's space object, of where a fragmentation event occurs involving the launching State's space object, or if a space object which the launching State has registered pursuant to Article II.1 of the Convention on Registration of Objects Launched into Outer Space becomes uncontrollable, or if there is a reasonable expectation that the launching State will be unable to assume or resume the space object's' intended function, the launching State shall immediately inform the other States Parties to the Protocol or the Secretary-General of the United Nations.

Conclusion

To prevent future collisions and space debris events rather than mitigate the current status of miscellaneous objects in space, state parties will be required to track and report elements and the status of any objects launched into outer space. These parties will be required to inform other states parties or Secretary-General of the United Nations of a life-threatening, rogue object.

WORKING GROUP CONCLUSION

The outcomes of the Working Group are reflective of delegates who were interested and engaged by the topics, and responded to the challenges in the time available. Of particular interest was that the need for more regulation was recognised in a number of presentations given at both the Space Generation Congress the International Astronautical Congress the following week. Considering the interest shown by delegates in continuing the efforts of the Working Group, it is likely that there will be further endeavours to consider and draft amendments to the OST.

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WORKING GROUP 4: SPACE INNOVATION

EXECUTIVE SUMMARY

In this report, the arguments already made are reemphasized - that the Moon Village concept offers a unique opportunity to further knowledge, enlarge the economic sphere, and provide humanity with a unifying goal for peaceful cooperation (1,2). In order to realise this vision in the current environment, the following recommendations are offered to space agencies and relevant organisations:

- The creation of a communications strategy which identifies and targets key stakeholders in government, business and society. The messaging for all groups should rest on a global vision, focused on the classic three S's of a permanent lunar presence (supplies, science and staging), and also on a fourth S - society. Such a concerted effort is required to connect and motivate stakeholders in the absence of a dominant driving organisation.
- The enlistment of a professional marketing agency to conduct a campaign based on the communications strategy. The 'Rosetta' and 'Curiosity' marketing campaigns showed that trained marketing professionals are very effective at reaching a broader spectrum of audiences outside the space community - a key enabler for a global Moon Village movement.
- The establishment of a bottom-up coordination group at the United Nations level to provide governance and legal frameworks. This is necessitated by the challenge of integrating nation-states interests into the Moon Village vision. A prominent successful example of this approach is the Paris Climate accord.
- The promotion and/or subsidisation of shared power and data infrastructure on the lunar surface. Subsequent lunar missions will benefit from extra survivability, a nascent lunar economy, and the immediate practical benefit of in-situ data and power. Having this infrastructure in place on the Moon reduces risks and costs, while enabling commercial growth.
- Creating lunar-analogue testbed environments for companies and researchers, especially those traditionally not involved in space, to test technology and conduct research. Agencies have the unique capability to provide these facilities, with some prominent examples being NEEMO and HI-SEAS. Such facilities could be coupled with the creation of dedicated business incubators for companies interested in commercial lunar activities. Hubs like this will be a key enabler for the nascent stages of a sustainable lunar economy.

ACRONYMS

ESA	European Space Agency

HI-SEAS	Hawai'i Space Exploration Analog and Simulation
ISS	International Space Station
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
NEEMO	NASA Extreme Environment Mission Operations
UN COPUOS	United Nations Committee on the Peaceful Uses of Outer Space

GROUP PARTICIPANTS

Figure 1: Participants of the Space Innovation Working Group sponsored by the European Space Agency at the Space Generation Congress

Name	Position	Nationality
Josef Wiedemann	Moderator	Germany
Daniel Wischert *	Rapporteur	Germany
Timothy Fist *	Rapporteur	Australia
Piero Messina, Strategy Department at ESA	Speaker	Italy
Kyle Acierno, Managing Director at iSpace Europe	Subject Matter Expert	Canada
James D. Burke, retired JPL lunar settlement and	Subject Matter Expert	USA

exploration expert		

Adam McSweeney	Delegate	England
Ahmed Abdi	Delegate	Netherlands
Alberto Fedele	Delegate	Italy
Ani Vermeulen	Delegate	South Africa
Anna Thomas	Delegate	USA
Bruno Sarli	Delegate	Portugal / Brazil
Davide Petrillo	Delegate	Italy
Deepak Atyam	Delegate	USA
Enrique Garcia Bourne	Delegate	France / Spain
Graeme Taylor	Delegate	England
John Conafay	Delegate	USA
Kseniia Lisitsyna	Delegate	Russia
Livia Savioli	Delegate	Italy
Longee Guo	Delegate	New Zealand
Maria Grulich	Delegate	German
Matjaz Vidmar	Delegate	Slovenia
Mohammad Iranmanesh	Delegate	Belgium / Iran

Narayan Prasad	Delegate	India
Orzuri Rique	Delegate	Spain
Radim Badsi	Delegate	France / Czech Republic
Sungmoon Choi	Delegate	South Korea
Veruari Erind	Delegate	Italy / Albania

* Members who contributed to the final report

INTRODUCTION

With the International Space Station (ISS) approaching the end of its life-cycle, humanity is at a critical tipping point for human space exploration. Several nations and private companies are currently planning independent programs that target the Moon in the near-term (0-10 years) and mid-term (11-25 years), providing the international space community with the opportunity to collaborate. The vision of a Moon Village was put forward by the European Space Agency (ESA) Director-General for a new open partnership wider and stronger than the ISS to promote diversity in an open architecture environment (1).

The Moon Village is intended as an open-ended framework embracing multiple users for multiple and diverse utilisations. The Moon Village will require robotic, automatic and human-tended systems making it suitable for the participation of all nations with different degrees of space or technological capabilities.

Moreover, the Moon Village will offer the opportunity to forge new alliances between public and private entities to expand the permanent presence of humankind beyond Low Earth Orbit (LEO) to further our knowledge, enlarge our the economic sphere of our activities and provide humanity with a unifying goal for peaceful cooperation. Finally, the Moon Village is intended to unfold in the context of a unique governance scheme and could become an innovation platform and research network for the 21st Century.

An opportunity to design a new interplanetary life beckons. The challenge: how to collectively prepare for novel, cost effective and agile programs for space settlement and allow for space agencies, philanthropists, citizens and commercial space to create an integrated, mutually reinforcing strategy? Shifting from isolated impact to collective impact is not merely a matter of encouraging more collaboration or public-private partnerships. What is also needed is the sense of shared values, sources of pride, common language, and trust in others' intentions to tackle the issues and problems that emerge "off-plan".

The Moon Village vision is ambitious, but it is achievable in the coming decade if all the key actors in the Moon Village ecosystem collaborate effectively.

WHY A MOON VILLAGE?

Discussions about the Moon Village concept often lack sufficient context. In the introduction this report has attempted to summarise the *what* of the Moon Village. This section is an attempt to summarise the *why*. Traditional arguments for lunar settlement rest on what is commonly referred to as the *three S's;* supplies, science and staging:

Supplies	The lunar regolith contains resources important for both Earth and space applications: ● Rare Earth metals, used widely in electronic devices ● Silicon, which could be mined to create solar panels ● Water, vital to sustaining a human presence, as well as for conversion into rocket fuel ● Helium-3, a possible future energy source
Science	The Moon provides a unique environment for several scientific missions: ● Understanding the formation of the Earth through the record of bombardments apparent from the lunar surface ● The far side of the moon provides a radio quiet location from which to peer deep into the universe ● The lunar low gravity environment provides opportunities for medicine and pharmaceutical research, among other fields
Staging	A permanent presence on the Moon will facilitate further missions into our solar system and beyond: ● Development and testing of key technologies such as habitats and in-situ resource utilisation ● Acting as a staging point for longer journey

While the *'Three S'* model is a useful mnemonic explaining the straightforward reasons for establishing a settlement on the Moon, the initial recommendation is to add a fourth 'S', integral to the Moon Village vision and to inspiring a global movement - *'society'*. Society encapsulates the spirit of the Moon Village as the iconic initiative of the 21st Century - an initiative not just to deepen knowledge and enlarge economies, but also to create a unifying goal for peaceful international cooperation.

Society	Establishing a permanent presence on the Moon provides a powerful opportunity to further the cooperative spirit of the ISS by: ● Fostering partnerships and friendships between governments and peoples ● Fostering collaboration between public and private entities ● Expanding the culture and future of humankind beyond Earth

The Moon Village - supplies, staging, science and society. If these goals are seen as desirable, then the next question to answer is how to help realise them. This is where the ensuing recommendations will focus.

RECOMMENDATIONS FOR ENGAGEMENT WITH NON-TRADITIONAL SPACE PLAYERS

The participation of non-traditional space players is crucial to the success of the Moon Village vision. First; who are these players, and why are they important?

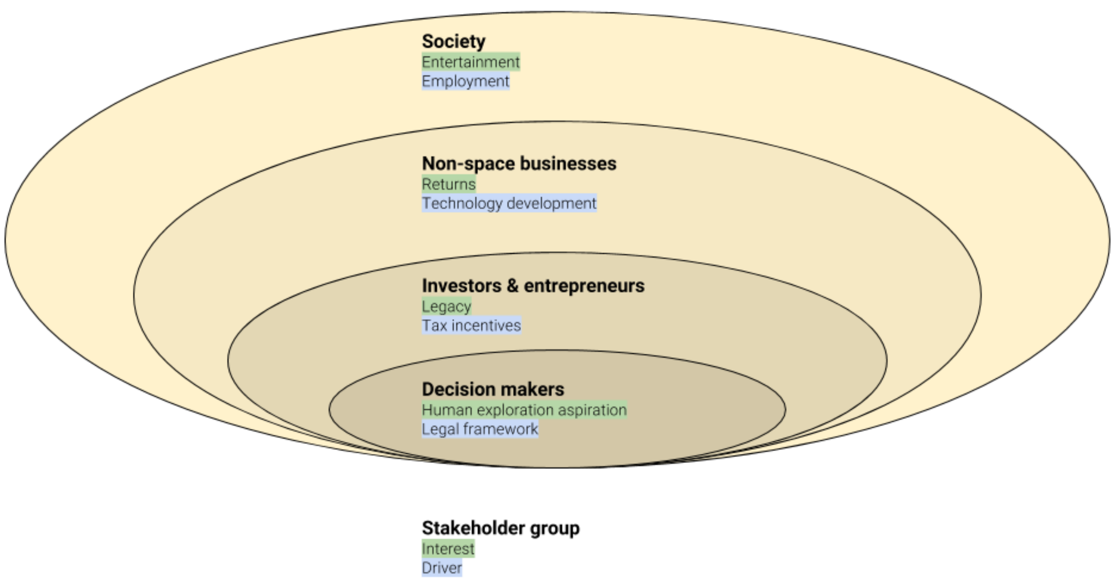

Figure 2: Key stakeholder groups

Four key stakeholder groups have been identified, shown in Figure 2. Buy-in from each of these is important, and it is also crucial to understand the key motivators for each group, keeping in mind that these will also vary within the groups themselves. For example, some investors will be motivated by legacy, but most will also be motivated by financial returns.

It is also important to understand the relationships between different groups. Decision makers will be highly influenced by public opinion, so any successful engagement effort with society will also likely be effective at swaying decision makers in government. Commercial actors in the middle two groups will respond both to decision makers (legislation within which they can operate) and to society (customer groups which they can tap into).

Given all of this, the following roadmap is proposed for engagement with these groups, to be carried out by any and all parties interested in furthering the Moon Village vision (space agencies, independent associations, governments):

	Near term (0-10 years)	Mid term (10-25 years)	Long term (25+ years)
Overall goal	Establish and target well-defined user/stakeholder groups, where each group has well understood needs and a clearly articulated vision.	Create an inclusive environment which allows the establishment of a variety of jobs and businesses for long term permanent settlement.	Establish a permanent settlement to consolidate the Moon village mission.
Government	Lobby and build up a network of Moon Village champions, providing pressure for the funding of national projects. See *Recommendations for Inspiring and Enabling an International Partnership* below.	Push for the provision and funding the infrastructure for lunar activities, enabling investors to establish business cases. See *Recommendations for Developing Lunar Commercial Activities in the Near Term* below.	Lobby for the funding of missions which exploit Moon as a springboard for exploration missions beyond cislunar space.
Business	Promote the benefits and investment opportunities involved in lunar activities. See *Recommendations for Developing Lunar Commercial Activities in the Near Term* below.	Connect businesses and investors with government initiatives.	Promote new business opportunities in space tourism.
Society	Adopt a broad communications strategy, with a focus on social media. See	Continuous public engagement to maintain public interest in the Moon	Establish lunar media (TV/events) to stimulate general public interest.

	Recommendations for Creating a Global Awareness Movement below.	village.	

RECOMMENDATIONS FOR INSPIRING AND ENABLING AN INTERNATIONAL PARTNERSHIP

Participating space agencies have already established a successful LEO outpost which engages international partners to pursue a common goal - the ISS. The ISS has shown that human presence in space cannot be extended without the capabilities and resources of international and commercial partners.

To further expand international partnerships in the future with respect to the more ambitious Moon Village vision requires a strategy to build stronger relationships between partners with existing relationships in space, and to look for opportunities to build new partnerships. To succeed in both of these areas the working group has narrowed down multiple ideas to two key recommendations.

Initiate a coordination group

The first recommendation is the formation of a central Moon Village coordination group. This group would transact between different stakeholders - principally nation-states, and in doing so respect all stakeholder goals and provide governance and legal frameworks to enable the Moon Village to be established. Such a coordination group would require a proper mandate, and as such the initial suggestion is a bottom-up organisation composed of nation states, facilitated by an organisation within the United Nations such as the Committee on the Peaceful Uses of Outer Space (UN COPUOS).
A coordination group is required because integrating all parties' interests is challenging, and requires negotiating power and political credibility. Centralising coordination at this level will also allow new opportunities to come to the fore and strengthen the collective vision and commitment to the Moon Village project.

A prominent example of a bottom-up international agreement on this scale is the Paris Climate Accord. While having suffered setbacks, this agreement is largely seen as successful at involving and coordinating a large number of nations towards a common goal while taking into account the various interests and concerns of relevant stakeholders.

Initiate a communications strategy / campaign

The second recommendation is to initiate a communications strategy and resulting campaign which communicates the benefits of the Moon Village concept to a wide audience. See *Recommendations for Engagement with Non-Traditional Space Players* above for specific points of focus for the strategy.

The justification for establishing such a strategy is simple. An international partnership around a Moon Village requires awareness of the potential and concepts involved. In order to generate new ideas and funding sources, attract a wider interest and supporter base, and link the efforts of the scientific community, governments and private companies, an effective communications strategy is crucial. The mining and ocean exploration communities in particular are good examples to look to for such strategies.

RECOMMENDATIONS FOR CREATING A GLOBAL AWARENESS MOVEMENT

As many great space endeavours have before, the realisation of the Moon Village will require a strong support of all the decision-makers involved. However, this working group and the Moon Village Association (2) have independently come to the conclusion that support is needed from a broad spectrum of stakeholders beyond the usual space community, including civil society, industrial companies, the financial sector, arts and others.

Formulating a clear and relatable goal will facilitate the engagement of all the parties involved. Converging efforts is easier when potential stakeholders can relate to a clear and concrete objective rather than abstract ideas.

Furthermore, partnering with professional marketing agencies can help lead the awareness movement strategy. The way in which the National Aeronautics and Space Administration (NASA) dramatized Curiosity rover’s Mars landing in the memorable “7 minutes of terror” and ESA kept the public interested throughout the whole duration of the Rosetta mission with its strong engaging social media initiatives proves that trained marketing professionals are very effective at reaching a broader spectrum of audiences - even outside the space community.

RECOMMENDATIONS FOR DEVELOPING LUNAR COMMERCIAL OPPORTUNITIES IN THE NEAR TERM

In this section, “lunar commercial opportunities” are defined as activities which can provide physical or logistical support, resources, or infrastructure to generate revenue from operations in the lunar environment. The major lunar commercial opportunities have been outlined in our introduction above under *Why a Moon Village?* Here, the opportunities which are most promising in the near term (<10 years) are presented, and recommendations are provided to develop them. The assumptions which accompany these recommendations are as follows:

- Assumption 1: In the near term, transportation to the Moon will be possible and accessible
- Assumption 2: In the near term, there will be economic incentives for lunar commercial activities (e.g. a compelling business case for resource extraction)
- Assumption 3: In the near term, there will be a standardised and modular way of connecting lunar payloads to electronics support systems (e.g. data and power).

Given these assumptions, this report will now describe two recommendations which are feasible in the near term.

Establish shared infrastructure

Figure 3: Solar photovoltaic array field northeast of Las Vegas, Nevada, United States (3)

The first recommendation, oriented towards space agencies, is to promote the establishment of shared, centralised and standardised power & data infrastructure and services first. This promotion might be done by providing “bankability” for any commercial actor interested in building this infrastructure, by promising to utilise the resultant services if they are established. A similar strategy is employed by NASA in guaranteeing ISS supply mission contracts to companies who prove cargo transportation services.

The justification for this “infrastructure-first” focus is that subsequent lunar missions will benefit from extra survivability, a nascent lunar economy, and the immediate practical benefit of in-situ data and power. Having this infrastructure in place on the Moon reduces risks and costs, while enabling commercial growth.

Establish technology testbeds

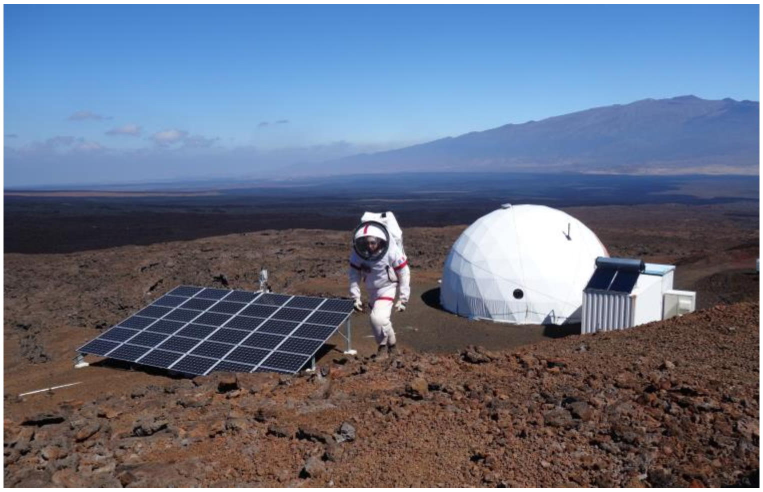

Figure 4: The Hawai'i Space Exploration Analog and Simulation (HI-SEAS) (4)

The second recommendation, key to developing lunar commercial opportunities, is for space agencies to offer lunar-focussed environments for companies, labs and universities to conduct research. Agencies have the unique capability and to provide lunar analogue environments and test facilities which other actors, particularly commercial actors not traditionally involved in space, will not have access to. Low gravity, temperature, radiation and pressure environments will be key for technology testing.

Successful examples of such projects in the past are the ISS, NASA Extreme Environment Missions Operations (NEEMO), and the Hawaii Space Exploration Analog and Simulation (HI-SEAS), pictured above.

RECOMMENDATIONS ON HOW SPACE AGENCIES CAN FACILITATE THE MOON VILLAGE

International partnerships will be important to the Moon Village and spaceflight future in general. Space agencies will have a critical role as facilitators of this vision in creating effective partnerships that bring together the technical strengths, resources, and capabilities of all parties involved. To increase the robustness of the Moon Village architecture and increase the probability of its success, four tasks have been proposed for the space agencies involved.

Define Clear Goals

The Moon Village has been presented as an open architecture providing the opportunity to create diverse community of public and private organisations that work on the moon together. Apart from this vision (purposely kept very vague) portraying the large scope of potential activities, the Moon Village needs a clear direction and narrative which the community can relate to and follow.

Lead, Coordinate & Commit

The Moon Village idea is pushed forward by Jan Wörner, the Director General of ESA who wants to see this vision become a future reality. However, ESA does not want to lead on important issues such as guidance, financing, etc. The Moon Village needs an organisation to coordinate development and lead the community towards the goal.

Develop Required Building Blocks

The Moon Village is intended to grow incrementally as an open, international effort. However space agencies should support the development of critical technologies and help build up the vital infrastructure needed.

Create, Support and Fund Dedicated Business Incubators

As the Moon Village concept is intended for many users with many uses, space agencies should encourage innovation and new Moon-based businesses through dedicated networks and incubators. Furthermore, they should encourage new actors globally to join the Moon Village community.

CONCLUSION

The Moon Village vision is a common destination for multiple users and multiple uses where different nations can collaborate together. The Moon represents a prime choice for programmatic, technical, scientific, operational, political, economic, and inspirational reasons.

The ISS has achieved an unparalleled level of cooperation which has continued largely unaffected by any crises occurring on Earth. The Moon Village will take these international partnerships one step further by requiring the engagement of new players and forging new alliances between public and private entities including non-space industries.

Necessary approaches for engagement have been examined and recommendations have been presented in this report. It should be emphasized that the working group has come to the conclusion that although the Moon Village is meant as a vision open to any and all interested parties and nations, at least some degree of coordination will be needed to efficiently make use of potential synergies of all interested parties. Thus, a clear and relatable goal put forward by a party (private institution or space agency) that is willing to lead, coordinate and commit seems inevitable. Creating a global awareness movement will further ensure the Moon Village idea will reach a broader spectrum of audiences outside the traditional space-faring nations and encourage new actors globally to join the Moon Village community.

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WORKING GROUP 5: SPACE TRANSPORTATION

EXECUTIVE SUMMARY

The disruption of the traditionally stable launch vehicle market by new commercial players is driving the space transportation sector through its greatest period of change. Although this unprecedented level of growth is aiding in increasing the accessibility of space, it does not come without its challenges. In order to identify, analyse, and address the challenges facing the current and future launch sector, the Space Transportation Working Group at the 2017 Space Generation Congress assessed the existing and incoming stakeholders, their changing needs, and the roles each could play in meeting these challenges. This aim was encapsulated in the following goal statement:

Addressing future challenges to foster an economically sustainable launch market,

The primary stakeholders in the sector (government space agencies, commercial industry, and launch customers) are undergoing changes in their traditional roles, enabling increased cooperation. In parallel, upcoming stakeholders, such as academic institutions and non-government organisations, may provide support in brokering these developing partnerships. These interactions almost always involve compromise, and from this analysis the following trade off challenges were focused on:

1. Innovation and risk
2. Global collaboration vs National interests
    a. Global collaboration - commercial vs institutional
    b. Addressing security issues

RECOMMENDATIONS

After analysing these individual challenges and how they affect the sector, the following recommendations were developed:

1. Governments should facilitate innovation by providing market support, while managing risk responsibly through effective regulation.
2. The barriers to international technology exchange should be reduced, in order to support global collaboration and further commercialisation.
3. Space agencies should engage in more intimate collaboration to limit the duplication of efforts at an international level.
4. Education on working within international export regulations should be provided through an independent body to help grow international trade and cooperation.

As the launch sector is rapidly evolving and the interdependent challenges being faced are both complex and detailed in nature, this Working Group recommends that the Space Generation Advisory Council establish a permanent Space Transportation Project Group, to serve as an ongoing forum for topics related to space launch.

WORKING GROUP PARTICIPANTS

The Space Transportation Working Group included 23 delegates from 12 different nations, with every inhabited continent on Earth represented within the group. The participants included:

NAME	ROLE	COUNTRY
Matthew Richardson	Moderator	Australia
Joshua Kiefer	Rapporteur	Germany
Marta Lebron Gaset	Rapporteur	Spain
Christian Bach	Delegate	Germany
André Bauer	Delegate	Australia & Germany
Chris Beauregard	Delegate	USA
Brittany Chamber	Delegate	Australia
Sukmin Choi	Delegate	South Korea
Phillip Dahm	Delegate	Australia & Germany
Dennis Daub	Delegate	Germany
Karl Domjahn	Delegate	Australia
Filip Drazovic	Delegate	Australia & Serbia
Jack Hooper	Delegate	Australia
Sungmin Lee	Delegate	South Korea
Hamish McPhee	Delegate	Australia
Johanna Pardo	Delegate	Germany & Colombia
Viha Parekh	Delegate	Australia & India
Vilde Rieker	Delegate	Norway
Mehdi Scoubeau	Delegate	Belgium
Sonali Sinha Roy	Delegate	India
Andrew Wilson	Delegate	Scotland
Seun Yinka-Kehinde	Delegate	Nigeria & Australia

The Space Transportation Working Group would like to thank Dr. Justin Hardi of the German Aerospace Centre (DLR) for volunteering his time as a subject matter expert, and Mr. Clay Mowry of Blue Origin for volunteering his time as an invited speaker. The Working Group delegates are also grateful to Blue Origin for their support of the Working Group.

INTRODUCTION

The space transportation sector is currently undergoing the greatest period of change in its history. Where once the public sector was the greatest driver in the launch vehicle market, we now see the dynamic growth of the commercial industry. The introduction of new technologies and cost reduction methodologies has taken this traditionally non-competitive market and is transforming it into a viable business venture. Multiple new launch companies, including Blue Origin and SpaceX, are starting to disrupt the historically stable monopolies held by heavyweights such as the United Launch Alliance (ULA) and Ariane Group. In addition, the emergence of CubeSats and the commercial value of earth monitoring data has created a new market for small payloads, with companies such as Rocketlab and Virgin Galactic vying to be the first dedicated and commercially viable small satellite launch provider.

Although this growth is driving forward at a fast pace, there are multiple challenges faced by the sector that are potentially creating bottlenecks for new and existing commercial opportunities. The aim of this Working Group was to investigate these challenges, focusing on three key issues that exist today and in the future, along with providing recommendations to both the public and private sectors on methods to mitigate any detrimental impact to this industry.

This investigation was guided through an analysis of the following questions:

1) Who are the potential future stakeholders within the sector, and how might customer needs vary from the traditional solutions?
2) What are the challenges that the sector and its stakeholders may face in meeting these new needs?
3) Which stakeholders have the capability or responsibility to meet these challenges, and what role could non-government organisations play in this process?

From this analysis the following goal statement was developed to guide the subsequent recommendations:

Addressing future challenges to foster an economically sustainable launch market

In order to adequately address this goal, the following three facets must be explored:

1) How is economic sustainability defined?
2) Who are the stakeholders within the sector?
3) What are the challenges facing them?

These questions are addressed in the following sections.

ECONOMIC SUSTAINABILITY

In order for a market to survive into the long term (whether emerging, transitioning, or stable), it must be economically sustainable. For the launch market, the two enabling factors for this sustainability were identified as:

1) Developing competitiveness
2) Ensuring continued demand

Developing the competitiveness of the sector not only focusses on how individual companies meet their individual customers' needs, but also how the sector as a whole is able to produce products and services that are profitable. As exemplified in Game Theory [1], co-opetition between companies and stakeholders may play a key role in solidifying the competitiveness of the sector.

However, even the most competitive industries must have continued demand to survive. This demand provides the necessary revenue for maintaining the current sector capability and enhancing it via growth.

Other types of sustainability, such as political and environmental, will also have an impact on the economic viability of the launch sector, however these factors were not considered for this investigation.

SECTOR STAKEHOLDERS

As the launch market is rapidly developing, the various stakeholders and their inputs are changing as well. Therefore to identify the challenges facing the sector, the impacted stakeholders must be established. The current and upcoming stakeholders were identified as:

- National governments and their ministries
- Governmental space agencies and institutions
- Commercial industry
- Academic and scientific institutions
- Private customers and end users
- Non-government organisations and industry organisations

Their influence on the space transportation sector varies depending on the role of each stakeholder. Stakeholders such as governmental space agencies, commercial industry and customers have a primary influence on the launch market as they have direct involvement in how that market evolves. However, the role they each play is changing. For example, NASA is transitioning to becoming an enabler for the development of commercial launch services through assigning contracts that aid in supporting the financial outlay. The varied appetite for risk and innovation within the commercial sector contrasts with the relatively risk averse policies adopted by government agencies; this is a significant challenge to be addressed to promote growth yet still maintain a strong safety focus.

Although academic institutions and industry organisations have played a secondary role to the main stakeholders, their impact may grow as the sector develops. The current climate of globalisation and cooperation has increasingly come under threat over the past couple of years by competing national interests. This is no different in the launch market, with many countries seeking to develop an indigenous launch capability and technology trade controls that limit collaboration between nations. It may develop that the role of these independent bodies will become increasingly more significant in promoting and brokering partnerships that will aid in the growth of the sector.

SECTOR CHALLENGES

As discovered, the competing interests of the stakeholders gives rise to trade-offs that must be compromised. Although the challenges facing the sector are wide in scope and varied, two key trade-offs were investigated:

1) Innovation and risk
2) Global collaboration vs National interests
    a) Global collaboration - commercial vs institutional
    b) Addressing security issues

Firstly, innovation and risk explores the compromises that must be made in order to balance higher risk innovative technologies and methods that can aid in growing the sector with the need for reliability and a strong safety focus. Secondly, the trade-off between global collaboration and national interests is strongly contended as countries wish to both grow their own space-based industries quickly but also retain national sovereignty. This will be investigated through an analysis of methods for promoting global collaboration within both the commercial and governmental markets, and an examination of the current security issues facing the launch sector with respect to technological trade controls.

Balancing Innovation and Risk

The global space transportation market is rapidly evolving and includes new actors from the public and private sectors. The shift from the traditional dynamic has provided a number of promising technological developments and may significantly impact the industry as a whole, as well as a number of other interrelated markets. However, it is important to consider the effects of these developments from the perspective of risk management to strike an ideal balance between promising innovation and responsibility to stakeholders. Risk in the launch industry is a high-stakes endeavour with combined payload and launch vehicle costs in the hundreds of millions, not to mention the inclusion of especially sensitive payloads, which may include highprofile scientific missions, sensitive national security satellites, or even human lives. Below are some recommendations:

Market Support

To ensure effective and responsible market growth, governments should play a key role in the facilitation of launch sector innovation and risk management. From a financial perspective, the world's governments have historically acted as facilitators through the offset of technology development and ongoing operational costs. Institutional markets, in their undertaking of large-scale projects with greater funding capacity, have provided economy of scale benefits to commercial markets. Such support could prove especially useful in the space transportation industry, where current market demand cannot quite justify a multiplicity of providers. This helps with mitigating risks related to overreliance on a single provider. Similarly, governments can also bear related risks, such as supplemental costs in excess of a launch provider's accident insurance coverage. As an additional benefit of government support, technology buyback has occurred in cases where significant late-stage government investment is necessary to assist companies in need, avoiding market collapse and encouraging growth.

Regulation

Regulation of the commercial launch vehicle markets relates to certification of the launch vehicle, as well as launch site and in-orbit requirements. It is a necessary part of mitigating stakeholder risk, particularly when the potential impact of a catastrophic loss on the stability of the broader industry is considered. On the other hand, over-regulation has the potential to stifle technological innovation, and further barriers to entry for new actors. Thereby, the regulatory architecture must consider this balance of innovation and risk. The United States' approach for example, is a Congressional moratorium on the Federal Aviation Authority's (FAA) regulation of commercial human spaceflight until 2023, while a licensing framework has been implemented for other commercial launch activities [2]. Correspondingly, a phased introduction of regulations developed in conjunction with industry is recommended. Industry's voice in shaping regulation is already well-considered in aviation regulation, and standard processes exist for industry comment and appeal of draft-laws, prior to their enactment by regulatory bodies such as the European Aviation Safety Agency (EASA) and the FAA. Considering the extensive history of aviation regulation, we recommend the framework of the commercial launch vehicle market regulation lean on the framework in place for the aviation industry, at both the national and international level. This also aids to address the challenges of launch vehicle market regulation due to ambiguities in the boundaries air and space, and complexities introduced due to often multi-national projects.

Global Collaboration

Research and development activities in the space transportation sector have historically received a major boost from the benefits of international and public-private collaborations. In recent times, national space agencies have increasingly shown interest in international collaborations. Furthermore, with the advent of the New Space era, the efforts of enthusiastic *astropreneurs* have resulted in growing privatisation of the space industry, which was previously dominated by government agencies. Some private space companies have achieved remarkable milestones in space transportation, firmly establishing their feasibility as manufacturers, launch service providers, space explorers, and space tourism firms. This has led to the establishment of public-private partnerships in the space industry, with private companies and government agencies forming increasingly symbiotic relationships. It is therefore highly desirable to cultivate global collaboration in the space industry, involving both government and private agencies. Such collaborations, based on international cohesive policies, can help in providing shared access to space transportation infrastructure, resources, technology, and data.

Global collaboration is heavily dependent on the national interests of participating nations. Therefore, it is essential to ensure that cross-country partnerships related to space transportation do not oppose these interests. There is a general sense of national pride involved with successful space missions by national space agencies. Such missions promote the growth of the domestic economy and add to the nation’s technological achievements. Some nations follow a policy of economic protectionism to safeguard their domestic industries from foreign competition. In such situations, it is difficult to establish international collaborations. Further, the ultimate aim of some national space agencies is to ensure independent indigenous access to space, without relying on other nations. Government-owned space agencies use public funds for their space programmes and are hence accountable to their citizens for the optimised utilisation of resources. Moreover, space transportation technology is intimately related to missile technology and defence applications. Collaborative projects can be complicated by many of these factors, which can lead to a reluctance to engage fully in international and cross sector partnerships. The Working Group recommends a number of methods that could help in balancing national interests with the benefits of global collaboration. Here are the Working Group recommendations:

Clear divisions between defence and civil applications of space can help in safeguarding national security while promoting collaboration with international partners. Commercial and civil government missions should be isolated from military space activities, keeping defence-related aspects confidential while encouraging greater internationalisation of the civil industry. Private companies can play a vital role in this collaborative and multinational approach. Just like other technology industries, international licensing of space technologies can be supported, facilitating both an additional revenue stream for commercial space actors, and stronger international cooperation in technology development. This can greatly help to eradicate reproduction of the same technology by different space agencies, ensuring that time, money, and resources are invested in innovation rather than unnecessary and uninventive duplication. Research should always be conducted in a multifaceted approach, but where there is unnecessary overlap industry actors should be able to share, sell, or license technology if they desire.

The commercialisation of the space transportation industry can be accelerated by promoting international collaborations involving both public and private entities. Such collaboration is already proving highly successful, with examples like the International Space Station and the Orion spacecraft [3] proving that deep collaboration between nation states and private companies can produce great leaps in space technology. Such projects bring together technology and expertise from large scale national space agencies as well as private companies like Lockheed Martin, Airbus Defence and Space, and Boeing.

The space transportation industry can draw inspiration from the emergence of civil aviation regulation and governance in the 20th century. Aviation is a field that was largely controlled by the military or defence agencies before it was commercialised. Owing to the close similarity between early aviation and the current state of space transportation, drawing parallels between these two industries is quite useful. The Working Group recommends the establishment of globally accessible launch pads or spaceports in various parts of the world, emulating the concept of airports. Similar to Air Traffic Control (ATC) and Missile Technology Control Regime (MTCR), a Space Traffic Control service is recommended, which would have information about the launch timings, orbital trajectories, commercial payload specifications, and other necessary details of every spacecraft launch around the globe. This should not necessarily be a central body but should form an international framework for the control of space traffic while protecting national sovereignty and security. With the rapid commercialisation of the space industry and increasing frequency of launches, managing traffic will surely become a challenge in the near future.

To summarise, the Working Group recommends the cultivation of global collaboration in the space transport industry by reducing barriers to international technology exchange, supporting further commercialisation and emulating the architecture of civil aviation, while encouraging more intimate collaboration between space agencies to limit duplication and increasing efficiency in the creation of a next-generation space transport technology.

Addressing Security Issues

Restrictions on technology transfer between nations are in place because some technologies needed for launch systems can be used for military purposes. Therefore, a variety of rules exist in different nations that determine which technology can cause security issues. The existing limitations make the sharing of information difficult and hence slow the advancement of capabilities in the launch industry. The most far-reaching example is the International Traffic in Arms Regulation (ITAR). Advancements in collaboration are stunted by an extensive licensing process imposed on U.S. companies and international partners, negatively impacting technological development and market growth. Other countries have similar standards to regulate technologies that are security liabilities.

Commercial markets for space launch vehicles benefit from greater competition caused by loosened restrictions. Access to the most cost effective solution without going through a long and expensive restriction review process is desirable. American companies are losing international contracts for commercial satellite launches [4] and as a result the American industry has restricted trade opportunities and is therefore limiting indigenous payloads to expensive local prices. Although it is not impossible to collaborate in the current ITAR environment, it may cost commercial companies too much. By improving the process of gaining clearances, the market will become more globally active and economically sustainable.

Although armament restrictions reduce globally cooperative launches, there are still cases in which international stakeholders have combined their efforts. For example, the Ariane programme is a good example of successful international collaboration in the launch sector. Existing partnerships can be used as a guide for modification of current regulation. The Working Group has the following recommendations:

Abolish or change unnecessary regulations to facilitate international collaboration and competition. Where this is not possible, facilitate collaboration by supporting companies in understanding the possibilities under current regulation. Increased collaboration under the current regulations is expected to contribute to a gradual process of improvement. A review of successful international projects can serve as an example for future collaboration and guide decisions on modification of current regulation.

OTHER CONSIDERATIONS

Due to the large scope of this topic, the Working Group could not focus on the every issue that was discussed. However, three important areas which were debated centred around environmental, political, and socio-economic considerations of space transportation.

The environmental impacts of space transportation are an important and compelling area of interest. With a growing need for space transportation, the environmental impacts of exhaust gas into the atmosphere has become an increasing area of concern within the industry. In this respect, despite the actual effects of this process still being poorly understood [5], there has been a sharp increase in research in recent years to gauge the life cycle environmental impacts of different launchers (from raw material extraction, through production, manufacturing, and use, to final disposal) and to find environmentally-friendlier launch techniques [6]. In addition to terrestrial-based considerations, impacts of human activity to near-Earth space is also a great industrial concern due to the accumulation of space debris. Without proper restriction and supervision, the impacts of space debris may render space inaccessible for future generations, thus immobilising the space transportation market [7]. For this reason, there is an urgent need for the monitoring of launches and the management of space debris.

Political and socio-economic considerations for space transportation are wide ranging, but this Working Group, narrowed them down to accessibility to space, private-public partnerships, prioritisation of resources, and technology. In particular, it was deemed very important to consider the role that future space policy will have on making space accessible to all. In addition to this, the manner in which private and public organisations can support one another to strengthen the launch industry whilst also gauging society's opinion on what should be prioritised was also considered to be vitally important to create an economically sustainable launch market. Finally, it was considered that technological advances in the space transportation industry would ultimately dictate the future direction and success of the space sector. In this regard, the industry should continue to seek further technological advancements in current launch systems whilst investigating the possibility of creating new types of launch vehicles, styles or techniques including reusable rockets and interplanetary rocket technology.

Due to the limited discussion of these issues by the Working Group in view of time constraints, it is recommended that a permanent SGAC Project Group relating to space transportation be created which could continue to work on such concerns in more depth.

RECOMMENDATIONS

Through the investigation described in this report, the Working Group proposes four key recommendations to address future challenges in fostering an economically sustainable launch market:

1. Governments should facilitate innovation by providing market support while managing risk responsibly through effective regulation.
2. The barriers to international technology exchange should be reduced in order to support global collaboration and further commercialisation.
3. Space agencies should engage in more intimate collaboration to limit the duplication of efforts at an international level.
4. Education on working within international export regulations should be provided through an independent body to help grow international trade and cooperation.

Finally, given the rapidly evolving launch vehicle market, the complexity of constructing a sustainable industry and the dependant emerging markets, the Group recommends that SGAC establishes a permanent Space Transportation Project Group as an ongoing forum for topics related to space launch.

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WORKING GROUP 6: SPACE TECHNOLOGY

EXECUTIVE SUMMARY

The 16th Space Generation Congress, held in Adelaide, Australia in 2017, established a Working Group on the subject of Laser Communications in Space. The working group reviewed the topic and the current state of the technology and identified different application scenarios for which this technology could be used.

The working group then investigated the state of standards which are currently in place to govern the use of the technology. Universally agreed upon standards are not yet in place. For example, the NASA and ESA systems which are currently in operation both use different wavelengths. For this specific issue, the working group has concluded that the best way forward is to develop systems and standards with compatible infrastructure so that flexible platforms can operate across both (or multiple) standards. The working group identified that development costs and technical complexity are key challenges in achieving this standard and that the complexity of the negotiations is also a key challenge. To address these challenges, the working group recommends that costs be distributed as widely as possible through the creation of joint programmes and that the standards should be broad and formulated in a manner which allows a certain degree of flexibility. A living document generated by all stakeholders is seen as a key recommendation to address the complexity of negotiations.

In parallel, the working group also focussed in more detail on the “human elements” of the process of developing the standards. Challenges here include encouraging industry support, accounting for cultural differences, and dealing with the diversity of technological maturity within industry. To address these challenges the working group recommends promoting the benefits of standardisation, to hold regular “in-person” meetings, to establish a dedicated liaison between stakeholders, and to use the location of the Consultative Committee for Space Data Systems (CCSDS) meetings as a tool to encourage participation. The working group also recommends gathering information from relevant stakeholders and incentivising the major stakeholders to represent the interests of their subcontractors.

WORKING GROUP PARTICIPANTS

Name	Position	Nationality
Kate Becker	Subject-Matter Expert	USA
Ken Grant	Subject-Matter Expert	Australia
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Graham Johnson	Rapporteur	UK
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Ahmad Shaqeer	Delegate	Malaysia
Alex Miller	Delegate	Canada
Alexandra Long	Delegate	USA
Andrew Gibbs	Delegate	Australia & Canada
Christian Gilbertson	Delegate	USA
Doris Grosse	Delegate	Germany & Australia
Emma Kohlhagen	Delegate	Australia & Germany
James Murdza	Delegate	USA
Junho Lee	Delegate	South Korea
Kaveh Razzaghi	Delegate	Iran
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Roxy Fournier	Delegate	Canada
Sarah Wittig	Delegate	Australia & Netherlands
Steven Shumsky	Delegate	USA

ABBREVIATIONS

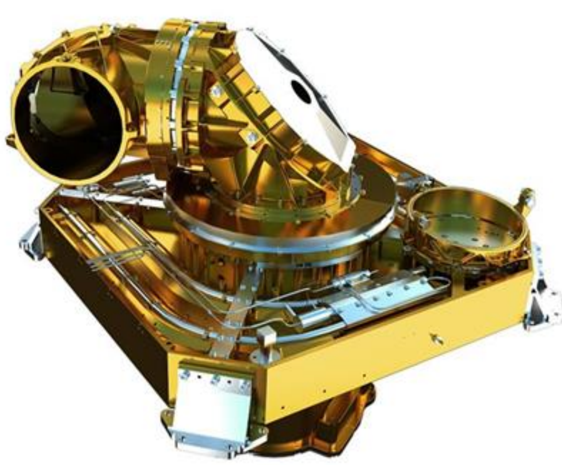
CCSDS - Consultative Committee for Space Data Systems
DVB-S2 - Digital Video Broadcasting - Satellite - Second Generation
EDRS - European Data Relay System

ESA - European Space Agency
FSOC - Free Space Optical Communication
ICD - Interface Control Document
LADEE - Lunar Atmosphere and Dust Environment Explorer
LEO - Low Earth Orbit
LLCD - Lunar Laser Communications Demonstration
NASA - National Aeronautics and Space Administration
OSI - Open Systems Interconnection
OTN - Optical Transport Network
RF - Radio Frequency

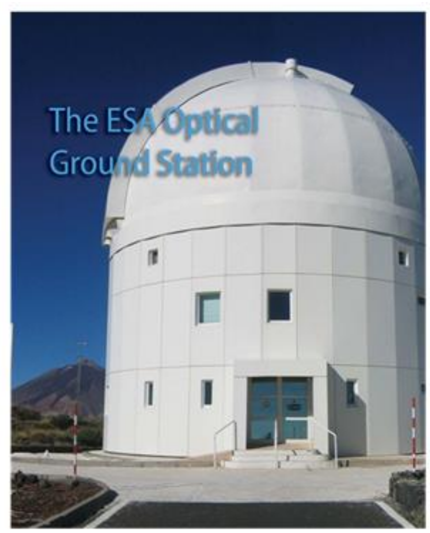
INTRODUCTION

Laser communication involves the exchange of information using laser beams in the near-Infrared spectrum. Free-space optical communications (FSOC) is an exciting new technology which is currently being developed for use in space missions.

The main hardware elements of a laser optical communication system are a laser terminal (to transmit) and an optical telescope (to receive). Examples of a spacecraft terminal and a ground station are shown in Figure 1.



Optical Communications Payload
TDP 1 for Alphasat (ESA)



Optical Ground Station
(ESA)

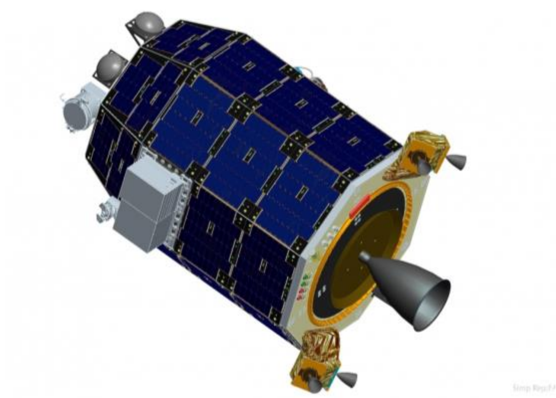
Fig 1: Example of Laser Terminal and Optical Ground Station (Image Credit: ESA)

When compared to existing radio-frequency (RF) communications, laser optical communication has the potential to offer a number of advantages and/or differentiators:

- Substantially higher data-rate (for an equivalent mass and volume)
- Improved security (since the narrower beam is harder to intercept)
- Quantum cryptography (an application which is not possible with RF communication)
- Simpler ground station infrastructure and equipment

Several national space agencies and industrial contractors have been investigating and developing this technology. The National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) have both demonstrated the systems in orbit, some of which are listed below:

- **Lunar Laser Communications Demonstration (LLCD), NASA:** The LLCD demonstration consisted of a laser terminal on board the Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft and three ground terminals on Earth. The system successfully demonstrated a downlink rate of up to 622 Mbps, which is substantially better than has ever been achieved by an RF link [1].
- **European Data Relay System (EDRS), ESA:** The European Data Relay System uses two laser terminals flying on board commercial geostationary satellites. The system is used as a space-to-space link, as it provides a relay to a satellite in Low Earth Orbit (LEO) [2].



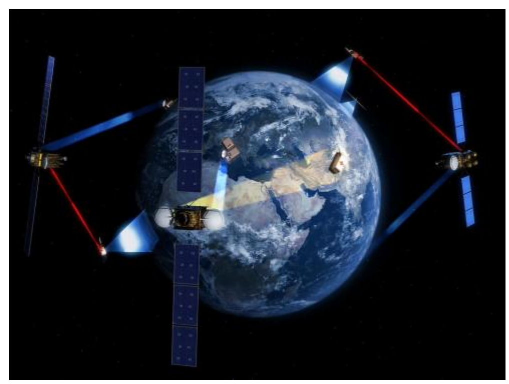


Fig 2: LLCD (Image Credit: NASA) Fig 3: EDRS (Image Credit: ESA)

A number of potential future applications for optical communications systems are considered in a later section of this report.

Standards

As for any communications system, a set of standards are required to ensure interoperability between hardware and systems from different organisations. These standards shall follow the Open Systems Interconnection (OSI) model which defines seven different layers:

- Layer 7: Application Layer
- Layer 6: Presentation Layer
- Layer 5: Session Layer
- Layer 4: Transport Layer

- Layer 3: Network Layer
- Layer 2: Data Link Layer
- Layer 1: Physical Layer

Following this layer approach enables interoperability, which in turn lowers the barrier for entry for new competitors, reducing industrial complexity and encouraging synergy between diverse actors. The lowest two to four layers are the key layers still to be defined for FSOC.

The body with primary responsibility for defining these standards is the Consultative Committee for Space Data Systems (CCSDS). The CCSDS was founded in 1982 by the major space agencies of the world, and provides a multi-national forum for the development of communications and data systems standards for spaceflight [3].

Working Group Task

The purpose of the Working Group was to explore the common standards to enable interoperability between laser communication systems. NASA and other international space agencies are collaborating to develop FSOC standards through the CCSDS. Many commercial providers and universities have announced plans to deploy FSOC systems, ranging from low-cost, high bandwidth downlinks from CubeSats in LEO, to sophisticated laser crosslinks between constellations of satellites in LEO and beyond. There is even discussion of commercial FSOC links from deep space. Providers are also proposing to develop networks of commercial optical ground stations. However, there appears to be no common industry position on FSOC system interoperability to enable the level of cross-support required by international space agencies.

The Working Group addressed the following questions:

1) Brainstorm about the wide range of link scenarios/applications for this exciting new laser communications technology.
2) Consider the challenges in finding a “common” interoperable FSOC mode—akin to the International Telecommunication Union (ITU) Optical Transport Network (OTN) standard agreed upon by the ground-based fiber telecommunications industry.
3) Provide recommendations about how to achieve a common industry position on FSOC system interoperability to enable the level of cross support required by international space agencies (Interoperability agreements/Leveraging of Existing standards (e.g., OTN, DVB-S2), Interface Control Documents (ICDs)).

APPLICATION FOR LINK SCENARIOS

Optical links are useful in diverse configurations:

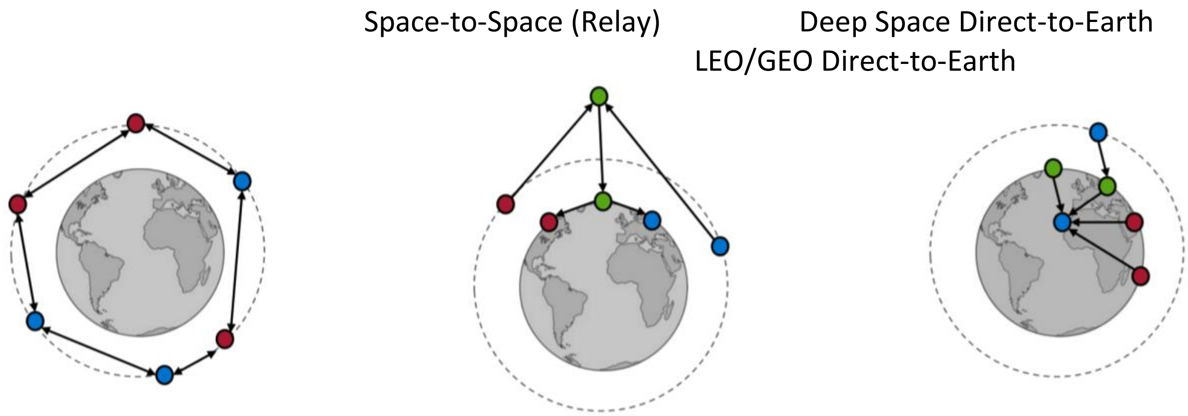


Fig 4: Link Configurations for applications of FSOC (Image Credits: NASA [4])

Each configuration has unique challenges:

- High-accuracy pointing/tracking
- Atmospheric effects
- Dynamic link range

Potential applications for the emerging technology have been identified by the group as follows:

- Rural Wifi
- Secure Communication Network
- Deep Space Navigation
- Asteroid Tracking
- Satellite Ranging
- Interplanetary Teleoperations

In order to arrive at constructive recommendations for interoperability among systems, the Working Group divided into two subgroups, one explored the scope of standardising technical specifications while the other investigated ways to negotiate among stakeholders involved in the development and applications of such systems.

SCOPE OF STANDARDS

The CCSDS consists of an Optical Communications working group that meets twice a year (in Fall and Spring), assigned with the task to publish and revise standards for FSOC systems. In the current standards, there are two major frameworks implemented for optical space communications, each employing different wavelengths for optical links (1064 nm and 1550 nm). The development of these systems is still in its infancy stage. Advancing these frameworks to their full potential demands an architecture built around them (e.g. ground stations, antennas, personnel), with a set of associated technical specifications and tailored regulations. Furthermore, one should not discard the possibility of additional competing systems being created prospectively for optical space communication purposes.

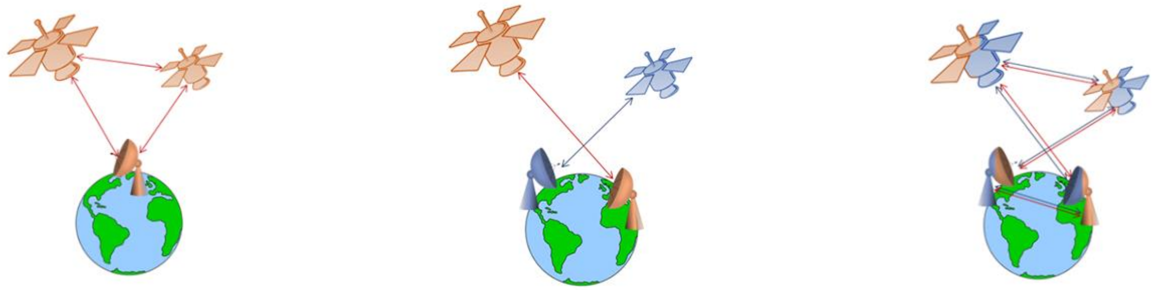
There are, however, different approaches concerning how these frameworks can be developed in the future. Three possible scenarios are envisioned, each differing in the level of integration of these systems, or platforms. These scenarios are described below:

- Scenario 1: In this scenario, one of the multiple platforms is selected as the standard one and the remaining systems cease being implemented for optical space communications. This has the potential of facilitating adoption among all stakeholders and limits end-user costs, but constrains technology innovation and industrial output, in addition to the fact that the technical limitations of the selected platform cannot be compensated for (i.e. with the use of a different wavelength).

- Scenario 2: In this case, two (or more) platforms are adopted and implemented independently. Contrary to Scenario 1, specialized technology can be developed for each of the setups, and the technical shortcomings of a system can be overcome with the use of another system(s). However, keeping all architectures independent for space communications increases costs for the end-users (whether at the individual or organizational level), which ultimately must pay for handling all independent networks proportionally.

- Scenario 3: Finally, a flexible platform can be embraced as a means of compromise between all stakeholders. The idea is that two (or more) systems are developed in parallel, but share a compatible infrastructure which supports them, including onboard hardware, ground stations and personnel. This compatibility allows combining the advantages of each system, surpassing their respective limitations. In such a scenario, innovation is promoted, as new technology must be developed to accommodate multiple systems and the interfaces between them. There is an initial research, development, and implementation cost which is mitigated during the operational stages by the fact that physical infrastructure is shared across the networks, making this scenario cost-efficient for users in the long term. Moreover, a degree of robustness and redundancy is inherently embedded in such a setup, given that in case of off-nominal conditions (e.g. bad weather, hardware malfunctions, etc.) an interoperable network enables former competing platforms to collaborate and deliver joint solutions. Similarly, it increases cooperation at the technical and political level, not only within nations but also globally. This is vital for fostering relations of trust and peace on the international stage. Ultimately, the potential to reach end-users with an interoperable network is higher than with single independent systems, making this alternative both attractive to investors and beneficial to society as a whole.

One fixed standard | Two-independent standards platform | Multi-compatibility



a) Scenario 1. | b) Scenario 2. | c) Scenario 3.

Fig 5: Illustration of the identified scenarios

Overall, the multi-compatible approach conceptualized in Scenario 3 is deemed by the group as the most suitable one due to the interoperable capabilities it provides, along with the advantages mentioned above, maximizing the benefit to end-users. In order to realistically implement such a scenario, there is a set of non-trivial challenges which must be tackled, particularly with regards to prescribing standards which must be agreed upon, adopted, and implemented by several stakeholders. The identified main critical challenges are described in the next subsection. Thereafter, the respective recommendations are presented.

Challenges

Three main challenges have been identified in the frame of what the definition of standards should consider in order to materialize an interoperable network:

1. **Cost in development and operation**: The standards should take into account short and long-term associated costs of development and operation, not only from the providers' side, but also from the users' side. Clearly there is an initial investment cost required for developing and setting up a flexible architecture which accommodates two (or more) competing systems. This has a reflection on the scale of end-user adoption. Too costly a system will be unattractive for users. Due to the magnitude of costs involved, a solution must be found during the standards design process.

2. **Technical complexity**: The complexity of implementing an interoperable system is directly connected to the required flexible nature of the hardware and infrastructure comprising of interfaces, ground stations, legal regulations and personnel, which should be able to work interchangeably with the two (or more) systems. This means that there has to be a harmonization from bottom to top in terms of wavelength, modulation, scheduling, data link lasers, safety of lasers and overall system knowledge. A compromise must therefore be found between formulating new standards from scratch, which could be utterly disruptive, and simply integrating existing standards

from current technologies, which could be outdated for the purposes of a multi-compatible architecture.

3. **Complexity of negotiations**: Designing standards which must be implemented and adopted by all stakeholders is an intricate process. All parties have to continuously be involved, have access to, and exchange information. They must ultimately agree not only on technical issues, but also on the legal framework along with the overall infrastructure and data processes. This requires a huge level of commitment, political will, technical dialogue, and understanding of the framework.

Recommendations

To address the above identified challenges, the following recommendations are proposed:

Cost in development and operation

In order to keep the development costs of an interoperable network low, the technical research and development efforts should be distributed as much as possible between all the parties involved. The creation of joint programmes between agencies, researchers, and industry partners benefits from shared know-how and the consideration of different interests into the process, delivering solutions which fit both governmental institutions and the private sector.

In order to decrease operational costs of the network, agencies should facilitate data sharing and implement vehicles for information exchange. This allows for the flexible architecture to react in real time in case off-nominal situations arise. An example of such an event is if the visibility/communication link between a satellite and ground station A is foreseen to be impaired when the satellite passes overhead due to weather (clouds, rain, etc.). In this situation, ground station A could then communicate this to another station on the network, station B. Then station B could schedule, in advance, an allocation period for this satellite to transmit information to the ground upon its passage over station B. This would remove the need for the satellite to have to wait for another passage over station A, especially if repeating weather events are predicted to occur in the area. This is extremely useful when on-board memory storage of raw science data is limited and needs to be transmitted to ground periodically.

Technical complexity

The standards should be broad and formulated in a manner which allows a certain degree of flexibility in terms of technology development. This in turn will keep industries from bottlenecking and will help promote cutting-edge research and innovation. Simultaneously, the definition of functional interfaces should not be ambiguous but clear and detailed since interfaces are at the core of a multi-compatible network.

The to-be-defined standards should be derived from existing technologies and established protocols. This enables a smooth transition process between technologies for all stakeholders. Examples are on the technical side, concerning radio-frequency specifications. The adopted existing standards should also be integrated with the new standards which have to be generated in order to create and setup the interoperable infrastructure. For instance, on the regulatory side, guidelines must be created to ensure laser safety for satellite-to-satellite links.

Complexity of negotiations

A living document generated by all stakeholders should be distributed to the involved parties during the development process. In this way, all stakeholders can be simultaneously updated on the latest progress and understand how they are affected by it.

The standards should reflect a level of cooperation between all stakeholders, ensuring that partners commit to the adoption of the developed standard. Perhaps a supervisory and mediatory mechanism can be designed to support this process. Only by developing a common agreement and understanding can such an ambitious project be successful and impact society in a positive way.

MEDIATING STAKEHOLDERS

The focus of this subgroup was addressing the "human elements" in the process of developing the standards. The stakeholders consist of space agencies and industry (ranging from major companies to small start-ups). Thus the constituents are diverse in terms of size, available resources (for contribution to such standardization processes), and in their motivation and vested interests in the final standard. Given the international nature of the stakeholders, another element to consider is the cultural differences with how contributions and negotiations are handled by the various representatives.

Challenges

In this context, the challenges in mediating the stakeholders were grouped into three elements; encouraging industry support, accounting for cultural differences, and diversity of technological maturity within industry.

1. **Encouraging industry support:** Ideally, anyone who would be a potential end-user of this standard in some way should be represented in the process of developing it. This is to ensure the final product is relevant and is actually applied by industry. However the process of developing a standard requires time and effort from the stakeholders. Simply the cost of sending a representative to attend a meeting may be negligible for larger companies, but may be judged as unjustified by smaller companies, especially if their focus is on a small component of a larger FSOC system. However, such smaller

companies would be the greatest potential beneficiaries of the standard, since in principle the standard will open up business opportunities by ensuring interoperability.

2. **Accounting for cultural differences:** In general, it is considered that holding meetings where people are physically present (as opposed to teleconferences) is much more effective. However, even if representatives of all relevant parties are gathered together in one room, having a constructive and progressive meeting is not ensured. Cultural differences (not only related to nationality, but also in “company culture”) can be a significant factor when it comes to sharing information and contributing to decision-making processes. It may be the case for instance that a particular representative in the meeting is present for listening purposes, not necessarily to contribute (particularly on-the-spot) on behalf of their company/agency. Also, something as obvious as a language barrier can play a role in that the presentations or intricacies of the discussion points are not understood instantaneously. However, this can be mitigated provided good quality minutes are recorded at the meeting itself and there is sufficient time before/after the meeting for providing feedback.

3. **Diversity of technological maturity within industry:** The industry stakeholders may have technological capabilities ranging from a full end-to-end FOC system with already developed hardware, to a small start-up planning to develop a modulator or optical element that would be suitable for integration in such a system. Such diverse technological capabilities and roadmaps within industry imply a similar diversity in interests and motivations for what they want to achieve as a final standard. For pre-existing technology, the standard might be enveloping their technology, or even excluding it, in such a way that the standard may inadvertently favour or harm certain companies. Thus, it is seen as a major challenge to achieve the actual goal of the standard (i.e. unifying efforts and allowing for interoperability and entry of new players), and not to instead create a blocking point for new players to enter this technology market, nor to give competitive advantage to existing companies. This challenge is compounded by the fact that larger companies have more influence in shaping the standard to their needs. Also, for competitive reasons, companies might be reluctant to be open about their technology capabilities and roadmaps for future technology development.

Recommendations

To address the above identified challenges, a series of recommendations was generated.

Encouraging Industry Support

Promote the benefits of standardisation to applicable partners to encourage industry buy-in. Many established stakeholders working with optical communications already have operating procedures and in-house standards. These stakeholders would provide a wealth of information and expertise that could prove instrumental for developing effective standards. However, the standards could end up conflicting with their previous procedures. A promotion campaign would serve to quell these doubts and encourage participation.

Have regular in-person meetings. In person meetings encourage participation from attendees and provides an opportunity for presentation on equal grounds for attending stakeholders. Hosting these meetings regularly would also push development of the standards.

Overcoming cultural differences between nations

Establish a liaison to ensure flow of communication between stakeholders. Cultural and language barriers dramatically inhibit international cooperation. A liaison position would work to mitigate these barriers and make input as easy as possible. This role could incorporate tasks such as translation, document distribution, time zone conversion, converting local standards to international equivalent, follow up on stakeholders, etc.

Give people time to review and provide input on the documents. Document distribution and submission deadlines must be done in a timely manner but must not exclude stakeholders due to cultural reasons. Distribution and submission dates must not favour one nation. The time between these occurrences must also be long enough that stakeholders' cultural differences do not inhibit participation, including local holiday periods.

Use location of the meeting as a tool to encourage participation: The choice of meeting location could significantly impact nation participation. If meetings were always held in similar locations, then this could discourage different nations from participating. Being the host country also encourages participation in discussions. Due to these reasons, the meeting location should be varied and used as a tool to ensure fair representation and encourage the participation of quieter stakeholders.

Representing all levels of technological maturity within industry

Gather information from relevant stakeholders on their priorities. Each stakeholder would likely be developing optical communication technology to a different goal. The context and priorities of each stakeholder would provide useful insight into the motivation behind their recommendations.

Incentivise the big stakeholders to represent the interests of their subcontractors. Large, well established companies employ several subcontractors. If a subcontractor is undertaking more work in optical communication development than their parent company, the subcontractor's input may be more useful for standard development. To this extent, the parent companies need to be incentivised to appropriately represent the interests and opinions of their subcontractors.

Make funding available to enable meeting attendance for smaller partners. Small partners entering the field of optical communications may not have the free capital to allow their employees to take time off work and travel. By making some funding available, this would assist small partners in representing themselves at a higher-level during discussions.

CONCLUSION

The Space Technologies Working Group was assigned the task of exploring challenges associated with developing the common standards required to enable interoperability between free-space optical communication systems. The group identified two main themes which were investigated and discussed in detail:

- Scope of standards
- Mediating stakeholders

In each of these areas, the working group has identified three key challenges that could hinder the development of common standards, and has produced a set of recommendations to address these challenges.

A brief summary of the recommendations are as follows:

- Collaboration between agencies, researchers, and industry partners
- Open access to data and information
- Allow flexibility while defining functional interfaces in detail
- Research established standards and integrate them with new ones
- Distribute a living document during development
- Agree and commit to standards
- Promote the benefits of standardization to stakeholders
- Have regular in-person meetings
- Establish liaison to ensure flow of communication
- Give people time to review and give input on the documents
- Use location of the meeting as a tool to encourage participation
- Gather information from stakeholders on their priorities
- Incentivize big stakeholders to include their subcontractors
- Make funding available to enable attendance of smaller partners

The working group is pleased to present these recommendations to the United Nations Committee on the Peaceful Uses of Outer Space. Implementation of these recommendations shall optimize flexibility without compromising interoperability of the systems and foster a large, diverse community to drive innovation and development.

REFERENCES

1. Overview and results of the Lunar Laser Communication Demonstration - LLCD, Boroson, D.M, et al, Proceedings of SPIE.

2. European Data Relay Satellite System (EDRS) Overview, URL: https://artes.esa.int/edrs/overview, Accessed: 12 October 2017.
3. Consultative Committee for Space Data Systems website, URL: https://public.ccsds.org/default.aspx, Accessed: 12 October 2017.
4. Schieler, Curt. “Considerations for FSOC Interoperability”, NASA Laser Communications Interoperability and Regulatory Workshop, 12 July 2017.

SGAC ACTIVITIES AT IAC 2017

SGAC Workshop on Human Space Settlement (Registration Required)
Sunday, 24 September 2017, 10:00 – 17:30
Adelaide Convention Centre, Meeting Room L1a

In the influential game theory book, "Co-opetition" (Brandenburger and Nalebuff, 1996), the "game" of market interactions is described by the proposed PARTS model (which stands for the following model components: Players, Added value, Rules of the game, Tactics to manage perceptions, and Scope). The subject of this workshop will be focused on recent human settlement plans proposed by both the global public and private sectors. The output of the workshop will be recommendations for presentation to the U.N. COPUOS derived from the study's results and conclusions.

More information: http://spacegeneration.org/event/sgc/space-generation-congress-2017/144-sgc/sgc-2017/2010-sgac-workshop-at-the-68th-iac.html

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Communicating Activities Using Visual Stories (Registration Required)
Sunday, 24 September 2017, 10:00 – 16:00
Adelaide Convention Centre, Riverbank Room 1

The aim of the workshop is to unearth the creative potential of those active in the space industry, and familiarize space professionals with visual media tools, and different types of art that could be used to communicate ideas and concepts from the space sector to different stakeholders including the general public. This workshop also aims to bring together a network of individuals interested in art/science, communication storytelling and social engagement to help share ideas and develop new collaborations.

More information: http://spacegeneration.org/event/sgc/space-generation-congress-2017/144-sgc/sgc-2017/2043-communication-workshop-iac-2017.html

SGAC/AYAA/Space Foundation Booth Reception
Tuesday, 26 September 2017, 15:30
Adelaide Convention Centre, Booth #71

This is the annual reception of the SGAC in partnership with the International Space University (ISU) and the IAF's Workforce Development/YPP Committee. Join the reception, and enjoy some drinks and nibbles while you network with other young professionals in the space sector! No registration needed, this event is FREE to all SGC 2017 delegates, registered IAC 2016 young professionals, and invited guests

SpaceGen Entrepreneurs

Wednesday, 27 September 2017, 16:00 – 18:00

Adelaide Convention Centre, Hall C

SGAC's SpaceGen Entrepreneurs will be held at Hall C of the Adelaide Convention Centre on Wednesday, 27 September at 16:00h, followed by a networking cocktail at 17:00h at Foyer E. SpaceGen Entrepreneurs is designed to connect entrepreneurs and potential entrepreneurs with start-up veterans and Venture Capitalists, Investors, Business Angels and Business Incubators. The SpaceGen Entrepreneurs format is the following:

- *Start-up ecosystem panel* (30 min): The panel will feature several prominent space entrepreneurs and investors from the space start-up world sharing their experiences and tips for success.
- *Entrepreneur's TED-style talk* (30 min): Three inspiring entrepreneurs from all over the globe will share the personal stories behind their ventures. Learn about the challenges they overcame, their experiences in the start-up world, and how they found their path to success.
- *Networking cocktail* (1h): After the event there will be a networking cocktail hour for entrepreneurs and potential entrepreneurs to meet with investors, VC's, business incubators and members of the space start-up landscape.

ESA-SGAC Global Networking Forum: Hacking the Growth Challenges of Space Start-Ups: The Role of Private and Public Investors

Thursday, 28 September 2017, 11:30

Adelaide Convention Centre, Hall D

In recent years the number of start-ups developing new concepts and technologies in space both in upstream and downstream has been increasing. Several countries have announced incubation and acceleration programmes to support these start-ups. Investment in space companies is rising, and the first specific instruments to support space ventures have been created. The participation of private investors is gaining relevance and seems to be extremely important for the consolidation of the business models of the space start-ups. The panel, consisting of space start-ups, private investors and agencies' representatives will open a discussion on the growth and consolidation challenges of these start-ups. The open dialogue will answer questions on the main issues that space start-ups identify when dealing with investors, the view of the investors on start-ups that may have a longer return-on-investment timeline and business models that still need to be proven, as well as the role of the public organizations to enable the growth of start-ups.

ORGANISING TEAM

A team of dedicated volunteers makes up the organising team of the 16th Space Generation Congress. These passionate students and young professionals have worked tirelessly to ensure SGC 2017 delegates enjoy the best possible experiences and opportunities while in attendance. On behalf of the SGAC Executive Office, we thank them for their time and dedication.

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2017 Congress Manager

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2017 Deputy Congress Manager

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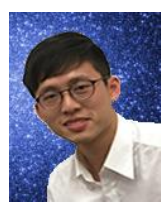

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SGAC WOULD LIKE TO EXPRESS OUR GRATITUDE TO THE SGC ORGANISING TEAM FOR THEIR DEDICATION AND HARD WORK OVER THE PAST YEAR. THIS EVENT COULD NOT HAVE BEEN POSSIBLE WITHOUT THEM!