SPACE GENERATION ADVISORY COUNCIL

SGC 2016 GUADALAJARA

FINAL REPORT

SPACE GENERATION CONGRESS GUADALAJARA 2016

SPACE GENERATION
ADVISORY COUNCIL

In support of the United Nations Programme
on Space Applications

c/o European Space Policy Institute (ESPI)
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LETTER FROM THE SGC CHAIRS

Dear SGC Delegates,

Welcome to Guadalajara! We are very excited to meet you all at SGC 2016. In reviewing all the applications, we are happy to see a mix of former and new participants. We've capped the number of participants to ensure a high level quality of participants discussing top space issues and to have the ability to get to closely know each other. Please use this platform to meet young space leaders from all over the globe, and perhaps brainstorm opportunities for collaboration beyond the next three days!

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.

Remember, 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), and our work has been cited internationally; this is your chance to be heard by the space community. Make it count!

We wish you a wonderful time in Guadalajara and we 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,

Stephanie Wan
SGAC Chair

Ali Nasseri
SGAC Co-Chair

LETTER FROM SGC ORGANISING TEAM

Dear SGC 2016 Delegates,

This year we celebrate the extraordinary 15th anniversary of the Space Generation Congress! Over the past 15 years, the Space Generation Congress has grown into one of the key events for the next generation of space professionals. The event draws in delegates from around the world, heads of space agencies, and high-profile representatives from government, industry and academia.

On behalf of the SGAC Office and Space Generation Congress 2016 Organising Team, we are pleased to welcome you to Guadalajara, Mexico. The annual SGC is an excellent opportunity to share your ideas and experience, initiate collaborative projects, and network with like-minded people in the space sector. The discussions and recommendations over the three days at SGC will be presented at the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) sub-committee meeting in February 2017. This is your chance to have your opinions and ideas heard on an international platform.

Over the past 12 months, the SGC 2016 Organising Team has put in endless hours of volunteer time to the development and planning of SGC 2016. We would particularly like to acknowledge the SGC 2016 Organising Team for their outstanding contributions to what we believe will be an engaging SGC programme. We would also like to acknowledge the support of all our sponsors that make it possible for SGAC to host the annual SGC, and their commitment in advancing tomorrow's space sector leaders to grow their network. Please take advantage of a broad range of affiliated activities accompanying SGC 2016.

Regards,

Minoo Rathnasabapathy
SGAC Executive Director

Carmen Victoria Felix
SGC 2016 Congress Manager

SGC 2016 CONGRESS OVERVIEW

SPACE GENERATION CONGRESS (SGC)

The Space Generation Congress is an annual conference bringing together top young minds from around the world to focus on key space topics. As the only event of its kind, SGC offers the next generation of space leaders the opportunity to network and to examine critical questions that are facing the space and international community at large.

AIMS OF 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 all over the world. From the perspective of the Space Generation Advisory Council, it allows us to consolidate our international links in order to best represent and facilitate 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.

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.

Group picture of the Space Generation Congress 2016 participants

CONGRESS SCHEDULE

Wednesday, September 21st					
09:00 – 12:00	**Moderators Workshop** (Holiday Inn Guadalajara Expo - Guadalajara Room) - Invitation Only				
16:00 – 19:00	**SGC Registration** (Holiday Inn Guadalajara Expo - Lobby)				
19:30	**Departure to Optional Dinner** (Meeting Point at Salon Foayer)				
19:40 – 22:00	**Optional Dinner** at Sirloin Stockade				
22:00	**Departure from Optional Dinner** to Hotel Holiday Inn Guadalajara Expo				
Thursday, September 22nd					
8:30 – 9:00	**Late Registration** (Holiday Inn Guadalajara Expo – Salon Foayer)				
9:00 – 9:30	**SGAC 2016 Welcome** (Plenary – Auditorium El Gran Salon) Presented by Minoo Rathnasabapathy, SGAC Executive Director and Stephanie Wan, SGAC Chair				
9:30 – 10:15	**Invited Speakers**				
10:15 – 10:30	**Coffee Break** (Salon Foayer)				
10:30 - 12:30	**Working Group 1:** **The Proving Ground By NASA AES** **SME:** E. Mahoney **Moderators:** N. Herrmann & A. Delgado **Room: PLAZA II**	**Working Group 2:** **UNISPACE+50 By SWF with support of AEM** **SME:** C. Johnson **Moderator:** M. Pellegrino **Room: PLAZA I**	**Working Group 3:** **Spectrum & Op. Challenges with the Emergence of Small Sats By NASA SCaN** **SME:** C. Mindnich **Moderator:** JC. Lopez **Room: PLAZA III**	**Working Group 4:** **Earth Observation Programmes** **SME:** Y. Muraki **Moderator:** M. Driedger **Room: GRAN SALON I**	**Working Group 5:** **Space Situational Awareness, with support by AEM** **SME:** J. Castillo **Moderators:** C. Entrena **Room: GRAN SALON VI**
12:30 - 13:30	**Lunch Break** (Kiosko Area)				
13:30 - 14:30	**Scholarship Winners Presentations** (Plenary – Auditorium El Gran Salon)				
14:30 - 15:45	**Working Group 1:** **The Proving Ground By NASA AES** **SME:** E. Mahoney **Moderators:** N. Herrmann & A. Delgado **Room: PLAZA II**	**Working Group 2:** **UNISPACE+50 By SWF with support of AEM** **SME:** C. Johnson **Moderator:** M. Pellegrino **Room: PLAZA I**	**Working Group 3:** **Spectrum & Op. Challenges with the Emergence of Small Sats By NASA SCaN** **SME:** C. Mindnich **Moderator:** JC. Lopez **Room: PLAZA III**	**Working Group 4:** **Earth Observation Programmes** **SME:** Y. Muraki **Moderator:** M. Driedger **Room: GRAN SALON I**	**Working Group 5:** **Space Situational Awareness, with support by AEM** **SME:** J. Castillo **Moderators:** C. Entrena **Room: GRAN SALON VI**
15:45 - 16:00	**SGC Official Group Picture**				
16:00 - 16:15	**Coffee Break** (Salon Foayer)				
16:15 - 18:00	**Working Group 1:** **The Proving Ground By NASA AES** **SME:** E. Mahoney **Moderators:** N. Herrmann & A. Delgado **Room: PLAZA II**	**Working Group 2:** **UNISPACE+50 By SWF with support of AEM** **SME:** C. Johnson **Moderator:** M. Pellegrino **Room: PLAZA I**	**Working Group 3:** **Spectrum & Op. Challenges with the Emergence of Small Sats By NASA SCaN** **SME:** C. Mindnich **Moderator:** JC. Lopez **Room: PLAZA III**	**Working Group 4:** **Earth Observation Programmes** **SME:** Y. Muraki **Moderator:** M. Driedger **Room: GRAN SALON I**	**Working Group 5:** **Space Situational Awareness, with support by AEM** **SME:** J. Castillo **Moderators:** C. Entrena **Room: GRAN SALON VI**
19:30	**Bus Departure to Opening Dinner** (Meeting Point at Lobby)				
19:50 – 22:30	**Opening Dinner** at Santo Coyote				
22:30	**Bus Departure from Opening Dinner** to Hotel Holiday Inn Guadalajara Expo				

Friday, September 23rd					
9:00 – 9:10	**SGC Day 2 Welcome** (Plenary – Auditorium El Gran Salon)				
9:10 - 10:15	**Working Group 1:** **The Proving Ground By NASA AES** **SME:** E. Mahoney **Moderators:** N. Herrmann & A. Delgado **Room: PLAZA II**	**Working Group 2:** **UNISPACE+50 By SWF with support of AEM** **SME:** C. Johnson **Moderator:** M. Pellegrino **Room: PLAZA I**	**Working Group 3:** **Spectrum & Op. Challenges with the Emergence of Small Sats By NASA SCaN** **SME:** C. Mindnich **Moderator:** JC. Lopez **Room: PLAZA III**	**Working Group 4:** **Earth Observation Programmes** **SME:** Y. Muraki **Moderator:** M. Driedger **Room: GRAN SALON I**	**Working Group 5:** **Space Situational Awareness, with support by AEM** **SME:** J. Castillo **Moderators:** C. Entrena **Room: GRAN SALON VI**
10:15 – 10:30	**SGAC Project Groups Coffee Break** (Salon Foayer)				
10:30 – 11:30	**Invited Speakers**				
11:30 - 12:30	**Working Group 1:** **The Proving Ground By NASA AES** **SME:** E. Mahoney **Moderators:** N. Herrmann & A. Delgado **Room: PLAZA II**	**Working Group 2:** **UNISPACE+50 By SWF with support of AEM** **SME:** C. Johnson **Moderator:** M. Pellegrino **Room: PLAZA I**	**Working Group 3:** **Spectrum & Op. Challenges with the Emergence of Small Sats By NASA SCaN** **SME:** C. Mindnich **Moderator:** JC. Lopez **Room: PLAZA III**	**Working Group 4:** **Earth Observation Programmes** **SME:** Y. Muraki **Moderator:** M. Driedger **Room: GRAN SALON I**	**Working Group 5:** **Space Situational Awareness, with support by AEM** **SME:** J. Castillo **Moderators:** C. Entrena **Room: GRAN SALON VI**
12:30 - 13:30	**Lunch Break** (Kiosko Area)				
13:30 - 15:30	**Working Group 1:** **The Proving Ground By NASA AES** **SME:** E. Mahoney **Moderators:** N. Herrmann & A. Delgado **Room: PLAZA II**	**Working Group 2:** **UNISPACE+50 By SWF with support of AEM** **SME:** C. Johnson **Moderator:** M. Pellegrino **Room: PLAZA I**	**Working Group 3:** **Spectrum & Op. Challenges with the Emergence of Small Sats By NASA SCaN** **SME:** C. Mindnich **Moderator:** JC. Lopez **Room: PLAZA III**	**Working Group 4:** **Earth Observation Programmes** **SME:** Y. Muraki **Moderator:** M. Driedger **Room: GRAN SALON I**	**Working Group 5:** **Space Situational Awareness, with support by AEM** **SME:** J. Castillo **Moderators:** C. Entrena **Room: GRAN SALON VI**
15:30 - 15:45	**Coffee Break** (Salon Foayer)				
15:45 - 16:15	**Invited Speakers**				
16:15 - 18:00	**Working Group 1:** **The Proving Ground By NASA AES** **SME:** E. Mahoney **Moderators:** N. Herrmann & A. Delgado **Room: PLAZA II**	**Working Group 2:** **UNISPACE+50 By SWF with support of AEM** **SME:** C. Johnson **Moderator:** M. Pellegrino **Room: PLAZA I**	**Working Group 3:** **Spectrum & Op. Challenges with the Emergence of Small Sats By NASA SCaN** **SME:** C. Mindnich **Moderator:** JC. Lopez **Room: PLAZA III**	**Working Group 4:** **Earth Observation Programmes** **SME:** Y. Muraki **Moderator:** M. Driedger **Room: GRAN SALON I**	**Working Group 5:** **Space Situational Awareness, with support by AEM** **SME:** J. Castillo **Moderators:** C. Entrena **Room: GRAN SALON VI**
19:00 – 22:00	**SGAC International Cultural Night** (Holiday Inn Guadalajara Expo, Swimming Pool Area)				
Saturday, September 24th					
9:00 – 9:30	**Scholarship Winners Presentations** (Plenary – Auditorium El Gran Salon)				
9:30 – 10:45	**Working Group 1:** **The Proving Ground By NASA AES** **SME:** E. Mahoney **Moderators:** N. Herrmann & A. Delgado **Room: PLAZA II**	**Working Group 2:** **UNISPACE+50 By SWF with support of AEM** **SME:** C. Johnson **Moderator:** M. Pellegrino **Room: PLAZA I**	**Working Group 3:** **Spectrum & Op. Challenges with the Emergence of Small Sats By NASA SCaN** **SME:** C. Mindnich **Moderator:** JC. Lopez **Room: PLAZA III**	**Working Group 4:** **Earth Observation Programmes** **SME:** Y. Muraki **Moderator:** M. Driedger **Room: GRAN SALON I**	**Working Group 5:** **Space Situational Awareness, with support by AEM** **SME:** J. Castillo **Moderators:** C. Entrena **Room: GRAN SALON VI**
10:45 – 11:00	**Coffee Break** (Salon Foayer)				
11:00 – 12:00	**Invited Speakers**				

12:00 - 13:00	**Lunch Break** (Kiosko Area)				
	The Proving Ground By NASA AES **SME:** E. Mahoney **Moderators:** N. Herrmann & A. Delgado **Room: PLAZA II**	**UNISPACE+50 By SWF with support of AEM** **SME:** C. Johnson **Moderator:** M. Pellegrino **Room: PLAZA I**	**Spectrum & Op. Challenges with the Emergence of Small Sats By NASA SCaN** **SME:** C. Mindnich **Moderator:** JC. Lopez **Room: PLAZA III**	**Earth Observation Programmes** **SME:** Y. Muraki **Moderator:** M. Driedger **Room: GRAN SALON I**	**Space Situational Awareness, with support by AEM** **SME:** J. Castillo **Moderators:** C. Entrena **Room: GRAN SALON VI**
15:10 -15:25	**Coffee Break** (Salon Foayer)				
15:25 - 15:45	**Invited Speakers**				
15:45 - 17:30	**Working Group Presentations** (Plenary – Auditorium El Gran Salon)				
17:30 – 17:45	**Closing Remarks** (Plenary – Auditorium El Gran Salon)				
18:40 – 19:30	**Bus Departure to Closing Dinner** (Meeting Point at Lobby)				
19:30 – 22:00	**SGC Closing Dinner** at Hacienda La Providencia				

SGC 2016 CONGRESS SPEAKERS

Charles F. Bolden	Administrator, National Aeronautics and Space Administration (NASA)
David Kendall	Chair of the Committee on the Peaceful Uses of Outer Space, United Nations
Francisco Javier Mendieta Jimenez	Director General, Mexico Space Agency
Kiyoshi Higuchi	President, International Astronautical Federation; Technical Counselor, Japan Aerospace Exploration Agency
Mr Lluc Diaz	Engineer, Technology Transfer Programme Office, European Space Agency
Brett Biddington	Executive Director, IAC 2017 Local Organising Committee
W. Michael Hawes	Vice President & Orion Program Manager, Lockheed Martin Space Systems Company
Jean-Yves Le Gall	President, Centre National d'Etudes Spatiales (CNES)
Jason Crusan	Director of Advanced Exploration Systems Division, National Aeronautics and Space Administration
Rosa María Ramírez de Arellano y Haro	General Director of International Affairs and Space Security, Mexico Space Agency
Daniel Oltrogge	Senior Research Aerodynamicist, Analytical Graphics Incorporated (AGI) Center for Space Standards and innovation
Krystal Wilson	Project Manager, Secure World Foundation
Yusuke Muraki	Space Engineer, Japan Aerospace Exploration Agency

CONGRESS STATISTICS

SGAC was pleased to welcome a diverse representation of delegates from an array of countries and regions. 132 delegates were invited to participate at SGC 2016, together with 13 speakers and six Subject Matter Experts. SGC 2016 attendees came from more than 32 countries across six continents. This diversity is a major contributor to the development of a truly international voice of the space generation that SGAC strives to represent.

This year, SGAC increased the number of scholarships awarded to its members! A total of 75 scholarships, which included technical paper competitions and SGAC Young Leaders Awards, allowed SGAC members from all over the world to attend the SGC 2016 and the IAC 2016.

These figures clearly demonstrate SGAC's international influence, and that the organisation's continued development gives SGAC the momentum to establish a distinct network highly representative of young space professionals and university students.

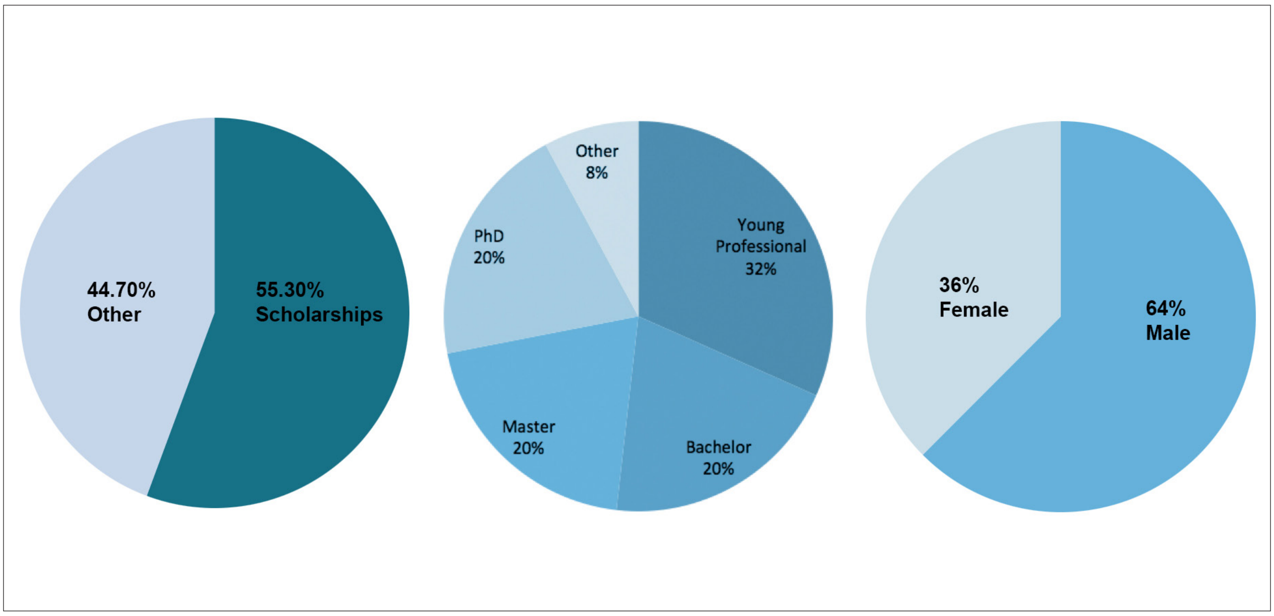
132
DELEGATES

32
COUNTRIES REPRESENTED

73
SCHOLARSHIPS

13
SPEAKERS

6
SUBJECT MATTER EXPERTS



SCHOLARSHIP WINNERS

SGAC awarded five SGAC Young Leaders Awards to international university students and young professionals based on their demonstration of exceptional academic and professional contributions to the global space sector.

NAME	COUNTRY NAME	AWARD
Mahesh Thakuri	Nepal	IAF ESL Grant
Marek Novak	Czech Republic	IAF ESL Grant
Ishraj Shatirsingh Inderjeet	Mauritius	IAF ESL Grant
Oniosun Temidayo	Nigeria	IAF ESL Grant
Sinead O'Sullivan	Ireland	IAF ESL Grant
Marta Rocha de Oliveira	Brazil	IAF ESL Grant
Jonathan Kolbeck	Costa Rica	IAF ESL Grant
Geraldo Salazar Diaz	Cuba	IAF ESL Grant
Tijesu Ojumu	Nigeria	IAF ESL Grant
Michaela Musilova	Slovakia	IAF ESL Grant
Yuval Brodsky	Israel/Canada	IAF ESL Grant
Manisha Dwa	Nepal	IAF ESL Grant
Upasana Dasgupta	India	IAF ESL Grant
Lisa Stojanovski	Australia	IAF ESL Grant
Brittany Zimmerman	USA	IAF ESL Grant
Travis Doom	USA	Future Space Leaders
Kavya K Manyapu	USA	Future Space Leaders
Danielle Wood	USA	Future Space Leaders
Alexander Gibson	USA	Future Space Leaders

NAME	COUNTRY NAME	AWARD
Javier Stober	USA	Future Space Leaders
Tara Halt	USA	Future Space Leaders
Tomoya Mori	USA	Future Space Leaders
William J. O'Neill	USA	Future Space Leaders
Sarah Beattie	USA	Embry-Riddle Scholarship
Brock Little	Australia	Young Australia Space Leaders Scholarship
Simon Clifford	Australia	Young Australia Space Leaders Scholarship
Katherine Cox	Australia	Young Australia Space Leaders Scholarship
Kate Dent	Australia	Young Australia Space Leaders Scholarship
Angeliki Papadimitriou	Greece	Young ESA Scholarship
Hansley Noruthun	Mauritius/UK	SGAC Leadership Award
Ramasamy Venugopal	India	SGAC Leadership Award
Caroline Thro	France/Germany	SGAC Leadership Award
Daniel Brack	Israel	SGAC Leadership Award
Chantelle Dubois	Canada	SGAC Leadership Award
James Murdza	USA	iSpace Competition
Melanie Grande	USA	NASA AES Scholarship
Derrik Best	USA	NASA SCaN Scholarship
Britani Maskley	USA	NASA SCaN Scholarship
Wei-yu Louis Feng	Taiwan/Sout Africa	SSPI Satellite Futures Scholarship
Estephania Flores Aguilar	Mexico	SSPI Satellite Futures Scholarship
Aurthur Vimalachandran	India	SSPI Satellite Futures Scholarship
Marcel Kaufmann	Germany	DLR Standout Student Scholarship
Manfred Ehresmann	Germany	DLR Standout Student Scholarship
Daniele Mazzotta	Italy	ASI-SGAC Grant
Simone Flavio Rafano Carnà	Italy	ASI-SGAC Grant
Salvatore Sarno	Italy	ASI-SGAC Grant

NAME	COUNTRY NAME	AWARD
Luigi Colangelo	Italy	ASI-SGAC Grant
Andrea Antonello	Italy	ASI-SGAC Grant
Alice Barthe	French	OHB Competition
Octavio Ponce Madrigal	Mexico	OHB Competition
Edward Barks	USA	Space Solar Power
Simon MolgatLaurin	Canada	Move an Asteroid Competition
Carlos Manuel Entrena Utrilla	Spanish	Space is Business Competition
Luis Angel Castellanos Velasco	Mexico	SGAC – AEM Scholarship
Adriana Cristina Pliego Carrillo	Mexico	SGAC – AEM Scholarship
Antonio Eduardo Gutierrez Nava	Mexico	SGAC – AEM Scholarship
Jose Gerardo Mora Almanza	Mexico	SGAC – AEM Scholarship
Hanna Mendoza Ruiz	Mexico	SGAC – AEM Scholarship
Federico Arturo Martinez	Mexico	SGAC – AEM Scholarship
Sofia Andrea Huerta Ramirez	Mexico	SGAC – AEM Scholarship
Andrea de la Torre Aceves	Mexico	SGAC – AEM Scholarship
Francisco Javier Jacome Gonzalez	Mexico	SGAC – AEM Scholarship
Oscar Federico Rosas Castillo	Mexico	SGAC – AEM Scholarship
Yair Israel Piña Lopez	Mexico	SGAC – AEM Scholarship
Diana Yeseli Silva Guerrero	Mexico	SGAC – AEM Scholarship
Jose Trini Escobar	Mexico	SGAC – AEM Scholarship
Christian Daniel Caballero	Mexico	SGAC – AEM Scholarship
Raul Enrique Estrella Camacho	Mexico	SGAC – AEM Scholarship
Jose Emmanuel Morales Robles	Mexico	SGAC – AEM Scholarship
Dante Ovidio Valdovinos Gaspar	Mexico	SGAC – AEM Scholarship
Juan Carlos Mariscal Gomez	Mexico	SGAC – AEM Scholarship
Miriam Yolanda Meza Tovar	Mexico	SGAC – AEM Scholarship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SGC 2016 SESSION REPORTS

Group picture of the Space Generation Congress 2016 participants


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CISLUNAR PROVING GROUND

Supported by NASA Advanced Exploration Systems (AES)

NAME	ROLE	NATIONALITY
Jason Crusan	Speaker	USA
Erin Mahoney	Subject Matter Expert	USA
Armando Delgado	Moderator	Mexica/USA
Nicole Herrmann	Moderator	USA
Andreas Winther Rousing	Delegate	Denmark
Andrew Powis	Delegate	Australia
Brittany Zimmerman	Delegate	USA
Chantelle Dubois	Delegate	Canada
Dennis Daub	Delegate	Germany
Florian Marmuse	Delegate	France
Ishraj Inderjeet	Delegate	India
Jennifer Pouplin	Delegate	USA
Jonathan Kolbeck	Delegate	USA
Kate Howells	Delegate	Canada
Kavya K. Manyapu	Delegate	USA
Kyle Acierno	Delegate	Canada
Laura Bettiol	Delegate	Italy
Lisa Stojanovski	Delegate	Australia
Mahesh Thakuri	Delegate	Nepal
Manisha Dwa	Delegate	India
Marek Novak	Delegate	Denmark
Maria Grulich	Delegate	Germany
Marta Rocha de Oliveira	Delegate	France
Maxime Sixdeniers	Delegate	France
Michaela Musilova	Delegate	Slovakia
Oniosun Temidayo	Delegate	Nigeria
Rebecca Browder	Delegate	USA
Sumana Mukherjee	Delegate	India
Surmit Bhui	Delegate	India
Tara Halt	Delegate	USA
Thomas Swaffield	Delegate	USA
Tristan Perkins	Delegate	Australia

1. INTRODUCTION

As a continuation of the 'Pioneering Space Exploration' theme from SGC 2015, the Proving Ground Working Group (WG) of SGC 2016 focused on addressing some of the fundamental questions about enabling space exploration beyond Low Earth Orbit (LEO) utilising proving grounds. Although rooted in NASA's effort for the Journey to Mars, the main objectives of the WG were to identify technologies, infrastructure, and global governance models to establish a Cislunar Proving Ground with international collaboration. The main objectives of the working group were two-fold:

1. Design a recommended mission architecture identifying global assets and capabilities and harnessing the full potential of Cislunar space.

2. Develop a global governance strategy to foster collaborative international participation in the Proving Ground.

The first objective was to identify a design reference mission along with science and exploration activities that can leverage anticipated technology elements during both crew habitation periods and during dormancy periods, when there is no crew. This architecture was based on one crewed flight per year and a realistic projection of launch capabilities from various governmental and commercial partners. For the second objective, the team developed recommendations for a global governance strategy to actively enable the proposed mission architecture, while recognising common standards, systems, commonalities, and public and private partnerships, thereby fostering collaborative international participation in the proving grounds.

1.1. Demographics

The Proving Ground WG was represented by a wide diversity of demographics in students and young professionals from around the globe with 25 delegates from 10 different countries. The United States of America represented 34 %, while Canada and France represented 11 % each, followed by other European, Asian, and Australia countries. Additionally, the WG defied the stereotype of a male-dominated science technology engineering and mathematics (STEM) field, as females made up over 60 % of the team. It was a team that brought to the conversation a wealth of perspectives, insights, and practical knowledge to pioneer the future of space exploration.

1.2. Sponsorship and Background Material

The formation of the Proving Ground Working Group for the Space Generation Congress 2016 was sponsored by the National Aeronautics and Space Administration's (NASA) Advanced Explorations Systems Division (AESD), who provided the framework for the conversation. Background material and knowledge was combined from the Global Exploration Roadmap of 2013, the UN COPUOS Long-term Sustainability of Outer Space Activities Guidelines, NASA's Human Exploration Objectives, and NASA-identified Strategic Knowledge Gaps (SKGs)[1]. Using this extensive material and outcomes from the 2015 Pioneering Space WG, the group could begin the conversation and then make suggestions to establish and achieve Proving Ground goals.

2. PROVING GROUND

As the name suggests, a proving ground is a training area to test new technologies and prototypes to enable future exploration activities. As such, in the context of space exploration, the Proving Ground represents an environment in which to innovate, demonstrate, and validate capabilities required for humans to pave the way for long-duration deep space exploration. Beyond Low Earth Orbit destinations, Cislunar space-defined by the sphere of influence of the moon whether in orbit or on the surface--has been recognised as the next step and the Proving Ground for many space agencies with advanced exploration goals. As NASA's Journey to Mars indicates, actors may use the "multiple stable staging orbits… to practice deep-space operations with decreasing reliance on Earth" [3].

2.1. Approach/Process

In order to address the objectives of the WG, the team was divided into four sub-groups with individual focus areas, including mission activities for crewed missions and dormancy periods, and opportunities for fostering collaboration using international governance and infrastructure. The subgroups reconvened to collaborate on findings from each area, provide feedback, and to form the framework of recommendations to the UN. Figure 2 provides an overview of the subgroups.

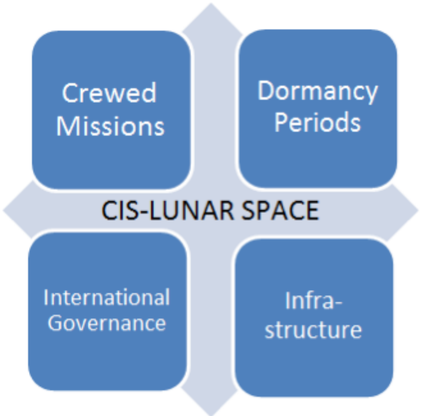


Figure 2. Sub-group focuses of the Proving Ground Working Group.

It was clear in discussions about an exploration architecture that there is a wealth of topics that various parties have passions for, and that there is no easy way to prioritise one over another. The group strived to develop results that could not only accomplish NASA's Human Exploration Objectives, but also adjust current plans to incorporate new perspectives introduced by the international participants in the congress. The international participants were also there to provide the perspective from the young generation and future leaders in aerospace, and they often introduced up-and-coming technologies that have not yet been recognised for strategic objectives or perhaps have not yet been properly funded. The group coordinators worked to keep the focus on identifying activities and objectives which could maximise the use of anticipated assets.

3. PART 1: INFRASTRUCTURE ELEMENTS & POTENTIAL COLLABORATIVE ARCHITECTURE

3.1. Anticipated Infrastructure Elements

This section provides an overview of the infrastructure elements that are currently available or will be available in the near future to utilise and prove technologies in the Proving Ground to enable future deep space missions. Certain mission elements, technologies, and capabilities are under development today or have been significantly advanced in recent years such that they can be counted on to both enable and enhance future missions. It is important for space agencies as well as commercial ventures to recognise these developments and maximise their use. The team spent a significant portion of the time identifying these anticipated elements so that future mission architecture and campaign work can understand what reliable capabilities will be available. The intent was to make this list as realistic as possible, i.e. what can truly be anticipated, but with some room to be optimistic about the addition of funding and progress in other areas.

The anticipated elements were identified for six fundamental fields of space exploration activities. Initially, the anticipated elements chart, shown in Fig. 3, focused on launch capabilities. Under the guidance of the AESD coordinators, this discussion began with the NASA Space Launch System (SLS) currently under development. Other launch providers were then included, such as the Russian Soyuz, the French Ariane rocket series from Arianespace, the USA private company SpaceX's Falcon Heavy, and others. It is the hope of the team that all options can be utilised when accomplishing global exploration goals in the Proving

Ground. With this support, what can we launch into orbit? What new capabilities can we demonstrate? What will empower our missions? These and other questions led to the development of an extensive list of autonomy and robotics, in-space propulsion systems, power, communication, and other technologies.

3.2. Proving Ground Mission Architecture

Using the anticipated elements identified, the group aimed to prioritise a set of activities that could be accomplished during crewed missions and dormancy periods in the Proving Ground. The ground rule dictated a minimum of one crewed launch per year, with missions ranging from thirty to approximately one hundred days. The dormant period would be defined as the time wherein architecture elements remain in Cislunar space, but uninhabited. The state of the habitat or habitation system, whether it would be completely powered down or partially powered, left partially pressurised or unpressurised, etc., was not specified.

The group took an incremental approach in defining a recommended design reference mission. This allowed for advancing and demonstrating technologies within the Proving Ground as building blocks to enable our journey towards Mars and other deep space activities. As such, a two-year timespan for Cislunar operations was considered from 2027 through 2029 in order to suggest an example mission architecture. Assumptions were made, as shown in Fig. 3, including a pre-assembled habitat configuration by 2027, necessary flight systems already validated, and resupply capabilities in place. This architecture would fulfil two essential goals: first, to maximise the use of the anticipated elements, as discussed previously; second, to promote global collaboration across various aspects of the campaign. To accomplish the first goal, a variety of launch partners are recommended for the deployment of the many mission elements. Additionally, the campaign shall fly newly developed technology and use the Proving Ground missions to validate these capabilities for future long-duration deep space missions, including both on the Martian and lunar surfaces.

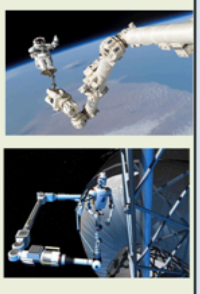
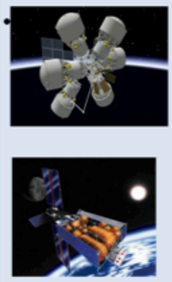
Launch Capabilities	Autonomy & Robotics	In-Space Propulsion	Power	Technologies/ Capabilities	Communication
• SLS (Block 1b) • Ariane 6 • Long March 7 • GSLV • Angara V • Soyuz • HII-A and HII-B • Commercial partners (e.g. SpaceX Falcon Heavy)	• Robotic arms for boulder retrieval (potentially from NASA's ARM project) • Virtual Reality • Haptic Robotics • Artificial Intelligence	• Solar Electric Propulsion • Standardized Common Fuel • In-space refueling using surface in Situ fuel	• High efficiency solar cells • High capacity batteries • Nuclear/ thermal power systems • Space Solar Power	• ISRU • Nanosats • Bio-regenerative life support systems • 3D printing and additive manufacturing (mining, processing) • Lunar surface sensors, measuring ionization of regolith for communication and for radiation • Surface Exploration Vehicle • Radio telescopes • Lunar surface habitats, including inflatable • On-orbit habitation elements • Surface rovers and landers • Orbiters/ relay satellites • Artificial gravity and closed loop systems (Desired)	• Laser/Optical • Ka Band • X-Band • UHF • Lunar Positioning System (LPS) • Disruption Tolerant Network
					

Figure 3. Anticipated elements for the cislunar Proving Ground and beyond.

The suggested Cislunar mission architecture is shown in Figure 4. The two-year timeline is represented on the top, and each distinct mission segment is highlighted by an orange column. The crewed missions will incrementally increase from 30 to 60 to 120 days, each separated by approximately three hundred days of dormancy. Each red box represents a main objective, which each themselves have specific technologies and techniques to be tested.
Looking at the extensive list of desired capabilities, an effort was made to prioritise according to technologies and activities that can be tested and accomplished during the short missions that require crew support and what can be re-visited later during longer missions. Details on each segment of Design Reference Missions created by this team can be found in the appendix. For example, the first and shortest crewed missions will look at small scale, personal radiation protection technology for the Radiation Objective, initial Psychology Objectives, and a small scale bioregenerative life support system. Integrated Objectives will validate international standards for hardware, software, system interfacing, etc. Certain objectives, like the Radiation and Communication Objectives, are continuous throughout the crewed and dormancy periods. Later, crews may test advanced Medical Objectives, integrated crew habitation and survival technologies (for radiation, physiological countermeasures, and psychological approaches), and large scale closed life support systems. There are various transition activities from crewed to dormancy periods, and from dormancy to preparation for crew arrival. Example activities include deployment of autonomous experiments and potential for remote shutdown and restart of air revitalisation and water reclamation systems. Dormancy periods themselves will involve Maintenance/ Logistics Objectives, such as system health and status monitoring and control; Autonomy Objectives, such as terrain characterisation and remote control of experiments; ISRU Science Objectives, such as oxygen production and other regolith processing.

Dormancy No. 1 was chosen to deploy the Surface Exploration Vehicle (SEV) and ISRU technology to the surface of the moon in 2027, when autonomy and remote operations would be demonstrated and validated. Following this dormancy period, two astronauts from the sixty-day crew would descend to the surface. While on the surface, the SEV would be used for up to fourteen days of surface operations for the crew. During this time, the reliability and capability of the systems would be truly validated. Teams on the ground could then use the results as an analogue to a worst-case scenario wherein a future long duration lunar surface mission is required to evacuate the habitat and survive in the SEV only. This would be an important check in the box for both Mars-oriented and Moon-oriented exploration strategies.

In addition to technology development and validation, each crewed mission and dormancy period would include science objectives. The second goal to inspire global collaboration will hopefully be most easily accomplished through providing all countries, all space agencies, and all private ventures the opportunity to perform science missions both with crewed support and remotely during the dormancy periods. There is a small globe icon on the Design Reference Mission graphic beside the various objectives categories to represent this international perspective.

Eventually, as various countries, agencies, and private ventures are contracted or take the lead in developing various capabilities, as listed here in the orange boxes, small flags and logos can be added to this kind of timeline graphic, just like the small globes are already positioned, providing an infographic delineating the global reach of this Proving Ground venture.

4. PART 2: GLOBAL GOVERNANCE STRATEGY

In accordance with the mission architectures and capabilities discussed above, we recognise the importance that the Proving Ground will play in the future of human space endeavours. We also recognise that any successful exploration campaign will involve both governmental and private actors and will create opportunities for further involvement by a myriad of new actors. To ensure that this space is explored and utilised in a safe and sustainable way, it is critical for those primary actors to coordinate immediately and plan for anticipated governance challenges.

Our concluding recommendation for this section describes the formation of a governing body which could monitor the range of activities being undertaken within the Proving Ground, enforce safe operation, and foster collaboration between actors. This governing body would be the next step from such international bodies as exist already, including the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), the International Space Exploration Coordination Group (ISECG) [4,5], and others, where this next step would imply a more active role in both governance and decision making. We recognise, however, that the development of such a committee would be a monumentally challenging feat in itself. Therefore,

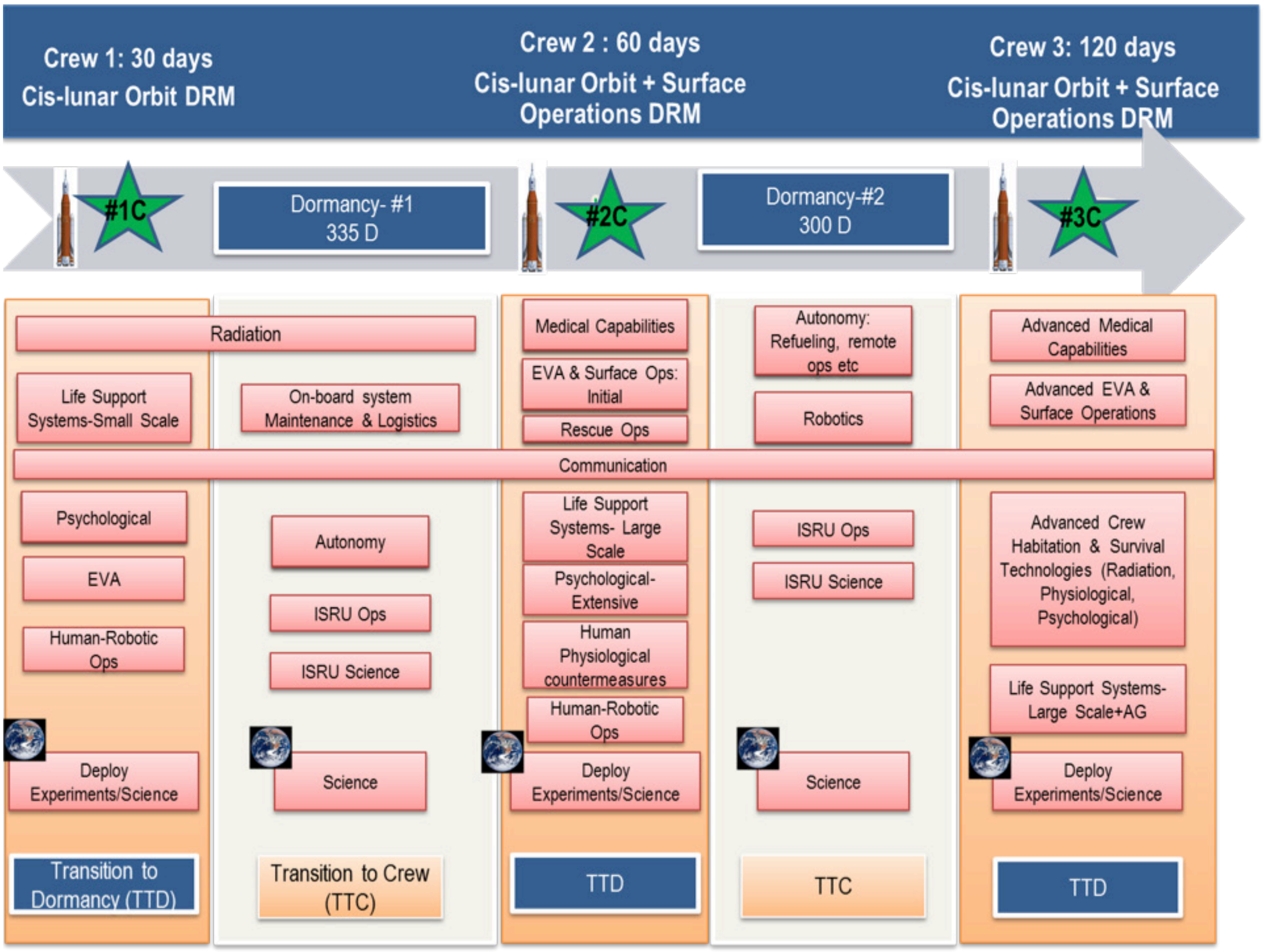


Figure 4. An example design reference mission.

the recommendations are presented here in an incremental approach enabling future development of such a global governance committee.

We believe that access to the Proving Ground should be available to all players ranging from national agencies to private industry and academia. Therefore, in the discussion that follows, we define an "actor" as either a state entity with ambitions for Cislunar activity or a private entity with advanced plans for Cislunar activity. We include the adjective "advanced" in this definition in an effort to include spacefaring commercial entities without opening the door to all those who simply aspire to act in Cislunar space. We believe that there will be ample opportunities for commercial ventures in Cislunar space. However, the development of a governance strategy shall be limited to those with credible plans to contribute to the development of the Proving Ground.

4.1. Collaborative Discussions

*Actors should be encouraged to **discuss** their intentions, goals and resources.*

While this initial recommendation may seem somewhat self-evident, it is a critical first step towards long term collaboration. To begin to develop a governance strategy, the participating actors must first be aware of each other's plans, objectives, resources, timelines, constraints, and other factors that may influence the development of Cislunar space. Therefore, our first recommendation is that an exploratory discussion of this nature take place. At the very least, the benefit of such discussion is to promote a safe operational environment in Cislunar space and perhaps promote the future development of common goals and shared infrastructure.

Certain bodies of able representatives already do exist which enable such discussions, for example UN COPUOS--with the UN Office of Outer Space Affairs (UNOOSA)--and ISECG [4,5]. These assemblies embody the aim of this recommendation with their commitment to "review international cooperation in peaceful uses of outer space" (UNOOSA, 2016) and create "a sustained, affordable agenda of globally coordinated space exploration" (Ouellet, 2014). Should a new governing body be established, extensive experience can be drawn from assemblies such as these.

4.2. Orbit Allocation & Situational Awareness

Actors should ensure a safe and efficient management of resources, namely the management of orbits and situational awareness in Cislunar space.

Although cislunar space is currently all but devoid of artificial satellites, the history of manned development from LEO to GEO has proven that this can rapidly change [7]. Even after decades of an increasing population of space debris inhabiting Low Earth Orbit, there is still no international consensus or planned mitigation strategy for how to deal with this potential technological disaster. Likewise, it has been challenging to ensure the fair allocation of valuable orbits--particular in geostationary orbit--for emerging spacefaring states and private ventures.

We therefore believe that it is imperative to take steps to prevent similar problems by agreeing upon a strategy in advance of operations in Cislunar space. Indeed, Cislunar space has several points of interest which would strongly benefit from the early implementation of management. The L1 Lagrange point provides easy access to both lunar and Earth orbits and is the ideal location for a deep-space habitat from which to base lunar or returned asteroid missions [8]. Additionally, the L2 Lagrange point is optimal for the location of a communications satellite for covering the far side of the moon [9].

Although no such mechanism exists at this time, there are examples of management structures that can inform the development of a strategy for Cislunar space. For example, the International Telecommunication Union's management of geosynchronous orbits provides an example of managing orbital and spectral allocations [10].

As a crucial component of this management strategy, it is also imperative that a system be set up which provides situational awareness to all actors to avoid potential disasters which may risk lives, assets and the future utilisation of critical allocated orbits. The Space Situational Awareness Working Group of SGC 2016 focused on Space Situational Awareness, and their results can additionally be found in this report.

4.3. Compatibility & Standardisation

Actors should work towards compatible systems in the view of a shared utilisation of systems. Such collaboration could include the development of standards.

Critical to the sustained presence of humans in Low Earth Orbit over the past several decades has been the strong collaboration between international space agencies, such as the breakthroughs made in science and international collaboration aboard the International Space Station [11], as well as the recent launch of the asteroid sampling mission OSIRIS-REx managed by NASA in collaboration with France's Centre National d'Études Spatiales (CNES), Japan Aerospace Exploration Agency (JAXA), and the Canada Space Agency (CSA). There are as well the traditional strong domestic partnerships between agencies and private contractors [12]. While actors may have somewhat diverging ideas of how human exploration beyond LEO will evolve, it is well acknowledged and inevitable that these actors will collaborate on infrastructure in order to succeed with their ambitious plans [13]. We therefore believe that a huge advantage could be gained if actors collaborate from the outset to develop a common set of standards or shared infrastructure and reduce the cost of future in-space collaboration [14].

This concept of shared infrastructure is certainly not new, and common standards would maximise the efficiency of collaboration by governing the development of new technology. The International Space Station is a successful example of shared infrastructure that is capable of sustaining a small but permanent population in LEO. From this we recommend that actors coordinate before developing their Proving Ground technologies in order to facilitate future collaboration and the sharing of infrastructure. See Appendix B for more on recommended common infrastructure and standards.

4.4. Collaboration and Inclusion

*Actors should **collaborate** to develop common mission architectures and to enable and promote the participation of a growing diversity of actors, including those from developing countries.*

We believe that collaboration should also be inclusive. That is, major actors shall be motivated to work with and invest in actors with reduced capabilities and experience within the sector. Such actors could include space agencies from developing nations and private entities that exhibit strong promise in their product development and business strategies.
The purpose of this recommendation is twofold. First, to enable actors to participate in Cislunar activities and develop their own technological capabilities, providing a stimulus to their industry and offshoot technological benefits. Second, to bring new players into the fold of an already collaborative and safely managed environment within Cislunar space to ensure that new players do not pose an operational safety challenge for well established players.

4.5. Governance

Actors should elect or designate amongst them an Inclusive Managing Committee that shall monitor and facilitate the development of Cislunar activities. This committee shall be given the power to supervise and facilitate the management of high level operations that impact all actors in Cislunar space.

Recommendations 4.1 through 4.4 lend themselves to the creation of a governing body that could monitor and facilitate the development of Cislunar activities. We term this body an "inclusive managing committee" to emphasise that such an organisation shall represent the interests of all actors in a way that is both fair and inclusive and which promotes always the peaceful uses of outer space.

To be clear, this recommendation does not suggest the formation of an international space agency, since we believe that such an endeavour is currently overly ambitious and is unlikely to be agreed upon by primary actors. However, such a governing body should have the power to oversee the management of high level elements that impact all actors within the Proving Ground. Examples of such elements may initially include situational awareness, orbital allocation, and common standards, but may grow to include the management of shared communication infrastructure and the utilisation of lunar assets.

Such an organisation should draw on the precedents that led to the collaborative development of the International Space Station and may draw on models such as the European Space Agency [15] or the European Organisation for Nuclear Research (CERN) [16] as well as governing bodies such as the International Telecommunications Union [10].

We acknowledge that determining the structure and powers of such a governing body is a task nearly as monumental as the development of space architectures themselves. We do not presume to recommend any particular structure for this governing body, but we are confident in our assertion that such a body will be necessary. We therefore recommend that actors who plan to operate in Cislunar space determine how the governing committee will function. Some important considerations for the formation of such a committee are detailed in Appendix C.

5. CONCLUSIONS

While the Working Group provided recommendations for a mission architecture in the Cislunar Proving Ground with an incremental approach, along with recommendations for governance and international collaboration, it is challenging to predict what capabilities, assets, and systems will be available for utilising Cislunar space within the next decade. A shared infrastructure in Cislunar space is required to plan, operate, and guarantee access and safe collaboration for all actors and enable future human exploration of deep space destinations. Most importantly, a global governance strategy of collaboration should be considered immediately from the outset to ensure sustainable activity and operations in Cislunar space.

APPENDIX A

Table 1: Segment-1, Crew Launch #1: 30 day crew mission Cislunar orbit DRM

Systems	Capabilities tested
Radiation Objective	Validation of smaller scale, personal radiation protection technology.
Life Support System Objective	Small scale bio-regenerative life support system (extension of ISS studies). Consistent growth of fresh food in space, compare and possible down-select between hydroponics and aeroponics, system sizing for 4 crew for 30 days, nutrient cycling analysis. Validation of air revitalisation systems.
Communication Objective	Using international standard for comm systems. Validate operational capability with comm delay. Autonomy vs. ground support for crew activities and maintenance of systems in case of failure.
Psychology Objective	Sensory stimulation using visual and audible techniques.
EVA Objective	Zero G space suit validation. Maintenance and logistics procedures and operations
Human-Robotics Interaction Objective	Human behaviour when interfacing with robot to develop the robot.
Integration Objective	Validation of international standards for hardware, software, system interfacing, etc.
Transition to Dormancy	Deploy autonomous experiments. Shut down air revitalisation and water reclamation systems

Table 2: Segment-2, Dormancy #1: 335 days.

Systems	Capabilities tested
Maintenance/ Logistics Objective	System health and status monitoring and control. Space dust and debris monitoring and mitigation.
Autonomy Objective	Terrain characterisation and down-select of future landing sites and sites of scientific interest. Resupply mission and validation of international docking adaptor. Remote control of experiments from Earth.
Communications Objective	Contact and teleoperation of lunar rover from Earth. Validate operational capability with comm delay. Validation of new comm technologies, e.g. laser.
ISRU Ops Objective	Deploy, land, and operation of surface extraction technologies. Validation of power systems.
ISRU Science Objective	Oxygen production and other materials processing from regolith.
Transition to Crew	Robotic or autonomous restart life support systems.

Table 3: Segment-3, Crew Launch #2: 60 day crew mission Cislunar orbit + surface DRM.

Systems	Capabilities tested
Life Support System Objective	Transition to large scale systems validation.
Communication Objective	Contact and teleoperation of lunar rover from Cislunar.
Psychology Objective	Validation of facial recognition. All sensory stimulation technologies (visual, audio, VR, etc.).
EVA Objective	Lunar surface exploration in SEV. Validate reliability and lifetime of SEV/ rover(s).
Rescue Ops Objective	Testing technologies for crew rescue and evacuation. Deployable emergency habs. Validation of procedures.
Physiological Countermeasures Objective	Small scale artificial gravity module. Vibration platforms.
Medical Objectives	Instruments for surgery, cross training.
Science Objective	Using artificial gravity and vibration platforms for relevant science experiments.
Transition to Dormancy	Deploy autonomous experiments. Shut down air revitalisation and water reclamation systems.

Table 4: Segment-4, Dormancy #2: 330 days.

Systems	Capabilities tested
Autonomy Objective	Refuelling, including from ISRU. Remote control of experiments from Earth. Remote operation of lunar landers and rovers.
Robotics Objective	Virtual reality and haptics robotics for science experiments and feedback. Operation of robot in the dormant hab without crew, and comparison with combined human-robot performance.
Communications Objective	Ground stations on lunar surface using new comm systems and international standards for systems interfaces.
ISRU Ops Objective	Continue to deploy, land, and operation of surface extraction technologies. Validation of power systems.
ISRU Science Objective	Oxygen production and other materials processing from regolith.
Science Objective	Continued remote operation and data retrieval from globally funded science experiments. Testing planetary protection technologies (lunar surface, sterilisation, monitoring and containment of possible contamination). Testing life detection technologies (lunar orbit or surface or ISS).
Transition to Dormancy	Robotic or autonomous restart life support systems.

Table 5: Segment-5, Crew Launch #3: 120 day crew mission Cislunar orbit + surface DRM.

Systems	Capabilities tested
Life Support System Objective	Large scale systems. Closed loop life support. Artificial gravity structure.
Radiation Objective	Virtual reality and haptics robotics for science experiments and feedback. Operation of robot in the dormant hab without crew, and comparison with combined human-robot performance. Ground stations on lunar surface using new comm systems and international standards for systems interfaces. Continue to deploy, land, and operate on of surface extraction technologies. Validation of power systems.
Psychology Objective	
Physiological Countermeasures Objective	
EVA Objective	Continued EVA and surface operations.
Medical Objectives	Advanced objectives.
Science Objective	Continued global participation.

APPENDIX B: Examples of Common Standards and Shared Infrastructure

This appendix supports the third recommendation of the Global Governance Strategy (see Section 4.3) with a list of examples of where actors could collaborate on common standards and shared infrastructure. Much of the listed examples of common standards lends itself to the creation of shared infrastructure. Since spacecraft commonality will improve the capabilities of actors to collaborate, with physical technology, in Cislunar space.

Common Standards

- Docking ports - Already under development by NASA [reference], a common docking port system would be the first step of many towards enabling joint missions between actors into Cislunar space.

- Power systems - Almost as integral to the matting of space-faring hardware as a docking port is the commonality of power systems. Mismatch of power requirements and limiting loads could risk the damage of critical hardware.

- Life support systems - The commonality of life support systems is important for two reasons. If two spacecraft share the same standards for their life support, then this will clearly reduce the risk for system integration in Cislunar space, particularly if we consider that mismatched systems could impose unforeseen loads or consequences for secondary spacecraft systems. However, more subtly, commonality of life support systems may play an important role for procedural compatibility of human spaceflight. Particularly, if two actors adhere to different safety standards for their astronauts and those two actors produce incompatible life support systems, it may be procedurally impossible for them to mate and share their infrastructure in Cislunar space. Below is a brief list of life support systems which could benefit from common standards.

    - Water purification.

    - Spacecraft atmosphere - particularly pertinent when consider a common docking system.

    - Radiation shielding levels - This may become a serious issue for as of yet unagreed upon standards for safe levels of exposure to astronauts.

    - Spacesuit commonality - This standard will simply reduce the complexity of collaboration in space if all spacesuits adhere to a common standard and function.

- Computer Hardware and Software - With the increasing role that computer play in spacecraft operations. It is imperative that some common standards are implemented to ensure the safe compatibility of hardware and software.

- Common propellant - Although a challenging standard to implement. A common standard in propellant would greatly enhance collaboration in Cislunar space. This could lend itself to entire actors or operations being focused on the creation (by in-situ technologies) or positioning of fuel depots in Cislunar space.

- Shared Infrastructure

- Communication systems - With an eye towards efficient management of orbital allocation in Cislunar space (particularly with reference to the L2 Lagrange point) it would be extremely beneficial for actors to set up a shared communications system. This is particularly pertinent for operations taking place on the far side of the moon.

- Fuel Depots - If a common standard in propellants can be agreed upon, this would lend itself well to the creation of fuel depots or perhaps in-situ fuel creation (whether from asteroid or lunar resources). Propellant could then be purchased by actors as required and reduce the expensive task of launching all propellant from the Earth's surface, greatly enhancing the capabilities in Cislunar space and beyond.

- Emergency backup facility - Such a facility could be partially financed by all actors and include emergency supplies of fuel, atmosphere, water and food. Perhaps even a vehicle for quick Earth return. Such a facility would only become possible after significant development and agreed upon collaboration in Cislunar space.

APPENDIX C: Example Structure of an Inclusive Management Committee

As discussed in Section 4 and particularly in recommendation 4.5, setting up a global governing body for operations in Cislunar space would be a challenging exercise. While over the course of the congress proceedings we did not hope to detail the structure of such a committee, we discussed some important attributes which could improve its chance of creation.

As emphasised by the name, the committee should be inclusive. That is to include all actors by the definition given in the introduction to Section 4. However, the creation of such a committee will evidently be at the whims of those actors who currently possess a great deal of influence within the space community and who currently have advanced plans for Cislunar activities. Examples include NASA, ESA [3], Roscosmos, CNSA, ISRO, JAXA. Therefore, we considered implementing a distinction between *key actors* and for lack of a better word *peripheral actors*. To be classified as a *key actor*, an actor must pass some kind of threshold. Whether that be in the degree of advancement of their plans for Cislunar space, financial contributions to the development of technologies or experience within the sector. *Key actors* should be entitled to exert a larger degree of influence on the decisions made by the committee based on their increased contributions.

All new actors joining the committee (whether at its inception or in the future) would be categorised into one of these groups. However, the barrier between these two types of actors should be fluid and the transition from *peripheral* to *key* actor should be determined by that actor's performance relative to the threshold and not at the whims of the current key actors.

We wish to emphasise that such a concept has not been thoroughly thought through and acknowledge the challenge of favouring major players in the space industry while also providing an inclusive environment for all. There are certainly alternatives to the above, although it would be challenging to approve we could grant all actors equal rights within the committee. Or perhaps we could designate several tiers of influence depending on each actor's contributions (this however may lend itself to one actor having a disproportionate amount of influence over all others).

The Exploration Working Group at SGC 2016.

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UNISPACE+50: SHARED VISION COMMON ACTION

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1. INTRODUCTION

Over the last 60 years, space activities have increased both in number and importance. In contrast to the Cold War era, today's space environment involves a growing number of actors across the sector, including governments and space agencies, international and intergovernmental organisations, universities and NGOs, corporations, and start-ups. More than 1,400 operational satellites, owned and/or operated by around 80 countries and commercial entities, provide a wealth of services and benefits for billions of people on Earth. Private actors are becoming a major driver in the global space economy, estimated to amount up to 330 billion US Dollars, the outlook of which is expected to increase further due to the development of mega-constellations for global internet broadband service and low-cost launch capabilities [1]. All this has contributed to making outer space increasingly congested, contested and competitive [2]. It is a limited resource that needs to be protected through a shared vision and a common action. In this context, the United Nations has organised a global conference on the exploration and peaceful uses of outer space - the UNISPACE+50 which will be held in Vienna in June 2018.

2. UNISPACE+50

UNISPACE+50 is the fourth conference of the UNISPACE conference series and will mark the 50th anniversary of the first conference. Taking stock of the accomplishments of – and lessons learned from – the three previous conferences (UNISPACE I in 1968, UNISPACE II in 1982, and UNISPACE III in 1999), UNISPACE+50 aims to articulate a new long-term vision for space around four main pillars (see Figure 1), investigating challenges and responses to global space governance. The conference, along with the wider strategic reflection that it brings, is also expected to become a milestone for the long-term development of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) (including its subsidiary bodies and secretariat) and related stakeholders, and offers a unique opportunity to strengthen unified efforts in shaping the future of space.

The UNISPACE+50 process can be summarised as shown in Figure 1. The 2030 UN agenda for sustainable development – consisting of 17 sustainable development goals (SDGs) and 169 related targets, and aimed at stimulating action over the next 15 years in five critical areas (people, planet, prosperity, peace, and partnership) – infuses the five cross-cutting areas, on which the seven thematic priorities are based . These thematic priorities will enable UNISPACE+50 to take actions and produce concrete deliverables under the four pillars for socio-economic sustainable development which, in turn, are expected to foster and facilitate the implementation of the 2030 UN agenda for sustainable development.

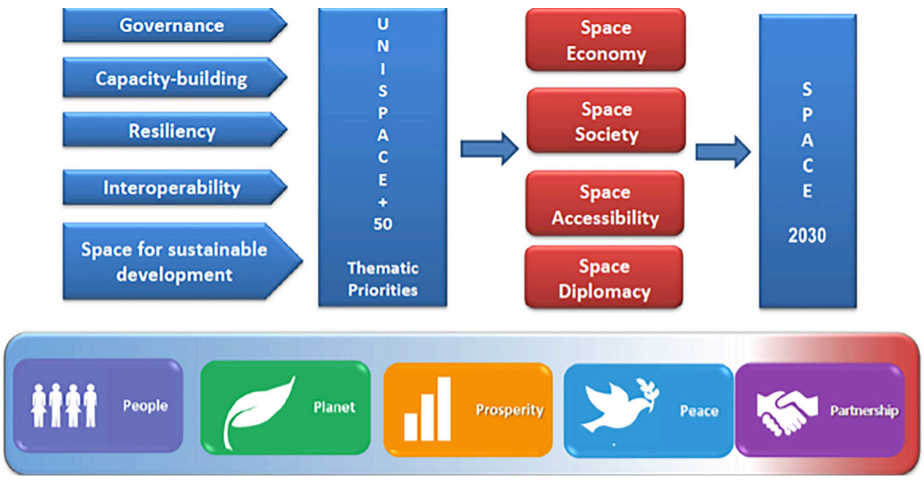

Figure 1. The UNISPACE+50 Process (source: Di Pippo et al. – Presentation by UNOOSA of the paper IAC-16,E3,4,1,x34407 [3]).

As a result of UNISPACE III, the Space Generation Advisory Council (SGAC) attributes heightened importance to this conference series and is expected to play an important role in nurturing the dialogue pertaining to UNISPACE+50 and the wider strategic review promoted by the UNOOSA. From the organisation's beginnings at the 1st Space Generation Forum, held in conjunction with UNISPACE III in 1999, SGAC has grown to more than 4,000 members from over 100 countries.

Over the past 17 years, SGAC has continually contributed to UNCOPUOS, and has recently seen its recommendations quoted by a number of delegations. In this light, SGAC continues to achieve its goal, set out at UNISPACE III, to share the views of the future generation of space leaders, focusing on their long-term visions for space and the tools with which to act.

3. SCOPE OF THE WORKING GROUP

Against this background, the aim of the UNISPACE+50: Shared Vision, Common Action Working Group has been:

- To collect inputs from students and the young generation of space professionals about what matters to them with respect to the exploration and uses of outer space.
- To articulate and frame a new long-term vision for space that aligns with – to the greatest extent practicable and in a manner consistent with the UNISPACE+50 principles – the views of the future generation of space leaders.
- To identify the role that SGAC can play in the UNISPACE+50 process and the wider strategic reflection promoted by the UNOOSA.
- To prioritise areas of further cooperation between SGAC and the other parties involved in the UNISPACE+50 process and strategic review.
- To offer a number of actions for SGAC to move forward with and define common grounds for shared action.

4. METHODOLOGY

In order to fulfil the aforementioned goals, the UNISPACE+50: Shared Vision, Common Action Working Group brainstormed to identify priorities, upon which a unified vision for the exploration and uses of outer space was created. From there, five objectives were derived in order to be able to reach such a vision, and a number of concrete ideas for actions were offered to enable the completion of the objectives. Sub-groups conducted deep discussions on the individual objectives and actions which could be taken by SGAC in support of these. The vision, the objectives, and the actions, were revisited and discussed several times to ensure they were representative of the entire Working Group.

5. VISION

UNISPACE+50 brings together a broad range of stakeholders, often with clashing priorities. However, all of these actors know that they can pursue collective goals through a shared vision and common action. In the light of potential evolutions and future scenarios regarding the exploration and uses of outer space – such as the growing number and internationalisation of space actors, greater competition and involvement of private actors, growing accessibility to space, increasing congestion of earth orbits and saturation of the radio-frequency spectrum, cyber-attacks to space systems, in-orbit servicing, asteroid mining, and big data – the vision for the future of space that SGAC wants to pursue is:

'To ensure the ethical, sustainable, and peaceful access to – and use and exploitation of – terrestrial and outer space environments for generating tangible societal benefits, in a manner that is consistent with the international legal framework and that enhances international cooperation'.

6. GOALS

In order to reach such a long-term vision for space, five objectives have been identified and a number of actions in support of these have been proposed. Not only could these actions contribute to nurturing the strategic reflection promoted by UNOOSA in the framework of the UNISPACE+50 process, but they could also offer SGAC potential avenues for the future and ideas about how to evolve in partnership with its stakeholder.

6.1. Strengthening the outer space regime

This goal ties back to the pillar of Space Diplomacy.

With the number of actors interested in space capabilities growing, outer space risks being exposed to additional strategic competition, with concerns ranging from the proliferation of space debris and increased crowding of Earth orbits, to the management of orbital resources and radio-frequency spectrum, to the weaponisation of outer space and other deliberate threats to space systems [4]. The current outer space regime is thus seen as increasingly inadequate to confront the ongoing dynamic changes in the space environment. New architectures and approaches that go beyond those envisioned even a few years ago would therefore be welcome. Given the lack of shared values among space actors with respect to the secure and sustainable access to and use of space,working toward shared interests and goals could form the basis for future consensus [5].

6.1.1. Defining ethical principles of responsible behaviour in outer space activities

The international space community has long pursued efforts to preserve access to and use of outer space for the benefit of mankind. This includes multilateral initiatives to improve global space governance, both in terms of mechanisms for international cooperation and instruments for regulating space activities.
One option for moving forward in this domain is to create an inclusive process aimed at identifying and defining widely agreed-upon ethical principles of responsible behaviour in outer space to which states voluntarily commit themselves. There will be great value if such a process takes place under the UN umbrella, notably in the framework of UNCOPUOS – the main multilateral forum for the development of space regulations.

As a COPUOS permanent observer, SGAC is willing to stimulate and be an active part of this process, and is open to provide inputs that can help foster the development of these ethical principles for responsible space behaviour. This work can best be pursued if complemented by a specific SGAC project group focused on investigating such principles and carried out in cooperation with other COPUOS delegations and observers interested in the matter upfront. Effectiveness in pushing forward this agenda can also be enhanced if the United Nations General Assembly (UNGA) starts working on a resolution for principles of responsible behaviour in outer space [5].

6.1.2. Improving multilateral cooperation and ensuring compliance with international agreements

While global space governance will not be easily rationalised into any common model soon, the work of the UNGA (notably the Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities) and of the COPUOS (notably the Working Group on the Long-Term Sustainability of Outer Space Activities) shows that some progress can still be made even in the presence of clashing priorities. It is thus of utmost importance to continue work on and push forward existing initiatives, as well as ensure compliance with those proposals for which diplomatic support has been already expressed. A review of how principles and recommendations of major diplomatic initiatives have been or are being applied can help ensure compliance and set the path for others to follow [5].

SGAC is willing to support and be involved in any of these potential reviews, especially if this exercise is conducted under the UN umbrella. Where compliance with international agreement is slowed by national laws, SGAC can play a crucial role in raising awareness of the benefits that the development of mechanisms of national law would have in fostering voluntary measures for enhancing confidence and preventing mistrust amongst space actors. SGAC national and regional points of contact, with the support of the Executive Office, can organise activities to sensitise policy makers and legislators. Additional efforts from the UN, including the development of reports on the implementation of recommendations and guidelines from already existing initiatives, would facilitate compliance with international agreements and strengthen the outer space regime [5].

6.1.3. Engaging in multiple multilateral forums

No single venue addresses all aspects pertaining to the exploration and uses of space. While the UN is the main forum for discussing these issues, talks take place in multiple UN bodies. These include the UN General Assembly, particularly its First Committee and Fourth Committee, as well as the Conference on Disarmament (CD), the UN Committee on the Peaceful Uses of Outer Space (COPUOS), and the International Telecommunication Union (ITU). Each of these has its own governance arrangements, memberships and rationale, highlighting the opportunities that can be created with active engagement in all of them.
Where allowed by law and regulations, SGAC can undertake a reflection on the possibility of joining all of these forums as an observer (or any appropriate status depending on the specific forum) and submit a formal request when the political conditions permit.

6.1.4. Enhancing bilateral cooperation

Effectiveness in strengthening the outer space regime can be enhanced via bilateral cooperation. There will be great value in establishing appropriate relations with like-minded partners, especially within the framework of the UN. In shaping this bilateral cooperation, it makes more sense to build on existing initiatives and prioritise action with long-standing partners. Within the COPUOS, for example, a number of delegations and observers (e.g. SWF, IAA, IISL, IAASS) are pursuing efforts to ensure the long-term sustainable use of outer space. In particular, SWF is currently developing a Handbook for New Actors in Space, the aim of which is to provide them with a broad overview of the fundamental principles, laws, norms, and best practices for peaceful, safe, and responsible activities in space[5].

SGAC can engage and liaise more closely with such delegations and help spread their initiatives through its internal and external networks. This can be done, among other things, by developing appropriate project and/or working groups to provide analysis on specific topics of interest.

6.1.5 Linking global space governance with the 2030 agenda for sustainable development

Space activities of any kind leave footprints on the ground, which render the outer space and terrestrial environments deeply intertwined. Both environments need to be protected and preserved, and this should not come at the cost of the other's sustainability. In light of lowering the environmental impact of outer space activities on Earth, additional sustainable development practices are needed. The UNISPACE+50 strategic reflection, of which the 2030 agenda for sustainable development is one of the main inputs, offers the right opportunity to address this issue at the intergovernmental level.

One idea for moving forward in this area is to include the UN sustainable development agenda, with particular regard to the topic of terrestrial sustainable development, as a new agenda item of COPUOS in 2018. The aim of this new agenda item will be to motivate space actors to display a high degree of care in conducting terrestrial space-related activities.

While the formal submission of a proposal for a new agenda item is up to UN member states' delegations in COPUOS, SGAC can advocate for the creation of such an agenda item, either by partnering with other delegations sharing the same concern or by means of a technical presentation on the topic in the next COPUOS sessions. This can be complemented by an ad-hoc study on the environmental benefits that this new approach brings. ESA, for example, would be a suitable partner to engage, as it is pursuing the Clean Space initiative , for which additional synergies would be welcome.

6.1.6 Shaping data policy for ethical uses of space data

While the proliferation of commercial space actors will contribute to lowering the price of space-related products and data, not all communities will have the resources necessary to benefit from them. Satellite data obtained from governmental programmes can thus be made freely accessible to support the pursuit of the sustainable development goals, notably in the fields of education or emergency response.
SGAC can act as a bridge between the relevant user communities and those governmental agencies providing data. In addition to this, through its working groups, SGAC can undertake further studies to identify potential data policy sharing models and mechanisms for sustainable development and ethical uses, especially if this matters to a number of COPUOS delegations and other observers.

6.2 Making international cooperation the norm for future space activities, recognising it as a long-term investment for all parties involved

This goal ties back to the pillars of Space Economy and Space Diplomacy.

There will be great value if space activities, including the creation of the necessary knowledge and expertise, are accomplished via international cooperation, with the inclusion and consultation of the largest number of stakeholders.

Fostering and promoting the inclusion of developing countries and aspiring space-faring nations in space projects and programmes, within the limit of their own capabilities, can be an avenue for maximising benefits for all parties involved. To win support from established space actors in including those with limited capabilities, international cooperation in space needs to be approached as a long-term investment. While this may not provide immediate returns (except for a cost-effective workforce), it can help build trust and confidence amongst space actors and ensure support from newcomers for other initiatives, not necessarily in the field of space. This approach will also ensure that international cooperation is not seen from new space actors as a one-way provision for space products and services.

Establishing effective international cooperation also requires diversity, both in terms of nationality and type of the players involved. In order to realise this goal, SGAC can advocate for greater inclusion and diversity of actors while making statements on the occasion of COPUOS sessions. In addition to this, in order to act as a model and set the path for others to follow, SGAC can further promote and organise activities in aspiring space nations, ensure diversity in each project it undertakes (for example, by guaranteeing at least one representative per geographic region), and seek additional support from these regions by acting as a bridge between their own space-related entities and personnel eager to be engaged in SGAC activities.

6.3 Making space activities a significant source of socio-economic benefits for all humankind and informing the general public of the ensuing opportunities

This goal ties back to the pillars of Space Economy and Space Society.

Although modern societies are heavily reliant on space systems, the vast majority of people are still not aware of how, and to what extent, outer space impacts our daily lives.

Public outreach will prove beneficial to raise awareness amongst governmental and commercial actors, and the general public alike, of the benefits and opportunities that space brings. Effectiveness in pushing forward a public outreach agenda and enriching the space community can be enhanced when a clear vision and appropriate synergies have been identified, including through cross-sectoral collaboration.
Besides the numerous workshops and congresses that SGAC already organises to inspire young generations, it will be important if SGAC can also organise local events to specifically sensitise national governments and related agencies about the socio-economic benefits of space activities. This will also contribute to expanding SGAC's presence in countries having little to no space tradition.

There will also be great value if SGAC could address and liaise with non-space organisations, such as associations of industries active in those domains where the use of space products and data is envisaged. This cross-sectoral cooperation can take the format of either dedicated joint workshops aimed at informing these communities of the benefits offered by the use of space services and applications in their own industrial sector, or more structured cooperation that foresees SGAC's involvement in support of specific projects, including public outreach campaigns. SGAC could also respond, on its own or as a member of a consortium, to public or private calls for the development of communication plans pertaining to the use of space services and applications, such as those advertised in the European R&D programmes (e.g. Horizon 2020).

Public outreach and diversification of the space community will prove more beneficial (and credible) if national governments increase transparency of budget allocation and provide the public with efficient access to databases and educational tools that facilitate involvement in space endeavours.

Finally, it is necessary that nations actively promote and support the development of space activities, with a special focus on domains where socio-economic benefits are higher. This can best be pursued if returns on space investments are appropriately communicated and quantified by means of independent impact assessments and socio-economic studies. Not only do these analyses need to include earth observation, navigation, and telecommunications, but also domains which have not been traditionally taken into consideration, such as launchers, human spaceflights, and space exploration.

6.4 Encouraging capability development and capacity building, and placing space topics on national political agendas

This goal ties back to the pillars of Space Economy, Space Society, and Space Accessibility.

Building capacity across space markets and placing space on national political agendas can best be pursued if policy makers and legislators are properly informed of the benefits resulting from space investments.

In order to facilitate this goal, SGAC can act as a force to raise awareness amongst governmental actors of the benefits that space investments have on both the society and economy. Within the US there are events such as 'take the Hill', where students and young professionals can meet with politicians who work on 'The Hill' (for or with the federal government) to advocate for the advancement of space on their agendas. SGAC can play a role in spreading this kind of action to other countries, along with lessons learned on the most effective ways to market and sell space as a positive political action item.

Another option to move forward in this area is to increase knowledge-sharing of space technology and policy between different nations at all levels of experience. This includes linking spacefaring nations with those that aspire to become established space actors, and newcomers into space to one another. This capacity-building approach will have two major benefits. First, the experienced nations will be able to set the developing ones up for success by advising on topics such as the development of a national space policy. This will prevent the less experienced actors from having to re-learn lessons which have already been understood on the global scale and also prevent re-inventing the wheel. Second, by linking aspiring space-faring nations to one another, for example by providing them an appropriate network or forum for discussion, they will be able to collaborate among themselves and with the main international actors on major projects which may be unfeasible or impractical for them to conduct alone, but by working together, and gaining advice from experienced nations, they will have a far higher likelihood of success. The UNCOPUOS is a suitable platform for facilitating such exchanges and making the debate large enough to increase likelihood of success.

SGAC can facilitate these goals through both encouraging the sharing of best practices by highlighting the benefits it brings and conducting space capacity building activities on its own. These may include fostering collaborations across nations, sectors and disciplines, providing opportunities to participate in a variety of missions, multiplying student opportunities and encouraging nations (and the UN) to do the same, including through competitions, internships and scholarships for higher education, and of course, building upon the current SGAC project groups. Throughout all of this, an increased awareness of space will be developed throughout the nations to the point where it will be necessary for them to become a main part of the political agenda.

6.5 Advancing the space sector so as to be a leading force in major technology development

This goal ties back to the pillars of Space Economy and Space Society.

It is beyond reasonable doubt that military research and expenditures have traditionally led advances in technology development. At the same time, it is indisputable that modern societies have largely benefited from the exploration and use of outer space. For example, today the United States' space and technological leadership still benefits from the efforts made 50 years ago in the field of manned space missions.

In order to raise awareness of the existing links between advancements in the space sector and technology development, and to make space a leading force in major technology development, work can be done around three main pillars.

Firstly, the establishment of multidisciplinary bodies to pursue technology transfer and develop spin-off technologies will prove to be beneficial. This can be performed at both the national and international level. At the international level, Centres of Excellence (perhaps modelled on the existing NATO centres) may be created to generate space knowledge that will be shared with other nations afterwards. This will allow a base of knowledge to be built within these and other countries. At the national level, dedicated space offices can then use this new knowledge to address and solve local issues, for instance the assistance of satellite technology to agricultural communities. SGAC could support these initiatives by organising global forums and workshops on technology transfer and spin-offs, as well as establishing multidisciplinary project/working groups to analyse the impact of such initiatives and to think of potential spin-off technologies.

Secondly, increasing awareness of the commercial and high-tech benefits from investing in space technology and exploration will contribute to defining a pillar around which governments and industries can articulate and calibrate their own visions, policies, activities and priorities, connecting ideas to the capabilities and resources available. This will enable governments to channel investments in the space sector, as decision makers will be better informed about the potential avenues for space research and development. Additionally, the creation and enhancement of financial mechanisms for public and private investment in space will further this objective, since it will provide additional funding and support which is needed to effectively push forward. SGAC is well placed to inform and support both public authorities and industry.

Thirdly, the development of a strategy for sharing patented space technologies that are developed with public funding is envisioned. Patented space technologies that are developed through the use of public funding should also be made available for public benefit. Through this mechanism, there will be increased understanding of the benefits of space technology and it will act as a catalyst for innovation from the higher availability of the patents.

7. CONCLUSION

From the development of these goals and the means to accomplish them, there are a number of actions which must take place in order to ensure success. The first of these is the effective integration of the working group results into a long-term SGAC strategy, in a way that contributes to both the UNISPACE+50 conference – which already includes the strategic review of the future of space promoted by UNOOSA – and the SGAC vision and mission. Secondly is the incorporation into new working group ideas, for example the development of cross-disciplinary groups to develop spin-off technologies. Thirdly, in order to build upon the findings of this working group, greater engagement with and within COPUOS is needed, as are the development of new projects under the SGAC's project groups and awareness campaigns. Finally, all of these ideas will be presented by the Executive Director of SGAC at key events leading up to UNISPACE+50 .

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The UNISPACE+50 Working Group at SGC 2016.

GROUP PARTICIPANTS SPECTRUM & OPERATIONAL CHALLENGES WITH THE EMERGENCE OF SMALL SATELLITES

Sponsored by NASA's Office of Space Communication and Navigations (SCaN)

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Introduction

The radio frequency (RF) spectrum for space telecommunications is becoming increasingly stressed with the emergence of small satellites (CubeSats, etc.) and satellite constellations for broadband internet. The RF spectrum is a limited resource that is of high importance for all nations to ensure proper communications. It is through the rapid expansion of spectrum users that several technologies may not follow national or international standards and potentially pose a threat to the use of the allocated spectrum.

With the increasing demand of satellite communications, there is also an increasing risk of interference between satellites due to the improper use of the satellite spectrum. The demand for smaller, short-lived satellites requires obtaining frequencies in a shorter time than a national agency can manage and a shorter span than what the International Telecommunication Union (ITU) may offer. It is through a revision of the frequency coordination process that a more modern approach could be responsive to the dynamic nature of new space systems, yet maintain order and avoid frequency interference.

Demographics

The working group consisted of 22 delegates from seven different countries. The group's diversity allowed for fruitful discussion that considered major, minor, and emerging space sector players who have a vast interest in the use of radio frequency spectrum and the reliable accessibility thereof.

Team Approach

The Spectrum & Operational Challenges with the Emergence of Small Satellites Working Group attempted to solve the topics at hand by first identifying and defining the stakeholders that have an interest in the use of RF spectrum. These included: governmental, non-governmental, military, civilian, for-profit and nonprofit stakeholders. Upon identification of stakeholders a number of value propositions were developed to suit their respective needs. These value propositions were grouped according to areas of common interests amongst the stakeholders identified. These interests were used as guiding principles to develop an innovative solution that will help the majority of stakeholders to alleviate the challenges of RF spectrum management and allocation. The team's approach is illustrated in Figure 2.

The work was guided by two subject-matter experts for RF spectrum use and policy. Krystal Wilson from the Secure World Foundation provided expertise on regulations from the ITU, which is the body responsible for the management of the RF spectrum; and Chris Mindnich, a legislative liaison for Overlook Systems Technologies, served as an expert in terms of policy and legal procedures for obtaining permission to utilize the RF spectrum.

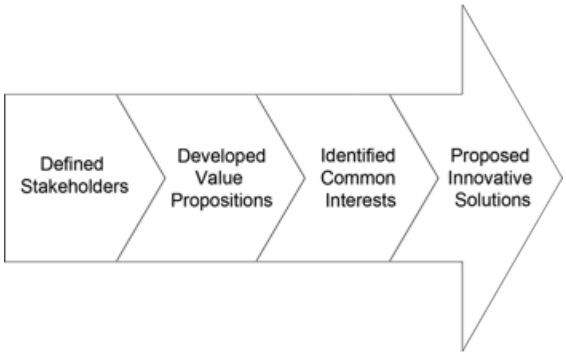

Figure 2: Design team approach

Work Logic

Using the approach described above, stakeholders were classified into three main groups: for-profit, non-profit, and regulatory bodies. The team's overall logic, observations, and results are listed as follows:

- For the for-profit stakeholders, three main value propositions were identified. First, a protected access to RF spectrum bands, with long-term exclusivity, is desired to be able to provide reliable services (commercial or otherwise). Second, the process for RF spectrum acquisition and utilisation should be streamlined to reduce project and service lead times. Third, the licensed body should have autonomy over their acquired frequency bands to use and distribute access by their own assessment.

- The nonprofit stakeholders are highly interested in the improvement of the allocation process for frequency bands. This is because nonprofit projects often run on strict timelines and can be severely impeded by lengthy frequency allocation processes. Nonprofit stakeholders are especially interested in the adaptation of current policies to suit the needs of the small satellite market.

- Regulatory bodies are primarily interested in ensuring a fair and equal consideration of all spectrum interests. In the case of national regulatory bodies, this is often limited to ensuring the accessibility of the specific nation to desired RF bands. These bodies are also interested in maximising the number of quality parallel services to bolster their respective economies, scientific communities, and observation and intelligence gathering. Last but not least, regulatory bodies want the frequency allocation and spectrum filing process to be flexible enough to allow the incorporation of emerging technologies. With this, a rapid response to changes in the market can be accommodated efficiently.

Proposed Solution

The innovative solution proposed by the Working Group consisted of a one-stop-shop educational tool with resources and easy-to-understand guidelines on three focus areas: policy and regulation procedures, frequency allocation, and interference mitigation. This tool would educate and empower all space participants. The tool attempts to meet the following objectives:

- Streamline international and national processes in order to make them accessible to large and small satellite developers.

- Promote transparency on frequency availability to enhance access and equality through innovative avenues of allocation.

Educate participants on the best-practices, techniques, and standards to minimise the risk of frequency interference. The Working Group was divided into sub-teams addressing the tool's three focus areas. The results of the sub-team's research, observations, and proposed solutions are detailed in the sections below.

Policy and Regulation Procedure

The policies regarding the management of the radio frequency spectrum are mainly governed by

the members of the ITU, who meet every three to four years during the World Radiocommunication Conference (WRC). The agenda of each WRC is decided during the previous WRC, and late changes and additions to the agenda are very rare. This makes the adaptability of RF policies inherently slow, which impedes fast-changing markets like the small satellite market or the interests of mobile internet service providers, who compete with satellite communication services. After the WRC, the decisions made during the conference are incorporated by the ITU. These regulations are then fulfilled by national administrations, who authorise and license specific services and frequency bands. As the RF spectrum is a limited natural resource, the WRC and ITU's decisions and policies are the subject of strong lobbying by various stakeholder groups.
The ITU and national bodies divide RF spectrum users in three categories: commercial, experimental, and amateur. RF spectrum application for a commercial application comes with significant cost, while the costs for the other two types are minimal. Because the filing process for experimental and amateur satellites is also faster than the process for commercial satellites, many commercial entities launch as experimental or amateur satellites. This reduces the available spectrum for real experimental and amateur applications and increases the risk of frequency interference in the respective frequency bands.

The Outer Space Treaty of 1967 gives nations the autonomy to manage and regulate their own space activities. This includes the allocation of the RT spectrum, which consequently must abide by ITU and WRC regulations. The sub-team who worked in this area investigated the policy and regulation procedures in three different countries: the United States, Mexico, and Germany (European Union), in order to identify best practices. The team proposed to share these procedures in the one-stop-shop resource tool, so that countries around the world can align to international best practices and increase transparency in policy and procedures.

Frequency Allocation

Frequency allocation or filing for frequency bands is the procedure to obtain a license or permission to transmit radio waves on a specific frequency band over a defined region of the world. The ITU recognises three main regions. Region 1 includes Europe, Russia, the Middle East, and Africa. Region 2 includes America and Greenland. Region 3 is the remainder of Asia, Oceania, and Australia. Different regulations and frequency policies apply to each region, as market and therefore RF spectrum saturation is dependent on the developmental state of each region. Filing times vary greatly for each country as each national entity interprets ITU policies according to their national laws, causing different filing processes to emerged.

Multinational stakeholders often try to mitigate long frequency allocation times by applying it in countries with faster processes. This is an unfair advantage for stakeholders that operate multinationally over stakeholders that operate on a local level. Furthermore, fast applications processes might imply less scrutiny on the side of the national body, which may lead to an increased risk of frequency interference, which reduces or impedes the reliability of a number of services.

Thus, a simple software tool called FASE (Frequency Allocation Search Engine) should be developed to mitigate the aforementioned issues. A unified frequency allocation tool managed by the ITU would allow for direct and easy access to regulations and to check the possibility of frequency use for a desired user application. Managed by the ITU, FASE would allow for seamless incorporation of decisions by the WRC and updates on regulations, which would make it a credible reference for any stakeholder interested in using RF spectrum. National regulatory bodies that are members of the ITU would be responsible for updating their respective databases connected to the recommended frequency allocation tool. See Figure 3 for an illustration of the proposed graphical user interface for FASE.

Interference Mitigation

The ITU and regional telecommunication regulators developed standards and regulations including interference mitigation considerations. Interference is the main factor that limits high-capacity mobile communications. It affects the reliability, performance and coverage of wireless and satellite systems. It is also a concern to the public and national security.

Another problem comes with the fact that after successful application of a frequency band, a satellite needs to transmit on this frequency within seven years. If this does not happen, the frequency band can be allocated to another user. This often leads to the launch of small satellites that transmit simple data with the sole purpose of fulfilling the frequency reservation requirement. Such missions use significant economic

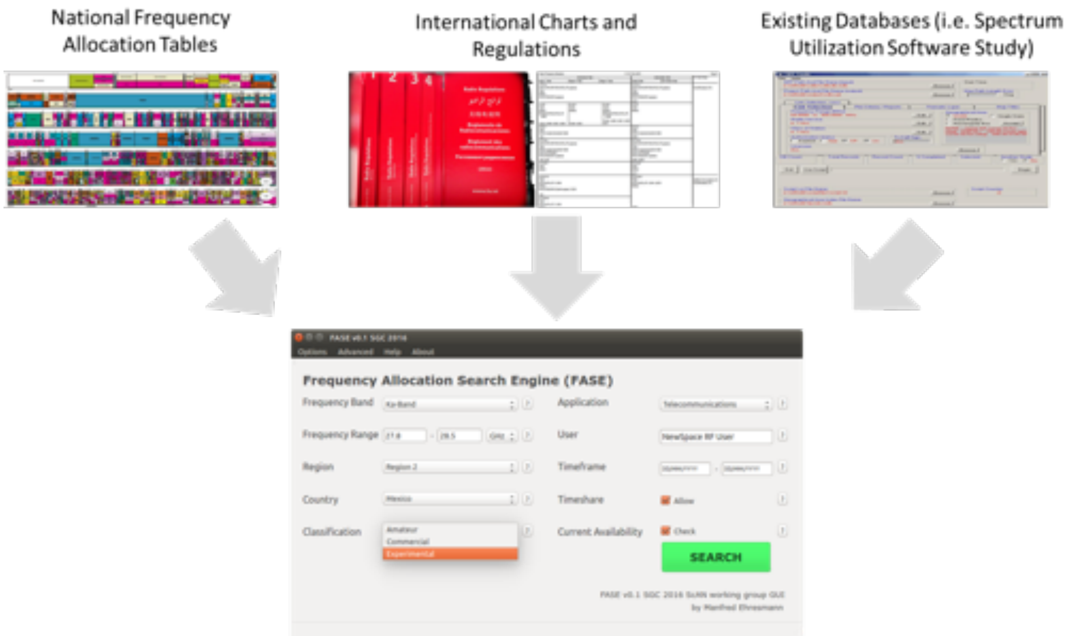

Figure 3: Frequency allocation search engine (FASE)

resources just to cope with regulatory issues.

A technological solution to the more heavily utilised RF spectrum might be enabled by using frequency time sharing. This would allow multiple users to transmit on the same frequency by specifying different transmission dates and times during the allocation process to avoid transmission during the same time. This would multiply the number of users without exceeding the capacity of RF spectrum. The team proposed the inclusion of technologies, lessons learned, and other standards in the tool in order to mitigate frequency interference.

Summary

The innovative solution proposed by the Working Group consisted of a one-stop-shop educational tool with resources and easy-to-understand guidelines on three focus areas: policy and regulation procedures, frequency allocation, and interference mitigation. This tool would educate and empower all space participants. The tool attempts to meet the following objectives:

- Streamline international and national processes in order to make them accessible to large and small satellite developers.
- Promote transparency on frequency availability to enhance access and equality through innovative avenues of allocation.
- Educate participants on the best-practices, techniques, and standards to minimise the risk of frequency interference.

The Working Group concluded that the proposed tool would contribute significantly in mitigating interference to maximise the use of this limited resource. Although it seems that the demand for frequencies would be increased by small satellites operators, the allocation will be feasible when the technical and safety requirements are met, therefore it will not interfere in any frequency already occupied and vice versa.

The tool would provide reliable frequency information for users where they carry out their activities and the support of high standards of quality and efficiency in data transmission. This information adds value to telecommunications companies and stakeholders defined by the Working Group, strengthening the economic activities of this sector. In short, this tool would provide invaluable information regarding the use of the transmission frequencies for either large or small users of these signals, ensure that the operations of small satellites will not cause interference in big networks or satellites constellations, and will operate in safety. If an interference occurred, since the tool would be constantly updated, the possible causes of interference would be easier to track. This would allow appropriate action to be taken in consideration of the legal framework of the country or region where the interference happened.

The risk for frequency interference is significantly reduced by such a tool, as a direct check for users on similar transmission frequencies could be directly implemented and risk of interference be displayed. The option to permit time sharing on a desired frequency band would increase the effective use of the natural limited RF spectrum, as multiple users are more capable of utilising a designated frequency band to the fullest in comparison to a single user.

The tool allows for the streamlining of the frequency allocation process for any stakeholder. Non-profit, amateur, and start-up entities would experience the most relief from the burden of the process, allowing their growth and productive use of frequency bands. This would also enable the fair and equal utilisation of spectrum for any stakeholder as access to it would be less limited.

Conclusions and Observations

The SGC 2016 Working Group on Spectrum & Operational Challenges with the Emergence of Small Satellites discussed the problems of the increasing demand of RF spectrum use, especially in regard to the increase in users caused by the trends of needing small satellites for various applications. It became clear that the bandwidth limitations of the RF spectrum, the risk of frequency interference for a higher number of users, and the reduced mission times are not compatible long-term to current processes to file for allocation of a frequency band.

During the development of this report, on October 21st 2016, the White House announced a series of initiatives addressing the issue of small satellites. Entitled 'Harnessing the Small Satellite Revolution', one of the proposed initiatives included a new Small Spacecraft Virtual Institute. The virtual institute is described as a 'one-stop shop for best practices, lessons learned, and standards for all phases of smallsat development,' which is similar to the initiative this team proposes.

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The Telecommunications Working Group at SGC 2016.

SPACE SITUATIONAL AWARENESS

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Working Group Definition

The main aims of the Space Generation Congress (SGC) 2016 Space Situational Awareness (SSA) Working Group were to define SSA, review current SSA initiatives worldwide, identify technical and policy challenges, and, finally, to propose effective frameworks and cooperative mechanisms to tackle these challenges, with particular reference to data interoperability and data sharing. To this end, it was first necessary to highlight the most relevant aspects of SSA to provide focus for the Working Group.

SSA Definition

Space Situational Awareness is the capacity to gather a sufficient understanding of the outer space environment so that useful insights regarding its future evolution can be determined.

The main threats to the outer space environment are near-Earth objects (NEOs), space weather events, active satellites, and space debris. Space debris appears to be the most important threat today, as it can limit our access to space. In July 2013, more than 170 million pieces of debris smaller than 1 cm (0.4 in), about 670,000 piece of debris of 1–10 cm, and around 29,000 larger pieces of debris were estimated to be in orbit [1]. Figure 2 illustrates a computer-generated image of space debris as observed from high Earth orbit (HEO).

Space debris represents a risk to space assets and hinders the growth of the space industry. Left unchecked, space debris could become an economic hurdle to space access, or worse, evolve into an irreversible problem. Unlike NEOs, the problem of space debris is entirely human-made and we have much more control over its fate. It is a human problem that can be resolved with technical, legal, policy, and political decisions. Given the urgency of the situation, this report focuses on the challenge of space debris.

Space debris consists of whole and fragmented non-functional, man-made objects either left from old satellites or spent rocket stages, or caused by collision events; debris varies in size from millimetres to metres. Figure 3 shows how rapidly the number of objects has increased and how it will increase over time. With projected exponential growth of space debris (the Kessler syndrome), the problem of space debris will become increasingly critical if mitigation does not occur.

To mitigate the threat of space debris, several passive and active debris removal systems have been proposed. In addition, monitoring, tracking, and preventing debris proliferation can be very useful and can support the long-term stability of the outer space environment. As the number of stakeholders active in the outer space environment increases, the level of SSA needed to support operations must also increase. A reliable, comprehensive, and accessible database would benefit the prevention of collisions; however, this would require an international level of effort, knowledge-sharing, and collaboration. Regarding the different debris removal options, technical problems must be solved and political consensus must be reached over technology that does not raise security concerns.

This report details the main actors and shareholders, outlines the current status of SSA initiatives, and provides recommendations for a holistic solution towards mitigation.

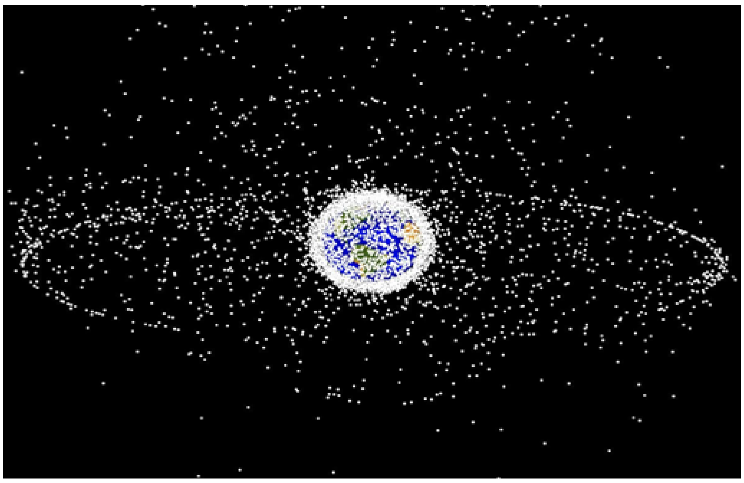

Figure 2: Representation of the Catalogued Space Debris in Earth Orbit

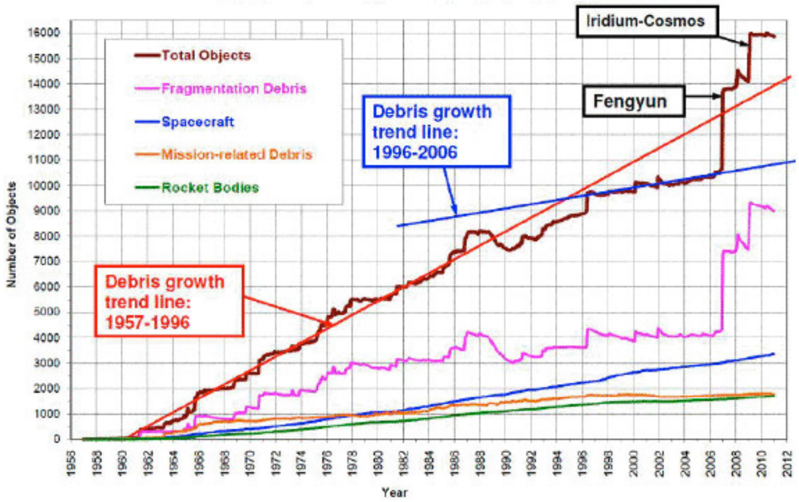

Figure 3: Historical and Projected Growth of Space Debris [2]

Actors and Stakeholders

In order to determine appropriate solutions to SSA issues that affect the space community at large—particularly space debris—it is necessary to consider the various entities involved in the implementation of proposed solutions or policies as well as their respective motivations and interests. Three main groups of interested stakeholders are identified below:

1. States
2. Business and Academia
3. International Organisations

Each group is motivated by different drivers, and all face barriers regarding the formation of new space policy. These are summarised in the sections below.

States

States are certainly the most powerful actors as they still possess or at least still significantly fund space-related technology. Moreover, states are accountable for the activity conducted by them and by private actors that launch from their territory. From that perspective, states do not have power to influence what and how items are launched to space, but can effectively implement what has been accepted on the international level.

States might be driven by economic interests, but space as a domain gives states a very specific advantage on the global scale, thus they might also be driven by power interests. In the end, some scholars argue that states are much more driven by norms to act appropriately and in a way that is expected by other states. In this way, norms are critical when it comes to finding a solution to the space debris problem.

If the Kessler syndrome is considered to be a problem for a particular state, the state will be motivated to deal with space debris to secure its own access to space. However, the Kessler syndrome is not only a problem over the territory of a particular state, but a problem over all territories of all states. In that perspective, dealing with the Kessler syndrome does not fulfil only a selfish interest of one state, but benefit interest of all states. Space debris itself can be a unifying component for further development in international politics as any defection by a free-riding state will be immediately punished by physics. Defection is not an option and thus the prospects of cooperation are much brighter than in other international issues.

The most important prerequisite to such cooperation is open development, deployment and operation of dual-use space debris mitigation technologies that deepen trust and avoid concerns, miscalculations, and misunderstandings in international relations. Following a norm of responsible behaviour in space will decrease the creation of space debris, but active removal is critical to avoid national security concerns.

Business and Academia

Any space-related business entity is motivated by the need to achieve profitability to ensure its continued existence. Thus, policies that provide extended business opportunities will be of great interest to this group. In a related manner, new policies that provide incentives to develop new space technologies and research will incite support from academic entities, since these would be willing to contribute with new ideas and technical innovations to solve problems such as space debris. Furthermore, entities from both business and academia are motivated by the opportunity to boost technological development and maintain the transfer of said technologies for future generations. It is in the interest of business to have safe access to space. However, with a decreasing amount of sizable debris, the business of debris removal will not thrive, but much more probably decline if states do not raise the subsidy of removal. Perceiving space debris as purely a business opportunity in this perspective does not make sense. It has to become a public service operated by business. Such a public service cannot be funded by space superpowers only, but should be understood as a prerequisite of becoming a space faring nation.

International Organisations

An international organisation is an 'organisation established by a Treaty or other instrument governed by international law and possessing its own international legal personality' [3]. In particular, organisations involved with the regulation of orbital operations are of interest here. The above drafted organisational model needs to be governed by a global entity; states have developed international organisations in order to reach these objectives.

Instead of needing to manage discordant policies from various entities around the world, international organisations have the capacity to design universal perspectives that are more easily respected by participating entities as norms of international behaviour. International entities such as the United Nations (UN) possess universal support in the development and implementation of policy, which renders credibility and weight during its implementation.

The effectiveness of policy-making in international organisations is reduced by slower decision making processes, but is also usually protected from national perspectives as states do not want to see international organisations overwrite the legitimacy of a nation state. An international organisation must represent the interests and goals of multiple national entities; the arrival at a general consensus among all participating entities becomes a more complicated process. However, as shown above, space debris mitigation efforts can easily propose a more cosmopolitan solution as the problem is global by principle; so even national interests might easily play a role in cosmopolitan objectives.

Conclusion

While these three stakeholder groups may have differing interests and barriers, all are united by a common driver: collision avoidance. All stakeholders in space development have a vested interest in minimising collisions to maintain both the economic and physical sustainability of space access. The brief analysis above should show the particular roles these actors would play in reaching the desired objective of safe orbit.

Existing SSA Capabilities

Global SSA capabilities consist of national, international, and private efforts. These capabilities are currently provided by a number of entities to determine, track, and predict the location of space objects. Typically, monitoring and tracking of orbiting satellites and debris are conducted using ground and space-based radar and optical systems to execute the processes of detection, correlation, characterisation and orbit determination. The following describes the most relevant efforts regarding SSA.

The Joint Space Operations Center (JSpOC) of the United States (US) maintains a reliable US-centric database with some sharing agreements. JSpOC depends on the Space Surveillance Network (SSN), a distributed network of sensors in over 20 tracking sites across the world. Advances consisting of new S-band sensors are expected to increase JSpOC's catalogue by nearly tenfold in the future [4].

Russia maintains the next most significant surveillance system, relying on both military and academic research capabilities to maintain a catalogue of space objects [5].

Finally, the European Space Agency (ESA) Space Debris Office also manages a database (DISCOS) of unclassified tracked space objects, relying mainly on sensors in Germany and France. ESA space debris operations involve collision avoidance and re-entry analysis. DISCOS information is available to research institutions, government organisations, or industrial companies of ESA member states [6].

The primary international committee coordinating outer space activities is the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS). It plays a role in space debris activities by providing information and regulations to member states. Many of these roles are carried out by the UN Office on Outer Space Affairs (UNOOSA), the secretariat to UN COPUOS. Separate from the UN, the Inter-Agency Space Debris Coordination Committee involves cooperation among states' space agencies. It attempts to provide technical solutions that UN COPUOS can support.

There are a number of significant non-governmental SSA entities, both commercial and academic. The Space Data Association, founded in 2009 as a response to the Iridium-Cosmos collision, is a cooperative agreement between leading commercial satellite operators and JSpOC; its main responsibility is to provide conjunction assessments. Led by Analytical Graphics Inc. (AGI), the Space Data Association collates satellite location data from a range of sources in order to warn of potential collisions or radio frequency interference. AGI also runs the Commercial Space Operations Center (ComSpOC), which similarly takes commercial satellite data and uses AGI's advanced modelling software to detect, track, and characterise space objects [7].

The International Scientific Optical Network, organised by the Russian Academy of Sciences, is an SSA network made up of scientific and academic institutions from around the world. It operates a wide range of telescopes from about 24 observatories across 11 countries, and focuses on tracking high-orbit space objects. The extensive geostationary orbit observations made by the International Scientific Optical Network have led to the discovery of a significant number of newly catalogued space objects [8].

Limitations of Existing Groups

Unfortunately, current SSA capabilities cannot satisfy today's demand due to the constantly increasing use of the space environment. Each existing organisation with SSA capacity is lacking in at least one of the following abilities:

- Maintaining a complete and unrestricted catalogue
- Allowing fair access to those who need it
- Implementing standards consistently

Current government SSA initiatives involve decision-making that is more often influenced by geopolitical or economic reasons rather than the increasing threat of the space debris belt. Some current government capabilities, notably in the US or Russia, date back to the Cold War and, therefore, have limitations on the quantity of data that can be stored in catalogues.

The Space Data Association does not have the geopolitical limitations of governmental organisations, but relies on the participation of commercial satellite companies for positional data and funding. It must also deal with the potential unwillingness of companies to share positional data with their competitors. The International Scientific Optical Network, as an academic and scientific venture, has the limitation of funding (which is usually supplied through government grants).

Recommendations

The threat of space debris proliferation and the accompanying risk of collision with operational spacecraft, combined with the inefficiency of the current SSA capabilities in satisfying current demand, highlights the need for an ambitious international and cooperative entity. The entity should have a network of open-source databases of global SSA sensors and data. If powerful states support the establishment of a new entity that would deal actively with space debris, it might be possible to step over the inevitable geopolitics emanating from low trust between states active in space debris removal.

In this way, as a first step, the entity should collect public and nonpublic accessible data on space debris and spacecraft to maintain a complete and unrestricted catalogue. Furthermore, we recommend that such an entity develops through UNOOSA to gain trust between participating nation states and entail decisive power from the beginning.

For both passive and active mitigation measures, the following recommendations for the centralised entity are divided into three main phases:

Phase 1: Data Acquisition and Tracking

Data acquisition and tracking should commence as soon as possible and build on current SSA initiatives. A comprehensive, standardised database of debris should be compiled on a voluntary basis, where participants receive conjunction warnings in return for providing details of their satellite operations. End of life (EOL) plans will be documented and tracked. The database should include information currently available from tracking stations willing to share data. To promote data sharing and international collaboration, the organisation would ensure confidentiality and anonymity of satellite information, and conjunction warnings would only include the necessary information in order to ensure a safe avoidance manoeuvre. The organisation should also advise the UN regarding policy, by establishing a framework for future space law regarding insurance, accountability, responsibility, and data access.

Phase 2: Progressive Utilisation

Progressive utilisation will build on Phase 1 by refining the comprehensive holistic model of space debris. More return can be offered to participants in the model, by submitting recommendations for orbit access. By tracking EOL plans, trends can be identified and recommendations made for design of future operations. Further, in this phase, the organisation should develop an initial incentive strategy for active mitigation to prepare nation states for further active space debris removal by technology that may raise national security concerns. This includes developing a database of debris that can be removed, either because it is not owned by any entity, or it is permitted by the owner to be removed. Owner identification of all debris should be defined, in order to clarify liability. For policy purposes, the organisation should address international laws and treaties regarding ownership and active mitigation, to establish a clear understanding of liability when active removal becomes commonplace.

Phase 3: Support for debris management

In Phase 3, the organisation should provide support and incentives for active debris removal. An insurance premium can be added to all new launches that do not demonstrate successful EOL plans. Alternatively, an EOL fund could be established, whereby operators pay a deposit for each item added to outer space. Upon demonstration of a successful EOL plan, this deposit would be returned by the newly created entity that would administer the fund and organise businesses in active debris removal operations. If the EOL plan were unsuccessful, this deposit could be offered as a reward to any entity that removed the debris. Regarding policy, the organisation should investigate standardisation of design features, such that all new objects have common in-orbit servicing attachment points and eventually in-orbit recycling capability. It is extremely important that the newly created entity inform all the space-faring nations operating satellites in Earth orbit about its operations, plans for active removal, and operation in orbital vicinity of their assets to preserve trust in it and between nation states that support it.

Conclusion

Space debris proliferation represents the most relevant threat to the future use of the space environment. As this issue cannot be solved by a single government or agency, and as cooperation between these entities seems to be easy achievable, we recommend that a unified global entity be formed to monitor space objects comprehensively. By creating an independent organisation, a more refined model of space debris can be designed. This organisation would collect all available data and form a global model of spacecraft removal concepts and active debris operations. This is a task that can be done right now, without waiting for various parties to decide on how they handle their delicate data. In the follow-up steps, collision warnings and orbit recommendation can be offered. This is possible without releasing delicate information to third parties. By gaining additional trust, advanced support can be offered for all entities interested in space and its resources. By creating this entity, an interface for all stakeholders would be available for further improvement of our current space situational awareness.

In sum, the solution proposed by the Working Group can be broken down in the following steps:

1. Create a global, independent entity, supported by the UN and space-faring nation states.
2. Collect data on space debris and spacecraft.
3. Create a simulation model to improve space situational awareness.
4. Offer collision warnings and orbit recommendations.
5. Declare end of life plans and measurements for space debris.

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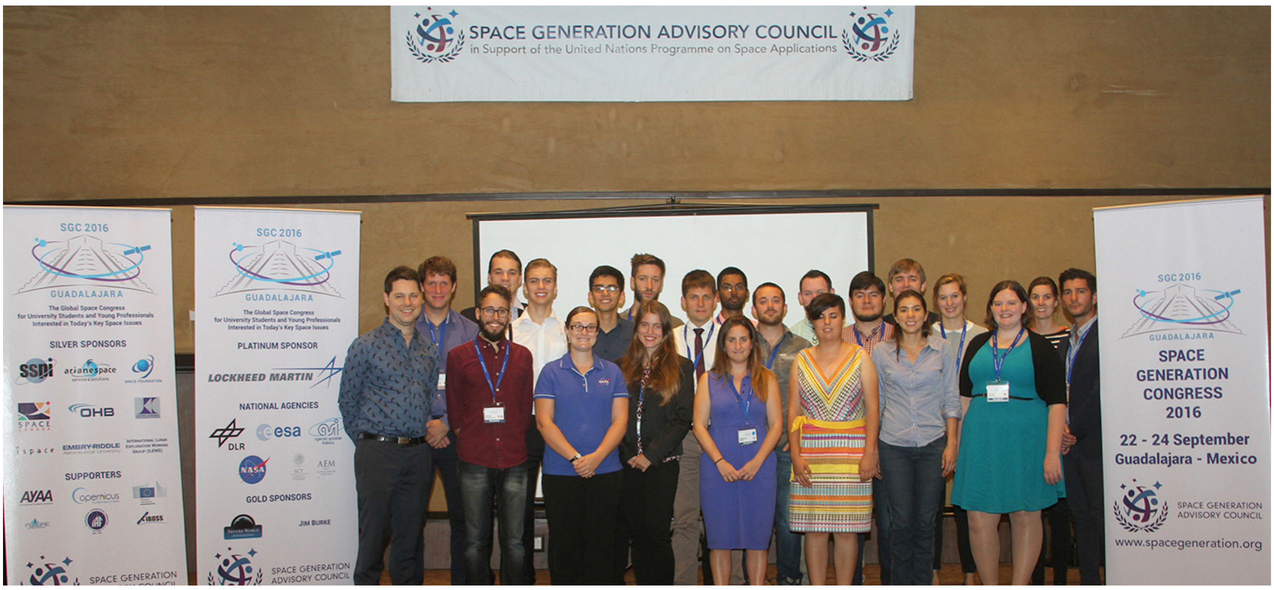

The Space Situational Awareness Working Group at SGC 2016.

EARTH OBSERVATION
CURRENT CHALLENGES FACING MARKET ENTRY AND UTILISATION OF DATA

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INTRODUCTION

Earth observation from outer space provides reliable, routine and consistent information on a global scale. It can be defined as the gathering of information about Earth's physical, chemical and biological systems using remote sensing technologies such as satellites, aerial sensors and ground-based observations. When combined with 'in-situ' observation, it can become an extremely powerful tool for monitoring our environment, especially in decision-making and locating resources.

EO data is collected using two primary methods: active, and passive sensing. Passive sensors collect light that is reflected or emitted by the target, typically in the visible or infrared spectrums, using optical cameras. Meanwhile, active sensing is performed using radar arrays, which emit pulses of microwave energy towards the target and measure the reflected signal. Regardless of the sensor type, the resulting data is transmitted from a satellite to ground stations where data is processed and distributed accordingly. The use of accurate and frequent satellite imaging data is critical to many facets of society including: the study of climate change, tracking biodiversity, and weather forecasts. This data is becoming increasingly more accessible due to investments by governments and private organisations.

Lastly, in addition to the questions outlined in the executive summary, the team also proposed a number of strategies that can help promote greater awareness of EO programmes, services and applications. The end goal is to accelerate the integration of EO products into the market and foster their use in different applications.

CURRENT STATE OF THE MARKET

Overview

The current global market for EO services is valued at around $1.8 billion (USD), as highlighted in Figure 1. In 2010, the market was valued at approximately $999 million1 *, more than doubling over the last few years. The EO downstream market sector includes industries such as: defence, infrastructure, natural resources, energy, location based services, maritime, disaster management, in addition to many others. The sector continues to grow, and forms part of the Satellite Services market, which comprises around $127.4 billion of the total satellite industry's global revenue, which was reported as $208.3 billion in 2015. Presently, 60% of EO sales are made to the defence sector, whilst disaster management accounts for the lowest percentage.

* Originally reported as £640 Million, converted to USD using the 31 December 2010 exchange rate of 1.561 GBP/USD

With more than 50 countries now investing in EO programmes, the market for commercial EO data is expected to reach $3.5 billion by 2024 (Fig. 2). Regionally, the Asian markets, Latin America and Africa are expected to have strong growth profiles. Natural resource management, engineering & infrastructure, location-based services (LBS), and defence are expected to be the main application areas supporting growth [2].

Trends and Opportunities

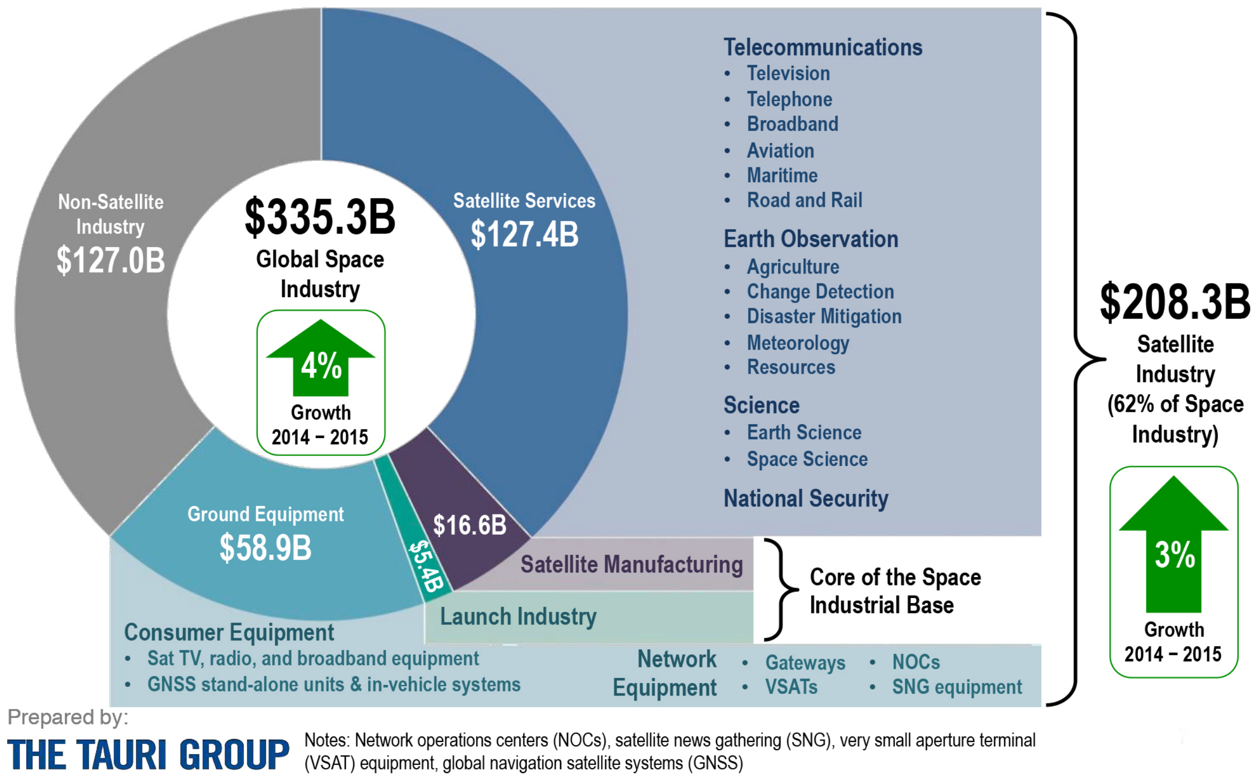
In the past most global EO services were offered by a small number of operators, with the main objectives being to:

- Support Governments as primary customers
- Provide high resolution imagery
- Process and advance data for custom-designed payloads

With emerging competitors and new partnerships, the market is rapidly changing. It is estimated that over the next decade, the number of EO satellites launched will almost double from 149 to 288 by 2021 [4]. This is mainly driven and financed by the information technology (IT) and analytics sector needing to meet requirements, such as: growth of customer base (raw/processed data & imagery), value-added products, and rising numbers of smaller, low-cost satellites.

The main targeted markets are:

- Agriculture-Food



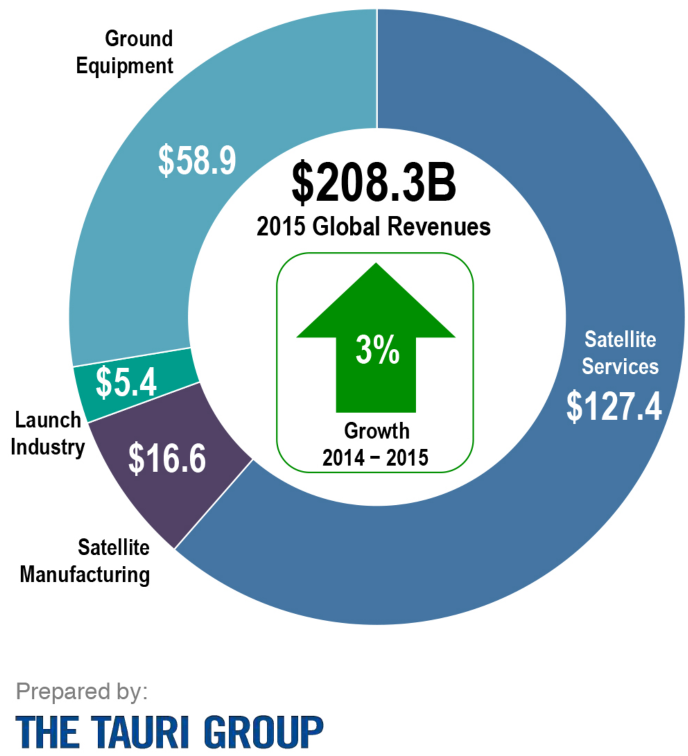


Figure 1: Overview of EO Service Market "2016 State of the Satellite Industry Report" Satellite Industry Association, Prepared by Tauri Group [2].

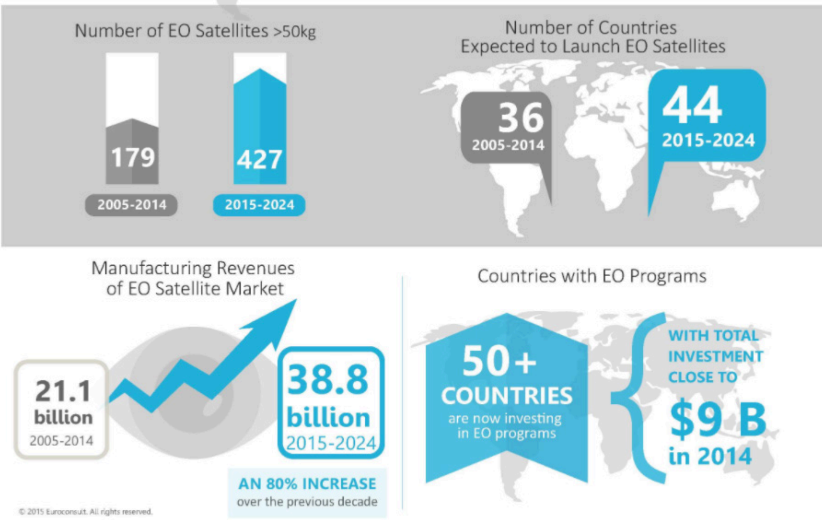


Figure 2: Earth Observation Market Trends, Euroconsult 2016 [3].

- Banking & Insurance
- Environment and Carbon monitoring
- Maritime
- Mining
- Oil & Gas

Value-Added Products for these markets include:

- Land covered maps to monitor ecosystems
- Urban development
- Weather monitoring
- Map creation
- Disaster management
- Topographical information

Sales Market and Data Sources

The government still remains the primary user of EO data and services, accounting for over 80% of all commercial revenues. Additionally, according to Spacetec Partners, 70% of the total global revenue for EO commercial data sales is captured by two major companies: Digital Globe (25%)(+25% from merger with GeoEye) and Astrium GEO (20%) [5].

Depending on user requirements and strategies, EO satellite data is mainly distributed as below [5]:

- Direct sales from companies: preferred for key clients and anchor tenants
- Direct access to the satellite: preferred by international government customers, particularly defence, for allowing more secure access to the satellite for direct data reception
- Sales through dedicated resellers, or exclusive distribution agreements: allows the operating company access to local markets through regional distributors. The creation of these regional resellers distributing data from multiple satellite systems is in effect creating a further localised step in the value chain between operators and end-users or service providers
- Sales from company websites, e.g., online image libraries or hosted satellite data archives, or satellite tasking through online portals: offer easy access to satellite data for end-users that require less costly archive data

Several different distribution models already exist for distributing EO data, including free access, paid per image, and paid subscription services. The methods used by several organisations are summarised in Table 1.

Table 1: Free and Paid Earth Observation Data Sources

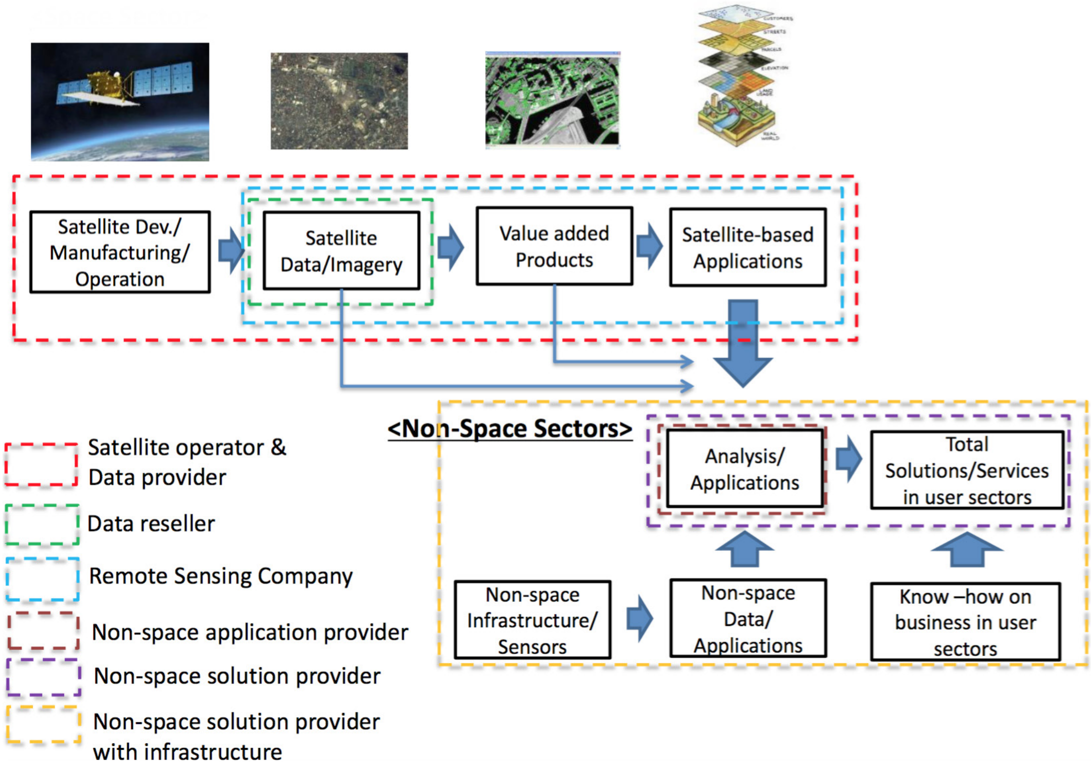


Figure 3: Example of the current EO Downstream Business [4].

Free Data	Paid Data
Copernicus (ESA/EC)	Planet
Landsat (NASA/USGS)	Radarsat (CSA)*
	ALOS-2 (JAXA)*
	UrtheCast

*Data is provided by third party distributors

The data provided by EO satellites is typically given in a raw form to ensure that it contains as much useful information as possible. Unfortunately, this means that EO data is often indecipherable for end users who are unable to analyse and interpret the data themselves. As the needs of each end user are unique, the challenge of translating raw EO data into pre-packaged solutions has been largely left to the private industry.

Several initiatives have been created to stimulate new businesses to enter and grow this earth observation downstream industry, one of the most successful models being the ESA Business Incubation Centre programme. This programme provides European based entrepreneurs with financing and technical knowledge to assist in applying space technology, including earth observation data.

Other organisations in the sector that are also working towards similar projects include:

- UNCOPUOS
- Earth Observations Groups
- World Bank
- Organisations such as the Asian Development Bank (ADB) which is currently utilising EO data in analysing world problems

STAKEHOLDERS

In order to identify and address the obstacles in the market segment, a stakeholder analysis was conducted as follows;

Primary Stakeholders: United Nations (UN), Regional governments, International Astronautical Federation (IAF), International Institute of Space Law (IISL), World Development Bank, Asian Development Bank (ADB), European Investment Bank, European Commission

This was further divided into three main categories:

- Providers
  Manufacturers, Distributors, Upstream, Ground-based station, different space agencies, educators, platform access, (interpreters/facilitators), emerging markets, IT Companies, Incubators, Sales, Commercial satellite launchers e.g. Spire, Skybox, Planet Labs
- Users
  Public, NGOs, Military/defence, Commercial, space industries, government, emerging markets, academia
- Applications
  Disaster management, agriculture, oil companies, medical, navigation, weather, traffic, marketing, medical, livestock

Table 2: Summary of obstacles faced by the EO downstream business

Resolution*	Data
Frequency*	
Price	
Continuity	
Lead time	
License	
Lack of total solution (data & resolution)*	Provider
Lack of non-space downstream services providers*	
Lack of communication between space sector to non-space customers*	
Lack of needs understanding	
Used to conventional approaches	User
Not familiar with space solutions (limited knowledge of industry)	
Lack of collaborations	
Unclear Cost-benefits	

*Key obstacles highlighted by the working group

CHALLENGES FACED BY GOVERNMENTS AND INDUSTRY

Several obstacles relating to the commercialisation of EO were identified, this includes problems such as financing, frequency of imaging, finding the right business strategy and clients, as well as the lack of education and support in data handling and access. An overview of the challenges which were identified can be found in Table 2. Both governments and industry are currently facing a number of issues, such as ensuring compliance with international and local laws and regulations. As such, the government itself must provide a political framework. Confidence in the continuity of data provision by the government may also affect the industry, and communication is important in maintaining this confidence. The government may be responsible for disseminating the available data to the correct user.
Governmental organisations are currently facing obstacles in the form of low political support for EO programmes, which can be attributed to a lack of confidence, technical skills, or experience. Challenges are also posed by poorly developed laws and regulations, symptoms of an absent political framework. Other factors that slow the EO commercialisation progress include ineffective communication between govern-

ment and private industries, difficulties in data access between relevant parties, and finally the way in which information is disseminated to the public. On the private industry side, bureaucracy, the lack of pre-existing contracts and unattractive business models discourage private industry from taking risks to start a business in the EO sector.

RECOMMENDATIONS

There are many actors required to deliver a seamless supply-chain for EO data, encompassing those gathering user requirements, providers of space and ground infrastructure, and those utilising the data to generate useful products and services. A key element will be to ensure that programmes remain user-focused in order to meet the growing requirements for new commercial opportunities, environmental monitoring obligations, or novel scientific observations. The flowchart in Figure 4. presents a possible solution to future challenges of the EO market.

Since successful EO-based services call for cross-sector collaborations, a smart way of sharing resources is required to achieve good results. What we propose is a vast database, supervised by an international organisation to facilitate interactions among several partners.
This type of global infrastructure will not only contain raw data that can be processed by qualified providers, but also standard products delivered by both space and non-space data providers in order to:

1. Facilitate EO data sharing and interfacing
2. Make high quality EO data cheaper and more available in short time frames
3. Allow a wider range of service providers to develop complete data solutions based on the user's needs.

These needs can be identified efficiently through regional forums. The whole cloud will be conceived as the

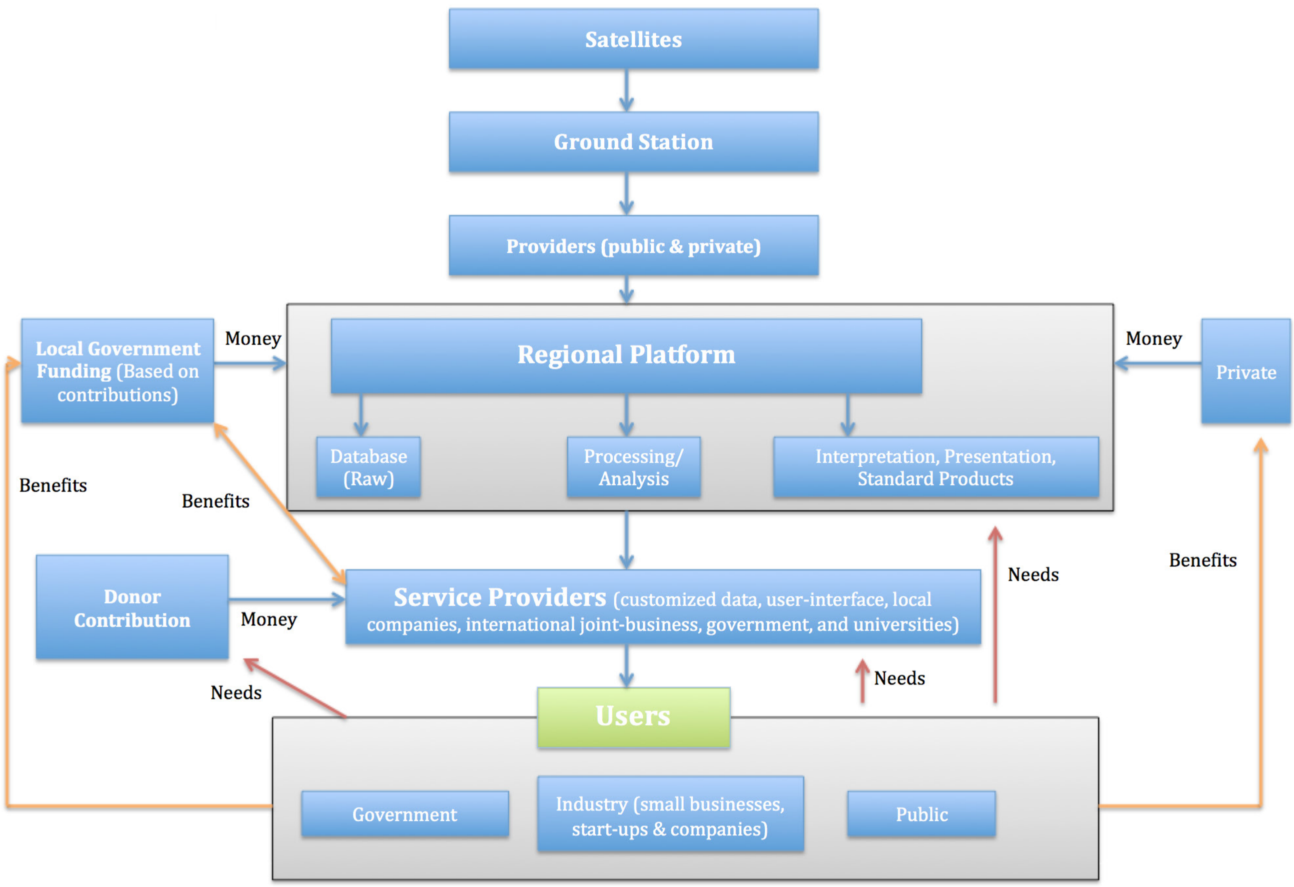


Figure 4: Proposed Organisational Structure

sum of several platforms managed at a regional level by local delegates. In this way, each regional platform can be organised according to local peculiarities (such as market demand, government necessities, private agencies requirements, etc.) and improved considering the feedback from entities such as research centers and universities, mainly aware of the potential behind a good exploitation of EO data.

Such a way of pooling regional capabilities to realise an appealing and easily accessible cloud will make the project feasible from an economic point of view. Indeed there are good preconditions for success, being both local governments and private agencies directly involved in the management of single platforms and potential donors attracted by this problem-based architecture, that focuses on the demands of various regions and customers.

How to fully exploit Earth Observation data?

An initiation of a data processing mechanism to provide data to end-users effectively is needed. A successful example would be the Copernicus project operated by the EU. Examples from private industry would be Digitalglobe and Planet Labs that operate data-sharing platforms at a cost. Landsat in the USA also provides processed data at a cost.

Furthermore, there is a requirement of technical training to provide people with the expertise necessary to work on the data application platforms. Lastly, satellite operators need to have a tailored specific end product for specific end users, instead of merely make data available and letting the end user find a solution themselves.

Data providers will also benefit from joining such a circle, by learning about both the niche and regional markets in order to create business opportunities. For instance, a partnership between regional non-space industries and global space EO operators will benefit both sides in creating an understanding of potential markets, and allow for the establishment of associated business models.

What would be the role for the public and private sectors?

Government can introduce EO products to local and regional markets in cases such as disaster management. Earth observation data as applied to disaster management should come from various sources, including ground and air data collected by multiple sensors. For private industries, there is a need to raise awareness of the potential of EO data, and to introduce this potential to executives in the hopes of influencing decision making in a positive way. In addition, there is the potential for new business opportunities, such as companies specialising in post-processing data for customers.

The current problem faced in utilising EO data comes from accessibility due to restrictions on data sharing, but this can be solved by collaborations between incubators from different regions to exchange knowledge, needs and customers. There are a variety of mechanisms available, many of them government-based and mostly tailored for specific countries and regions. The restrictions on data sharing are mostly due to defence issues. There is also some misperception about the potential of EO customers in the non-space market, and how to get them involved in EO utilisation. Additionally, it would be advisable to involve EO consultants in the project phase to discuss which wavelengths the customer needs, the required frequency, and the best software tools to use. Furthermore, there is a need to make EO operators more knowledgeable about their customers, have them brainstorm with potential customers to facilitate decision making throughout the process. The need to spread awareness about EO to the public by making EO processing courses and tutorials more available in universities and online websites is also essential.
Finally, supporting routes for new/startup EO providers with funding, knowledge, connections and market were suggested. The need to turn successful EO based academic research to a commercial service or user cannot be undervalued.

CONCLUSION

The 2016 Space Generation Congress Earth Observation Working Group identified several challenges currently facing the Earth Observation industry. Through group discussions and consultation with subject matter experts, the group identified several recommendations to increase the rate of market uptake in the earth observation industry:

Make high quality data cheaper, and make on-demand EO data more accessible

Create a single depository (regional platform) from which application/utilisation companies can get data, upon agreement with satellite operating company
Combine EO data from different operators, as well as combining frequently visited data to provide enhanced purchase incentives

Furthermore, recommendations on how government agencies and private industry can collaborate with one another to meet the public demand were also suggested. The ultimate goal is to enhance the accessibility and performance of the earth observation industry for the welfare of our society.

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The Earth Observation Working Group at SGC 2016.

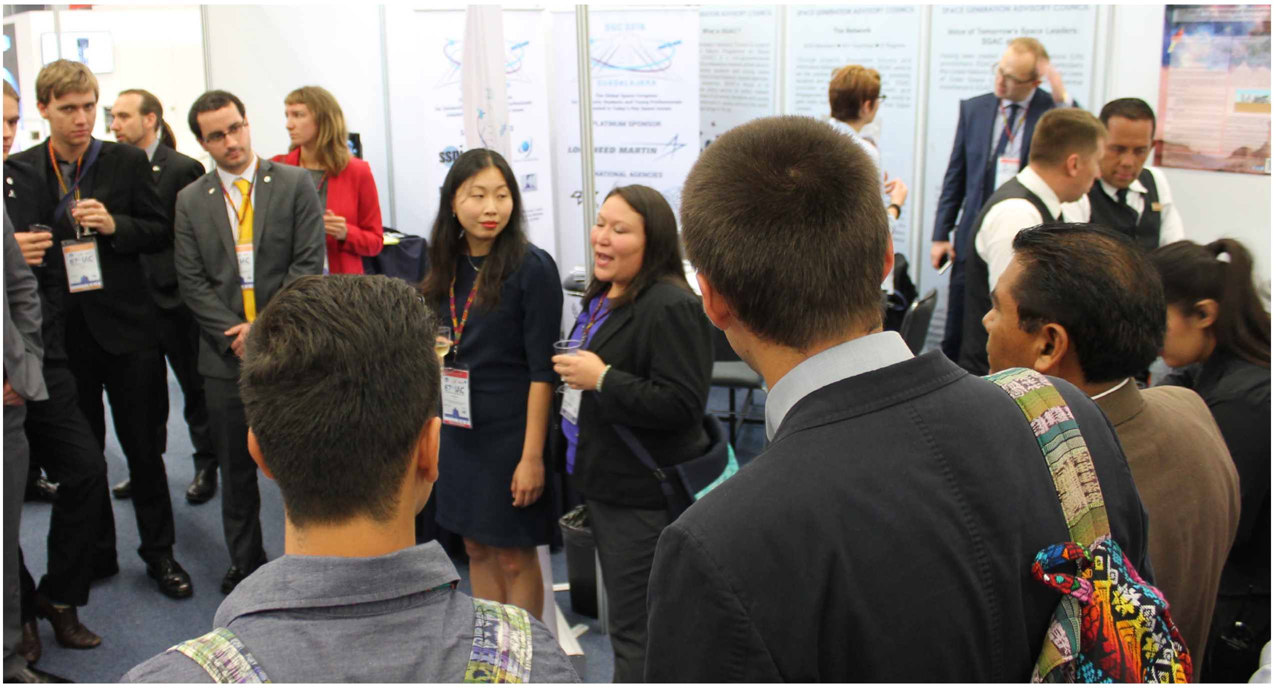
ACTIVITIES AT IAC 2016

The Space Generation Advisory Council organized several side-events throughout the 67th International Astronautical Congress held from 26 to 30 September, 2016 at the Expo Guadalajara convention centre. Here are some highlights!

SGAC Mars Analogue Simulation Workshop to discuss progress on the Poland Mars Analogue Simulation Mission - 25 September, 2016

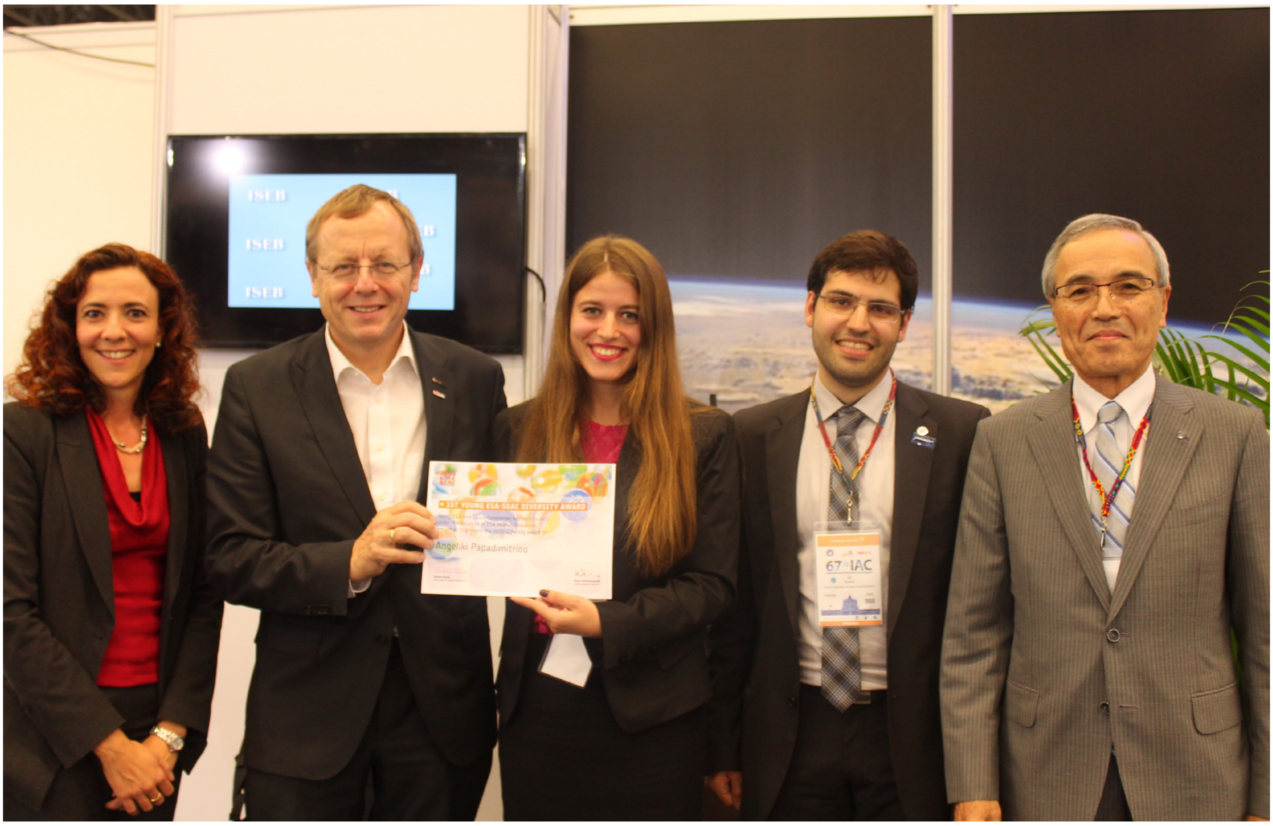
SGAC Alumni Gathering Informal was attended by 150 alumni and members - 27 September, 2016

Global Networking Forum - Making the Moon Village and Mars Journey Accessible and Affordable for All - 28 September, 2016


SGAC and Space Foundation Booth Reception - 28 September, 2016

SGAC organised Global Networking Forum on Technology Transfer - How to Make the Most of It? - 29 September, 2016

YPP Networking Event Panel Discussion: Success of Commercial Space Ventures - An Inspiration for the Next Generation - 29 September, 2016

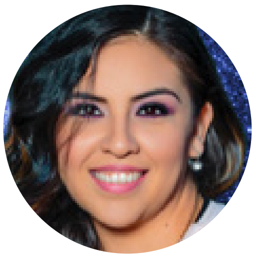


First SGAC-YoungESA Diversity Award Ceremony was held with represntatives from ESA and the IAF to award the award and to exchange views on diversity - 29 September, 2016

SGAC Organised Astronaut Talk with Sandy Magnus (STS-119, Expedition 18, STS-126, STS-112, STS-135) - 29 September, 2016

ORGANISING TEAM

A team of dedicated volunteers makes up the organising team of the 15th Space Generation Congress 2016. These passionate students and young professionals have worked tirelessly to ensure SGC 2016 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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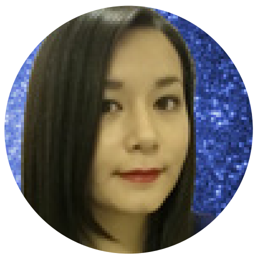

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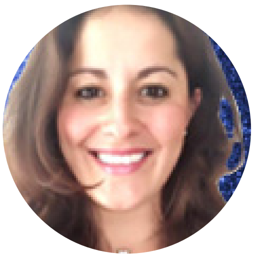

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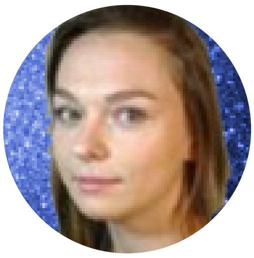

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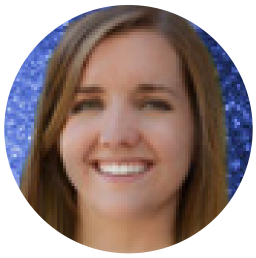

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Photo courtesy: SpaceX