International Space University

# Space Studies Program 2015 Activity report

2015.6.6 - 8.7

Saho Yajima Graduate School of Engineering Tohoku University, Japan

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### 1. Overview

From June 6th to August 7th in 2015, I attended the Space Studies Program 2015 (SSP15) held by the International Space University. SSP15 was held in Athens, US and host was Ohio University. There were 99 participants from 26 countries.

### About SSP

The Space Studies Program (SSP) is an intensive nine-week professional development course for postgraduate students, as well as for young and seasoned professionals of all disciplines. It is a unique educational experience with a curriculum that covers the principal space-related fields, both technical and non-technical. The topics range from engineering, physical sciences and space applications, to life sciences policy, management, business, and humanities.

The SSP is organized into three interrelated phases; Phase 1 - Core lecture Series; Phase 2 - Department Activities (DA); Phases 3 – Team Project (TP).



Fig. 1 SSP Academic Program Overview.

### What I expected for SSP15

Minimum success

- · To learn about space and interdisciplinary space development
- To learn another country's culture
- To improve my English skills

#### Advanced success

- $\cdot$  To make network for the future
- · To know what I can do for space development

• To get the answer of some questions like: "Why is space development important?" and "Why humans (not robots) need to go to space?"

### What I got from SSP15

- · Knowledge about space and interdisciplinary space development
- · Knowledge about another country's culture and also Japanese culture
- · Improved English skills and advance my goals
- · Improved my confidence
- $\cdot$  I learnt how to enjoy life with passion
- · Good friends and access to alumni network
- · Some particular skills like: making games, basic step of salsa, martial arts etc.



Fig. 2 Official class photo.

### 2. Core lectures

### About Core lectures

The Core Lecture Series and associated workshops ensure that participants have a basic grounding and common knowledge in the fundamentals of all disciplines that are relevant to space programs. It also serves to ensure that participants understand the relationships among the various disciplines in any space-related activity. All participants attend the core lectures and fundamental workshops, which create the basic framework of knowledge to prepare them for informed and balanced judgement and subsequent teamwork.

Each major aspect of space activities is presented in a series of lectures designed primarily for non-experts; thus, medical specialists can understand the lectures on propulsion, and engineers and lawyers can understand the lectures on the effects of weightlessness on the human body. The lectures do not go into depth or enter into significant detail in any subject, to illustrate a point. The great breadth and diversity of the subjects means, however, that a large quantity of material is covered. Many core lectures are grouped around clusters or themes to highlight the interrelation among disciplines.

### What I expected for and learned from Core lectures

It is very important to have interdisciplinary knowledge because it is necessary for making a project succeed and give better explanations from various points of view. Therefore, I have tried to learn space or interdisciplinary space development and I had some confidence that I already have basic scientific knowledge about it. However, it's difficult to learn policy, economics and law aspects in Japan. So, attending the Core lecture series and making my knowledge interdisciplinary was my strongest motivation to join this program.

Finally, I learned much more, such as humanities or specific engineering fields like space applications not only policy, economics and law. But this doesn't mean the other lectures were meaningless, actually, all lectures were good lessons for non-native to learn English words related to space in order to prepare for next phase.



Fig. 3 The Scene of Core lectures.

# 3. Department

### About Department

The SSP is structured around seven academic departments and three TPs. This organization provides an anchor that allows smaller groups of participants to focus on a particular discipline of interest as they learn. Each participant chooses a department during the first weeks of the program.

The SSP Departments are:

• Space Engineering (ENG)

- Space Sciences (SCI)
- Human Performance in Space (HPS)
- Space Applications (APP)
- Space Management and Business (MGB)
- · Space Policy, Economics, and Law (PEL)
- Space Humanities (HUM)

The Departmental activities provide deeper examination of some of the topics covered in the core lectures. The groups are smaller than in the core lectures, thus allowing for exchange of knowledge, ideas and opinions, as well as hands-on activities. The department activity slots provide an important opportunity for participants to interact with faculty members, visiting lecturers, and Teaching Associates to build their professional network. These activities provide a mean for participants to become sensitized to the cultural differences that govern personal interaction and negotiation skills in light of this cultural diversity.

#### What I expected for and learned from Department

I selected PEL department following my original motivation to learn more about PEL aspects. We selected department in week 2, and I hesitated to select PEL because of my English skills. It was announced that PEL activity was containing a lot of discussion, and with non-related background and language handicap, it was easy to imagine that it would be much harder than just receiving lectures. But I thought that selecting another department was escaping, so I made up mind.

Every DA day we did a simulation after a short lecture. And as I expected, I could not join almost all simulations because it required not only discussion skills but also negotiation skills. However, it was a good choice, because I could learn a lot even by just staying and listening. In the core lectures, we had already learned some laws or politics issues related to space, but we did not know how it works in the real part. So we learned how difficult it is to make some agreements between people in different positions. Also, the disappointment of not being able to negotiate has motivated me to improve my English. This experience has changed my goal of English skills: I want to use English like a native speaker from my current basic conversation skills.

We also had an individual project that the task was selecting topics and making some proposal to decision makers. I selected the topic of space debris problem, and made a proposal of making a treaty for active removal of space debris. Of course, this was my first time to think and search law or business aspects, and I was surprised how complicated it was to make just one treaty proposal. Fortunately, after building the main structure of my proposal, I could interview a person currently working on this problem and that brought me better understanding about it.



Fig. 4 Presentation of Individual project and DA members.

## 4. Team Project

### About Team Project

To develop the TPs, participants work in interdisciplinary and intercultural groups to produce comprehensive analyses and proposals regarding an international space project or topic of relevance in the space sector. Participants choose one of the TP topics and work on that topic for the duration of the SSP session. When the TP work requires specific information, participants can turn to their departmental experts.

### Theme

- 1. Planetary Defense
- 2. Vision 2040
- 3. Monitoring Environmental Effects of Hydraulic Fracturing Using Remote Sensing: Tracking Fracking

As set of deliverables, Team Project Plan, Executive Summary, Final Report, and Final Presentation are required.

I selected Vision 2040. This Team Project studied the trends in major areas driving space exploration and development in order to construct multiple 'Vision(s)' of what the year 2040 could look like. Based on their serious look into the future, the team recommend strategic actions that ISU should implement to prepare its students and program participants better for the future world landscape.

### What I expected for and learned from Team Project

As I mentioned before, my main aim was core lectures, so I did not have any special

expectation for TP. However, I can say TP was the very thing that shows my growth.

Team Project started from 2nd week. In first few weeks, I could not propose anything and sometimes it was difficult even just following. But after few weeks, when we started to work in small groups, gradually I came to be able to commit little by little. In the final part to make strategy, I could propose some basic idea from my background experience of space education. In addition, I had an opportunity to present in the Final Presentation. That seemed to improve other participants' opinion about me, and brought me confidence to speak English.



Fig. 5 Final presentation and TP members.

### 5. Conclusions

I already mentioned about how I improved English and my knowledge, so I'll try to write about other aspects as conclusion.

Through the whole program, I could reconfirm how attractive space is. I loved space and was involved in space education activities before SSP. Although I know how education is important and space is a good topic for it, I also felt the limitation of our activity because the kids (and their parents) who come our events usually have interest in science or space already, and the number of people we can inspire is limited. That means it is difficult to increase the people who is interested in science. But SSP recovered my motivation, and I got friends who are also interested in STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. Now we are starting new projects to inspire people who are not interested in science.

SSP was just a 9-week program, but it was so concentrated that it felt like 1 year. We had a lot of events from morning to night. In addition to these events, we tried a lot of new thing like making movies or computer games, dance, martial arts, or outdoor activities. I can say these 2 months were the most joyful time in my life. Of course, it was because we were separated from normal life. But I surely learned how to enjoy life, how to be tough, and to have confidence in myself. So this is not the end, just beginning

of my new life. Like the slogan of this program, I will continue to increase the awesome. Also I would like to inspire others by talking about my experience.

# Acknowledgments

This program was sponsored by the Boeing Higher Education Program and the Institute of Fluid Science (IFS), Tohoku University. I would like to thank to Professor Naoto Wada. I also acknowledge the International Space University for its helpful scholarship for this program.

# Appendix

I added two reports that I have involved during SSP as appendix.

- DA individual report
- TP final report

Appendix 1

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# Proposal of making a treaty for active removal of space debris

Saho Yajima SSP15 participant This is a proposal from JAXA to the Ministry of Foreign Affairs of Japan that will be presented as a deliberate item on the agenda of next meeting of UN COPOUS.

If we think realistically, it might be rational to propose loose framework convention and strict protocol (like United Nations Framework Convention on Climate Change and Kyoto Protocol to the United Nation's Framework Convention on Climate Change). However, I dare to think about treaty because I want to make a system all countries involved and it is difficult to write essay in the form of Framework convention.

### 1. Background of proposal

Today, launching small satellites is increasing rapidly and human flight will be increasing too with the private sector entrance. Of course, these activities are leading to increase the number of debris, and at the same time, the possibility of collision is increasing too. It is important to avoid collision if it is of unmanned spacecraft, even more if it is a manned spacecraft. Failure of avoidance means loss of crew in the worst case. However, avoidance maneuvers are a waste of time and resources in the aspect of research missions, such as the ISS.

Usually small satellites are put in lower orbit and have shorter life, but as long as they are staying orbit, they have possibility to collide with other debris. In addition, small satellites can easily lose their control or communication because of their experimental aspects. So the increasing small satellites population is not a negligible problem.

According to the research <sup>[1·2]</sup>, if we remove 5-10 large sized debris in major orbit every year, we can avoid rapid increasing of debris by collision. But this simulation does not consider recent rapid launch growth, and this tendency will be accelerated in the future. So we think about debris as a severe problem to keep orbit safe.

From these situations, we think it is important to actively remove debris. But the description of IADC guidelines (Space debris mitigation guidelines of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space) we only have regarding space debris is meant only to endorse not increasing the debris population, and there is no legal binding. Therefore, we want to propose to make a system to endorse also active debris removal.

It will be possible to start removing debris in few years because the ways to remove

debris are researched by JAXA or some private companies. It is also one aim to make a new business model that embroiled private sector as well as making common knowledge importance of debris removal. At the same time, it does not intend to negatively impact in space exploration.

### 2. Main contents

### 1. Object

All the debris in the space are object of removal except satellites under operation. All the debris are ranked by priority of remove (ex. size, trajectory, possibility of explosion). In principle, we impose to remove the enough amount of debris that can avoid rapid increasing by collision.

### 2. Amount of debris

The amount of debris of each country is defined as the debris produced during the mission and the ones staying in space after mission is complete. It is increased when the country produces new debris in the mission, and decreased when the country removes debris (not limited own country's debris) or debris extinct by reentry. In the exceptional case of reentry due to a removal mission by another country, it is not counted as the aforementioned reentry. The mission is defined as complete when all the countermeasures to avoid break up are performed (Ex. releasing fuel, compressed liquid or energy of battery). Also we can call the finish of mission in the case of permanent loss of control or communication.

The increase of debris by collision after the mission is not added except in the case on purpose (not applying enough countermeasures to avoid collision is included). But increasing of debris by collision during mission lifetime is added to the country doing operation.

### 3. Removal responsibility

Although each country is responsible to remove debris when notified by supervisory body, it is not necessary for the country to remove them itself, it is possible to request another country or the private sector. In the case of failure to remove by the time limit, the country has to pay a fine enough to remove the debris and the supervisory body will contract a debris removal company instead of the country.

### 4. Notification from the supervisory body

Points are defined weighting debris priority rank and number of debris. Each country has points equivalent to the amount of debris that it has produced. The removal responsibility is based on these points. Each country has to remove the debris amount equivalent to the points notified by supervisory body in the notified time limit. In the case of a joint project that involves several countries, proportion of points allocation can be decided freely between these countries and has to be reported to the supervisory body.

### 5. Removal mission

Removal missions are also considered missions, and therefore, an increase of debris as a result of a removal mission (due to mission failure, for example) is also added to the country operating such mission.

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   ([2-4] are written in Japanese)

# Appendix 2

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### SPACE STUDIES PROGRAM 2015 FINAL REPORT

# **V B S I O N** 2040



# ₩**₽**\$**I**@N 2040

Final Report

International Space University Space Studies Program 2015 © International Space University. All Rights Reserved. The 2015 Space Studies Program of the International Space University was hosted by Ohio University, Athens, Ohio, USA.

On the cover: the visionary's eye scans the explorer's map, as Earthly blue shifts to Martian red.

Electronic copies of the Final Report and the Executive Summary can be downloaded from the ISU Library website at <a href="http://isulibrary.isunet.edu/opac/">http://isulibrary.isunet.edu/opac/</a>



International Space University Strasbourg Central Campus Parc d'Innovation 1 rue Jean-Dominique Cassini 67400 Illkirch-Graffenstaden France Tel +33 (0)3 88 65 54 32 Fax +33 (0)3 88 65 54 47 e-mail: publications@isu.isunet.edu

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### **Team Project Staff**

Gary Martin – Chair Aleksandar Jacimovic – Teaching Associate

### **Visiting Lecturers**

Heather Allaway Jacques Arnould James Allen Dator Juan de Dalmau Jean-Jacques Favier Don Flournoy Josh Hopkins Matt Killick Jayar La Fontaine Alexander MacDonald Maryam Nabavi Walter Peeters William Pratt Chris Sallaberger Chris Stott Randy Sweet

# LIST OF PARTICIPANTS

Andreia Fatima Sorice Genaro	Brazil	<b></b>
Antonio Rodenas Bosque	Spain	6
Arnau Pons Lorente	Spain	6
Daniel Mater	United States of America	
Danielle Potchter	Israel	٥
Didunoluwa Obilanade	United Kingdom	
Elburz Sorkhabi	Canada	÷
Hugo Filipe De Jesus Simões	Portugal	۲
Hui Zhou	China	*2
Izan Peris Martí	Spain	6
Jacopo Panerati	Italy	
Jayaraju Thirumani	India	8
Lan Li	China	*2
Maria Lucas-Rhimbassen	Canada	+
Marta Rocha de Oliveira	Portugal	۲
Martinus Sleegers	The Netherlands	
Michael Fryer	Canada	+
Michaela Musilova	Slovakia	٠
Niamh Shaw	Ireland	
Niti Madhugiri	India	8
Oriol Gásquez García	Spain	6
Orla Punch	Ireland	
Petter Evju Skanke	Norway	
Praveen Nair	India	8
Reinhard Tlustos	Austria	
Roy Naor	Israel	۵
Ryan Clement	Canada	÷
Saho Yajima	Japan	•
Semion Semionov	Israel	۵
Shaojun Wu	China	*)
Thomas Pearson	Canada	+
Vera Gutman	Israel	۵
Wendy Mensink	The Netherlands	
Xigang Yao	China	*2
Xiuyun Cao	China	*2

# ABSTRACT

Space exploration has always been full of inspiration, innovation, and creativity, with the promise of expanding human civilization beyond Earth. The space sector is currently experiencing rapid change, as disruptive technologies, grassroots programs, and new commercial initiatives have reshaped long-standing methods of operation. In the last 28 years, the International Space University (ISU) has been a leading institution for space education, forming international partnerships, and encouraging entrepreneurship in its over 4,000 alumni. In this report, Vision 2040 projects the next 25 years of space exploration and analyzes how ISU can remain a leading institution in the rapidly changing industry. Vision 2040 considered five important areas of the space sector: real-time Earth applications, orbital stations, lunar bases, lunar and asteroid mining, and a human presence on Mars. We identified the signals of disruptive change within these scenarios, including underlying driving forces and potential challenges, and derived a set of skills that will be required in the future space industry. Using these skills as a starting point, we proposed strategies in five areas of focus for ISU: the future of the Space Studies Program (SSP), analog missions, outreach, alumni, and startups. We conclude that ISU could become not just an innovative educational institution, but one that acts as an international organization that drives space commercialization, exploration, innovation, and cooperation.

# FACULTY PREFACE

This has been an amazing summer at Ohio University in Athens, Ohio, especially for the energetic and inspiring people making up the Vision 2040 Team Project. They worked and played long hours throughout the course of SSP15 and they pooled their creativity to make a significant contribution to ISU.

ISU has maintained a unique leadership position within the space community for 28 years. The Vision 2040 plan looks into the future to continue ISU's evolution over the next 25 years against the backdrop of major achievements of humanity's expansion into space.

The team studied the trends in major areas driving space exploration and developed multiple 'Visions' of possible scenarios in the year 2040. Based on their research, the team identified skills and recommended strategic actions that ISU and other universities should implement to prepare their students for the future world landscape.

The TP Vision 2040 team brought together 35 talented participants from 17 countries. The team members experienced how to work in ISU's interdisciplinary, international, and intercultural (3Is) environment. They produced this excellent well-thought out report and hopefully formed lasting friendships along the way.

In the end, we are proud of what this talented team has accomplished in such a short time. It will be good to see how their space careers grow after SSP15 and we look forward to working with them as friends and colleagues into the future.

Gary Martin, Chair Aleksandar Jacimovic, TA

# **PARTICIPANTS PREFACE**

The problem with the future is you never really know where it is going.

All our lives, it dangles in front of us, a cosmic carrot hovering just out of reach, leading us towards our wildest dreams or our darkest nightmares, and ending up somewhere in between. The past, we may still argue about it, but at the end of the day, it's all said and done. We may live in the present, but we're only temporary residents, nomads running from one time to the next, always just passing through and never able to catch our breath.

But the future, that one's still up for grabs.

Throw 35 people from around the world into a room, give them guidance over the future of something called an International Space University, and tell them to create a vision for 2040 for this institution most have only known for a couple of weeks. Toss experts at them from around the world, swamp them with a sea of post-it notes, whiteboard notes, and google forms. What do you end up with?

At first, chaos. This half of the room can't talk to the other half, not only because they don't speak the same language, they don't even speak the same discipline. Multiple sides are ready to argue for what they believe in, not realizing their opponents are merely making the same point in a different way. Egos get caught up in semantic struggles (do we want people to *speak* for us or *represent* us?), everyone is an expert, and no one is ready to give up their vision without a fight.

But the future waits for no one. It dances beyond the horizon as we squabble in the present, reminding us of the insignificance of our disagreements against the unfathomable expanse of time. As we look toward it, we find ourselves humbled. Differences must be set aside, conflicts resolved, all our efforts must be redirected and redoubled towards this adopted child in our arms. In 25 years, this child will have come of age, and the guidance it needs to achieve greatness is our shared goal, our shared responsibility.

They say that the flow of time is from order to chaos, but humanity has always been the type of species to run against the grain. Faced with adversity, we forge partnerships. Faced with disorder, we organize teams. Faced with disunity, we embrace.

In the end, we look to the future. We look to what ISU is, what ISU wants to be, and what we want ISU to be. We mix all our ideas into the same crucible and use its fire not just to create a roadmap for the future, but an entire satellite navigation system. Like the cosmos, the future still lingers before us, just out of reach and enormous by comparison. But we've got our eyes trained straight on it and our arms are reaching in unison. We may never actually grab the thing, but you know we are going to try.

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# LIST OF ACRONYMS

3ls	International, Intercultural, Interdisciplinary
AI	Artificial Intelligence
CASC	China Aerospace Science and Technology Corporation
CNSA	China National Space Administration
CSA	Canadian Space Agency
ESA	European Space Agency
GNSS	Global Navigation Satellite System
IAA	International Academy of Aeronautics
IAC	International Astronautical Congress
IAF	International Astronautical Federation
ISECG	International Space Exploration Coordination Group
ISRO	Indian Space Research Organisation
ISRU	In Situ Resource Utilization
ISS	International Space Station
ISU	International Space University
JAXA	Japan Aerospace Exploration Agency
LEO	Low Earth Orbit
MOOC	Massive Open Online Course
MSS	Master of Space Studies
MVP	Minimum Viable Product
NASA	National Aeronautics and Space Administration
OC	Online Course
PPP	Public-Private Partnership
SGAC	Space Generation Advisory Council
SSP	Space Studies Program
STEAM	Science, Technology, Engineering, Arts, and Math
STEM	Science, Technology, Engineering, and Math
UN COPUOS	United Nations Committee on the Peaceful Uses of Outer Space
UN STC	United Nations Scientific and Technological Major Group
VASIMIR	Variable Specific Impulse Magnetoplasma Rocket
VR	Virtual Reality

ISU is for dreaming undreamt dreams

James Allen Dator

# **CHAPTER 1 – INTRODUCTION**

The goal of the Vision 2040 team project is to envision the evolution of education, science, space activities, and culture, to create strategies the International Space University (ISU) can implement to prepare future space professionals. ISU has multiple stakeholders, some of whom sponsored this study including the National Aeronautics Space Administration (NASA), the European Space Agency (ESA), and the Centre National d'Études Spatiales (CNES), as well as commercial corporations such as The Aerospace Corporation, Lockheed Martin Corporation, and The Boeing Company. These stakeholders are interested in the education of future space professionals. With this in mind, we envisioned the state of the space industry in 2040 and how these changes will affect national space agencies, aerospace companies, engineering companies, ISU alumni, and future ISU participants.

Focusing on both the current and potential stakeholders, we provide roadmaps and actionable strategies for ISU to build on its strong reputation as a force in the space sector at the forefront of innovation, education, space policy, and international relations. These strategies were identified through the analysis of scenarios that we believe will be characteristic of space activity in the year 2040. These scenarios focus on real-time Earth observation, Earth orbital stations, lunar settlements, lunar and asteroid mining, and a human presence on Mars. After researching current innovative and disruptive technologies likely to impact the space sector before 2040, we put together a plan for ISU to use these technologies. We reviewed how current external developments affect the space industry, underwent visioning exercises with experts in futures studies, and considered how ISU must adjust to this ever-changing political, social, and economic climate.

Through this research, we identified skill and knowledge gaps within each envisioned scenario to create a representative list of skills that would be desirable in future space professionals. We used this list to identify five interesting areas of focus that could each address multiple skill gaps. If ISU developed these areas of focus, it would benefit the university, its stakeholders, and its participants. These five areas are the future of SSP, the potential of analog missions, the need for outreach both inside and outside the space sector, the importance of the alumni network, and the relationship between startups and ISU. We defined a 25-year strategy that ISU can implement immediately with short-term and long-term results. Our hope is that by following this roadmap, ISU will continue to be a world-renowned center of excellence for space studies by the year 2040.

### **1.1 Aims and Objectives**

Vision 2040 provides actionable strategic roadmaps for ISU to remain a leading educational institution for the next 25 years and beyond.

We forecasted the possible futures of global education and networking and studied how these changes might affect ISU in the coming decades. Envisioning different scenarios for space from geopolitical, scientific, socio-economic, cultural, and technological perspectives, we proposed strategies that will ensure that ISU maintains an important role in the future.

The tasks required to achieve our objective included:

- predicting future space developments
- forecasting new methods of learning
- reviewing current long-term ISU goals
- identifying key challenges in the space industry for current and future ISU stakeholders
- envisioning what kind of skills are necessary to address the identified challenges
- identifying what role ISU plays in providing these specific skills
- recommending new educational, technological, and management approaches
- creating a full 25-year strategy to keep ISU on the cutting edge of the rapidly changing environment.

Key tasks as defined in the ISU SSP15 Handbook are presented in Table 1 along with the locations where they are addressed in the report.

Task	Chapter(s)
Research on predicted space developments, disruptive technologies, changes in educational methods, and similar areas.	2.1, 2.2, 2.3, 2.4, 2.5
Review the current long-term goals of ISU as described in the ISU Credo and the recent 2012 Academic Council Strategic Roadmap.	3.1, 3.2, 3.3, 3.4, 3.5
Identify current and potential ISU stakeholders in the space sector and associated industries.	3.1, 3.2, 3.3, 3.4, 3.5
Create a list of key challenges facing space industry, space science, and associated endeavors.	2.1, 2.2, 2.3, 2.4, 2.5
Envision the skills and knowledge necessary to address the challenges.	3.1, 3.2, 3.3, 3.4, 3.5
Explain how ISU could provide these specific skills and knowledge, developing its unique culture and partnerships with other institutions.	3.1, 3.2, 3.3, 3.4, 3.5
Recommend new educational, technological, and management approaches to keep ISU at the forefront of the rapidly changing environment.	3.1, 3.2, 3.3, 3.4, 3.5
Define a full 25 year strategy or strategies for ISU, considering the potential results of intermediate short-term strategies.	3.1, 3.2, 3.3, 3.4, 3.5
Define a set of parameters that could track the implementation of the strategy in the short and long term.	3.1, 3.2, 3.3, 3.4, 3.5
Document findings and produce practical and actionable recommendations that will assist decision makers and influence the future direction of ISU.	3.1, 3.2, 3.3, 3.4, 3.5

### Table 1 – Tasks from the SSP15 Handbook

### **1.2 Project Scope**

To meet the project objectives, Vision 2040 selected and studied five different scenarios that we believe will characterize space activity from now until the year 2040: real-time Earth applications, orbital stations, lunar bases, lunar and asteroid mining, and a human mission to Mars. We identified challenges and roadblocks that could prevent these scenarios from becoming reality.

We analyzed the challenges and roadblocks of all of the scenarios together to create a list of skills that would be necessary for future space professionals. Our portrayal of these scenarios is not intended to be a precise prediction of the future. It is an analysis of the general trends and challenges that are likely to occur in the next 25 years and the representative skills necessary to solve them.

Using the trends from these five scenarios, the team envisioned a multiplicity of roles that ISU could have in the space sector in the next 25 years. Vision 2040 developed strategies in five areas of focus that the team determined were the most important to ISU: the future of SSP, analogs, outreach, alumni, and startups. The strategies are intentionally broad as they are intended to provide actionable ideas to consider and study further. They are not business plans or feasibility studies, and they do not include elements such as cost estimates. The feasibility of a project can greatly depend on a large list of factors such as ISU being financially, administratively, politically, and logistically in a position to take on a scenario.

This project emphasizes the development of human space exploration, for example a crewed mission to Mars. The team decided to focus on these elements of space exploration because of ISU's emphasis on the exploration of space for the benefit of humanity as outlined in its Credo (Diamandis, Hawley and Richards, 1995). We researched other areas related to non-human space exploration, including robotic probe exploration of planets beyond Mars, astrobiology, and cosmology, but determined these areas to beyond the scope of this report.

### **1.3 Mission Statement**

We have summarized our aims, objectives, tasks, and scope for Vision 2040 in the following mission statement:

Vision 2040 will provide strategic roadmaps for ISU by forecasting future scenarios in space exploration and development. We will identify signals of disruptive change, their underlying driving forces, potential challenges, and the skills that will be necessary to overcome those challenges. We will create actionable recommendations to ensure that ISU and its stakeholders have a significant role in the future of space.

### **1.4 Methodology**

Forecasting possible futures and assessing strategic actions for ISU was a challenging mission. Given a broad subject to address, Vision 2040 engaged in research, brainstorming sessions, and debate to define and manage our project's scope. The result was a fluid organizational structure, that changed drastically through three distinct phases of our project.

First, we examined larger societal trends driving the space sector. We worked with prominent figures from diverse fields such as policy, technology, and culture to forecast a number of possibilities for the future. To organize our research, the team split into groups, each tasked with a specific area of interest and a mission to forecast more detailed models. Inspired by the ISU structure, we divided our teams according to the seven ISU departments: space applications, space engineering, human performance in space, space humanities, space management and business, space sciences, and space policy, economics, and law. While the original departments dealt primarily with space exploration, we used these departments as a starting point to envision future developments on Earth as well. Each team presented its findings to all other members.

Second, we identified trends specific to space exploration and development. To analyze the possible scenarios, we searched for real-world events that signaled these trends, such as the Google Lunar XPRIZE, and the underlying driving forces behind them, such as a renewed interest in the Moon. These identified signals and underlying driving forces were used to identify a set of challenges that would hinder the development of these scenarios. These challenges were used to create a representative list of the major skills that would be required for future space professionals, as shown in Table 2. These skills are not exhaustive, but frequently recur throughout the scenarios.

Our third and final phase consisted of using the knowledge collected to make recommendations for strategic actions to address the skills required in the future. As our project's specification included ISU by name, we identified five main areas of focus potentially relevant to ISU, focusing mostly on the SSP as the area of ISU with which we were most familiar. These included strategies for reforming SSP, hosting analogs, increasing ISU's outreach, ISU's alumni, and incubating startups.

Skill	Definition
Entrepreneurship	Development of new for-profit space companies
Communication and negotiation	Effective exchange of information across cultures and states to form agreements in law, business, and science
STEAM education	Science, technology, engineering, arts, and mathematics education
International cooperation	Streamlined processes for international technology transfer, space operations, crew support, and mission control activities
Big data analysis	Efficient processing of massive quantities of data from remote sensing applications
CubeSat technology	Small, cheap, satellites based on the modular cube standard with dimensions of 10 centimeters on each side
Life support systems	Technologies related to sustaining human life in orbit, the Moon, and Mars
Advanced spacecraft technology	Spacecraft technology necessary for future exploration, including propulsion, power, communication, navigation, thermal, structural and control systems
In situ resource utilization	Harvesting resources in space for use by spacecraft and lunar or Martian base stations
Public outreach	Engaging and educating the general public about space
Crew selection and training	Reliable methods for choosing appropriate crews and preparing them for long duration missions
Space policy	Defining clear, achievable, long-term goals and regulations for national space agencies, the commercial sector, and international partnerships

### Table 2 – Skills and Definitions



Figure 1 - The three phases of the team project.

# **CHAPTER 2 – VISIONARY THEMES AND TRENDS**

We began with a detailed literature review based not only on ISU sources, but also published articles from universities, NGOs, governments, and commercial enterprises. Expanding on material covered in the core lectures, we consulted with experts on futures studies, policy, business, culture, and other relevant areas. Building on this research, we created five scenarios that we believe will characterize space initiatives in 2040: real-time Earth applications, orbital stations, lunar settlement, lunar and asteroid mining, and a human presence on Mars. Appropriate mission statements were formulated for each scenario alongside corresponding signals, drivers, challenges and skills defined below.

Signals are events, products, services, experiences, or cultural developments that exemplify a major change. Drivers are defined as the deeper forces underlying groups of signals. We considered them under social, technological, economic, environmental, or political categories. Challenges are defined as problems that could impede, or are already impeding, the development of signals and drivers.

Skills are defined as areas of applied interest, knowledge, education, professional abilities, and social skills. To determine where there are skill gaps, we looked at what areas of education, professional development, social development, and other forms of expertise would be necessary to overcome the identified challenges.

After choosing five main space missions, our team was split into five groups: real-time Earth applications, orbital stations, lunar settlement, lunar and asteroid mining, and human presence on Mars. The signals, drivers, challenges, and skills for each of the above scenarios are detailed in this chapter with appropriate diagrams and illustrations.

### 2.1 Real-Time Earth Applications: Observation and Telecommunication

The satellite industry represents the largest portion of today's space industry, accounting for over 60% of the total revenue of the global space industry (SIA, 2015). Most commercial analyses divide satellite applications into three major areas: space-based Earth observation, satellite telecommunication, and Global Navigation Satellite Systems (GNSS).

The main motivation for the improvement of satellite technology has been to increase the speed and frequency at which information is acquired, processed, and propagated to the ground (NASA, 2014a). We envision in 2040 a more interconnected world with global access to real-time Earth observation data and telecommunication systems across multiple platforms with a greater range of resolutions and bandwidths. This cross-disciplinary use of satellite technology will lead to increased activity in satellite constellations and open access to data, allowing for a variety of applications for the general public.

The total number of active satellites today is almost 1,000, out of the approximately 6,000 launched over the course of the last 60 years by more than 40 countries (UCS, 2015). Space-based Earth observation capabilities have already changed our lives dramatically. For example, NASA's Earth Science Enterprise and its partners can now reliably predict climate variability and change over oceans and landforms, and analyze the implications of these changes for food production (NASA, 2003).

Earth observation services are still a relatively small part of the entire satellite services market. In 2014, their total revenues accounted for \$1.6 billion of the approximately \$120 billion satellite services industry (SIA, 2015). The majority of this market is in the satellite telecommunication industry, with a market of over \$100 billion, primarily from satellite television providers (SIA, 2015). More than 250 million people now use satellite radio and television services (SIA, 2015), although the majority of telecommunications are not provided by satellites (IDATE, 2014).

### 2.1.1 Signals and Drivers

This section reviews the technological, economic, and social trends currently arising in the space applications industry, particularly in Earth observation and satellite telecommunication. We will also explore the industry drivers, the potential services that these trends may enable.

The number of nanosatellites, launched to support Earth applications, has increased by a factor of six in the past five years, with a total of over 120 in 2014 alone (SIA, 2015). A CubeSat, as defined by California Polytechnic State University (2009), is a nanosatellite with a 10 cubic centimeter volume. CubeSats are popular with the academic community and some branches of government because of their relatively low cost and simple construction. CubeSat components can even be bought online since much of their hardware is standardized. As of 2015, CubeSat projects involve over 100 universities, high schools, governments, science groups, and private firms developing payloads. These small satellites are not suitable for all mission objectives, especially those requiring "large transmitter powers, antenna arrays, or optical apertures" (Guven, Velidi, and Behl, 2012) but improved on-board processing capabilities mean that smaller and cheaper satellites can conduct missions that used to require large satellites. Since 2012, the Canadian Space Agency (CSA) and industry partners such as MacDonald, Dettwiler and Associates (MDA) have sponsored inter-university competitions for the design of these small satellites (CSDC, 2014). In 2015, ESA announced it will offer transportation to the asteroid belt to six CubeSat designs (ESA, 2015a), and NASA announced a \$5 million campaign for the development of CubeSat technologies, including propulsion and deep-space communication (NASA, 2014b). This interest in CubeSat technology will only continue to grow as "80% (or more) of program goals can be achieved for 20% of the cost" (Baker and Worden, 2008), allowing a larger number of new actors to enter the space sector.

Progress in satellite telecommunication systems has so far been defined by steady improvements in key technologies such as attitude control, solar panels, and antennas, with occasional disruptive innovations such as turbo codes. In the current decade, initiatives bringing greater Internet access to less connected parts of the world, such as Sub-Saharan Africa, have become a transformative trend. These initiatives include Google's high-altitude balloons, Project Loon (Google, 2015a), Facebook's Internet.org (Facebook, 2014), and networks like O3b (O3b, 2015) and OneWeb (Knapp, 2015a), which aim to use satellite constellations to connect developing countries to the communication grid. This rise in activity further demonstrates a need for more expertise and experience in the field of small satellite systems.

In terms of Earth observation, we can forecast that real-time, low-cost, tailored applications will become publicly available thanks to the development of commercial remote sensing satellite systems incorporating the latest technologies. In a space-based sensor web architecture, various sensors operate in different orbits to provide customized spatial, spectral, and temporal resolutions to both individuals and corporations worldwide. These systems would allow, for example, a potential for better management of disasters, as well as improved biosphere and weather forecasting capabilities (NASA, 2014a).
In summary, we identified that the main signals and drivers for real-time Earth applications are the growth in the nanosatellites industry, initiatives to provide global connectivity, and advances in commercial remote sensing systems. In the next section we will discuss the challenges that may hamper the development of these technologies.

### 2.1.2 Challenges

In addition to the signals and drivers for future developments in real-time Earth applications, we must also consider any problems that may disrupt their development. This section identifies and explains the main challenges affecting the development of these signals and drivers.

One of the biggest challenges for future space applications near Earth is the increase of space debris in Earth's lower orbit. Currently, there are more than 400,000 objects with a size of one centimeter or more in Low Earth Orbit (LEO) (NASA, 2014c). If we develop active debris removal measures and post-mission disposal techniques, we can prevent preferred orbits from becoming overpopulated and unusable in the near future. The phenomenon known as the Kessler effect (Kessler and Cour-Palais, 1978) states that when the debris density surpasses a certain threshold, a cascade effect in collisions will lead to an exponential growth of debris fragments. This problem could become worse with the rapid increase in CubeSat launches, leading to the accumulation of orbital hazards from defunct satellites.

While commercial computer systems on Earth evolve at a pace that is slowing but still reasonably close to Moore's law predictions, most of the computer hardware used in space applications is several generations out of date (Bajracharya, Maimone and Helmick, 2008). The increase in spatial, temporal, and spectral resolutions also pose a challenge for Earth observation systems. More data does not necessarily mean better science and applications, particularly if we are unable to effectively analyze it (Benediktsson, Chanussot and Moon, 2012). Another challenge is the amount of spectrum that regulatory bodies, such as the International Telecommunication Union (ITU), would be willing to preserve or allocate for space activities.

### 2.1.3 Skills

In the two previous sections we presented trends in real-time, Earth-focused, space applications and the challenges the industry will face in the near future. This section identifies the skills, initiatives, and expertise that the space application community and ISU should develop to cope with such challenges.

CubeSat technology is valued by universities, corporations, and government organizations who seek their development to perform valuable scientific experiments and missions in space (Chin, et al., 2008). Guven, Velidi, and Behl suggest that "in addition to fulfilling communications, remote sensing and space science applications, CubeSats are particularly suitable as a focus for the education and training of young scientists and engineers" (2012). Using CubeSats, universities can give their teachers and students a more practical and interdisciplinary learning experience in every phase of a satellite mission (Guven, Velidi and Behl, 2012). CubeSats have significantly reduced the cost to access space, allowing for new opportunities for entrepreneurs. There is also potential to increase the amount of remote sensing applications. Processing data from these sensors, commonly known as big data analysis, is a major computational challenge.

In the context of new policy, the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) has set up the Working Group on Long Term Sustainability of Outer Space Activities to develop and evaluate practices, technical standards, and policies relevant to space

environment sustainability for all space stakeholders (COPUOS, 2010). UN COPUOS only provides voluntary guidelines for reducing the creation of orbital debris. Improving communication and negotiation could lead to a proactive way to address the practical and policy concerns regarding space debris. A possible policy could be the creation of a commercial market for active space debris removal.

The research community has proposed several different techniques to accelerate the postmission disposal of satellites. Active removal techniques, such as missions proposing the use of robotic arms to de-orbit inactive satellites, pose a number of political challenges, as they can be seen as technology that has dual-use in military and civilian sectors. Current approaches based on passive mitigation techniques include drag sails, balloons, and tethers. These approaches should be made available for nanosatellites, including the incorporation of end of life disposal in the design (Smyth, et al., 2014), given that the major threat of space debris is the number of objects and not their size.

As we mentioned in the previous section, one of the limitations of current space systems is the quick obsolescence of their computer hardware. The reason for this is the high level of reliability required by satellite systems and the long testing process needed to guarantee it. A new way to address this problem is through computing systems with fault-tolerant and self-healing capabilities based on artificial intelligence methodologies (Panerati, Abdi and Beltrame, 2014). The next generation of satellites could host on-board computers with capabilities comparable with contemporary supercomputers.

### **2.2 Orbital Stations**

In the year 2040, we envision community-based orbital stations in space that will serve a number of different functions. In addition to current facilities for scientific research and communication, the private and public sector will create and operate new facilities for education, tourism, industry, and culture. These facilities can be used by astronauts to perform experiments and study space sciences in the unique microgravity environment. They can reduce the cost of deploying satellite constellations by acting as in-space deployment facilities for CubeSats (David, 2011). They can also provide a number of benefits to humans on Earth by augmenting existing technologies taken for granted such as satellite television and communication, or by transforming the method and speed at which we can observe the Earth (Messerschmid and Renk, 2010).

To realize this vision, we must address a number of challenges on both a national and international level. The transition from government-led space activities to cooperative commercial efforts will require re-examination of the current legal frameworks. We will need to address the engineering challenges in relation to life support systems, radiation protection, and launch vehicles. We will also need international policies to clarify and resolve issues around topics such as spectrum allocation, property rights, and technology transfer.

### 2.2.1 Signals and Drivers

In the early days of spaceflight, prominent space theorists such as Konstantin Tsiolkovsky and Hermann Oberth were among the first to propose the concept of orbital stations. The Soviet Union became the first nation to launch an orbital station with its Salyut program, which operated from 1971 until 1986 (Messerschmid and Renk, 2010). This program, which eventually led to the multimodular Mir Space Station, represented a shift in emphasis from human exploration of the Moon towards inhabited space stations. The United States responded with its first inhabited space station, Skylab, in 1973. Following the end of the Cold War, thanks to improved international relations, the United States worked with the Russian Federation, as well as authorities in Europe, Japan, and Canada, to create the International Space Station (ISS) (Messerschmid and Renk, 2010). In 2011, China launched its first orbital test module, Tiangong-1, for a space station planned in 2020 (Moltz, 2011).

The success of both Mir and the ISS greatly pushed the boundaries of space sciences and engineering, opening up new capabilities of human involvement in space (Messerschmid and Renk, 2010). The private sector, in particular, became much more involved in transportation both to and from space, as well as in the daily operations on the space stations. Britain announced plans for a new spaceport (Cable, 2015). A private spaceport in New Mexico, Spaceport America, has already been constructed and is presently serving Virgin Galactic, SpaceX, and a few smaller aerospace companies. This particular facility has the capacity to support future commercial space adventures (Knapp, 2015b).

With the growing interest in commercial space, many companies have been imagining uses for space stations. Bigelow Aerospace, Orbital Technologies, and Nanoracks have already launched, or have plans to launch, commercial space stations for a variety of purposes (Orbital Technologies, 2011). Currently, companies like Nanoracks and Urthecast are using the ISS for scientific and commercial purposes. In the future, more CubeSat and nanosat companies might prefer to build and deploy satellites from space stations rather than commissioning dedicated launches from Earth (David, 2011). Companies like Planetary Resources, which are focused on asteroid mining, could use orbiting stations as a waypoint on their ventures further into space (Levin, 2015). Deep Space Industries, who have plans for space-based manufacturing, would also like to use orbiting stations for similar reasons (DSI, 2015). Private enterprise will likely become an even larger driving force in the exploration and commercial development of space.

Scientific research communities will want to continue using space laboratories, observatories, telescopes, and other instrumentation in orbit, to avoid the effects of Earth's atmosphere and gravity. A variety of scientific research activities are currently on-going on the ISS, focusing both on microgravity experiments (Evans, et al., 2009; NASA, 2014d) and Earth observation (Atkinson, 2013). The unique orbital environment offers an important platform for scientific research experiments and astronomy.

The realm of space, historically considered one of primarily scientific, governmental, or commercial interest, is also a place for cultural expression. We have already seen signals of this cultural drive in the form of charismatic astronauts like Chris Hadfield, who used music and creative video work to reach millions (Aron, 2013), as well as space tourists like Cirque du Soleil CEO Guy Laliberté, the self-proclaimed "first clown in space" (Moskowitz, 2011). In the future, as human presence aboard space stations becomes more economical and common, we can envision these orbiting platforms becoming centers of artistic production, theatrical production, journalistic investigation, cultural narratives, space spirituality, and research hubs for the social sciences.

In summary, we identified the main signals and drivers for orbital stations in the growing interest in commercial space and the increased interest by the research community, as well as the arts community, in microgravity experiments. In the next section we will look at the challenges that might disrupt their development.

#### 2.2.2 Challenges

Before the full development and use of multi-purpose space stations can be achieved, we must overcome challenges, particularly in the realms of engineering, international policy and law, and creative thinking.

First, launching a spacecraft into orbit requires a lot of energy, constraining both the potential mass and volume of orbital stations (Wertz, Everett and Puschell, 2011). If we cannot develop new methods of transportation to orbit, the engineering challenge will be to develop new materials and structural designs that will allow for the construction of suitable habitats within current launch requirements (Liu and Shufeng, 2012). Another related constraint is the fact that orbital stations need to be resupplied regularly. While we can theoretically develop closed loop life support systems to provide supplies for human crews, future Earth-orbiting stations, especially those in LEO, would require more efficient propulsion systems and launch vehicles to become economical. For example, the cost of constant refueling and resupplying missions heavily influenced the decision to de-orbit the Russian Mir station. Micrometeoroids and orbital debris, whose real-time tracking is expensive and technically difficult, also pose a significant threat to orbital stations (NASA, 2010). Radiation poses a specific threat to electronic systems and is especially challenging for long duration human habitation in space (Qualls, et al., 2001).

The interaction of national policies, laws, and multilateral agreements will also continue to pose a challenge, particularly as the sector transitions from a realm of competitive government programs to a more cooperative, international, and commercial collaboration. For such activities, we would need to immediately review existing laws and treaties. New policies would need to address the use of space for purposes beyond traditional science and engineering (DeGroot, 2009). Organizations such as UN COPUOS, formed during a government-driven era of space exploration, will need to adapt to more commercially-driven times. Major space companies have invested several billion dollars in space and will compete fiercely in pursuit of a return on investment. The expanded commercial use of space might also result in disagreement and conflict over issues such as the management of space debris, spectrum allocation, property rights, technology transfer, military use of orbital stations and related technologies, and the ethical and legal issues connected to an increased human presence in space. In the context of the creative and cultural use of space, divisions remain between organizations driven by practical considerations like feasibilities, realism, and budget limitations, and those with a more forwardthinking approach to space stations driven by science fiction, cultural imperatives, and radical innovations (Griffin, 2007).

In summary, the biggest challenges facing the development of orbital stations include spacecraft launch and resupply design constraints, radiation exposure, changes in space policy, and placing a cultural value on the arts in space.

#### 2.2.3 Skills

To take full advantage of space development, we will require different types of skilled personnel. The international space community, for example, must focus on international cooperation to formulate and enforce appropriate laws and policies. We may need alternative dispute resolution techniques, such as mediation or arbitration, to deal with the inherent uncertainties of space activities. Countries participating in international collaborations in space must establish clear laws and policies to avoid potential disputes and ensure continued cooperation in support of orbital stations. Personnel skilled in communication and negotiation will be vital to the space sector. Commercial initiatives in the space industry require entrepreneurs with substantial investments and public-private partnerships (PPPs) that rely on the previously mentioned skills. Collaboration with governments and policy makers is crucial for the success of the space sector. Such cooperative business and management methods and practices will aid in attracting public investors, and will create effective strategies and alliances. These practices can be extended to partnerships with existing non-governmental organizations (NGOs) that may increasingly be interested in space-based solutions.

The next generation of orbital stations will require developments in advanced spacecraft technology. Providing food for any human presence in space remains a primary issue in engineering space habitation (Yokota, et. al, 2006 cited in Katayama, et. al, 2008). An effective and self-sustaining artificial habitat will assure the continued growth of the human population in orbit and working towards deep space missions. Plants will be important in feeding the crews through closed loop life support systems, making reliable plant growth in controlled microgravity environments mandatory for successful space farming (Link, et al., 2003; Quantius, et al., 2014). Years of experience on the ISS show that it is possible to control the growth of plants in such environments (Link, et al., 2003).

Entomophagy, the use of insects for food, in space-based agricultural schemes could supply vital proteins, amino-acids, and other nutritional needs (Katayama, et al., 2008). For future space tourism and deep space missions, we must also develop biogenerative technology. Researchers worldwide are focusing on potential solutions for closed loop life support systems, including hyper-thermophilic aerobic composting bacteria (Kanazawa, et al., 2008). To assure the sustainability of a long duration human presence in space, we will need to develop expertise in space agriculture.

To prepare for this future with more humans in space, we will need people with both strong technical and strong creative skills. We will need to encourage more Science, Technology, Engineering, Arts, and Mathematics (STEAM) education. That is, we need to include Arts into the Science, Technology, Engineering, and Mathematics (STEM) concept. STEAM education will facilitate crossovers between faculties of arts and sciences at the university level. Public campaigns—such as artist residencies and competitions—will encourage artists and members of the public to envision the opportunities of space stations. The space cultures of the future will need not only skilled professionals capable of reflecting, challenging, and innovating on their experiences in space, but also of communicating those ideas to the public.

### 2.3 Lunar Settlement

One of the scenarios we portray is a vision in which we return to the Moon and build a settlement. By 2040, some 71 years will have passed since humanity first landed there on the Apollo 11 mission.

The lunar base vision includes a variety of parallel opportunities for lunar research, lunar industry, lunar settlements, an intermediate station, and lunar tourism.

Lunar research refers to "lunar scientific exploration involving three types of investigations: science *of the Moon*, science *from the Moon*, and science *on the Moon*" (ISECG, 2007). We will use this research to better understand Earth's largest natural satellite and to gain the knowledge necessary to advance humanity further into space.

Lunar industry will use the Moon for commercial purposes and it is one of the major reasons to return to the surface of the Moon. Early ore exploration showed that the Moon holds elements scarce on Earth, offering unique manufacturing opportunities. Mining and product manufacturing, using both robots and human crew, can support a lunar base and its activities, but will be expanded upon in section 2.4 Lunar and Asteroid Mining section of this chapter.

A settlement will be a vital part of the lunar base. This settlement can serve as accommodation for a permanent or temporary community to support the industry, research facility, and intermediate station, and can be the base for lunar tourism. We could use viable lunar settlements to address problems of overpopulation on Earth, or to preserve humanity's existence in the event of an extinction level cataclysm on our home planet.

The Moon as an intermediate station is an important stage in planetary exploration. The idea is to make outer space more accessible, to make the journey more efficient, to overcome payload and cargo limitations, and lower the costs by a layover in the lunar base.

Lunar tourism envisages making space more accessible, and also improving public outreach by inspiring more people to explore space. Lunar tourism represents a side project that supports the economy of the local community and fulfills the desire of space exploration for the masses.

### 2.3.1 Signals and Drivers

The signals and drivers are the elements pushing this scenario forward. We have identified different signals demonstrating an interest among countries, companies, and members of the public in settling the Moon (Fecht, 2013; Hollingham, 2015).

Some of the signals are common to all of the lunar scenarios. The aim of affordable and reliable access to the Moon has motivated space companies and agencies to develop enhanced launch technologies. SpaceX is interested in having reusable launch systems and NASA is designing new and more capable rockets like the Space Launch System in collaboration with Lockheed Martin and Boeing. These organizations are revolutionizing the sector and pushing for more affordable access to space.

The science-fiction genre inspires the public immeasurably (MacFadyen, 2014), as the Apollo missions did in the 1960s and 1970s. Both fantastic and real cultural phenomena help us to imagine ourselves as an interplanetary species. The Google Lunar XPRIZE and other design challenges are capturing the attention of existing companies or helping fund new ones, boosting the public awareness of these kinds of missions.

NASA, ESA, JAXA, ISRO, and CNSA have all performed missions on the Moon's surface or in its orbit in the past 15 years (The Planetary Society, 2015). Moon research has been getting a lot of attention with programs such as Lunar Mission One and NASA Resource Prospector (NASA, 2015a), but there is also interest in learning how to build and operate an extraterrestrial base and improve life support systems as exemplified in the Self Deployable Habitat for Extreme Environments (SHEE) (Doule, et al., 2014) and the new waste management systems tested in the ISS (NASA, 2011).

Today's propulsion technologies have limited range and rely on prohibitively expensive propellants. Deep space exploration missions could use the Moon as an intermediary station for further destinations, both for refueling and storing products for planetary exploration. The current

research on in situ resource utilization (ISRU) might enable the use of the Moon's own resources as propellant, avoiding the need to carry extra fuel from Earth (Fecht, 2013; Hollingham, 2015).

Space tourism has also been a major new driver in opening up new space technologies. As seen in design competitions like the Ansari XPRIZE (Kai, 2011), and current offers for lunar orbit missions from Space Adventures (Space Adventures Ltd., 2015), lunar tourism will generate profitable ventures by providing space experiences to a high-end tourism market branching out from the nascent suborbital industry. Emerging companies like Golden Spike intend to provide transportation services to and from the Moon for both passengers and cargo (Forbes, 2014). Astrobotic offers more novel products, such as MoonMail, a service that allows individuals to pay to have their personal keepsakes delivered to the lunar surface (Astrobotic, 2014).

In this section, we identified an increased interest in affordable and reliable ways to get to space, for lunar missions and space tourism, by space agencies and private enterprises. We define these to be the signals and drivers for future lunar missions and in the next section we will look at challenges that may disrupt the establishment of a lunar base in the years ahead.

### 2.3.2 Challenges

The most important challenge for any lunar base mission is adequate funding, although mission designers must also address technical difficulties such as the need for easier access to space. There are challenges that are relevant to the whole scenario, while others are specific to certain missions and sub scenarios.

There is a strong probability that commercial companies will take the lead on the lunar settlement. To cope with shrinking budgets, governments and agencies will need to get involved in PPPs. A good relationship between private companies and governments will be essential. International organizations, such as the UN, will need to review current treaties and agreements to resolve legal issues around funding, ownership, and other concerns.

To actually build a lunar base, the main challenges will be technical ones. These challenges include the safe and cost-effective transportation of all the equipment, supplies, and people, as well as the establishment of a sustainable and fully functional settlement. The main knowledge gaps we are still facing are in fast and reliable refueling technology, reliable landing and relaunching systems, and in reliable heavy-lift launch vehicles that can answer the intensive needs for supply, merchandise, transportation, and communication.

Another major difficulty will be finding the right ways to pursue public outreach and engage governments. There will be a need for fundraising from private investors. To establish a lunar base, popular support will be of critical importance, as the public needs to be sufficiently interested in developing a lunar presence for a market for commercial enterprises to be established and attract government support.

The main problems facing a lunar settlement are a gravity one-sixth that of Earth and the need for long duration multi-function life support systems. An additional challenge includes caring for the population sent on the mission. The desired settlement population should incorporate a variety of ages, genders, nationalities, beliefs, and other demographics. A lunar base mission requires an intense selection and training program with strong considerations put toward crew composition, to ensure a well-knit, and diverse lunar community. To prevent and respond to illnesses and hazards, the base requires a health system and other services regulated by a governing structure.

In the case of lunar tourism, we foresee specific challenges regarding a sustainable business plan to make it profitable, affordable to most people, and enduring. Tours will rely on promotional campaigns to appeal to the public and communicate the safety of the experience. Tourist companies will need to establish reliability and credibility, and ultimately remain liable in the case of negligence.

In summary, the main challenges facing the establishment of a future lunar base are primarily financial and technical, as well as getting support from governments and the public.

### 2.3.3 Skills

Creation of a lunar base requires development of several advanced spacecraft technologies. Demand for the transportation of materials, equipment, and facilities between the Moon and Earth will increase. To transport those payloads, we need to develop a heavy-lift space vehicle, whose capabilities might exceed current launch vehicles. Currently unused propulsion technologies, such as nuclear propulsion (Bruno and Dujarric, 2013), might be required to achieve these goals.

Taking into account human components, the critical issues will be the safety and cost of the space trip. We need to develop a safer, more reliable, and cheaper spacecraft and life support system to enable further human exploration of the Moon. The development of the new spacecraft will require competition and cooperation among the traditional and emerging commercial companies and space agencies.

Having a human presence on the Moon will create a high demand for energy. Based on the evolution of the energy infrastructures and supply capability, an energy hub (Geidl, 2007) to meet the energy demands for long term habitation on the Moon will be required. Both nuclear technology and the advanced storage of solar power could help meet these demands.

New methods of crew selection and training will play an important role, taking into account crew compositions, compatibilities, and team roles. As with an ISS mission, we need to pay more attention to human health and performance on any long duration missions away from Earth than we would on our planet. We would use dynamic medical and psychological monitoring techniques.

Since getting to the Moon is so expensive, securing sufficient funding and developing a clear space policy will remain a constant concern. We need new public outreach strategies that will engage the public and raise awareness of the benefits of these missions, as well as promoting their commercial potential. Crowdfunding and government support will also be important aspects.

Research settlements and tourism activities will require new structures and the construction of habitable sites for long-term or permanent settlement. The life support and recycling systems, especially ones that take advantage of on-site resources, will be critical for humans to maintain an everyday existence on the Moon or especially to perform extravehicular activities.

The future space sector will be much different from the one we know and will need to be approached in a different way. We expect NewSpace companies to lead human exploration, and their interaction with government agencies will set the framework for future missions. Agencies in

developing countries will also play an increasingly important role in these aspects. A common roadmap for all these actors needs to be found and established.

### 2.4 Lunar and Asteroid Mining

Exploration of space, while inspired by humankind's curiosity and appetite for adventure, also has the inherent benefit of allowing access to a vast supply of untapped resources. As space access increases, resources in limited supply on Earth can be augmented by resources from space. In the coming 25 years, space resources could be used on space missions, greatly reducing the cost and complexity of deep space exploration.

In situ resource utilization (ISRU) processing and use of space resources are growing trends in both the public and private space sectors. Current ISRU projects are focusing on fuel production to reduce the cost of long duration space missions. Water on the Moon and on asteroids, and carbon dioxide on Mars can all be turned into rocket fuel, and there will be an ISRU experiment on the next NASA Mars mission scheduled to fly in 2020 (NASA, 2014e). ISRU has the potential to ignite manufacturing in space as well. Although more complex than the simple harvesting of extraterrestrial resources to make fuel, the initial stages of space manufacturing could emerge in the next 25 years, especially with a wider terrestrial development and adoption of 3D printing in the space sector (Lipson and Kurman, 2013).

Among other challenges, extracting space resources will need new interdisciplinary technologies. Using ISRU successfully will require a combination of developments in sectors like aerospace, mining, chemistry, industry, engineering, and manufacturing. International treaties and national policies will need to be created to address the uncertainties in regards to the extraction and use of resources from celestial bodies.

### 2.4.1 Signals and Drivers

We envision that future space travel will become increasingly accessible to the general population. As more people travel to and from space, the increased spread of information could lead to greater interconnectivity and a wider sharing of ideas and accomplishments, further driving the use of space-based resources.

Existing missions to the Moon, asteroids, and comets are currently driven by space science. Examples of these missions include JAXA's Hayabusa 1 (JAXA, 2013) and Hayabusa 2 (JAXA, 2015), NASA's Asteroid Redirect Mission (NASA, 2015b) and the OSIRIS-REx mission (NASA, 2015c), and ESA's Rosetta mission (Glassmeier, et al., 2007). Some countries have rededicated their entire programs to the exploration of the Moon. These include China's Chang'e program (Tate, 2014) and the Indian Chandrayaan program (Subramanian, 2014). Both have successfully launched lunar orbiters and have plans for future landers. Additionally, the Chinese program has already landed one rover and has plans for a robotic sample return mission. Private entities are also getting involved, for example, the Google Lunar XPRIZE is offering \$30 million to whichever team can send a rover to the Moon using primarily commercial funds (Google, 2015b).

The increased interest in the Moon and asteroids, and the technology developed from space science missions is in turn enabling the creation of more missions targeted towards the use of space-based resources. These missions generally look at resource identification and extraction. For the Moon, NASA is developing the Resource Prospector mission (NASA, 2015a) to determine the viability of extracting useful amounts of water from the lunar poles. The results of this mission

could prove to be transformative for space travel beyond the Earth-Moon system, as harvested resources could be used as fuel to reduce the initial launch costs of spacecraft.

Additional research is also being conducted on the use of the lunar regolith material to build structures on the Moon (Mueller et al., 2014). The concept is compelling enough to be part of NASA's proposed architecture to send humans to Mars (Drake, 2009). ISRU experiments are being incorporated into missions such as NASA's Mars 2020 rover, which will produce oxygen from carbon dioxide in the Martian atmosphere (NASA, 2014e). The commercial sector is also getting involved, with companies such as Moon Express looking to mine lunar resources (Maharaj, 2013), and companies like Planetary Resources and Deep Space Industries pursuing asteroid-based resources (Lewis, 2015).

Once the resources are acquired, improved manufacturing techniques could allow for processing the material without returning it to Earth. Additive manufacturing techniques show great potential for creating a wide variety of tools and parts with minimal infrastructure requirements. This technology is already being proven on the ISS with the 3D printer supplied by Made In Space (NASA, 2014f). A new generation of 3D printers will soon be flight-tested by ESA (Brabaw, 2015) and China (XINHUA, 2014).

As these technologies mature, new regulatory legislation will be required. This process has already begun in the United States, with legislation being introduced to specify the ownership of asteroid resources (Messier, 2015).

In summary, we have identified that changes in regulatory legislation, increased public and private activities in missions to celestial bodies, and the development of technologies such as ISRU and 3D printing are the signals and drivers of change in lunar and asteroid mining.

### 2.4.2 Challenges

The exploitation of extraterrestrial resources presents several challenges. First, the science and engineering behind such projects will have great complexity, owing to the high risk and cost of space transportation. Development of these advanced spacecraft requires breakthroughs in aerospace engineering, geology, chemistry, environmental science, robotics, manufacturing, and mining technologies. The advent of NewSpace and the exponential advance of technology may generate disruptive innovations that would completely change this sector (Young, 2015). Organizations will need to be agile to adapt to ever-changing environments.

The main challenges are socio-political and economic, as opposed to technical. There is an open discussion about the economic feasibility of lunar and asteroid mining, with certain studies confirming its long-term viability (Andrews, et al., 2015) and others denying it (Craig, Saydam and Dempster, 2014). Considering the ever-changing and uncertain nature of the market, companies will need to adapt their internal organization to allow for agility and mobility. The two main proposed strategies are to use mined resources for space-based activities or to bring resources back to Earth. The former would largely involve space-based fuel systems and manufacturing, and would generally be less expensive. The latter would involve bringing raw materials back to Earth for purposes like manufacturing or energy creation, such as the use of Helium 3 in future fusion reactors. Returning materials to Earth, however, would be more expensive and, according to Kleinschneider, et al. (2014), economically unviable. The option would become more interesting if we demonstrated that acquiring materials this way could relieve the pressures that mining places on Earth's environment.

Competing political interests and relationships may cause more tensions than partnerships, and space leaders must be prepared for potential breakdowns in relations and how to resolve them. In 2040, there should be an international legal framework that regulates all exploitation of space resources in a way that reflects the complex relationship that will exist between humankind and the space environment. This framework must also consider international thinking, global environmentalism, and the demands of human settlement in space. A distinction should also be made between lunar mining for commercial purposes on Earth and for missions to Mars and elsewhere. While both types of mining should undergo rigorous environmental testing, any materials being brought back to Earth should undergo additional testing to ensure no hazardous elements are introduced. Asteroids could also be a source of space materials, the mining of which would not directly impact Earth's environment and they may represent a more attractive solution from an environmental perspective.

The waxing and waning of public interest in space activities remains an ongoing challenge in attracting government funding. The high costs of space activities requires very large initial investments that need to be sustained during long-term ventures. This has typically been the realm of very rich individuals, but as we discuss in the section 3.5 Startups strategies, smaller and more agile companies are able to compete. In this section, we identified the technical, sociopolitical and economic challenges facing lunar and asteroid mining.

### 2.4.3 Skills

Mining celestial bodies, such as the Moon and other objects near Earth, will present new challenges, and the space sector workforce will require a versatile skillset to address them.

First, there needs to be greater focus on scientific and technical education particularly in the fields of: space systems engineering, chemistry, geology, mining, space-based manufacturing, environmental science, robotics, and aerospace. Space systems engineers will envision, design and execute the multiple mining missions, while chemists and geologists will analyze the composition of raw materials and ultimately design and implement better mining methods and ISRU capabilities. Mining and manufacturing teams will extract and process resources in new environments—overcoming the challenges of working in a vacuum with low gravity, strong temperature gradients, high levels of radiation, and other concerns. Environmental scientists will assess the ecological impact of mining activities, both on celestial bodies and on Earth. Roboticists will develop new control and automation systems, increasing the autonomy of robotic operations. Aerospace, mechanical, and electrical engineering will still be core competences underpinning each building block of any space mission.

Space policy and international cooperation will continue to be a major challenge for mining space-based resources. Future space leaders will require a solid knowledge of international law and political science both in the private sector and in national space agencies. In this globalized political landscape, communication and negotiation skills will be key to promoting international cooperation, prioritizing missions, as well as negotiating budgets and partnerships. Public interest will have a great deal of importance either for fostering government or private investment in the sector. Space leaders will need to be media savvy, friendly, and have the ability to connect with non-technical audiences through social media, as "social media have become coordinating tools for nearly all of the world's political movements" (Shirky, 2011).

Besides technical and political skills, we need creative education, as the complexity of the problems involved requires an artistic as well as a scientific perspective. As all missions in space, including mining missions, should respect earthly interests, it is essential that the general public

is granted the opportunity to engage with and provide feedback on these operations. The need for public funding of these operations will also require inspirational leaders, communicators, and storytellers to illustrate their importance to the people of Earth.

### 2.5 Human Presence on Mars

By the year 2040, we envision humanity will set foot on Mars. We believe this mission will be the culmination of years of international collaboration and will involve landing on and exploring the surface, as well as returning safely home to Earth. Humankind's first steps on the Martian surface may also pave the way for a subsequent permanent presence on Mars.

This mission will be revolutionary. First and foremost, it will mark the first step in humanity's journey to become a multi-planetary species that will be able to survive beyond Earth. Second, the evidence of water (Martin-Torres, et al., 2015) provides the opportunity for scientists to study both the possibility of extraterrestrial life in outer space, as well as the possibility and feasibility of ISRU techniques. ISRU techniques could process resources on Mars for the creation of habitat building materials or fuel, which would lower the cost associated with exploration and habitation in the Mars environment.

These large opportunities come with equal challenges. As space activities become a matter of increasing international collaboration, governments and international organizations need to review existing policies and create new ones to allow for more fluid collaboration between countries around the world. The space industry needs to address technological challenges associated with advanced propulsion systems, radiation shielding for astronauts, and telemedicine to improve the technical and economic feasibility of a human mission to Mars.

### 2.5.1 Signals and Drivers

In this section we will look at different combinations of signals and drivers to determine the feasibility of a crewed mission to Mars by 2040. For the mission to be successful, a few governing drivers must remain consistent over the next 25 years.

The rapid growth of NewSpace, with its conjunction of private investors, crowdfunders, entrepreneurs, and business angels, represents a healthy revolution in the commercial space sector. In turn, the role of space agencies continues to shift towards partnerships with the private sector as shown by the enabling initiatives such as the Commercial Crew and Cargo Program (NASA, 2014g). In agreement with the National Space Policy Committee (2010), the government role will continue to shift from a monopolistic director of space activities to the role of a facilitator and enabler of private and non-government initiatives. In the international arena, the emergence of India, China, Brazil, and South Africa as space-faring nations has already altered the traditional landscape, enlarging the market and the capabilities of the space community as a whole. Since both India and China have explicitly stated in their national policies that Mars is an objective of their respective space programs (Johnson-Freese, 2007), they will likely contribute to any international crewed mission to Mars.

The increased media interest in space and the political debates on the topic have renewed the public interest in space missions (Thurkettle, 2015). Just as NASA found important initial support from Disney studios (Wright, 1993), we believe that the media can be an effective mechanism for convincing policy makers to provide adequate funding for a human mission to Mars. A human mission to Mars would greatly interest the scientific community, with both space agencies and private research companies already developing and conducting analogs to test the viability of

various approaches to the mission. The perception that a crewed mission to Mars is feasible within the next decades has attracted increased levels of funding (Ehlmann, 2005) for the research of the psychological and physiological effects of long term spaceflight.

Inadequate propulsion technology still is the main bottleneck for a crewed mission to Mars. The development of powerful rockets in the private sector, such as the SpaceX Raptor (Seedhouse, 2013), may lead to breakthroughs in propulsion like rockets which use liquid oxygen and methane propellants, and the advanced electrical propulsion system known as the Variable Specific Impulse Magnetoplasma Rocket (VASIMIR) (Chang Díaz, 2000).

Our analysis suggests a number of overarching social, economic, and technological drivers. Newly available commercial opportunities in space are driving an increase in investments and in public-private partnerships in the business of space. Likewise, international cooperation has driven a greater sharing of budget costs and political risk, as well as joint technological development. A rise in public support has encouraged more political willingness to commit to these missions (Thurkettle, 2015). Research advances in life support technology, as well as human physiology and psychology in space, have mitigated but not solved the problems posed by resource management, food production, radiation exposure, muscle and bone mass loss, and pressure on mental health. Research and development of new propulsion systems should lead to reductions in the cost and time of spaceflight, larger payload capacities, and greater capabilities of thrust, impulse, and reusability. All of these drivers will experience significant challenges that may undermine the success of a crewed mission to Mars by 2040.

### 2.5.2 Challenges

Any potential crewed mission to Mars must address challenges related to culture, policy and technology, as well as the underlying challenge of funding.

Continued media interest, and by extension interest from the public, in human exploration of Mars is critical to any mission being funded. However, public interest in space has been fleeting in the past, and many governments have limited budgets for promoting their space programs (Ehlmann, 2005). Should initiatives such as the proposed Mars-centric reality TV show Mars One fail to get off the ground, public interest in Mars could dwindle or disappear entirely. Certain members of the scientific community argue for prioritising the search for extant or extinct Martian life, a search that could be jeopardized by contamination through a crewed mission to Mars (National Research Council, 2007; Meltzer, 2012). This has led to an ongoing ethical debate between these members of the scientific community and the supporters of human exploration of Mars, which will likely cause further delays, particularly if life on Mars is discovered.

In terms of policy, human missions to Mars will probably require an international collaboration. This would be similar to the framework governing the ISS, where the communication between international partners is handled by NASA mission control, which coordinates the complex scientific and engineering projects (NASA, 2014h). To avoid backward contamination of Earth by potential Martian life, governments working with scientific communities will have to put in place appropriate policies. The US has introduced some relevant policies, but numerous other international regulations and treaties would need to be negotiated in the case of a Mars sample return or human two-way mission (Race, 1996).

The development of the NewSpace economy will require more initiatives from individuals and companies, as well as the advancement of available space technologies. This could involve the

expansion of commercial crew and cargo projects, based on the success of NASA's Commercial Crew and Cargo Program (NASA, 2014g).

There are still technological limitations to be overcome, including the development of advanced propulsion systems, radiation shielding for astronauts, telemedicine, ISRU, long duration mission life support systems, and 3D printing of a variety of materials. Both mental and physical health risks would have to be addressed thoroughly for a human mission to Mars lasting up to three years (Horneck and Comet, 2006; Campbell, 2007). Mitigating these risks would require improved astronaut screening processes, pre-spaceflight training, analog environments, and management of mission crews from mission control. There is a great need to improve the communication between Mars and Earth (Ormston, 2012), perhaps through several efficient backup communications systems, to allow quality communication with crews in deep space. This could in turn have great spin-off value for the commercial sector.

Ultimately, however, the costs associated with a human mission to Mars will be the main factor underlying the previously mentioned challenges. The estimated cost of a mission to Mars is between \$6 billion (Mars One, 2015) and \$450 billion (Ehlmann, 2005), with the primary costs derived from the need for a return and the complexity of the mission. Funding for a mission to Mars is expected to be an international effort between participating countries through means such as cost sharing and contract allocations (Explore Mars Inc., 2013). The private sector, through both established contractors (Boeing, Lockheed Martin) and NewSpace companies (SpaceX), is expected to have significant investment and involvement in any Mars mission.

### 2.5.3 Skills

While a crewed mission may not occur until the 2030s or 2040s, relevant skills need to be developed by the international community now to address the challenges associated with going to Mars. The culture, policy, and technology challenges faced can be surmounted by developing skills across competencies including education, crew selection and training, advanced spacecraft technology, in situ resource utilization, and life support systems.

To address the cultural concerns of a crewed Mars mission, it may be necessary to improve STEAM education. The emergence of open online education for all could popularize these fields, introducing space education at an early age. Startups could provide real hands-on learning for business and arts-oriented people as well. Sponsoring internships at startups could be a useful means of providing education and new sources of revenue. Effective public outreach of a crewed mission to Mars will make that mission more likely to succeed.

A crewed Mars mission will generate policy challenges such as international cooperation, crew selection, and training. Governments from around the world will need to have a formal governing or decision-making body that can be used to coordinate the activities of the mission. New mission policies will need to be developed for crew selection and training, to determine whether telemedicine or a dedicated flight surgeon would be more beneficial for long duration human spaceflight. Prospective crews should undergo extensive long term analog simulations prior to launch, with strict select-in and select-out criteria determined by the results. Documenting formal policies for this international cooperation, as well as crew selection and training, will be imperative to ensure the success of not only the collaboration, but also the Mars mission.

# CHAPTER 3 – ISU IN 2040

In the previous chapter, we presented and analyzed five scenarios that we believe characterize space initiatives in 2040. From the results of this analysis, we have also identified a series of skills required to overcome challenges associated with each scenario.

The next phase in our mission was to define which areas ISU should further develop to address these skill gaps. After an extensive analysis, we prioritized five strategic focuses for ISU, including the future of SSP, outreach, analogs, alumni, and startups. We addressed each of these five areas of focus by providing a 25-year strategy for ISU.

### 3.1 The Future of SSP

Rapid technology advances require an agile workforce. To sustain the rapid growth of commercial space, we need to have capable space professionals with skill and imagination. Now is the time for ISU to take the lead on educating the space leaders of the 21st century in a 21st century way.

SSP has been an industry leader for space education and professional development since its creation in the late 1980s, and to maintain that leadership, SSP will need to evolve as society changes. The objective of this strategy is to reorganize SSP into a cutting-edge space education program with global prestige and a strong network of capable leaders.

To accomplish the objective, the first step is to incorporate online education technologies into the program, to both increase outreach and ISU branding, and enable a tailored experience focused on advanced technologies and future trends. For ISU to remain an innovative educational institution, it must increase and improve on its online presence and start online education.

SSP will be divided into two sections, one online and the other offline. Together they would include more outreach, technology education, hands-on experiences, and connections with the actual space sector. It will be the natural evolution of ISU's emblematic program into the prestigious exemplar program for the space sector.

### 3.1.1 Strategies

### Online

The online section will make use of emerging trends and disruptive technologies in the communication and education fields, such as online courses and virtual reality (VR). The future SSP will be developed in several parallel initiatives.

First, an outreach stage will be focused on multilingual educational materials for younger students and teachers, thanks to partnerships with ISU stakeholders already committed to this field such as NASA, ESA, CASC, ISRO, and JAXA. It will promote STEAM education and increase the global awareness of ISU.

The second stage will be the core lectures series stage, basic and intermediate courses, covering the whole current core lectures of the SSP in an OpenCourseWare approach (Attwood, 2009) by using videos, slides, and interactive materials. The basic course will be open to

students around the world to access anytime and anywhere for free. At the end, the students will take an online quiz to qualify for the intermediate course. The intermediate course will use the same format but will contain more advanced content and have a small enrollment fee, to financially sustain the online section. Students will be evaluated in a final online exam costing a small fixed fee. The exam will check for the interdisciplinary knowledge of the core lectures and problem solving skills in a creative and thought-provoking way. It could be a requirement for SSP admission. To improve access, the course could be offered in several languages such as English, Mandarin Chinese, Russian, French, Spanish, Portuguese, Hindi, Japanese, and Arabic. Scholarships will be provided to the highest scoring participants and will be used to attract talent from emerging economies and soon-to-be space-faring nations.

### Offline

The core lectures will be removed from the SSP and the overall duration will be reduced to eight weeks. The whole program will focus on applied learning, preparing the ISU participants to be leaders in advanced spacecraft technology, space policy, public outreach, and entrepreneurship.

The first two weeks will be devoted to a new series of distinguished lectures on cutting-edge technology. These would replace the core lectures that are currently aimed at providing a wellrounded overview of all of ISU's departments, as these would be transitioned into the online section of SSP. Top-level experts in a specific field will explain ongoing and future research projects. The objective is to start the program by inspiring participants with fascinating material, and deep conversations. These lectures will be recorded and added to the alumni database after the SSP. ISU alumni will continually advance their knowledge with newer material, such as videos, texts, and audio recordings, released after the end of an SSP session. The participants will select from a greater variety of workshops, expert panels, and theme days. There will be more hands-on experiences using disruptive technologies and an on-going examination of future trends. Using data gathered during the online part, the SSP will become a tailored experience. Each participant will be offered a list of initial suggestions for courses, lectures, workshops, theme days, and hands-on experiences that the data suggests will provide the participants with a more meaningful and applied learning experience. Each participant will engage with professionals in their field of interest through networking sessions. Team projects will be actionable after the completion of the SSP.

At the end of the SSP, participants will be able to do an internship with a wide range of ISU stakeholders, take part in ISU analogs, start their own business in an ISU startup incubator, or return to their employer with new and improved skills.

### 3.1.2 Skills and Scenarios Addressed

ISU should consider the changes that are going to happen in educational methods in the future. It must adapt by identifying the drivers of change, acquiring skills in a timely manner, and offering new forms of education. Education methods of the future will be changed drastically by drivers such as the democratization of knowledge and access, instability of markets and funding, digital technologies, global mobility, and integration with industry (Ernst & Young, 2012).

ISU should embrace these coming changes with open arms. ISU should involve stakeholders in setting goals for the university and determining its priorities, policies, and procedures. The potential barriers that ISU may face regarding online education may include a hesitation to adopt unfamiliar technologies, a lack of financial resources, organisational and systemic barriers, and a shortage of expertise particularly in new technologies such as online course development, big data analysis, and virtual reality. To address these challenges, ISU should focus on developing its

competencies in the areas of information technology, online delivery, course registration, accessibility, retention, funding, and support services. ISU can collaborate with other crossdiscipline educational institutions in shouldering the necessary funding and remaining relevant in a changing educational environment.

Applying this strategy will completely transform the SSP into a new program capable of tackling challenges posed by our future scenarios. These include the need for global education and outreach, a more technically educated workforce, and an increased public interest in the space sector.

The new online and offline strategy for the SSP will provide ISU alumni with better skills in cutting-edge technologies, thanks to the tailored educational approach.



Figure 2 – Proposed structure of the future SSP.

### 3.1.3 Why ISU?

Online

ISU's primary focus is in space education, which has gone through major changes in the past 25 years. With the rapid onset of new computer and communications technology, education has become more international, intercultural, and interdisciplinary. Access to education has increased, especially outside of Western countries (Altbach, Reisburg and Rumbley, 2009).

The increasing accessibility of the Internet and wealth of information available has driven traditional institutions, such as Massachusetts Institute of Technology, Harvard University, and Yale University, to develop massive open online courses (MOOCs) for open education (Daniel, 2012). These institutions have democratized education by allowing everyone to participate in their courses for free. While these classes do not replace their traditional programs it is an unmistakable trend in education. At the same time, entirely new educational programs have started online, such as the Khan Academy, which offers high school level tutorials (Dijksman and Khan, 2011).

ISU has always defined itself as an innovative educational institution and must continue to reinvent itself. An online presence is necessary to remain a competitive educational institution, when compared to online institutions such as Coursera, Udacity, and Codeacademy, who provide varying levels of online education in a number of different fields (Korn and Levitz, 2013). With directed online advertising, ISU can target prospective students who are likely to be interested in ISU, and so can make contact with them at a low cost. This will increase the awareness of ISU and help improve enrollment.

A set of pre-SSP lectures can ensure that all students are caught up on general space knowledge before starting the SSP. This will improve their SSP experience, and allow the offline program to be more detailed and hands-on. ISU can also use the data collected from online coursework to keep track of its own progress and make quick changes to improve.

Although there are limitations to online education, such as less face-to-face interaction, improved technology in the next 25 years can continue to enhance the open learning experience. Virtual reality is a future technology that can be used in a range of learning environments, with programs already being developed for kindergarten and secondary schools (Merchant, et al., 2014).

### Offline

ISU must reform the offline space studies program alongside the online one to fully adapt to future trends in education. One major advantage of moving a portion of education online is that it allows for more flexibility in education during offline activities. Once everyone has completed the core competences online, the organizers of the offline SSP can use data collected from the online portion of the course to corroborate it more closely with the interests of participants. It can customize the program in a number of ways such as changing lecturers based on interest of participants, creating workshops based on identified skill and knowledge gaps, and proposing team projects based on the participants' existing skillsets to ensure the highest quality team output.

A more applied approach to the SSP could also foster more innovation by giving participants more firsthand experience with technology they may not otherwise have encountered. It will take a greater advantage of the 3Is, because it will require more applied cross-disciplinary work as opposed to the passivity of listening to individual lectures.

### 3.1.4 Importance for Stakeholders and Partners

ISU should change its educational program to intensify relations with the key stakeholders. The alumni network, national space programs, and the private space industry all stand to benefit from more highly educated ISU students who have hands-on experience in space-related activities. Online education will allow a greater number of people from more diverse backgrounds to become aware of and have access to ISU educational material, which will also increase the visibility of ISU and the space industry. The wider student body, and the data that can be gained from online course work, can also be used by the industry and space agencies to determine the existing skillsets of the general population.

# 3.1.5 Twenty-five Year Strategy

OC - Online courses Tech - Adoption of enabling technologies SSP - Offline part

Year	Area	Objective	Strategy	Partners	Tracking
	ос	Outline and start the pilot of the online core lecture series	Create the course outline Set up the online infrastructure Organize alumni and faculty to create course materials Test the pilot with alumni and prospective students	Online education platforms such as Coursera, edX ISU alumni	Pilot running by the beginning of 2017. Testing of trial version finished by 2020.
2015 (ActionStep)		Start the outreach stage	Collaborate with space agencies and companies to create online materials for children	NASA, ESA	Materials available online by the end of 2016
	Tech	E-learning skills acquisition	ISU needs the skills to successfully organize the OC	Online education platforms such as Coursera, edX	Online core lecture series testing finished by 2020.
	SSP	Start transforming the SSP into a more hands-on experience	Design new workshops centered around acquiring practical experience (ex: CubeSat building)	ISU alumni Space startups	SSP participants' feedback
	oc	Online core lecture series fully deployed	Improve the course with the feedback gathered from students during testing Start and test the final exam with alumni or future students	Online education platforms such as Coursera, edX ISU Alumni	Official deployment by 2020. Feedback from students.
2020		Solid platform for children's space education created (outreach)	Make a multilingual system Make a system for users to upload their own material Include more organizations	NASA, ESA, JAXA, ISRO, CSA, CNSA Companies or any groups who have space education materials	Increased quality and quantity of materials
	Tech	OC Database Fully deployed	Create a database to store all the data gathered from the OC students	Software firms and/or universities with knowledge on computer science	The amount and quality of data stored.
	SSP	Departamental activities and team projects redesigned	Analyze the strong and weak points of department activities and team projects	ISU faculty and alumni	Alumni survey and student feedback
2025	oc	First new SSP model takes place	Use final exam as a selection method for SSP Marketing strategies to position ISU as a reference in online/offline space education	Online education platforms such as Coursera, edX ISU alumni and faculty	At least 10,000 students enrolled on the basic course and 500 on the intermediate course.
	Tech	Big data is used to analyze ISU's database	Big data skills acquisition Building of algorithms	Software firms and/or universities with knowledge of computer science	Detection of participants' and alumni interest trends

### Table 3 – The Future of SSP

	SSP	The first new SSP model takes place After the SSP infrastructure is established: internships/ business incubators/ analogs	Link the SSP program with the strategies of startups and analog missions Foster relationships with stakeholders to promote internships Select lecturers for the new and advanced lectures	ISU Business Incubators/ ESA Incubators, etc. ISU analogs and other analogs like MDRS ISU stakeholders	At least 80% of the participants who wish to do so will be able to choose one of those three options after the SSP.
	oc	The OC becomes an interactive community	Community concept implementation in the OC Connection with the alumni	ISU alumni	At least 100,000 students enrolled on the Basic course and 5,000 on the Intermediate course. 50% of the alumni stay active
2030	Tech	VR to be adopted in the OC	VR skills acquisition	Software firms and/or universities with knowledge on computer science	VR successfully implemented in the OC
	SSP	SSP takes place partially in space	Set up of the training sessions prior to trips into space Organization of the period in space during the SSP Establishment of solid partners required along the value chain such as launchers	Space agencies and private companies ISU alumni	Number of students per year that visit space thanks to ISU
	oc	ISU OC becomes the top online course in space education	Marketing and ISU branding Alumni referral program as a selection technique for the SSP due to a higher demand for participants	ISU stakeholders ISU alumni Marketing experts	Higher number of students enrolled compared to all other space education online courses
2035	Tech	The adoption of mainstream VR	VR skills refinement	Software firms and/or universities with knowledge in computer science	VR successfully implemented in all ISU activities
	SSP	VR SSP on the Martian surface	Create a VR experience that simulates an SSP on the Martian surface	ISU stakeholders ISU alumni VR experts	Four SSP are organized per year, at least one of them is used through VR
	oc	Collaborative experience with immersive VR technologies becomes the central part of the OC	Design a full immersive VR experience for the OC	ISU alumni Software firms and/or universities with knowledge in computer science	At least 100,000 students enrolled on the Basic course and 50,000 on the Intermediate course 90% of the alumni are active
2040	Tech	First studies on Artificial Intelligence (AI) for educational purposes	AI skills acquisition	Cutting-edge AI research institutions	Technology implementation in regular activities
	SSP	First SSP on the permanent space campus	Design the first SSP conducted in ISU's space facilities or other human space settlements	ISU alumni ISU stakeholders	Six SSPs are organized per year with children inspired by 2020 now able to attend themselves First SSP on the permanent space campus conducted successfully

### **3.1.6 Conclusions**

By 2040, ISU will organize six SSPs per year to meet the demand for space professionals from different organizations in the space industry. At least one SSP per year will be fully conducted in a space campus, while others can be hosted in a VR environment simulating the surface of Mars. The 3Is will be extended to more people, contributing to the ultimate goal of achieving international cooperation in space activities.

The online revolution has already affected the education sector and will become even more transformative in the coming years. With the use of improved big data processing techniques and VR technologies, the educational sector will be completely transformed by 2040. ISU should incorporate the latest technologies to transform the SSP into a more learning-intensive experience, with more focus on hands-on experiences and the latest technology trends.

This strategy is not a suggestion for the improvement of ISU: it is a guide to its survival in the new educational framework. ISU and its stakeholders will benefit from better outreach, branding, and improved learning outcomes for the students. This will result in a larger, more tech-educated and interconnected alumni workforce, who will be able to tackle the challenges ahead by mobilizing international efforts.

### 3.2 Analogs

From the five scenarios envisioned in the first chapter, we see a clear signal of a growing human presence in space, particularly the possibility of an ISU facility in space around 2040. We believe that ISU can lead the way in establishing a university in space. ISU could provide experience that would greatly benefit real space missions as they evolve and advance.

ISU (2015) states that it specializes in providing graduate-level training to the future leaders of the emerging global space community. The university offers its students a unique core curriculum covering all disciplines related to space programs and enterprises. It includes space sciences, space engineering, space applications, space policy and law, human performance in space, space business and management, and space humanities. We believe that ISU can provide a hands-on experience and a state of the art space education by owning an analog facility for missions and research. ISU could become an analog hub led by its faculty, participants, and alumni all over the world.

ISU participants and alumni could gain valuable experience through analog facility planning, mission design, research, communication, negotiation, operational experience, and preparation for attending ISU's space campus. The partners and stakeholders of ISU will have a big role in this strategy. We prepared our strategy on a 25-year scale, and defined stepping stones for the short and long term.

Today, there are several analog sites around the world run by educational institutions, government agencies, and commercial entities. As the space industry is growing, ISU may be able to fill a niche in the analog market.

### 3.2.1 Strategies

We propose the foundation of a permanent analog research and training program, designed and run by ISU, keeping the organization at the vanguard of space education and preparing its students for the future of spaceflight. We envision a four-phase plan for ISU to create its own

analog facilities over the next 25 years, ending with an ISU facility in space. We also see ISU as a hub for future analog missions led by, and with the participation of, ISU students and alumni all over the world. See Table 3 for details.

### Phase 1:

During the first few years of our 25-year strategy, we propose the building of a small analog facility at ISU's central campus. ISU is already gaining momentum with analogs by hosting the SHEE in its high-bay in 2015 (Doule, et al., 2014). This new analog facility at ISU's central campus could be designed during a future SSP session in the form of a team project, and constructed during the subsequent MSS program. The costs can be limited by using existing resources, such as the high bay at the Strasbourg campus, and engaging students with the design. ISU can use its extensive alumni network, members of which have successfully conducted analog missions before with Mars 500, the Mars Desert Research Station (MDRS), the Austrian Space Forum, and the Hawaii Space Exploration Analog and Simulation (HiSEAS) (Urbina and Charles, 2014; Mars Society, 2015a; Binsted and Hunter, 2013). Once operational, this small facility can be used by ISU during its programs, as well as being leased out to external partners who could conduct their own missions under the oversight and coordination of an ISU director.

ESA is currently planning to build its own fully fledged lunar analog at the European Astronaut Center in Germany (ESA Luna project), which is also planned to be used for educational purposes (Hoppenbrouwers, et al., 2015). ISU could play an active role in the use of this analog from the beginning. It could use this unique chance to run educational analog missions at the same place as European astronauts are being trained for real Moon missions.

### Phase 2:

ISU will start designing a phase two high-fidelity facility, while taking advantage of the additional knowledge it acquired in space analog operations. This facility will be designed as a multipurpose environment to simulate various aspects of space missions. We envision it to be robust and adaptable to different mission scenarios such as LEO, Moon, Mars, or asteroid missions.



Figure 3 – Proposal for ISU's analog facility.

### Phase 3:

This phase involves a leap in ISU's capabilities and ambitions. During the 2030s, we expect ISU to establish an educational program held in space, with a short duration mission using commercial space resources. The number of partners and alumni distributed across the space sector allow these activities to become feasible through joint ventures between ISU and agencies or corporations.

### Phase 4:

We foresee constructing and operating an ISU facility in space by 2040. ISU will organize expeditions, educational programs, and executive training workshops at its campus in space. Participants and staff will train at the ISU analog facility before traveling to space. The space campus will also simulate space missions and long duration space habitation.

### 3.2.2 Skills and Scenarios Addressed

The futuristic scenarios of orbital stations, lunar settlement, lunar and asteroid mining, and human presence on Mars will rely heavily on analogs to prepare for the space expeditions. We envision that exploration and exploitation of space will grow exponentially, increasing the need for analog facilities.

Based on our analysis, we believe that the future exploration and exploitation of space will need more scientific and technical education related to mining, exploration, and settlement. The analog facility could be used as a platform to attract students to STEAM education by using outreach strategies such as public engagement campaigns or hosting educational sessions for students. It would enable the collaboration of ISU with other institutes that share common interests in these sectors and improve technology for life support systems and promote international cooperation.

In addition to serving the academic needs of ISU, the facilities could also be used by commercial companies. As stated in the lunar settlement scenario, future missions will increasingly rely on public-private partnerships. Owning an analog facility will enable ISU to stay relevant in the changing marketplace and allow it to offer another service to commercial space enterprises. The simulations inside the facility could address different needs, such as having a regolith surface analog for rover testing, vacuum chamber for space hardware, or habitat for long duration missions.

The space tourism business sector should also be considered. These companies could use the ISU facility as a means of training space tourists in an analog environment. The location could also generate revenue from paying space tourists looking to prepare themselves before launch. An analog facility such as ISU's can serve as an unofficial filter in the application process for space missions. A candidate with analog experience on his or her resume will stand out from the crowd. A greater number of space missions will raise the demand for trained space travelers, resulting in a growing need for crew selection and training programs.

Two challenges the space industry faces are acquiring funding from private investors and convincing the public that space exploration is important. ISU's analog facility will be an excellent means of contributing to this global effort, while keeping ISU economically stable and relevant. ISU should involve the public in the analog missions to spread interest and inspiration. They could be social media followers, on-site auditorium audiences, or they could even take an active

part, for instance by having a position in mission control or as a crew member inside the analog environment.

### 3.2.3 Why ISU?

Prioritizing analog research will allow ISU to grow in its technical expertise, while maintaining its strengths and foundational principles. This area of research is strongly connected to the 3Is of ISU and could be used in a stepping-stone approach to achieve the long-term goal of having a facility in space.

With astronauts in a high-risk and a high-cost environment, proper testing of mission equipment is crucial. Analog facilities provide an excellent testbed to learn about hardware at various stages of development, as well as procedures to be used in space. As long as people are exploring space, high-fidelity simulation facilities will be a key part of any space program.

We believe that ISU has a great opportunity to fill a niche in the space sector. We have already seen several small-scale analogs conducted as part of SSP15, each emphasizing a unique aspect of space operations. They include remotely-controlled rover missions looking at operational challenges in engineering, a crewed Martian mission focusing on interactions between humans, and other smaller scale analogs. This interest in analogs is demonstrated by the SSP15 participants, who have voluntarily created a working group aiming to prepare future analog missions. We have also learned about several alumni who are actively involved in larger scale analogs, such as the Mars 500 mission (Urbina and Charles, 2014). We can use their expertise to achieve our vision.

The operation and development of complex systems are inherently interdisciplinary, which lines up perfectly with one of the principles of ISU. Instead of trying to compete with well-established academic institutions on fundamental technological research, ISU can focus on how these technologies can interact with one another in a space-like environment. This focus on technology would foster collaborative relationships that would be mutually beneficial to ISU and its partners. This broad collaboration could feed the other two Is of ISU, by developing international partnerships that span various cultures as well.

An endeavor such as this one would not be entirely without competition. There are other analog facilities working towards similar goals. A few of these include: NASA's Habitat Demonstration Unit and Extreme Environment Mission Operations (Loff, 2012a; Loff, 2015b), MDRS (Mars Society, 2015a), UND NDX (Pedraza, 2014), the Flashline Mars Arctic Research Station (Mars Society, 2015b), HiSEAS (Binsted and Hunter, 2013), and the Desert Research and Technology Study (Romig, 2010). Each one fills its own role, but there are other roles that ISU could address such as emphasizing the challenges of dust mitigation or exploring the complex interactions between astronauts and robotic elements. We envision ISU using its network to fulfill such an analog role.

### 3.2.4 Importance for Stakeholders and Partners

According to Genaro and Loureiro (2015), change is occurring more rapidly because of the influence of globalization and increasing competition, as well as technological, environmental, and social constraints. The docking of Space X's Dragon capsule at the ISS in May 2012, was a historic moment where a new stakeholder, in this case a commercial enterprise, managed to achieve a strategic goal that had previously only been accomplished by governments (Anderson, 2013). ISU must adapt its strategies to remain competitive in a changing educational system by looking for new partnerships with current and potential stakeholders.

Freeman, et al. (2010), argue that rapid social, political, and economic changes have created a turbulent business environment that can be difficult to manage. Organizations must be ready to react rapidly to changes and assure their competitive advantage. Genaro (2014) points out that strategic planning focusing on stakeholder management can be an indispensable tool within organizations.

ISU not only has the 3Is education, but also a great capacity to implement initiatives and partnerships. Its alumni network extends worldwide, helping the university attract new partners and potential stakeholders. The MDRS crew 147 analog mission (MDRS Crew 147, 2014) was organized by ISU alumni demonstrating the capacity of ISU's network in real-world initiatives.

For ISU to be a sustainable hub of space analogs, a strong network of partners and stakeholders is necessary. Students will have the opportunity to develop their academic activities within an analog environment, and to put in practice all of the subjects studied during ISU programs.

The SSP program model must be adjusted to achieve the best results from these analogs. ISU will need to focus not only on the experience for students, but also on producing scientific results according to the needs and expectations of the ISU stakeholders. Current and potential ISU stakeholders are interested in space analogs systems. These include: alumni, the scientific community, space tourists awaiting flights, and start-up companies. The analogs can be used to develop new systems for space suits, radiation shields, and communication devices, creating opportunities for companies and new entrepreneurs to establish a partner relationship with ISU as a testing facility. Creating a partner and stakeholder network will be essential to advancing faster towards future deep space missions.

### 3.2.5 Twenty-five Year Strategy

Year	Objective	How	Partners	Tracking
2016 - 2017	SSP16 TP dedicated to the design of an analog facility for the high-bay at the central campus MSS 16/17 students construct the analog environment in the high-bay area at the central campus in Strasbourg	Search for sponsors and partnerships and additional funding	Private space industries and startups that are interested in building part of an analog system	Implementation into MSS final grading Appointment of a project superviser
2018	Operation of the high-bay analog facility (1 <sup>at</sup> phase)	Incorporation of the analog high-bay into the ISU programs Fundraising for the 2 <sup>nd</sup> phase Search for collaborators for the 2 <sup>nd</sup> phase	Students who are interested in being part of an analog experience Companies that are interested in testing their products	Quantity and quality of research projects being conducted using this facility
2020	Planning of the permanent analog facility Requirements given by ISU students and stakeholders	Implementation of the planning into ISU programs and its use by real design companies Establishment of a facility directorate to manage it	Space agencies, students, alumni, private industries, rich entrepreneurs/alumni	Appointment of a project committee

Table 4 – Analogs

2025	ISU analog facility built and operating (2 <sup>nd</sup> phase)	Faculty and students will use the facilities. Establishment of partnerships with other research groups or agencies.	Space agencies, students, alumni, private industries, rich entrepreneurs/alumni	Amount of ISU research projects and external entities leasing this facility.
2030	ISU program in space	ISU students and faculty will be sent into space to carry out educational programs. This could be done in small rotating groups in either commercial space stations, a lunar or Mars settlement.	Commercial partners who own their own space facilities	Contracts with facility owners Funding from agencies and other academic sponsors Submitted research proposals
2035	Start of the construction of the ISU space facility	Search for sponsors and partnerships, additional funding	Space agencies, students, alumni, private industries, rich entrepreneurs/alumni	Design reviews, engineering models, and component tests
2040	ISU facility in space built and operating	Organization of the expeditions and the training in the ISU analog facility	Commercial partners will build the facility for ISU. Agencies/companies/ governments will help fund this initiative	Financial status, implementation of maintenance plan, and the amount of science output

### 3.2.6 Conclusions

The inclusion of the analog experience in ISU's curriculum would contribute enormously to the accomplishment of the educational and space exploration goals embodied in the ISU Credo. Indeed, since the success of any space mission requires extensive training in multiple analog environments, the addition of this skill into the DNA of ISU would help participants, alumni, and faculty to lead and carry out space missions later in their careers. Experiencing analog missions during the SSP could even change the life of the participants, providing them with unique skills, knowledge, and a new mindset (Urbina and Charles, 2014).

In turn, this strategy will also help keep ISU at the forefront of the space community by producing remarkable scientific research, developing advanced technologies, and providing a unique platform for crew training for long duration spaceflight. The overall plan, with its different phases, will make ISU a hub for international analog initiatives. The strategy involves using the ISU alumni network, partner companies, and space agencies, to carry out analog projects that pave the way for space exploration. The proposed roadmap provides a comprehensive solution with specific steps for the next 25 years. In the short term, the goal is to start carrying out analog experiments using the existing facilities in the ISU Central Campus. In the long term, this strategy aims to have a permanent ISU facility in space.

Although there are several educational institutions, government agencies, and commercial entities across the globe carrying out space analog missions, ISU candevelop innovative analog experiments, thanks to its 3Is philosophy and its outstanding network of alumni professionals. This strategy does not strive for a competitive relationship with these entities, but for a collaborative one. ISU can become the leading center for the space community, leading humanity towards a multi-planetary existence.

### **3.3 Outreach**

To ensure that ISU maintains a leadership position over the next 25 years, ISU must strategically change how it engages the space community, the general public, governments, agencies, and other key stakeholders. The outreach efforts presented in this section are designed to enhance ISU's overall brand and guarantee that ISU becomes a guiding force for the international space community of 2040. ISU should focus on inspiring and educating its stakeholders and the public

about the peaceful exploration of space. We propose that ISU achieve these goals in two phases. The first focuses on establishing the ISU brand from 2015 to 2025, the second focuses on using that established brand to take a new level of action until 2040.

### 3.3.1 Strategies

During the initial branding phase, ISU should strive to promote its image and activities on a global scale using social media and traditional media, by partnering with public figures, and by participating in conferences. Throughout this process, ISU must maintain its focus on the 3Is. ISU must get public support to increase space sector investment, particularly using popular online tools. ISU's extensive alumni network should also be used for this purpose, together with endorsement from inspirational public figures, such as Neil deGrasse Tyson, Chris Hadfield, Brian Cox, Yi So-yeon, Sergei Krikalev, and others. ISU should advocate its position by becoming more involved at international and multidisciplinary conferences, similar to the TEDx ISU conducted in 2012 (TED, 2012). ISU could take initiatives to create its own conferences in a similar fashion to TED events.

We recommend that ISU develop an international academy, modeled on the USA's National Academy of Science that brings all of the top American scientists together to create "objective advice to the nation on matters related to science and technology" (NAS, 2015). In a similar fashion, ISU would be an advisory council that helps set priorities across disciplines and nations in the space sector. As an independent organization, ISU would act as a neutral international space mediator, allowing for more communication and collaboration between countries such as the US and China. ISU would build interconnected space communities to serve as a global meeting place for peaceful ideas involving space.

### **3.3.2 Skills and Scenarios Addressed**

Until 2025, we will focus our outreach strategies more on making ISU a well-known and established brand in the space sector. With significantly improved brand recognition by 2025, we will move into a more active phase, positioning ISU as an international mediator on space issues. In both phases, ISU will use its strengths, in particular its extensive alumni network (Schoenberger, 2000), its experienced staff, and the 3Is philosophy.

ISU will use these public outreach strategies to go from raising awareness to the delivery of advisory or consultation services. To raise awareness, we will use our presence at international conferences, such as TEDx (TED, 2012), the Web Summit, South By Southwest, our social media presence, and support from public figures (Byrne, 2013). Our outreach strategy will involve a marketing campaign to generate public support for space activities (Renault, 2015). We would provide information in the primary language of our audiences whenever possible. ISU can build on its existing credibility, diversity of cultures, and staff quality.

Once an increased public presence has been established, we will deliver services as a highly respected brand in the second phase of our strategy. We will act as an international space advisory group to establish connections between professionals and organizations.

The challenges addressed by our strategies range from getting ISU to be a recognized authority in space affairs to gradually finding a larger purpose for the institution. Our outreach strategies will help ISU engage the public like never before. Through following these strategies, ISU could more easily find additional funding from new partners and attain a new academic status. Our marketing campaign strategy will help attract the commercial sector and inspire more people to

look at space and ISU. The space sector is missing an international institution to develop consensus and establish worldwide goals for space exploration. ISU can promote and lead in the creation of neutral guidelines for the space sector and be a public leader in promoting STEAM education.

The lack of funding was one of the main challenges in the realization of a lunar base, as studies suggest a cost range from \$50 to \$90 billion for a very modest sized habitat (Johenning and Koelle, 1986). In our strategy, crowdfunding and the engagement of governments and public will address this problem.

Our strategy does not deal directly with the existing technological limitations, demand for transporting materials, equipment, and facilities to the Moon or back to Earth, power, safety, and cost for the space trip. It deals with the process of raising awareness can be a catalyst for an increase in technological research. In the context of increasing real-time Earth applications such as observation and telecommunication, our strategy does not cover the associated increase of space debris in Earth's lower orbit. It does, however, address the challenge of needing to analyze large amounts of data. By raising awareness, the interest in analytic solutions around big data would be increased. The additional funding of our outreach strategy will promote more diverse and practical programs in ISU, such as an expansion of the existing EyasSat Classroom satellite program (Zdybski, Doule and Esteves, 2010) to include launches as well as development. ISU acting as a space moderator will help create, or advise on measures to promote, a commercial market for active space debris removal.

The realization of orbital stations has similar challenges and skills needed to the ones mentioned above in terms of engineering, international cooperation, space policy, and creative thinking. Our strategy will address the need for more entrepreneurial initiatives in the space industry through substantial investment and public-private partnerships, not only because of the establishment of the brand, but also thanks to building of trust with commercial organizations. In the lunar and asteroid mining scenario, our strategies address all of the main needs, including engaging the general public and promoting the relevance of STEAM education. In the final scenario of establishing a human presence on Mars, we face a lot of the same challenges and skills needed, including competencies such as education, crew training, propulsion, and life support systems.

### 3.3.3 Why ISU?

With the advancement of the Internet and the growing use of social media to convey knowledge and information, there are now more methods than ever for everyone to send out their opinions on any topic. It is imperative for ISU to be able to keep up with this changing social structure to further the ideals of ISU. For the ISU brand to maintain relevance in a changing world, we would enhance the influence of ISU in the year 2040. Updating its website and revitalizing its brand image will allow ISU to compete more successfully on an international stage.

Being a clear and unique brand on the Internet gives ISU an international reach. The ability to compete against the bigger institutions and space companies in terms of brand would allow ISU to have a much bigger influence on those outside the space sector. For example, SpaceX is known globally by those who do not even know what exactly it is that they do, thanks to the company's media coverage and unique branding. The other two Is, intercultural and interdisciplinary, will be emphasized during the later phase. With the formation of an independent space institution for international space advisory services, we would be able to combine all the different cultures of space-faring nations into an organization that can benefit the whole space community. This would be done by merging the ideas and activities of different nationalities that

may be seeking the same goal but using different methods. Again, the advisory board would work on an interdisciplinary level because there would be members who are active in each area of the space industry. The members would be from different countries and backgrounds advising on legal, policy, and scientific issues to achieve similar goals using different methodology.

With the creation of conferences similar to TED or others, ISU would be creating an event which combines the 3Is into one activity. Having the ISU conference all over the globe, with representatives from all nations would emphasize the international and intercultural aspect of ISU. Having lectures and activities involving all aspects of the space industry would then establish the interdisciplinary aspect.

ISU's role is to establish these projects to create an international collaboration in the space industry that is independent of political and governmental incentives. There are institutions which conduct similar activities but on much smaller scales than what ISU could produce. ISU should think about creating such a conference to raise its profile outside of the space sector. There a range of industries which could see the potential of applying the skills acquired at ISU events into their own work force. Given that ISU is space-oriented, embracing other industries at these events would spread understanding of the space industry.

### 3.3.4 Importance for Stakeholders and Partners

The outreach strategies for ISU will have a significant impact on how ISU engages different stakeholders during both phases of the strategy. The activities outlined for each phase are different, but many of the stakeholders are the same for both. The current and future stakeholders of ISU include ISU faculty, ISU students and participants, the general public, national space agencies, governments, and special interest groups such as the United Nations.

As ISU participates in more conferences, including events such as TED talks, it will become even more important for ISU faculty to engage stakeholders. While ISU faculty have a lot of experience giving talks as part of the core lecture series, a change of focus may be needed for those same faculty to provide TED talks. Lectures will have a broader, less knowledgeable audience, require more multimedia content, and take less time. As ISU takes on an active role in international space mediator faculty will also need to include government liaisons and policy makers. This transformation of ISU faculty can ensure that ISU remains successful in 2040.

ISU students will remain stakeholders during the initial phase, as the students can help with the coordination and execution of ISU's participation in conferences and TED talks. SSP participants and MSS students will be able to assist with the conferences. Students would also assist with social media and other outreach strategies during their time at ISU. With improved branding, the degrees and certificates earned at ISU will also gain more value. During the later years of the strategy, ISU students may have an increased global prestige as more students begin to participate actively in the international academy of space, creating works that can impact real political decisions and outcomes. This will further reinforce the 3Is focus of ISU.

ISU participation in conferences and organization of a TEDx event will improve the ISU brand and engagement with the general public. This could become a positive feedback loop with the general public increasing their interest in space, increasing their interest in ISU, thereby improving ISU's engagement at conferences and TED talks. With a growing influence, the general public may be directly impacted by decisions made by ISU's academy. Space agencies and governments from around the world will become stronger stakeholders in ISU by 2040. While a number of space agencies are currently sponsors of ISU, emerging space nation agencies will likely become sponsors in the future. While governments may not be a primary stakeholder during the early phase, it is expected that they will be the primary stakeholder during the later phase. Encouraging governments to participate in the international academy of space, to identify space priorities and stimulate open discussion of space policy and actions, will require active participation by all space-faring nations, as well as substantial coordination of these activities by ISU.

As ISU begins to form its international academy of space, we expect that special interest groups will become key stakeholders, using their influence and resources to encourage participating governments to make policies that align with the special interest groups' goals. ISU will need to address these needs as part of the organization and funding of the new academy.

#### 3.3.5 Twenty-five Year Strategy

Phases	Year	Objective	Strategy	Partners	Tracking
	2016	Improvement of engagement in international space conferences	Extending the SSP through informing participants of conferences that could be attended to showcase work such as the IAC. Promote the ISU brand by participating in and hosting events similar to TED talks	Institutions and host nations of the conferences such as IAF and IAA Alumni from different fields	The proportion of participants at conferences with ISU lectures. The amount of papers and talks. Detailed Survey for satisfaction, feedback, and ideas for improvement
First phase: branding	2020	Enhancement of connections with space organizations	Enhance associations with the UN office for Outer Space Affairs Keep connecting with entrepreneurs Interaction with space agencies from different countries	UN STC SpaceX and emerging companies NASA, ESA, CASC and others	Statistics of interactive activities The amount of mediation
focus	2022	ISU becomes widely recognized by public	Space community activities Broadcast space development news in all media outlets including print, television, and social media Publish printed articles in Newspapers and Magazines Educate online	Social media tools company Community committees	The view count and click-rate online Ad revenue The amount of people involved
	2025	ISU becomes the international peaceful space mediator	Build good relation with space organizations Create the professional group for international mediation	UN COPUOS Senior space experts from relevant fields Space agency	The number of space missions procured by ISU The satisfaction of partners
Second phase: action focus	2030	Complete the development of new peaceful space exploration roadmap	Evaluation of the space development status Define the challenge and vision 2050	The International Space Exploration Coordination Group Famous international space specialists	Recognition The financial and political commitment level of nations in response to the exploration roadmap

### Table 5 – Outreach

				Space agencies	
	2035	Preliminary form of the space network	Create communication mechanisms among the space-faring nations Use a variety of media platforms for networking	Space agencies Governments Relevant universities Public	The level of traffic and number of entities using this network
	2040	ISU becomes the space hub across the globe	Advice on international collaboration regulations	UN Space organizations	The coverage of countries Participation of the members

### 3.3.6 Conclusions

In conclusion, outreach to the space sector and the general public is an essential area in which ISU needs to invest resources for it to be a vital part of the future space environment. The strategies proposed are divided into the branding-centered phase, occurring from 2015-2025, and a more active phase, occurring from 2025-2040. We recommend that ISU revitalize and modernize its image and brand through the redesign of its media outlets, developing more open educational channels such as online access and conferences like TEDx, and create its own independent multinational and multidisciplinary space advisory service. This would allow ISU to have a great, unbiased impact on the space sector.

### 3.4 Alumni

The definition of alumni (CASE, 2013) is a group of graduates or former students from a particular college or university that are often viewed as valuable asset. The strategies discussed will focus on three main areas related to ISU's alumni: the global network, the alumni representative on the ISU board of trustees, and alumni associations based nationally or organizationally such as CAISU and ISU\*USA (CAISU, 2015; ISU\*USA Alumni Association, 2015). Each of these areas has potential to promote ISU differently.

Certain challenges must be overcome to access the full potential of ISU's alumni. First, alumni must be activated and given the feeling that they are gaining something by participating. Second, ISU competes with other space-promoting organizations like the International Academy of Astronautics or the Space Generation Advisory Council (SGAC) (SGAC, 2015), meaning alumni might find their time and loyalties divided amongst multiple organizations.

ISU faces the long term strategic problem of passing along leadership to the next generation. While recent SSP or MSS program graduates are excited to maintain connections made within their class, the university should build stronger connections between different graduating classes. ISU must evaluate the effectiveness of networking proposals, keeping in mind that a lot of interpersonal communication happens informally without the university's knowledge.

#### 3.4.1 Strategies

Our main goal is to activate all alumni in leading ISU into the future, through three main strategies, each with a number of initiatives and specific implementation plans. These strategies include strengthening and building existing alumni connections, as well as widening the alumni role in ISU guidance and involving the alumni in the creation of applied projects inside ISU.

#### The global network

We propose strengthening existing connections and building new ones between different ISU generations through a mentor-mentee system. Small groups with shared professional interests will pair at least one older alumnus or alumna with a more recent SSP participant or MSS graduate. This will extend the network and give alumni the opportunity to meet each other, share information, or create partnerships for new ventures. Another initiative could be a skills database of ISU students, alumni, and ISU partners and stakeholders such as space agencies or companies. This initiative could further extend into a virtual forum for ISU partners and stakeholders that would like to access the collective skills and knowledge inside the greater alumni network.

#### Alumni associations

As mentioned in the introduction, the national alumni organizations, can and should play an important role in strengthening existing connections. These activities rely on the alumni themselves rather than the ISU organization, but ISU can support and promote those organizations with regards to this strategy. One basic initiative could involve asking new graduates to present their team projects or department activities from the SSP to their fellow organization members when they return to their home country.

ISU could also provide a conference for alumni to renew and upgrade their skills. Currently, there is only one annual alumni meeting, a weekend conference including lightning talks, speednetworking sessions, and a space masquerade. First, ISU should schedule the alumni conference to run in parallel with the keynote speakers invited to speak during the SSP evening event programs, to attract wider participation. We are not suggesting that these events would provide significant new learning for the alumni, but rather an opportunity to attend special events aimed specifically at SSP participants. By expanding the alumni conference to a week, including activities for families and sightseeing, it could be possible to attract a larger mass of alumni, to expand on the idea of the ISU family, and build a larger variety of connections. For the longer term, ISU should consider situating the alumni conference within another broader ISU space conference in association with successful events (Byrne, 2013) like Web Summit in Ireland, TED, South By Southwest in Texas, C2SV in California, or RISE in Asia.

To encourage collaboration and communication between alumni, we propose weekend alumni idea creation events, similar in style to the hackathons (Maxxor, 2013) which have emerged from the computer programming industry. At such events, groups of participants gather to work intensively on specific projects over a short 36-48 hours period. Like a mini-team project experience, we could implement this hackathon initiative to encourage alumni to gather, network, and work together to create applied projects from inside ISU, using these weekend idea creation events. This initiative would build on the existing alumni network to create research and business opportunities exclusive to ISU staff, alumni, participants, and partners. Alumni using these events could incubate new ideas and transition their ideas into reality.

### Alumni representation on board of trustees

We suggest widening the role of global alumni in ISU guidance. There is currently an alumni representative on the ISU board of trustees, whose main responsibility is to represent the ISU

alumni at the board meetings. This representative is elected by the alumni and any of the ISU alumni can propose nominees for these elections, which are held every two years (Bovet, 2013). For fairness and to ensure that alumni representatives don't always originate from the same continent, a geographical rotation scheme is implemented. Votes are cast online on the ISU Community website. If no nominee receives more than 50% of the votes, a second round is organized between the two candidates having gathered the highest number of votes. In the last election (2013), about 5% of alumni participated in the vote (Bovet, 2015). The next election for alumni representative occurs in fall 2015 . With such a low turnout in voting, this may reflect that the alumni may not be fully aware of the value of an elected alumni member on the board of trustees.

There is a class representative elected from every graduating class of SSP and MSS programs. There are currently no formal committees between the alumni representative on the board of trustees and the class representatives (Bovet, 2015). We suggest that the alumni representative should consider expanding their responsibilities to liaise with class representatives directly. For instance, the alumni representative might get more involved in organizing the annual conference, outreach activities, or other initiatives to further activate the alumni.

At the intersection of the strategies mentioned above to strengthen the bonds between ISU generations and involving alumni in ISU guidance, we also suggest that ISU continues the oneweek Executive Space Course and the 12-day Space Odyssey Institute. (ISU, 2013). Both of those programs were aimed towards worldwide executives and managers in space agencies, companies, and organizations. While their operation depends heavily on funding, they are a valuable means for ISU to align with space sector companies and institutions and enhance the prestige of the alumni network. Additionally, ISU should consider engaging its alumni to participate in STEAM activities, such as outreach events, to increase its profile among the global alumni community, or applied team projects to help students to gain work experience.

### 3.4.2 Skills and Scenarios Addressed

The graduates of ISU, employed in space agencies and private space enterprises around the world, have a pivotal role in negotiating projects and influencing policy. ISU should focus on developing relevant skills such space policy, entrepreneurship, communication, and negotiation, and international policy and law over the next 25 years.

Activating the alumni is the key element of the ISU strategy to offer a strong network of global contacts across the space sector that will encourage the development of interpersonal skills. The use of a mentor-mentee system can ensure that communication skills are developed before, during, and after a participant's time at ISU. A skills database can instigate alumni communications and negotiations through new alumni ventures and collaborations. A longer alumni conference and idea creation events provide opportunities for communication and negotiation skills to be challenged in an environment open to rapid collaboration. The one-week Executive Space Course and the 12-day Space Odyssey Institute provide direct opportunities for a large number of people who would like to attend an ISU program but may not be able to accept the time commitment of SSP or the MSS.

We forecast that over the next 25 years that ISU will become a hub influencing policy makers, scientists, and corporations through its strong alumni network. These skills of communication, negotiation, and international policy and law are required for a number of our forecasted scenarios. Stations in Earth's lower orbit will be heavily affected by space debris policies and international collaborations. A human presence on Mars will require the collaboration of

government and commercial actors, as there is doubt whether a single organization would have the resources to perform the mission alone. Lunar and asteroid mining will be surrounded by political uncertainties regarding ownership of resources from space, and a strong political framework is necessary to enable these developments. Finally, real-time earth applications will rely on creative communication skills to translate large amounts of data into useful applications that all people can benefit from.

### 3.4.3 Why ISU?

To keep up-to-date in a constantly changing environment, ISU must adapt to trends in the space sector. Our alumni are a key resource for that adaptation, as they are best positioned to bridge the gap between the academic world of ISU and the worlds of companies and organizations around the world. ISU cannot afford not to use this resource to its fullest potential, and new strategies are needed to engage and activate the alumni in assisting in the future development and expansion of ISU. Implementing initiatives, such as skills databases or mentor-mentee programs, will encourage alumni to work together in future business and scientific collaborations.

The 3Is principle is intrinsic to ISU's success, attracting diverse cultures and professional backgrounds to come and work together across a broad range of skills. This interdisciplinary, international, and intercultural approach is reflected in ISU's alumni. It may occasionally be wiser and more beneficial to the space community to target specific subsections of the alumni in order to achieve a broader goal. ISU should consider designing other events that target specific audiences for specific events. A more flexible approach to the 3Is, where disciplinary and slightly more exclusive initiatives are created, should be adopted when planning national ISU alumni initiatives, but all the while maintaining the values of international and intercultural collaboration.

In addition, the wide range of resources offered by ISU to other institutions and private enterprises through its alumni network will provide a wider global reach for ISU. If ISU does not implement this strategy, it will not have the necessary resources to obtain its dream of being a university in space. This plan requires the combined will and engagement of the alumni and their institutions over the next 25 years.

### 3.4.4 Importance for Stakeholders and Partners

As ISU is an educational institution, its alumni are one of its major partners and stakeholders. The connections created during the participation in ISU programs are also beneficial to other stakeholders, such as the private sector and space agencies, as international cooperation. The flow of ideas and personal-professional connections allows a greater advancement of space exploration. Specific initiatives can also create new partnerships or strengthen old ones between the alumni, ISU, and other organizations.

Through engaging the alumni, ISU can affect future stakeholders that will come from the graduates themselves or their direct connections. As an international, intercultural, and interdisciplinary entity with alumni in a majority of the world's key space players, ISU would have a unique opportunity to affect these players and create partnerships with both existing and new institutions.

Engaged alumni are necessary for the success and expansion of ISU in the next 25 years. With this strategy, we believe ISU will become the world leader in educating future space leaders, and in mobilizing its alumni towards influencing policy makers, scientists and business for the years to come.

# 3.4.5 Twenty-five Year Strategy

Year	Objective	Strategy	Partners	Tracking
2015	Raise awareness of increased alumni involvement	Contact all class representatives and have them contact as many alumni as possible Plan involvement of SSP16 participants before the program next year and next year Master's program alumni. Connect with active alumni at the IAC ISU Alumni Survey 1- benefits of Alumni	Class representatives Active alumni Permanent staff SSP veterans ISU	Number of mail responses Feedback from class representatives Results of ISU alumni Survey
	Develop new methods of effective alumni communication	Survey of alumni #2 how they would like to stay virtually connected with each other Analyze existing social media such as Facebook, Linkedin, Wechat Analyze alumni networks from other institutions to see if ISU needs an alumni website and if logos or layout should be changed	Social media companies ISU Alumni Space companies and agencies	Response to survey #2 Result of survey and analysis
2016	Alumni conference	Evening Panel events of SSP moved to correlate with alumni conference Mentor-Mentee program launched at alumni conference	Keynote speakers	Numbers at alumni conference
	Idea creation weekend	Alumni members establish idea creation weekend events	Incubators and accelerators that host idea creation weekends, such as Ycombinator and Techstars	Engagement of Alumni
	Executive Program	ISU re-establish executive program, to attract middle and higher management from space industry	Space agencies Private space Space policy makers	New alumni members in key positions in space industry
2017	Setting up a skills database of ISU students and alumni	Analyze existing skill databases with ISU IT team and set a budget Ask alumni/students if they would like to see skills database and what their suggestions are Contact agencies/companies to check their interests in a ISU skill database	Social media companies ISU Alumni Space companies and space agencies Companies offering database services	Result of analysis Responses and suggestions from alumni Responses from agencies and companies
	Alumni conference- make connections with WebSummit, SxSW, C2SV, RISE, TED, etc	Research Tech/Innovation conferences to establish a new ISU Space Conference from 2020 onwards	Conference	Conference metrics and attendance Media coverage of conference
2020	Establish Mentor-Mentee program according to specific alumni interests	Create small groups based on same professional interests for ISU alumni and new SSP participants	ISU Alumni Space companies and space agencies Private space companies	Annual report of activities that is published on website and social media

# Table 6 – Alumni

	ldeas creation events signal emerging technology	Ideas lab to engage more alumni collaborations within ISU	Ideas creation events	Increased engagement from Alumni
	Embed alumni events within other conferences	Have an ISU dedicated space within conferences, to increase awareness of ISU and to attract more alumni and new students	Conference	Expansion of SSP attendance due to global access and interconnectivity
	ISU invites experts from emerging Space industry growth areas (Brazil, South America, etc) & to contribute to SSP and MSS programs	Emerging space industries contribute to SSP and MSS programs	New Space Agencies	
2020-2025	Organizing ISU-conferences to increase the prestige and brand of ISU and bring alumni to world conferences	Presence at world conferences	Alumni Private Space companies	
2026-2035	Alumni conference	ISU sets up its own space conference	Alumni	Annual Conference is nopositioned as a key calendar event in the space industry

### 3.4.6 Conclusions

ISU considers their alumni to be assets of great importance, and clearly any strategic focus for ISU must include the forging of partnerships with its past students and participants. The ISU alumni strategies we proposed in this chapter target the role of alumni as guiding the wider global space sector and as well as ISU itself. Currently there are a number of initiatives run by ISU and alumni to maintain connections between graduates and the central campus, including Facebook groups and ISU website updates, but we have seen that alumni engagement could be higher in certain areas. Looking 25 years into the future, with an ever-growing number of alumni progressing further along in their careers into more senior leadership roles in the space sector, the need for ISU to keep its alumni engaged will only continue to grow. The challenge for ISU will be to maintain a strong cross-generational connection as the institution evolves and adapts over time. With these strategies, ISU should be able to brings its alumni together, and strengthen its bond with policy makers, scientists, business executives, and other former graduates who have gone professional. Through bringing its network together, ISU and its partners can work towards making the dreams of today, the realities of tomorrow.

### **3.5 Startups**

The International Space University was conceived in 1987 as an innovative institution to act as a beacon, bringing space-minded people together from all over the world. From the beginning, ISU received support from the traditional space stakeholders, namely space agencies and major private corporations. In the last couple of decades, a new generation of space development, increasingly commercial, has arisen. One of the features of NewSpace, which "includes companies that are likely to be flatter, flexible organizations that are consumer-focused, innovative, willing to take risks, and focused on new technology solutions" (Hay et al., 2009), is its agile approach to entrepreneurship which is expected to have a predominant role in future space activities. While ISU has an indirect connection to space startups like Spire Global Inc.
(Gage, 2014) through the initiatives of alumni, its current structure does not allow ISU to be a stakeholder in the emerging NewSpace sector, compromising its long-term sustainability.

The main challenges ISU faces as an organization are related to the evolution of its internal culture. Generally speaking, organizations tend to lose their initial disruptive momentum and creative agility over time because of increased bureaucratic complexity and decision-making structures. ISU can avoid this pitfall by building links between ISU and the commercial, experiential, and transformational space sector. ESA has recognized the need to build links between their agency and new commercial ventures, and has created business incubation centres across Europe specifically for this purpose. (ESA, 2015b)

The power of ISU lies in its alumni network that spans the space industry and agencies from around the world. The growth of the commercial space sector could potentially create knowledge and skill gaps within ISU. At present, the institution does not retain any shares in the new private ventures that are founded by graduates. We propose the following strategies to support the creation and retention of an incubator program so that ISU can be an environment where new companies are created and thrive.

### 3.5.1 Strategies

The broad strategy that ISU should adopt is the establishment of a new startup incubator system as part of the ISU institution. This startup incubator will be the core of a new for-profit ISU partner organization, while the academic part of ISU can remain a not-for-profit organization and continue to have the support of space agencies.

ISU is currently registered as a not-for-profit under its academic mission. ISU participants often bring new knowledge and ideas to fruition, often in the form of new ventures. To attract investment for the creation of these new ventures, we recommend the creation of a for-profit organization following successful models like Singularity University (Singularity University, 2015) and famous incubators like Y Combinator (Y Combinator, 2015).

The startup incubator will open the door for sizeable investments through the creation of two programs, one placed at the ISU campus in Europe and the other near Silicon Valley in the US. The use of the ISU main campus can lower the initial costs and infrastructure associated with the creation of a startup incubator. The incubator in Silicon Valley will be able to create new partnerships with many disruptive entities and talents located there. This will grow over time to become a global network of incubators, with a network of mentoring alumni, strategic alliances, and a large number of investors. As each startup passes through the startup incubator, ISU will retain a percentage of the ownership, or equity, in the startup ventures. This creates a growing stock portfolio that can be leveraged for further investments in the startups or ISU.

The first stage of the startup incubator will comprise a program for space entrepreneurs lasting between three and four months, based on the model of other successful technology startup acceleration programs such as Y Combinator (Y Combinator, 2015), where a large pool of resources will be provided to develop a minimum viable product (MVP) or proof of concept at the end of the program. A variety of resources will be available to participants including software, new manufacturing hardware such as 3D printers, and active mentorships. These mentorships will be provided by ISU alumni, staff, and industry professionals within the ISU network. The projects will be presented to a panel of investors at the end of the program.

After the first stage, the startup incubator will serve as a host for two to three years for the new ventures, as this duration is the mean time to market for the products of the new startups. The new ventures will stay at the startup incubator building and have access to all the resources they need to develop their product. Unlike the first stage, the longer program will ask the companies to develop their businesses at an arm's length from ISU. After this period, startups will graduate from the incubator, and by then, they should be ready to put their first product to market, and ready to grow by themselves.

As part of the startup incubator, we envision the formation of an idea creation department for experimenting with new concepts that have the potential to disrupt the present state of technology. This department of the startup incubator is envisioned with two fundamental goals:

- Consider solutions that can provide radical improvements
- Pursue radical ideas for a very limited amount of time to determine their feasibility and impact

This idea creation department will have an approach similar to Google X (Miller and Bilton, 2011). An idea is adopted for a very limited amount of time to rapidly iterate on its feasibility and impact, and to free the researchers and developers from common concerns such as scalability and cost. After this initial period, the ideas will be either dismissed or pursued as startups in the incubators.

In the long run, research on disruptive technologies, such as artificial intelligence and nanotechnologies, should find refuge in and will be used by the idea creation department. Such topics could include disruptive technologies and their impact on society as a whole, as well as other groundbreaking questions. This approach will allow ISU to be at the forefront of major technological advances. The final aim of the startup incubator is to operate a idea creation lab in space by the year 2040.

Parallel to the ISU acceleration program, we propose events like hackathons or Startupweekends (Messier, D., 2014) as a part of the startup incubator. These can serve as a catalyst to build up new teams and ideas that come into the acceleration programs.

We could use a new facility in Earth's orbit or on the Moon to operate as a creative space where new perspectives could be achieved. The overview effect, described by astronauts as a change in awareness after watching Earth from space, would create new mental perspectives (White, 1998) that could greatly change how businesses and products are developed, as well as how humans interact during these developments. In 2040, the need for imagination and creativity will explode when automation replaces traditional forms of work. The creative facility in space will fulfil those needs to develop creativity, imagination, and design. Through immersion in a space-based environment, participants will be able to envision a whole new set of products and services.

### 3.5.2 Skills and Scenarios Addressed

The shift in the space sector to commercial endeavors is giving more importance to the creation of companies. These companies are already forecasting the scenarios we envisioned: Planet Labs for dynamic Earth observation (Hand, 2015), Bigelow Aerospace for orbital space stations (Boyle, 2015), Astrobotic for a lunar base (Kramer, 2014), Planetary Resources for asteroid mining (Lewin, 2015), and SpaceX for a human presence on Mars (Carroll, 2013).

The scenarios we envision demonstrate the need for skills that would put ISU graduates in the best position for success, with entrepreneurship being a key skill that we want to encourage. Promoting concepts and turning them into businesses that will help move ISU closer to fulfilling the goals of the scenario. The support and expertise given by ISU will help both the startups involved and ISU by creating a growing stock portfolio that can be leveraged for further investments.

The influential position ISU will reach in the future will address some of the challenges of the scenarios. ISU will lead international cooperation being a mediator between the private and public sectors by managing communication and negotiation as an impartial and international entity. The university will become integral to space policy creation and outreach to an increasingly broad public about the scenarios. Public awareness and support will lead to increased government funding for space activities.

The idea creation lab will place ISU on the forefront of innovation, dramatically increasing the chances of finding solutions to the technological challenges of advanced spacecraft technology or propulsion. The achievement of a space-based idea creation lab will be a great milestone for both skills and challenges.

### 3.5.3 Why ISU?

This strategy allows ISU to provide different skillsets to future leaders of the space industry, such as entrepreneurship, technical skills, teamwork, leadership, and creativity. The variety and scope of different startup opportunities would increase the breadth of education that ISU could develop. The new ISU alumni class will not only have the background provided to previous generations of alumni, but also new skills to solve real business and societal needs.

The system creates a win-win scenario for all the parties involved as the startup incubator will retain a percentage of the ownership in the startup ventures. This allows ISU to be a stakeholder of the startup and reciprocally the startup will become stakeholder in ISU. The startup incubator will act as an intermediary between the newly formed startups and the corporate and government stakeholders of ISU.

Startup companies created by the interdisciplinary, international, and intercultural community at ISU's startup incubators could expand globally, leading to multinational companies and international recognition for ISU as the program expands. ISU alumni make up a community of professionals from diverse disciplines and this strategy provides new opportunities for ISU to harness their expertise for a common goal. By using this new model, ISU, the startup incubator, and the startup all benefit from each other.

### 3.5.4 Importance for Stakeholders and Partners

Current ISU stakeholders, consisting of government agencies and private space corporations, will benefit from this strategy. Government agencies will have access to a network of new commercial ventures that agencies like NASA are actively engaging to address specific technology gaps (Steitz, 2012). Another example of this is that NASA is using commercial technologies to provide cargo access to the space station, via the Commercial Orbital Transportation Services (COTS) program (Turnbough, 2012).

For large corporations, this new startup incubator is both a threat and an opportunity. The rise of the number of commercial companies can signify an increase in the customer base of large space corporations. At the same time, these new ventures can potentially create new products or services that disrupt the market and threaten the commercial sustainability of large corporations.

Due to the potential profitability of the startup incubator, new stakeholders will emerge for ISU. These new stakeholders can help fund the startup incubator through building a strong, reliable, and loyal community of investors. The process of building this community within the space sector will require resources and skills specifically dedicated to this task, such as community and knowledge management, loyalty programs, and interpersonal skills.

Having the alumni actively involved both in mentoring and in funding will also help reinforce the alumni community. Mobilizing the alumni community is imperative to the success of ISU and the startup incubator for harnessing all of their knowledge, creative ideas, innovative products, and international resources. This allows the startup incubator to have a high potential of being funded from its very inception and of creating a growing stock portfolio for further investment.

### 3.5.5 Twenty-five Year Strategy

The aim of this strategy is to provide a roadmap that identifies the key milestones and objectives required to create the startup incubator, including short-term actionable objectives and long-term goals.

The plan may be implemented from 2016 through stakeholder analysis and feasibility studies around the startup incubator. Creating the infrastructure, obtaining funding for the incubators, and market research, will be the main objectives of this phase. ISU can hold events like hackathons, an event where a group of software developers collaborate over a short period of time on projects (Briscoe and Mulligan, 2014), or startup competitions to help create ideas, serve as outreach tools, attract investors, and test the size of the market.

In 2018, ISU should create two incubators, one on the Strasbourg main campus and one in Silicon Valley. Both incubators will be managed in parallel and the startup incubator will take advantage of the exchange of ideas between them. After the first startup incubator program is finished, the first class of startups will begin their two-year period in which they receive mentoring, technical, legal, and business support from the startup incubator. Associations and partnerships with legal and policy-making bodies will help. By the end of the two-year period, the first products from the startups will be released to market and hopefully their success will serve as a measurement of the processes and inform potential areas of improvement. The current statistics of Y Combinator show that more than 30 of their startups achieved values in excess of \$100 million in the course of their first 10 years (Manalac, 2015). This signal shows the potential for this model to be successful.

In the following years the startup incubator will serve as a link between all the new startups created. The startup incubator will remain one of the main stakeholders of the startups as they progress beyond the incubator. The team dedicated to running the incubator, and the volume of activities, will increase as more startups will finish the program and take products or services to market.

By 2024, ISU will be perceived as an authoritative brand and all the startups that the incubator supports will have a stronger public presence and status within the market. To develop unconventional ideas that will likely turn into disruptive technologies and support new ways of thinking, ISU should develop the idea creation lab. This new department within the startup incubator will attract new investors and entities will be interested in partnering with ISU.

Starting in 2026, taking advantage of the brand strength associated with ISU, an expansion will be performed over the course of the next eight years. This expansion includes opening a new incubator in each of Asia, South America, Australia, and Africa. The new incubator centres will use all the expertise and knowledge gained from the other labs and will rely on the strong ISU brand. Alumni from different parts of the world will be able to directly support ISU in their own countries. Surveys and polls will help keep track of the brand perception and success, as the involvement of local government agencies helps to expand the incubators.

In 2034 after finishing the expansion, ISU will have a dominant position in the space sector. The former startups will be successful companies and concurrently alumni will have decision-making positions in government agencies. ISU can then define international roadmaps to coordinate common efforts among all the space actors, and can be seen as an entity that benefits humanity as a whole, uniting different government and private sector efforts for common goals. The construction of a new creative facility in space will solidify ISU's position as a leader in the space sector.

In the following years until 2040, the main objective is to maintain the global position of the incubators and improve their global network. By 2040, ISU should have connections with a majority of entities involved in the space sector.

The global scenario in 2040 will be totally different from the one we know today. New generations might have different mindsets and aspirations. To embrace these new perspectives, we have to prepare the roadmap and that means creating incubators where disruptive innovations might thrive and generate enough income to enable ISU to attain an independent and neutral status on the international scene.

Through the expansion and strengthening of its brand, what it stands for, and how it is actioned, ISU will gain a dominant position in the space sector and become one of the main international authorities. Space pioneers will turn to it for guidance, knowledge, and skills. Unlike corporations and agencies, ISU should position itself as an independent actor, choosing its stakeholders carefully from the space community. That community must remain open-minded to distant possibilities and horizons for both technology and humanity. Through a startup incubator, ISU should prove to be an environment fostering radical collaboration and creativity.

Table	7 –	Startups
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Period	Milestones	Strategy	Partners	Tracking
2016-2020	Startup incubator creation to first product to market.	Create/Lease startup incubator infrastructure. Hosting events world wide (conferences, Hackathons, startup competitions). Startup incubator starts working, Two sister incubators in Europe (ISU campus) and Silicon Valley. Growing stock portfolio, the incubator gets part of the ownership assuring a two-way strategy that the incubator gives quality advice and counseling and it gets benefit from the companies.	ISU board ISU alumni (and interested companies owned by them) Venture capitalists	Measure interest of private markets in startup competitions and number and quality of applications. Attract investors for ISU incubator. Analyze market needs by associating with other space industries for future feedback and planning
2020-2024	Quality branding Creation of idea lab	Idea lab facility built in startup incubators Idea lab events are held regularly to foster ideas for startups	Financial funds ISU board ISU alumni International commercial partnerships Association and partnership with legal and policy making bodies, governments	Survey interest of different entities, private investors. Measure the interest of the market in the incubator.
2026-2034	Global expansion in four phases.	Start incubators expand to Asia, Australia, Africa and Sotth America Funding supported by startup incubators in North America and Europe	Financial funds ISU board ISU alumni International commercial partnerships Association and partnership with legal and policy making bodies, governments	Evaluation of the current startups' health.
2036-2040	Space leader Facility in space	Create a professional dedicated team of legal, business and outreach advisors that work for the incubator.	Financial funds ISU board ISU alumni International commercial partnerships Association and partnership with legal and policy making bodies, governments	

### **3.5.6** Conclusions

According to our recommendations, ISU will follow a 25-year strategy that will lead to the creation of both a not-for-profit and a for-profit organization. The for-profit organization will create an international startup incubator network with a radical idea creation department that enables the ISU to grow into a leading and independent authority within the space sector by 2040.

The startup incubator will consist of a program of three to four months, including mentorship and resources to develop a minimum viable product. Following that, mentors and industry professionals will help the startups bring their products to market within two years. The graduating entrepreneurs will be able to grow their startups independently and give back to the ISU community by mentoring new participants.

Confronting the challenges and developing the skills needed for our future scenarios will be the main objective of the startups. The characteristic 3Is will be key to the success of this strategy and will be represented by current and future alumni involved in the incubator.

The current stakeholders of ISU will continue to remain involved in future endeavors, along with the addition of new stakeholders, to increase ISU's presence and influence in the space sector. The startup incubator will hold equity in the new startups creating a mutually beneficial situation.

## **3.6 Recommendations**

Organizations must define their strategies years in advance to achieve success in forecasted scenarios. This chapter provides strategies in five areas of focus that ISU can use to prepare participants for a professional future in the space sector. These five areas of focus are the future of SSP, analogs, outreach, alumni, and startups. Each area of focus defined a 25-year strategy that ISU can begin following immediately as it seeks to remain a leading space institution up to and beyond 2040.

The future of SSP will be transformed by technologies such as virtual reality, big data analysis, and a growth in web capabilities. The 3Is will be extended to more people, contributing to the ultimate goal of achieving international cooperation in space activities, as suggested in the ISU Credo. This will result in a larger, more tech-educated, and interconnected alumni workforce, able to tackle the challenges ahead by mobilizing international efforts.

By including the analog experience in ISU's curriculum, the university would contribute enormously to the accomplishment of the educational and space exploration goals embodied in its Credo. Analogs would also help keep ISU at the forefront of the space community, providing a remarkable environment for scientific research, advanced technology development, and crew training for long duration spaceflight. The overall plan, with its different phases, will make ISU a hub for international analog initiatives.

Outreach to the space sector and to the general public will remain an essential area for ISU's growth in the next 25 years. We strongly recommend that ISU invest resources to revitalize and modernize its image and brand. Strategies such as developing more open online educational channels, hosting and attending conferences like TEDx and South by Southwest, and creating its own independent, multinational, and multidisciplinary space advisory service, would give ISU a greater impact on the space sector.

The greatest assets developed by ISU in SSP and MSS programs are the alumni. ISU must create and sustain connections between past participants and ISU. These connections will be critical in developing new programs and activities through partnerships with alumni in key leadership roles around the world. Looking 25 years into the future, the challenge for ISU will be to maintain a strong cross-generational connection as the institution evolves and adapts over time.

The space sector has an increased number of startups interested in creating disruptive solutions and we recommend ISU create a for-profit organization to develop an international startup

incubator network. ISU can begin an investment portfolio by fostering startups and retaining a small percentage of ownership in each. The idea creation department within the incubator would enable ISU to build a strong presence in the commercial space sector.

Recommending the future direction of ISU continues to be the greatest challenge for Vision 2040. Each focus has proposed different goals for ISU in 2040, including the development of an ISU space program, becoming a leader in the commercial sector, and becoming an international space mediator for future space activities. Despite these different goals, the resulting proposals are complementary.

ISU as a hub for professionals and future space activities was identified as an end goal for three of the five areas of focus: outreach, analogs, and alumni. This demonstrates that ISU as a hub for future space professionals is an important element in the future of ISU for our team members and our influencers, and should be strongly considered in any future ISU developments.

The objectives and strategies for the future of SSP, analogs, outreach, and startups all involve different ways of empowering, connecting, and activating the alumni as the leaders of future ISU activities. This demonstrates that the alumni should be considered as a valuable asset in any chosen ISU endeavor in the future.

The future of SSP, analogs, alumni, and startups all had different variations of the use of a facility in space, an idea which has been in ISU's Credo and ideals since its inception. This long-standing ideal signals that there are possibilities and use cases for an ISU facility in space.

# **CHAPTER 4 – CONCLUSIONS**

Vision 2040 began with thorough research of the current trends in the space sector and its broader context. From this analysis, we built a set of recommended strategies for ISU to become a leader of the space community: a hub that brings together its alumni and influences policy makers, scientists, and businesses. The ISU will always continue working towards our greatest dreams for space exploration.

We identified five future scenarios that, jointly or independently, we believe will define the next 25 years of space: real-time Earth applications, orbital stations, lunar settlement, lunar and asteroid mining, and a human presence on Mars. These five scenarios present clear signals of change in the space sector. The current evolution of space businesses is clearly being influenced by the emergence of NewSpace, upcoming space-faring nations, disruptive technologies, and global connectivity. We believe that ISU can be a catalyst for innovation, not only riding this wave of change, but also using it to accomplish the dreams embraced in the ISU Credo. ISU should foster and stimulate space exploration, and eventually bring education into space itself, changing forever the concept of education.

To achieve these five envisioned scenarios, ISU must recognize and overcome technological challenges around life support systems, propulsion, and big data analysis, as well as cultural challenges such as online education, access to space, public support, government support, international cooperation, and the involvement of the private sector. To address these challenges successfully, we identified and analyzed several representative skills that will be critical for the future professionals of the space sector.

The representative skills were entrepreneurship, communication and negotiation, STEAM education, international cooperation, big data analysis, CubeSat technology, life support systems, advanced spacecraft technology, in situ resource utilization, public outreach, crew selection and training, and space policy. The combination and grouping of skills led to the creation of our strategic areas of focus that could address these future skill gaps.

We have devised five strategic areas of focus to provide the identified skills: the future of SSP, analogs, outreach, alumni, and startups. Each strategy outlines a 25-year roadmap of actionable items to help ISU to continue shaping the future space sector. The strategic plans encompass a variety of enabling actions such as building analog facilities in the Strasbourg campus, organizing TED-like conferences, creating startup incubators, embracing online education with a renewed SSP format, and transitioning the alumni network to a true space family. For all these actions, we have identified the potential partners that ISU could work with and methods for tracking the successful accomplishment of the plans.

The strategies we provide deviate from ISU's current role as an international university, and embrace a number of additional roles in the future. A few of these roles can transform ISU's current function, while others are natural evolutions and additions. Implementing any of these strategies would require an examination of the current management structure, financial status, and organizational motivations. For example, our startups strategy requires ISU to create a for-profit branch that would require new management and leadership.

Our hope is that ISU will take the lead in this evolving environment by providing the necessary information and tools to its participants, partners, and stakeholders. We believe that ISU should

commit itself to rethinking education around a new set of skills and ideals, combining the 3Is through the future of SSP, analogs, outreach, alumni, and startups.

Since its inception, ISU has been an institution known for pushing the boundaries of education towards new frontiers. With these roadmaps in hand, it will continue to do so well into the 2040s.

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# **APPENDIX A**

## Envisioning the future...

Different disciplines, different cultures, different languages, and different nations, Still came together those lovers and dreamers, owing to their common passions! Under the umbrella of ISU, met all hearts pining for space exploration, Skyward dreams and knowledge sharing was their summer vacation!

How would 2040 look like... and all had a different vision! Devise strategy and a path forward, was their herculean mission!

Different voices and opinion, Growing chaos and confusion, Stressed them out and increased the tension!

Then out of the brain churning emerged a realization... That all their differences were a mere illusion!

With the dawn of wisdom, clearer was their vision, Future could not be lopsided, but some beautiful combination! The different colors had to combine to form the rainbow of union, A stellar future was to be created, dissolving all their division...

All for the future and a future for all, satisfying everyone's aspirations... Lunar base, Asteroid mining, Human mars mission or orbital stations! While leaping forward they didn't forget designing for earth applications... Conceiving this awesomeness, they received good advice and inspirations!

The wise elders advised to be creative and hopeful along with a bit of caution, Learn from history and consider all aspects while straying on wild imagination! Then minutely examine, plan and ponder before designing a strategic direction, Remember the great responsibilities you bear, when they put your strategy to action!

They heard from one, they heard from all, the young and the old of so many region, All want progress coupled with peace... man, machine and nature co-existing in unison! Let not man lose his love, kindness and humanity amongst all mechanization, And with nature quenching his soul... there were omens indicating a cosmic religion!

Let the little birdie fly out of its nest, empowered with the strength of morality and education... Soaring the seamless skies, with wings of hope and heart at earth in all sincere devotion!

Niti Madhugiri

# **APPENDIX B**

## MoonBnB's business model – Example of a Startup from future ISU incubator

To show how a startup incubator will work, here we give an example of a company that has gone through the program. We will look at the fictional case of MoonBnB<sup>™</sup>, a startup whose mission is to create collaborative space analog communities, providing transformational experiences for human development and space tourism. MoonBnB<sup>™</sup> looks at the increasing need for exploring both external realms and internal insights. Their vision statement is as follows:

MoonBnB's journey goes both beyond and within. Think of the overview effect experienced by astronauts in space. It provided them with a whole new perspective about Earth as the "pale blue dot". Such a new perspective is filled with new ideas which could potentially create opportunities in terms of research, science, interpersonal skills, and social outreach. It could foster the development of creative ideas and far-fetched opportunities. Participants could gain enlightenment just by being there, feeling the moment and taking an active part in the given context. Self-sustainable and crowdsourced creative facilities in outer space environments are MoonBnB's ultimate vision.

The business model canvas is a tool to represent the structure of the aforementioned startup. This is how ISU could help bring this company to fruition through its incubator program. Ideas could come from participants and students attending ISU programs, such as SSP or MSS. In this case problems could be given as a projects and the ideas and solutions worked out could be carried on as new ventures. New student ideas could be incorporated.

Key Partners	Key Activities	Value Proposition	ns	Customer Relationships	Customer Segments
- PPP - Universities, ISU, SU, XPRIZE - AMES (NASA) - SETI - Hollywood - Smithsonian - JPL - Pisces - SpaceX - Blue Origin - Tourism industry - Space angels	Analog mission design     Standards design     Funding research     Creative strategies     Community building     Infrastructure design     Events management     Experience and service design     Educational research     Key Resources     Real estate     Unique places     Ski camps     Facilities     Space architecture     Staff     Network     Board and advisory committee     Grassroots creativity	Collaborative sp communities pro transformational human enchantm endeavours like : - Transformation - Insight - Overview effect - Unique places - Network Facilities: - Space village o - Desert, underw extreme environn - Space educatic research, and tes	ace analogue viding experiences for ent and space space tourism. al experience t r campus ater, and ments n, recreation, sting facilities	ISU generated standards     Crowdfunded/sourced     customization     Community connection     Collaborative economy     ISU, MoonBnB, and user generated content     Aspirational marketing     Awareness     Channels     On site (on the field)     Permanent or temporary analog bases     University, Pre-schools, Events     Online (Edutainment)	B2B (space industry, public or private) - Corporate (Exec/Mgt) - Educational sector - Startups - Communities B2C (space tourism) - "Rocket set" Ex: network, cruise ship, etc
Cost Structure		Revenue Streams			
- Insurance - Real estate - IP - Legal fees - R&D - Design - Manufacturing		<ul> <li>Public sources (space agencies)</li> <li>Private (sponsorships and philanthropy)</li> <li>Self-generated (auto-finance): Facilities lease, Sci-Fi literature subscription, renting out silos, MoonBnB commission (similar to AirBnB), testing rates, experiential missions</li> <li>Space angels</li> </ul>			

Figure 4 - The business model canvas of MoonBnB.

ISU's business incubator can help with customer relations, spreading the stories of the companies, engaging the public, and the community of space enthusiasts. That way, ISU's network will probably become customers of the space startups, and will help with the outreach and marketing strategy.

Key activities can also be supported by the organization, including infrastructure, product design, and a network of beta testers. Mentorship is a core resource that the incubator will provide.

Since ISU has a focus on networking, this will be translated into partners and investors for the incubator.

# **APPENDIX C**

## Creative letter from a visioning exercise

Dear ISU,

Since I am you and you are me, I am sure it is as equally surreal for you to read a letter from your future self as it is for me to write one to my younger self. At times I find it hard to remember what I was like a quarter of a century ago. I was only 28 years old and in the middle of an existential crisis. I find it even harder to picture the harsh world of those days. It all seems so faint and far away. In some way we needed that world, though. I needed that world. As a means to picture a better one, like the current one.

If I could only send you a video of 2040, you would not believe your eyes. A shift in mindset together with revolutionary technologies have fundamentally altered the world. The realization that we all depend on each other and depend on nature to survive as a species has led to a new economy where the preservation of ecosystems and social capital are the cornerstones of our most essential virtues. The phenomenal rate of technological advance has enabled the full restoration of our damaged ecosystems. Practically free energy, in combination with global internet usage, and technologies such as 3D-printers and robots have allowed people to become much more independent. They are no longer subject to market forces and central governments, as they can mostly provide for themselves. With solar-powered 3D-printers, people have even managed to build houses in the middle of the Sahara. The third industrial revolution has turned consumers back into producers by giving them the opportunity to design their own products, often virtually with people from all over the world, and produce them autonomously.

This increased autonomy has also led to an increased independency from national governments, making them increasingly obsolete. This is due to both to new technologies and an increased general skepticism towards the outdated centralized democratic system inherited from the 20th century. People of poorer nations never felt comfortable in the nation-state system that was an ultimate result of colonialism. City-states arose all across the globe, offering considerable advances on a global level. Because there are so many of them, no single one has the illusion of possessing enough power to subjugate the others. This forces city-states to work together on urgent global issues more than nation-states ever could. The world of 2040 is also much more balanced and just. Poorer parts of the world have had the opportunity to catch up in terms of development.

Although you are undoubtedly delighted to hear about how your preferred future has turned into reality, I am sure you will be even more thrilled to hear that you have had an important role in it. Indeed, it was you who spread the message that everything is connected. You showed that we only need one profound look from above to understand what matters most in life. You imagined my world and helped make it come true. You joined forces with people who shared your cosmopolitanism and together you reached out to all parts of the world. You inspired people through education to better their lives by setting up social businesses that connected all spin-ins and spin-off of the space sector. Your research on closed-loop life support systems through analogue missions, for example, has not only contributed to us becoming a multi-planetary species but has also significantly enriched our understanding of Mother Nature. This has improved our ability to restore ecosystems. Everything is connected. Your moral authority has

encouraged the exploitation of Outer Space resources to reduce the human load on our environment and to enable settlements in outer space.

Perhaps the most exciting development you have been a part of is the Brainet. You inspired startups and big thinkers to dream of technologies that were thought of as impossible, and you gave them the tools they needed to create them. By connecting our brains, you showed we can unite our forces and become a super-brain to literally become interconnected. It only took people with our mindset, like our alumni, to think and solve many world and space problems together. That was what we wanted and we actively pursued this dream. It not only transformed us into a hub of space activities, but also into a hub of thought.

We hope this letter encourages you to hold on to your sense of imagination. We know that dreaming is not an easy task when you are faced with realism, but as you have just read, the world will change as it always has. So it is up to you to make it change for the better by slowly transforming your world into mine.

Yours truly, ISU







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LOCKHEED MARTIN



