FINAL REPORT

SPACE GENERATION ADVISORY COUNCIL

IN SUPPORT OF THE UNITED NATIONS PROGRAMME ON SPACE APPLICATIONS

SPACE GENERATION CONGRESS NAPLES 2012

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2012 | SPACE GENERATION ADVISORY COUNCIL

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In Support of the United Nations Programme on Space Applications
C/o European Space Policy Institute (ESPI)

Schwarzenbergplatz 6
Vienna A-1030
AUSTRIA

Email: info@spacegeneration.org
Website: www.spacegeneration.org
Phone: +41 1 718 11 18 30
Fax: +43 1 718 11 18 99

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Cover Image: On 13 February 2012, the first Vega lifted off on its maiden flight from Europe's Spaceport in French Guiana. Credits: ESA - S. Corvaja, 2012

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Sponsors and Partners

The 2012 Space Generation Congress (SGC) would not have been possible without the generous support of our sponsors. This year sponsors provided subject matter experts, speakers, reports, data and other means of support to the intellectual content of the Space Generation Congress. The Space Generation Advisory Council (SGAC) would like to thank them for their contributions to one of the most successful Space Generation Congresses to date.

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Letter from SGC Chairs

As Chairs, we are very happy that Space Generation Congress 2012 was a resounding success! Our organising team overcame all associated challenges with putting together an event of this magnitude, and we all managed to have an exciting and productive event that hopefully exceed not only our expectations, but those of everyone else as well. Participants enjoyed listening to and socialising with captivating space agency leaders and industry professionals, and spent time to brainstorm issues regarding space activities of today. We are also proud that the PR & Communications team spread the great news about the congress to the world right when everything was happening. It is great that the congress photographers captured great and fun moments of this SGC that we can share and remember. We also had for the first time ever a Fireside chat with space agency leaders and a space football match and a duo rocket launch campaign!

We enjoyed the Congress very much, and above all seeing old colleagues and friends, and meeting new ones! We are also looking forward to the SGC 2012 Report that will be present the outcomes of the works that all delegates have done during the last three days of September 2012.

As we look ahead to Space Generation Fusion Forum and Space Generation Congress 2013: let's work towards a masterpiece for future congresses!

To infinity and beyond!

Catherine Doldirina

SGAC Chair

CJ Nwosa

SGAC Co-Chair

Letter from SGC Congress Manager

Space Generation Congress 2012 has been an absolute success. Last year's Congress in Cape Town, South Africa, set the bar very high, and beating last year's records has been a difficult feat.

This year was marked by an important change in leadership, as well as the organisation of the Congress itself. This transition had the potential to be reflected in the event in two different ways: either through organisational setbacks, or through strength and vitality elicited by fresh faces. Of course, the SGC 2012 team, comprised of 20 individuals from 16 countries, chose the latter. We worked hard since the very beginning to offer delegates one of the best congresses SGAC has ever prepared. With a solid legacy left by SGAC's former Executive Director and Congress Manager, Ariane Cornell, and a strong willingness to improve this year's Congress, this year's Organising Team and I worked hard to beat records. Now we can proudly say: mission accomplished!

Space Generation Congress 2012 welcomed the largest Asia Pacific delegation in the event's history, with more than 30 delegates hailing from the region. The Congress had participation from the highest number of countries yet recorded and hosted exceptional working group presentations. SGAC granted 28 scholarships and awards to enable delegates' participation at this year's Congress and, for the first time, recipients were all awarded full funding. SGC 2012 also held the inaugural SGC International Night, a spectacular event that allowed delegates to share and strengthen the importance of collaboration between countries. Further achievements included the first SGC Fireside Chat, which featured five highly distinguished representatives from five international space agencies.

We would like to personally thank the Organising Team for their hard work and dedication in making the 11th Annual Space Generation Congress a truly historic event for the Space Generation Advisory Council. We look forward to seeing you back at next year's event in Beijing, China for what will be another remarkable Space Generation Congress!

Andrea Jaime Albalat

Executive Director and Congress Manager

SGC 2012 Conference Overview

Delegates at the 11th Annual Space Generation Congress in Naples, Italy

The Space Generation Congress (SGC) is the annual meeting of the Space Generation Advisory Council in Support of the United Nations Programme on Space Applications. Participants are top university students and young professionals with a passion for space. With this Congress, SGAC aims to hone and promote the voice of the next generation of space sector leaders on the topic of international space development. The three days of SGC 2012 brought together both young and experienced students and professionals in the space sector travelling from 44 countries for inspiring, resourceful engagement with their peers. The event, in its 11th year, was hosted in Naples, Italy from 27 to 29 September, just days prior to the 63rd International Astronautical Congress (IAC). The Congress had 134 delegates. This year registration attracted applicants from over 58 countries, which demonstrates SGAC's ever-growing network of international members, as well as the high caliber of the organisation and its events.

Attendees heard 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).

Similarly, leaders from these space organisations had the opportunity to gain insight into the fresh, innovative and bold perspectives of the incoming space generation on the five main themes of SGC 2012: Industry, Agency, Society, Exploration and Earth Observation. SGC 2012 was supported by several sponsors and organised by a committee of volunteers from across the globe. The 2012 Space Generation Congress would not have been possible without either so SGAC would like to express its gratitude and appreciation.

speakers

Lorenzo Campo	Research Fellow at the Department of Civil and Environmental Engineering, University of Florence
Marco Ferrazzani	Legal Counsel, Head of the Legal Department, ESA
Berndt P. Feuerbacher	President of the International Astronautical Federation (IAF)
William H. Gerstenmaier	Associate Administrator, Human Exploration and Operations Directorate, NASA
Jacques Gigou	Technical Coherence Manager, ESA
David Kendall	Director General Space Science and Technology, Canadian Space Agency (CSA)
Kiyoshi Higuchi	Vice President, JAXA
Yasushi Horikawa	Chairperson of UN COPUOS and Technical Counselor at JAXA
Francisco Javier	General Director, Mexican Space Agency (AEM)
Mendieta-Jiménez	
Cosimo La Rocca	Advisor to the President, Italian Space Agency (ASI)
Asra Najam	Economics Student at the University of Michigan, 2012 SGAC $pace is Business! Competition Winner
Ryoko Nakamura	Young Professional at JAXA, 2012 International Space Solar Power Competition Winner
Matthew A. Noyes	Mechanical Engineering Student at the University of Rochester, 2012 OHB-SGAC Competition Winner
Sung Wook Paek	PhD Candidate in the Strategic Engineering Research Group at MIT, 2012 SGAC Move an Asteroid Competition Winner
Michael K. Simpson	Executive Director, Secure World Foundation
Johann Wörner	Chairperson of the Executive Board, German Aerospace Centre (DLR)
Badri Younes	Deputy Associate Administrator, Space Communications and Navigation (SCaN) Programme Office, NASA
Confirmed but unable to attend:	
Mario Cosmo	Technical Director, Italian Space Agency (ASI)
Antonio Fabrizi	Director of Launchers, ESA

Please see www.youtube.com/user/spacegeneration for selected presentations.

SPACE GENERATION CONGRESS NAPLES 2012

Day One

- Executive Director, Andrea Jaime, together with SGAC Chair, Catherine Doldirina and Co-Chair, CJ Nwosa, welcomed delegates, and expressed her excitement and optimism for this year's event.
- Executive Director of Secure World Foundation and Spotlight Speaker for the Society Working Group, Michael Simpson, addressed delegates about the use of space for humanitarian relief, and emphasised the importance of fusion between space technology and society.
- Deputy Associate Administrator for NASA Space Communications and Navigation (SCaN) and Spotlight Speaker for the Exploration Working Group, Badri Younes, discussed exciting future plans for space communications.
- Delegates dispersed into each of their working groups to discuss the specific topics assigned for their project.
- The 2012 OHB Scholarship winner, Matthew A. Noyes, presented his innovative ideas on reducing the risk threatening space assets due to space debris.
- SGAC Project Co-Coordinators, Emmanuelle David and Alanna Krolikowski, introduced current highlighted SGAC Projects, and invited their respective Leads to provide brief overviews of the Project Groups' activities. Two new projects, SGAC's Small Satellites Working Group and Space Law Working Group, were announced and officially inaugurated during the presentation.
- SGC 2012 delegates participated in the Opening Dinner, a multi-course meal hosted at La Bersagliera, in the heart of Naples.

SGC Delegates

Day Two

- The winner of the inaugural International Space Solar Power Competition, Ryoko Nakamura, discussed her concepts for the transmission of power harvested in space from the Sun, and how it could be brought down to Earth.
- The 2012 SGAC Move an Asteroid winner, Sung Wook Paek, outlined his inventive technical solution for deflecting Near Earth Objects (NEOs) using paintballs.
- Associate Administrator of the Human Exploration and Operations Directorate at NASA and this year's SGC Spotlight Speaker for the Agency Working Group, William Gerstenmaier, spoke of the importance of successfully communicating the happenings in space to the general public. He also presented the advantages of having humans in Low Earth Orbit over automated systems, for example, the direct observation of phenomena such as the Aurora Borealis from orbit.
- Research Fellow at the Department of Civil and Environmental Engineering at the University of Florence and Spotlight Speaker for the Earth Observation Working Group, Lorenzo Campo, highlighted the importance of Earth Observation in monitoring environmental effects such as desertification, climate change and in managing resources such as water.
- SGAC Chair, Catherine Doldirina, introduced delegates to the International Astronautical Congress with her presentation, *Getting to Know the IAC*, where she offered insight and handy tips to prepare delegates for the momentous annual Congress, which follows SGC.
- Delegates participated in the first-ever SGC International Night, hosted at Hotel Punta Quattro Venti. Representatives were invited to introduce aspects of their respective countries through presentations, cuisine, songs, dances or performances. Delegates were engaged in many interactive and exciting activities, making the night a huge success.

Left: Agency Spotlight Speaker, Bill Gerstenmaier, during his speech at SGC
Right: SGC International Night

Day Three

- Winner of the inaugural SGAC $pace is Business! Competition, Asra Najam, presented her ideas and perspectives on opportunities and challenges currently faced by entrepreneurs and investors in the space sector.
- Legal Counsel, Head of the Legal Department at the European Space Agency (ESA), Marco Ferrazzani, spoke about the European Space Agency and its relation to various other national space agencies in Europe.
- Technical Coherence Manager at ESA and Spotlight Speaker for the Industry Working Group, Jacques Gigou, addressed a variety of ESA's launch capabilities and applications of the Vega, Ariane 5 and Soyuz rockets.
- President of the International Astronautical Federation (IAF), Berndt Feuerbacher, addressed the Congress, emphasising the importance of space exploration.
- Chairperson of the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), Yasushi Horikawa, concluded the morning's presentation series with an excellent presentation outlining the goals of UN COPUOS, as well as the importance of space in society and the necessity for international collaboration to achieve new feats.
- SGAC hosted its inaugural Space Generation Congress "Fireside Chat", featuring a distinguished panel of guests from various space agencies. Panelists included Johann-Dietrich Wörner, Chairman of the Executive Board of the German Aerospace Center (DLR), Francisco Javier Mendieta-Jiménez, General Director, Mexican Space Agency (AEM), David J.W. Kendall, Senior Executive Advisor to the CSA President, Kiyoshi Higuchi, Vice President, Japan Aerospace Exploration Agency (JAXA) and Cosimo La Rocca, Advisory to the President, Italian Space Agency (ASI). SGAC Chair, Catherine Doldirina, moderated the session. The Fireside Chat focused on the integration of the new generation into the current and future global space sector. The panellists briefly explained their programmes for young professionals and their future plans where the new generation is needed. The delegates were very interested in future plans on exploration in their respective agencies and in the types of skills the space agencies are now looking for in the new generation.
- Throughout the Congress, delegates were divided into five Working Groups where they focused on a specific area of interest that is prominent in today's space industry. On the final day, SGC 2012 delegates presented their novel perspectives on space issues within the themes: Industry, Society, Agency, Earth Observation and Exploration. The results, conclusions and recommendations that were presented to the audience were devised and discussed throughout the Congress. These presentations were also given to many of the day's Featured Speakers. Summaries of SGC 2012 Working Groups' findings can be found under "Congress Themes and Recommendations".
- The SGC 2012 Closing Gala Dinner was attended by SGC 2012 delegates and prominent international leaders of the space sector at the beautiful Villa Signorini. The dinner provided delegates with a valuable networking opportunity, as they were seated with various representatives of a number of international space organisations. Guests were addressed by General Manager for Human Space Flight at Lockheed Martin, John Karas, who portrayed a positive outlook for the space sector. Chairman of the Executive Board of the German Aerospace Centre (DLR), Johann-Dietrich Wörner gave the Keynote address who outlined the importance of international collaboration and the next generation of space advocates within the space sector.
- During the Closing Gala Dinner, SGAC's Co-Chairs, Catherine Doldirina and CJ Nwosa, and SGAC Executive Director, Andrea Jaime, presented certificates to the 28 delegates who were granted scholarships or awards.
- The Congress reached a close as SGAC Executive Director, Andrea Jaime, thanked SGAC's sponsors, partners, and supporters, and praised the great work dedicated by the SGC 2012 organising team.

Catherine Doldirina (SGAC Chair), David Kendall (CSA), Francisco Javier Mendieta (Mexican Space Agency), Johann Wörner (DLR), Cosimo La Rocca (ASI) and Kiyoshi Higuchi (JAXA), during the SGC Fireside Chat

Industry Spotlight Speaker, Jacques Gigou (ESA) during his speech at SGC

SGAC Young Leadership Award winners at the SGC Closing Gala Dinner

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At the core of SGC 2012 were the working groups, where delegates discussed their views on the development of space and prepared a set of recommendations to be published internationally by SGAC. Each working group will eventually produce a report on their discussions and recommendations, which will be shared with the United Nations as well as SGAC sponsors, members and alumni from around the world. SGAC would like to thank the key session supporters, NASA SCaN, Lockheed Martin, Secure World Foundation and SGAC's Anonymous Donor, for making these SGC working groups possible.

Industry – Space Transportation

Supporter: N/A

Subject Matter Expert: Emmanuelle David (France)

Moderator: Remy Chalex (France/Brazil)

Launch of Vega. Credit: ESA

The Industry working group focused on space transportation and the role of the new European launch capability in the international sector. They linked it to the Congress' host nation, as the Italian industry is the main partner of the new European launcher, VEGA, whose first flight in February 2012 was a success.

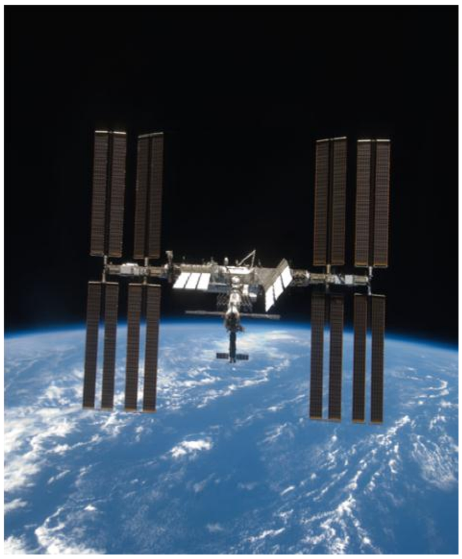
The group listed countries with launch capabilities and explored how to increase the number of countries with this unique ability, what each country could offer, the differences between these countries, potential challenges and the sensitive issue of competition versus collaboration. Particular emphasis was placed on the European launch capacity and where it stands in the international context, especially in light of the recent success of the VEGA launch, the Soyuz's new launch platform at the European Spaceport and potential collaborative efforts with other regions around the world.

They devised the following recommendations and conclusions:

- Encourage established space-faring nations to strengthen their relationships with emerging space-faring nations to foster global growth and collaboration on launch efforts
- Advocate for the development of launch capacities in new space nations to encourage global competition within the launch industry
- Enable the emerging private sector to access and create markets to foster competition, innovation and efficient operation capacity
- Support international efforts to promote national policies requiring launch vehicle operators to deorbit upper stages
- Support the creation of international mechanisms to introduce more safety and sustainability into launch vehicle operations and site practices such as sharing best practices for safety at ground facilities and international research on environmentally responsible fuels and vehicles
- Explore opportunities to foster international trade and cooperation in spite of relatively stable national and international controls on space exports and technology transfers, such as using agency prerogatives and exemptions available within the existing US export control regime and creating an international expert group to study "buffer" or "interface" technologies that address transfer concerns

Delegates working during the Working Group Sessions

Agency – The International Space Station



International Space Station. Credit: NASA

Supporter: Lockheed Martin

Subject Matter Expert: Dr Michael Hawes (USA)

Moderator: Kat Coderre (USA)

The Agency working group discussed the potentials for future maintenance of the International Space Station (ISS). In 2010, main partners of the ISS agreed to extend their inputs for at least another decade. Major contributors such as Japan, Russia, USA and Europe have committed to extend the life of the ISS up to 2020, or possibly even 2028. However, in light of the economic crises affecting some of these partners, several cuts have been implemented in their respective budgets for space activities. The retirement of the Shuttle and the current void in its place are making it increasingly difficult to access the Low Earth Orbit station.

The group examined the implications and benefits of this extension at an international level, the utilisation of the ISS as an analogue platform for human exploration, as well as outreach projects to promote the ISS, such as mobile applications, websites and human spaceflight programmes.

They reached the following recommendations and conclusions:

- Transform the ISS into a commercial facility

- Use the ISS as an analogue for a Mars mission
- The ISS as the main outreach tool to promote space agencies space activities
    - Smartphone apps
    - Shuttle Carrier Air flight Museum

Society – Space for Humanitarian Relief

Supporter: Secure World Foundation

Subject Matter Expert: Tiffany Chow (USA)

Moderator: Ross Findlay (UK)

Pakistan Floods. Credit: GeoEye

The Society working group established how space data could help support humanitarian tasks focused on people who need assistance. Humanitarian relief during natural or man-made disasters requires rapid decision making with accurate, real-time data that only satellites can provide. They can, for example, be used to find good locations for refugee camps, support logistics and planning, and for monitoring reconstructive activities. Damage estimates and planning data are crucial for reconstruction activities. NGOs are known for using space-derived data to influence the behaviour of governments and to provide public awareness and verification of war crimes.

The group recognised how space is used in humanitarian efforts in conflicted areas and how NGOs such as the World Health Organisation (WHO), Red Cross and Doctors Without Borders are currently implementing space tools.

They presented the following recommendations and conclusions:

- Create a new Centre for Responsive Information for Safety and Security (CRISIS) within the United Nations Operational Satellite Applications Programme (UN O SAT) to act as an impartial, international coordinating body for providing space-based information in support of humanitarian relief
- Develop an interface between users, data providers and the public by setting up technical, legal and cost standards; initiating field data requests, exchanges, processing and delivery; increasing public awareness, visibility and participation; and tailoring of the processing approach based on priority

Members of the Society Working Group with the Subject Expert Matter, Tiffany Chow (Secure World Foundation)

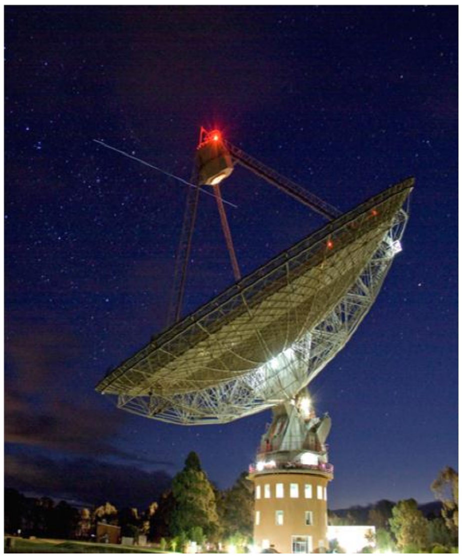
Exploration – Communications for Exploration

Supporter: NASA SCaN

Subject Matter Expert: Stephanie Wan (USA)

Moderator: Victoria Alonsoperez (Uruguay)

The Exploration working group considered the difficulties of overcoming communications in space exploration. As space agencies focus their exploration programmes to destinations beyond the ISS and to the Moon, Near Earth Objects and Mars, space exploration is becoming an increasingly popular discussion.



Parkes Radio Telescope. Credit: NASA

The group discussed the importance of communications in exploration programmes, tele-medicine, crew support, communications challenges such as time-delay, as well as the importance of a crew's self-reliance during non-real-time communications with mission control.

They raised the following recommendations and conclusions:

- Special consideration should be given to Mars. International cooperation was identified as a key parameter. Other major concerns include distance, time delays, accessibility, insufficient data rates and coverage, non-optimal utilisation of space resources, barriers concerning data sharing and the standardisation of related methodologies
- Recommendations were made towards the standardisation and globalisation of technologies, technology transfer and development, as well as the development of an internationally integrated network of multiple small satellites
- Standardisation and globalisation could be achieved through implementing backwards compatibility to help ease the transition into new technologies when meeting the set technological requirements; incorporating communication protocols and a framework for private companies
- To ensure the sustainability of Martian orbits, development could be made towards an internationally integrated network of multiple small satellites with standardised interfaces, where it is affordable to have dedicated communication relays or the inclusion of relays on

other spacecraft, such as fuel storage, where dedicated relays are able to use higher orbits. Furthermore, to keep up with new technologies and needs, it is possible to use more satellites with shorter lifespans by implementing the concept of 'mass production'

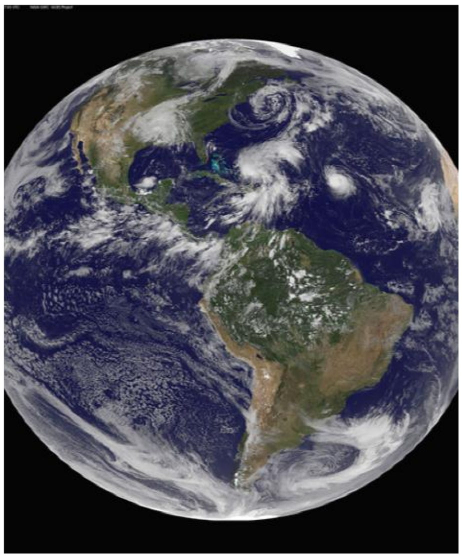
Members of the Exploration Working Group during the Working Group Sessions

Earth Observation – Space Resources for Water Management

Supporter: SGAC's Anonymous Supporter

Subject Matter Expert: Noemie Bernede (France)

Moderator: Mariel Borowitz (USA)



Earth from GEO. Credit: NOAA

The Earth Observation working group explored the ways in which space technology could contribute to the improvement of Earth's water management through various methods. Desertification, access to drinking water, and the management of water-related emergencies are some examples of problems faced by countries across the globe, particularly those in developing regions.

The group discussed previous water-related natural disasters that have occurred around the world and the national emergency strategies that followed. They discussed current space technologies that are available for the purpose of water management such as Earth Observation satellites and remote sensing. Finally, they discussed how aware developing and developed countries are of the capacity for space technology to improve water management.

They expressed the following recommendations and conclusions:

- Promoting data sharing, collection and research by coordinating to ensure continuity of data collection; encouraging standardisation of data formats; increasing the availability of data by ensuring low costs, reduced restrictions and streamlined access to data by users; and encouraging incentives for data use by awarding scholarships, providing grants for data use and initiating competitions
- Supporting applications by continuing programmes – such as The International Space Station SERVIR Environmental Research and Visualization System – to make use of data; building on established regional initiatives, for example, ESA TIGER or Global Earth Observation System of Systems (GEOSS); prioritising local capacity-building through cooperative or exchange projects and site demonstrations
- Engaging stakeholders by raising public awareness of the benefits of Earth Observation through the utilisation of social media such as YouTube or television, as well as integrating programmes into Science, Technology, Engineering and Mathematics (STEM) education; raising awareness with decision makers at the governmental or national level by quantifying the return on investment in terms of money, knowledge acquisition and prestige, as well as presenting specific regional applications that may be of benefit to society

Members of the Agency Working Group with Subject Matter Expert, Dr. Michael Hawes (Lockheed Martin)

SGAC closed registrations for the Space Generation Congress on 24 July, with more than 250 applications from 58 different countries.

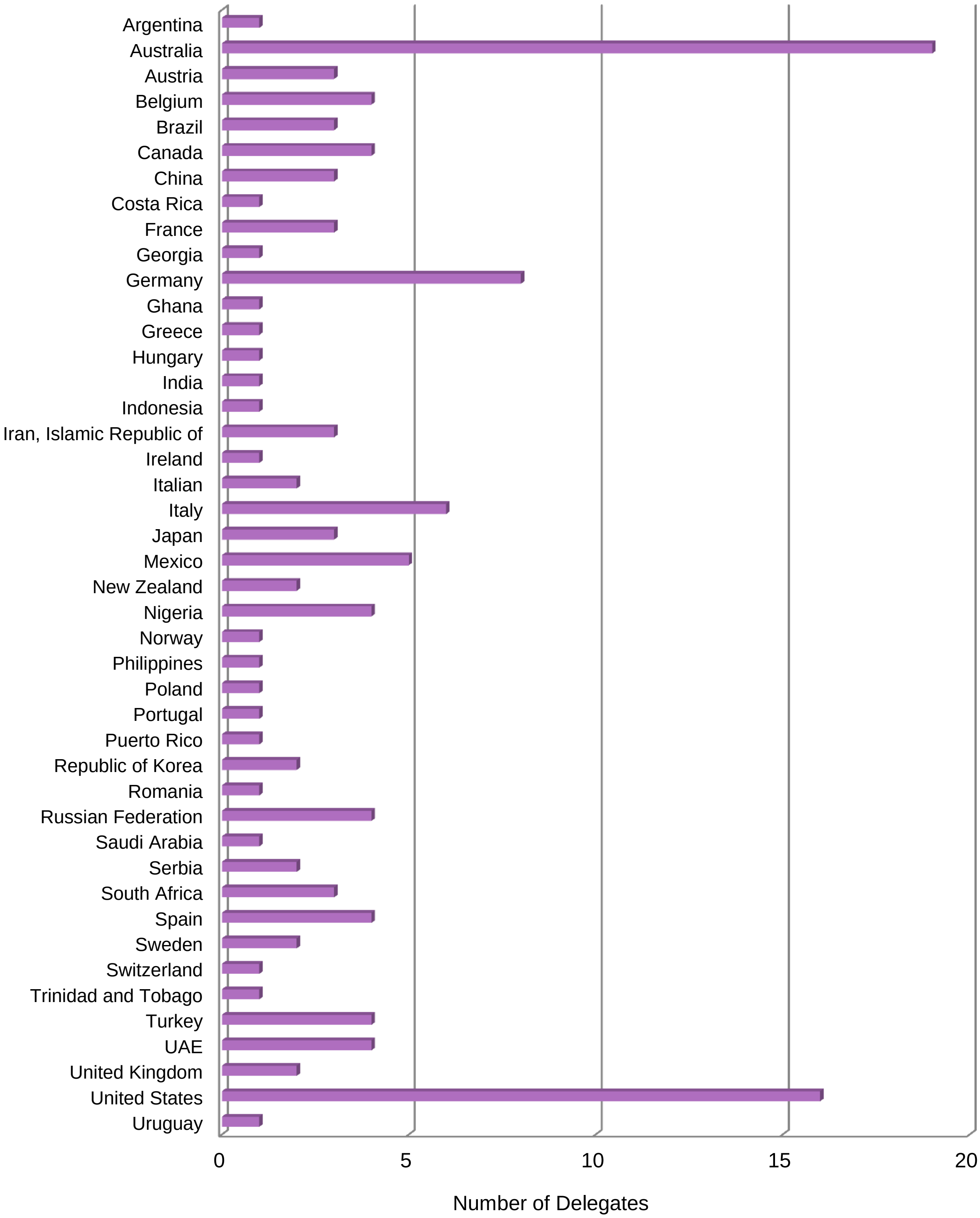
After a diligent selection process, a total of 134 delegates participated in SGC 2012. Of those 134, 28 participants from 15 countries received scholarships with assistance from SGAC and its partners to attend SGC 2012 in Naples. There was a relatively even distribution of genders amongst final delegates, with 40% women and 60% men, an achievement that is uncommon for events in the space sector. Delegates came from vast and varying backgrounds, with 29% undergraduate students, 15% masters students, 11% PhD students, 41% young professionals and the remaining 5% dedicated to other areas of industry. SGAC believes that these statistics truly demonstrate SGAC's international influence, and that it continues to grow. This development gives SGAC the momentum to establish a distinct and highly representative network of young space professionals and university students.

SGAC is also pleased to have welcomed a diverse representation of delegates from an array of countries and regions. SGC 2012 attendees came from more than 44 countries across six continents, setting another Space Generation Congress record. This internationalism is a major contributor to the development of a truly international voice of the space generation that SGAC strives to epitomise.

Networking opportunities during the coffee breaks

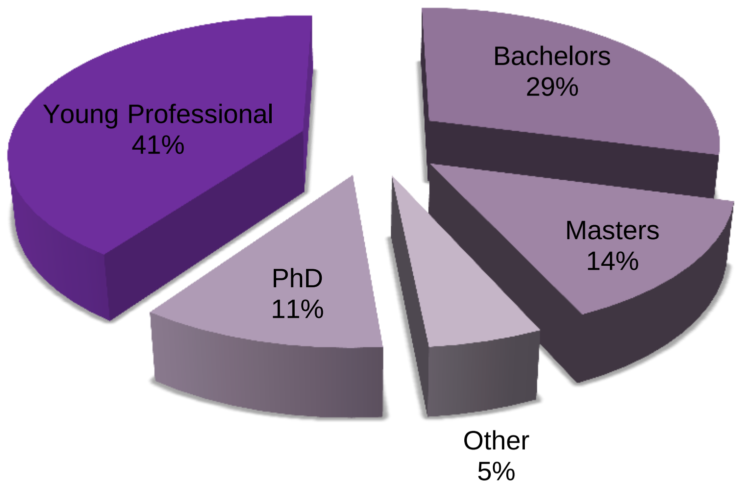
Representatives from 44 countries participated in SGC 2012. The highest percentage of delegates came from Australia, followed by the United States, Germany and Italy.

SGC Delegate Citizenship



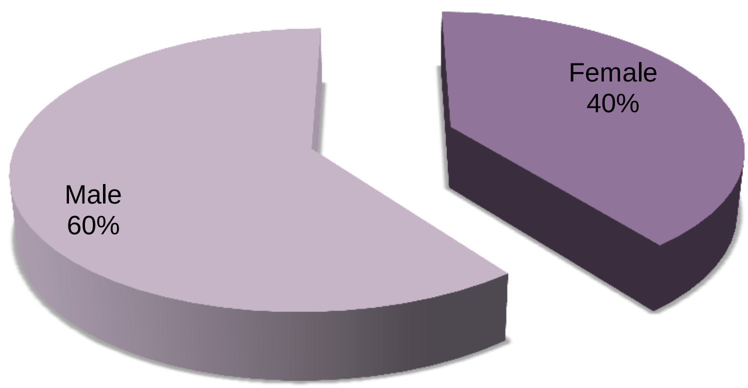
Whilst the majority of SGC delegates were students across the undergraduate, masters and PhD levels, close to 45% were young professionals working within industry, in a postdoctoral position or working in space agencies.

Professional Status of SGC 2012 Delegates



SGAC is proud to have had relatively even gender distribution amongst the pool of delegates at SGC 2012, with a 40% female representation. This is a phenomenon that deviates from the norm in events in the space sector and SGAC is pleased to see such gender balance at the event.

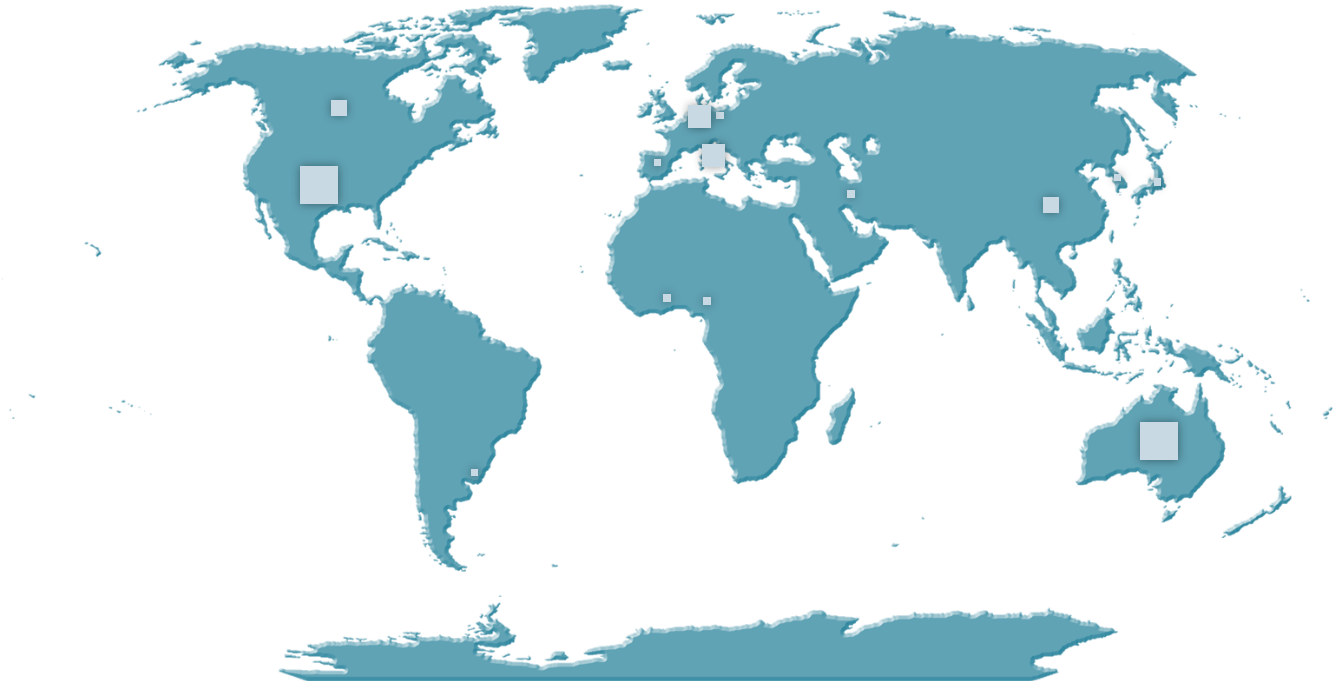
Gender of SGC 2012 Delegates



scholarship statistics

This year, SGAC provided 9 Young Leadership Awards to the organisation's outstanding members to attend SGC 2012, as well as 19 scholarships to competition winners. 15 countries from 6 continents were represented. As one of SGAC's goals is to facilitate opportunities for young members of the international space community to join together to discuss space issues, the 28 scholarships are seen as a key indicator of the success of SGC 2012.

Distribution of SGC 2012 Scholarships



Last Name	First Name	Grant	Country (main)
Fisher	Scott	Young Leadership Award	Australia
Roy	Elizabeth	SSPI Satellite Futures Scholarship	Australia
Somalwar	Utpreksha	AYAA Australian Futures Award	Australia
Yeh	Jack	AYAA Australian Futures Award	Australia
Kumar	Abhijeet	AYAA Australian Futures Award	Australia
Rose	Laura	SGAC Young Leadership Award	Canada
Vigneron	Adam	SSPI Satellite Futures Scholarship	Canada
Sun	Junzi	Young Leadership Award	China
Lu	Zhuoyan	Peter Diamandis Scholarship	China
Nizenkov	Paul	DLR Standout Student Scholarship	Germany
Baumann	Jean-Pierre	DLR Standout Student Scholarship	Germany

Last Name	First Name	Grant	Country (main)
Deiml	Michael	DLR Standout Student Scholarship	Germany
Afful	Michael	SSPI Satellite Futures Scholarship	Ghana
Nasseri	Seyed Ali	SGAC Young Leadership Award	Iran, Islamic Republic of
Emanuelli	Matteo	SGAC Young Leadership Award	Italy
Durante	Daniele	La Sapienza Scholarship	Italy
Nardecchia	Luca	La Sapienza Scholarship	Italy
Nakamura	Ryoko	Space Solar Power Scholarship	Japan
Paek	Sung Wook	SGAC Move an Asteroid Scholarship	Korea, Republic of
Olubunmi Emmanuel	Akinwumi	OHB Scholarship	Nigeria
Bielicki	Damian M.	SGAC Young Leadership Award	Poland
Aymerich	Edu F.	SGAC Young Leadership Award	Spain
Alonsoperez	Victoria	SGAC Young Leadership Award	Uruguay
Laygo	Katrina	SGAC Young Leadership Award	USA
Najam	Asra	SGAC $pace is Business! Scholarship	USA
Borowitz	Mariel	Washington Space Business Roundtable Scholarship	USA
Noyes	Matthew A.	OHB Scholarship	USA
Kohler	Hannah	SGAC-SCaN Summer Intern Programme Scholarship	USA

schedule

	WED, 26	THU, 27	FRI, 28	SAT, 29	SUN, 30
08:30	Delegate Arrivals & Registration	Late Registration			
		Bus Departure	Bus Departure	Bus Departure	
09:00		SGC 2012 Welcome	SSP Competition	Space is Business	
		Spotlight Society Speaker	Working Group Time	Mr Marco Ferrazzani	
		Spotlight Exploration Speaker		Spotlight Industry Speaker	
10:00					
		Coffee Break	SGAC Projects Coffee Break	Coffee Break	
		Working Group Time	Working Group Time	Dr Berndt Feuerbacher	Friendly Space Football Match and Rocket Workshop (Optional)
11:00				Dr Yasushi Horikawa	
				Group Picture	
				Working Group Time	
12:00					
		Lunch	Lunch	Lunch	
13:00					
		OHB Competition	MAA Competition	Working Group Time	
		Working Group Time	Spotlight Agency Speaker		
14:00					
			Working Group Time		
				Fireside Chat with Space Agency Leaders	
15:00					
				Coffee Break	
16:00		Coffee Break	Coffee Break		
		Working Group Time	Spotlight Earth Observation Speaker	Working Group Presentations	
			Working Group Time		
17:00					
		SGAC Projects Info Session		Free Time	
18:00					
		Free Time	Getting to know the IAC		
			Free Time		
19:00					
		Bus Departure			
		Transit			
20:00	Optional Dinner (@ Hotel Punta Quattro Venti)	Opening Dinner (@ La Bersagliera)			
				Closing Gala Dinner & Final Speech (@ MAV)	
21:00			International night (@ Hotel Punta Quattro Venti)		

SGC 2012 Organising Team

Name	Citizenship	Role
Catherine Doldirina	Georgia	Chair
Chijioke (CJ) Nwosa	Nigeria	Co-Chair
Andrea Jaime	Spain	Executive Director and Congress Manager
Cynthia Chen	Australia	SGAC Summer Intern
Matteo Emanuelli	Italy	Logistics Lead Coordinator
Pierre van Heerden	South Africa	Logistics Co-Coordinator
Kate Becker	USA	Project Lead Coordinator
Carmen Felix	Mexico	Project Co-Coordinator
Natassa Antoniou	Greece	Project Co-Coordinator
Edu F. Aymerich	Spain	Delegate Lead Coordinator
Guzel Kamaletdinova	Russia	Delegate Co-Coordinator
Muhammad Shafiq	Pakistan	Delegate Co-Coordinator
Wissam Rammo	Germany	Communications Co-Coordinator
Nunzia Paradiso	Italy	Local Organising Team
Simone Pirrota	Italy	Local Organising Team
Andrea Faber	Italy / Australia	Local Organising Team
Dragos Paun	Romania	Local Organising Team
Benjamin Stepin	Germany / Australia	Local Organising Team
Christopher Vasko	Austria	Multimedia Technician
Reinhard Tlustos	Austria	Multimedia Technician

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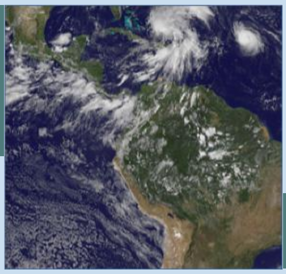
Earth Observation – Space Resources for Water Management



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SPACE TRANSPORTATION

Group Participants

Name	Position	Nationality
Remy Chalex*	Moderator	Brazil, France
Julio Aprea*	Subject Matter Expert	Argentina, Spain
Emmanuelle David*	Subject Matter Expert	France
Jean-Pierre Baumann*	Rapporteur	Russian Federation
Damian Bielicki*	Rapporteur	Germany
Matteo Emanuelli*	Rapporteur	Poland
Scott Fisher*	Rapporteur	Italy
Abhijeet Kumar*	Rapporteur	Australia
Asra Najam*	Rapporteur	United States
Luca Nardecchia*	Rapporteur	Italy
Paul Nizenkov*	Rapporteur	Germany
Sung Wook Paek*	Rapporteur	Republic of Korea
Dmitry Arakcheev	Group Member	Norway
Roger Birkeland	Group Member	Australia
Alanna Krolikowski	Group Member	Canada
Ryan Laird	Group Member	United Kingdom
Philipp Maier	Group Member	Germany
Nunzia Maria Paradiso	Group Member	Italy
Laurent Michiels	Group Member	Belgium
Justin Park	Group Member	United States
Tasman Powis	Group Member	Australia
Wissam Rammo	Group Member	Germany
Ekaterina Rezugina	Group Member	Russian Federation
Bruno Sarli	Group Member	Brazil
Angelika Schuck	Group Member	Australia, Canada
Jeroen Van den Eynde	Group Member	Belgium
Vladeta Zmijanovic	Group Member	Serbia

***Members whose participation resulted in the final report**

1 Introduction

Human curiosity continuously drives forward new eras of innovation. These eras require profound restructuring in how we approach the technological advancement that comes our way. Over the past decade, the launch market has experienced several institutional, commercial and technological shifts that have altered the global landscape. These gradual changes have been highlighted by several recent events, including the retirement of the Space Shuttle, the development of new European Vega small launcher and the first launch of the Russian Soyuz by Arianespace at the European Space Agency's Kourou Spaceport.

The global launch sector consists of private entities and government institutions that pursue the design, development and operation of launch systems, facilitating access to space. The organization of the launch sector is key in determining the viability of the launch industry as a whole.

The current launch sector is dominated by government and institutional customers, who account for 73% of spacecraft launches [1]. This makes it a highly concentrated market, with most of the power being exercised by government buyers. The industry is also fully dependent on the national procurement of launches, meaning that most countries rely only on their national launch capability (shown as 90% for civil launches) [1]. Commercial customers for launch services include telecommunications satellite operators and research partnerships.

Countries without launch capability rely on established space nations to provide launch services. At present, the United States, Russia, Europe, China, India, Ukraine, Israel, Iran and Japan possess the capability to insert objects into orbit [1]. A number of emerging space nations are working to obtain this capability, including South Korea (KSLV) and Brazil (VLS-1). These developments support reasons of national interest and technology development.

There has been a recent paradigm shift in the United States launch market, with government launch services now solicited from private companies via the Commercial Orbital Transportation Services (COTS) and Commercial Crew Development (CCDEV) programs. These programs focus on fixed-price, pay-for-performance milestone-based contracts as opposed to the traditional cost-plus-fee approach used in previous space transportation programs.

The entrance of these new players affects the landscape of the space industry. This report discusses the challenges and potential outcomes which arise from these developments, as well as presenting a re-evaluation of the established European launch sector in response to emerging launch service providers. The political and regulatory considerations between both established and emerging launch service providers, and between established providers, will also be discussed.

2 The Role of New Actors with Launch Capabilities

The past decade has seen emergence of new actors with launch capabilities. These new actors can be classified into two distinct groups: emerging space nations, who are intent on developing an indigenous launch capacity; and newly formed commercial aerospace companies operating within developed spacefaring nations. The Industry Working Group discussed the challenges created locally and globally by the emergence of these new actors. This section provides a summary of these challenges and offers several recommendations aimed at concurrently mitigating negative impacts and bolstering positive impacts of new players.

2.1 Access-to-Space in Emerging Space Nations

There is no explicit requirement for emerging space nations to establish their own independent launch capability. Countries with sufficient economic strength are capable of purchasing foreign space technology products such as satellites, and using launch capabilities of foreign countries in order to meet their requirements for space infrastructure. Despite this, the number of countries making efforts to have indigenous space technology including launch capabilities is increasing [2].

Two examples of emerging space nations investing in access-to-space technologies are South Korea and Brazil. In 2009 South Korea held its first launch of a Russo-South Korean rocket at its own launch site, NARO Space Center [3], and is currently developing the Korean Space Launch Vehicle (KSLV-I/II) [4]. The Brazilian Space Agency has set aside $650 million USD [5] for the construction of five launch pads able to be used by commercial operators, and is concurrently developing their own Satellite Launch Vehicle (VLS-1 V4) to be launched in 2013 [2].

Many reasons exist for nations to independently establish themselves within the launch market. These range from commercial interests, technological competitiveness, and economic and political power, to security concerns. These reasons are not unique to emerging space nations – nations such as the United States, China, Japan, Europe and India seek to remain competitive for the same reasons [2].

It is unlikely that these competing interests induce optimal synergies between spacefaring nations without an established global framework. Nations developing indigenous launch capabilities do not have the knowledge base of established space nations and hence are likely to make avoidable, costly and sometimes fatal mistakes (for instance the 2003 Alcântara VLS accident, where the Brazilian Space Agency's VLS-1 V3 exploded on the launch pad, killing 21 people [6]). There currently exists some cooperation between individual states (e.g. India's use of the Russian RD56M cryogenic propulsion system in the upper stage of their Geosynchronous Launch Vehicle (GSLV)), but no global framework exists [2].

2.2 Access-to-Space in Emerging Commercial Aerospace Companies

Emerging commercial aerospace companies such as SpaceX, Sierra Nevada and Blue Origin are innovating both technology and processes that can produce more cost-effective and capable launcher systems. Innovation, cost and economies of scale are major challenges when developing launcher capabilities. This is especially pertinent when considering the limited launch market. For this reason the ability to build low cost and efficient launcher capabilities is important and needs to be encouraged and assisted.

The identified challenges for emerging commercial aerospace companies are primarily to do with their relatively small size compared to established commercial aerospace companies (e.g. Boeing, Lockheed Martin) and include:

- Emerging companies who typically sign milestone-based contracts (such as COTS and CCDEV) are unable to absorb failure, setbacks or cost overruns as well as established companies which work using a cost-plus-fee approach.
- There will always remain barriers for government/defence projects to be launched on a commercial rocket. Technology Readiness Level standards and existing contracts may force government to continue to use established companies (e.g. United Launch Alliance) even if new actors (e.g. SpaceX) are able to offer a more affordable solution.

However, one advantage in favour of emerging commercial companies is that they are not as restricted or regulated by government protocols, and enabling them to take greater commercial risks.

2.3 Recommendations

After identifying the challenges associated with new actors in the launch market, the Industry Working Group decided upon three recommendations to promote new opportunities and to mitigate any negative effects of these new players. The first two recommendations focus on the support that the international community can provide to emerging space-faring nations, with the third recommendation concentrating on how national governments can promote the success of new commercial players in the private market.

2.3.1 Recommendation 1

Encourage established space-faring nations to strengthen their relationships with emerging space-faring nations in order to foster global growth and collaboration on launch efforts.

Strengthening relationships between established and emerging space-faring nations helps to decrease risks inherent in developing new launch systems by enabling increased technology transfer and sharing of best practices. Intuitively, it would seem that the emergence of a new player in the launch industry is detrimental to established nations, as increased competition results in lower potential market share. The impact however can be beneficial if judged across the entire enterprise. At times it is more cost effective for space infrastructure to launch from a partner state, due to more suitable systems or launch location.

A prime example of this is India's PSLV, which is capable of placing satellites into sun-synchronous orbits, a service which previously was only commercially viable from Russia [2]. Over its 19 years of operation, more than half of the 55 satellites it has placed in orbit have been foreign satellites, from a host of spacefaring nations including Germany, France, Russia and Japan.

The establishment of an interagency framework for the purpose of developing launch technology was considered as a means of enabling dialogue between nations. This has the potential to grow into an international organisation and regulatory body, capable of serving as a mechanism for technology transfer. Of course there are significant challenges associated with this due to the dual use purpose of the technology; the establishment of a regulatory body would work to help identify nations which focussed on increasing military might and nations focussed on fostering their own space program.

Established space-faring nations have the ability to positively affect the space programs of emerging space-faring nations, which has flow on effects for both the individual nations and for the global launch industry at large.

2.3.2 Recommendation 2

Advocate for the development of launch capacity in new space nations to encourage global competition in the launch industry.

This recommendation follows from the previous, as alongside a review of existing space policies it is believed that global efforts should be developed towards advocating and encouraging the establishment, development and progress of launch capacity in new space nations.

It is believed that by allowing new space nations to develop national launch capacity there will be an increase of research and innovation, especially if it encourages the development of new facilities, education and national priorities. This increase in innovation will be directly correlated to advancements in space-proven technology across all disciplines of the launch industry, including design, prototyping, research, manufacturing, testing, onboard technologies, ground support, tracking and recovery. As these developments reach globally standard technology readiness levels there exists an influx of launchers with new technologies that are more efficient, effective and cheaper. As a result there is greater competition, which further accelerates growth and progress.

As new space nations build their own capabilities they also build new systems policies, thus ensuring that the encouragement in developing launch capacities leads to nations developing holistic space programs.

Again a misdirected race for space access or a one-direction launcher utilisation policy by space-faring nations can be mitigated or avoided if this recommendation is taken in the context of building an international collaboration network or an international interface, whereby national security priorities are maintained, but allowing existing space nations to meet with new space nations and advocate for the development of their space activities, in particular regarding launch capabilities.

2.3.3 Recommendation 3

Enable the emerging private sector to access and create markets in order to foster competition, innovation and efficient operational capacity.

The emerging private sector is proving to be a leading provider of low-cost, efficient, effective and reliable space launch services. Recent successes of the SpaceX Falcon 9 and its twelve launch contract with NASA is evidence of the level of competence that the private sector is reaching. A predominant customer of launch vehicle and service providers is the government; however, as mentioned above, significant challenges face the private sector in terms of pre-existing government contracts, high security arrangements and a lack of 'black box' agreements for such customers. This has the potential to lead to stagnation in the industry. In addition, protecting national capability may prove to be counterproductive for the global launch industry as a whole. A notable example is the prohibition of US payloads being carried on foreign launchers. It is believed that by removing critical barriers to existing markets for emerging companies, as well as creating new markets in terms of international cooperation and collaboration for service/vehicle provision, there will be an influx of capability, thus forcing companies (both existing and emerging) to innovate competitively. This will result in greater choice, flexibility and cheaper launch capabilities.

Adopting national policies such as 'black box' technology is critical to this recommendation. Government and defence projects can carry 'black box' status whereby the payload is closed and secret from the vehicle/service provider and is installed by representatives from the customer with technical direction only from the provider. This will allow security protocols to be retained within a private sector business provision.

3 Economic Considerations of European Launchers

Europe has historically dominated the commercial satellite launch market, holding over 50% of the market share [7]. The emergence of new actors with space launch capability means that the European market must evolve to meet the challenges and economic advantages offered. The following section discusses European launcher competitiveness in the global landscape, as well as the necessity to drive forward the private industry in order to achieve optimal success.

3.1 Cost of European Launchers

The payload mass and cost overview of the three European launchers is given in Table 3.1.1.

Table 3.1.1: Cost of European Launchers

	Payload Orbit	**Payload Mass [kg]**	**Est. Total Cost [M€]**	**Price per kg [€/kg]**
VEGA [8]	700km#	1 500	32 [9]	21 333
Soyuz [10]	820km#	4 400	50 [11]	11 364
	GTO	3 250		15 385
Ariane 5 ECA [12]	LEO	20 000	120 [13]	5 713
	GTO	10 000		11 429

To be able to compare the prices to other launchers, the price per kilogram of the maximum payload is given (it should be noted that this assumes using the full payload capacity, otherwise the price per kg rises accordingly to the real launched payload mass). Table 2 gives the payload mass and price of the SpaceX launchers Falcon 9 and Falcon Heavy (assuming 1USD=0.787EUR).

Table 3.1.2: Price of SpaceX Launchers

	Payload Orbit	Payload Mass [kg]	Est. Total Cost [M€]	Price per kg [€/kg]
Falcon 9 [14]	LEO	13 150	54	3 232
	GTO	4 850		8 762
Falcon Heavy [15]	LEO	53 000	128	1 901
	GTO	6 400	83	10 206
	GTO	12 000	128	8 395

Even though it is not yet assured that SpaceX can meet their projected prices for the Falcon Heavy, this comparison shows the potential challenges ahead for Arianespace.

Note however that the price per kg might be misleading as it depends on the actual payload mass launched. A customer would not purchase the use of a Falcon Heavy to launch a small satellite when they could pay less by using a smaller launch vehicle that accommodates the capacity needed. Otherwise, they would be paying full-price for extra capacity that is not required.

3.2 Competitiveness of Europe

With the current organization of the launch sector, Europe captures most of the GEO satellite market, with Russia dominating the launch of LEO satellites [1]. Europe's equatorial launch site at Kourou and impressive performance record (52 consecutive successful launches of the Ariane 5) result in a high quality service that is favourable for commercial customers. Europe's capabilities have also recently been expanded with the introduction of the medium-lift Soyuz and small-lift VEGA launchers. Thus Arianespace is better accommodated to compete for smaller operations.

Furthermore, the US has taken their launchers (e.g. United Launch Alliance) off the commercial launch market, giving launch preference to their own government and military satellites (which comprised one-third of worldwide demand in 2011 [1]). Therefore, these launchers are no longer competing against Arianespace. However, the situation might change when companies like SpaceX try to capture part of the market.

Europe's Ariane 5 ECA rocket has a unique payload capability to lift ten tons to GTO [10]. At present the main competitor to the Ariane 5 is the Russian Proton launcher [1], which is capable of lifting six tons to GTO [16]. The Falcon Heavy, currently under development by SpaceX, has the potential to directly challenge the Ariane 5's payload capacity, with a projected capability of 19 tons to GTO [17].

While Ariane 5 ECA is serving the heavy-lift market, the European Soyuz and VEGA launchers complete the offered range of launch capabilities for medium- and small payloads. This development makes it possible to compete outside the GEO satellite market and provides a more flexible launcher family with smaller, cheaper launchers (albeit at a higher cost per kilogram, see Section 3.1).

3.3 Recommendations

They offer recommendations detail how the European space transportation industry can manage costs in order to increase competitiveness on a global scale.

3.3.1 Recommendation 1

Transfer ESA technical oversight of subsystem and component levels to launcher system integrators in order to reduce the cost of development programmes

Differences in launch prices between established European launchers and American private industry (e.g. SpaceX) can be attributed to a limited number of primary factors, namely that private entities are smaller, have a more specialised workforce and lower organisation complexity, minimise levels of outsourcing and have limited agency oversight for lower level design decisions [18]. Specifically, the reduction of agency oversight for the Falcon 9 was estimated at decreasing the development costs from $3.977B [18] to $300M [19]. In this business model, the contractor (i.e. SpaceX) is able to make design decisions at the subsystem and component levels, with system level verification carried out by the customer (i.e. NASA). The removal of external agency design reviews at all levels results in a decrease in cost.

The European Space Agency would be able to reduce costs by emulating this process. The reliability and performance of the launcher must still be able to be verified by system level tests, however technical oversight of all subsystem and component levels should be moved to the for launcher system integrators. Such a procedure may however be difficult to transfer to Europe. Specific issues which require further consideration are the complex organizational structure of the European Space Agency and the need for geographical financial return.

3.3.2 Recommendation 2

Recognise the potential of small launchers, such as VEGA, as a cost-effective response to the current trend towards small satellites and miniaturisation.

Small launchers like VEGA, which held a successful maiden voyage in 2012, have a lower development and manufacturing cost than medium- and heavy lift launchers, and can be used as a less risky option for developing new technologies, while at the same time offering a response to the miniaturization trend of modern spacecraft [1]. Small launchers like VEGA offer a payload capability from 300 kg up to 2 500 kg depending on the desired orbital destination [20] – this smaller payload mass (and therefore lower total launch cost) enables new payloads from emerging space-faring nations, academic institutions and private entities. New applications for small and cube satellites would be developed and the idea of easy space access can be promoted.

While the global market of small satellites (<500 kg) increased in the last five years, the small launcher market (<1500 kg) did not react to this development. As such most of these spacecraft were launched as non-primary payloads and in clusters on bigger launchers. [1] Though multi-launch capabilities might be a good way to utilise the full capacity of a launcher, and decreases the price for each customer, it adds to the complexity of launch operations (e.g. finding suitable satellites). Small launchers like VEGA answer the recent trend and offer more flexibility for customers with small satellites.

With regards to the European launch sector, VEGA can be seen as a completion of the European launcher family, with Soyuz serving the medium-sized payload market and Ariane 5 the heavy-lift market. Moreover, it allows countries like Italy to enlarge their involvement in space transportation.

3.4 Unresolved Recommendations

In addition to the recommendations outlined above, several other possible solutions were discussed in detail. Although consensus was unable to be reached for these topics, they were discussed at length and hence are mentioned here to provide a comprehensive summary of the Working Group discussions.

3.4.1 Simpler Systems

A possible way to decrease launch costs in the European market is to simplify launch services. This stems from the idea used by the Russian Federal Space Agency and their dependence upon reliable Soyuz technologies for launch systems. The success of the Soyuz technologies indicates that systems do not need to be complex to achieve their goals and serve the market. Moreover, heritage and simple technologies can help to cut the costs associated with development and risk, and seem an adequate choice for the current situation.

There was further discussion on the possible use of smaller launchers (such as VEGA) as technology testbeds for long-term larger launcher development, due to their relatively low costs (such as the Ariane 5). The technology could hence be rolled out to heavier launchers once it is flight proven on a smaller scale. VEGA is a perfect example of this, utilising three solid stages with proven and relatively simple propulsion systems, but with innovative graphite fiber/epoxy resin engine cases in order to reduce engine mass [21]. This resulted in the first stage P80 engine being the largest single launcher engine ever built, and the third stage, Zefiro 9, the most efficient solid propulsion launcher engine in the world [22]. This technology, now proven with VEGA, could now be rolled out to heavier launchers.

It should be noted that there was considerable debate about the feasibility of this structure, particularly given the current emphasis of the European Space Agency to support the development of new and innovative space technologies.

3.4.2 Development of the Private Sector

Among the major topics discussed was the excitement involving the development of the private sector. The development of this sector allows for the emergence of competition, achieved through the propensity of firms to undercut each other.

It was recognized that developing the private sector is a way to decrease operating costs. The emergence of SpaceX in the United States marks the beginning of this era.

Furthermore, private firms have autonomy in deciding which operations to engage in. They are not subject to same level of bureaucracy and scrutiny as government-led operations. However, it is important to note that SpaceX’s largest customer is the US government, and even though SpaceX is not government owned, the buying power of the US government allows them to dictate which products and services SpaceX provides.

Compared to the United States, the European private sector faces issues regarding the number of launches needed to sustain a viable market. Europe requires fewer launches than the United States per year, meaning that it is more difficult for competitive companies to sustain themselves without government support.

The current trend of miniaturisation in satellite technology may lead to more opportunities and customers, which may, in turn, lead to the creation of a bigger, self-sustainable European market.

Furthermore, the American private sector has been pioneered by billionaire entrepreneurs willing to take risks in the space industry by creating unique business plans. However, in Europe, commercial companies such as Arianespace emerged with the intention of taking on the role of government in launching satellites. Hence their remains a fundamental difference in the philosophy behind the European launch sector.

4 Policy and Regulatory Considerations of Space Transportation

Policy, regulations, and technical expertise, form the backbone of space programs. It is no surprise that the emergence of new actors with launch capabilities and the changing shape of the global launcher market brings several political and regulatory challenges that must be considered. These include space debris, range safety, launcher sustainability and export regulations. This section provides a discussion of these identified issues, and provides recommendations on ways to address them.

4.1 Space Debris

Upper stages that remain on orbit are already a serious debris problem, as they are often large objects and form a significant portion of the on-orbit debris [23]. The Inter-Agency Space Debris Coordination Committee has established space debris mitigation guidelines [24] that are voluntarily followed by partner nations. In accordance with this, certain established launch vehicles, such as the Vega, Delta IV and Proton-M/Breeze-M possess the capability for deorbit of their upper stage, depending upon mission trajectory and payload [25-27].

Conversely, emerging space nations are not required to focus on minimising orbital debris, concentrating instead on developing technology in order to achieve the specified goal (i.e. place an object in orbit). Partially-failed upper stages pose a further threat to space debris, as they place volatile material in orbit which has the potential to explode and hence increase the amount of debris. This is exemplified by the 2012 explosion of the failed Russian Breeze M upper stage, which was launched earlier that year [28].

In relation to the de-orbiting the upper stages of launch vehicles and debris removal, the Outer Space Treaty [26] grants jurisdiction and control over an object in space to the launching state. Further problems arise, however, if the object would be removed by another party. It might pose potential liability issues or even intellectual property issues. Additionally, according to the Registration Convention [30], the launching state is not required to provide any information about debris created after the launch. It may sometimes pose a practical problem of determining the launching state. What is more, some space objects are not registered at all.

4.2 Safety Issues

Emerging space-faring nations are at the early stages of developing their capabilities, which means a wide spectrum of launch practices. This has the potential to cause safety issues where proper care is not taken with storage or range safety, highlighted by the Alcântara VLS accident in Brazil, 2003 [31]. The question hence arises whether the new space-faring nations have to pass through the initial dangerous failures of previous space programs, or if it is possible to work on preventing them.

4.3 Ensuring Sustainability of Launching Capabilities

The entrance of new players to the space market means more payloads, more launches, and potentially more issues in ensuring the sustainability of launch capabilities. Key examples of sustainability issues of an increased number of launchers are the increase in air pollution due to plumes from launch vehicles [32], and the increase in space debris due to partially-failed launchers (e.g. the Russian Proton-M Breeze failure in 2012 [28]).

4.4 Export Regulations

Intellectual property and export regulations, such as the United States' International Traffic in Arms Regulation (ITAR) or similar regulations in other countries are current barriers of international collaborations within the space industry. The purpose of these regulations is to prevent the proliferation of dual-use technology, which can be appropriated for military purposes, by means of an export control. They also restrict technology retransfer, where old hardware from experienced space nations is sold to emerging space nations. The effect of these regulations is exemplified by the recent issues between Europe and Russia, with the European ExoMars mission unable to use a Russian Radioisotope Thermoelectric Generator (RTG) [33].

4.5 Delimitation of Airspace and Outer Space

Delimitation between airspace and outer space has not yet been created, and it is important to note that air law and space law are two completely different legal regimes in this respect. According to Article II of the Outer Space Treaty, outer space and all celestial bodies are not subject to national appropriation by any means, while the Chicago Convention grants every country full and exclusive sovereignty over their national airspace [34]. Delimitation is therefore important not only because of the sovereignty issue, but also because of its impact on launching, liability, intellectual property, and other issues.

Over the years the UN COPUOS received many proposals regarding demarcation between airspace and outer space. However, to this day there is no legally binding definition for the term. There are few legal documents where some definitions concerning specific areas can be found, which could be a base for an internationally accepted definition. Within the EU Regulations can be found for a definition of “space qualified [objects]” which refers to “products designed, manufactured and tested to meet the special electrical, mechanical or environmental requirements for use in the launch and deployment of satellites or high altitude flight systems operating at altitudes of 100 km or higher” [35]. Another legal definition can be found in Section 8 of the Sporting Code of the Fédération Aéronautique Internationale (FAI). It stipulates that to gain international recognition of flights in space by men and women “all flights must exceed an altitude of 100 km in order to qualify for records” [36].

Until one legally binding demarcation is established, countries must operate within existing legal boundaries.

4.6 Recommendations

A list of recommendations has been made facing the challenges that have been presented so far regarding policy and regulatory considerations of space transportation. The recommendations are on promoting international efforts on various aspects: not only promoting the deorbiting of the new upper stages but also promoting the idea of launch sustainability and sharing the safety practice for launch base. Moreover, while it is recognized that export control rules on space technology cannot be removed, the creation of technology interfaces for launches show promise to enhance collaboration between nations without risk of technology transfer.

4.6.1 Recommendation 1

Support international efforts to promote national policies requiring launch vehicle operators to deorbit upper stages.

It has been identified that debris mitigation is required to prevent the generation of a runaway amount of debris in the so-called Kessler syndrome [26]. Fostering a global consensus on space debris mitigation is necessary. The Industry Working Group recommends that space-faring nations support international efforts in encouraging launch vehicle operators to deorbit upper stages. This can be accomplished through a modification of the existing upper stage such as adding a restart capability, increasing the fuel capacity or developing innovative systems of passive de-orbiting (i.e. solar sails, tether, drag augmentation device, etc.). As previously mentioned, several launchers have already been equipped with this capability.

4.6.2 Recommendation 2

Support the creation of international mechanisms to introduce more safety and sustainability into launch vehicle operations and site practices, such as:

- The sharing of best practices for safety at ground facilities;
- International research on environmentally friendly fuels and vehicles.

Support of the creation of international mechanisms to introduce more safety and sustainability into launch vehicle operations and site processes is a way to help countries develop safer and more reliable space programs. It also prevents incidents that can affect the perception of nearby countries and the general public on the reliability of space programs. Sharing such practices for safety at ground facilities and mitigation strategies for disaster management would avoid transfer of security-sensitive technology.

As previously mentioned, new players mean new launch attempts and even if it seems to be a far scenario, we must start thinking of the sustainability of space transportation, in both the launch and dismissal phase. Therefore it is recommended to study a more sustainable and internationally coordinated access to space involving the research of green propellants, as well as into systems to avoid explosions of the remaining propellant once the rocket is considered debris. The explosion of remnant upper stage propellant not only causes an increase in the amount of debris (e.g. the Russia's Proton Breeze-M explosion on October 16, 2012 [28]), but in some cases also releases harmful chemical substances into the atmosphere. For example, hydrazine, a standard space propellant, reacts with ozone and hydroxyl radicals producing ammonia and nitrogen gas, which posed possible issues in the Phobos-Grunt re-entry [37].

4.6.3 Recommendation 3

Explore opportunities to foster international trade and cooperation in spite of relatively stable national and international controls on space exports and technology transfers, such as:

- Using agency prerogatives and exemptions available within the existing U.S. export control regime;
- Creating an international expert group to study "buffer" or "interface" technologies that address transfer concerns.

For purposes of national security, export control regulations such as ITAR are necessities and are unlikely to change in the short term. Agencies and companies of emerging countries have to work according to the laws and policies, and should investigate alternatives or allowances within the regulations when requesting access to specific technology.

Nevertheless, it has to be recognised that these regulations (especially ITAR) are often applied too broadly, hindering the international collaborations as well as new actors' entry into the space industry. In the long term, the export control regulations should work to be more tailored to specific technologies and players, expediting access to allowable technologies but not compromising the core of the regulations themselves.

From the non-commercial side, sharing non-security-related technologies such as launch management and range safety could be a starting point. From the commercial side, policymakers (and industry beneficiaries) should balance the national security and economy. Regarding to this, it has to be remembered that "ITAR's impact of increased regulations also meant America's worldwide market share in satellite technology declined from 83% to 50% in 2008" [38]. A restructuration of the policy is necessary to distinguish between dangerous and safe technologies to export.

Another way to work around these strict regulations is to create an institutional framework for compartmentalized missions that will protect national security of spacefaring nations. Within this framework, spacefaring nations could meet at collaborative interfaces such as universal adapters serving as a buffer, as successfully demonstrated in compartmentalized projects including Soyuz launches in French Guyana and the Sea Launch platform.

5 Conclusion

The space launch industry is a complex organism, which is constantly evolving. It is multifaceted, and the needs of individual players and issues must be balanced against the needs of the global industry. The SGC Industry Working Group has come to the conclusion that both cooperation and competition are required for a successful industry to be realised. International cooperation is key for emerging space nations in order to ensure that lessons learned from the past are properly taken into account. Also cooperation is important between space agencies, traditional aerospace companies and the private sector, so as to reduce duplication of oversight and hence costs. Competition, however, remains a driver for both innovation and cost reduction, especially within the private sector. There is admittedly a fine balance that must be reached between the two values of collaboration and competition; if the key players can remain steady on this tightrope, then global growth and stability of the industry will result.

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ISS UTILISATION: 2020 AND BEYOND

Group Participants

Name	Position	Nationality
Kathleen Coderre*	Moderator	USA
J. Michael Hawes*	Subject Matter Expert	USA
Michael Deiml*	Rapporteur	Germany
Matthew Noyes*	Rapporteur	USA
Adam Vigneron*	Rapporteur	Canada
Bustanul Arifin	Group Member	Indonesia
Seungmi Chung	Group Member	Republic of Korea
Guerric de Crombrugghe	Group Member	Belgium
Andrea Faber	Group Member	Australia/ Italy
Anja Frey	Group Member	Germany
Lívia Galhego	Group Member	Brazil
Conny Hansson	Group Member	Sweden
Guzel Kamaletdinova	Group Member	Russian Federation
Ben Kefford	Group Member	Australia
Michael Kretzenbacher	Group Member	Australia/ Germany
Katrin Park-Speck	Group Member	Switzerland
Shivani Patel	Group Member	Australia
Simone Pirrota	Group Member	Italy
Magaly Sandoval	Group Member	Costa Rica
Romy Seth	Group Member	Canada
Nathan Silvernail	Group Member	USA
Rogel Mari Sese	Group Member	Philippines
Christopher Thang	Group Member	Australia

***Members whose participation resulted in the final report**

1 Goal of this Study

With the extension of the International Space Station program until 2020 and possibly beyond 2020 (de Seldig 2010) (Clark 2010), attention now turns to station utilisation. In this report, we will highlight possible uses of the ISS until and beyond 2020. We will then delve deeper into two fields with long-term implications for space programs: Mars exploration and education & public outreach. By doing this, we hope to continue the dialogue on ISS utilisation to maximise its benefit for humanity.

2 The International Space Station: An Introduction

The International Space Station (ISS) is the largest man-made orbital structure ever built. It is fully operational at the moment and its system lifetime is not yet met. Five major partners have been involved in ISS development and operations: NASA, ROSCOSMOS, JAXA, ESA and CSA. Thus the ISS can be seen as a successful ongoing international collaboration.

The ISS is a unique tool for research and development, because projects can be performed in a micro-gravity, high-radiation environment, which can be supported by humans in space for long durations. No other space vehicle currently has these capabilities. Either satellites are unmanned (which makes it difficult to adapt on unforeseen outcomes of experiments), or they stay in orbit just for a few days or weeks as the Space Shuttle has done.

Hence, the ISS opens access to a variety of new projects and experiments. However, the ISS competes for funding with other programs. NASA's Mars exploration program in particular requires significant investment limited by the agency's overall budget. The funds allocated to the ISS are capable of accelerating the Mars exploration program. Thus NASA had discussed stopping the ISS program, but it was decided that the ISS will be maintained until 2020 with a possible option of extension until 2028 (de Seldig 2010) (Clark 2010). This decision was in accordance with NASA's partners being unwilling to abandon the station at this point. ESA's Columbus module, for example, has been in orbit since 2008 with a decade-long lifetime that has yet to be exhausted (ESA 2010). All of the partners are now in the process of formal concurrence with the 2020 extension.

3 Uses of the ISS Beyond 2020

What will happen to the ISS after 2020? In general there are three options:

1. De-orbit and termination, which will incinerate major parts of the ISS and deposit the rest across the ocean.
2. Salvage certain modules of the ISS, boosting them to a graveyard orbit until they can be repurposed in Earth orbit, lunar orbit, or at a Lagrange point.
3. Continue operation beyond 2020.

This discussion focuses on the third option. There are some difficulties which must be adequately studied and overcome when considering ISS use beyond 2020. At that time many components will be near (if not in excess of) their expected lifetime. A risk analysis must be performed to evaluate this decreasing marginal return.

Furthermore, operational costs are high and must be mitigated to make an extension attractive. More efficient systems are likely to exist in 2020. Opportunity costs resulting from new endeavours and technology must be weighed against the value of the station. At the moment this value seems to be still higher, but there must be a more detailed study to examine if this still holds in 2020. Evaluation depends on the option, chosen for the use after 2020. In this paper four different paths for continued operation are studied:

1. Using the ISS as a space tourism hotel;
2. Using the ISS as a mining post-processing facility;
3. Parking the ISS in lunar orbit as exploration outpost; and

4. General-purpose commercialisation of the ISS.

It is anticipated that fourth point will yield the most promise.

3.1 Using the ISS as a space tourism hotel

The ISS can be used as a space tourism hotel after 2020. Therefore further modules will have to be launched into space, or existing modules will have to be transformed. Tourists would have a unique experience, which they share only with a few other people from the world. It would be a novelty for mankind to have a tourist destination in space. On the other hand, a hotel requires staff, which increases the operational costs. Thus a vacation on the ISS would be very expensive and also more dangerous than a typical hotel. Overall there are many difficulties and it is questionable if it is possible to earn money in such a business. Thus this utilisation plan is less promising.

3.2 Using the ISS as a mining post-processing facility

In this option the ISS would be utilised as a manufacturing facility for materials harvested from extraterrestrial bodies such as the moon or asteroids. The ISS can mitigate costs of these endeavours by reducing investment in new infrastructure. A further advantage is that automated processes can be inspected and maintained by stationed astronaut crew.

Note that during post-processing, waste becomes difficult to dispose of while in orbit. Thus it may be more efficient to perform the post-processing on the lunar surface and leave waste behind. But the biggest problem with this option is that the implementation of lunar mining projects would have to start relatively soon.

3.3 The ISS in a lunar orbit

A third option is to put the ISS in a lunar orbit and use it as “SkySupport” for lunar ground missions and/or as an assembly platform for interplanetary spacecraft. This option has multi-purpose applications for future exploration missions. However, communication issues arise if the ISS is in lunar orbit due to lunar eclipse periods. This can be solved by extending existing satellite communication networks. The velocity increase required to transfer the ISS from low Earth orbit to lunar orbit will be both complex and expensive due to the stations relatively large mass. It will also become more difficult to maintain the ISS at a lunar orbit. Overall it is a possibility if significant funds are invested in extended lunar and Mars exploration programs.

3.4 ISS Commercialisation

The fourth option for post-2020 ISS operation is general commercialisation. In this approach, a private utilities company takes over logistics for the ISS. Industry can purchase or rent module research racks and hire their own astronauts for research and development. Module ownership would still belong to ISS partner agencies.

A tiered pricing strategy allows individualisation and parallels the station’s modular design. In the long run, “shares” of the ISS can be traded as in a stock market on a per-country basis. Thus US companies can buy shares of the NASA-owned modules; European industry can purchase shares of modules developed by their country’s space program, and so on. This affords more transparent and efficient resource allocation. Furthermore, the station can still function as a production facility for goods requiring micro-gravitational manufacture. These products are ideally made for mass market profitability.

There are many advantages to general commercialisation. Each partner can sell its portion to its domestic industry, which maintains sovereignty. It frees resources for exploration missions, transferring operational costs to the private sector. The main purpose of the ISS will shift from basic research to applied science. As viable commercial output increases, so does the value of the space station.

This scenario may be difficult and time consuming to implement with each partner nation's consensus, which must be taken into account. Furthermore, the private sector has no obligations concerning the ISS beyond financial incentive, which makes successful marketing essential for sustainable operations.

3.5 Recommendations

It is recommended to continue operation of the ISS beyond 2020 to drive space commercialisation forward. The near term implication is that a framework must be developed allowing private industry to organise their space development program. To incentivise industry, basic research should be scaled down in favour of applied science.

4 International Space Station as Mars Analogue

Analogue missions are an important preparatory step for human space exploration (NASA 2011). The recently released Global Exploration Roadmap (ISECG 2011) affirms these efforts while providing an ultimate goal for further exploration: the planet Mars.

4.1 Analogue Missions for Mars

A variety of analogue missions have been conducted in support of future Mars exploration (Felix 2009). Some modelled the harsh Martian environment using earthbound extremes; example programs include expeditions to the Flashmine Mars Arctic Research Station (FMARS) on Devon Island and the undersea Aquarius habitat in the Florida Keys. Others, such as the Mars500 program, focused on the human aspect of exploration through long-term operations in isolation.

The experience gained from research conducted in these analogue environments has led to considerable improvements in exploration practise and technology. These advances have been recorded by the Mars Society, which keeps a database of all publications related to simulations performed at its analogue stations (Mars Society 2012). This record preserves the role of analogue missions in the exploratory process, ensuring long-term mission viability and affordability.

4.2 The International Space Station for Mars

Continuously occupied for over ten years, the International Space Station (ISS) is humanity's greatest research platform for long-term space habitation. It is therefore an appealing candidate for certain aspects of Martian analogue activity.

From a physiological standpoint, it is the only current laboratory for long-duration human-rated microgravity testing. While the effects of microgravity (e.g. bone loss, muscle atrophy, space motion sickness) have been identified, much is to be determined about the long-term implications of this environment (Ball & Evans 2001). A particularly pressing concern is the emerging issue of astronaut vision loss, a phenomenon not fully understood (W. Gerstenmaier, personal communication, 28 Sept 2012). Further study will solidify whether artificial gravity will be required for a human mission to Mars.

As an on-orbit human habitat, the ISS possesses operational qualities ideal for analogue missions. With a full-time crew and dedicated ground control operating by space-appropriate telecommunications it models the operational setup of exploration missions. Both daily and emergency operations are implicitly affected by the isolation[1], confinement, and stresses inherently associated with the extreme environment of Earth orbit. In addition, the ISS is well-suited for the development of mission practices in microgravity; notable among these are space medicine practices, necessary for any long-duration mission.

The astronauts onboard the ISS are under a constant psychological strain effected by an "operational setting in which time-critical decisions with major consequences are required." (Williams 2009) This emulates aspects of the strain presented by of long-term exploration, where crewmembers will have to deal with induced psychiatric problems with no possibility of evacuating an affected individual. Further research and mitigation techniques are required, both in team selection and preparation and in problem mitigation as they emerge (Clément 2003).

Above all, the key strength of the ISS as an analogue mission laboratory is its ability to model these characteristics (physiological, operational, and psychological) simultaneously.

4.3 Advantages for ISS partners

The use of the ISS for a Martian analogue mission program holds definite benefits for the current ISS partners. The new program will provide the opportunity for international and commercial cooperation, potentially enticing new partners to the ISS effort. The analogue missions will provide new material for the already-established means of ISS public outreach to the benefit of both programs. Finally, participating nations and organisations will gain experience in autonomous operations, experience applicable across a wide range of fields.

In addition to these benefits, Mars analogue missions are in line with many of the "Lessons Learned" from the ISS program to date (Laurini 2011). By their nature, analogue missions embody the ideals of early planning and ensuring mission affordability by identifying many of the risk factors and operational details. The Lessons Learned can also shape the analogue mission profile. Any analogue mission aboard the ISS must appeal to all partners through appropriate interdependencies and country-specific returns. In addition, care must be taken to ensure such a program provides tangible benefits for public support.

4.4 Completed Analogue Missions

Analogue activities in support of Mars exploration have been conducted onboard the ISS:

1) At the end of ISS Expedition 6, a malfunction during Soyuz re-entry caused the spacecraft to enter ballistic mode and land some 475 kilometres off target. The crew was forced to perform autonomous egress and basic survival activities. This, coupled with the six-month stay in space, realised an (unplanned) Martian landing analogue (Pettit 2010).

2) Crews onboard the ISS repaired an exercise bicycle without real-time communication from the ground, relying instead on pre-recorded instructions in a simulation of Mars communication delay (W. Gerstenmaier, personal communication, 28 Sept 2012).

4.5 Proposed Analogue Missions

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[1] Note that the ISS is the not the only laboratory capable of simulating such an environment:
"From a technical standpoint (i.e. communication with the mission control, command/data handling), ground-based analogue missions can simulate sufficient 'isolation condition'. The isolation was reinforced by the several hours of nitrogen purging required before we come out of the [Aquarius] habitat to surface. These operationally challenging conditions in case of an emergency made us feel more like in a space flight."

- Koichi Wakata, JAXA astronaut, ISS Expedition 18/19/20, NEEMO 10 (personal communication, 30 Sept 2012)

In anticipation of future Mars analogue activity, NASA has established the ISS Testbed for Analog Research (ISTAR) program. This program plans a series of analogue missions of increasing length and fidelity. The first will feature one crew member operating on time-delay, with later missions evolving based on early results (Lee 2012).

In addition, plans were recently announced to conduct a one-year expedition to the ISS. This expedition, consisting of one American astronaut and one Russian cosmonaut, will allow long-term physiological effects to be examined more closely (Kraft 2012).

4.6 Recommendations

4.6.1 AnalogRecom: Perform one-year expedition.

A one-year simulation will allow a focused study of long-term physiological effects without significantly disrupting the current six-month schedule of ISS expeditions.

4.6.2 AnalogRecom: Include 3 or 4 crew members and ground control in analogue simulation.

A multi-member flight simulation supported by a dedicated team of ground control personnel will provide the most realistic analogue of the significant undertaking required for an actual Mars mission. The remaining astronauts onboard the ISS will ensure that normal station activities continue.

4.6.3 AnalogRecom: Involve private companies and countries that are not ISS partners.

As a future Mars mission will be an international endeavour, analogue missions provide an early opportunity for new international partners. New industry partners can specialize and ultimately reduce costs through competition.

4.6.4 AnalogRecom: Emphasise public outreach.

Involving the public at all levels will ensure continued support for future Mars exploration.

5 Using the International Space Station as an Outreach Tool

The International Space Station is a valuable asset to encourage interest in Science, Technology, Engineering, and Mathematics fields, as well as a general interest in space and the societal contributions of space programmes. To use this asset effectively, the outreach activities must be clearly defined.

What audience should outreach target? There are many standing to benefit from outreach -- young students who want to learn about space, older students who want to do research in space, the general public outside the space sector, and political representatives are all affected in different ways by a space programme, and outreach should target their specific desires.

Should the space station be used directly for outreach, or should it be a focal point for discussion? Students and the general public can be directly involved in the day-to-day activities of the ISS through astronaut interaction, student experiments onboard the station, and interactive smartphone technologies. However, time and resources dedicated to outreach have a direct impact on ISS research output.

Will outreach include all nations or only ISS-partner nations? ISS partner nations deserve to have their citizens see the products of their investments. However, if the ISS is to be truly international, non-member nations should be included, especially if outreach can stimulate interest in science and engineering or show the benefits a space programme can offer developing countries.

5.1 Recommendations

5.1.1 Target Audiences

ISS outreach should focus on three core audiences. The first audience, young children and students, represent a group who may one day become the scientists and engineers of tomorrow. Outreach should emphasise interactive, hands-on activities encouraging problem solving, the scientific method, and so-called "citizen science." They should encourage "active" participation; for young students, this could involve games to design and build their own space station. For older students, this could mean opportunities to perform research with ISS resources, much like an existing NASA programme for students to perform microgravity experiments on board a modified jet.

The second audience, non-technical public, represents members of the general public who may not be interested in pursuing careers in science, but who would like to learn about space. Programmes for this audience may be passive (televised explanations of long-term benefits, such as spinoff technologies resulting in vaccine development). Outreach must keep the public informed about their investment, and reinforce the positive effects on society.

The third audience, political representatives, have similar motivations to the general non-technical public, with the exception that outreach should focus on short-term benefits such as job creation and economic impact. These benefits stimulate continued investment in space.

5.1.2 Use of the ISS in Outreach Programmes

The use of the ISS for direct public outreach is recommended in some limited cases. There has been considerable success in the past with radio communication between students and ISS crew, and such use to should be expanded to non-partner nations.

Furthermore, the Center for the Advancement of Science in Space (CASIS) was recently formed to encourage business ventures and scientific research in sustained microgravity through ISS resources; such a programme can easily be used for student research on board the station.

Due to scaling issues, it is preferable that a majority of outreach not directly involve the ISS. However, for the young children and students audience, ISS interaction is highly preferred.

5.1.3 ISS Outreach in Non-Member Nations

It is recommended that resources be allocated to support outreach using the ISS in non-member nations. Outreach will help instil an interest in science and technology amid students - this is vital for growing the economies of developing nations. The general public and political representatives of developing nations will be made aware of the ways in which space-related technology can improve lives indirectly (through vaccinations and other technologies developed on the space station) and directly (crop-monitoring and weather monitoring). This will allow these nations to consider them as a means of improving the domestic standard of living. Further, it may allow for investment in their own or collaborative space programmes.

5.2 Types of Outreach Programmes

5.2.1 Smartphone/Web Technology

It is recommended that smartphone and web technology be explored for general public outreach. In developed nations, smartphones are highly interactive, personalised media delivery systems that have excellent potential for information delivery. Example media platforms include NASA TV, ISS Live (a smartphone application which streams flight data from the space station), SpaceLab for iOS (originally used to perform space-based experiments in microgravity, it is now available for the public to get a sense of tasks performed by ISS crew members), and popular games like Angry Birds Space. Through these channels, smartphones allow the public to learn about space in fun and exciting new ways.

However, smartphone and web technology should not be relied on exclusively. At present, developing nations do not yet have the required infrastructure for this to be effective. Furthermore, applications must “go viral” to have a widespread effect, and there is no definitive formula for creating a successful mobile application. Finally, it is not very “hands-on” despite the interactivity. To truly encourage future scientists and engineers, real-world activities are needed.

5.2.2 Hands-On Programmes

It is recommended that hands-on programmes be used for all audience subgroups. These activities allow participants to directly see or experience the results of space technology. Example activities include communicating directly with the ISS through radio, meeting astronauts, seeing and using examples of space spinoff technology or hardware, museums and exhibits, experiencing simulated space missions, and engineering interest programmes with building and design components.

The intent is to provide tactile, learning experiences that are much less forgettable than consuming electronic media. Students might develop their own space station as part of an engineering competition. The general public might go to one of the many new museum locations for the retired space shuttles. A politician might visit a local space centre to see the technology being developed and what local businesses are expanding due to that investment. These programmes are more difficult to implement than electronic media, but offer higher-quality experiences that can potentially be used in developing nations without required technology infrastructure.

5.2.3 Citizen-Science Programmes

It is recommended that citizen science programmes be implemented for the young children and students and general public subgroups. Citizen-science serves a function beyond typical outreach -- they allow real contribution to scientific knowledge. These programmes may be electronic or hands-on in nature. Though they are difficult to create, these opportunities instil an interest in actually doing science, not just learning about it. For students, this means encouraging future careers in technical fields. For the public, this means playing a role in technological progress regardless of background.

A recent example includes a game regarding a then-unsolved protein-folding problem which, upon release, was solved within days by the public. An ISS-related example could be a smartphone game to manoeuvre the ISS out of the way of incoming space debris. By harvesting thousands of player manoeuvres, the most efficient path could be calculated.

A more hands-on activity might allow students to actually perform research on board the space station (for which CASIS is an excellent application), analyse climate data collected on the station, or to write more efficient software for a given system.

5.2.4 Shuttle Carrier Aircraft Flying Museum

In order to best combine the previously discussed recommendations into a single course of action, the public relations success NASA recently experienced by flying space shuttles on a tour around the United States before delivery to museums should be noted. Now that the Space Shuttle has been retired, the Shuttle Carrier Aircraft is available for a new use. Given findings regarding the importance of hands-on programmes and reaching out to the public, it is recommended that the Shuttle Carrier Aircraft be converted into a flying museum dedicated to the International Space Station and other space endeavours. This museum may contain ISS interior module mockups, a radio for communicating with astronauts in the ISS, exhibits to showcase spinoff technology or other outreach, and hands-on interactive experiences discussed previously. The museum, being mobile, can travel to both ISS-member and non-member nations, acquiring funding through local museums, educational institutions, political groups, donations, entry fees (based on the nation’s discretionary income), and capitalise on other activities such as air shows in a given location.

Some nations have already had success with this type of system, from NASA’s United States shuttle tours to the use of a mobile bus museum in the Philippines. A programme like this allows outreach to be brought directly to the people, leveraging existing resources and targeting each audience subgroup in turn.

Regardless of the paths chosen, the ISS remains a strong candidate for space-related outreach potential for nations around the world.

6 Conclusion

The ISS is a valuable international space asset, and can continue to be so following the end of its currently scheduled lifetime in 2020. The SGC Agency Working group recommends offsetting high maintenance costs by selling or renting portions of the space station to private industry. Portions owned by a specific government should be distributed only within those countries, to preserve the sovereignty of the parent nation's assets. These assets will be used to encourage applied research, development, and manufacture of products and materials requiring a long-term microgravity environment. Some sections of the ISS should be kept available for long-term Mars analogue research in support of future exploration. Finally, the ISS has excellent potential for public relations. Outreach programs should encourage interest through new smartphone and web technologies, hands-on programs, and citizen-science activities within all nations. All of these strategies can be combined through the repurposing of the Shuttle Carrier Aircraft into a traveling "museum" educating and involving the public in benefits and opportunities afforded by the ISS and space technology.

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SOCIETY SESSION REPORT – SPACE FOR HUMANITARIAN RELIEF

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CRISIS: CENTRE FOR RESPONSIVE INFORMATION FOR SAFETY AND SECURITY

Group Participants

Name	Position	Nationality
Ross Findlay*	Moderator	United Kingdom
Tiffany Chow*	Subject Matter Expert	United States
Edu Aymerich*	Rapporteur	Spain
Zhuoyan Lu*	Rapporteur	China
Laura Rose*	Rapporteur	Canada
Jack Yeh*	Rapporteur	Australia / New Zealand
Natassa Antoniou	Group Member	Greece
Brooke Balogh	Group Member	Australia
Laszlo Bacsardi	Group Member	Hungary
Elizabeth Blaber	Group Member	Australia
Ho Hin Cheung	Group Member	China
Katerina Czech	Group Member	Russian Federation
Ece DaÄŸdeviren	Group Member	Turkey
Olavo De Oliveira Bittencourt Netto	Group Member	Brazil
Sandra Gonzalez Diaz	Group Member	Spain
Takafumi Harada	Group Member	Japan
Nicole Herrmann	Group Member	United States
H. Aziz Kayihan	Group Member	Turkey
Aafaque Khan	Group Member	India
Julia Leeson	Group Member	Australia
Daniel Martinez Arenas	Group Member	Mexico
Amanda Mowle	Group Member	United States
Yuta Nakajima	Group Member	Japan
Aaron Persad	Group Member	Canada
Vik Udyawer	Group Member	New Zealand
Burak Yaglioglu	Group Member	Turkey

***Members whose participation resulted in the final report**

1 Introduction

A humanitarian crisis is a crucial point of difficulty or danger to the health, safety or security of people. It is a potential turning point where a decisive and pivotal decision must be made and, depending on the courses followed, human health and safety can either be restored or worsened. Currently, we are not isolated from crises: economic calamities, natural and manmade disasters, health epidemics and armed conflicts are all sources of concern. In these scenarios, decision makers must take rapid actions to resolve the situation.

Accurate, real-time data is indispensable for efficient and rapid decision-making in crisis-based humanitarian relief. Fortunately, space applications offer numerous benefits for assistance, including via remotely-sensed data and earth observation technology. However, there are many challenges associated with utilizing this data in support of humanitarian relief efforts. These challenges include:

1. How to raise awareness about the use of space for humanitarian relief;
2. How to get the right data to the right people at the right time;
3. How to efficiently coordinate between data users and providers;
4. How to ensure data affordability and sustainability;
5. How to overcome political obstacles (such as conflicts of interest among parties);
6. and, How to best exploit social networking and new media tools.

Based on these concerns and after three days of intensive teamwork and discussion, the 2012 Space Generation Congress (SGC) Society Working Group proposes the establishment of a Centre for Responsive Information for Safety and Security (CRISIS), an international coordination body for providing space-derived information in support of humanitarian relief.

The organizational purpose of CRISIS is to act as an interface between data providers and users, to apply political pressure and to promote public support. It will also address novel ways of incorporating new media tools alongside space assets.

2 Current Trends

Satellite resources have, since their inception, provided society with a unique vantage point for identifying physical anomalies on Earth. The origins of these aberrations can be categorised as either natural or man-made and differ in the processes of data flow from Earth observation satellite resources to the end user.

In the case of natural disasters, the objective of each party involved is identical: to provide the necessary resources to support disaster management and relief in an efficient manner. The response framework includes aspects such as the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) [1] and Services and Applications for Emergency Response (SAFER) [2], which facilitate the flow of information to end-users in a timely fashion. In the case of humanitarian catastrophes, the parties involved typically operate on their own and towards their own agendas. The political chaos which can ensue includes issues of national security, government/private conflicts of interest, and technology disclosure. This hinders effective data delivery and response in time-sensitive humanitarian disasters.

Earth observation data and geographic information systems (GIS) have an expanding role in the decision making process, particularly in areas of environment, human security, vulnerability reduction, emergency response and recovery. A variety of actors operate in this realm, including those from the public and private sectors, international organizations, and civil society such as non-governmental organisations (NGOs). The establishment of commercial constellations of high-resolution Earth observation platforms such as IKONOS, QuickBird and EROS-B are allowing NGOs the ability to detect and respond to human rights violations. [3] Properly equipped, NGOs can complement formal responses from national governments and international bodies towards humanitarian relief. However such evidence is only supplementary and requires integrated ground information to spur legal action.

The UN Operational Satellite Applications Programme (UNOSAT)[4] is the primary impartial body dedicated to developing and applying integrated satellite solutions towards UN goals and objectives. UNOSAT makes available to countries and NGOs affordable access to satellite solutions in the areas of investigation, assessment and monitoring.

A multitude of NGOs currently exist in a decentralised network to address the various natures of human rights crises on a global scale. These include Amnesty International[5], Human Rights Watch[6] and the American Association for the Advancement of Science (AAAS)[7]. However, many of the possible actions available for mitigating humanitarian crises lie in the realm of national and local laws and institutions. The fickleness and legalities that exist between governments and the UN often results in an ineffectual response.

Case Study – Zimbabwe, 2005

In 2005 the Zimbabwean government initiated Operation Murambatsvina, a home destruction campaign, for political purposes. Reports initially surfaced of towns where the homes of opposition supporters had been destroyed and satellite imagery was used to identify such instances. Initially, the identification of specific locations proved difficult due to poorly mapped areas and shared local place names. This issue was resolved by integrating the existing information databases of NGOs with the LandSat GeoCover satellite imagery and NGO ground staff verifying the information. **Error! Bookmark not efined.** Further images were then obtained from the commercial Quickbird satellite showing the before and after maps of affected towns (see Figure 1). These images allowed Amnesty International to generate 24 hours of unprecedented media coverage and Zimbabwe Lawyers for Human Rights to launch proceedings against the government at the African Union. The end result was an increase in public awareness and support along with applied political pressure.

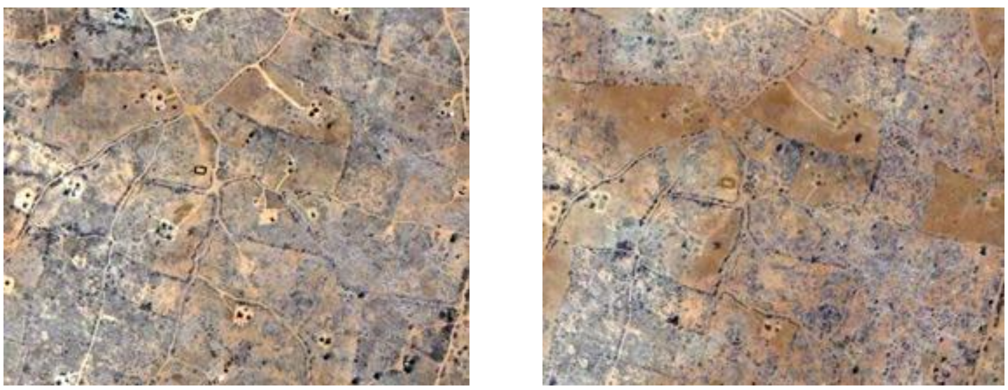

Figure 1: Left image shows Killarney settlement on 22/08/04; right image shows Killarney settlement on 07/09/05, after Operation Murambatsvina. It is estimated that the Operation removed the majority of the 465 structures viewable in the earlier image. (Image source: ***[Error!***

3 Development Needs and Challenges

While UNOSAT represents a concrete effort towards the application of space assets for humanitarian relief, a number of opportunities for improvement exist:

3.1 End-User (NGO)

As a possible end-user, NGOs need to be connected with data that is useable, timely, and affordable. Despite the importance of the first two factors, the third factor – cost – is typically the one of most importance for NGOs. Obtaining raw data instead of processed images is likely to be more financially viable for NGOs, but the organization would then have to find resources for image processing. The presence of in-house volunteers with image processing expertise has proven effective for Shelter Associates, an NGO in India that tracks slums to relocate people to permanent housing. Such a model, however, may not be feasible for all NGOs, especially those who are just beginning to incorporate satellite imagery into operations or who are unsure of the value of remote sensing imagery.

Furthermore, many NGOs are unaware that satellite imaging is available for such purposes. Even if an NGO is cognizant that satellite data is obtainable, it still may not realize that such data could be valuable for its own operations. There are many efforts to improve awareness, but arguably the most successful of these public relations campaigns has been the Sentinel Project [8], an effort championed by American film star and activist George Clooney. The increased visibility brought by his celebrity undisputedly increased the awareness of the utility of satellites for humanitarian causes. Social media has helped to close the gap between NGOs and data providers, but more active approaches are needed, based on the current views of NGOs.

3.2 Data Provider (Government Space Agency or Private Industry)

In the case of natural disasters, government space agencies and private industry have provided satellite data for relief efforts. This data sharing often occurs under the mandate of the International Charter on Space and Major Disasters [9], an international treaty that requires signatories to freely share Earth observation data with countries affected by natural disasters. Data release is accompanied by the risk of exposing trade secrets and confidential company data, but assisting in these relief efforts can also prove beneficial to a company or government's image through positive publicity and improved public perception of their efforts.[10]

Humanitarian relief missions, however, are inherently controversial topics where additional political complications must factor into the already momentous task of connecting data providers and users. For instance, the integrity of new borders or the status of a refugee camp can be highly charged issues. The possibility of embarrassment, either to one's own country or to an ally, is realistic with the release of satellite data and both industry and government agencies may be reluctant to acquiesce to all requests. Although most reputable and respected satellite-imaging companies declare their willingness to provide data – free of cost in many cases – to NGOs for humanitarian causes, it is unclear whether these proclamations readily translate to action in a politically sensitive situation.

Many companies have established an application process to vet the organizations requesting the data and to gauge the validity of their requests. There does not, however, appear to be any feedback to ensure that the data provided is used for the purposes originally described. To maintain a mutually beneficial framework of data transfer, the providers must be confident that their data is being used for its intended purpose. Anonymity may provide companies with a sufficient safeguard to allow the release of data without invoking the displeasure of influential parties; legal protection is also crucial to sustain data release for humanitarian efforts. Based on the volatility of any human rights crisis, unfortunate consequences and unpredictable events cannot be excluded as a possibility. Whatever the outcome of the crisis, companies or governments who release satellite data in good faith for humanitarian relief should not be subjected to adverse legal action.

3.3 Third-Party Facilitator

Providing the correct data to the correct people at the correct time in a useable format – and all for an affordable price – has already proven to be a challenge, even in the case of environmental disasters where all parties are in favour of a resolution and there is minimal political resistance. Connecting data providers with end users via a third-party facilitator has proven effective in these instances. Planet Action[11], an initiative started by Astrium GEO, partners with several well-established satellite imaging companies to enable data processing and release to environmental NGOs in support of climate change research.

There is no equivalent organization specifically for humanitarian relief, but such a model would prove useful. An independent centre tasked with facilitating communication among various industrial, governmental, and non-governmental partners would enable easier and timelier access to data. Such an organization could take charge of either data processing or training on processing software, thus allowing companies to provide comparatively inexpensive raw data instead of costly processed data. To minimize costs further, the third-party organization could employ crowdsourcing to aid with data processing, based on the success of this in other fields. The third-party facilitator can also provide guidelines to ensure that the final images are formatted correctly and that data is used for the intended purpose. Finally, the third-party organization could engage in outreach activities to recruit new industrial partners, encourage more NGOs to use their services, and involve the wider public in its cause.

4 Recommendations

The main recommendation is the following:

To create a new Centre for Responsive Information for Safety and Security (CRISIS) to act as an impartial, international coordinating body for providing space-derived information in support of humanitarian relief.

Various aspects of this recommendation will be addressed in the following sub-sections:

4.1 Independent coordinating body

As mentioned above, the interface between the users (NGOs) and data providers (e.g. space agencies, private companies) is currently a weak point. The establishment of a third-party organization, hereafter referred to as CRISIS, would facilitate easier transfer of data from providers to end-users.

The functions of CRISIS would be slightly different from what UNOSAT is normally responsible for. Hence CRISIS should be established as an independent entity, outside of UNOSAT, or incorporated into UNOSAT by expanding UNOSAT's mandate.

A diagrammatic representation of CRISIS is provided in Figure 2.

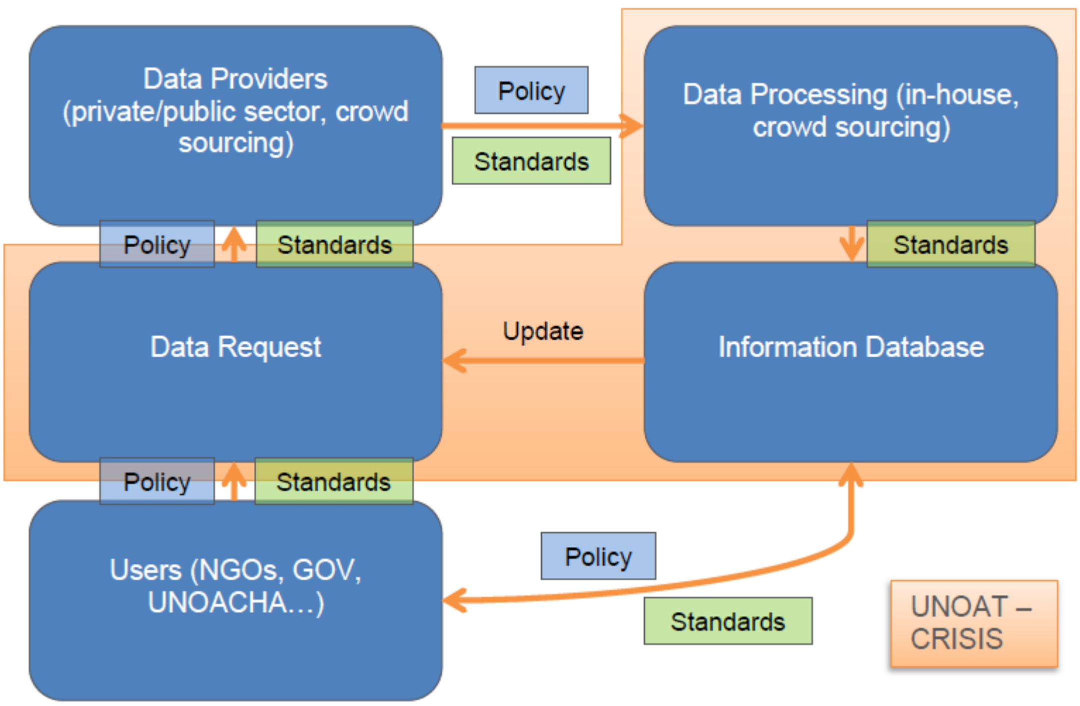

Figure 2: Overview of the envisaged interfaces between users and providers under CRISIS

As shown in Figure 1, CRISIS is responsible for handling all data requests, exchanges between data users and providers, data processing and storage of information for later use. Each interaction is governed by the use of standards and implemented policy. CRISIS is also responsible for categorizing the level of response (discussed below) and for ensuring that any user request is valid.

Furthermore, a monitoring function should be established to verify that any requested data is used for its specified purpose and not for any commercial gain or competitive advantage. This is necessary to maintain strong data provider participation.

4.2 Developing standards

Developing standards will be one of the main challenges for CRISIS to address. The Centre must first establish technical, cost, and legal standards.

From a technical point of view, it is important to have a standardized process and format for data requests and deliveries, among other procedures. Such standards would facilitate the use of this data and avoid unnecessary effort or incompatibility of systems. Standardization at this stage optimizes the use of the available assets from the point of data capture to end usage, ensuring that valid information is provided at the correct place and at the correct time.

For cost standards, the main recommendation is that for critical humanitarian crises, the data provided and service rendered should be provided at no cost to the users. This requires an objective means for evaluating the severity of any given crisis. Trained operators will use standardised checklists to colour code the severity, with this colour code determining what level of support is need and available, and at which price. For example, for critical events, a “red” denomination would imply rapid, free service; for slowly developing potential crises, a “yellow” indication would indicate low-priority and minor cost.

CRISIS will also need to address legal standards. The challenge is significant if the Centre is to be established within UNOSAT. UNOSAT is not currently experienced with legal aspects; thus, they must either operate outside their current mandate or collaborate with other UN or external entities to address this legal area.

It is also important to protect the anonymity of any companies or agencies that provide raw data to CRISIS, to ensure that NGO’s and other bodies are uninformed of the provider’s identity. As such, a provider should be able to choose between publicly acknowledging any contribution it makes to a humanitarian crisis response or remaining anonymous in the case of politically sensitive events. Anonymity would also prevent unanticipated negative consequences for the private industrial entity if the humanitarian crisis deteriorates further. This would provide an additional legal framework to protect data providers and thus ensure that these partnerships are sustainable.

4.3 Crowdsourcing

Crowdsourcing is a process that involves outsourcing tasks to a distributed group of people using a range of communications and media. One aim of CRISIS is to harness the power and capabilities of crowdsourcing at both the data provider and data processing levels of the system. For satellite data and imagery, visual processing by means of the human eye offers a more accurate alternative to current data sorting algorithms and software (albeit at a much slower rate). In such sensitive and critical issues of humanitarian disasters where the livelihoods of many are at stake, accuracy is paramount and crowdsourcing can aid with this.

There are two main geography based crowd sources: a smaller, local crowd with access to affected areas; and a significantly larger crowd away from the affected area but connected via other communication channels.

At the data provider level, the primary data source originates from the affected crowd and may come in numerous forms, from a simple text message to the more complex multimedia social networking tools. These all contribute towards the data gathering operations in all phases of a crisis.

At the data processing level, various pieces of satellite data (e.g. remote sensing images) could be distributed to the crowd to detect any differences over time. Examples include the destruction of property or the mobilisation of military hardware. Disseminating only a fraction of the total information to different parties in the crowd prevents data misuse by affiliated parties. Distributing multiple copies of the same data to multiple data processors improves the credibility of processed results by majority voting.

Involving the crowd not only enhances the overall flow of data from the providers to the end-users, but also directs the public spotlight on the situation and the parties responsible.

Current crowdsourcing applications are a scratch in the vast field of potential. Scientific crowdsourcing is still in its early stages, and is typically in the form of competitions and data processing targeted specifically at the scientific community. CRISIS should look to closely align its scientific tools and strategy with existing social network infrastructure and technological trends. Features such as an emergency button, a designated hashtag or a crisis account on Facebook or Twitter, would go a long way in making data and emergency services more accessible to the local crowd. Strategies such as gamification are also applicable to the data processing level of the CRISIS system and are effective with younger generations. In the right circumstances, these could also be used as an educational tool to educate and enhance social awareness.

The use of crowdsourcing for low level (e.g. evolving or low priority) threats would allow moving the limited staff of NGOs and governmental bodies to a validation role (of the crowd-processed data), releasing much needed resources towards other pressing areas of the crisis response.

4.4 Outreach

As was briefly mentioned earlier, there is a general lack of awareness about the potential for space-derived information to contribute to humanitarian relief. Efforts should also be made, via CRISIS or externally, for outreach activities targeted to the general public and NGOs. Increasing the public's awareness of what can actually be done within the space sector and what is already being done would improve its health. Many national space agencies and other space-related organizations engage in public outreach and education. CRISIS could partner with these organizations to design, develop and execute outreach programs focused on the use of space-derived information in times of humanitarian crisis. Programs that focus on case studies as narratives would be particularly effective in drumming up public support.

Another recommendation is for increasing public involvement in these activities and fostering their participation in humanitarian relief. There are many ways to participate, but crowdsourcing is one promising approach to consider as discussed above. Lessons can be learned from other areas where crowdsourcing has been used. For example, international competitions have been held to encourage crowds to identify the differences between two images taken of the same location. In addition to outsourcing some data processing, this approach has the added benefit of increasing public awareness of the issue.

Lastly, CRISIS could engage in outreach campaigns targeted at NGOs. This will likely require more tailored outreach efforts such as identifying the mission and needs of a particular NGO and crafting an argument for how space-based data might facilitate their work.

5 Conclusions

Recognizing the pivotal role of the application of space-derived data in humanitarian disasters and the necessity of greater awareness of the utility of satellite data in such circumstances, an impartial international organization, CRISIS, is proposed.

CRISIS should act as an interface between the data provider and end-users. In this role, CRISIS would ensure that accurate data is delivered on time, at an affordable price and to the people or authority that is in need of the data. CRISIS protects data providers by allowing them to remain anonymous in the case of politically sensitive events and helps to bridge the information and data gap between NGOs and those data providers who hold the data but have limited channels for distribution. CRISIS would also standardize the process, in particular at all stages of the data request and delivery and in matters of liability and confidentiality. Finally, crowdsourcing could be used to free up NGO resources for low-priority or developing crises, as well as to encourage public support and participation.

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EXPLORATION SESSION REPORT – COMMUNICATIONS FOR EXPLORATION

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COMMUNICATIONS FOR EXPLORATION

Group Participants

Name	Position	Nationality
Victoria Alonsoperez*	Moderator	Uruguay
Stephanie Wan*	Subject Matter Expert	USA
Daniele Durante*	Rapporteur	Italy
Hannah Kohler*	Rapporteur	USA
Seyed Ali Nasseri*	Rapporteur	Canada/Iran
Elizabeth Roy*	Rapporteur	Australia
Utpreksha Somalwar*	Rapporteur	Australia
Phillippa Blaber	Group Member	Australia
Luis Ferreira	Group Member	Portugal
Javier Galindo	Group Member	Spain
Maria Daniela Graziano	Group Member	Italy
Dayne Kemp	Group Member	South Africa
Klaus Kornfeld	Group Member	Austria
Louise Lindblad	Group Member	Sweden
Dusan Marceta	Group Member	Serbia
Shannon Mason	Group Member	Australia
Behnoosh Meskoob	Group Member	Iran
Dragos Paun	Group Member	Romania
Pascal Renten	Group Member	Germany
Rebecca Rodriguez	Group Member	Puerto Rico
Timothy Szwarc	Group Member	USA
Safoora Tanbakouei	Group Member	Iran
Reinhard Tlustos	Group Member	Austria
Simon Vanden Bussche	Group Member	Belgium
Christopher Vasko	Group Member	Austria

***Members whose participation resulted in the final report**

1 Introduction

Currently, space agencies around the globe are focusing their exploration programs on the Moon, Near-Earth Objects (NEOs , such as asteroids) and Mars. One of the main difficulties in making such journeys lies in maintaining communications with the distant spacecraft. Communication systems are indispensable in enabling exploration, and without them such missions would be fruitless.

The main objective of the Space Generation Congress 2012 Exploration Working Group was to analyze the current situation in space communications and to draw recommendations for improving existing capabilities, as well as for future systems. The recommendations outlined below focus on Mars exploration.

2 Current and proposed Mars missions

The first robotic exploration missions to Mars were carried out by the USSR and the United States in the 1960s. Both efforts experienced failures, and lead to new technologies which brought later missions a higher rate of success.

The high scientific interest and relative ease of access to Mars has always made it one of the most popular targets for interplanetary missions. There are currently three spacecraft orbiting Mars, with two rovers operating on the surface. Figure 1 outlines currently operational missions and future planned missions.

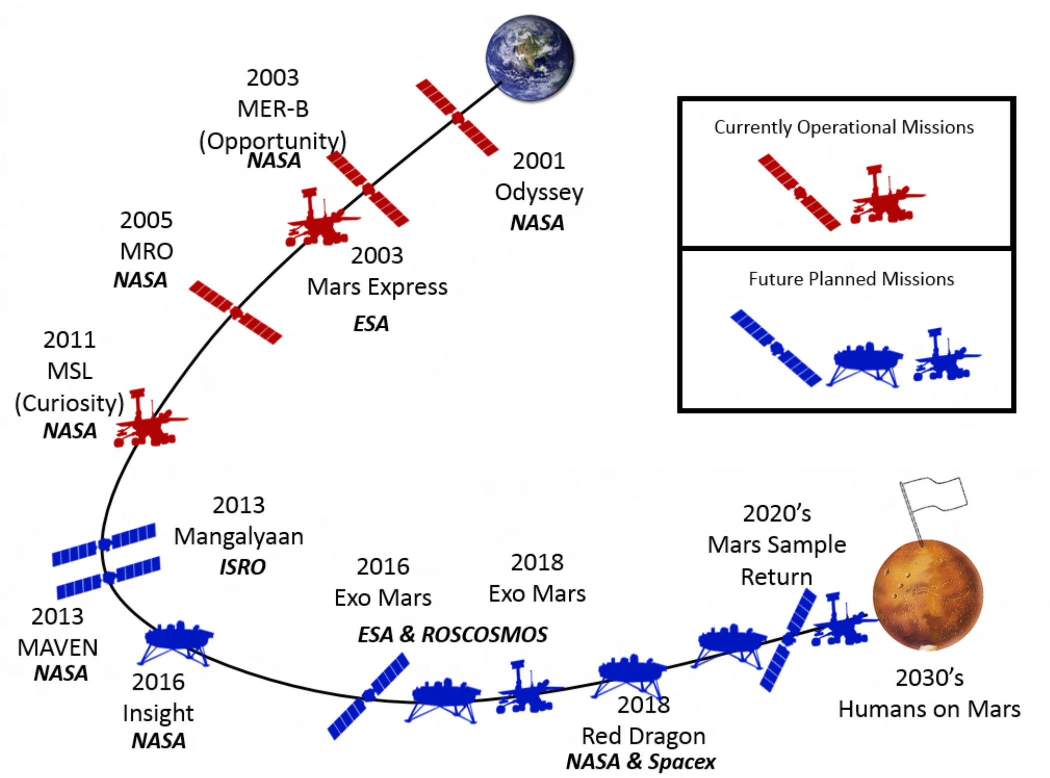

Figure 1: Scheme of current and future Mars missions

Odyssey is a robotic spacecraft developed by NASA and launched in 2001. Odyssey has been used extensively in the past decade as a mediator for communication between the rovers on the surface of Mars and NASA engineers. About 85% of images and other data from the NASA rovers *Spirit* and *Opportunity* have been relayed to Earth via Odyssey. Of the two NASA rovers launched in 2003, only Opportunity is still operational. Opportunity's original mission was to last for 90 sol (Martian days), but the rover has exceeded expectations and continued to function for more than three thousand sol, covering almost 35 Km in the process. Another important orbiter is the ESA mission *Mars Express*, launched in 2003. Mars Express consists of two parts, an orbiter (still operational) and a lander, Beagle 2, which failed during descent and landing. The Mars Express orbiter has performed scientific measurements and sent data back to Earth since 2004, and has also been crucial in relaying signals for the NASA rover Curiosity during its entry, descent and landing in 2012. The third element orbiting Mars is the NASA spacecraft *Mars Reconnaissance Orbiter* (MRO). MRO demonstrated the use on Mars of the K_a-band at 32 GHz for higher data rates, up to 6 Mbit/s estimated, ten times faster than previous Martian orbiter. In the future, deep space missions which require high data-rate will use 32 GHz K_a-band. The last rover to land on Mars, *Mars Science Laboratory* (also, known as *Curiosity*) landed in August 2012. The innovative entry, descent and landing phase of the rover was assisted and recorded by the orbiters already present around the planet. [1] [2]

Although the number of operational spacecraft and landers operating on and around Mars is small compared to the 13,000 satellites orbiting Earth, the great distance between Mars and Earth makes communication difficult. The large volume of data collected makes transmissions more and more difficult. Where data throughput is limited, scientists might have to select which parts of the full data set to be sent back to Earth. The situation will only get worse in the future as currently planned missions become a reality. As we can see in Figure 1, six new missions are scheduled to be launched within the next few years. These missions utilize another four probes, as well as four landers and two more rovers, bringing the total number of functioning elements on and above Mars to fifteen, or triple the current assets.

The growing number of human-made objects on Mars will create higher signal traffic and make it difficult to communicate with Earth in the years to come. Additionally, in the not-so-distant future, it is possible that a manned mission to Mars may be realised. In that case it would be vital to have a constant connection with the astronauts and their needs, since it is more than only scientific data being transmitted. All this requires the development of systems, whether ground-based or orbital, dedicated exclusively to communications between Martian probes and ground stations. These measures would enable the storage and transmission of all the data collected, without losses due to, and despite, the difficulty of a mission to Mars.

3 Issues

Exploration missions to Mars encounter similar difficulties as for exploration missions to the moon, except on a much larger scale as a result of the greater distances involved. In addition, problems arise when the two planets are on opposite sides of the solar system due to the loss of line-of-sight. The issues of potential loss of line-of-sight and significantly larger distances were identified as obvious major differences between Lunar and Martian communications environments, and therefore issues to be considered.

The ever increasing capability for improved or new forms of data means a larger amount of data is able to be collected, and therefore also needs to be stored and processed. While developing technologies enable this growing data collection capability, a limiting factor is the current storage and processing capability. Data storage is limited by hard drive weight in a weight-budgeted spacecraft, and processing is limited by computing power and availability. These are issues identified as relevant to the issue of Martian communications, with preferential focus directed towards the limit on processing capability.

Frequency allocation is an ever-present and increasingly urgent concern. There is research being done into methods of more efficient modulation [3]; however there is still very limited space in the frequency spectrum for the rising amount of data to be transmitted. While this is a largely apparent issue in the space industry, in the discussion of space communications it still needs to be identified as a majorly relevant issue.

A less technically focussed issue is the limited international collaboration actively being undertaken by the major players in space. There are such high stakes involved in terms of financial stability, safety and time until next launch opportunity in space operations. While there is a necessity to maintain the competitiveness of the industry, there is also the potential to achieve more in less time with increased international collaboration, and a more global market. There was a general identification of repeated technology; that is, technology being developed by more than one entity for application to the same problem. As mentioned, this maintains the competitiveness of the market, but this was also identified as a relevant issue, given the potential for two problems to be solved instead of one.

Additionally, there was also an identification of the issue of limited involvement of less “space-developed” countries in space communication operations. While they may not have large scale capability such as spacecraft development or launch, some do have the ability to process data or engage in observation tasks. This was identified as an extension of the issue of limited international collaboration.

4 Recommendations

4.1 Standardisation and International Collaboration

Standardization and international collaboration are key to achieving a peaceful and effective space communication environment. One of the ways standardization can be achieved is by the implementation of backward compatibility, or the implementation of new systems that are compatible with older technology, to the greatest extent possible. Making backwards compatibility a priority will ensure that older communications elements will not become obsolete with the advent of new technology, preserving processing power, relays, and other extant resources until they can be replaced. This will help ease the transition into the new and updated technology. When the set technological threshold is met, the older technology operation can be ceased and the space exploration communication can rely solely on the newer and more efficient technological systems.

Presently space communications policy is developed by the Consultative Committee for Space Data Systems (CCSDS). This organization was founded by the major global space agencies in 1982, and has been dedicated to enhancing governmental and commercial interoperability and cross-support, while also reducing risk, development time and project costs [4].

It is recommended that the CCSDS expand its role and act as one body which reinforces current and future space communication policies on all space exploring nations. In the past, more than 500 space missions have chosen to fly with CCSDS developed standards—and according to the CCSDS, this number is increasing. It is recommended that these standards be revised and expanded to cover all aspects of space exploration, especially space communications, and to maintain a systematic and proper structure to space laws. It is unnecessary to create another organization when CCSDS can be improved. In the future, all nations will therefore have to adhere to the space exploration policy set by an organisation such as the CCSDS for space involvements.

This era also brings a unique opportunity for private firms to launch space-based projects. This is a positive sign as it reinforces the work done by the space agencies around the world. However, it is recommended that the private sectors should also be obliged to adhere to a standard space policy and to agree to the following of the set standards by a certain law enforcing entity.

International collaboration is the key to success in space for mankind. Space exploration will succeed at a more efficient rate if all space exploring nations work together to achieve the same goals. Nations can possibly outsource parts of a mission to other countries in order to save time and also to engage more countries around the world in any space exploration venture. This will encourage international collaboration and increase the efficiency of producing space-worthy systems. This collaboration will also make it easier to reinforce and adhere to a set space policy. International collaborations however can prove to be challenging due to various political statuses of nations. This will need to be incorporated when assessing the feasibility of international collaboration.

4.2 Technology and Network Architecture

Currently relay or direct-to-Earth communication is used from Mars. There is a time delay of 7-14 min depending on Mars' location on its orbit around the sun. The bandwidth currently in use is X-band (8-12 GHz) and data rates range from 500-32000 bits/s for direct-to-Earth communication to 2Mb/s through orbiters. Future needs might reach data rates in excess of 1 Gb/s. Hence, changes in technology and network architectures will be required. Recommendations with this regard will be outlined in this section.

4.2.1 Optical communication systems

The data rate requirements of future missions have increased significantly since the early Mars missions. Furthermore, for future human missions to Mars, it is likely that video will also need to be transmitted due to humankind's interest in seeing what is happening (similar to lunar missions).

As a result of the increase in data rate requirements, optical communication systems will be key for future Mars missions. These systems can provide higher data rates (for example, up to 5.5 Gb/s has been implemented in LEO [5] and up to 1 Gb/s is estimated for Mars [6]), and specific ground stations are already available (examples include ESA's ground station in Teide in the Canary Islands and Jaxa's NICT optical ground station (OGS) in Koganei, Tokyo). However, as optical communication systems are susceptible to environmental interference (for example, the inability to transmit through cloud coverage), backup solutions using conventional radiofrequency (RF) communication should be maintained.

During the transition phase when some older satellites are still using radiofrequency signals, a process is needed to allow the optical systems to communicate with the older RF systems. Hence, it is recommended that all new data relay satellites be equipped with both optical and RF communications capabilities and a means of signal conversion, both for redundancy purposes and for backward compatibility. Unfortunately, this will increase the cost associated with such satellites.

Another issue with optical communication is their high pointing requirements, which requires a high-accuracy attitude control system (ACS) onboard such communication satellites.

4.2.2 Development of advanced onboard data handling and processing systems

With advancements in the field of electronics, smaller and faster processors are being developed that may allow onboard data processing to compress raw data or turn them into useful scientific results. By sending only these processed results to Earth, a significant reduction in data volume can be achieved. Moreover, electronic advancements also allow higher capacity data storage, which will help in the data transfer when there are narrow communication windows available.

4.2.3 Assess the use of software-defined radio (SDR) and software-defined antenna (SDA)

Given high rates of technological change, it is difficult for space systems already in orbit to adapt to new developments. Moreover, space systems often surpass their service life and operate for many more years. This leads to new technologies being developed but not implemented in new systems (e.g. landers), as extant orbital systems cannot support them. A way to solve this flexibility and adaptability issue is to use software-defined radio (SDR) and antenna (SDA) systems [7]. In SDR systems, hardware components such as mixers, filters, amplifiers and modulators are replaced by software components. Hence, the system may be remotely upgraded and is redefinable. SDA systems are designed in a way that they have the same characteristics for any frequency. Through this method, new technologies may be implemented in the systems without the necessity of a physical (and costly) upgrade, increasing adaptability and encouraging the evolution of the entire communications network.

4.2.4 Increase redundancies in the network and system

Currently, only three orbiters exist in orbit around Mars with the capability to transmit data back to Earth. With the increase in future deep-space missions and the possibility of human travel to Mars, an increase in the number of orbiters is needed in order to increase redundancy in the system and to ensure that at least one orbiter is communicating with the specific mission site at all times. This will increase the robustness of the communication architecture to a level necessary for human missions.

Complimentary components can also be used when higher data transfer rates are needed. Probes may be equipped with alternative communications systems, which on one hand increase robustness and on the other could allow simultaneous communication via these complimentary systems and thus increasing data throughput.

4.2.5 Develop an international integrated network of multiple small satellites with a standardised interface

An international network with a centralised command centre and involving assets of different nations (including both ground and space segments) would allow for a more flexible and cost effective solution. The developments of regional networks — which are also integral local components of the international network — would also aid this. Many legal and political hurdles exist which may slow the establishment of such a network, however the advantages would outweigh the effort involved.

The network must be flexible enough to accept any evolving assets, such as those from private companies. The central command would be an international coordination team and would work to ensure that the system is sufficiently robust and dependable.

With current advances in satellite miniaturization, small satellites (weighing less than 500 kgs) could be used to ease the process of collaboration and provide incentives for countries to participate (as the cost of micro-satellites is far less than that of large satellites). Each country could develop its own small satellite (micro-,nano- or pico- satellites) and include it as a contribution to the international network. These small satellites may be modular and mass produced, reducing their production and design costs. The lower lifespan of these satellites means that the system will be better adapted to new technologies and needs, as it will be upgraded more rapidly.

4.2.6 Assess the affordability of dedicated communication relay satellites versus relay capabilities on other spacecraft

Analysis needs to be made on assessing the affordability of installing dedicated communication satellites in orbit around Mars, as opposed to including relay capabilities on scientific/carrier spacecraft as is currently the case. In the future, spacecraft which are used as fuel storage for human missions to Mars may be used as relays in the same manner.

Dedicated communications orbiters around Mars would likely have a reduced size, leading to lower launch costs. Moreover, there will be more flexibility over the final orbit choice if no scientific constaints exist. As a result, satellites may be stationed at higher orbits (such as an aerostationary orbit, where the satellite stays above the same point on the Martian surface), thus resulting in full coverage over the Martian surface. Another application of this approach is the creation of a navigation/communication system for Mars. If the natural resources on Mars are to be exploited in the future, such a system will be indispensable due to the need to navigate several vehicles on Martian surface much the way GPS technology is used for navigation on Earth. Dedicated relay satellites may even be located at Lagrangian points.

4.2.7 Sustainability of Martian orbits

With parallels to the developing issues of space debris around Earth, the sustainability of Martian space must not be forgotten. Similar to orbital debris mitigation rules developed for Earth [8], rules and regulations should be put into place to prevent orbital debris issues with Mars, focusing on orbital positioning, de-orbiting and any additional measures.

4.2.8 Maintenance of current systems as redundant assets

As we move forward with developing new systems, older systems are decommissioned. Currently, outdated orbital systems are simply de-orbited. For ground stations, however, the best solution seems to be maintaining them as part of the network. We will not always have all the most up-to-date equipment installed at all our ground stations, and one approach for integrating new technologies is to equip some of the stations during the transition phase with the new systems and leave others unaltered for day-to-day services. This will increase redundancies in the system and reduce costs.

4.2.9 Use of Commercial-Off-The-Shelf components

The use of Commercial-Off-The-Shelf (COTS) components should be assessed, to see if development costs can be reduced for any part of the system.

5 Conclusion

International cooperation is an essential aspect of future space exploration. Through cooperation, more ambitious and scientifically exciting missions can be undertaken due to efficiency and cost benefits. Global standardization is thus a key for success to ease interfaces between different systems.

New relay satellites should be equipped with both optical and RF communications capabilities, a means of signal conversion, and data storage units. Software defined radio (SDR) systems should also be utilized to allow remote upgrading of in-orbit communication systems. The use of complimentary systems to allow communication via different means will increase robustness and throughput.

An international network for space communication, to which all nations should contribute, would allow individual nations to develop small satellites at modest cost, which could then be combined with the assets of other nations to provide a high-performance, integrated network.

Finally, as most current communications from Martian orbits rely on the communication capabilities of satellites primarily designed for science and observation missions, it should be assessed whether dedicated communication/navigation satellites could be stationed around Mars to increase quality and reliability of Mars-Earth communication. Rules and regulations should also be drawn defined in order to ensure the sustainability of Martian orbits.

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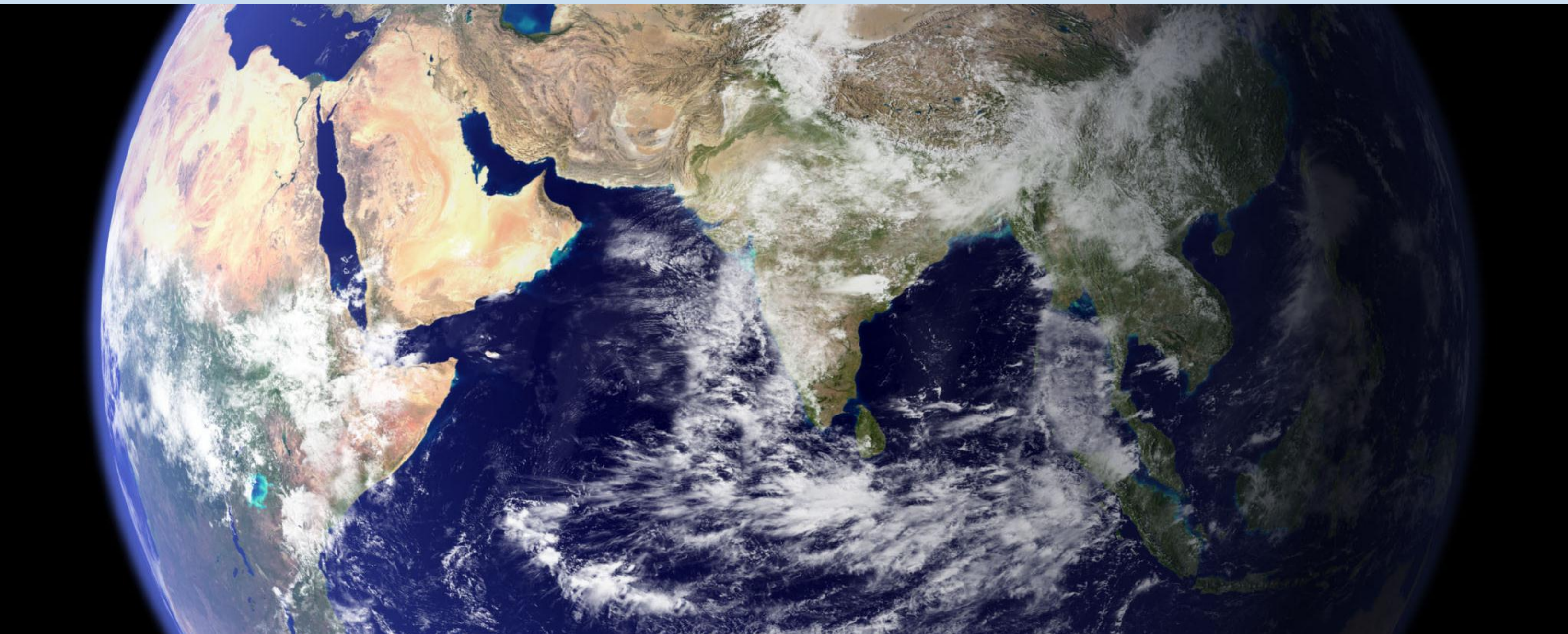

SPACE APPLICATIONS FOR WATER MANAGEMENT

Group Participants

Name	Position	Nationality
Mariel Borowitz*	Moderator	United States of America
Noemie Bernede*	Subject Matter Expert	France, Germany
Michael Afful	Rapporteur	Ghana
Cynthia Chen	Rapporteur	Australia
Katrina Laygo*	Rapporteur	United States of America
Ryoko Nakamura	Rapporteur	Japan
Benjamin Steppin	Rapporteur	Australia
Junzi Sun*	Rapporteur	China
Nouf Al-Jalaud	Group Member	Saudi Arabia
Ahmed Al Menhali	Group Member	United Arab Emirates
Shamma Alquassim	Group Member	United Arab Emirates
Alejandro Alvarado	Group Member	Mexico
Phillipa Blaber	Group Member	Australia
Sara Bruni	Group Member	Italy
Carlos Cardenas	Group Member	Mexico
Ashley Chandler	Group Member	United States of America
Patrick Crowley	Group Member	Ireland
Daniel Czech	Group Member	South Africa
Hector Hernandez	Group Member	Mexico
Jo Hill	Group Member	South Africa
Olabamiji Olojo	Group Member	Nigeria
Minoo Rathnasabapathy	Group Member	South Africa

***Members whose participation resulted in the final report**

1 Introduction

Water is one of the most fundamental resources, needed for drinking, agriculture, sanitation, and industry. Water scarcity and recurrent flooding occur regularly and continue to strongly impact many regions around the world, especially in developing countries. Other phenomena such as glacier melting, erosion, and desertification, also pose numerous risks to the environment and affected communities, although sometimes in less obvious ways. As it is a vital component of everyday life, the issues and practices of water management continue to be a rising challenge for stakeholders and decision makers. Space-based Earth Observations (EO) is valuable for water management and assessment of the water cycle on local, regional and global levels and in providing information (with peaceful objectives) for events that may span the borders of multiple countries. A great number of space technologies such as land and marine observation, along with weather satellites, are available and allow for the precise monitoring and measurement of water resources and factors that influence the water cycle.

The goals of the working group were to:

- Identify the importance of using EO for water management by assessing the current situation
- Identify the stakeholders in the sector of water management and issues, such as the lack of or access to data
- Recommend ways to improve or enhance the use of EO in water management

2 What is Water Management and How is it Space Related?

In order to identify current space-based technologies that are currently used or have the potential to be used for water management, the group first established the scope and definition of water management. For the purposes of this report, water management in three different but connected areas – *water for consumption, water for agriculture, and safety* – were considered as the main focus. Accessing clean water and monitoring water quality and resources are vital to the consumption component. Improving or enhancing agricultural productivity and benefiting from ecosystem services are vital to the second focus area of agriculture. Enhancing water-related disaster (e.g. floods and landslides) management and improving sanitation fall within the third focus area of *safety*. The group sought to make concrete connections between EO applications and secure, sustainable access to the basic living necessities such as food, water, and shelter.

2.1 Current Satellite Technologies Utilised for Water Management

Currently, there are a number of satellite technologies that are being utilised for water management. The groups included both active and passive remote sensing technologies, and were categorised according the specific measurements and applications to water management.

2.1.1 Active Satellite Remote Sensors

Active satellite remote sensors, such as microwave and radar sensors, provide their own form of radiation to highlight a study area, as opposed to passive ones that simply detect radiation. Radar, also known as **RA**dio **D**etection and **R**anging, is the most common form of active microwave sensing. The advantage of radar lies in its wide range of imaging conditions, wherein it is able to penetrate clouds and image an area during day or night. Radar altimeters and scatterometers are also considered active sensors. They can measure the distance to the ground of a spacecraft with the transmission of short microwave pulses or can transmit short microwave pulses to measure the reflected energy. [1] The data from these two instruments can be used to study vegetation, soil moisture, and changes in snow distribution, for example.

2.1.2 Passive Satellite Remote Sensors

Passive remote sensors detect the emitted energy from the imaged area. Applications of passive microwave remote sensing include meteorology, hydrology, and oceanography [2], all of which are critical for water management practices. Various surface parameters such as salinity, soil moisture, sea ice, precipitation, and the amount of water vapor and liquid water can also be measured. Passive multispectral (MSS) systems can sense visible and infrared portions of the electromagnetic spectrum. Blue, green, red, and infrared wavelengths are measured for water discrimination and mapping, soil and vegetation studies, and vegetation discrimination and mapping (for example, assessing agricultural health and productivity). Thermal infrared sensors measure the surface temperature and thermal properties of a target area. [3] Since water areas are usually very distinguishable from their surrounding areas, analysing infrared images allow for a better understanding of the distribution of water on the surface, the monitoring of evapotranspiration, [4] and the location of possible water sources.

2.1.3 Satellite Measurements and Applications for Water Management

Table 2.1.1 below details the current satellite measurements from both active and passive remote sensor satellites, and their specific applications to water management.

Table 2.1.1: Current Satellite Measurements from Both Active and Passive Remote Sensor Satellites

Satellite Measurements	**Water Management Applications**
Soil Moisture	Drought / vegetation health
Rainfall	Global flood and landslide monitoring
Ocean Color	Oil spills, water quality indicators, biological activity
Elevation Data / Interferometry	Flood and wetland mapping, landslide
Sea Surface Height	Ocean tides and circulation
Wind Speed	Weather forecasting near coastlines
Snow Cover / Sea Ice	Snow melt estimation, flood forecasting
Extent of water areas	Mapping of water resources

2.1.4 Examples of Existing Satellite Missions Dedicated to Water Management

Examples of current satellite missions dedicated to water management include:

- **Tropical Rainfall Measuring Mission (TRMM)**, a joint space mission between the National Aeronautics and Space Administration (NASA) and the Japanese Aerospace Exploration Agency (JAXA) to monitor and study tropical rainfall.
- **JASON-1,** a joint mission between NASA and Centre National d'Etudes Spatiales (CNES) of France to monitor global ocean circulation, improve global climate predictions, and monitor El Niño events. [5]
- **Gravity Recovery and Climate Experiment (GRACE)**, a joint mission between NASA and the German Aerospace Center (DLR), which measures differences in Earth's gravity as an indicator of water. GRACE data is extrapolated to assess changes in global ocean circulation, groundwater, sea levels, and exchanges between ice sheets or glaciers and the ocean. [6]
- **TERRA, AQUA, Landsat 7, Earth Observer 1 (EO1), and the Advanced Spaceborne Thermal Emission Radiometer (ASTER)** are a part of NASA's **Land-Cover/Land-User Change Program (LCLUC), and is** an interdisciplinary science programme consisting of several satellite sensing systems utilised for LCLUC research, which include studies on water and energy cycle impacts and food security. [7]

3 Stakeholders in Water Management and their Current Issues

3.1 Stakeholders

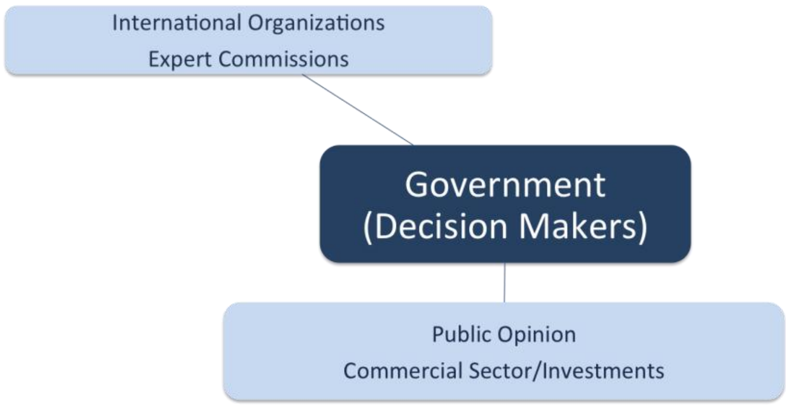

Figure 1. Stakeholder interaction diagram, depicting top-down and bottom-up approaches to governance of water resources.

Water resource management involves many stakeholders, ranging from the general public and local governments to private industry and international multilateral organisations, all of whom have different objectives. It is essential that stakeholders are identified and considered in developing plans to utilize space-based technologies for water management. Stakeholder engagement ensures that the right information is available to the right people at the right time.

Based on the ubiquitous necessity of water, each person is essentially a stakeholder but not everyone participates in decision making on water resource management. However, current trends towards democratisation, privatisation, and globalisation are beginning to make it possible to include local households, companies, and a multitude of other stakeholders in both the development and implementation of new plans and policies. [8] For example, the government in the United Republic of Tanzania has developed a new policy and legal framework that involves local famers as one the main stakeholders in water resource management. [9]

The high number of stakeholders involved in water management and their diverging interests impact decision making processes (such as budget allocation) and communication strategies regarding the technologies available. Synergies and collaboration are key, in particular for a better implementation of space technologies in water management.

3.2 Current Issues Faced by Stakeholders

Despite the fact that space-based technologies, and especially EO, are recognised worldwide as valuable tools for international development and water management, many issues still exist that limit accessibility and widespread use of these technologies. The main problems facing developing regions, who are most in need of water management assistance, are:

1. **Lack of awareness**: Organisations and individuals who could benefit from EO and remote sensing for water management applications are not aware of the available technologies.
2. **Need for capacity building**: The capabilities must be enhanced, mainly in developing countries, to allow for a sustainable use of space technologies.
3. **Lack of infrastructure for collecting and analysing satellite data**: Better organisational processes are of high importance to make the best use of collected data
4. **Data access, purchase and sharing**: In countries with no national space agencies, there is frequently no organisational framework to access EO data. The role of national government is critical to the success of any initiative in these areas.

5. **Lack of funding**: Financial resources are not consistently available for purchasing EO data, including a lack of organisational or political processes to create a budget for institutions that need space technologies.
6. **Limits of in-situ monitoring:** In-situ monitoring is important and valuable, but it can be difficult or impossible to collect in-situ measurements in remote areas. Even in areas where in-situ measurements are taken, it is important to use satellite data to validate findings and get more comprehensive coverage. In this way, satellite data both complements existing in-situ measurements and provides data on areas where in-situ measurements cannot be taken.

4 Recommendations

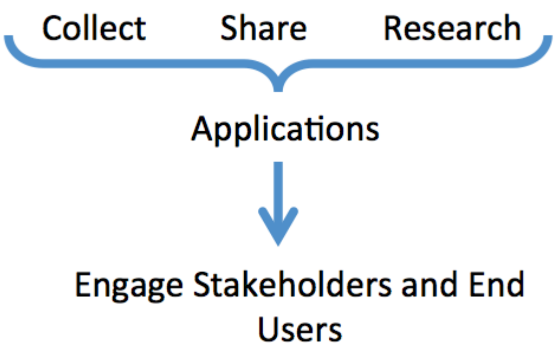

Figure 2. Satellite Water Management Application Workflow

The EO group put forth four recommendations to better integrate space-based EO into current water resources management approaches. The recommendations take a streamlined and interconnected approach (Figure 2) of collecting and sharing satellite data, in parallel with research on potential uses of this data in the area of water management. This knowledge can then be used to develop and improve water management decision-making applications. Finally, it is essential to engage stakeholders and end users to ensure the applications are put to use and meet the needs of the community. The recommendations are:

4.1 Collection and Sharing of Data, Conducting Applied Research:

The collection and sharing of data must be coordinated among space agencies and data distributors in order to ensure the continuity of data. To allow maximum use by a broad range of stakeholders, the data formatting should be standardised and the accessibility of data must be increased, especially high-resolution imagery. This can be achieved through lowering costs and minimising restrictions for the peaceful utilisation of data, as well as providing incentives for data use. Such incentives include competitive grants or scholarships for data use applied to water management concerns in the awardee's study area, and competitions following the X Prize Foundation model.

4.2 Identifying Applications for EO Data:

There are countless examples of where EO data can be applied to water resource management, including monitoring groundwater depletion to mapping aboveground water sources and flood sites. To ensure continuity in application focus areas, stakeholders and end users should take advantage of current programmes that are effectively making use of the data, such as SERVIR, a collaborative project between NASA and the United States Agency for International Development (USAID), which addresses issues such as drought in Africa with satellite imagery. Stakeholders and end users are encouraged to build onto or model programmes after successfully established regional initiatives, such as the European Space Agency (ESA) TIGER initiative and the Global Earth Observation System of System (GEOSS) Asian Water Cycle Initiative.

4.3 Prioritise Local Capacity Building:

International, regional, local cooperative projects, and exchange programmes among university students and the public are recommended in order to expand the EO user base and increase the effectiveness of its applications towards water management. Site demonstrations, in which local community members meet with scientists, engineers, and university students utilising space-based EO for water management would be an effective way to tangibly transition research results and data to the public. For example, a demonstration of how radar and digital elevation model (DEM) data is effective in determining where to build sanitation systems will allow for the practical use of the data, combined with field measurements for validation.

4.4 Engage Stakeholders and End Users:

In order to raise public awareness of the benefits of space-based EO, social media outlets such as YouTube, radio, television, Facebook, and Twitter can be integrated with crowdsourcing map tools such as Ushahidi and OpenStreetMap. On a standalone basis, these social media outlets can be key drivers in expanding general public awareness of the tangible connection between spaced-based EO and how it can improve or enhance everyday life, with a focus on the vital resource of water and its management. Remote sensing and Geographic Information Systems (GIS) courses should be further integrated into Science, Technology, Engineering, and Mathematics (STEM) education from an earlier time frame, preferably prior to the university level. Finally, decision makers on the national government level must be made aware of the benefits of space-based EO for water management and their direct impacts on the lives of citizens. This can be achieved through the identification of metrics to quantify the return on investment in integrating EO into water management. These would include information on resources and money leveraged, knowledge acquisition, and levels of prestige. Applied science researchers, engineers, and university students are highly encouraged to partner with local and regional water resource agencies and conduct research within a specific water resource application of the region. This will build both the capacity of the researcher and the end user to utilise and disseminate space-based EO products for improved decision support, and address near-term (and eventually longer-term) community concerns of water management.

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NAPLES 2012

SPACE GENERATION
ADVISORY COUNCIL

Schwarzenbergplatz 6
Vienna A-1030
AUSTRIA
info@spacegeneration.org
www.spacegeneration.org
+43 1 718 11 18 30 Fax: +43 1 718 11 18 99