In support of the United Nations programme on Space Applications
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table of Contents</td>
<td>3</td>
</tr>
<tr>
<td>Sponsors and Partners</td>
<td>4</td>
</tr>
<tr>
<td>Letter from the SGC-Chairs</td>
<td>6</td>
</tr>
<tr>
<td>Letter from the SGC Congress Manager</td>
<td>7</td>
</tr>
<tr>
<td>SGC 2014 Conference Overview</td>
<td>8</td>
</tr>
<tr>
<td>Speakers</td>
<td>10</td>
</tr>
<tr>
<td>Congress Highlights</td>
<td>11</td>
</tr>
<tr>
<td>Congress Statistics</td>
<td>18</td>
</tr>
<tr>
<td>Scholarship Statistics</td>
<td>20</td>
</tr>
<tr>
<td>Schedule</td>
<td>22</td>
</tr>
<tr>
<td>SGC 2014 Organising Team</td>
<td>23</td>
</tr>
<tr>
<td>SGC 2014 Session Reports</td>
<td>24</td>
</tr>
<tr>
<td>Entrepreneurship and its role in Space Industry</td>
<td>26</td>
</tr>
<tr>
<td>CubeSat Swarms - Communication Networks and Policy Challenges</td>
<td>40</td>
</tr>
<tr>
<td>On-Orbit Servicing - Commercial Opportunities with Security Implications</td>
<td>52</td>
</tr>
<tr>
<td>Ethics and Policy of New Human Space Exploration Strategies</td>
<td>64</td>
</tr>
<tr>
<td>Earth Observation for Maritime Services</td>
<td>76</td>
</tr>
</tbody>
</table>
SPONSORS and PARTNERS

The 2014 Space Generation Congress (SGC) would not have been possible without the generous support of our sponsors. In addition to financial support, sponsors provided subject matter experts, speakers, reports, data and other assistance to the intellectual content of SGC. The Space Generation Advisory Council would like to thank them for their contributions to one of the most successful Space Generation Congresses to date.

Platinum Sponsors

Lockheed Martin

Secure World Foundation

Space Communications and Navigation (SCaN) of the National Aeronautics and Space Administration (NASA)

Anonymous Supporter

Gold Sponsors

Society of Satellite Professionals International

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Australian Youth Aerospace Association (AYAA)

The Future Space Leaders Foundation

International Astronautical Federation

University of Toronto Aeronautics Team

Toronto Students for the Advancement of Aerospace
LETTER FROM THE SGC CHAIRS

Dear members, colleagues and supporters,

We are very proud of the 2014 Space Generation Congress. This year, we celebrated the 15th anniversary of the Space Generation Advisory Council, making this congress especially important.

Toronto, Canada, was home to the 13th annual Space Generation Congress - the first Congress we have completely sold out. 128 delegates from 40 countries spent three days discussing, networking and learning about exciting, new space topics - supported once again by an excellent line-up of top-level speakers and a strong SGAC team on the ground.

This year’s Gala Dinner also sold out with over 260 participants! We were honoured to have the presence of SGAC founding member Bob Richards and listen to a video that Peter Diamandis sent us congratulating SGAC. During the evening the attendees also listened to very inspiring speeches made by NASA Administrator Charles Bolden and Lockheed Martin Vice President John Karas. Furthermore, the Director of the United Nations Office for Outer Space Affairs, Simonetta di Pippo, made a speech highlighting the relationship between the United Nations and SGAC over the years. The evening culminated with the announcement that SGAC Flags would be flown to space as a courtesy by our partner, Lockheed Martin.

This year’s SGC was a complete success and we are very happy about it. It set a very high standard for future SGCs and we are already working on the next one!

Chris Vasko
SGAC Chair

Victoria Alonso Perez
SGAC Co-Chair

LETTER FROM THE SGC CONGRESS MANAGER

The Space Generation Congress 2014 has been a tremendous success. Last year’s congress in Beijing, China, set the bar very high as usual, but we were determined to get the best that Canada had to offer to us.

This has been my third and final year as manager of the congress, and the 15th anniversary of SGAC increased the excitement of celebrations. This year, the 13th Space Generation Congress has exceeded, once again, by far all expectations. Following signatures with the International Astronautical Federation (IAF), SGC was officially recognised for the first time as an Associated Event of the International Astronautical Congress (IAC) - an achievement of which I personally and the rest of the Executive Council are especially proud.

It has been a pleasure to work with the SGC Organising team this year; a team comprised of great young professionals and students who worked very professionally with high standards during their free time to offer the best to our delegates. We worked hard from the very beginning to offer delegates one of the best congresses SGAC has ever packaged. Now we can proudly say: mission accomplished!

Space Generation Congress 2014 sold out this year, which has never happened before and is a sign that the event is reaching more people and continues to grow year after year. The congress recorded participation from 128 delegates and almost 30 speakers and experts from more than 40 different countries, and hosted exceptional working group presentations. SGAC, together with its partners, granted 25 scholarships and awards to enable delegates’ participation at this year’s congress and the International Astronautical Congress. SGC 2014 also held the 3rd SGC International Night, a spectacular event that allowed delegates to share the importance of collaboration between countries. Further achievements included the largest Gala Dinner ever organised by SGAC, with 260 guests and yet another sold out event.

I would like to personally thank the Organising Team for their hard work and dedication in making the 13th Annual Space Generation Congress a truly historic event. I look forward to seeing you back at next year’s event in Jerusalem, Israel for what will be another remarkable Space Generation Congress!

Andrea Jaime Albalat
Executive Director and Congress Manager
The Space Generation Advisory Council (SGAC) aims to hone and promote the voice of the next generation of space sector leaders on topics relating to international space development. The Space Generation Congress (SGC) is SGAC’s annual meeting in support of the United Nations (UN) Programme on Space Applications. Top university students and young professionals with a passion for space travelled from 40 countries to attend three days of SGC 2014. The 128 delegates enjoyed an inspiring and resourceful engagement with their peers at the congress, held at the Holiday Inn hotel in Toronto, Canada on September 25th to 27th in the days prior to the 65th International Astronautical Congress (IAC).

Delegates gained exposure to perspectives on space issues from the world’s leading space organisations, including: the International Astronautical Federation (IAF), National Aeronautics and Space Administration (NASA), and the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS).

In demonstrating the symbiotic relationship, leaders from these space organisations gained fresh, innovative and bold perspectives from the incoming space generation on the five main themes of SGC 2014: exploration, earth observation, small satellites, on-orbit servicing and entrepreneurship. Several sponsors along with a committee of volunteers supported the activities at SGC 2014. Without supporters and dedicated volunteers, the 2014 SGC would not have been possible, and SGAC would like to express its sincere gratitude and appreciation.
**SPEAKERS**

- Robert Bell: Executive Director, Society of Satellite professionals International (SSPI)
- Charles Bolden: NASA Administrator
- Chris Boshuizen: Co-Founder and CTO of Planet Labs
- Jason Crusan: Director, Advanced Exploration Systems Division at NASA
- Simonetta di Pippo: Director of United Nations Office for Outer Space Affairs
- Berndt Feuerbacjer: Former IAF President
- Mike Hawes: Vice President and Orion Programme Manager at Lockheed Martin
- Kiyoshi Higuchi: IAF President and JAXA Vice-President
- Yasushi Horikawa: Technical Counsellor, JAXA
- Scott Madry: Executive Director of the Global Space Institute
- Sandy Magnus: Executive Director of the American Institute of Aeronautics and Astronautics (AIAA)
- Daniel Rey: Head of Systems Engineering for the Space Exploration Branch of the Canadian Space Agency
- David Revay: Entrepreneurship competition winner
- Clemens Rumpf: 2014 Move and Asteroid OHB-SGAC competition winner
- Sam Scimemi: Director for International Space Station at NASA Headquarters
- Thomas Sinn: Space Solar Power competition winner
- Erik Seedhouse: Norwegian-Canadian suborbital astronaut
- Thomas Sinn: Space Solar Power competition winner
- Jan Wörner: Chairman of the executive board of the German Aerospace Center (DLR)
- Jack Yeh: Entrepreneurship competition winner
- James Zimmerman: President of International Space Services, Inc.

**CONGRESS HIGHLIGHTS**

**Day One**

- SGAC Executive Director Andrea Jaime along with Chairs Chris Vasko and Victoria Alonsoperez welcomed delegates. They expressed their excitement and optimism for this year’s event, and introduced the new Deputy Executive Director Minoo Rathnasabapathy.
- The 128 delegates, speakers and experts introduced themselves very briefly.
- Members of the SGC Project Team Michael Deiml, Noemie Bernede, Adam Vigneron and Jan Svoboda introduced the five working groups to the delegates in a presentation.
- Daniel Rey from the Canadian Space Agency and spotlight speaker for the On-Orbit Servicing group gave a presentation with insights into the future of on-orbit servicing.
- Erick Seedhouse, from Astronauts 4 Hire and spotlight speaker for the Exploration working group, addressed the delegates describing the new Research Specialist Program that will train scientists to carry out research in space.
- Following these spotlight speeches, delegates split into working groups to start discussions.
- After lunch, the Space is Business 2013 Competition Winners Jack Yeh (New Zealand) and David Revay (Australia) presented their specific space business model ideas. Clemens Rumpf (Germany) introduced insights on his paper that won the OHB Move and Asteroid competition.
- Delegates dispersed for coffee and networking break followed by working groups to discuss the specific topics assigned to their project.
- SGAC Executive Director Andrea Jaime and members of the Project Groups introduced the eight currently active SGAC projects and provided overviews of their activities.
- At the end of Day One, SGC 2014 delegates attended the Opening Dinner, where they were able to enjoy a great local dinner at the Toronto waterfront with additional networking opportunities.
Day Two

- SGAC Chairs welcomed the delegates for a second day and introduced the first speakers.
- Jason Crusan, NASA’s Director of Advanced Exploration Systems Division, presented NASA’s exploration plan, including fundamental changes to the Deep Space Network needed to support these goals.
- Chris Boshuizen, Planet Labs Founder and CTO discussed his entrepreneurial journey from an undergraduate student in Australia to SGAC Executive Director, before founding Planet Labs and launching 72 satellites in 2014, one third of the total satellites launched globally.
- After a networking and coffee break, IAF’s Jim Zimmerman presented ‘The Hitchhikers Guide to the IAC,’ with an overview of IAC and IAF highlights, emphasising activities targeting young professionals and students.
- Chris Vasko, SGAC Chair, followed with advice to SGAC delegates attending IAC, particularly focusing on IAC activities of importance to young delegates.
- Delegates next focused on working group discussions with input from subject matter experts.
- At the end of the day, Scott Madry presented space technologies for Earth Observation, particularly for maritime applications.
- In the evening, delegates participated in the third edition of the SGC International Night. Representatives were invited to introduce aspects of respective countries through presentations, cuisine, songs, dances or performances. Delegates engaged in many interactive and exciting activities, making the night a huge success.

Day Three

- Jan Wörner, Chairman of the Board of Directors at the German Aerospace Center (DLR) welcomed the last day of SGC with a very dynamic and interesting presentation.
- SGAC Chair Chris Vasko next presented a history of SGAC to commemorate its 15th anniversary, with an emphasis on the great work from volunteers around the world and SGAC’s extensive growth.
- After a coffee break, Berndt Feuerbacher explored the ambition and innovation required for the Rosetta and Philae comet mission, an example of a mission that pushes limits of humanity and returns the spirit of exploration.
- Mike Hawes, Vice President and Lockheed Martin’s Orion Programme Manager, followed with an overview of the Orion Programme and recent developments.
- IAF President Kiyoshi Higuchi continued the tradition of welcoming SGC delegates and stressed the importance of the younger generation in the space sector.
- The panel ‘ISS: Benefits down to Earth,’ with experts including Sandy Magnus (former astronaut and current Executive Director at AIAA), Sam Scimemi (Director of International Space Station, NASA), Nicole Buckley (Chief Scientist, Life Sciences and the International Space Station, CSA), and Yasushi Horikawa (Technical Counselor, JAXA) was the highlight of the final day. It demonstrated the importance of international collaboration through the ISS program and was moderated by SGAC Chair Chris Vasko.
- Delegates concluded the conference with working group presentations, and received feedback from other delegates and senior experts. The working group final recommendations will be presented in February 2015 at UN COPUOS.
- The Executive Director and SGAC Chairs closed the congress, and expressed support and thanks to partners and sponsors who made SGC a reality, in addition to speakers, subject matter experts and the SGC organising team who were responsible for success during the year.
SGC Closing Gala Dinner

This year, SGAC Closing Gala Dinner sold out at 260 young professionals and senior experts on September 27th, 2014 at the Ontario Science Center in Toronto, Canada. This special evening commemorated SGAC’s 15th anniversary, and attendees were inspired by speeches from NASA Administrator Charles Bolden and Lockheed Martin Vice President John Karas. Peter Diamandis, space pioneer and an SGAC founders, sent a video congratulating the organisation and UN Office for Outer Space Affairs (UN OOSA). Simonetta di Pippo, UN OOSA Director, gave a speech highlighting the relationship between the UN and SGAC over the years.

The evening concluded with a symbolic handover ceremony of an SGAC Flag from SGAC Executive Director and Chairs to Lockheed Martin Executives Randy Sweet, Jim Crocker, Mike Hawes and John Karas. SGAC flags will be flown aboard Orion EFT-1. SGAC would like to thank Lockheed Martin for the opportunity to fly the flags on the EFT-1 capsule, further cementing the partnership between the two organisations.

SGAC at the International Astronautical Congress

The Space Generation Advisory Council had an extensive programme of activities organised during the International Astronautical Congress, in addition to the SGAC booth at the exhibition hall that serves as the meeting points for young professionals and students attending IAC. This year’s SGAC reception was held in conjunction with the International Space University and WD/YPP IAF reception. Three of these activities are highlighted with individual reports on the SGAC website.

SGAC Workshop to Discuss the Upcoming ESA Ministerial

The day after the conclusion of SGC, SGAC organised a four-hour workshop at the Metro Toronto Convention Centre to discuss upcoming European Space Agency (ESA) Council at Ministerial, scheduled for December 2nd, 2014, in Luxembourg. The workshop, inspired by Kai-Uwe Schrogl at ESA, focused on themes close to the younger generation, including the relevance of ESA in fostering a stronger European identity and the importance of international collaboration especially with countries that have a strong connection to Europe but with a small or non-existent space industry.

Dr Schrogl, ESA’s Head of Relations with Member States Department in the Director General’s Cabinet, provided an up-to-date overview of the agency and relationship with the European Union and the member states. More than 20 delegates, mostly from Europe, provided community perspective on topics of importance to ministers of the ESA member states, including launchers, continuation of European commitment to the International Space Station (ISS) partnership beyond 2020 and the evolution of ESA. Delegates also discussed levels of geographical return - the way ESA redistributes the projects according to contribution of each country and the importance of the European participation in the ISS program.

The workshop produced a position paper, published and distributed to ESA officials and ministers in November. A second workshop and meeting will take place in two years, prior to the next ESA council at Ministerial level, to provide additional European space policy makers with perspectives from future space leaders.
Launching Minorities and Students into Space Professions

This year’s SGAC event at the 2014 IAC Global Networking Forum featured a discussion panel entitled ‘Launching Students and Minorities into the Space Profession.’ The panel, moderated by SGAC Deputy Executive Director Minoo Rathnasabapathy (South Africa/Australia), explored current barriers for students and minority groups. The panel focused on women and persons from emerging and developing countries, professionals in non-traditional technology industries and students facing experiential, economic or social barriers. Panelists provided guidance for aspiring professionals to overcome these barriers and how strong equity practices strengthen the space community.

Johann Dietrich-Woerner, Administrator of DLR, shared his pragmatic perspective on why the community should promote diversity: divergent perspectives offered by different cultures, background, or genders are an untapped source of potential innovations for the space industry. He supported diversity as not only a facet of social change but immense economic value.

Jeremy Wang (Canada), Outreach Director and Rocket Propulsion Lead of UTAT, emphasised the importance of multi-dimensional diversity and benefits of early student design team involvement. He noted that the meaning and success of a project often draws on interdisciplinary teams with unique but cohesive values, experiences and personality traits.

Claudia Kessler, co-founder of Women in Aerospace (WIA)-Europe, offered her insights on female involvement and human ambition. Undeterred by the historically male-favoured environment of engineering, she persevered and currently holds the position of chief executive office of HE Space. She supports female high flyers in their career development, and pointed out that societal stigma about the aerospace industry is not worth forsaking doing what one loves.

Andrea Boese, Head of the Diversity and Equal Opportunities office at DLR, advocated top-down measures to promote student and minority involvement. Simultaneously, however, individuals must educate themselves about the field and institutionalised structures must be removed to welcome all individuals.

Tahir Merali, owner of OrbitOne Consulting, is in favour of space entrepreneurship and early involvement. The private space industry is continually growing and one way for students and minorities to change the landscape is by taking the initiative to start their own projects. He noted that the meaning and success of a project often draws on interdisciplinary teams with unique but cohesive values, experiences and personality traits.

Finally, Nassim Bovet, Head of Admissions and Alumni Affairs at the International Space University (ISU), stated that diversity enriches the academic and social quality of a learning environment. ISU is an example of this paradigm, with its students coming from all walks of life and representing a multitude of nations coming together to form a community and explore common interests.

At the end, the floor opened to the audience for questions. Despite the productive discussions, a panelist noted the need for more work and future meetings. The well-received discussions highlight that the people who need to better understand the value of diversity are those who don’t care and are responsible for current state of underrepresentation of minorities.

Roundtable, Space Security and Governance:
The need of a space policy before or after developing space activities

The SGAC Space Law and Policy Project Group organised a roundtable on Space Security and Governance on October 2nd, 2014 at the IAC, offering more than 14 IAC and SGC attendees the opportunity to discuss on how space technologies can assist governments to address national security issues for an international audience. The roundtable consisted of a 6-member panel: Werner Balogh of UN OOSA, Enrique Pacheco of the Mexican Space Agency, Philippe Clerc of CNES, Cesar Jaramillo of Space Security Index, Stephanie Wan of NASA Headquarters, Dorina Andoni of Leiden University, Hannes Mayerand of the Institute for Canon Law, Karl Franzens of the Institute for Public Law at the University of Graz. Project group co-lead Sandra Cabrera-Alvarado (Mexico) chaired the panel. The panelists discussed the following key questions:

- What the term or concept ‘space security’ means;
- Whether space regulatory framework would ensure a responsible approach to exploration and use of outer space for the benefit of all humankind;
- How to develop and balance state legislation pertaining to national security and public interests with principles set forth in the Outer Space Treaty, and what compromises, if any, are necessary;
- Whether states should first develop a space policy and legal framework and then a space program, or vice versa, and the advantages and drawbacks of each scenario with respect to space security and governance.

The final detailed report with the results of the discussions that answered the above questions was also published in the SGAC website.
SGAC closed registrations for SGC in September with more than 250 applications from 55 different countries. After a diligent selection process, 128 delegates were invited to participate at SGC 2014, together with 14 speakers and 10 Subject Matter Experts. Of those 128, 25 participants from eight different countries received scholarships from SGAC and its partners. At 39% women and 61% men, there was a relatively even distribution of genders amongst final delegates, an uncommon achievement for space sector events. Delegates came from varying backgrounds with 24% undergraduate students, 15% masters students, 18% PhD students and 42% young professionals. SGAC believes that 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.

SGAC is also pleased to welcome a diverse representation of delegates from an array of countries and regions. SGC 2014 attendees came from 40 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.

Representatives from 40 countries participated in SGC 2014. The highest percentage of delegates came from the United States of America, followed by Australia, Canada, and Germany.
SCHOLARSHIP STATISTICS

This year, SGAC provided two Young Leadership Awards to the organisation’s outstanding members to attend SGC 2014, as well as 23 scholarships to competition winners representing eight countries. These additional 23 scholarships were provided in collaboration with partners AYAA Aerospace Futures, DLR, OHB, SSPI and NASA SCaN. As one of SGAC’s goals to facilitate opportunities for young members of the international space community and join together to discuss space issues, the 25 scholarships are seen as a key indicator of SGC’s success in 2014.

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This list includes recipients from various countries and grants from different organizations, indicating a diverse and inclusive approach to supporting young space leaders.
## SCHEDULE

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<td>Coffee Break - 15 years</td>
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<td>19:00</td>
<td>Opening Dinner - Bar Milano</td>
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### SGC 2014 ORGANISING TEAM

- **Chris Vasko** (Austria/Hungary) - Chair
- **Victoria Alonso Perez** (Uruguay) - Co-Chair
- **Andrea Jaime** (Spain) - Executive Director and Congress Manager
- **Reinhard Tlustos** (Austria) - SGAC Intern to Vienna Office
- **Minoo Rathnasabapathy** (South Africa/Australia) - Deputy Executive Director
- **Adam Vigneron** (Canada) - Project Co-Coordinator
- **Jan Svoboda** (Czech Republic) - Project Co-Coordinator
- **Noemie Bernede** (France) - Project Co-Coordinator
- **Michael Deiml** (Germany) - Project Co-Coordinator
- **Charlotte Kiang** (USA) - Delegate Co-Coordinator
- **Shivani Patel** (Australia) - Communications Co-Coordinator
- **Aaron Persad** (Canada) - Local Organising Team
- **Alana Bartolini** (Canada) - Local Organising Team
- **Ali Nasseri** (Canada) - Local Organising Team
- **Dario Schor** (Canada) - Local Organising Team
- **Jeremy Wang** (Canada) - Local Organising Team
- **Ilji Jang** (Mexico) - Logistics Co-Coordinator
- **Aaron Persad** (Canada) - Photography and Video Coverage
- **Reinhard Tlustos** (Austria) - Photography and Video Coverage
- **Michael Deiml** (Germany) - Photography and Video Coverage
- **Luis Ferreira** (Portugal) - Photography and Video Coverage
SGC 2014
SESSION REPORTS

ENTREPRENEURSHIP AND ITS ROLE IN SPACE INDUSTRY 26

CUBESAT SWARMS – COMMUNICATION NETWORKS AND POLICY CHALLENGES 40

ON-ORBIT SERVICING – COMMERCIAL OPPORTUNITIES WITH SECURITY IMPLICATIONS 52

ETHICS AND POLICY OF NEW HUMAN SPACE EXPLORATION STRATEGIES 64

EARTH OBSERVATION FOR MARITIME SERVICES 76
# ENTREPRENEURSHIP AND ITS ROLE IN SPACE INDUSTRY

## Group Participants

<table>
<thead>
<tr>
<th>Name</th>
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<th>Role</th>
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<tr>
<td>Ken Davidian</td>
<td>USA</td>
<td>Subject Matter Experts</td>
</tr>
<tr>
<td>Chris Boshuizen</td>
<td>Australia</td>
<td></td>
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<tr>
<td>Jan Svoboda*</td>
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*Members whose participation resulted in the final report.*
1. INTRODUCTION

Sustained development of the commercial space sector hinges on a thriving entrepreneurial environment. Start-ups foster market diversity, competition and technological evolution leading to profitable innovation. While innovation occurs at the level of the individual, entrepreneurship requires both personal initiative and a fertile socioeconomic environment. Poor cultural perceptions, perceived technical risk and general lack of awareness may negatively impact entrepreneurial development and the growth of the commercial space sector. This is a serious concern, as commercial space acts to mobilise business-minded innovators while repurposing current space technologies for direct application on Earth.

At the 2014 Space Generation Congress, the Entrepreneurship Working Group investigated the three levels of space entrepreneurship:

- **Microscopic**: perspectives and challenges faced by the individual entrepreneur.
- **Mesoscopic**: impact of start-up accelerators and events that serve to create awareness and unite like-minded individuals;
- **Macroscopic**: impact of culture on willingness to enter space, the role of government policy in enabling entrepreneurship and interactions between competing businesses.

This report provides an overview of entrepreneurial status in the space industry. The group examined several regions to evaluate barriers to entrepreneurship, followed by the perceived difficulty of succeeding in the space sector. The working group’s discussions gave rise to a number of recommendations, highlighted at the end of each section.

2. STATE OF ENTREPRENEURSHIP IN THE SPACE INDUSTRY

The space sector increased to 4% of the global economy in 2013, reaching a new record of 314.17 billion USD \(^{[1]}\). The majority of this growth was through commercial economic expansion, with commercial products, services, infrastructure and support industries constituting more than three- quarters of the global space economy \(^{[1]}\). Entrepreneurship plays an increasingly important role in the commercial space economy by contributing technical innovations, cost efficiencies and new business models.

Space entrepreneurs have played a particularly prominent role in the satellite industry. Space start-up companies have advanced Earth remote sensing by developing and launching smaller satellites than traditionally used for this purpose. Although the sensor resolution in these small satellites is lower than larger satellites, they provide high quality and current information by operating in large constellations and revisiting locations more frequently. This model provides a novel product for many applications against which traditional operators have not been to compete. The increased commercial use of small satellites has given rise to a competitive small satellite launch market. Although these new companies are bringing innovation to the market and utilising space on an unprecedented level, the number of start-ups directly related to space is still very low \(^{[18]}\).

Entrepreneurial individuals also initiated the commercial space tourism industry. Recognising the commercial opportunity in suborbital spaceflights, several new companies are developing ways for customers to experience space flight. These companies include the start-up Zero2Infinity, which plans to use high altitude balloons, along with companies like Virgin Galactic and XCOR Aerospace, which endeavour to employ powered space vehicles. Although no commercial flights have been achieved to date, they have built and tested a number of prototypes.
The Entrepreneurship Working Group researched the European Union (EU), Japan, and Russia for major trends in meso- and macroscopic entrepreneurship. Ken Davidian, the Director of Research at the Federal Aviation Administration (FAA) Office of Commercial Space Transportation, guided an examination into each country’s culture, government policies and economic factors to characterise its entrepreneurial potential. This investigation yielded insights about the role of local values, societal stigma, economy, government policy and other demographic indicators in the growth of the space industry. The results suggested that the working group’s recommendations should include how to promote changes that impact the dynamics and structures defining a socioeconomic environment.

3.1 The European Union

The EU has a significant influence on the European entrepreneurial environment. European-wide regulatory framework harmonisation is on-going, but has not yet achieved consistency in all relevant fields. One such example is insolvency law, which establishes jurisdiction, recognition and applicable law with respect to cross-border insolvency [10].

Based on recent European Commission data [11], public attitude toward entrepreneurship is generally positive in the EU. Almost 9 of 10 EU citizens agreed that entrepreneurs were job creators, with the majority also believing that entrepreneurs created new socioeconomic environment.

The importance of European entrepreneurship is underlined by the fact that more than 99% of European businesses are small to medium enterprises (SMEs). SMEs provide two out of three jobs offered in the private sector and contribute to more than half of the total value created by businesses in the EU. SMEs are the true backbone of the European economy, being primarily responsible for wealth and economic growth, next to their key role in innovation and research and development (R&D) [10].

Diverse funding sources are available to European entrepreneurs looking for start-up capital. The European Angels Fund (EAF) is an initiative advised by the European Investment Fund, a leading financial institution in the European Private Equity market [12]. EAF provides equity to Business Angels and other non-institutional investors for the financing of innovative companies in the form of co-investments. The initiative has been operating in Germany through a virtual structure, and there are plans to expand the initiative to other European countries and regions [14].

The EU also has space-focused incubator facilities, mainly represented by European Space Agency (ESA) Business Incubation Centres, that help create viable businesses and new jobs by providing support to more than 75 companies every year in Europe. More than 200 start-up companies have received support to date [15]. Similarly, a large number of cities across Europe offer counselling and support services. The Ostwerkstadt Leptzig project reached 528 businesses with 795 counselling sessions between 2009 and 2012. During that period, the project also created 196 jobs and 56 apprenticeship opportunities, and supported 60 entrepreneurs with their business start-ups [16].

3.2 Japan

Japanese culture places great value on being part of a group, as well as the opinion of family members [12]. The social evaluation system encourages conformity, and discourages failure. The desire to take risks and be independent is greatly tempered by the shame and embarrassment that would result from a failed venture [6]. Such an environment does not facilitate new ventures or a willingness to try and fail, a critical characteristic of successful entrepreneurs.

This culture permeates Japanese economic history. Zabatsu and Keiretsu, two large vertically integrated firms, have dominated the market, which made it difficult for small firms to find entry points into the markets [17]. The space industry is no exception to this. Due to the societal view instilled in Japanese youth, working for a large established company is a much more prestigious and respected choice, than to break away from the crowd to form a start-up [17]. Given this, the most qualified professionals tend to gravitate towards careers in large corporations and do not want to risk leaving. This tendency makes it difficult to secure the highly skilled individuals required to successfully start a business, stifling the development of new technology start-ups.

Due to the negative view towards starting a business, those who choose to begin a start-up tend not to have all of the required skills or sufficient understanding of business practices. In a 2012 survey conducted by the Global Entrepreneurship Monitor of 24 developing nations for levels of entrepreneurial, only 9% of the Japanese participants believed they had the skills required to start their own business [3]. Universities and other organisations are slowly addressing this issue by running classes for people interested in entrepreneurial activity, giving rise to the idea of the ‘weekend entrepreneur’ [2]. This is an attempt on a national level to encourage people who have regular salaries to use their talents in profitable start-up ventures.

To promote domestic entrepreneurship, renowned Japanese entrepreneur William Saito declared that the legal framework must change, especially bankruptcy laws [4]. Currently, if a start-up receives debt financing or equity, the equity of both the company and the individual are used as collateral, which puts high stress and full liability onto the entrepreneur. Furthermore, this debt goes beyond the life of the company and the founder; the debt is transferrable and if the start-up fails the founder must still repay the debt. In the event that the founder dies, the founder’s guarantor or family assumes responsibility of the unpaid debt. This burden of risk skew the risk-reward structure in Japan, making it even more difficult to promote entrepreneurship [4].

In recent years, however, some positive steps have been taken to increase entrepreneurship in Japan. The prime minister of Japan Shinzo Abe has attempted to revive the economy by loosening monetary restrictions on banks and a fiscal stimulus. He aims to promote entrepreneurship in Japan and double the rate of business start-ups by 2020 [18]. The Ministry of Education, Culture, Sports, Science and Technology has also adopted a hands-on program called START, which creates project and intellectual property strategies for technology start-ups that are risky but have great potential. START aims to put research achievements of universities and incorporated administrative agencies back into society. Universities have also started to create incubators and venture funds, as well as curriculums to promote start-ups [18]. This is
beginning to entice those who have followed the traditional path of study to begin their own companies before entering large corporations. Additionally, the Japanese space agency JAXA has a policy outlining its goal to bolster technological capabilities in the private sector, with spin-off technologies through public-private partnerships [8]. All of these methods and initiatives seek to increase entrepreneurship in Japan.

3.3 Russia

Russia has the world’s 11th largest economy by nominal GDP and has the highest per capita GDP of the BRIC countries, in part due to the growth of entrepreneurship [20]. Entrepreneurship activities were illegal in the Soviet Union, but today Russia is prospering with entrepreneurs. Russia has worked to expand the number of entrepreneurial activities within the country. The head of the Department of Science, Industrial Policy and Entrepreneurship of Moscow Alexey Komissarov pledged recently to make Moscow the Russian hub for small business growth [21]. This increased the number of entrepreneurship firms in Russia from 22 per 1000 people in 2006 to 35 in 2012 [22]. Despite the highly positive social environment and governmental attempts to increase entrepreneurial activities, there are still a significant number of barriers to entry, including:

- Poor quality of state-owned or controlled infrastructure services
- Restricted access to warehousing and distribution channels
- Weak mechanisms for resolving commercial disputes
- Lack of access to start-up capital and competitively priced credit
- Difficulties in obtaining suitable business premises and real estate
- Complexity or absence of procedures for business licensing, registration and inspections
- Corruption and organised crime [23]

Joint Venture Capital (VC) Funds, like DFJ-Aurora or the Virgin Green Fund, mobilise Russian capital and international venture expertise to make generous investments to start-ups and entrepreneurship ventures in Russia. Major Russian VC Funds include Rusnano, the Russian Venture Company and Almaz Capital [23]. Additionally, the Skolkovo Foundation, a non-profit organisation founded in September 2010 by the Russian government, accelerates transformation of Russia from a resource-intensive economy to an innovation-based economy. To achieve this objective the foundation oversees the creation of the Skolkovo Innovation Center, composed of companies and start-ups; development of innovative technologies, currently numbering over 1000; establishment of Technopark; and the partnership between Skolkovo Institute of Technology (Skoltech), a new graduate research university, and the Massachusetts Institute of Technology [24].

3.4 Summary and Recommendations

The working group selected and evaluated three regions, the EU, Japan and Russia, for entrepreneurial culture, structure and behaviours. The EU has inconsistencies in insolvency law between varying countries. Access to information, education and funding, however, are very good as the majority of businesses in the EU are often small to mid-sized businesses. Due to the fact that these businesses are known to provide many local jobs, the public has a positive view of entrepreneurial businesses and there is breadth of opportunity to grow in such an environment.

In Japan, the conservative culture, lack of governmental support and strong cultural pressure to work in large successful companies rather than small risky companies have all created a difficult environment for entrepreneurs to flourish or even establish themselves. The acceptance of entrepreneurship has recently grown in academic workshops, but has yet fully propagated into industry or government. Top-down reform must occur for new innovative companies to be successful in Japanese industry.

As first steps, initiatives by the Prime Minister and JAXA are advocating cultural change with the aim of increasing entrepreneurial activity.

In Russia, the attitude towards entrepreneurship is positive and seemingly successful on a microscopic level. Venture capitalists are available for entrepreneurs, and government programs also create the image of a healthy growth in entrepreneurial business. Inconsistent regulation and structure, as well as government corruption, however, are roadblocks for long-term entrepreneurial success. There is a platform for entrepreneurs to create start-ups in Russia, but lack of advanced support and consistent regulation causes them to stifle.

After comparing these different entrepreneurial environments, the Entrepreneurship Working Group has identified common challenges facing entrepreneurs that can be addressed at an international level. The group presents the following recommendations to UNCOPOUS relating to cultural and structural issues to increased entrepreneurial growth at the international level:

3.4.1. UNCOPOUS should support and facilitate lowering barriers to entry into space entrepreneurship.

An intellectual property archive that lists previous and current technology successes and failures mitigates the failure rate of new entrants. Allowing an open network of international entrepreneurs to exchange facility or innovation spaces and information could save entrepreneurs time and money in start-up hurdles and allow them to more efficiently develop ideas.

3.4.2. UNCOPOUS should create a platform for international entrepreneurial collaboration.

By promoting collaboration on an international entrepreneurial level, the cross-cultural exchange of how failure is accepted and how successful start-ups are structured and managed will enable a more open platform to learn how to develop ideas, overcome barriers and “leap-frog” their technology.

3.4.3. UNCOPOUS should help countries with a disadvantage by leveraging local facilities.

International collaboration and joint government and academic funding for local business development will foster entrepreneurial spirit in countries new to space activities.
4. MICROSCOPIC VIEW OF ENTREPRENEURSHIP

In contrast to the more formal analysis of meso- and macroscopic activity, the discussion of microscopic activity centred on first-hand experiences of space entrepreneurs. Chris Boshuizen, CTO of Planet Labs Inc., facilitated the discussion and recounted his own methods and successes in co-founding his Earth observation business. Common challenges include overcoming technical risks, striking a balance between conceptual design and rapid prototyping, differentiating oneself from other businesses, and acquiring external support, such as finances and mentorship. Unless mitigated, these obstacles may pose significant barriers to entry for space entrepreneurs.

The entrepreneurial space sector has the unique opportunity to drive progress in the commercial space sector. The proverbial “bottom line” remains the number one driving factor in the decision making process for large aerospace companies such as Boeing or Lockheed Martin. Start-ups, on the other hand, are not so restricted and have the freedom to invent and innovate without adhering to the whims of the majority shareholders. Start-ups will inevitably compete with each other; however, together they can develop new market synergies that can boost the entire industry and improve the prospects of future start-ups. For example, the launch capability developed by SpaceX allows new players to dispense with the need to develop their own launch technology and pursue loftier goals. The Entrepreneurship Working Group found that the motives for space-focused entrepreneurship varied between start-ups, and included:

- Improving services for under-developed countries and remote communities
- Opening up new frontiers for economic progress
- Developing dual application technology
- Utilising off earth resources to improve quality of life on earth
- Providing a platform for inspiration and the sharing of ideas
- Profiting financially and financial gain

4.1. Overcoming the Stigma of “Space is Hard”

Fuelled by enormous rockets that lift humans off of this world and satellites that travel ten years and land on a comet, the public perception of space endeavours is that ‘space is hard.’ This attitude develops the stigma that entrepreneurs in the space sector will face enormous challenges. Like any sector, space does have its challenges, but planning can help overcome these.

The stepping stone strategy can help overcome challenges. This strategy involves setting tangible, near-term goals and slowly building up to more ambitious objectives. This model is self-evident in most business cases, however within the space sector it is often lost in a sense of urgency to revolutionise the industry or put something in space. XCOR has successfully employed the stepping stone strategy to create a suborbital tourist vehicle and science platform. XCOR’s ultimate aim is to create an orbital launch vehicle for Mars; however, the development of a sound step-by-step process translates increased likelihood of success. Furthermore, if an endeavour does not succeed, the company will leave a legacy of success and innovation rather than a missed opportunity. To raise necessary initial funds, the Lynx vehicle was financed through the crowdfunding service Kickstarter, and those funds were used as leverage to achieve a greater funding level. Planetary Resources and Nanosatisfi also used similar approaches, demonstrating that it is possible to obtain start-up funding.

The space sector offers a certain excitement that inspires passion and motivates business owners but the history of development in the space sector also plays an important role in understanding the current climate. Political motivations of the 1960s and 70s initiated the enormous influx of funding into the space sector and rapid progress in technology development. After the race to the Moon, the decline of American-Soviet tensions reduced investment from previously unsustainable levels. An entire generation retained its expectations of cheap access to space, trips to Mars and space hotels, despite the decrease in investment. The Apollo program was an anomaly in the progression of space exploration, and the sector is only now beginning to return to a similar level of progress, albeit in a more sustainable and economic fashion. This ‘hangover’ from early days of the space race has motivated potential entrepreneurs, but also drives ambitious projects.

This history may explain why the space sector seems to be full of passionate and sometimes misguided entrepreneurs. Although many space start-ups are motivated by passion rather than profit, they must still be profitable to be successful in the long term. New concepts or passionate ideas must have a niche market or customer in mind, as success is directly linked to introducing achievable interim goals. This may require entrepreneurs to restrict their vision and ambition in the near term to make long-term aims achievable. Passion drives innovation and motivates employees, but can be a trap for new companies, so entrepreneurs must seek balance.

A user guide with advice to entrepreneurs may help overcome the initial trappings inherent to start-ups in the space industry. Such a guide would detail previous success stories and include a breakdown of reasons for success, invaluable roadmaps for any potential entrepreneurs considering an entrance into the sector. Minimising risk will increase the likelihood that someone will take the next step and develop a concept into a successful company. Evidence of progress and testing success are the best motivator for investors, thus additional methods that directly assist entrepreneurs with these initial trappings are required. Entrepreneurs need guidance and support from peers and mentors in the start-up business, from the space community or elsewhere. These strategies to break down the perceived stigma of ‘space is hard’ will encourage entrepreneurship in the space industry.

4.2. Successful Entrepreneurial Environments

From a microscopic perspective, individuals with passion, motivation and creative ideas are a crucial initial factor for entrepreneurship. Space start-ups need to work together, like a system of sub-systems, and exploit synergies to advance the community as a whole. For the entrepreneur to be successful, an adequate environment supporting them and their company is essential. The following factors are important:

I. Awareness and outreach
II. Funding opportunities
III. Networks/supportive structures
IV. Skills training and development
V. Access to resources and information
VI. Government policy and laws
VII. Access to expertise/mentors
VIII. Diversity and interdisciplinary projects
Many of these factors are not space specific but many of the required networks are. Facilitating further development of these incubator-style environments could vastly increase the success of space start-ups.

4.3 Challenge and Recommendations

Recommendations seeking to address the outlined issues must also promote a positive view toward entrepreneurs and call for access to key resources, networks and events. Awareness and access to effective support structures must be in place to yield sustainable space businesses.

The challenge of UNCOPUOS, space industry and governments lies in the development of an optimal environment in order to support entrepreneurs and their companies. During SGC 2014 the entrepreneurship working group presented the following recommendations concerning its general implementation, specifically for UNCOPUOS and SGAC.

4.3.1. Key implementations to Foster an Entrepreneurial Environment

- Promote the creation of incubation centres that allow entrepreneurs free after hours access to meeting rooms, resources and equipment. Each centre should be focused on a relatively narrow purpose to gather like-minded individuals.
- Promote organisation of conferences and events to allow further network development, such as regularly offering Hackerspace or SpaceUp events and training courses.
- Improve education through university and school curriculum modifications to include training or information relevant to entrepreneurial activities, and promote new training courses and mentoring programs.
- Improve information accessibility for entrepreneurs by creating databases of companies, people and resources involved or interested in NewSpace activities.
- Encourage funding sources through university grants, crowd sourcing programs and competitions. Funding should also be provided through alternate means such as financing use of open access laboratories or offering a three-month funding trail where a company can prove the viability of a product into the market.
- Create public and business awareness programmes in mainstream and social media, focusing on the benefits of entrepreneurship and challenges or barriers facing entrepreneurial activities.

4.3.2. UNCOPUOS should support programs developed to create successful entrepreneurial environments.

There are many pre-existing organisations, such as the not-for-profit eSpace, already offering programs that support creating and developing entrepreneurial space companies. UNCOPUOS should assist these organisations, ensuring all conditions required for a successful entrepreneurial environment are in place.

4.3.3. UNCOPUOS should provide incentives to organisations to encourage support of new entrepreneurial activities.

Companies and organisations can support entrepreneurs and start-up companies through mentoring, financial assistance and access to resourcing. To encourage greater support from established organisations and companies, UNCOPUOS should provide incentives such as awards and appreciation of support, ensuring that the efforts of these companies are widely recognised.

4.3.4. SGAC should seek to incorporate a SpaceUp type event into the IAC Young Professionals Program.

In order to encourage young professionals to expose their ideas it is proposed that an entrepreneurial competition be held during the IAC. To initiate the entrepreneurial process, it is proposed that each year a company provides a problem to be solved. Assigned groups would then have a limited amount of time to work on the problem and develop solutions, which would be presented to a panel of industry experts at the end of the event. The winning group would then have the opportunity to pursue this idea further at the discretion of the sponsoring company.

5. CONCLUSIONS

Since Sputnik’s launch 57 years ago, the space has been an industry dominated by governments. The few private companies in the sector were almost solely dependent on government contracts, the majority of which related to military and defence. With the rise of commercial space applications such as remote sensing and communications, large contractors thrived whilst smaller firms struggled to establish themselves. In the last few years, however, entrepreneurs have begun to find success in the space industry, particularly through miniaturisation, and the capital cost of space projects has plummeted.

There are clear benefits to the entrepreneurial spirit in the space sector. Entrepreneurs can quickly adapt and pivot, leading to innovative business models in what has become a relatively stagnant commercial sector. For this reason, encouraging development of space and encouraging entrepreneurship in the sector has become synonymous. Space is a business, and should not be limited by political or military ploys of projects.

The working group examined entrepreneurship at three different levels: macro-, meso- and microscopic. The recommendations included reducing risk of entrepreneurial activity and encouraging space start-up incubators. Unlike most industries, the development of space infrastructure has a wide range of benefits to all humankind, demonstrating how important it is to support entrepreneurs.

6. ACKNOWLEDGMENT

This research and discussion were undertaken during the Space Generation Congress in Toronto, Canada, in September, 2014. This report represents the continuation of the congress’ outcomes, and it is based on the ideas and recommendations of young professionals and students representing more than ten countries around the world.
7. REFERENCES

1. The Space Report 2014, Space Foundation
CUBESAT SWARMS
COMMUNICATION NETWORKS
AND POLICY CHALLENGES

ACRONYMS

LEO: Low Earth Orbit
DTN: Delayed-Tolerant Networks
IP: Internet Protocol
SDLP: Space Data Link Protocols
TC: Telecommand
TM: Telemetry
AOS: Advanced Orbiting Systems
Prox-I: Proximity-I
CCSDS: Consultative Committee for Space Data Systems
IOAG: Interagency Operations Advisory Group
ITU-T: International Telecommunication Union Telecommunication Standardization Sector
SIS: Space Inter-networking Service Area
COTS: Commodity-off-the-shelf
UHF: Ultra high frequency
ISM: Industrial, scientific and medical
RF: Radio frequency

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1. INTRODUCTION

The CubeSat standard started as a joint project between Cal Poly State University and Stanford University in 1999. At the time, skepticism focused on reliability and lifetime of such small satellites for serious scientific and commercial tasks. Since then, however, universities and industry have shown large data collection is possible with these previously underestimated satellites. Currently, CubeSat missions are low-cost, with a fast turnaround and short operational lifespan. Addressing challenges faced by CubeSat’s diverse user profile will ensure continued development (Figure 1.1).

The “CubeSat Swarms- Communication Networks and Policy Challenges” working group, comprised of 21 young space professionals from 15 nations, sought to outline challenges to small satellite use and provide recommendations. This report is intended to provide international policy recommendations to the United Nations Office for Outer Space Affairs to assist, advise and initiate policy that will provide structure and foster the growth of a global space network of CubeSats. Suggestions for short- and long-term timelines will be addressed to ensure smooth operation not only of individual CubeSats but also of small satellite swarm operations. Within this subject, the group focused on management of limited radio communication bandwidth and the effect of large constellations on the space debris environment.

One of the most important parts of any spacecraft is the communications subsystem, which requires a license to use radiofrequency (RF) bands. RF band allocation is highly regulated, costly and time consuming. The RF spectrum is divided into approximately 26 defined radio services, with each frequency in the radio spectrum allocated to one or more services (Figure 2.1). CubeSat communications systems are maturing rapidly and today, several radio manufacturers provide megabit-class transmitters compatible with the CubeSat size and power restrictions. As CubeSat transmitters become higher in frequency, more bandwidth is available for high-speed communications (11).

Small satellite operations are typically authorised to use the 145-148 MHz, 420-450 MHz, the industrial, scientific and medical (ISM) band of 902-928 MHz, and 2.390-2.450 GHz bands [5]. Most CubeSat missions use the 145-148 MHz and 420-450 MHz bands, with such low frequencies and narrow bandwidths limiting data transfer rates to about 50 Kbps. Use of the higher 902-928 MHz and 2.390-2.450 GHz bands allows wider channel bandwidths that enable data rates in excess of 2 Mbps.

Many small satellite missions currently involve experimental operations, including missions conducted under government contract. A comparison of CubeSat license usage is shown in Figure 2.2. Beginner users typically use amateur radio frequencies due to equipment and license availability while high-performance and military CubeSats use higher frequencies for communications.

As CubeSat communications transition to these higher frequencies, radios and ground stations are becoming more difficult and expensive to build. Much more bandwidth, however, is available in all the satellite services, including the amateur radio service, should teams decide they fit there.

2. CURRENT SITUATION ON CUBESAT COMMUNICATION

One of the most important parts of any spacecraft is the communications subsystem, which requires a license to use radiofrequency (RF) bands. RF band allocation is highly regulated, costly and time consuming. The RF spectrum is divided into approximately 26 defined radio services, with each frequency in the radio spectrum allocated to one or more services (Figure 2.1). CubeSat communications systems are maturing rapidly and today, several radio manufacturers provide megabit-class transmitters compatible with the CubeSat size and power restrictions. As CubeSat transmitters become higher in frequency, more bandwidth is available for high-speed communications (11).

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As CubeSat communications transition to these higher frequencies, radios and ground stations are becoming more difficult and expensive to build. Much more bandwidth, however, is available in all the satellite services, including the amateur radio service, should teams decide they fit there.
3. IDENTIFIED CHALLENGES

CubeSat communications challenges are divided into technical and policy challenges. The technical challenges are related to limitations of link budgets for small satellite missions that restrict the amount of science and bus telemetry that can be obtained from the devices. The policy elements have to do with the frequency allocation and registration for short lifetime projects.

3.1. Technical Challenges

The quality of a satellite signal is evaluated through a link budget. This estimates gain from the transmitter power, antennas and ground station capabilities, and subtracts losses from sources such as the atmosphere and interference. The end-result signal-to-noise ratio is used to evaluate signal integrity. Most CubeSats used one Watt for transmitter power with dipole and monopole antennas, severely limiting communication capabilities [12]. Estimating link budgets for these spacecrafts reveals that a lot of energy is spent overcoming atmospheric losses and path losses [22].

Atmospheric losses occur at low altitudes, and are attributed to atmospheric absorption and weather. Path loss refers to dispersion of the transmitted signal as it travels from the CubeSat to a ground station: the further from the source, the smaller the signal the receiver ground station will see of the original signal. Low-orbiting CubeSats experience minimum loss when the satellite is directly above the ground station and maximum loss when the satellite is at low altitudes just above the horizon. Furthermore, increasing wavefront exposure to low altitudes increases interference from other terrestrial applications. Despite operating at different frequencies, other applications, reflections from ground infrastructure and base noise level from industrial regions cause interference that affects the signal quality.

These challenges are not unique to CubeSats, but it is more difficult to compensate for signal losses due the typical low operating power of CubeSats. Technical challenges are complicated when CubeSats are grouped into a swarm. Each satellite in the swarm can use a different frequency or the swarm can share the same frequency, leaving the ground controller to sort out signals from individual satellites in the swarm. Although appropriate for larger spacecraft, use of individual frequencies for each satellite in the swarm wastes limited spectral resources. Shared frequency bands for smaller CubeSats does, however, increase interference between spacecrafts, which in turn places tighter requirements on ground equipment and reduces the link budget.

3.2. Policy Challenges

Protocols for frequency registration and allocation are designed for longer duration missions. Registering a frequency with the International Telecommunications Union (ITU) often takes a minimum of two years, whereas the time to design and build a CubeSat ranges from nine months to two years. As the policies governing CubeSats translate to extended timelines for registering frequencies, with the time required nearly as long as the combined spacecraft design and operational life. The long time needed to register frequencies makes this the rate-limiting step, grounding many spacecrafts.

4. PROPOSED RECOMMENDATIONS

To keep up with current developments in the field of CubeSat research, technological as well as policy changes are necessary. The recommendations to further expand the capabilities of CubeSat networks are presented in the following section.

4.1. Technological Recommendations

To provide sustainable communications, an intra-swarm constellation design must be considered, such as a mother-daughter communication framework for intra-swarm communications. Within a registered swarm, several daughter satellites would swarm one mother satellite with greater capabilities. The mother satellite will act as the trunk provider for communications with various ground stations on Earth (Figure 4.1.1). Individual CubeSats would communicate with each other and the trunk provider on traditional radio frequency links, but the trunk provider would utilise free-space optical communications that are an alternative to radio frequency [7].

Use of optical-based communications will allow larger bandwidths along with reducing spectrum and security issues. They may also fulfill the need for high-speed, seamless, and reliable communications in larger mother satellites until the technology is suitable for use in smaller daughter satellites. The performance of an optical communication link can be quantified using a link margin that is analogous to the link equation for any radio frequency links. Complications with optical links arise when links travel through the atmosphere: they suffer strong fading from index-of-refraction turbulence and encounter obstructions from clouds, snow, and rain [7].

Along with the technological recommendations for the communication network within a swarm of CubeSats, the larger inter-swarm communication network must also consider ‘swarms of swarms’ (Figure 4.1.2).

A swarm of swarms network architecture would rely on space-based relay communications utilising optical communication links and/or radio frequency communication links between the trunk providers of each swarm and the various ground stations established on Earth. Every CubeSat in orbit must be registered within a swarm to access the network. In consideration of inter-swarm communications, the working group recommends using disruption- or delayed-tolerant networks (DTN) to minimise data loss and increase reliability. A DTN is time independent and designed to operate over extreme distances, both of which are ideal for communications between a swarm in orbit and ground stations. Time independence ensures accurate and reliable store-and-forward functionality within the network, despite object or debris interferences that communication links may encounter between the initial transmitting and final receiving nodes [19]. Use of intra-swarm and inter-swarm constellations as well as optical communications and DTN networks will enable policies to standardise communication issues of CubeSat swarms in orbit.
4.2. Policies Enabling Innovations

New policy approaches are needed to promote innovation as well as investment. Expansion of current satellite and ground station numbers would improve global communication and decreases waiting time for data downlink. Ideally, the type of information transmitted on satellites and ground stations should not have an effect on the price, the speed or the quality of the network. Policies should be developed to promote such net neutrality with a seamless network that can grow with technology. The open market would promote competition, in turn spurring innovation.

Policies and procedures should establish liability as well as responsibility, and oversight of private sector activities and government interventions is still needed. The proposed registration activities below outline how the CubeSats could be tracked and registered to align with users holding responsibility in the network.

4.3. Necessary Transition Steps

As a long-term goal, the number of satellites and ground stations should be expanded to be available and cooperate within the newly proposed seamless CubeSat network. The globally established wireless Internet network is seen as an example to follow for this goal. Even if currently technological challenges remain, strong policies lay the path for future developments to be implemented.

Having international standards and a uniform global network for CubeSat communication would not only simplify communication protocols but it would also enable additional services particularly in remote places. This network could provide updated weather information or a reliable Internet connection for developing countries to enable additional services particularly in remote places. This network could provide updated weather information or a reliable Internet connection for developing countries through the operation of their own CubeSats in space.

4.4. Future Data Link Infrastructure

The recommended communication network architecture consists of four types of data links: CubeSat to CubeSat, CubeSat to Ground, Swarm to Ground and Swarm to Swarm (Figure 4.4.1).

The CubeSat to CubeSat data link exists between the various satellites or nodes within a swarm, while the Swarm to Swarm data link formed between the swarm mother or hub satellites to enable inter-swarm communications. Although the mother satellites will act as the primary uplink and downlink source to the ground stations, individual swarm CubeSats also have the capability to transmit and receive data directly from ground stations when necessary.

Every CubeSat within the network would be assigned an identification number. The network, comprised of ground stations and multiple CubeSat swarms, would be analogous to the structure of the Internet. There could be an infinite number of satellites and ground stations that can enter and gain access to the space network, similar to how a newly produced electronic device can gain access to the Internet as long as the service is paid for or as long as it uses the wireless network.

The Internet currently uses Internet Protocol (IP) as its primary network protocol to send and route data to different addresses or devices within a network. IP uses unique addresses to identify nodes within a network, and consequently the data on an IP network is organised into packets. These packets consist of a header containing identification and data. Headers, often contain the source of the data, the destination and other pieces of information about the data to accurately route information between two nodes of a network [15]. The working group suggests the adoption of a similar architecture for CubeSat swarms.

Each CubeSat in the network would have a unique address and each data link would use existing Space Data Link Protocols (SDLPs) such as Telecommand (TC), Telemetry (TM), Advanced Orbiting Systems (AOS), and Proximity-1 (Prox-1) to route transmissions. The Consultative Committee for Space Data Systems (CCSDS) has already established similar standards for IP implementation over CCSDS SDLPs in both spacecraft and ground systems by the participating agencies of CCSDS. Using CCSDS Internet Protocol Extension conventions, IP Data Units are transferred in packets within the CCSDS SDLPs [2].

Each CubeSat’s space address would contain a network number used to identify its swarm, analogous to the one provided by the Internet Network Information Center (INIC). The CCSDS, the Interagency Operations Advisory Group (IOAG) and the ITU Telecommunication Standardization Sector (ITU-T) should all consider standardising space network protocols along with assignment of a network addresses to CubeSats. The Space Internetworking Service Area (SIS) already supports the CCSDS in providing services and protocols to address networked interactions amongst the elements of a network containing ground stations and numerous swarms of CubeSats [2]. The IOAG is another viable alternative to the CCSDS because its purpose is to enable space communication and navigation interoperability across the international space community. Standards must also be defined to develop and use technologies for CubeSats and to foster growth of a reliable, robust CubeSat space Internet system. The ITU-T drives technological interoperability and can be utilised to develop consensus-based recommendations regardless of the size of a country, company or team producing CubeSats [9]. Consequently, each of these organisations could be a candidate to develop standards for the future network infrastructure of CubeSat swarms.

4.4.1. Registration

Presently, nanosatellites and picosatellites can be constructed in nine to twenty-four months, and survive one to five years in orbit [2]. With such short timelines, a new system is needed to register CubeSats ITU to ensure prompt launch and actual usage of the proposed communication architecture.

CubeSats can use multiple frequencies, the regulations vary for satellite operations and each country has its own domestic filing regulations in conjunction with ITU rules. Depending on technology use, there is also high potential to cause interference. Designated filing requirements for RF are not ideal for CubeSats: there is no model for registration with the ITU, resulting in lengthy filing times.
Ideally, a network of CubeSats that could communicate and send telemetry anywhere would facilitate global coverage. The working group proposes construction of a network where the user can register a unit to gain access. Similar to smart phone Wi-Fi architecture, users would enter a personal identification password to gain access to their CubeSat. User registration for the network would not be as onerous as the current licensing requirement, and could streamline the process for all users of the network. This will greatly reduce registration time and alleviate the burdens of filing satellites. Assigning each CubeSat an identification number provides a reference useful in construction of databases. Registration and identification number linking the user to their CubeSat would be required for launch, and would assign liability and ensure responsibility.

To satisfy current regulations, which limit unnecessary transmissions, CubeSats must include technology to cease communication upon command. With the proposed communication architecture, this can easily be done through software similar to remote operation and shut down of cellular phones. Such ‘kill-switches’ can prevent unwanted interference, as described below. Unwarranted interference confirms the importance of registration with ITU and developing regulations that are in line with the needs of the industry.

### 4.4.2. Standardisation

CubeSat standardisation is essential to maximise compatibility, interoperability, safety, repeatability and quality of the system, and is under development. There are two international standards for CubeSats: ISO/CD/17770 (Cubesat) for compatibility of Cubesat launches and ISO/CD/19683 (Testing) for improving reliability of small satellites. A newly proposed standard to define requirements of small-scale satellites was proposed and approved at ISO/TC20/SC14 meeting in May 2014, with target publication date in 2017.

There are currently no standards for CubeSat Swarms. The working group offers the following recommendations for standardisation of CubeSat swarms:

- Each CubeSat within the network should be assigned an identification number;
- Operators are expected to adhere to network requirements, and in turn can expect streamlined registration, high downlink speeds and equal priority for data transfers;

### 5. END-OF-LIFE PROCEDURES

Bandwidth is a limited resource for satellites. In idealised circumstances, the satellite is switched off after its mission is complete to allow a new satellite to use its allocated bandwidth. For occasions when a satellite malfunctions prior to shut down, the satellite may continue to broadcast uncontrollably and interfere with other satellite transmissions. In such cases, the bandwidth is unavailable for use by another spacecraft. This issue has great probability of being exasperated in coming decades with the increasing use of small satellites in LEO.

#### The Autonomous Kill Switch

The function of a kill switch should reliably halt the satellite’s transmissions to prevent unwanted interference after completion of its mission. Such a switch is activated at the end of the satellite’s life, but in the case of malfunction prior to end of life, a kill switch requiring an activation command would be useless. An autonomous kill switch could reduce risk of error in terminating a satellite’s broadcast functions. The kill switch could be activated following a timer countdown. If the timer is reset with each ground station contact, the functional satellite avoids premature shutdown. The appeal of this autonomous kill switch is in the event that a satellite cannot be reached or unexpectedly malfunctions, the satellite automatically shuts down and frees its bandwidth for the next user.

#### Sustainability

Small satellites may contribute significantly to space debris in LEO. Small satellites should comply with the standard 25-year rule applicable to every satellite in orbit, which states that every satellite should be removed from orbit or be placed in a so called graveyard orbit within 25 years after its nominal end of operations. While legally binding in France, this remains a guideline only at an international level. For small satellites, the installation of active de-orbit devices is challenging because of small payload mass capabilities. Pre-mission analysis, however, can ensure that small satellites are deployed into orbits that have a natural lifetime of less than 25 years to ensure sustainable use of limited space.
A well-crafted policy for Cubesat swarms is necessary to manage the increasing number of small satellites that are being developed and deployed into space by universities, government agencies and corporations. The guiding recommendation of the working group is to encourage standards that will enable a space-based communication network of CubeSat swarms similar to the Internet. This recommendation should provide structure and organisation to a global network of CubeSat swarms in space while simplifying satellite licensing. The time to register a small satellite for the proposed space-based Internet for CubeSats should be minimised while maintaining regulation and required spectrum management. Aside from single satellites, a simplified registration process for swarms of CubeSats would also be more efficient by establishing new baseline legal framework, rules and standards. This will help all the actors in this sector including entrepreneurs, licensing bodies and end-users by maximising efficiency and wisely using resources allocated to future planned missions.

7. ACKNOWLEDGEMENTS

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8. BIBLIOGRAPHY

ON-ORBIT SERVICING
COMMERCIAL OPPORTUNITIES
WITH SECURITY IMPLICATIONS

Abstract
Group Participants
1. Introduction
2. Current State of the Industry
3. Working Group Approach
   3.1. Stakeholder Definitions
   3.2. Simulation Results
4. Recommendations
5. References

ABSTRACT

The On-Orbit Servicing (OOS) working group discussed legal and political implications of developing a commercial OOS industry. The group considered the benefits that OOS and Active Debris Removal (ADR) can offer the satellite industry, as well as potential disadvantages for international relations between space faring nations.

To gain an accurate perspective of stakeholders involved in such a process, the OOS working group held a mock hearing for OOS licensing, with members of the working group assigned to represent stakeholders. Working group members presented their cases at a simulated domestic regulatory panel, constructed of members representing various government ministers, to fully explore stakeholder views. The mock hearings explored the challenges faced by OOS and ADR entrepreneurs as well as the benefit of regulation. The groups highlighted recommendations to ensure the practicality of OOS and determine how best to encourage licensing and regulation of such activities, as summarised below.

1. The United Nations (UN) should provide regulatory guidelines for OOS and ADR.
2. Government agencies should license OOS. The Federal Aviation Administration (FAA) has taken responsibility for licensing commercial space transportation in the United States and this should be extended to OOS/ADR missions to enable short-term advancement prior to further UN regulation.
3. Government should support OOS and ADR development to ensure continued demand. This includes leading by example on government satellites and potential launch levies to enable on-going ADR funding.
4. All stakeholders should prevent weaponisation of space through transparency of operations.
5. Nations should initiate international cooperation on ADR.

OOS and ADR will ensure sustainable use of satellites, particularly in LEO and GEO, for the coming decades. It is through transparency, economic stimulation and close monitoring that such endeavours will be successful.

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--- | --- | ---
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1. INTRODUCTION

Since the beginning of the Space Age in 1957, artificial satellites have been launched by several countries without much consideration for future activities in space. Objects, ranging from small ejectables to defunct satellites and burned-out upper stages of rockets, were frequently left in orbit. While larger objects such as the upper stages fall back to Earth relatively quickly, a number of dead satellites remain in orbit from the first years of the Space Age. In recent years the problems of space debris have become more widely known, most notably following the test of the Chinese anti-satellite system targeting non-operational Fengyun-1C satellite in 2007 and the collision of the American Iridium 33 and the Russian Cosmos 2251 satellites in 2009. In the case of Fengyun-1C destruction, 90% of the objects created by the explosion are believed to be circling Earth in long-lived orbits, potentially threatening active spacecrafts for years. The Iridium 33 and Cosmos 2251 collision two years later marked the first major impact of two spacecraft in orbit and led to a significant increase of individual debris objects. Although Cosmos had been decommissioned several years earlier, Iridium was operational prior to the catastrophic collision. Experts agree that once debris reaches a critical density, a single collision could lead to a runaway chain reaction, as new debris is created faster than objects are removed by natural or man-made processes. There is no scientific consensus when density for this so-called Kessler syndrome will reach the critical threshold, but it is clear that it would render large portions of the currently populated orbital bands unusable [3].

The combination of increasing space debris and limited orbital slots makes on-orbit servicing (OOS) of satellites both in Low Earth Orbit (LEO) and Geostationary Orbit (GEO) increasingly important. In GEO, the availability of orbital slots is inherently limited, constrained not only by the minimum safety distance between two objects but also by the risk of radio interference. Although LEO orbit availability is not as limited in GEO, many more spacecraft have been placed in orbit. The International Telecommunication Union (ITU) oversees allocation of slots, but in some cases the inter-satellite spacing is well below 100 km. Despite remarkable gains in efficiencies and performance of communication satellites achieved, the demand for new platforms in GEO is expected to continue rising [2], due to rising global demand for wireless communication and increasing utilisation of inter-spacecraft communication for manned and unmanned systems.

OOS of spacecrafts may help avoid overcrowding and the chain reaction of debris creation in both GEO and LEO by several mechanisms. A servicing spacecraft could be used to de-orbit larger pieces of debris, thereby reducing the probability of major future collisions. It may also re-fuel empty satellites that are otherwise functional so that they regain their station-keeping and collision-avoidance capabilities [1]. A third particularly interesting possibility for communication service providers owning expensive high-performance geostationary platforms is the on-orbit repair of defunct satellites. Spacecraft targeted for repair may include newer spacecraft specifically designed to be serviceable, but also older spacecraft already in orbit today. The latter category is not only technically challenging, but may also pose significant problems in developing new legislation.

To identify and analyse the current state of the OOS industry, the working group constructed a simulated regulatory hearing with group members assigned to represent relevant stakeholders. The hearing was carried out over two hours, where each stakeholder demonstrated the effects of a developed OOS industry on their interests. This provided an interesting opportunity for group members to adopt and further understand the views of different parties. Throughout the simulation, main concerns of the stakeholders were identified [4] and analysed. The report uses these areas of note to provide recommendations on legal and political issues to address during development of the OOS industry.

2. CURRENT INDUSTRY STATE

Industries and agencies have developed capabilities related to OOS for many years, although its utility for ADR has only recently been met with more widespread interest. American and Russian space agencies have carried out operations on multiple targets during the past decades [2] and new technologies now enable the extension of repair and service missions in space. The stakeholders involved in OOS industry are summarised below in Table 1, along with their influence on the industry. The dynamic of this industry is such that there is a conflict of interest between parties as outlined in section 3.1.

2.1 Previous On-Orbit Operations

US Space Transportation System (STS) allowed the first capture of a spacecraft in orbit for service operations. The five servicing missions to the Hubble Space Telescope (HST) are the most famous missions conducted using STS. The choice of HST also stands out, as it was the first telescope specifically designed to allow service and repair by astronauts. Recovery of Palapa B2 and Westar 6 satellites during STS-51-A in 1984 marked the first time artificial objects were actively removed from their orbit and, in this case, brought back to Earth [2].

More recently, assembly of the International Space Station (ISS) would not have been possible without the extensive involvement of astronauts and robotics. Although humans played a vital role in the many of the operations performed, robotic systems such as the Canadarm2 have demonstrated their extensive reliability and versatility required for OOS [2].
2.2 Recent Developments

To address the growing problem of space debris, private organisations and government agencies have devised methods to de-orbit large space objects with the use of spacecraft. Such OOS is an active research area, with most development work performed by or under contract with national space agencies. The lack of research and development by commercial industry is likely due to the uncertain business value.

MacDonald, Dettwiler and Associates Ltd (MDA) announced the first commercial small-scale refuelling mission in cooperation with Intelsat in 2010. The early design paradigm was a GEO fuel-depot satellite to refuel multiple customers’ communications satellites. It would also have the capability to move defunct platforms into a graveyard orbit and free expensive GEO slots. The project, however, was put on hold in 2012 after Intelsat dropped out of the collaboration and a new partner could not be found.

NASA has been performing a technology demonstration operation for robotic refuelling aboard the ISS since 2011. During Phase I and II of the Robotic Refuelling Mission (RRM), the station’s Canadarm2 and its Dextre telemanipulator successfully performed a series of refuelling tests on hardware that had not been designed for refuelling[3]. Tests with new experimental hardware are continuing.

The German DEOS mission (Deutsche Orbitale Servicing Mission) to be launched in late 2017 and the proposed e.Deorbit mission to de-orbit the inoperative ESA satellite Envisat are two further examples of OOS. Deorbiting Envisat is particularly crucial as this satellite could trigger a self-sustaining chain-reaction of debris creation, should it collide with another object.

These missions are examples of OOS in research and development. While there are currently no operative OOS systems in orbit, the first full-scale servicing platforms will be ready for launch in the coming years. Once the first systems have demonstrated their utility, it is likely that commercial industry will become more involved in OOS.

2.3 Legislation & Policy

Currently, policies concerning use of outer space and liability for operations in orbit are limited to two major documents: the Outer Space Treaty (Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies)[5] and the Convention on International Liability for Damage Caused by Space Objects[6].
3. WORKING GROUP APPROACH

To arrive at appropriate and constructive recommendations to develop OOS industry, the working group constructed a mock regulatory hearing with the major stakeholders. This procedure allowed the group to assess current industry status from varying points of view to further understand the implications of proposed regulation developments.

3.1 Stakeholder Definitions

Working group members were designated representatives of companies and customers with appropriate economic leverage while others represented government roles typically required for space-faring nations. The major stakeholders considered in the mock regulator, hearings are summarised below.

**OOS Service Provider:** Executive members of CanadaGOOS (Canadian Group for On Orbit Servicing) own intellectual property for Canadarm and have access to a modular spacecraft bus and space-plane platform. The priorities of the service provider are to demonstrate a successful business case whilst meeting the requirements of the regulators as well as local and foreign militaries.

**OOS Customer:** Executive members of EuroSat, a dominant telecommunications satellite service provider for Europe, Asia and the Pacific, launches an abundance (4-7 units per year) of geosynchronous satellites. The OOS customer seeks economic benefits through extending lifetime of future satellites and upgrading existing satellite units. The customers have reservations and concerns that the Service Provider might provide services to competing companies using capacities derived from the investment of EuroSat.

**Prospective Investor:** An individual has the monetary capability to invest 1-2 billion US dollars into the OOS industry. The investor’s main priorities include a significant return on investment and a successful business case. To ensure this, the prospective investor is keen to see innovation in the industry without restrictive governmental oversight; a clear and simple regulatory environment is desirable.

**Domestic Regulators:** The intergovernmental panel consists of members from the Foreign Ministry, the Executive Office of Science and Technology Policy and the Ministry of Aviation. The domestic military liaison will also be consulted. The concerns of each panelist making up the domestic regulators are as follows:

- Foreign ministry: to ensure compliance with international law and assure partners/allies of the continual peaceful uses of outer space.
- Executive Office of Science and Technology Policy: to set domestic policy and regulation under the appropriate economic and legal posture and to ensure that innovation in the industry is fostered for economic growth. The commercial feasibility of new space ventures must be promoted.
- Ministry of Aviation: to license and oversee OOS without discouraging innovation. The regulatory power of this body will be extended to include on-orbit operations.

**Domestic Military Liaison:** Highly ranked military officials with responsibility in classified reconnaissance and Earth observation areas are concerned with controlling land, air, sea and space. Its main concerns lie in the potentially hostile capabilities of servicing modules, as this is an avenue to weaponisation of space.

**Allied Country Delegation:** Foreign Ministry of an allied state is seeking to license and regulate OOS, with capabilities to open an international market.

**Non-allied Country Delegation (with military attaché):** The permanent delegation member of the United Nations from a non-allied country is mainly concerned about the possible hostile capabilities of OOS units and potential interference with spy satellites. The launch of an OOS unit could be viewed as a declaration of war.

3.2 Regulator Hearing Simulation Results

Each stakeholder made position statements prior to simulated regulator hearings. The main proposals and issues relating to each of the stakeholders are summarised as follows.

3.2.1 OOS Service Provider

An estimated 200 satellites will require servicing by 2020 [1]. OOS is an economically viable space venture that provides a commercial opportunity, particularly when accounting for graveyard orbit operations. The majority of technological capabilities required for such missions already exists with the remainder feasible in the short- to mid-term.

**Challenges:** Key legal and political concerns for the service provider are centred on mission performance and success, and potential asset damage of units registered to other launching states. The Outer Space Treaty (OST 1967) [7] and the Liability Convention (LIAB 1972) [6] cover liability of space operations extensively. Article VI of the OST allocates responsibility to the launching stage, whilst Article VII OST establishes liability of the launching state for damages to an “object or its component parts on the Earth, in air space or in outer space, including the Moon and other celestial bodies” as elaborated in articles II and III LIAB. Liability of debris generated as a result of OOS missions could be inferred by an extension of these documents. This has been broken down into a simple question and a potential strategy for removing any ambiguity that exists in current literature.

**Question:** Who is liable for future damage caused by mission related debris resulting from OOS missions and over what time frame is this liability maintained?

**Strategy:** The launching state shall remain wholly liable for any future damage caused by debris generated as a result of OOS missions in perpetuity.

An additional concern is the potential for OOS capabilities to be used for military/defence purposes, surveillance or corporate espionage. This would likely result in standards and regulations being consolidated, potentially reducing the commercial viability of the technology. Any policy that is derived from these concerns should not negatively impact the commercial viability of OOS.

Policy concerning the military/defence application of OOS might include extensions to existing security protocols to ensure that proximity operations, where an OOS satellite comes within 25 km of another launching state’s asset, are fully transparent. One strategy is to publicly announce proposed mission profiles, allowing foreign states opportunity to raise any concerns. This is particularly important when it comes to potential proximity of the OOS satellite with “unregistered” satellites.
3.2.2 OOS Customer

Challenges: The majority of the customer’s policy-related concerns arise from the lack of regulations. The customer would like to comply with the respective government’s security rules in order to have its satellites serviced. If the security policy created were too onerous, however, the mission costs would increase and reduce the customer’s financial gain.

Benefits of regulation: The potential OOS customer will most likely pressure policymakers to create regulations. As a result, the customer will be willing to comply or consider another state for launch. Without regulation, the customer would hesitate to sign contracts for OOS missions.

3.2.3 Prospective Investors

Challenges: Investors and sources of private funding for OOS are concerned not only with the success of the mission but also the commercial value of the service. The amount of freedom and degree of self-regulation are of high importance for the ability of an OOS company to be commercially viable and competitive. Financial supporters hold considerable leverage in a company at a national and international level. As a result, this leverage can be utilised to establish security and influence the design of a working industry. Despite the obvious challenges, this will be beneficial to the industry.

Benefits of regulation: To initiate international discussion, countries should compile a set of goals and requirements to enable a successful and sustainable agreement. These should be used as criteria when developing the policy that will guide the future OOS industry. A combination of private and public funding is likely important to ensure the on-going success of the industry. Potential funding streams include launch levies that would contribute to on-going ADR and OOS as well as the licensing of satellite spots, particularly in GEO.

3.2.4 Domestic Regulators

Challenges: The regulatory committee must determine the assignment of liability, both for mission success and long-term damages. Although launching states bear ultimate responsibility for damage to national and international space assets due to OOS, it is not economically feasible for governments to cover all liability for commercial activities, particularly in the short term. In addition, regulatory bodies must have adequate access to proprietary servicer and provider component and procedural specifications to guarantee minimal safety requirements are met, as both the servicing vehicle and the vehicle being serviced must be assessed for risks in the event of mission failure. Finally, the domestic regulators must ensure security of communications and ground control, particularly the confidentiality of information, and prevent the weaponisation of space.

Benefits of regulation: To satisfy these regulatory issues, OOS missions should be covered by mandatory private insurance. Insurance requirements may be partitioned into short-term based on mission success and long-term damage liability to third-party space assets or contamination of orbital sectors caused by space debris. The long-term insurance may not be cheaper but is required for a minimum number of years to mitigate costs to the launching state. To obtain proprietary information without discouraging private sector involvement, a trusted third party bound by non-disclosure agreements could verify compliance during safety reviews.

3.2.5 Domestic Military Liaison

Challenges: The domestic military liaison shares many views with domestic regulators, although security is a more pressing concern. Countries and commercial operators prioritise the security and confidentiality of their assets in space, making any collaboration with other entities for servicing or debris removal challenging. Both satellites undergoing servicing and satellites in close proximity to those being serviced are at risk for having proprietary information inadvertently exposed.

With the capability to control or destroy other satellites, OOS has great potential to be utilised as a space weapon. If misused, OOS could lead to a loss of trust and a potential arms race in space. System security is required to prevent misuse, but ‘military only’ control could lead to suspicion and is unlikely to be cost effective. On the other hand, increased transparency or poorly managed commercial companies could enable others to exploit vulnerabilities or expose technology and security information. Securing the homeland and proprietary information of is of utmost importance.

Benefits of regulation: Despite being an economically beneficial endeavour, OOS has the potential to be hazardous. Various entities will almost certainly attempt to develop weaponisation capabilities of units, even if prevention programs are in place. The government requires strong regulations to reduce this risk and ensure national security. Many of these considerations involve other nations, so risks must be managed to maintain sound foreign relations. Preventing weaponisation of space is crucial to allow easy access and sustainability of essential services.

3.2.6 Allied Country Delegation

Challenges: Allied countries generally support development of OOS regulations and recognise that an over-zealous military could restrict technological developments. Since the development of OOS capabilities may also enhance trade relations and technology sharing, allied countries should address trade embargoes and restrictions on import/export related material to maximise access for appropriate parties. The potential weaponisation of space and the lack of clarity surrounding liability sharing of spacecraft/launch vehicle are concerns that must be addressed prior to any action. For this reason, regulation must be developed such that the industry is monitored but not restricted.

Benefits of Regulation: Orbit manipulation by another entity has the potential to damage third party satellites. Results from such actions may cripple other nations, particularly following damage to economically critical GEO assets.

Regulation will set precedent and establish custom that carries weight in international law. Furthermore, establishing a forum to notify interested parties and discuss OOS in a proactive manner would greatly benefit allied countries.

3.2.7 Non-allied Country Delegation (with military attaché)

Challenges: Non-allied country delegations are concerned with weaponisation of space due to new capabilities of launched OOS units. Addressing security concerns surrounding the mission, such as how to prevent hacking or hostile takeover, are of utmost importance.

Benefits of Regulation: Due to the security concerns surrounding ADR and OOS capabilities amongst foreign delegations, transparency is required to ensure mission success and to aid communication with non-allied countries. Regulating these missions would increase cooperation and aid in the mitigation of potential weaponisation.
4. RECOMMENDATIONS

The development of an OOS industry is both technologically and economically viable. Servicing hardware in orbit will reduce space debris and mission cost as units become optimised for servicing. OOS of current satellites will either increase mission life or clear orbits for new missions. Additionally, maturity of the industry will encourage development in robotics and autonomous systems. The major stakeholders outlined all demonstrate conflicts of interest concerning the industry, and so establishment of a regulatory body to monitor future orbital activities is required. This body could also work to satisfy the need for transparency and confidence building between nations to ensure a secure industry. Based on the results of the simulated hearing the working group makes the following recommendations:

1. **Extension of Outer Space Treaty.** Currently, the country from which a spacecraft is launched bears ultimate responsibility and liability for the asset placed in orbit. In scenarios where objects are built in one country, launched by another country and serviced by a third country, the liability for damage inflicted on the serviced object itself or assets owned other parties may need to be reassigned. The group recommends that UNCOPUOS discusses OOS and ADR regulations with the outlook to develop working guidelines to be ratified by nations participating in OOS activities, including customers and providers.

2. **Government Agency Role extended to monitoring and licensing OOS and ADR activities.** UN regulation of ADR and OOS activities is likely to be a complex and long-term requirement. The working group recommends that national agencies, such as the Federal Aviation Administration (FAA) in the United States, be expanded to regulate and monitor such activities to maintain government relations and manage liability. Bodies such as the FAA have proven to be efficient in similar endeavours such as the regulation of commercial space transportation.

3. **Governmental support of OOS/ADR industry.** The conflict of interest and lack of current demand for OOS services renders support and funding by government institutions crucial for the development of the OOS industry. By creating demand for services, the government can provide the initial foundation of the industry and keep investors interested in the business. Governments may conduct technology demonstrator missions through supporting national space agencies, commissioning service missions for military or other governmental spacecraft and implementing additional launch levies to contribute to future ADR.

4. **Prevent weaponisation of space.** OOS clearly creates new possibilities for the weaponisation of space. Confidence in OOS must be established by demanding sufficient transparency of all operations. As this contrasts the confidentiality requirements of certain governmental missions, solutions to provide transparency whilst keeping military secrecy uncompromised should be discussed on an international level.

5. **Initiate global debris removal initiative.** To prevent runaway debris creation and create demand for OOS services, the working group recommends initiating a global project to remove defunct and unused objects from orbit as a potential UN-led initiative. As there is currently no urgent demand for debris removal missions from the commercial industry, projects are not likely to be initiated until it is more economically viable. Considering the current extent of debris, the possibility of the situation seriously worsening to the critical threshold cannot be ruled out.

6. **Initiate regulations for active debris removal.** Regulations to remove or prevent the creation of space debris are currently limited to non-binding documents such as the UN Space Debris Mitigation Guidelines. The working group recommends extension of existing guidelines and discussion of options to introduce fees for occupying orbital slots in both GEO and LEO. This would not only create demand for ADR services, but would also make the extension of spacecraft operations more economically viable.

5. REFERENCES

ETHICS AND POLICY OF NEW HUMAN SPACE EXPLORATION STRATEGIES

Group Participants

1. Introduction
2. Ethics of Human Space Exploration
3. Application of current Policies
4. Long Term Strategy for Space Exploration Policy
5. Case example: Concept of a One-way Human Mission to Mars
6. Summary of Recommendations
7. References

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1. INTRODUCTION

With one or two spacecraft launches per week, Earth orbit is becoming increasingly crowded. The abundance of launches, combined with the accumulation of defunct satellites, causes an increased risk of space debris collisions that threaten future activities. In response to this, spacefaring nations are working to develop regulation for sustainable use of Geostationary Earth Orbit (GEO) and Low Earth Orbit (LEO).

Future spaceflight and deep space exploration missions may similarly risk sustainability of space activities. Current policies are no longer relevant due to the increasing multinational nature of missions and involvement of non-governmental organisations.

Finally, ethical issues arising from new mission profiles, such as inclusion of volunteer participants and one-way missions for settlement warrant further evaluation. Such concerns prompt discussion on whether exploration activities should require more regulation.

The Exploration Working Group at the 2014 Space Generation Congress examined ethical issues arising from new mission profiles, and how to adopt policies to reflect the changing nature of human space exploration. Finally, the group held a mock inquiry on potential issues on a topic of recent interest, a one-way human mission to Mars. The report concludes with recommendations outlining the views of the SGC 2014 participants.

2. ETHICS OF HUMAN SPACE EXPLORATION

2.1. Overview

Government-run space programmes, which have dominated exploration activities in previous decades, have generally opted for low risk activities. In contrast, companies are more willing to propose and undertake projects deemed less risk-averse or even high-risk. New human exploratory proposals are risky by the nature of their endeavour, but many non-governmental organisations are willing to take on such projects.

These main actors in long-term human space flight also have fundamentally different objectives that do not necessarily align. Such differences can give rise to ethical dilemmas. Commercial entities have a financial responsibility to their investors, whereas government must support activities for the betterment of society. The sustainability of manned and unmanned activities is in the best interest of all stakeholders, but discrepancies in objectives and differences in ethical views must be addressed.

The group set out to discuss what is ethical for an individual, and the implications of ethical limits on the human space industry. There was no distinction between exploration and non-exploration or routine missions, or a justification for a risk threshold of ethical limits on the human space industry. There was no distinction between manned and unmanned activities is in the best interest of all stakeholders, but discrepancies in objectives and differences in ethical views must be addressed.

In the case of the proposed one-way human missions to Mars, volunteers will make up the flight crew and establish a human colony. The ethical implications of these new paradigms to advance exploration must be considered to ensure sustainable industry development.

The ethical board would convene to address ethical issues arising from these spaceflight scenarios. Many ethical issues rise from new crew compositions, mainly a combination of volunteers, paying tourists or recruited professionals. While recruited professionals may hold more sway, volunteers may be pressured into overlooking risk in favour of mission objectives. In the case of crew training, mission proposals must evaluate how much training and what type of training the crew must receive to minimise risk.

Mission planners and ethics boards must also evaluate the stringency of pre-flight health assessments, particularly for longer missions. Although some risk is expected, especially in the case of one-way missions, some reasonable guidelines for life expectancy must be established. The amount of medical care provided, especially in the event of critical injury or illness, is important to determine. For one-way settlements, there is a possible of pregnancy; reproductive rights and the crew’s responsibility to newborns must be established. Privacy standards related to medical care must be established to allow transparency between ground control and the crew. In the case of injury or illness leading to death, crews should have burial plans in place to prevent health issues to risk remaining crewmembers.

Burying a deceased crewmember on another planet, or other disruptions to planetary environments, would decrease the health risk to the crew but may have unforeseen consequences. For instance, unregulated exploitation of natural resources may irreversibly alter the environment or, in the case of water harvest, contaminate the source for future groups. In the case of scientifically valuable sites, reckless manipulation may hinder biological discovery. Similar to space debris resulting from defunct satellites, regulations should cover activities on newly settled planets to ensure protection of their environments.

Long-term missions also raise the question of resupply or rescue responsibilities of the launching state or mission organisation. Such responsibilities are especially important for one-way missions that have not yet become self-sufficient or if a volunteer crewmember changes his or her mind about participation in a mission. Due to the open-ended nature of one-way missions, a crewmember may change his or her mind about participation, and the ethical implications of forcing an unwilling volunteer to continue are unclear.

2.2. Issues for Discussion at Ethics Boards

Despite best efforts, many projects may not adequately reduce the risk to human life. This risk is amplified by the fact that future mission must consist of volunteers. In the case of the proposed one-way human missions to Mars, volunteers will make up the flight crew and establish a human colony. The ethical implications of these new paradigms to advance exploration must be considered to ensure sustainable industry development. The ethical board would convene to address ethical issues arising from these spaceflight scenarios. Many ethical issues rise from new crew compositions, mainly a combination of volunteers, paying tourists or recruited professionals. While recruited professionals may hold more sway, volunteers may be pressured into overlooking risk in favour of mission objectives. In the case of crew training, mission proposals must evaluate how much training and what type of training the crew must receive to minimise risk.

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2.3. Ethical Review Board

The group recommends that the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) establishes a review board, and each new endeavor submit a proposal for review. The board, including representatives from different sectors, would carefully evaluate proposals and how they address relevant issues. It would release a public report for each submitted proposal outlining its findings.

2.4. Summary

Our final recommendation regarding ethics of long duration spaceflight is as follows:

- UNCOPUOS should establish an Ethics Review Board to evaluate human spaceflight proposals
- Entities pursuing human spaceflight initiatives should address mission specific ethical issues.
- The review board’s recommendations should be made public.
3. APPLICATION OF CURRENT POLICIES

3.1. Overview

Given the unique nature of no return and settlement missions, a trending topic in space policy, current policy is inadequate for the challenges these missions pose. The working group focused on extending existing policies to meet the needs of these proposed missions.

3.2. Current Policy Environment

UN Space Policy, as related to human space exploration, is primarily governed by three declarations:

- The 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (referred to as the “Outer Space Treaty”) [3],
- The 1968 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (the “Rescue Agreement”) [4],
- The 1972 Convention on International Liability for Damage Caused by Space Objects (the “Liability Convention”) [5].

The Outer Space Treaty, the foundational document in space policy, was created to alleviate tensions during the Cold War. It limits military activities in space and affirms that outer space is not subject to claims of sovereignty. Most importantly, with regards to peaceful spaceflight, it sets forth guidelines for responsibility of objects in space, specifically that the state launching an object into space retains jurisdiction, control, responsibility for any damages caused by that object.

The Rescue Agreement and the Liability Convention are modifications to the Outer Space Treaty. The Rescue Agreement specifies that all states should provide support and assistance to astronauts or “space personnel” that land on or near their territory, while the Liability Convention specifies that the responsibility for any damages caused by a space launch rests with the state from which the launch originated. The current policy environment for cooperation in space exploration is largely dictated by the activities of the United States, particularly with relation to the International Space Station (ISS). The 1988 ISS Agreement sets forth a comprehensive plan for managing one of the greatest technological achievements: an orbiting laboratory. The construction and use of the ISS is complex and necessitates use of equipment from dozens of countries with language, technical and social barriers. The ISS Agreement set forth a detailed plan for construction, operation, and use of the space station as well as the division of cost, risk liability and ownership of any breakthroughs obtained through the research conducted.

3.3. Considerations for Current Policy

With the increasing number of players in the space sector, these existing policies must be extended to address new exploration strategies. Future missions will undoubtedly involve multiple parties or states, and as humanity pushes further into the Solar System, long-duration missions (in excess of six months) will become far more common. With the current growth of the commercial space industry, commercial human spaceflight must also be addressed as a possible future strategy. Two key areas of existing policy were identified as the focus of the new extension: future multiparty cooperation, and diversification of risk.

3.3.1. Multiparty Cooperation

Although it is the cornerstone of current space policy, the Outer Space Treaty addresses solely single state-operated space missions. There was no precedent for commercial or multi-lateral manned space missions when it was signed at the height of the Cold War. Current and future human space exploration strategies encompass more than a sole state actor, but UN policy does not reflect this growing multi-party environment. Cooperation between states and commercial enterprises is crucial to encourage growth in human space industry, and UN policy should reflect this.

3.3.2. Diversification of Risk

Under existing policies, the launching state remains liable for damage caused by the spacecraft. This policy has the potential to stifle collaborations between commercial entities and states. Placing the risk solely on the launching state discourages launch of high-risk ventures by commercial parties. Amending or revising the Outer Space Treaty and Liability Convention to allow liability sharing between the launching state and commercial party would appropriately address the needs of high-risk commercial space environment without being prohibitive.

3.4. Recommendations

Space exploration missions continue to involve multiple parties and are willing to take on higher risk activities and mission objectives, but the decades-old UN policy does not reflect this environment. The working group suggests that the UN recommends countries to examine the Multilateral ISS Agreement and use it as a model for cooperation and accessibility agreements in future multi-party missions. Furthermore, the UN should recommend countries adopt risk-sharing policies, similar to the US Launch Indemnification Policy, to share liability and reward in multi-party missions.
4. LONG TERM STRATEGY FOR SPACE EXPLORATION POLICY

4.1. Overview

Predicting the needs and possible outcomes of future missions is challenging, with diverse scenarios and contradicting expectations, and complicated by the involvement of human lives. The group focused on the following issues:

- Role of government and commercial initiatives
- Need for regulations
- Liability of parties involved in mission
- Property rights of scientific data and resources

4.2. Considerations

In the face of launch failures or crashes, stricter regulations may be favoured. Tight restrictions, however, may block development, while lack of regulation can lead to mission loss or, in the worst case, loss of human life. Commercial initiatives allow for more innovative projects that are not bound by governmental agendas. Policies should consider both commercial and government endeavours, and respect the different drivers and methods behind their programmes; regulators must strike a balance to foster industry development while reducing risk. Similarly, liability agreements should not place accountability on a single entity: diversification reduces the risk for all actors involved.

The need for regulations, guidelines or policies is highly dependent on mission type. End of life care will only be a small issue for sub-orbital flight or LEO flights, but will be relevant for a one-way human mission and settlement missions. Agreements for rescue are feasible for LEO missions but will become difficult for lunar missions and impossible for one-way Mars missions.

With respect to settlement missions, on Mars or other celestial bodies, the Outer Space Treaty states that no sovereignty can be claimed by nations on a celestial object, and that outer space shall be free for exploration. While the spirit of free exploration is desirable, such uncontrolled and unrestricted access risks competition for resources, damaging valuable scientific sites. Commercial mining of suspected lunar water deposits might contaminate both the water and site with potential for biological samples.

Finally, current regulations are mainly nationally organised, in particular for launching to protect third parties such as nature and inhabitants. Because future endeavours will likely be of international nature and the ‘playingfield’ will be off the Earth, the regulations will need to be made on an international level.

4.3. Conclusions and Recommendations

The group concluded that specific regulations on technical and medical aspects are not desirable, as they would likely hinder development. Instead, the group recommended that the UN establishes an internationally agreed set of guidelines and recommendations encompassing the following aspects of human missions:

- Astronaut selection criteria: physical, psychological, genetic, family relations and education
- Medical Care: preventative, immediate, end of life and post mortem
- Personal Care: personal items, privacy, family contact, and mission management
- Spaceship Design: consumable reserves and system redundancy or spares
- Rescue Missions: LEO rescue, planet landing rescue, resupply mission

These aspects shall be defined for the different mission types (with or without humans):

- Suborbital
- LEO lasting days or weeks up to 6 months
- Earth vicinity (Lunar or Lagrange points)
- Deep space to asteroid or Mars, including one-way or settlement mission and return missions

This international guideline matrix can be used as recommendations by government or commercial entities. These entities shall, however, be obligated to provide transparency on whether these guidelines are implemented or not and communicate this to the UN space committee and eventually to spacelift participants and their relatives. To address the question of liability and accountability, the group recommends including outer space affairs under International Court of Justice jurisdiction. In cases where one mission impacts another or an inhabitant of Earth, this court should be able to assess the extent of accountability and whether there was any negligence. In addition, the group recommends that the UN extend UNESCO World Heritage sites to protect scientific sites in space, including sites with the potential for life, historical landmarks, such as lunar landing sites, and resource sites such as lunar polar ice. Access to these sites shall either be forbidden or regulated.

To set up the guidelines matrix, to support the International Court of Justice and to extend the UNESCO World Heritage sites to outer space, the working group recommends the UN task this to the Space Technical Committee and the Space Law Committee. Additionally, the group recommends establishment of committees on Space Ethics and Space Science. These groups shall have representatives from all involved parties to avoid biased policies.

4.4. Summary of Recommendations

- The UN should develop a set of guidelines to be followed for each different type of human space mission
- The UN should extend UNESCO World Heritage to outer space and develop planetary protection policies
- The International Court of Justice should be given jurisdiction over international space legal issues
- The UN should set up a Space Science committee and Space Ethics Committee to support the International Court of Justice in the review of space legal cases
- The UN Space Technical Committee, Space Law Committee, Space Ethics Committee and Space Science Committee shall support and advise:
  - International Court of Justice for space matters
  - UNESCO World Heritage for outer space sites
  - Development of the aforementioned guidelines
5. CASE EXAMPLE: CONCEPT OF A ONE-WAY HUMAN MISSION TO MARS

5.1. Overview

Proposed one-way human missions to Mars have met with controversy in the media. The working group sought to assess the mission concept from technical, legal and policy perspectives as well as the view of the general public. To this end, the group developed a survey with the following aims:

- To gauge the level of support for a one-way human mission to Mars
- To understand the main motivations behind such a mission
- To understand public opinion on the minimum success criteria for such a mission

The finalised survey, developed in consultation with all group members, was disseminated through the SGAC Talk List, SGAC Facebook page, other working groups at the 2014 SGC, alumni groups from the International Space University and social media networks of working group members.

5.2. General Demographics

The group received more than 300 responses, with 70% male and 29% female. Students, young professionals and senior professionals accounted for 26%, 20% and 25% of respondents respectively. About two thirds were between 20 to 35 years old and more than half had obtained a Masters or higher-level degree. Two thirds of the respondents had degrees in engineering and physical sciences and one sixth had training in humanities and social sciences. Equal numbers worked in industry and educational organisations at 37% each. Non-for-profits employed 8% and the remaining respondents were employed in government.

5.3. Opinions on a One-way Human Mission to Mars

More than 60% supported a one-way human mission to Mars, while support for a return mission to Mars increased to 87%. Just over 40% stated their desire to participate in a one-way mission and 47% would support participation of a family member. The most cited reason for supporting a one-way human mission to Mars included inspiration and outreach (177 responses), future unforeseen benefits (160 responses), landing humans on Mars (160 responses), scientific discovery (150 responses) and technology spin-offs (114 responses).

5.4. Correlations

The group analysed relationships between various demographics. The most interesting findings are summarised below:

- Most people who would participate in a one-way mission to Mars would support a family member or significant other’s decision to participate in a one-way mission to Mars (Figure 1). Although most people who strongly disagreed with participation would not support a family member, there are a several people who would not participate in a one-way mission themselves or are neutral to the idea, but would support a family member’s participation.
- Males were slightly more inclined to participate in a one-way mission, with 47% of respondents inclined to participate in a one-way mission compared to 30% of females (Figure 2).
- Support for a one-way human mission to Mars increased with age (Figure 3). In fact, people aged 20-35 are the least supportive of such an endeavour.
- Support for a one-way human mission to Mars is slightly more prominent in space-related sectors compared to others (Figure 4).
- No meaningful relationship was found between education level or employment type.

5.5. Conclusion

The working group conducted a survey within the Space Generation Advisory Council and partner networks to obtain a better understanding of public opinion on the concept of a one-way human mission to Mars. More than 50% of respondents supported a one-way human mission to Mars, which was stronger in the aerospace and defence community. Men were more eager to participate in such a mission, and support for such mission was mainly due to inspiring society and the unforeseen benefits that may stem from such a mission.

Figure 1: Relationship between choosing to participate in a one-way human mission to Mars and supporting loved ones to do so.

Figure 2: Participation in a one-way human mission to Mars by gender.

Figure 3: Participation in a one-way human mission to Mars by age.

Figure 4: Support for the concept of a one-way human mission to Mars, with comparison between Aerospace and defence sectors and other sectors.
6. SUMMARY OF RECOMMENDATIONS

The Exploration Working Group has evaluated whether there is a need for international regulations or policies pertaining to outer space exploration. The working group focused on ethics, the modification of current policies and long-term strategy for space exploration policies and investigating the public opinion about the concept of a one-way human mission to Mars. For short-term, the working group recommends that:

• The UN suggest countries examine the multi-lateral ISS agreement, and use it as a model for cooperation and accessibility agreement in future multi-party missions. Such policy would better reflect the increasing multi-party nature of space exploration.
• The UN should suggest that countries adopt risk-sharing policies similar to the US Launch Indemnification Policy. This would further encourage multi-party missions by supporting higher risk missions.

For the long term strategy the working group recommends that:

• The UN should develop a set of guidelines pertaining human space flight.
• The UN should extend UNESCO World Heritage to outer space and develop planetary protection policies.
• The International Court of Justice have jurisdiction over space legal issues.
• The UN should set up space science and space ethics committees to support the International Court of Justice in the review of space legal cases.
• The UN Space Technical Committee, Space Law Committee, Space Ethics Committee and Space Science Committee shall support and advise the:
  • International Court of Justice for space matters
  • UNESCO World Heritage for outer space sites

Particularly for human exploration ethics, the working group recommends that:

UNCOPUOS establish an ethics review board to review human spaceflight proposals.
• Entities pursuing human spaceflight should address mission-specific ethical issues.
• The recommendations of the review board should be shared with the public.

7. REFERENCES

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EARTH OBSERVATION FOR MARITIME SERVICES

Group Participants

1. Introduction
2. Earth Observation for Maritime Applications
3. Recommendations
4. Conclusion
5. Acknowledgment
6. References

77
78
79
82
84
84
85

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1. INTRODUCTION

Space technology undeniably provides valuable contributions to manifold applications in the maritime domain. As a matter of example, such contributions include ship routing, environmental monitoring, law enforcement, and humanitarian matters. These applications, which will be of increased importance in the near future, cover scientific as well as operational activities and involve a wide range of stakeholders from the institutional and commercial sectors.

At the 2014 Space Generation Congress, the Earth Observation Working Group addressed space-borne remote sensing applications for maritime services and analysed the use of both active and passive Earth observation sensors. Synergies with satellite-based telecommunication and navigation services were taken into account. The working group dealt with the following aspects of the remote sensing applications for maritime services:

- Existing maritime applications and their users
- Current and potential space capabilities used for maritime monitoring
- Stakeholders involved in the sector
- Benefits of space technology in the field
- Challenges in the development and use of space capabilities for maritime applications
- Data access policies and their implication for various stakeholders

The Earth Observation Working Group’s discussions gave rise to a number of recommendations that are highlighted in this report. To provide a broader perspective, the recommendations presented in this report are prefaced with an overview about Earth observation for maritime applications.

2. EARTH OBSERVATION FOR MARITIME APPLICATIONS

2.1. Applications

There are an abundance of Earth observation applications for maritime services. Today, the following application areas, among many others, are requiring space-borne remote sensing technologies:

- **Shipping and Fishing:** maritime traffic monitoring, operational fisheries surveillance, ice monitoring and near shore bathymetry mapping
- **Intertidal Zone Monitoring:** tidal and storm effects forecasting and monitoring, delineation of the land/water interface, mapping shoreline features and beach dynamics, coastal vegetation mapping, and managing human impacts
- **Pollution Assessment:** oil spills and debris monitoring
- **Oceanography:** identification of currents, circulation patterns, shears, frontal zones, internal waves, gravity waves, eddies, and upwelling zones, together with the retrieval of shallow water bathymetry
- **Storm Forecasting:** wind and wave data retrieval
- **Fish & marine biological assessment:** monitoring of water temperature, water quality, ocean productivity, phytoplankton concentration and drift, aquaculture inventory, and coral bleaching
- **Security:** border surveillance and control, ship tracking, illegal fishing, illegal immigration prevention or search & rescue activities

An example of benefits of Earth observation for maritime services concerns the “Northwest Passage” in Canada. Due to the melting Arctic, the route passing in the north west of Canada has become more and more accessible and will become, among others, an important shortcut between Europe and China/US West Coast for shipping companies. For the bordering countries, it will be a major challenge to secure and protect the passage in terms of security and environmental matters. For this purpose, Earth observation capabilities bring a decisive value-added contribution.

The value provided by space-borne Earth observation technology, compared to other current technologies such as UAVs or on-site controls, lies mainly in the possibility to remotely monitor large areas. This allows for unnoticed surveillance and the provision of weather independent assessment capabilities thanks to radar technology.

Despite these benefits, roadblocks impede increased use of Earth observation technology in this field, namely due to technical limitations, national security, or limited financial resources. Making proper use of space-borne Earth observation for maritime services is a challenge, but a necessity for a large range of maritime applications. Such applications involve multiple stakeholders with different interests and are often impacted by international problems. In a later section, this report will introduce some recommendations to help address these political and technical issues.
2.2 Earth observation capabilities for maritime applications

As of today, passive and active space sensors are contributing to maritime monitoring (EO_5):

- **Passive sensors** detect only radiation emitted by the target or reflected by the target from a source other than the instrument. Reflected sunlight is the most common external source of radiation detected by passive sensors (optical sensors). However, additional types of passive sensors exist, sensing the energy emitted from the target itself in different wavelengths in the electromagnetic spectrum, such as the infrared or microwave bands (EO_01, EO_02). Some examples of passive sensors are on-board the Worldview and SPOT satellites.

- **Active sensors** emit energy towards the target (e.g. ground) and detect and measure the radiation that is reflected or backscattered. This category includes several devices, such as Light Detection and Ranging systems (LIDAR) or Synthetic Aperture Radar (SAR). Some examples of SAR instruments are on-board the TerraSAR-X and COSMO-Skymed satellites (X-band SAR) and the Radarsat satellite (C-band SAR).

Both passive and active technologies complement each other. For example, passive systems often allow for better identification, while active systems, such as SAR, allow for weather- and daytime-independent measurements. In addition, these space-based technologies can be employed in synergy with in-situ or airborne technologies (e.g. UAW) or provide additional space-borne monitoring capabilities, such as Automatic Identification Systems (AIS). The importance of these synergies and the complementarities of these various technologies were underlined by the Earth Observation working group.

2.3. Stakeholders

Within the context of using Earth observation data for maritime applications, four classes of stakeholders were identified (Table 3-1): Data Users, Data Providers, Policy Makers, and Decision Makers. A high-level description of each stakeholder is provided below:

- **Data Users** represent those who, at the end of the value chain, are making use of the Earth observation data (e.g. shipping companies, police, scientific institutions);
- **Data Providers** represent the public or private organisations providing the space-borne Earth observation data: they can be data resellers or satellites operators (e.g. space agencies, commercial companies);
- **Policy Makers** set the framework for what Earth observation data collect and how it should be distributed (e.g. space agencies);
- **Decision Makers** align the resources needed to implement the framework developed by the Policy Makers (e.g. government ministries/departments).

2.4. Technology

In our research, we identified several needs for the Data Users. Indeed, Earth observation covers a large variety of topics. We believe that the following requirements are necessary to effectively use space-borne remote sensing data for maritime applications:

- **(Near) Real-time data:** for ship routing, environmental monitoring, law enforcement and security, and humanitarian efforts. Moreover, instantaneous access to remote sensing data is very important for governments in order to plan for and respond to natural disasters.
- **Free or affordably priced data:** the access to remote sensing data should not be overly expensive; otherwise the use will be limited.
- **High Spatial Resolution:** high resolution data is very valuable to obtain more precise information.
- **All weather:** the data should not be dependent on the weather, cloud cover, or geographic location.

Therefore, as a consequence of the aforementioned requirements, we believe that the use of Synthetic Aperture Radar (SAR) is needed. But SAR itself cannot fulfil all Data Users needs (eg. need for high spatial resolution), therefore the following considerations were made:

- Developing a constellation of satellites with both SAR and optical instruments is desirable. Indeed, SAR is day-night and weather independent, whereas optical sensors can achieve higher spatial resolution (at the moment). optical sat following SAR sat on the same orbit, allowing cross-cueing.
- A sustainable framework for life expectancy of the system - developing a constellation takes time and one should consider the life expectancy of the satellites.
- Implementation of automatic data processing in order to produce real-time data and to provide near real-time access to the required information.

Additional benefits of the proposed satellite constellation with SAR and optical instruments are the improved timeliness of the products required by the Data Users as well as the possibility to implement state of the art data analysis (e.g. SAR based interferometer), enabling novel data application. Furthermore, the constellation based system increases the reliability and data continuity – essential prerequisites for sustainable commercial applications.

2.5. Current Challenges

The use of space-borne Earth observation technology faces a number of challenges. We found that they are essentially related to the following issues:

- **Technical:** insufficient resolution to identify a target, inadequate revisit times to effectively control a certain area, low data availability or even no access to the needed data;
- **Economic:** lack of funding impedes the development of a satellite constellation and hampers data purchase;
- **Political:** absence of international cooperation for allowing data sharing, low awareness of Earth observation benefits or even security issues associated with access to data or critical technologies (e.g. export regulations - ITAR);
- **Organisational:** limited communication between stakeholders leads to lack of awareness at various political levels.

To address these challenges, the working group has proposed several recommendations summarised in the section below:

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3. RECOMMENDATIONS

3.1. Effective communication between stakeholders

Following a high-level overview, it is evident that there is a need for stakeholders to communicate more effectively with each other. Furthermore, communication between stakeholders should lead to a common goal. Therefore, a specific decision process, so-called Stakeholder Engagement Cycle, is required for stakeholder engagement on maritime Earth observation issues.

Even at a lower level, “intra-stakeholders” often do not effectively communicate or agree among themselves. Therefore, it is important to introduce an additional decision procedure within each stakeholder in order to achieve an agreement on maritime Earth observation issues before approaching the other involved bodies. The stakeholder communication hierarchy is illustrated in Figure 3-2.

The stakeholder engagement process is initiated by the Data Users. This may be in the form of special institutions which voice the needs of different Data Users involved. Examples of international organizations linked to Data Users include: World Meteorological Organisation, Worldwide Fund for Nature, UN Food and Agriculture Organisation, Interpol - Project Scale, Marine Stewardship Council and many others listed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

3.1.1. Recommendation 1:

The UNCOPUOS should enable a forum where policy makers meet international organisations and other stakeholders in order to encourage information exchange.

Each stakeholder group already has mechanisms in place to identify the urgent and most compelling data needs of their respective members. However, there should be a platform for these stakeholder groups and other users to meet and to share ideas. The motivation for having these various groups meet is to identify the short- and long-term Earth observation maritime needs of the end-users.

3.1.2. Recommendation 2:

The UN COPUOS should support the space agencies in collecting user needs and in strengthening the link between Data Users and Data Providers.

The space agencies should know alternative space data providers and should be able to forward data user requests to them. If the data already exists, the space agency’s role would be to connect the users to specific data providers. If the data does not exist, the space agencies can facilitate collaborative data source development between various stakeholders.

Moreover, there is a need for better communication between Data Providers about the data that they have access to. For example, Data Providers could have regular symposiums to advertise each of their capabilities. This would also be a useful way to make Data Users aware of the type of data already available.

When the Data Users and Data Providers are communicating with each other, it is important that they identify a common goal. Their message to the policy makers should be consistent and convincing in terms of the benefit that their product would bring to the nation. For example, if Data Users and Data Providers identify the development of a new Earth observation maritime technology as their common goal (e.g. a near-real-time high-resolution SAR satellite constellation), they must show to the Policy Makers that the nation has a need for this technology and, in some cases, that they have the capability to develop it.

3.1.3. Recommendation 3:

The UN COPUOS should facilitate stakeholder interaction at the international level in order to share and gain access to foreign Earth observation data and maritime technology.

There is a need for stakeholders to not only communicate at the national level, but to also interact internationally as well. This will allow policy makers to govern who has access to the data, who owns it, and what legal requirements have to be satisfied, considering the common goals identified by the Data Users and Data Providers, and to develop international partnerships.

3.1.4. Recommendation 4:

The UN COPUOS should encourage Policy Makers to take decisions based on discussions with the Data Users and Data Providers. Policy Makers are responsible for the final decision in many situations, and should take into consideration the position of all the partners.

The policy makers’ role will be to convince the Decision Makers, on behalf of the Data Users and Data Providers, to allocate the necessary resources (e.g. funds) to build the new technology and/or acquire the Earth observation data. The Decision Makers will be interested in seeing a return-on-investment. As a result, the Policy Makers must have procedures in place to make sure that Data Users acquire the data they requested and that they are using it. In essence, the Policy Makers must enforce a feedback loop to confirm that the resources allocated by the Decision Makers are used by the Data Providers and Data Users so that the planned goal is achieved and that there are benefits to the nations involved.
4. CONCLUSION

Earth observation applications are beneficial to manifold maritime services and can be used by a wide range of end-users. The Earth Observation Working Group identified a variety of challenges in the use of Earth observation technologies for maritime applications. These challenges are briefly discussed in this report. They are essentially represented by technical challenges, political conflicts, limited allocated resources, insufficient international cooperation, and a lack of synergies and communication between stakeholders. Our recommendations focus on an improved communication and collaboration between the many stakeholders involved and we propose a Stakeholder Engagement Cycle as potential improvement. These recommendations aim to foster cutting-edge solutions to improve Earth observation applications in the maritime domain.

5. ACKNOWLEDGMENT

This research and discussion were undertaken during the Space Generation Congress in Toronto, Canada, in September 2014. This report represents the continuation of the Congress’ outcomes, and it is based on the ideas and recommendations of young professionals and students representing more than ten countries around the world.

6. REFERENCES

[EO_3] ESA Education http://www.esa.int/Education/6_Passive_sensors