INTERNATIONAL® SPACE UNIVERSITY

ANNUAL REPORT

Academic Year 2021-2022

International Space University

Back in 1987, three visionary university students had the inspiration for “an institution dedicated to international affiliations, collaboration, and open, scholarly pursuits related to outer space exploration and development. The International Space University (ISU) is a place where students and faculty from all backgrounds are welcomed; where diversity of culture, philosophy, lifestyle, training and opinion are honored and nurtured.” Today, ISU is a success story with 5400 alumni shaping the international space ecosystem in 110 countries. Within two years of graduation, over 80% of these alumni have found employment in academia, space agencies or industry.

ISU offers exciting programs for international postgraduate students and professionals, including the Master of Space Studies, the Space Studies Program, the Southern Hemisphere Space Studies Program as well as Executive Space Courses for upskilling and reskilling the future space workforce.

Since 2020, ISU has launched new online education with highly interactive and live programs with online mentorship and coaching. Most ISU programs can be delivered online in synchronous mode and still provide participants with the interactivity and professional networking for which the ISU is known for. ISU also fosters entrepreneurship and supports start-ups in its dedicated in-house incubator, accelerating the bridge between space and commerce. The space sector is increasingly integrated with global economic sectors. Space is key for a better understanding of our planet Earth, climate change, and for supporting the world’s overall socio-economic development in the years to come. The evolving space economy with new and emerging space countries, is developing a vibrant commercial and public space sector, with new unprecedented entrepreneurial leadership and private investment, offering ISU students and professionals exciting future perspectives.

In November 2021, ISU created the Space policy and entrepreneurship laboratory (SPEL) to cooperate with partners worldwide on space policy research and to support ISU’s in-house incubator.

Since January 2022, ISU is part of the Orbital Reef University Advisory Council and the only European university member. This status will offer possibilities for interesting projects and funding calls with multiple partners worldwide.

Contact Info:

1 rue Jean-Dominique Cassini

Parc d’Innovation

67400 Illkirch-Graffenstaden, France

info@isunet.edu

Phone: +33-3-88-65-54-30

Fax: +33-3-88-65-54-47

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1. Introduction

In 2022 the International Space University celebrated its 35th anniversary. With the arrival of New Space, new business models and partnerships between academia, research organizations and industry are emerging and ISU has been strengthening many cooperations in the last year.

Never have there been more space missions in the planning, or commercial companies, and emerging and developing space nations engaged in space ventures than today. The evolving space economy offers students and professionals of the International Space University (ISU) exciting future perspectives.

September 2021 saw the start of the Master of Space Studies (MSS) program returning to full in person classes by respecting COVID-19 measures that changed frequently during the year.

October saw the first edition of an Executive Space Course (ESC) in Tel Aviv.

November marked the start of the curriculum planning for SSP22.

In December, the second edition of the tailored Executive Space Course for Eumetsat employees, took place virtually.

January 2022 saw the start of the 11th edition of our five-week Southern Hemisphere Space Studies Program (SHSSP), a long-standing partnership with the University of South Australia. For the second time, the SHSSP was held fully online, and in two time zones: as in 2020 a very challenging experience for the 34 participants from 11 countries and for staff and faculty alike.

The Committee for Maintaining a Safe and Respectful Work and Learning Environment at ISU, chaired by Prof. Su-Yin Tan, which advises the ISU President, was created.

February had several milestones:

- The third ISU Adelaide Conference gathered around 900 attendees, mostly from the Asia- Pacific region. It took place during the SHSSP, from 3 to 4 February 2022. This professional conference was offered on-line free of charge and was fully organized by ISU alumni.
- The Discover ISU event was organized as a series of interactive presentations in three time zones allowing numerous prospective students to learn about ISU's offering,s in the absence of in-person opportunities.
- The faculty delivered key documents to continue the process toward the accreditation of the MSS program.
- The ISU Board of Trustees selected the proposal from the Brazilian team to host the SSP23 program.
- ISU Strategy 2025 was completed. The implementation will follow 7 goals:
    1. Global ISU Brand and International Outreach
    2. Master's Program Accreditation and Redesign
    3. Academic Strategy
    4. Best Behavior Practices
    5. Endowment Fund
    6. Entrepreneurship
    7. Optimize ISU Operation and Administration
- The resident faculty has summarized the current research activities in a Research Roadmap as a living document to secure research funding through acquisition of external grants.

March was a busy month for the MSS22 students during which they worked on the Team Projects and took exams.

April ESC Strasbourg took place in-person again after two years of online activity. The 12th April ISU, MSS22 students and the community celebrated ISU's 35th anniversary!

May The third edition of the Space Resources Professional Course was organized in person in Luxemburg, in collaboration with the Luxembourg Space Agency and the Colorado School of Mines. In May Mr. Goktug Karacalioglu followed Mr. Kenol Jules as SSP22 Director in Portugal. Also in May, we said goodbye to the MSS22 students who concluded their classes and departed to their in-person or virtual internships in companies, universities or space agencies.

On Friday 3rd of **June**, no just one but two classes - MSS20 and MSS21 - graduated with a Master of Space Studies diploma. The in-person celebrations included an official ceremony attended also by many friends and families.

At the end of June, the SSP hosted by Portugal Space and the Instituto Superior Tecnico (IST) Taguspark Campus in Oeiras, Portugal started in hybrid format with 107 participants.

July During the last weekend in July, over 150 alumni and other space professionals including heads of space agencies and astronauts, engaged in the online ISU Alumni Conference.

August saw the conclusion of SSP22 with interesting presentations of five Team Project reports. At the end of the month and as we are writing these lines, we begin to see the arrival of the new class of MSS23 representing 20 nationalities from four continents and a variety of backgrounds, making up for a promising class of 39 students.

Join us in wishing to ISU a successful and safe 2022-2023 academic year for its 36th year of ISU programs.

2. Summary and Key Figures

2.1 Participants in the ISU Programs

Program	Location	#Participants
Master of Space Studies Year A (MSS22-A)	**Central Campus**	**43**
Master of Space Studies Year B (MSS22-B)	**Central Campus**	**2**
Space Studies Program (SSP22)	**Oeiras, Portugal**	**107**
Southern Hemisphere Space Studies Program (SHSSP22)	**Online**	**35**
Space Resources Professional Course (SRPC)	**Luxembourg**	**38**
Executive Space Course 1 (ESC 1) Tel Aviv	**Tel Aviv, Israel**	**28**
Executive Space Course 2 (ESC 2) Eumetsat	**Online**	**16**
Executive Space Course 3 (ESC 3) Africa	**Online**	**26**
Executive Space Course 3 (ESC 4) Strasbourg	**Central Campus**	**17**

2.2 Employment statistics

In June 2022:

68% of the MSS21 alumni reported having a job, 5% of the MSS21 alumni reported continuing their studies and 27% reported being in another situation (such as working on a personal project, developing their own business or looking for employment).

2.3 Faculty

During the academic year 2021-2022, ISU counted:

- **78 Full Faculty** (see list in annex 1)
- **49 Adjunct Faculty** (see list in annex 1)
- **17 Associate Faculty** (see list in annex 1).

2.4 Alumni

After SSP22 and MSS22 graduation, ISU now counts **more than 5400 alumni** from 110 countries (see chapter 9 Alumni Affairs for more details).

3. Master of Space Studies - MSS22

3.1 Introduction

Due to the coronavirus pandemic, many participants of the MSS2020 and MS2021 cohort were not able to complete their mandatory internships and able to graduate. A significant number of both cohorts was still completing their internship during 2021/2022.

The class MSS22 started with in person classes, albeit under strict sanitary conditions. During the entire school year national restrictions on universities in France came into effect concerning COVID-19 testing and quarantine. However, universities in France stayed open the entire year.

The curriculum was affected due to many online lectures but never moved into fully remote teaching. By March 2022 all COVID-19 restrictions were lifted. The additional workload for the MSS team to both deliver the program and manage multiple student cohorts simultaneously over the last academic year has been very significant and has required considerable sacrifice.

Despite this, the team has responded in a highly committed and professional manner. The MSS 2020 and MSS2021 class celebrated their graduation ceremony in person on June 3, 2022.

3.2 MSS22 Cohort

Fig. 1: MSS22 class picture

Focusing now on the specifics of the Master of Space Studies (MSS) program 2022 (MSS22), Year A (MSS22A) counted 43 students from 20 countries with gender equality.

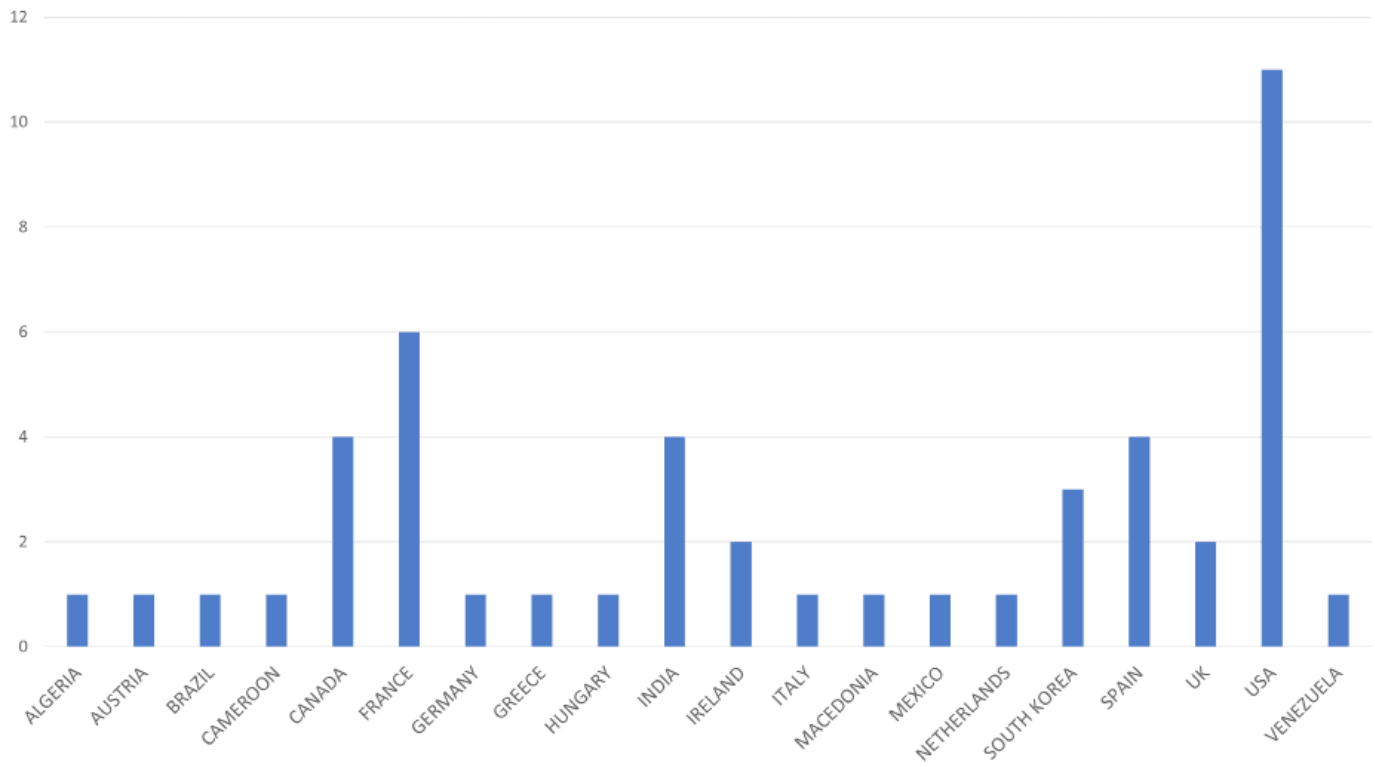


Fig. 2: Distribution of MSS22 participants per country including dual citizenships

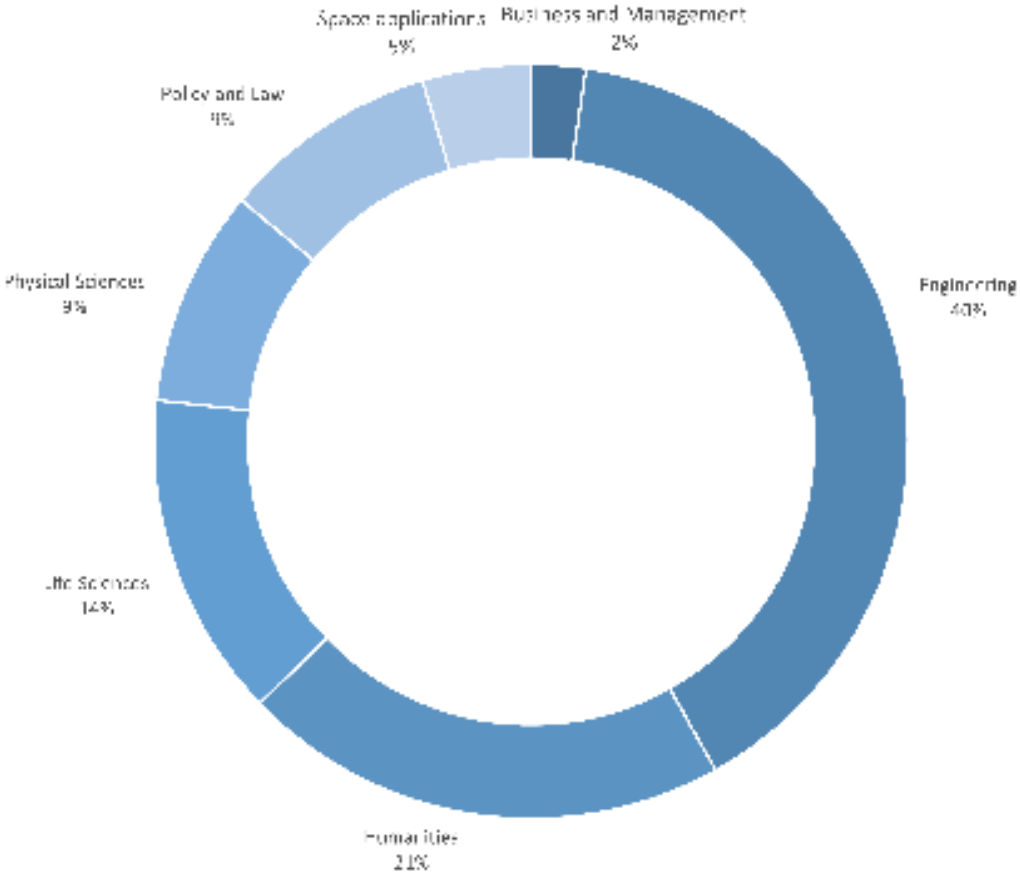


Fig. 3: Educational background of MSS22 participants

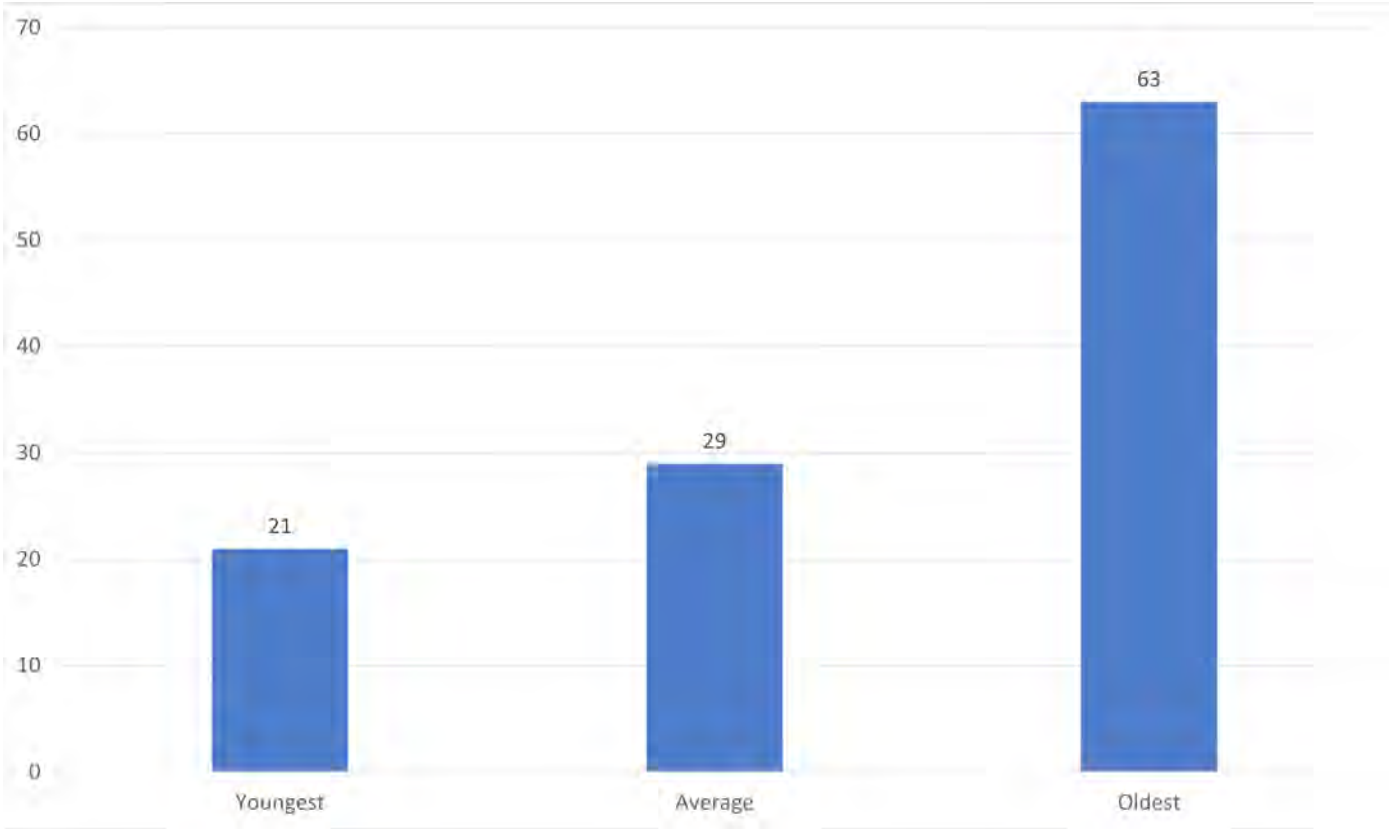


Fig. 4: Age Distribution of MSS22 participants

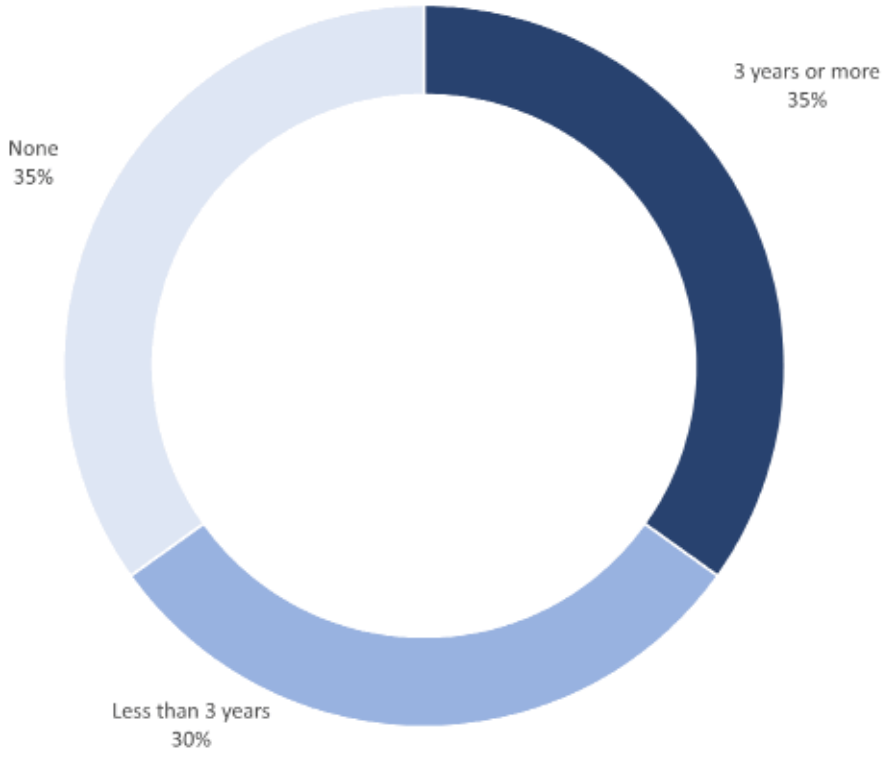


Fig. 5: Distribution of previous experience in MSS22

3.3 MSS22 Structure

Fig. 6: structure of MSS22A

For MSS22A, the electives were:

- M10-ABL Astrobiology
- M13-NSE New Space and Entrepreneurship
- M14-ARC Space Architecture
- M7-SPh Space Pharmacology

3.4 MSS22 Activities

The following professional visits were organized:

- SES Online professinal visit
- Aerial
- Astronomical Cathedral Clock
- Ries Crater Visit

Other activities included:

- Poster competition
- Space Architecture and Design Zero Gravity workshop
- Space Architecture Workshop - Habitability-SHEE Space Architecture

Fig. 7: Professional visit at the Ries Crater, Germany

After a two-year break, the MSS class could return to the Ries impact crater located in Nördlingen in Bavaria. The trip took place at the end of the M2, right after the lecture dedicated to asteroid impacts by Dr. Anna Losiak, so that the students had the required background to make the most of the visit. This year the visit also was the first trip out of campus after the winter and it clearly benefited the students (and joining faculty) in terms of bonding. Prof. Stefan Hölzl, director of the Ries Krater Museum and professor at LMU München, organized a tour of the interesting outdoor sites and guided us through his museum, feeding us with passion his extensive knowledge of the event and the physics.

Early September was associated with the MSS Tolyarenko Rocket Launch Competition. The monumental event honors our legendary colleague, Professor Nikolai Tolyarenko (1941-2015). Six MSS 2022 teams with the consultation of MSS 2015 alumnus, Dr. Adrian Eilingsfeld, designed, constructed and launched miniature rockets with almost impossible guidelines... Each rocket must have a quail's egg onboard, which must be returned unbroken. Each team must return working accelerometers and video cameras. Finally, each rocket was instructed not to exceed an altitude of 100 meters. Despite these impossible constraints, our students rose to the challenge and all rockets were successfully launched and recovered. Surely, a fine tribute to Professor Tolyarenko, a brilliant and inspiring teacher and mentor !

Early, dark January was a challenging time for MSS students with COVID-19 restrictions as they returned to Central Campus after a restful and joyous break. Fortunately, the annual Lego Robotics Competition was offered as an academic and inspiring tonic ! In early January, 2022, and with the characteristic support of Professor Yoshida of Tohoku University, our students designed, built and tested original, and robust robots. The objective was to collect 'gems' on the (virtual) surface of Mars within a competition field, while avoiding as many rocky obstacles as possible. Brilliant robots were forthcoming and the competition, on the day, was spirited. The cheering teams collected hundreds of 'gems' and Professor Yoshida was on Zoom for support and technical analysis. A joyous afternoon and a greatly inspirational experience for all !

This spring, NASA Astronaut and physician Serena Auñón-Chancellor gave a fascinating lecture on Medication Needs During Spaceflight Missions. She described in detail an accidental finding during a routine biomedical experiment, as well as its potential implications for that individual and future astronauts. Although the talk was a part of Dr. Wotring's Spaceflight Pharmacology Elective, it was enjoyed by the entire MSS22, who eagerly engaged with a wealth of questions about medical treatments in use now or being considered for exploration missions.

Fig. 8: Astronaut talk with Serena Maria Auñón-Chancellor, organized by ISU resident faculty prof. Wotring

Fig. 9: Part of the MSS22 Poster Competition outcome

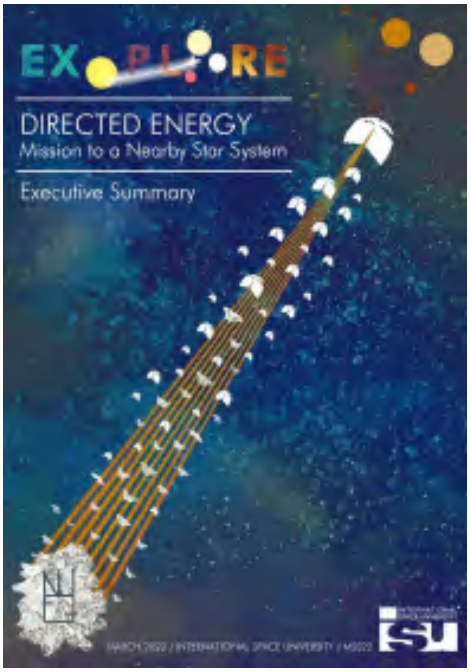
3.5 MSS22A Individual Projects

MSS22A carried out individual projects supervised by central campus faculty, some with the involvement of external advisors. The following individual project prizes were awarded:

- **Association of Space Explorers Europe Prize** - awarded to the student for the best Individual Project related to Human Space Flight: *Oriol Milian Adriazola - Design of mobile tablet-Smartphone lens for space application*
- **Hypatia Prize** - awarded to the student with the best Individual Project bridging Conceptual Research with Technology Design and Implementation in Space: *Martina Dimoska - 3D solar printer improvements and capability comparison with other additive manufacturing technologies*
- **Icarus Prize** - awarded to the student with the best Individual Project related to commercial space activities including business, financial or investment strategy: *Samy Nicolas Bouchalat- New LEO constellations as a paradigm shift for Media content services*
- **Manx Precision Optics Prize** - awarded to the student with the highest grade in their Individual Project: *Julie Lespagnol - Surface rover as lunar logistic element to define innovative concepts for lunar mobility systems*

3.6 MSS22A Team Projects

The MSS22A cohort carried out two team projects:



EX.PL.RE. A directed energy mission to a nearby star system

The team of 16, with special support from the Breakthrough Initiatives, addressed the issue of interstellar travel to the Alpha Centauri star system, our neighboring solar system. The technology they focused on was Directed Energy whereby a laser array is utilized to propel a swarm of miniaturized, gram-scaled, spacecraft into the interstellar medium at 20% the speed of light. The vast journey of some 40 trillion kilometers would take approximately 20 years. On route, the scientific payload on the light sails would collect pioneering data and, upon arrival at the Alpha Centauri system, would continue its scientific mission to provide humanity with a glimpse of what may await us in space. The miniaturization of the scientific payloads, the advancements in material science for the development of space-worthy structures, along with incorporating efficient radioisotope thermal generators and autonomous operation systems, would facilitate the success of this interstellar mission. An assessment of the Alpha Centauri system was also conducted as the swarm of spacecraft reaches its destination, and a better understanding of the exoplanets in that system would be facilitated. For example, can we locate another habitable planet for humanity in another solar system using the ancient methods of travel and exploration, a sail and some wind ? Such exploration would mark a new era of investigation and adventure. As usual, the students addressed the project from many different angles. In addition to the technical and scientific aspects, they proposed original solutions in terms of management and funding of the very long-term, costly project, and creative outreach activities to raise the interest of sponsors and the public alike.

STELA. Starship: impact on the SatCom industry

Starship is the SpaceX reusable launch vehicle and the world's most powerful rocket under development. It is hoped that the SpaceX flagship launcher: Starship, would not only disrupt it's intended plan for deep space exploration but will have an unintended splash over effect on all areas of the space sector especially the ever-expanding satellite telecommunication (Satcom) industry. It is expected to cause a significant impact in the following areas: reductions in launch costs, possibility of higher payload masses to orbit, provision of a larger payload fairing, and availability of frequent launches. Starship is expected to redefine all the four areas simultaneously unlike previous rockets.

The team project was supported by the Telecommunications and Integrated Applications (TIA) directorate of the European Space Agency (ESA) and executed by multidisciplinary team of 19 graduate students from 16 countries. The final report of the team project and other deliverables presented a critical analysis of the state-of-the-art of current launchers and a forward-looking perspective on the impact of Starship on satellite communication industry from the number, and capability of future satellites to be launched up to the innovative downstream applications with a focus on SatCom industry players, space agencies, and regulators to assess future initiatives.

3.7 MSS Internships

The internship dynamic was back to pre-COVID-19 times, with host institutions proposing as many internship opportunities as before the pandemic, taking place mostly onsite. Some host institutions still propose remote or hybrid internships. A great majority of MSS22 students favored onsite internships.

64% of the MSS22 Internships took place in a private company, 21% in a Space Agency and 15% in a university or research institution. 82% of them took place in Europe, 9% in Asia and 9% in North America.

A majority of the class is carrying out a long internship (between three and six months) and will graduate in December 2022. Only a few students carry out a short internship (three months) and will graduate in September 2022. Host institutions tend to propose long internships; this tendency had already been observed before COVID-19.

Fig. 10: two MSS22 students interning at Leanspace

3.8 MSS Accreditation

The completion of the international accreditation process for the Master's Program by the Accreditation Agency for Study Programmes in Engineering, Informatics, Natural Sciences and Mathematics (ASIIN) is an important step for the recognition of ISU.

Following the decision of the ISU Board of Trustees to embark on a process of accreditation of the Master's Program, the ISU resident faculty and staff prepared a Self-Assessment Report on the MSS 2021, consulted with the ISU Academic Council, and submitted the report to ASIIN in April 2021.

The evaluation report from ASIIN, received end September 2021, requested a redesign of the MSS program that complies with European Standards and Guidelines and has to achieve Level 7 of the European Qualifications Framework (EQF7).

Under the supervision of the Dean, the Resident Faculty, the Academic Council, and external experts, the MSS has been redesigned and is currently in evaluation.

Within the restructured Master's Program that will be divided into three semesters (18 months), it will be possible to have specialized disciplinary pathways. The overall pattern for a longer three-semester program with each semester acquiring 30 ECTS, will use 28-study hours/ECTS as the basis for the program design. The first semester will focus on bringing all students up to a similar level of interdisciplinary space knowledge.

The redesigned Master's Program will provide multiple pathways depending on the prior knowledge of the students, and will provide in-depth education in three tracks for students and professionals. Also, a 30-ECTS Master's thesis will comply with the required EQF level 7.

4. Space Studies Program (SSP22)

This year's Space Studies Program of the International Space University (SSP22) brought together 107 participants representing 37 nationalities and bringing a variety of backgrounds in science, engineering, humanities, and social sciences.

The SSP22 had a hybrid format, accommodating both, on-site and online participants.

The 9-week residential SSP22 (on-site program) took place in Oeiras, Portugal, from 27 June to 26 August 2022. This was the first SSP program after the COVID-19 pandemic, gathering all the participants, staff, and lectures in one site. The online part of the SSP22 program, took place from 27 June to 5 August 2022.

The content was delivered by around 202 instructors, many of them from the ISU Global Faculty, under the academic leadership of a team of 32 Faculty Chairs, including 21 Professional Visit Hosts, and 50 staff plus volunteers, resulting in about 415 persons involved in total.

Fig. 11: SSP22 participants

Fig. 12: Mission patch designed by SSP22 participants

4.1 SSP22 Participants

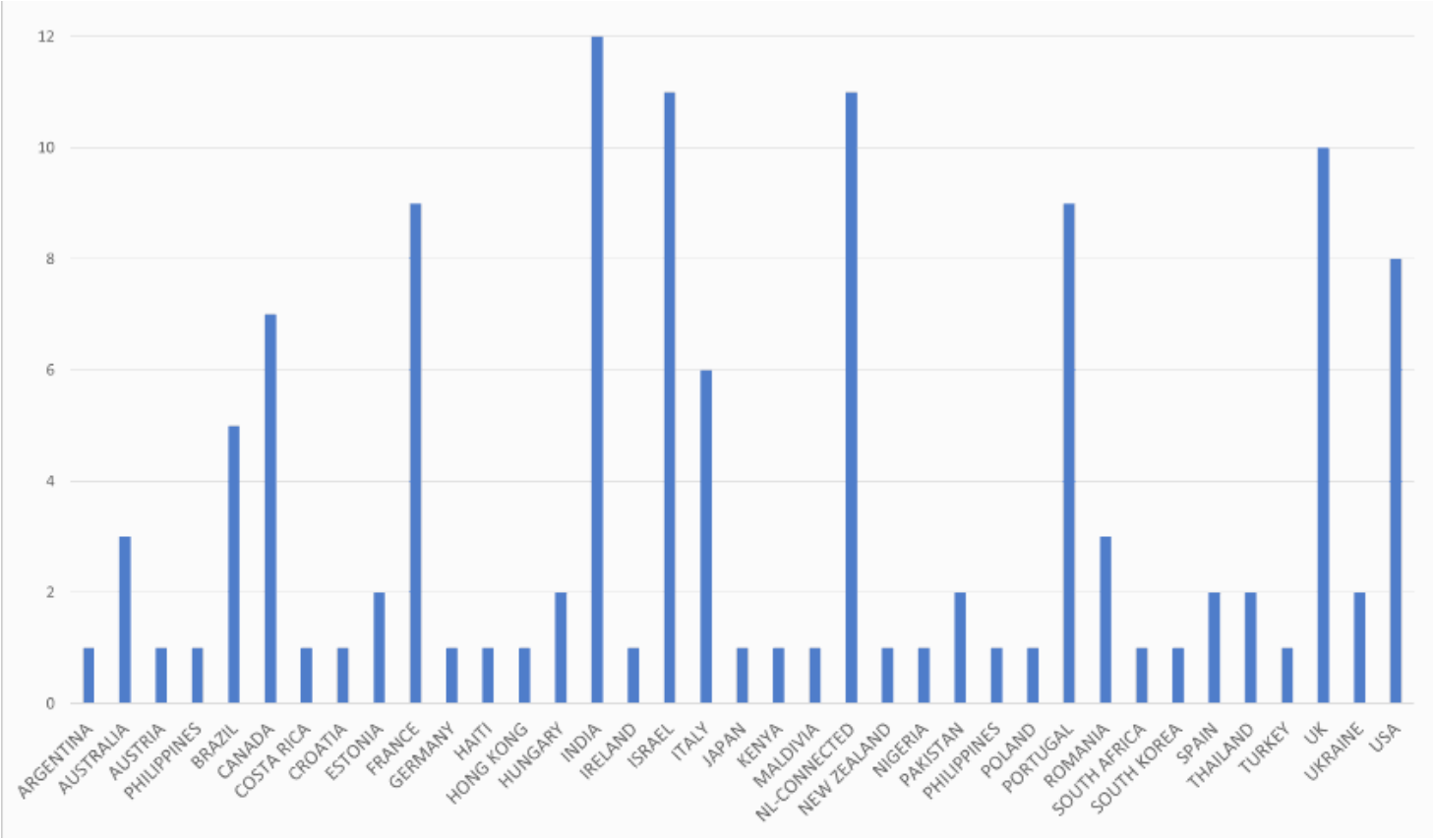


Fig. 13: number of SSP22 participants by nationality

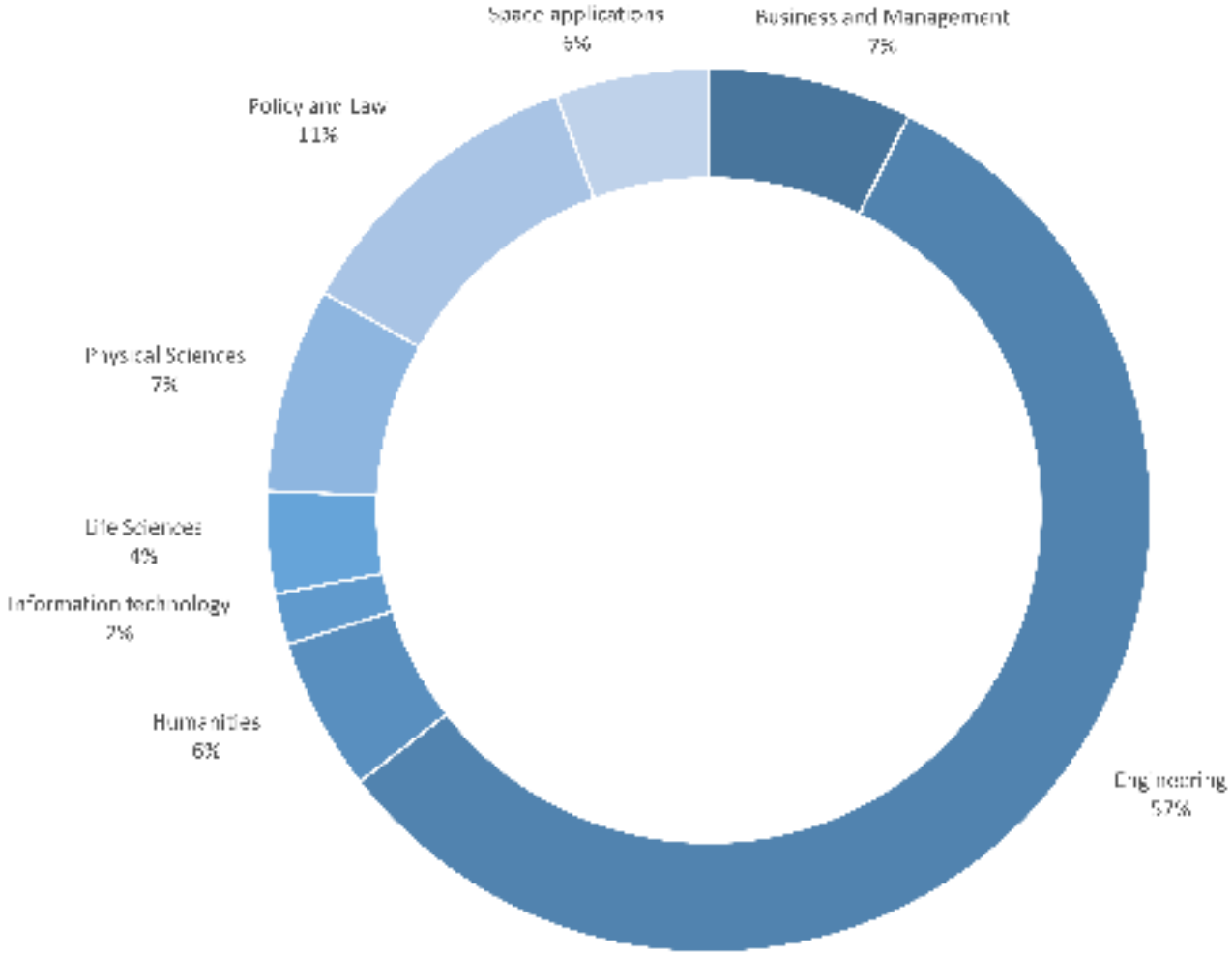


Fig. 14: Educational background of SSP22 participants

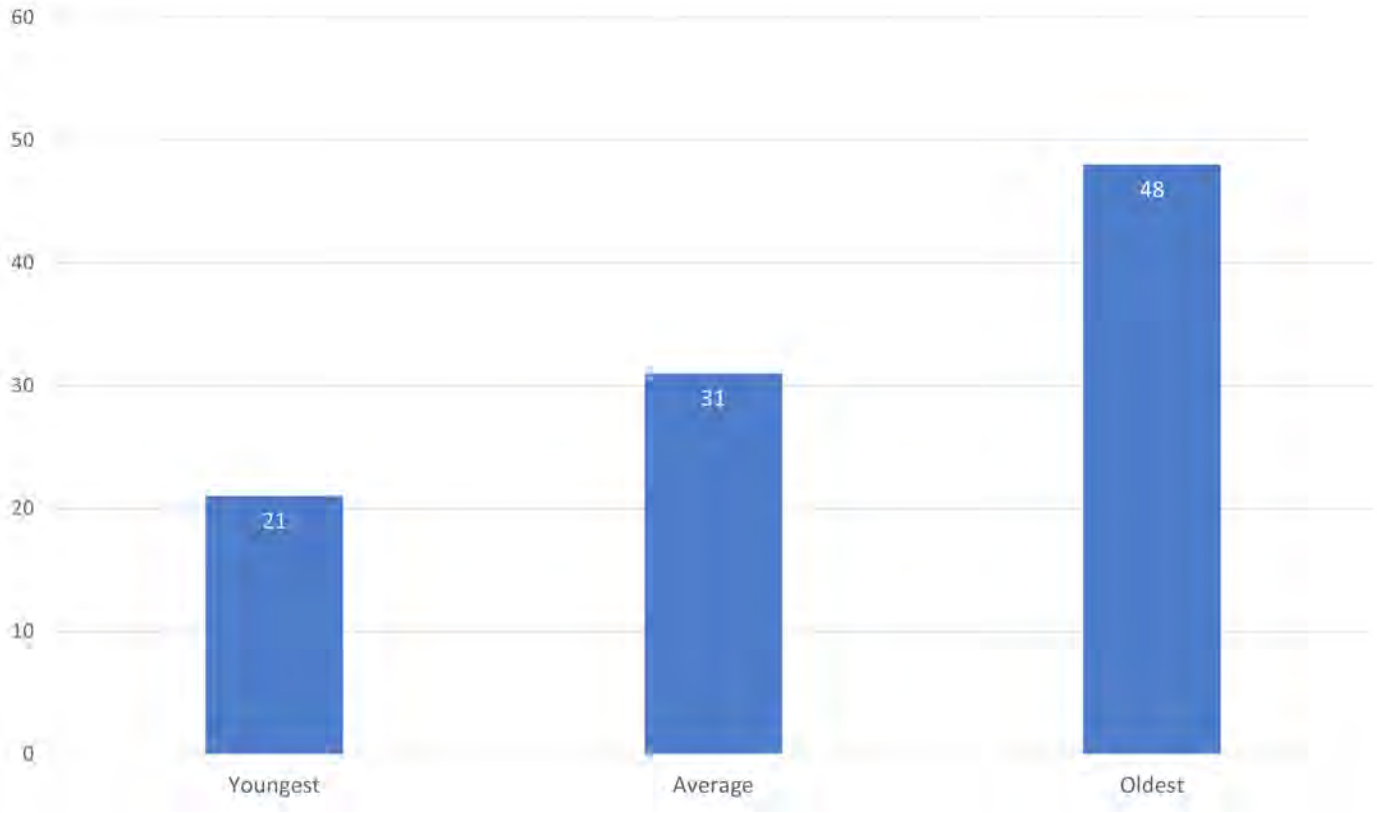


Fig. 15: Age Distribution of SSP22 participants

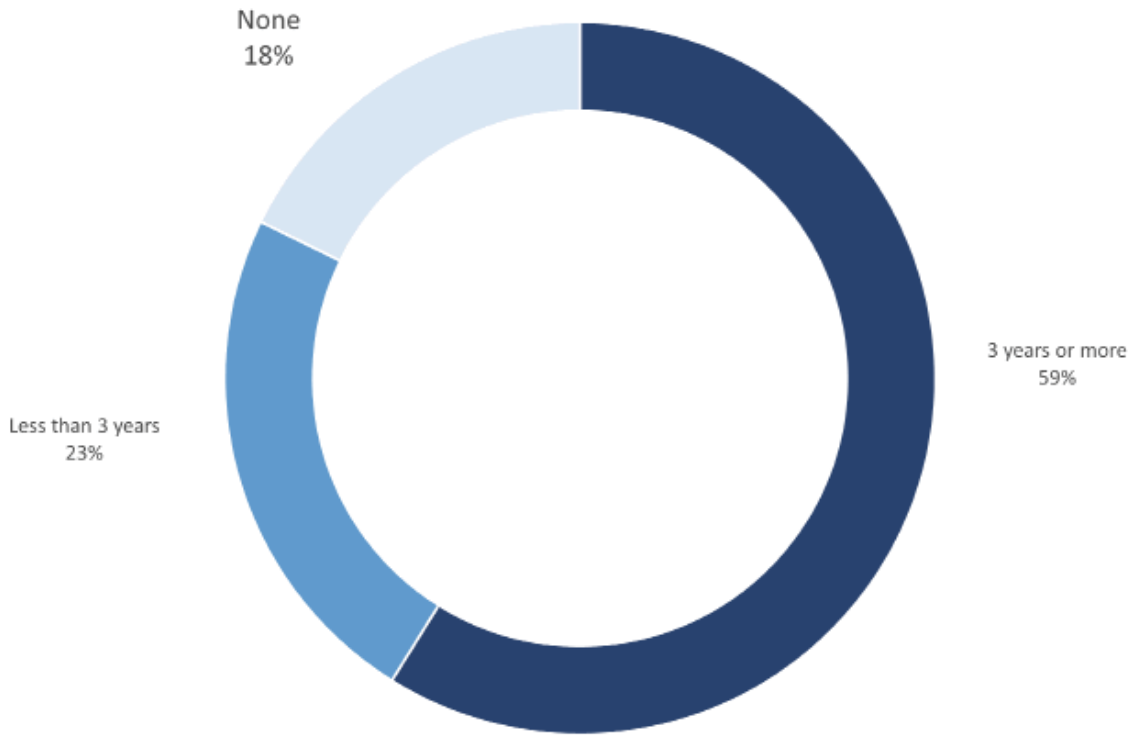


Fig. 16: SSP22 participants professional experience

4.2 SSP22 Program content

The SSP22 onsite curriculum offered the following components:

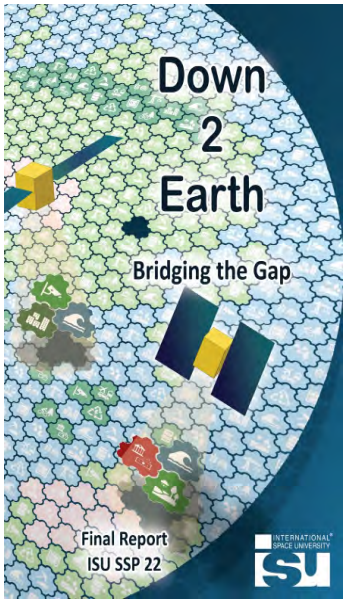
- Over 45 core seminars on all Space-related disciplines
- Over 40 hands-on workshops
- 12 half-day sessions offered by each of the 7 Departments: Sciences (SCI); Engineering (ENG); Human Performance in Space (HPS); Humanities (HUM); Management and Business (MGB); Policy, Economics and Law (PEL); and Satellite Applications (APP)
- 5 Team Projects presented in more detail in the next section
- Professional visits to Space-related Research facilities and companies in Portugal, including indoor & outdoor activities in cities like: Coimbra, Évora, Lisbon, Porto and Sintra.
- More than 15 distinguished lectures and fireside chats with prominent speakers from Academia, Government and Industry, including Astronauts
- A 48 hours non stop online Alumni Conference with 150 registered participants.

In total at SSP22, including the Core Seminar Series, Workshops, Team Projects, Department Activities, and the Distinguished Lectures, there were 318 hours of Academic Teaching.

Fig. 17: SSP22 onsite program structure

The SSP22 online curriculum offered 45 core seminars, 20 workshops, and over 70 hours of team project time, and 12 hours of mentorship.

4.3 SSP22 Team Projects



The SSP22 Team Projects tackled the following topics:

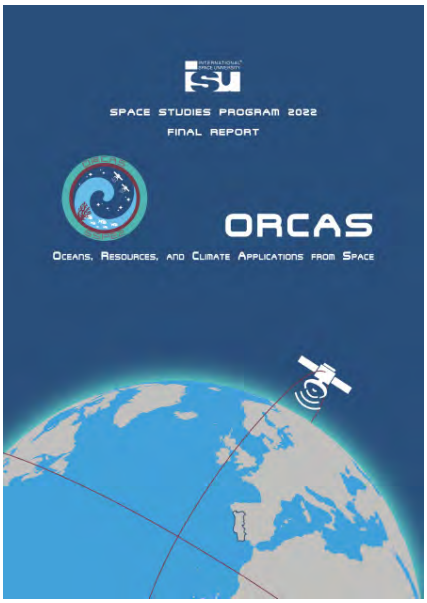
Team Project Down 2 Earth: bridging the gap *(Sponsored by AWS)*

Over the last few decades, the space sector has grown exponentially. In particular, the supply of space-based data has become much more prominent. Earth observation (EO), communications, and global navigation satellite systems (GNSS) are commercialized and provide valuable services for the global economy. Active satellites have grown nearly tenfold in the last 25 years, from 541 in 1996 to 4,887 in 2021 (Statista, 2021).
The team first assessed the space for non-space industry supply chain at a macroscopic scale, reviewing impactful gaps and future trends. Next, the team researched the space for non-space supply chain from a bottom-up perspective, analyzing the space-based services and data available, and the non-space downstream markets they serve.

Three markets were analyzed, and the satellite communications and GNSS markets are mature without significant gaps. However, there appear to be gaps in the remote sensing space for non-space supply chain. Satellite remote sensing does not have a space or non-space industry problem. Instead, it has a big data problem. Remote sensing satellites produce hundreds of terabytes daily, with hundreds of petabytes in storage. Building and maintaining pipelines that convert the data into user-friendly intelligence and value-creating solutions produce large overheads.

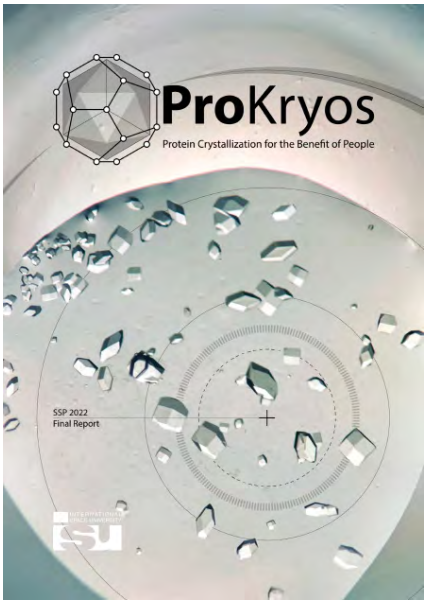
The team developed two business cases to address this gap, proposing solutions to reduce the overhead costs of turning data into intelligence valuable to non-space industrial clients. The business cases aim to reduce the technical and financial costs for non-space clients using remote sensing space-based solutions. They will enhance non-space industrial adoption of remote sensing space solutions upon success.

Team Project ORCAS: Oceans, Resources, and Climate Applications from Space *(Sponsored by AWS)*



In the last century, we, as a species, have become increasingly aware of how deeply interlinked our communities are with our oceans, climate, and planet. At the same time, we have become increasingly aware of the benefits of space based technology and space applications. Multiple international organizations have recognized that the deep interconnectivity in space-ocean-climate interactions allows for new and innovative solutions to our urgent climate crisis. One such group, the Atlantic International Research Centre (AIR Centre), was formed with the intent to promote an integrative approach to these topics in the Atlantic region. The AIR Centre is currently analyzing the feasibility of an 'Atlantic Constellation' of satellites in concert with multiple space agencies and other stakeholders in the Atlantic region, co-designed and developed to provide Earth observation data and address some of the critical topics and current needs in global and local coastal communities.

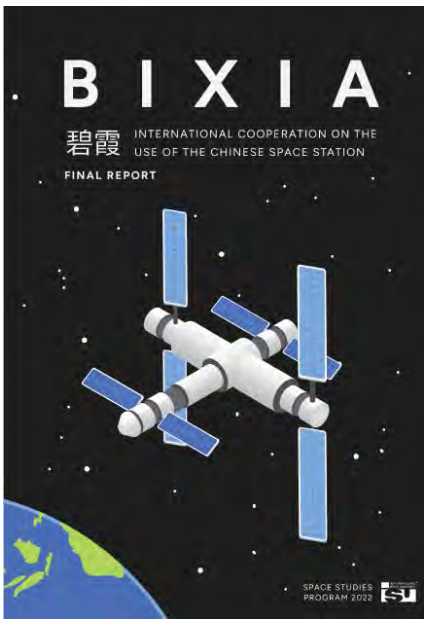
We here on the Oceans, Resources, and Climate Applications from Space (ORCAS) Team are providing additional research and analysis to support this and future platforms. In our report, we analyze the state of the art as well as the critical gaps and needs in five primary areas: maritime monitoring, ocean resource management, coastal hazard mitigation, data handling and sharing, and the governance and commercialization of marine observation systems. We then provide recommendations to stakeholders in the Atlantic Constellation project, both technological and programmatic, as steps that can be taken for this system or for other remote sensing systems in the future. We believe these recommendations would maximize the constellation's value for decision-makers and end-users if implemented. Throughout the report, we also emphasize that the interconnected nature of these topics is both a challenge and an opportunity. At the same time, numerous technical, societal, and economic hurdles exist to such an ambitious international platform. We believe that if those challenges are met correctly, this program and the AIR Centre's future efforts can provide a broad, powerful, positive impact on our communities, our oceans, and the planet they are all a part of.



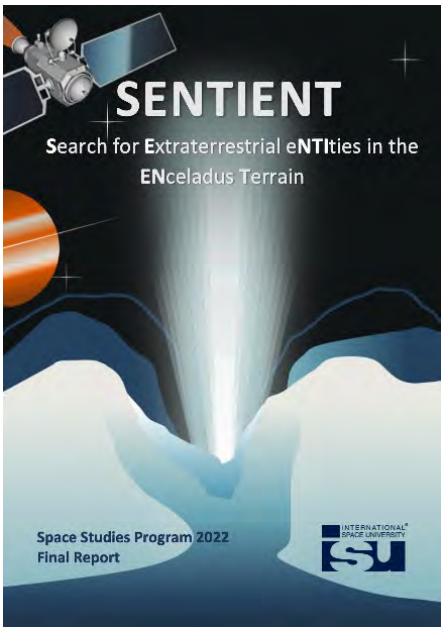
Team project Microgravity Business – Space R&D for the Benefit of Society

Our mission is to develop an orbital pharmaceutical factory, ProKryos-Panacea, with an initial focus on the mass production of crystalline protein drugs such as monoclonal antibodies (mAbs). Protein drugs can be used in the treatment of cancer, auto-immune diseases and other health related issues such a migraines and anaemia. The benefits of a microgravity environment for the production of protein crystals have been well documented. However, in the last ten years access to space has become cheaper and more readily available, making now the opportunity for such a business venture. This report investigates the current state of space pharmaceutical manufacturing, setting the scene for our business proposition. We then define a timeline of distinct phases required to make ProKryos-Panacea a reality, covering the scientific, engineering, business, and regulatory verticals to this grand aim. Our report culminates in a detailed description of our demonstrator mission, ProKryos-I, testing our novel hardware for the mass production of protein crystals suitable for pharmaceutical use. This report and the suggestions within it aim to unleash the potential of pharmaceutical manufacturing by paving a viable and life-changing pathway into space.

Team Project BIXIA International Cooperation on the Chinese Space Station *(Sponsored by Technology and Engineering Center for Space Utilization, Chinese Academy of Sciences (CSU,CAD))*



This mission aims to develop new technologies and methods which will support humanity in our common journey to the stars. The mission proposes to be the result of international cooperation, with the physical experiment graciously hosted aboard the new Chinese Space Station (CSS). Concurrently, BIXIA proposes an extensive outreach program, which seeks to educate and excite the world about this project.
The BIXIA mission statement is as follows:
To validate the use of supercritical fluids (SCF) aboard the CSS, to prepare for further development into ecological life support systems for use in long-term human space flight; using partners cooperating internationally, and sharing the research via a series of outreach programs.
Using SCF technology, this mission aims to produce new methods of sustainable plant growth in outer space. The wider goal is to integrate this technology into Controlled Ecological Life Support Systems (CELSS), to allow human outposts such as Lunar and Martian habitats to become self-sustainable. The initial payload will seek to validate the SCF and plant growth technologies, with a follow-up payload.



Team Project SENTIENT: Search for Extraterrestrial eNTIties in the ENceladus Terra : new methodologies in the search for life

Since the dawn of time, humans have been fascinated by the stars, wondering, what is out there?
Are we alone in the universe?
Science fiction has served astronomers, artists, novelists, and scientists alike, in pondering on this question, welcoming the uncertainty of what lies ahead in space exploration. Now, humanity's destiny beyond Earth is on the verge of a new phase of ground-breaking discoveries as we send robotic explorers on deep space exploration missions.
Our mission, SENTIENT, aims to further this quest and explore the possibility of life, past or present, on the icy Saturnian moon, Enceladus. The mission concept consists of a spacecraft composed of an orbiter and lander. The orbiter will contain remote sensing instruments to determine an optimal landing zone near the Tiger Stripes around the south pole.

The probe will then collect samples and data from the surrounding ice and atmosphere and transmit it to the orbiter, to relay it in turn back to Earth for further analysis for potential bio-signatures.
What if we do find life out there? This would in turn raise many other questions from the point of view of science, law, policy, and humanities. Apart from excitement, such an event is anticipated to incite mixed reactions from the public, including ethical concerns around interactions with newly found organisms. Apart from a whole new dimension opened to the scientific community, novel studies would need to be conducted on human behavioral change, new laws and policies would have to be developed, and fresh welfare policies across the globe implemented.
The SENTIENT mission aims to create a bridge to this new world of possibilities, where, finally, we are not alone in our universe. Since that first glimpse of the universe that the Hubble Space Telescope presented the world, the power of ingenuity would have moved us yet another step closer to the stars and beyond.

5. Southern Hemisphere Space Studies Program - SHSSP22

The twelfth Southern Hemisphere Space Studies Program was conducted online from 17 January to 18 February, 2022, in partnership with the University of South Australia (UniSA). Again this year, the program was delivered in two time zones: Asia Pacific and Europe, with some components delivered in each time zone separately, and daily sessions that brought together the entire class, especially for the Team Project (TP) work.

The five-week program was modelled on and designed to complement the Northern Hemisphere SSP each year during the Southern Hemisphere summer. It attracted a diversity of students at various levels of experience from both the Southern and Northern Hemispheres. The SHSSP22 cohort had 34 participants from 11 countries.

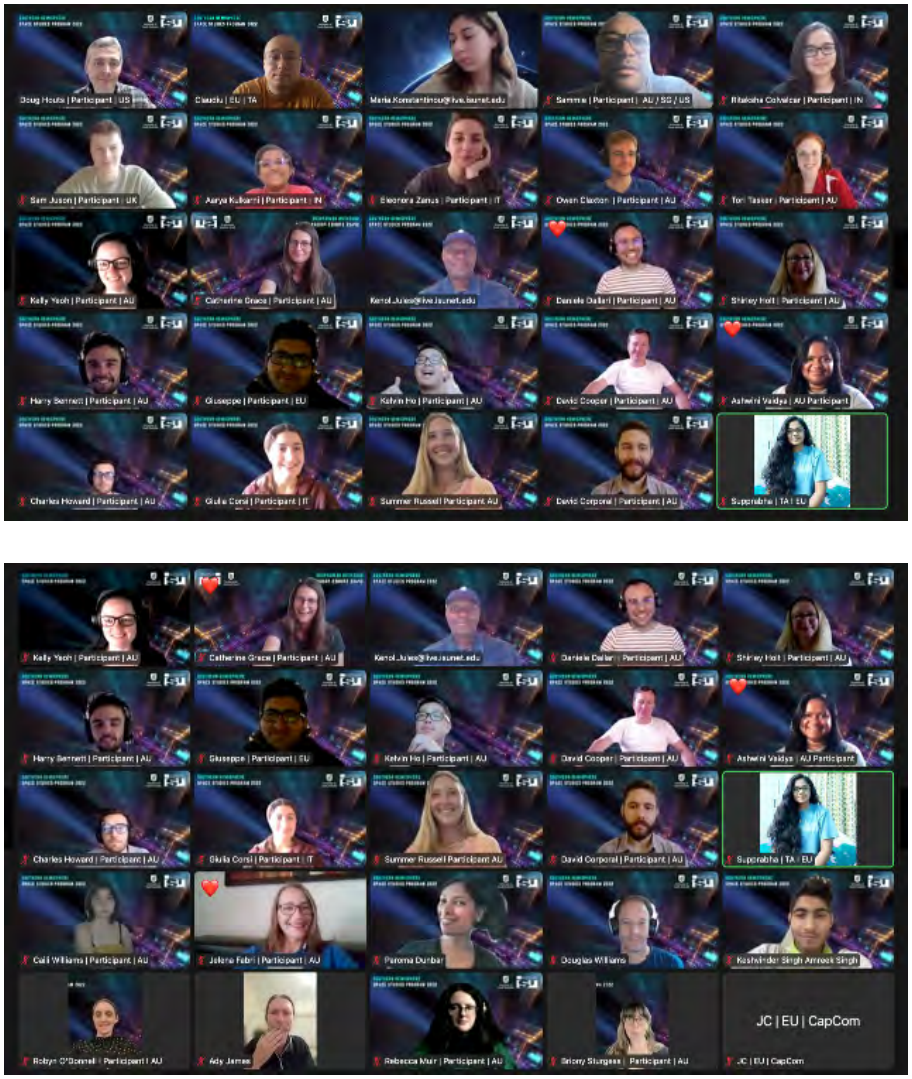


Fig. 18: SHSSP22 participants

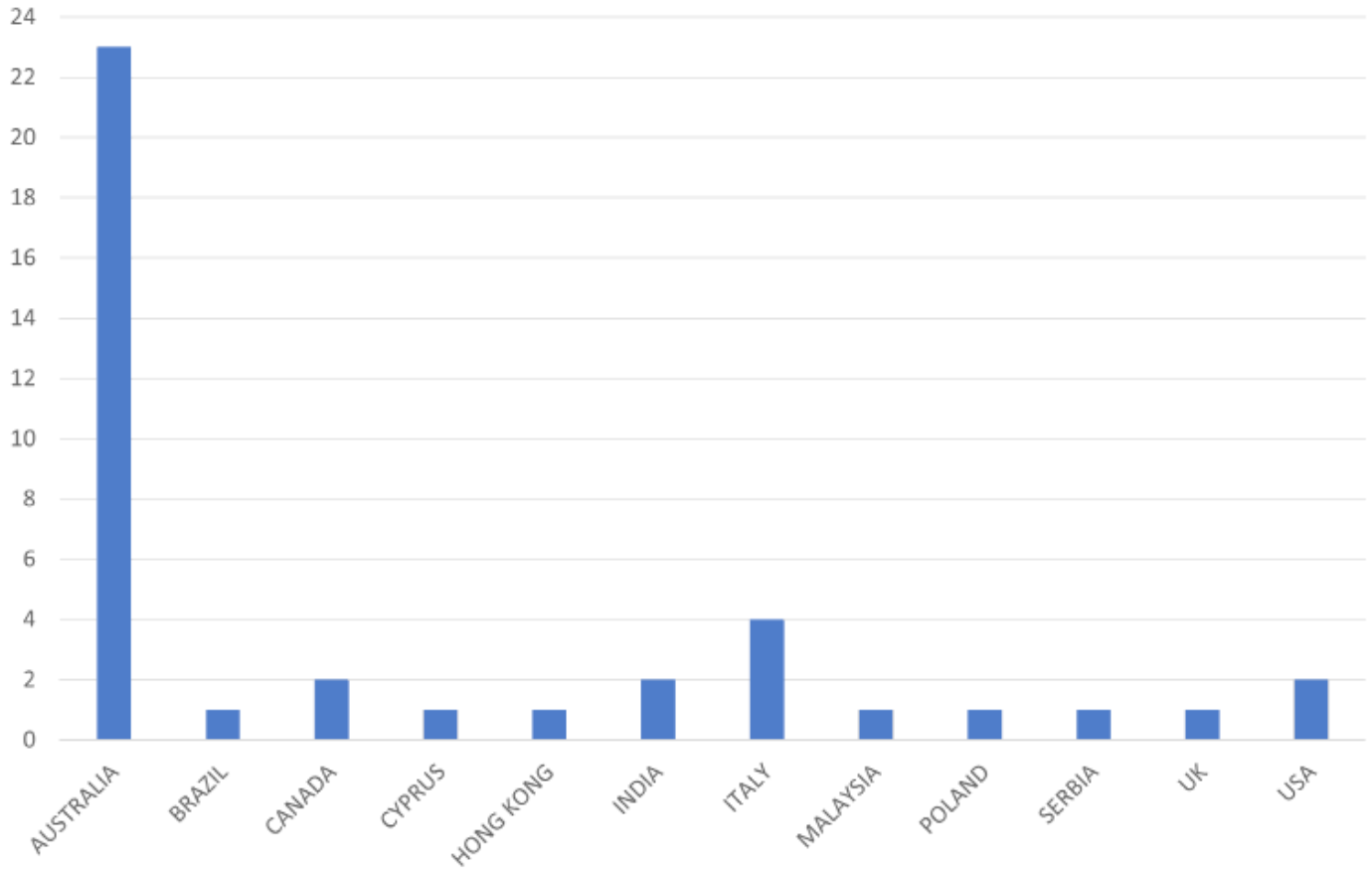


Fig. 19: Distribution of SHSSP22 participants by country

The distribution of educational backgrounds for SHSSP in 2022 continued to show a broad mix of disciplines:

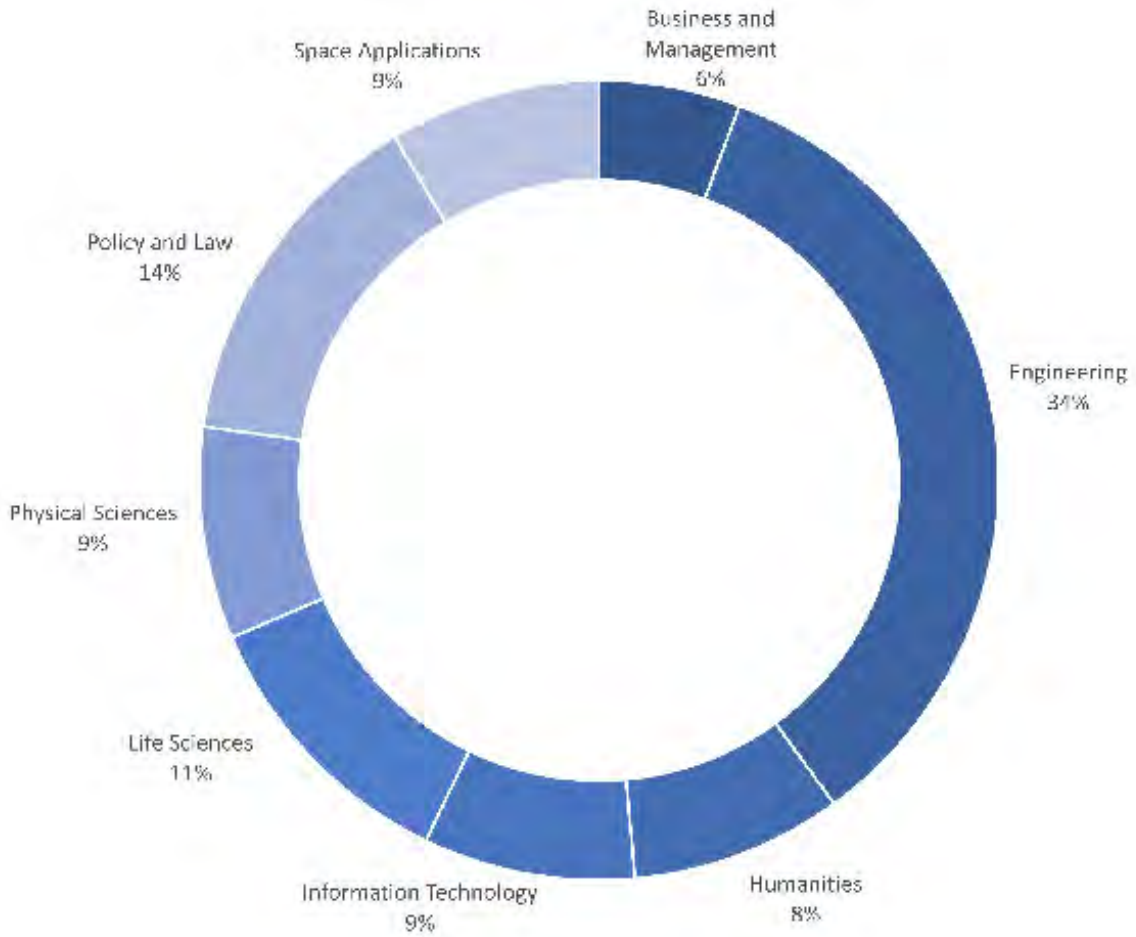
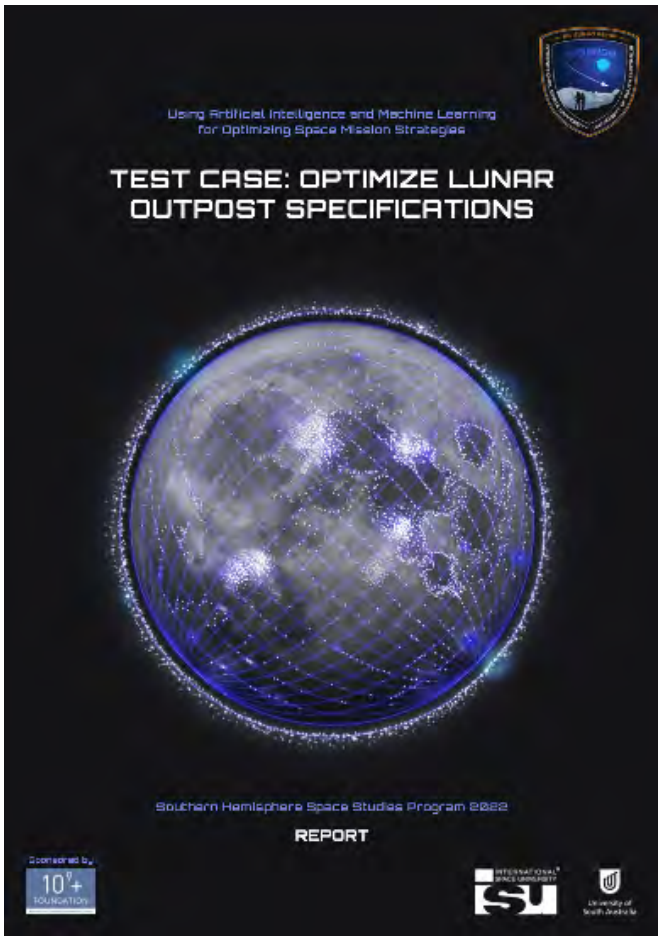


Fig. 20: Distribution of SHSSP22 participants by background

All participants received Certificates of Completion from ISU and Executive Certificates from the University of South Australia, and each year participants are eligible to receive 50 percent credit upon admission to the **UniSA Graduate Certificate in Space Studies.**

The SHSSP Core Seminar Series comprises one third of the program, presenting 23 lectures covering the world's space activities with a focus on space applications, services and policy. A broad understanding of the role of space, the current status of our capacity to use it and future directions, opportunities, and challenges for the space sector was presented in a manner clearly understandable to participants from a broad range of backgrounds, who were exposed to the International, Intercultural, and Interdisciplinary aspects of space.

Another one third of the program is allocated to hands-on workshops and the final one third is the group Team Project assignment to be completed in week 5.



The Team Project tackled by the class of SHSSP22 was "Using Artificial Intelligence and Machine Learning to develop Space Mission Strategies – Test Case: Optimize Lunar Outpost Location".

This study undertakes an interdisciplinary investigation into the application of artificial intelligence and machine learning to optimize the establishment of a lunar outpost. It focuses on seven core disciplines: space applications; engineering; management and business; human performance; science; humanities; and policy, ethics, and law.

A review of existing literature for each discipline informed the selection of target specifications to optimize. These specifications were evaluated, and outpost location optimization was selected as the primary subject of the study.

Five selected specifications were identified as needing to be satisfied: maximizing solar exposure; ease of terrain access; proximity to sites of scientific interest; minimizing environmental impacts on crew health; and access to resources.

The report identifies functional requirements that need to be satisfied by an artificial intelligence and machine learning application and develops a final proposed system. It then presents a prototype computational model for optimizing outpost location for terrain access.

A discussion of the ethical, policy and legal implications of the proposed system follows, and future extensions and improvements of the system are recommended, including applications for future off-Earth missions and the commercialization of AI as a service.

6. Short Courses

6.1 Executive Space Course (ESC21) Tel Aviv - Onsite

In collaboration with the Ramon Foundation, ISU hosted its Executive Space Course in Tel Aviv, Israel from 03-08 October 2021 - "Preparing investors and entrepreneurs for the entry of Israeli companies into the global space market".

Fig. 21: ESC21Tel Aviv

This course trained 28 participants in identifying and specializing in technologies appropriate to the age of private space and trends in the global space industry. The program was designed for executives, venture capitalists, high-tech, engineers and representatives of companies interested in developing within the new space sector.

The Executive Space Course in Israel was delivered in Tel Aviv to attract and appeal to participants and companies from the Middle East region. The International Space University's faculty included senior officials at NASA and the European Space Agency, experts from global consulting firms, investors, space mission managers, and well-known figures in the Israeli space industry.

6.2 Executive Space Course (ESC21) Eumetsat - Online

From experienced project controllers to newcomers in administration, all 16 handpicked Eumetsat employees benefited from ISU's Executive Space Course – the second edition tailored to Eumetsat's capacity building needs – taking place from 7 to 10 December 2021. The interdisciplinary introduction to global space activities of this course provided a 360° view of the space sector from space technology to policy.

Fig. 22: ESC21 Eumetsat participants

Lectures were delivered by both faculty and experts from ISU, and Eumetsat which also allowed attendees to discover internal expertise. Designing an Earth observation CubeSat was an interactive workshop which aimed among other learning outcomes to understand concurrent engineering. The course concluded with a lively panel discussion – moderated by ISU's past president Juan de Dalmau – debating the relationship between humanities and social sciences and space – including the future of space.

Panelists included:

- Phil Evans, Eumetsat DG,
- Pascale Ehrenfreund President ISU
- Mark Higgins, Eumetsat Responsible for user training
- Walter Peeters, ISU Space business and management professor

At the end of the week, participants got a better understanding of the overall space sector and the role of Eumetsat in the space ecosystem.

6.3 Executive Space Course (ESC21) Africa - Online

Fig. 23: ESC21 Africa

ISU and the South African National Space Agency (SANSA) joined forces to offer a successful inaugural Executive Space Course for the African region, held online from 01 to 04 February 2022. The course was attended by 26 professionals from government space agencies (SANSA and Portugal Space) and Angolan National Air Force. It was opened by the, at the time, Chief Executive Officer of SANSA, Dr. Valanathan Munsami (an ISU alumnus) and the President of ISU, Prof. Pascale Ehrenfreund.

The four-day program was delivered by 13 specialists from space agencies, academia, and industry experts including Hansjörg Dittus, University of Bremen and Jörg Kreisel, JKIC.

An overview about the history of space agency business given by Jean Yves Le Gall, former CNES President, the case study on the evolution of the Portuguese Space Agency by Hugo Costa and the panel discussion on the role of Africa in the space sector, including the President of the Italian Space Agency, Giorgio Saccoccia, the Chief of Space Applications section at the United Nations Office for Outer Space Affairs, Luc St-Pierre, and the Member of the Board of Portugal Space, Hugo Costa were especially appreciated, and triggered many questions.

6.4 Executive Space Course (ESC22) Strasbourg - Onsite

ISU's Central Campus Executive Space Course took place in-person from 04-08 April 2022 after two years of online activity. Past president Juan de Dalmau kicked off this edition by welcoming 17 participants from 11 countries coming to Strasbourg, France from as far as South Korea, Singapore, USA and Norway, Luxembourg, Isle of Man, amongst others.

This intensive one-week course aims to give an introduction into the space sector. It included sessions from seven space disciplines - from policy and law and entrepreneurship, to engineering, and satellite applications, a workshop from Valispace, a talk by ESA astronaut Reinhold Ewald and an insight into the journey of an ISU alumni founded start-up – SPIRE Global Inc. – given by one of the co-founders himself – Jeroen Cappaert.

At the closing, participants expressed that this course was not just "a course" but a whole and overall experience designed by ISU. One participant even stated that it was one of the best weeks of his life.

Fig. 24: ESC22 Strasbourg participants

6.5 Space Resources Course Luxembourg - Onsite

There was great success for the third edition of the Space Resources Professional Course (SRPC), co-organized from 2 to 3 May 2022 by the Colorado School of Mines CMS, ISU and the European Space Resources Innovation Centre ESRIC.

Angel Abbud-Madrid, the faculty lead for this course took the 38 participants from all backgrounds and industries on a “mining” journey to space and back. On the way participants learnt that Space Resource Utilization (SRU) or In Situ Resource Utilization (ISRU) is the use of natural resources from the Moon, Mars and other bodies for use in situ or elsewhere in the Solar System. Just like the first two editions - in-person in 2019 and on-line in 2021 - several ISU alumni attended this popular course.

Fig. 25: Space Resources Course poster

7. Research and Publications

7.1 Library Services

The Library has become a center of knowledge creation – a space where students improve skills that are necessary in the work ecosystem. ISU library facilitates information discovery and knowledge creation, guides and leads users in information technology.

More generally, ISU library works toward inclusion of access to information by providing access to current, high-quality information to support researchers on campus and worldwide.

ISU library is working toward UN 2030 agenda and some examples are:

Providing access to all to quality education and promote lifelong learning opportunities for all

Academic libraries are essential partners in study success. This year, we established the importance of the library's commitment to, and understanding of the pedagogy behind teaching, leading to a new collaborative approach with professors across the university to respond to their needs and the needs of the students for scientific information:

- We have completed a large benchmarking study to identify key academic databases (subscription and on open access) used in Higher Education: we identified the most relevant databases to ISU's curriculum and are working on solutions to offer an enlarged access to full-text materials.
- We have upgraded our Subject Guides which list selected sources by topics related to space. Publicly accessible.
- We have initiated cooperation with the University of Strasbourg (UNISTRA) libraries to provide enlarged access to subscribed e-resources for our students and professors. ISU library with its unique collection in space, will contribute to expand UNISTRA libraries' common online catalog by sharing its collection and make it more visible for students and researchers in the world.
- We acquired various items, on demand, (journal articles, proceeding papers, reports and books) to support students' learning and research. In academic libraries one can access scientific contents for free.
- For SSP22, we partnered with Instituto Tecnico Superior Library at Taguspark, Lisbon, Portugal to made sure SSP participants had access to academic e-resources and full-text as needed for the Team Projects literature search.

Achieve gender equality and empower all women and girls

- Reduce inequalities within and among countries
- Results of our 2022 library survey have shown that the majority of students feel welcome, comfortable and respected at the library
- Organized temporary book display about "women in space" and acquired books related to gender in the space sector.

Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

- We endeavor to measure the needs of our community, by using statistics and casual conversations. Our recent surveys among MSS22 class and MSS alum (class 2015-2020) have pointed out the need (-and importance) for skills in identifying quality sources of information, accurately and appropriately acknowledging the sources, finding open access resources, and staying current with news in the space sector
- The ISU librarian is taking an active role in teaching students to think critically about where information is coming from, make advanced searches and access information in an ethical way, so that they are better equipped to navigate the increasingly complex information landscape at the workplace.

Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

- We advocate for open access in higher education and answer questions about copyrights (droit d'auteur). We have discussed with professors academic integrity and "droit d'auteur" in Higher Education and how the library can work on new guidelines to better train and educate the students.
- The renovation of the Library spaces started in September 2022, and will provide new welcoming and inclusive spaces.

7.2 Research activities

ISU's resident faculty conduct research through collaborations with academia, research organizations and industry across the world, in areas such as Space System Engineering; Nanosats; Life Sciences and Space medicine; Lunar research; Planetary science and Astrobiology; Astrophysics; Space Policy and Entrepreneurship. In February 2022 the resident faculty has summarized the current research activities in a Research Roadmap as living document to secure research funding through acquisition of external grants. With this research roadmap, the faculty will explore synergies of research activities on Central Campus and strengthen the cooperation with strong partners from many universities and institutions in Europe and overseas.

Publications of Faculty Research are listed in Annex 2.

ISU faculty and students continued to pursue their research activities during the academic year, despite the restrictions set on research travels and conferences due to the pandemic.

Two students, Mr. Ezequiel Gonzáles and Mr. Adam Nawal, worked on their MSS theses year, on a part-time basis. The purpose of the project of Mr. Gonzáles was to reduce polarimetric monitoring of nearby **ultracool dwarfs** (≈1500 K) obtained on the Very Large Telescope of the European Southern Observatory in Paranal, Chile, to constrain the distribution of dust clouds in their atmospheres. Mr. Nawal is designing a **ChipSat** as a hosted payload on a CubeSat ; the ChipSat will function as a "black box" system for the CubeSat, intervening in the event of a CubeSat failure.

7.2.1 Grant proposals and acquisitions

Several external proposals to European and French funding agencies were submitted.
Grant - "Appel à Propositions de Recherche", APR, led by laboratories ICube, Strasbourg with ICA, IMT Mines Albi, was approved by CNES for 2022 and will allow Ms. Danijela Ignjatović Stupar to test at ISU **additive manufacturing technologies** under vacuum conditions. The aim of the project is that the ISU Vacuum chamber will be operational for printing with a 100-W, 1-µm laser (details about this project are described below). We submitted in April 2022 a proposal, whose result is pending, to the same CNES funding scheme in order to develop a **renewable electric source system** for the Self-deployable Habitat for Extreme Environments (SHEE) in 2023.

ISU was awarded a 36-month grant by the European Institute of Technology and Innovation (EIT) as part of the **HEI Initiative: Innovation Capacity Building for Higher Education** in June 2022. The HEI Initiative helps higher education institutions build the capacity to teach innovation and entrepreneurship. The EuroSpace-Hub project aims to digitally connect the space ecosystem in Europe, from tech transfer offices to industry, space accelerator networks, research centers, and other universities. The project will allow these actors to easily connect with financial opportunities from the Horizon Europe framework, the venture capital program, and the InnovFin initiative.

EuroSpaceHub will bridge the gap between academic institutions and industry, using a collaborative mindset and entrepreneurship programs inside the universities connected through tech transfer offices. The ISU Incubator and the ISU Space Policy and Entrepreneurship Lab (SPEL) will lead the ISU participation.
The EuroSpaceHub consortium has five full partners: ISU, Vilnius Gediminas Technical University (Lithuania), Complutense University of Madrid (Spain), Lunar Explorers Society (the Netherlands) and Collabwith Group (the Netherlands). These full partners are supported by 12 associate partners from eight countries, including one ESA business incubation center; two venture capital networks; three higher education institutions; two photonics and aerospace research centers; one technology park; one space foundation; and the Ministry of Economics in Lithuania.

The same month, ISU was awarded a grant by the European Commission Horizon Europe (HORIZON-CL4-2022-SPACE-01-72 - **Education and skills for the EU space sector**). The 36-month project will start on 1.1.2023. The goal of the ASTRAIOS project is to provide an exhaustive view and understanding of the current and future offer of space curricula and courses in the EU-27, characterize the demand from European space industry in the next 10–15 years, and identify actionable ways towards the alignment of the European space sector's curricula and qualification capabilities with skills required by the sector to foster innovation and increase EU competitiveness. A consortium of 10 experienced, recognized and uniquely complementary partners has been set up to implement the project. The consortium is specifically composed to reach a diverse and exhaustive representation of the European space ecosystem by gathering both Academia and Industry members. The consortium coverage also extends to an extensive geographical coverage of EU members with a reach in all countries to be investigated. The consortium members were thus selected to ensure complementarity and that all the main domains composing the space sector are covered, allowing the full identification and understanding of current, evolving and future needs that are specific to each segment of the industry, while providing the necessary network coverage to differentiate between national and geographical regions and take into account their respective specificities.

Through a competitive process, one internal call for proposals was issued to assign part of the resources allocated by the Board of Trustees for the fiscal year 2022. The goal is to develop internal and collaborative research projects and fund equipment and internships. The rest of the allocation was dedicated to the development of the life sciences and electronic laboratories, to prepare them to accommodate Master thesis of students of the redesigned MSS. Finally, funds were obtained from ESA within its "Space based services / applications addressing COVID-19 outbreak" - AO10377 call.

7.2.2 International Research Cooperation

Orbital Reef is a planned low Earth orbit space station designed by Blue Origin and Sierra Nevada Corporation's Sierra Space for scientific, commercial space activities and space tourism uses. Arizona State University (ASU) leads a global consortium of universities, the Orbital Reef University Advisory Council. First funding through the Space Act Agreement (Commercial LEO Development program) was announced in November 2021. Fifteen leading academic institutions with expertise in space and microgravity research are part of the University Research Advisory Council led by ASU, that will focus on academic community needs, stimulate research, advise novice researchers, evolve standards of conduct, and lead STEM outreach. ISU is a part of this consortium and will apply for funding to participate and contribute in this exciting initiative. Currently ISU is an active part of the STEM Outreach/Societal connection Working group of the Orbital Reef University Advisory Council. We hope to involve ISU students in the near future including for assignments, internships and workshops.

In the field of **life sciences**, Dr. Wotring worked with a group of European-based pharmacists, pharmacologists, and medical doctors to propose a **new ESA Topical Team** on Pharmacological Countermeasures for Space Missions. The proposal was awarded and work will begin in the Fall of 2022.

Dr. Wotring was invited to be part of a team led by the Hebrew University in a pitch for a flight opportunity on the lunar orbiter portion of the upcoming Beresheet 2 Mission. The project will investigate **stability of medications in a deep space environment**, and will also include partnerships with Charles University (Prague) and SpacePharma.

7.2.3 Research of Resident Faculty Members

As in the previous year, the faculty pursued research primarily in the following fields:

Ms. Danijela Ignjatović Ogrizovic Stupar:

From a **space application** point of view, Danijela Ignjatović Ogrizovic Stupar performed collaborative work with the Strasbourg engineering school École Catholique des Arts et Métiers (ECAM), focusing on two projects: "Lunar regolith laser sintering under vacuum conditions" and "3D solar printer on the Moon" where students from both institutions worked together under her supervision (from the ISU side).

a. Lunar regolith laser sintering under vacuum conditions

Additive manufacturing in combination with regolith, the main lunar in situ material resource, offers a solution for sustainable "live and work" mode on the Moon. Applying Selective Laser Sintering (SLS) technology will reduce the space transportation efforts from Earth, meaning that the cost of the space missions will be drastically reduced thanks to on-site manufacturing tools, parts, and infrastructure. An SLS prototype system focuses on control on the direction of laser beam (speed of galvo head) and process of thermal conditions (laser power, excessive heat accumulation in corner areas of the processed zone, and distances between the printed lines). Process modeling and energy input control are the main factors of successful outputs. This work shows how geometrical accuracy of a model can be improved by a good control process in 3D printing, avoiding the post-processing defects of the melting pool such as cracking, swelling areas, and bubbling effects. SLS tests were done on 0D, 1D, and 2D models (pearls, lines, and areas) (see Figure 26).

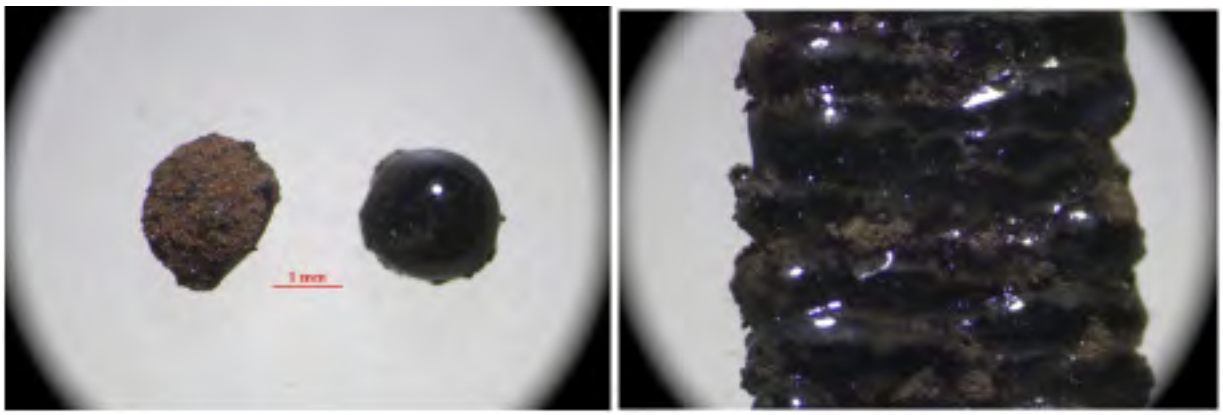


Fig. 26: Left:JSC-2A printed dots with 10W power and 5s exposure time, Image taken with 1x MAG; Right:SC-2A printed square with hatches 0.2mm, power of 10W and with speed of 1 mm/s

There are several factors that can not be tested on Earth, such as lunar environment, impact of solar wind on materials, and water content. Relevant process parameters are used in combination with regolith simulants JSC-2A, LHS, LMS, and EAC-1 (Ignjatović Stupar et al., 2021, 2022a, 2022b).
The final objective is to repeat the laser processing in simulating the lunar conditions using ISU's vacuum chamber with 10-2 mbar capacity to partially recreate the space/Moon condition.
This project is supported through the CNES APR grant FIGOLU in which laboratories: ICube, Strasbourg and ICA, IMT Mines Albi were involved as well. The same consortium had previously obtained funding from Inter-Carnot M.I.N.E.S in 2020 (MICA project - ICA/ICube 60 k€) and in 2021-2022 (ICube - API FABMOON - ICube - 8.6 k€).

b. 3D solar printer on the Moon

Using the solar 3D printer on the Moon to build shelters out of in situ resources such as lunar dust (regolith) would greatly reduce the need to bring materials from Earth. This work has led to the fabrication of two major parts: the design and realization of an electrically autonomous (due to solar panels and a battery) 3D printer by ECAM's students and a solar tracker by ISU students.

Fig. 27: Prototype of the Solar 3D printer

The objective of this project was to finalize the prototype while correcting the different design mistakes identified in the latest version of the project and integrate ISU's solar tracker to the system; see Figure 27). The 3D printer is built with a Fresnel lens donated by NASA. The lens focuses the Sun's light onto the top of a z-stage made of refractory bricks.

Additionally, Ms. Ignjatovic Ogrizovic Stupar is a part of another collaborative research project among the University of Novi Sad in Serbia, the University of Ljubljana in Slovenia, and Coal Mine Velenje in Slovenia. The research involved analytical and numerical solutions for better positioning in mines with potential extending application in space mining (Ignjatović Stupar et al., 2022a).

The results from 27 simulated environments show that a consistent network accuracy is achieved. Modifications of standard methods, involving gyro-theodolites, decrease the positional error to the level of a few cm, but introduce longer measuring time. This approach decreases the total number of manually performed measurements while, at the same time, keeps the network shape stable and makes the whole measurement campaign more economic in the sense of time spent in measuring. Analytical and numerical simulations conclude the first stage of the project with an improved concept for cm-level positioning in the underground tunnels. In the next step we will perform a test field simulating real conditions with highly controlled parameters, settings, and results. Confirmation of the mathematical model performance can be tested outdoors by performing control measurements with an independent method (preferably GNSS), but taking into account different environmental conditions. The final stage, testing in real conditions, is highly dependent on the underground corridor itself due to its configuration, including its connections with the external network, especially distribution of the vertical shafts. The period and scope of the real condition test will be determined after validation of the outdoor test.

The methodology elaborated in this research is consistent and, therefore, applicable to extraterrestrial bodies. The rich property of lunar material has attracted institutions, interested in planetary mining. New technologies, methodologies, and equipment adapted to lunar mining are an important research area.

Dr. Taiwo Tejumola

In the field of **System Engineering and Nanosats**, Dr. Tejumola primarily focused on two projects:

a. PLASMACube

ISU is contributing to one of the mission payloads of the ROMEO satellite currently under development at the IRS of the University of Stuttgart. PLASMACube is a miniaturized low-cost plasma measurement system that would be integrated as a mission payload of ROMEO Satellite. The main objective of the satellite is to develop a cost-efficient satellite bus that demonstrates new technologies in low (LEO) and medium earth orbit (MEO). The plasma instrumentation will apply the principle of double Langmuir probe for the characterization of transitional orbit (LEO to MEO) of the satellite.

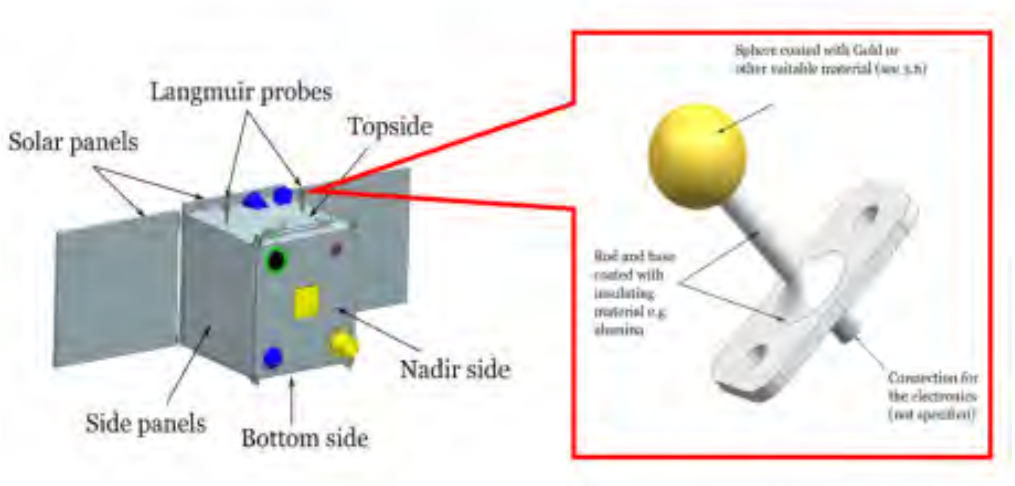


Fig. 28: Schematic view of the ROMEO Satellite with Double Langmuir probes as part of the ISU PLASMACube payload

b. Small Satellites Standardization Project

ISU's Space Systems Engineering Laboratory is playing an important role in the improvement of mission assurance of small satellite programs. This project is part of a global consortium of university networks involved in the development and operation of small satellites. This interdisciplinary research project is using applied-integrated systems engineering and best practices global data from mission development to in-orbit operations for the development of standards for small satellite development towards greater mission assurance and improving global space sustainability campaigns. These standards would benefit cooperation and exchange and hence further drive down cost and development time. More than this, reliability can be improved significantly as standards are in many cases a formalization of lessons learned and fostering collaboration and knowledge exchange.

Dr. Hugh Hill

In the last year, ISU had three peer-reviewed publications in the fields of Astrochemistry and Astrobiology with the contribution led by Dr. Hugh Hill. The publications were the result of long-standing international collaborations, e.g., with ISU MSS 2004 alumnus, Dr. Bhalamurugan Sivaraman, Atomic Molecular and Optical Physics Division, Physical Research Laboratory, Ahmedabad (India). A novel way of identifying hydroxylamine (NH2OH) in icy environments was reported. The latter molecule is noteworthy as it is a peptide (diminutive chains of amino acids) precursor.

In the case of the processing of astrophysical dusts and laboratory dust analogs, another study showed what happens to amorphous carbon dust in the interstellar medium (ISM) when it is undergoing energetic processing (Roy et al., accepted in Advances in Space Research).

Meanwhile at ISU Central Campus, the **Reddy Shock Tube** (RST) was used for astrobiological studies by two MSS 2022 Candidates. Specifically, seeds, tardigrades (segmented micro-animals) and bacteria were shocked. Initial data suggest that induced shock may be beneficial to the growth of some microorganisms, but further research is needed to identify the potential underlying mechanism/s responsible.

Dr. Bertrand Goldman

Two publications were accepted for publication with ISU contribution led by Dr. Bertrand Goldman. The first used the Pan-STARRS1 data to study photometric variability of ICRF3 quasars. Those quasars define the International Celestial Reference System, which is the current standard celestial reference system adopted by the International Astronomical Union, in the radio range. Using Functional Principal Component Analysis of the sparse and irregularly sampled Pan-STARRS1 data, we obtained uniform and compatible estimates of the variability amplitudes and average magnitudes between the five optical passbands and 2863 objects. The most surprising finding is a strong decline of the variability amplitudes with redshift toward z=3, which we interpret as the time dilation of the dominant time frequencies.

The second publication combines photometric monitoring of the MACHO and EROS projects searching for microlensing events due to compact objects in the halo of the Milky Way. This allows us to search for longer-duration events that could be caused by intermediate mass black holes, a population of hardly known objects that the detections of gravitational waves are now revealing. We can exclude that such objects with masses up to 1000 M contribute more than 40% of the Galactic dark matter.

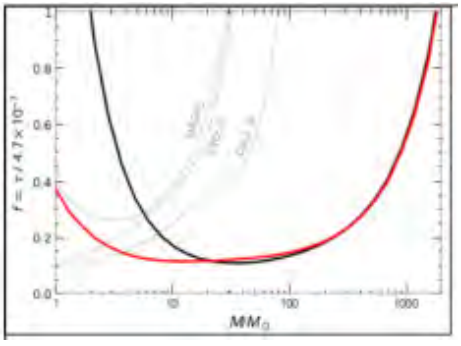


Fig. 29: 95% confidence-level upper limits on the fraction of the Milky Way halo mass in the form of compact objects of a given mass, as allowed by our analysis. Blaineau et al. (2022).

Finally, a year-B student has reduced rare high-precision time-sampled polarimetric imaging of three brown dwarfs, obtained with the FORS2 imager on the Very Large Telescope of the European Southern Observatory, and presented his preliminary result at European Astronomical Society meeting in Valencia, Spain, and at the Cool Stars 21 conference in Toulouse, France. Polarimetric data allow to constrain the distribution of dust in the atmosphere of ultra-cool dwarfs (250–2500 K). Our preliminary analysis shows hints of possible low-level polarization in two targets over a fraction of their rotational period, pointing indeed to variations in the cloud distribution, but needs to be confirmed.

Dr. Virginia Wotring

Under Dr. Wotring's guidance, the Space Life Sciences Laboratory has grown into a functional laboratory conducting pilot-scale investigations on effects of space analog environments on fundamental animal physiology and behavior. The mu-metal shielded low magnetic field chamber (Figure 30, upper) provides a 2 micro-Tesla environment, while the matching control chamber (lower) is at Strasbourg-normal 45 microTesla.

Fig. 30: Each chamber will hold 144 individual planaria in 6 24-well plates for experiments of moderate sample size

The new custom-built low-magnetic field environmental chamber and matching Earth magnetic field chamber were used in 2 different MSS22 Individual Projects and also by 3 visiting interns (from University of Nottingham, UK and University of Strasbourg; Figure 31). To permit additional lines of investigation involving the study of animal behavior, a specialized observation apparatus was constructed in January.

Fig. 31: MSS22 students Victoria Rendon using video microscopy to measure new growth in a regenerating planaria after exposure to a reduced magnetic field environment, one of the space analogs now used in the Space Life Science Laboratory

To permit capture of video recordings without disrupting an animal's light cycle, Infrared LED light is used in conjunction with a specialized infrared camera and custom software for Raspberry Pi. This new custom-built rig has already been employed in two pharmacology projects conducted by interns from the Pharmacy School, University of Nottingham, one of which will be presented at the upcoming IAC meeting. One MSS22 student will also be presenting her work on planarian regeneration in a low magnetic field environment as a model of wound healing in space. Two manuscripts describing the effects of low magnetic field space analog are currently in preparation, one describing the effects of pain-relieving medication on planarian behavior and the other detailing changes seen in planarian regeneration, a well-established model of human wound healing. There are opportunities for MSS Thesis projects and Individual projects to continue these investigations over the coming year, including use of alternate temporary rooms if needed, to accommodate the expected building renovations.

Walter Peeters, Nicolas Peter and Gongling Sun:

In the field of **Management and Business**, ISU launched a new lab, the **Space Policy and Entrepreneurship Lab** (SPEL) in the Fall of 2021, which is a dedicated research laboratory addressing the issues and trends in the domains of space policy and the space economy, including New Space worldwide. It draws on ISU multi-disciplinary Faculty expertise both from the ISU Central Campus and its extensive Global ISU Faculty network. The SPEL is hed by Prof. Nicolas Peter.

The objective of the SPEL is to serve as a global hub for space policy and entrepreneurship to facilitate international research on these topics, building on the ISU's 3Is approach involving academics, professionals from space agencies and industry, and alumni from ISU worldwide, and to train and educate the workforce of tomorrow.

The Lab investigates short- and long-term space policy and entrepreneurship trends on its own or in partnerships. The Lab also works very closely with the ISU start-up incubator and its personnel to support the development of the space economy. The SPEL has already been awarded major grants and contracts to share its experience on space entrepreneurship.

Research taking place within the Entrepreneurship Lab included NewSpace fundamentals in general and the aspects related to the **LEO constellations** in particular. Studies were made in terms of market differentiation for the planned LEO constellations and on suggestions for enhanced applications of the constellations. Most of the studies are summarized in papers that will be presented at IAC2022 in Paris, amongst others. A number of articles were published on NewSpace as a paradigm shift in peer reviewed journals (Peeters 2021, 2022a, 2022b), and on the risk for cyberattacks and consequences, accepted for the hi-level Space Policy journal (van Camp & Peeters, 2022). Further research is ongoing on micro-launchers as a dedicated possibility to place smallsats in LEO.

8. Space start-up incubator

Over the past 30 years, more than 110 successful space start-ups have been founded or co-founded by ISU alumni in 27 countries, some of which are now world leading New Space companies. To encourage entrepreneurship, ISU offers the discipline of space management and business in all its programs, covering topics such as marketing, finance, costing, technology transfer, New Space, and international project management. ISU alumni also benefit from an in-house space start-up incubator at its ISU Central Campus as well as services including coaching, starting with pre-incubation and access to financing.

A number of the companies which were hosted in the incubator, and were reported in previous year annual report, have further grown. Also, thanks to the ISU network, these start-ups have benefitted from contracts and financing support. Among those, two of the companies have now grown to such an extent, particularly in terms of staff, that they are presently planning to leave this incubation phase and are now looking for the appropriate accommodation to expand their growing business in dedicated offices outside ISU.

An important secondary asset for ISU is the fact that these companies have now grown to a sufficient critical mass, allowing them to accommodate ISU participants in internships, whereas, on the other hand, they also have an excellent opportunity to get in contact with ISU participants and alumni, providing job opportunities and hiring (e.g. by posting vacancies on the ISU website).

Thanks to the agreement between ISU and ESA, some of the incubatees have, in addition, entered into the ESA-BIC system, and others are in the process of application.

Gradually, demands for new incubation support are studied by ISU in terms of feasibility and Proof Of Concept, during the so-called pre-incubation phase. During this phase preliminary business plan pitch decks are evaluated by ISU in order to judge the possibility for local seed funding, in close contact with the local partners. This activity is performed in cooperation with the successful local SEMIA incubator of the University of Strasbourg providing expert advice, particularly where B2C aspects are concerned. This is based upon an agreement whereby ISU and SEMIA help each other in their respective fields of expertise. Other agreements facilitating funding of the incubators are initiated and solidified with potential MOUs, with the aim to expand the network internationally by working with well-known equity investors interested in the space area.

Potential new incubatees in pre-incubation are working in such areas as:

- Use of a combination of drones and GIS for agricultural support
- Use of Earth Observation data to determine green surfaces in towns (e.g. roof garden opportunities)
- Future pharmaceutical applications and microgravity research.

The success of the incubator has attracted a lot of attention from the local partners and from equity investors and therefore in a second phase a number of activities are now planned to boost this endeavor. These activities, presently initiated, include:

- Setting up a dedicated website collecting all information on how to apply, pre-incubation and support for business plans at one dedicated place
- Providing more information via flyers at events like IAC
- Extending the ISU value proposition related to the (pre-)incubation period
- Increasing the organization of start-up events in ISU such as ActInSpace and Cassini/Copernicus Hackathon.

An example of such events co-hosted by ISU in its facilities during the reporting period is shown in Fig. 32.

Fig. 32: Start-up event in ISU, SGAC Photo

9. Alumni Affairs

9.1 Alumni Statistics

As in previous years, employment of the previous MSS class has been used as a benchmark, as most of the participants in the professional development programs returned to their previous jobs (which would give a distorted picture). Approximately nine months after graduation, a questionnaire is sent to the MSS alumni asking for their job situation.

Due to the outbreak of COVID-19 in 2020, the usual dynamic of the internship has been different in 2021 again. Some internships were conducted remotely and some started much later than normal, leading the dynamic of the graduation of the MSS21 to be different from pre-COVID-19 times. Therefore, ISU proposed a third graduation date - May 2022 - like last year, because of the difficulties caused by COVID-19.

12% of the MSS21 students graduated in September 2021, 56% of the MSS21 students graduated in December 2021, 12% of the MSS21 students graduated in May 2022, and 20% of the MSS21 students were shifted to modular status. The percentage of students graduating after September was much higher than previous years. Likewise, the percentage of students shifted to the next cohort due to the modular status is very high.

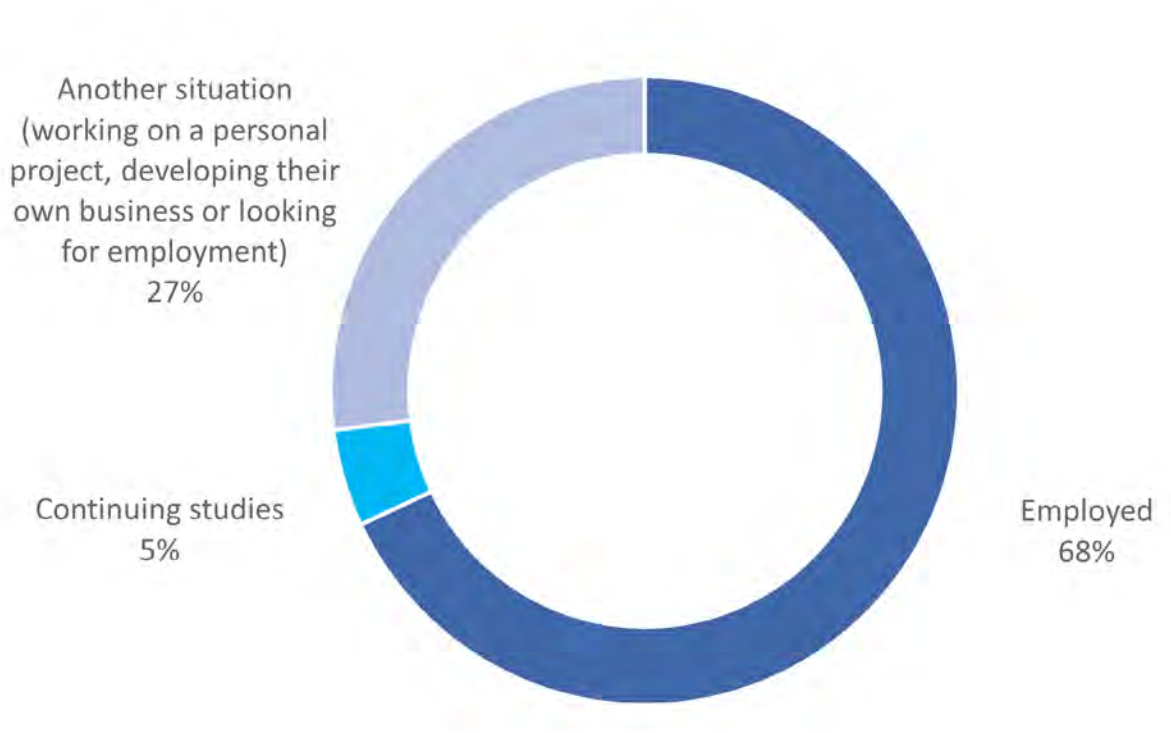


Fig. 33: Employment statistic of MSS21 alumni

The alumni who are fully employed obtained their position as follows:

- before graduation (46%)
- within 3 months after graduating (31%)
- more than 3 months after graduating (23%)

Among the respondents who answered that they were employed at the time of the survey:

- 54% reported working in the space sector
- 38% reported having a position somewhat related to the space sector
- 8% reported working in a field other than space.

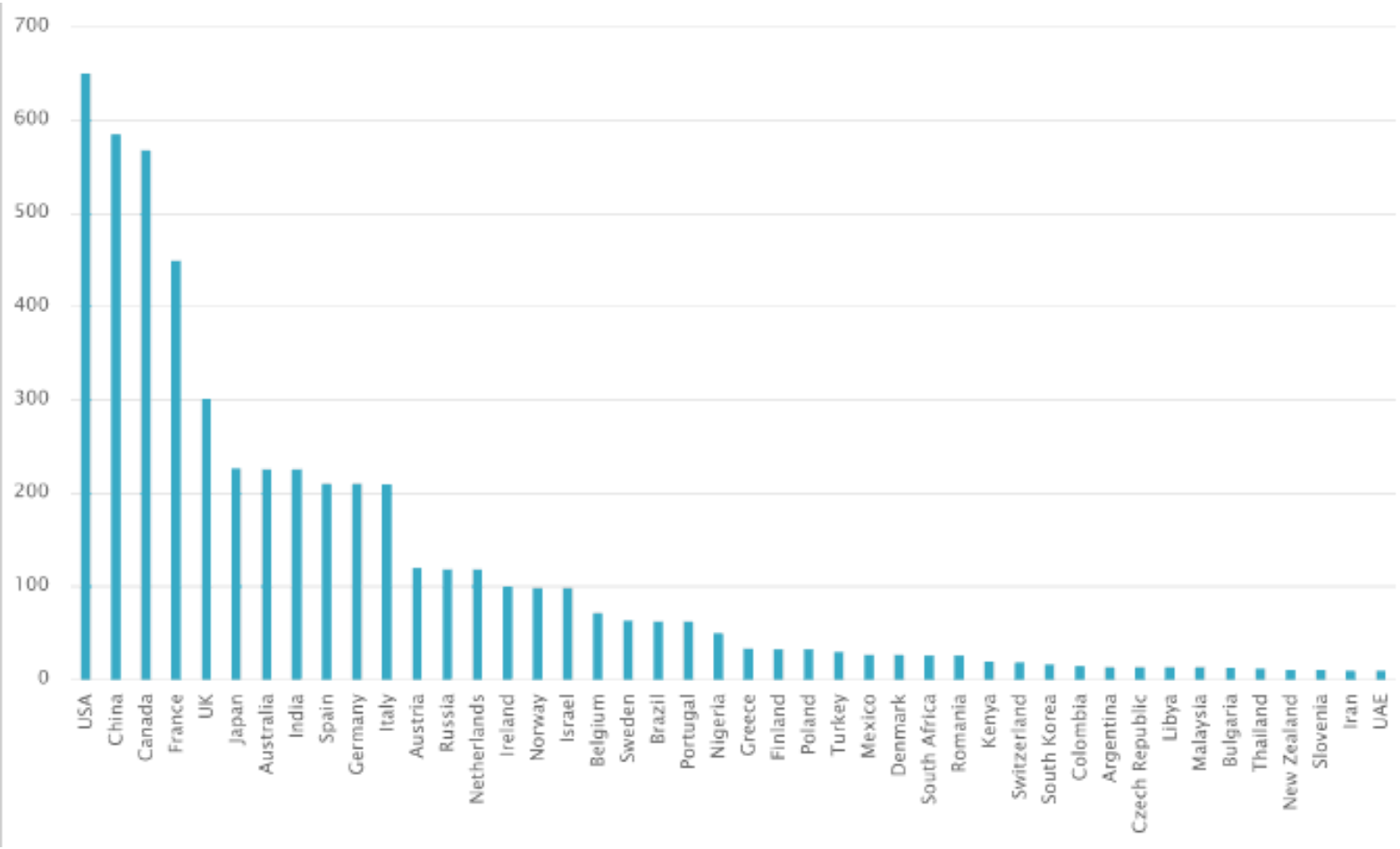


Fig. 34: Alumni distribution since start of ISU (top 40 countries only, September 2022)

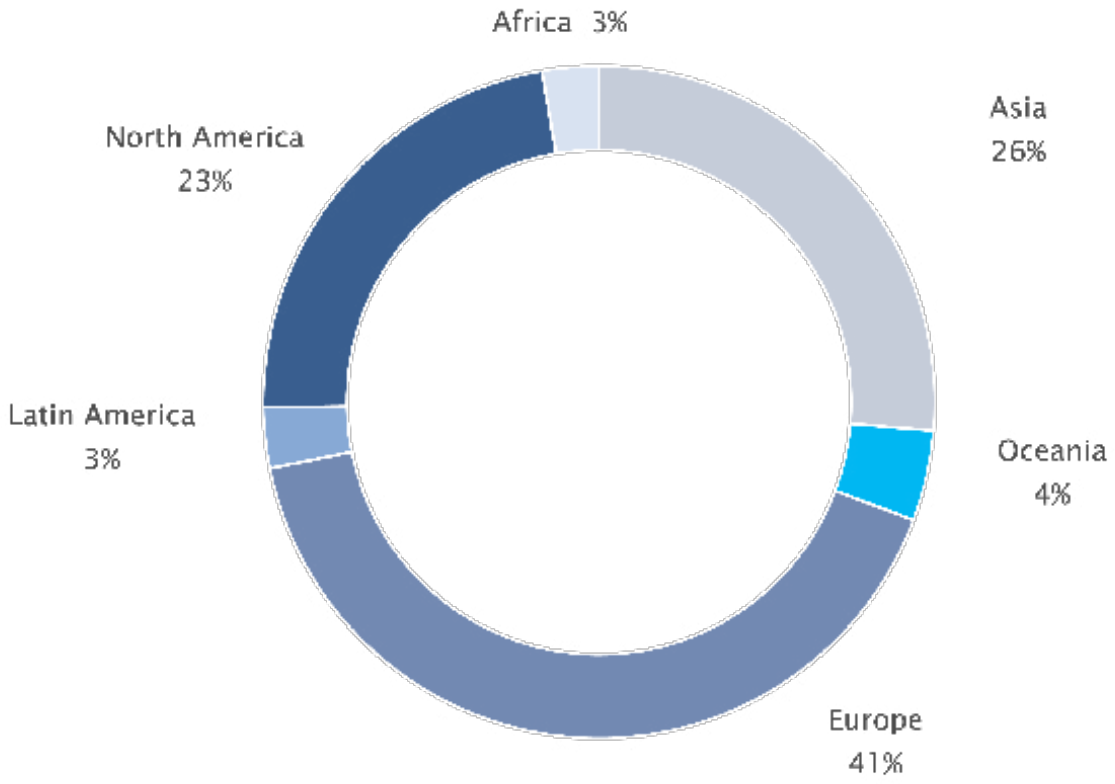


Fig. 35: Geographical distribution of ISU's 5400 alumni

9.2 Alumni Conferences

ISU Adelaide conference

The ISU Adelaide Conference 2022 took place online from 4 to 5 February 2022. The main theme of the conference was Space Junk and Overcrowding the Skies. There were a total of 973 registrations and over 50 speakers. The organizers received very good feedback from attendees and speakers. Overall the audience was very international : 1/4 from Australia and New Zealand, 1/4 from Philippines, almost 1/4 from India and 1/4 from the Rest of the World.

About 60% of registrants were students, but there were also significant attendee numbers from research, government, space agencies, defense. In total, nine hours of content were delivered over two days, and there was a great media coverage. The key stakeholders such as the four space agencies from the region were very satisfied, and great connections were made thanks to the diverse body of keynote speakers and panelists.

Fig. 36: ISU Adelaide Conference

ISU Annual Alumni Conference

Around 150 alumni and members of the ISU community traveled to Oeiras, from as far as Australia, New Zealand, and Hong Kong. We thank them all for their loyalty to their alma mater. ISU is also very grateful for the support received by the local organizing committee, IST at Taguspark, and The Aerospace Corporation for sponsoring the alumni dinner.

Thanks to the great organizational skills of ISU alum Inês d'Ávila, the 2022 alumni gathering, held from 29th to 31st August 2022, was as regular as clockwork, just like a space mission. She and the Portuguese team, in collaboration with ISU, prepared an exciting and informative agenda including the discovery of the local Portuguese culture and landmarks, networking with the Space Studies Program SSP22 participants, the celebration of alumni achievements, a space masquerade, and panels about the future of the space sector and ISU amongst other talks and events.

Fig. 37: ISU Alumni Conference

10. Faculty appointments

10.1 New Faculty appointments and Academic Council Elections

The professionals listed below have cumulated sufficient teaching time at ISU to join the Global Faculty, and they have accepted to contribute with their expertise to the ISU academic, research, and professional development programs.
The updated list of over 160 faculty members is accessible on the **ISU website** with links to the profile of each individual.
The procedures for faculty eligibility, appointments and currency are established in the **ISU Academic Handbook**.

- Promoted Full members of the ISU Global Faculty: Ana Diaz, Nahum Romero Zamora, Dimitra Stefoudi
- Appointed Adjunct Faculty: Hervé Cadiou, William Abraham da Silveira, Marcel Egli, Kyran Grattan, Vanessa Marto Nunez, Robert Jan Postema, Scott Ritter, Antonio Yukio Ueta

The Academic Council elections will take place in September 2022. For reference, the current Academic Council Members are:

Volker Damann (Germany), Chair of the Academic Council, ESA (retired), Germany
Lucy Stojak (Canada), Vice Chair of the Academic Council, HEC Montreal, Canada

Carol Carnett JD (USA), Legal Aid Bureau Inc., USA
Dan Glover (USA), Independent Consultant, USA
Maria Antonietta Perino (Italy), Thales Alenia Space, Italy
Geoff Steeves (Canada), University of Victoria, Canada
Su-Yin Tan (Canada), University of Waterloo, Canada
Virginia Wotring (USA), International Space University, France
Olga Zhdanovich (Russia), MODIS, The Netherlands MODIS, Netherlands

11. Special events and outreach

11.1 Special events

International Astronautical Congress

The International Astronautical Congress is the most important event for ISU in terms of recruiting new candidates for its programs. The efforts deployed by ISU to attend IAC 21 during the pandemic were not in vain. The IAC in Dubai was the first congress in the Arab world. The diverse and enthusiastic attendees, ranging from young students to seasoned professionals, took the opportunity to meet up with ISU staff and alumni to discuss their future educational paths and professional careers in space.

IAC21 welcomed over 5000 individuals from more than 110 countries. More than 150 alumni presented their papers and ISU team projects, or scounted for new business opportunities.

Fig. 38: MSS21 alumni winning an IAF "best interactive presentation" award on MSS21 TP Space and Oceans

ISU hosted a Master Class on Space

As part of the Eurometropolis of Strasbourg's partnership agreement with the French Space Agency CNES and its motivation to support the development of a local space industry based on space applications, the Eurometropolis and CNES recently organized – in collaboration with the ISU – a unique half-day of training for public authorities focused on the use of data and technologies coming from the space sector.

The objective of this Master Class was to demonstrate the usefulness of space data to support the implementation of public policies in various fields such as mobility, health, environment and urban planning. ISU President Pascale Ehrenfreund; Caroline Zorn, Eurometropolis of Strasbourg Vice-President in charge of higher education, research, student life, and innovation; and CNES innovation director Gilles Rabin welcomed participants to this ConnectbyCNES Master Class hosted at ISU. This Master Class also offered the opportunity to share issues among the participants, who primarily consisted of elected officials and community officials of the Eurometropolis of Strasbourg. They learned about CNES and ConnectbyCNES services, the use of space data, space applications, how space can help citizens, from a panel of CNES experts. Nicolas Peter – Prof. of the Practice in Space Policy and International Affairs at ISU – shared his experience with the audience on using space, particularly downstream activities to support public policies; he also answered questions related to ISU and its role at both local and international levels.

UKSEDS 2022

The UKSEDS National Student Space Conference (NSSC), now in its 34th year, is the premier event for students interested in space, usually uniting them with academics and professionals from across the country to network, share knowledge, and discuss the challenges facing the sector. NSSC 2022 took place on 5 and 6 March 2022 at King's College London, hosted by KCL Space society. As in every year, ISU was present.

SSEA Barcelona

ISU was present at the Symposium on Space Educational Activities (SSEA), organized by ESA's Education Office, which provides a forum for university students, professionals working in education, and other young professionals to present and discuss their experiences organizing, running and/or participating in Educational Activities related to Space. The 4th SSEA took place from 27 to 29 April 2022 in Barcelona, Spain. The local organisation team was led by the Universitat Politècnica de Catalunya · BarcelonaTech, with the close collaboration of the Institut d'Estudis Espacials de Catalunya (IEEC) and the Institut de Ciències del Cosmos (ICC-UB).

Fig. 39: ISU Community Members at SSEA 2022

SGAC event at ISU Central Campus

On Saturday 4 June 2022, ISU hosted SG[France] 2022 at ISU Central Campus. Under the motto "Road to Newspace", ISU partnered with the French Chapter of the Space Generation Advisory Council (SGAC) to organize a one-day event for international students and young professionals, ages 18-35. This cooperation builds on the partnership between ISU and SGAC signed at the occasion of the 2021 SGAC Congress in Dubai (UAE). A record 120 participants from 29 countries attended the event.

ISU President Prof. Pascale Ehrenfreund gave the introductory welcome and first inspirational speech to welcome the SGAC delegates, among them several ISU Alumni such as Elodie Viau from the European Space Agency (ESA) or Guillaume Tanier from Leanspace. Other inspirational speakers included Catherine Kavvada from the European Commission, Member of European Parliament Christophe Grudler, or Stanislas Maximin from Alliance NewSpace and Venture Orbital Space founder. Other keynote speeches were provided by representatives from the French Space Agency, CNES, and Clearspace.

Fig. 40: SG[France] 2022 participants

Many experts from the space industry, agencies and academia served also as experts on the technical roundtable. Prof. Nicolas Peter, ISU Faculty and Head of the Space Policy and Entrepreneurship lab (SPEL) co-organized the event and served as an expert in the Round Table 1 "Launch your business" to discuss the space economy and the role of the incubator including, ISU incubator in developing the New Space economy. He also served on the Jury to judge the best team presentation. The one-day event helped to devise recommendations of various working groups besides "Launch your business", but also on "Space systems development", "Space data and its uses across the lifecycle of space missions" and "New usage of space".

11.2 Outreach

For the second time, ISU invited prospective students and participants to join one of a series of three conferences, held on 19 February 2022, to learn more about those programs that we will offer in 2022 and 2023. The online open day started with the Asia-Pacific event, followed by the Europe-Africa event, before the Americas event closed the day two hours later. High-profile guests with various ISU experience illustrated the value of ISU education in a context relevant to the participants of each of the three regional events. For instance, for the participants of the Asia-Pacific event, Enrico Palermo, Head of Australian Space Agency, started the discussion, followed by alumni of Japan (Kenta Maruyama), China (Wu Fenglei), and India (Ashwini Gurudeo Vaidya). The Asia-Pacific event was coordinated by Emeline Paat-Dahlstrom.

The Europe-Africa event was moderated by ISU President Prof. Pascale Ehrenfreund, and featured alumni with profound understanding of the space sector and of its needs in terms of education, in both the public and private sector (Vera Pinto of the European Commission; Val Munsami, then Director of the South Africa National Space Agency; Maria Antonietta PERINO of Thalès Alenia; or Stan Kaethler, co-founder of the successful start-up LeanSpace, hosted in the ISU incubator).

Finally, alumni from the American region, often involved in ISU activities, such as Dr. Su-Yin Tan or Catrina Melograna who coordinated the event, delivered powerful and motivational testimonies of the benefits that they gained thanks to ISU and of their later contributions to ISU.

In all three events, the Head of Admissions and Program Directors explained the goals and teaching methods of each program, as well as the admission process. Finally, breakout rooms were organized for each program and attendees could meet in smaller groups with alumni of those programs, as well as the director to ask questions about the delivery, format, curriculum, general experience and career path after graduation.

Fig. 41: Discover ISU panelists and participants

Again this year, ISU also embarked on an international competition, led by our partner Space Science Engineering Foundation (SSEF). Guided by space experts, teenagers joined forces to prepare a project for space exploration and human settlement. Because of the continuing pandemic, the event was held as a virtual one for a second time. Similarly to the on-site competitions organized in the UK since 2008, dozens of teenagers from all over Europe worked over the week-end at the beginning of April to design a large human settlement on Phobos, which would become the cultural center for the solar system.

Two teams submitted their projects on Sunday afternoon, and a panel of space experts selected the winner. Several participants, distinguished by their peers for the quality of their contribution to the projects, went on to participate to the World Final (July 2022) hosted at NASA's Kennedy Space Center, Florida USA.

The impact on the participants to the European competition is profound, illustrated by the fact that several participants from previous editions return to support the event and gain confidence that they could pursue a career in Science, Technology, Engineering and Mathematics (STEM) and the space sector.

Fig. 42: SSEF Competition

12. International Relations

ISU is made up of a unique global network with a Central Campus in Strasbourg, hubs in the USA and the Asia-Pacific region, and partnerships with leading space organizations worldwide. ISU is supported by government agencies, corporations, foundations, and individuals worldwide that recognize the value of the University in promoting international cooperation and in developing the global space workforce. In 2021/2022 ISU has signed MoUs with several key organizations to excel in space education and science cooperation.

Collaboration between ISU and the Kyushu Institute of Technology (KIT)

The International Space University (ISU) and the Faculty of Engineering of Kyushu Institute of Technology (KIT), Japan joined in the Memorandum of Understanding (MOU) on the promotion of several academic exchanges between the two institutions including: joint research; exchange of academic material and academic publications; exchange of faculty members for research; discussion, and lectures; exchange of undergraduate and graduate students for study and research. Up to five students from each institution may participate in the exchange program in any given academic year.

Partnership between ISU and the Italian Space Agency (ASI)

At the occasion of the International Astronautical Congress (IAC) event in Dubai, the Italian Space Agency (ASI) and the International Space University (ISU) renewed their partnership by signing a Memorandum of Understanding on Wednesday 27th October 2021. It aims to enhance further the cooperation between both entities. Besides a number of cooperative actions at institutional level, such as exchange of lecturers, one very important element of this memorandum is the support of ASI to promising Italian young space professionals, namely to select and fund through scholarships a short list of Italian candidates to participate in ISU programs with one scholarship a year for the Master Space Studies (MSS), two scholarships a year for the Space Studies Program (SSP) course and three scholarships a year for the Southern Hemisphere Space Studies Program (SH-SSP) course.

Fig. 43: Mr. Giorgio Saccoccia ASI President and Prof. Pascale Ehrenfreund, ISU President on ASI's booth at IAC21

Cooperation with the School of Disruption of the Swiss Institute for Disruptive Innovation (SIDI)

ISU partnered with SIDI, an e-learning platform offering courses on emerging technologies and trends. The partnership follows the success of the Space Architecture & Design in-presence workshop held in April 2022 at ISU central campus. This course – in its digital version on the School of Disruption platform – has reached 1,000 participants from all over the world. Specific courses will be developed in the next months such as: Space Economy and Entrepreneurship, Human Performances in space. This partnership gives birth to the world's largest online education platform dedicated to space, an ambitious objective in perfect coherence with the ISU and SIDI mission to democratize access to innovation and contributes even more to the achievement of the frontier of life in space.

Partnership between ISU and the Space Foundation

On 11 April 2022 the Space Foundation, a non-profit advocate organization founded in 1983, signed an Memorandum of Understanding with ISU at the 37th Space Symposium (USA). The new partnership will allow both organizations to coordinate space and space awareness education programs focused on expanding the diversity and entrepreneurial engagement of the global space ecosystem and, in particular, between the Space Foundation Space Commerce Institute and the ISU Space Policy and Entrepreneurship Lab (SPEL).

Partnership between ISU and the Aerospace Corporation

ISU engages in a strategic cooperation with the Aerospace Corporation, a non-profit corporation incorporated. The Aerospace Corporation operates a federally funded research and development center (FFRDC) for the US Air Force. The Aerospace Corporation performs independent objective technical analyses and assessments for a variety of government, civil, and commercial customers. Aerospace operates the only FFRDC for the space enterprise. A specific example is collaborative research, studies and reports, conducted jointly with the ISU Space Policy and Entrepreneurship Laboratory and the Aerospace Center for Space Policy and Strategy.

13. Conclusions

ISU celebrated its 35th anniversary in April 2022. Today, the ISU faculty consists of more than 160 distinguished members worldwide and 5400 alumni, who are shaping the international space ecosystem in 110 countries. ISU also provides targeted space educations for the non-space audience and reskilling and upskilling training for the space workforce.

We hope you enjoyed reading this report. Please contact us if you want to engage with the International Space University in the future through participation in our education and research programs, mentorship, or sponsorship.

We wish you a successful academic year 2022-2023 and remain at your disposal to discuss any space-related topic.

The ISU staff and faculty

ANNEX 1: Faculty

ANNEX 1.1 ISU Faculty

Philippe Achilleas, IDEST, Université Paris Sud & ISU, France
Farhan Asrar, University of Toronto, Canada
Steve Brody, Aerospace Elder and ISU Faculty Member, USA
David Bruce, University of South Autralia/Flinders University, Autralia
Angie Bukley, The Aerospace Corporation, USA
Carol Carnett, Legal Aid Bureau Inc., USA
Ed Chester, Goonhilly Earth Station, UK
Jacob Cohen, NASA Ames Research Center, USA
Patrick Cohendet, Université de Strasbourg/HEC Montreal, Canada
John Connolly, NASA Johnson Space Center, USA
Bill Cowley, Institute for Telecommunications Research, Australia
Eric Dahlstrom, International Space Consultants, USA
Juan de Dalmau, International Space University, France
Volker Damann, International Space University, Germany
Michael Davis, International Space Univeristy, Australia
Emmanouil Detsis, European Science Foundation – ESF, France
Ana Diaz, Texas A&M University, USA
Kerrie Dougherty, Australian Space Agency, Australia
George Dyke, Symbios Communications, Australia
Reinhold Ewald, University of Stuttgart, Germany
Stefano Fiorilli, European Space Agency – ESA, Spain
Daniel Garcia Yarnoz, Spain
Andrea Gini, D-Orbit, The Netherlands
Daniel Glover, NASA Glenn Research Center (retired), USA
Bertrand Goldman, International Space University, France
James Green, NASA Headquarters, USA
Gerhard Haerendel, Max-Planck-Institut für extraterrestrische Physik (retired), Germany
Omar Hatamleh, NASA, USA
Hugh Hill, International Space University, France
Jeffrey Hoffman, Massachusets Institute of Technology, USA
Marcello Ingrassia, Italy
Dennis Irwin, Ohio University (retired), USA
Adil Rahim Jafry, Chandah Space Technologies, USA
Ady James, University of South Australia, Australia
Christopher Johnson, Secure World Foundation, USA
Joan Johnson-Freese, Naval War College, USA
Otto Koudelka, Technical University Graz, Austria
Ofer Lapid, Israel
Natalia Larrea Brito, Euroconsult, Canada
John Logsdon, George Washington University, USA
Tanja Masson-Zwaan, International Institute of Air and Space Law at Leiden University, The Netherlands
Ruth McAvinia, ATG Europe, The Netherlands
Christopher McKay, NASA Ames Research Center, USA
Bernd Madauss, Project Management Team Madauss, Germany
Gary Martin, International Space University, USA
Michaela Musilova, International Moonbase Alliance (IMA), Hawaï, USA

Joshua V. Nelson, USA
Barnaby Osborne, European Space Agency, UK
Norah Patten, Irish Centre for Composites Research, Ireland
Walter Peeters, International Space University, France
Joseph Pellegrino, One Web, USA
Maria Antonietta Perino, Thales Alenia Space, Italy
Nahum Romero Zamora, KOSMICA, Germany
Christian Sallaberger, Canadensys Aerospace, Canada
Niamh Shaw, Dream Big Space Communications, France/Ireland
Noel Siemon, Australia
Michael Simpson, International Space University (retired), USA
Robert Shishko, NASA Jet Propulsion Laboratory, USA
François Spiero, CNES, France
Geoffrey Steeves, University of Victoria, Canada
Dimitra Stefoudi, International Institute of Air and Space Law, The Netherlands
Lucy Stojak, HEC Montreal, Canada
Chris Stott, ManSat LLC, Isle of Man
Danijela Stupar, International Space University, France
Gongling Sun, International Space University, France
Su-Yin Tan, University of Waterloo, Canada
Taiwo Tejumola, International Space University, France
Remco Timmermans, Spaceside, UK
Diego Urbina, Space Applications Services, Belgium
Alain Wagner, Airbus Defence and Space, France
Jan-Walter Schroeder, Sensovo, Germany
Ray Williamson, Secure World Foundation (retired), USA
Pete S Worden, Breakthrough Foundation, USA
Virginia Wotring, International Space University, France
Soyeon Yi, Korean Astronaut, Republic of Korea
Kazuya Yoshida, Tohoku University, Japan
Vasilis Zervos, International Space University, France
Olga Zhdanovich, MODIS, Netherlands

ANNEX 1.2 ISU Adjunct Faculty

Andrew Aldrin, Florida Institute of Technology, USA
Heather Allaway, Texas A&M University, USA
Audrey Allison, The Boeing Company, USA
Julio Aprea, European Space Agency – ESA, France
Jacques Arnould, CNES – Headquarters, France
Merryl Azriel, Salient CRGT Inc. , USA
Jaime Babb, Canada
Melissa Battler, Mission Control Space Services, Canada
Nelly Ben Hayoun, Nelly Ben Hayoun Studio Ltd, UK
Philomena Bonis, Silverheights Public School Waterloo Region District School Board, Canada
David Bruce, University of South Australia (UniSA), Australia
Hervé Cadiou, University of Strasbourg, France
Graziella Caprarelli, Hypatia Scientifica Pty Ltd, Australia
Francis Chizea, National Space Research and Development Agency (NASRDA), Nigeria
Ryan Clement, University of Winnipeg, Canada
Philippe Clerc, CNES, France
Willian Abraham da Silveira, Staffordshire University, UK
Marcel Egli, Lucerne University of Applied Sciences and Arts, Switzerland
Kim Ellis, International Earth & Space Technology Pty Ltd, Australia

Stuart Eves, SJE Space Ltd, UK
Andre Farand, Institut du droit de l'espace et des télécommunications – IDEST, France
Kyran Grattan, Breakthrough Prize Foundation, Luxembourg
Barbara Imhoff, LIQUIFER Systems Group, Austria
Tricia L. Larose, Norwegian University of Science and Technology, Norway
Kris Lehnhardt, Baylor College of Medicine and NASA, USA
Anderson Liew, HSBC, UK
Zhuoyan Lu, China
Peter Martinez, Secure World Foundation, USA
Vanessa Martos Nunez, Universidad de Granada, Spain
Ioannis Michaloudis, Institute of Nanoscience and Nanomaterials, Greece
Maurizio Nati, ESA (retired), The Netherlands
Paolo Nespoli, European Space Agency – ESA (retired), Italy
Cory Newman, CAE, Canada
Andrée-Anne Parent, University of Quebec in Rimouski, Canada
Robert Parkinson, The British Interplanetary Society, UK
Robert Jan Postema, ESA-ESTEC, The Netherlands
Ewan Reid, Mission Control Space Services Inc., Canada
Scott Ritter, DLR, Germany
Daniel Rockberger, NSLComm, Israel
Claude Rousseau, Northern Sky Research, France
Alex Ryan, ISU, Australia
Kai-Uwe Schrogl, International Institute of Space Law – IISL, France
Matt Sorgenfrei, Cruise, USA
Julien Tallineau, Veoware Space, Belgium
Erin Telley (Tranfield), Instituto Gulbenkian de Ciência, Portugal
Irina Thaler, Racah Institute of Physics, Hebrew University of Jerusalem, Israel
Madhu Thangavelu, University of Southern California, USA
Robert Thirsk, Canadian Space Agency – CSA (retired), Canada
Antonio Yukio Ueta, Brazil National Institute for Space Research, Brazil

ANNEX 1.3 ISU Associate Faculty

Sheila Bailey, NASA Glenn Research Center, USA
Phillipe Berthe, European Space Agency – ESA, The Netherlands
Isabelle Bouvet, Airbus, France
Milan Cermack, Switzerland
Hansjörg Dittus, German Aerospace Center (DLR), Germany
Stacey Falzarano (Solomone), Chandah Space Technologies, USA
Arthur Guest, TreoScope Technologies, USA
Ozgur Gurtuna, Turquoise Technology Solutions Inc., Canada
Douglas Hamilton, KRUG Life Sciences, USA
Tarik Kaya, Carleton University, Canada
Wiley Larson, Stevens Institute of Technology, USA
William Marshall, Cosmogia Inc., USA
David Miller, University of Oklahoma, USA
Todd Mosher, Amazon, USA
Annelie Schoenmaker, W.L. GORE & associates, Spain
Isabelle Scholl, Intitute for Astronomy – University of Hawaii, USA
Alexandra Seneta, Department of Industry & Science, Australian Government, Australia

ANNEX 2: Research publications by ISU Central Campus Faculty

ANNEX 2.1 Peer-Reviewed Publications

Baqué, M.; Backhaus, T.; Meeßen, J.; Hanke, F.; Böttger, U.; Ramkissoon, N.; Olsson-Francis, K.; Baumgärtner, M.; Billi, D.; Cassaro, A.; de la Torre Noetzel, R.; Demets, R.; Edwards, H.; **Ehrenfreund, P.**; et al.: Biosignature stability in space enables their use for life detection on Mars, 2022, Science Advances, in press

Berghea, C. T.; Makarov, V. V.; Quigley, K.; **Goldman, B.**: Optical Variability of ICRF3 Quasars in the Pan-STARRS 3Pi Survey with Functional Principal Component Analysis, 2022, The Astronomical Journal, 162, 21.: 10.3847/1538-3881/abfc51

Blaineau, T.; Moniez, M.; Afonso, C.; Albert, J.-N.; Ansari, R.; Aubourg, É.; Coutures, C.; Glicenstein, J.-F. ; **Goldman, B.**; Hamadache, C.; Lasserre, T.; LeGuillou, L.; Lesquoy, É.; Magneville, C.; Marquette, J.-B.; Palanque-Delabrouille, N.; Perdereau, O.; Rich, J.; Spiro, M.; Tisserand, P.: New limits from microlensing on Galactic Black Holes in the mass range 10M<M<1000M, 2022, accepted for publication in Astronomy and Astrophysics, arXiv:2202.13819

Fan, H.; Schwartz, M.; Farhang, A.; Cox, N. L. J.; **Ehrenfreund, P.**; Monreal-Ibero, A.; Foing, B.H.; Salama, F.; Kulik, K.; MacIsaac, H.; van Loon, J. Th.; Cami, J.: (2022) Families and Clusters of Diffuse Interstellar Bands: a Data-Driven Correlation Analysis, MNRAS, 510, 3546, DOI: 10.1093/mnras/stab3651

Ignjatović Stupar, D.; Ogrizović, V.; Rošer, J.; Vižintin, G.: Analytical and Numerical Solution for Better Positioning in Mines with Potential Extending Application in Space Mining, 2022a, Minerals, 12(5), 640; DOI: 10.3390/min12050640

Riedo, A.; Grimaudo, V.; Aerts, J.; Lukmanov, R.; Tulej, M.; Broekmann, P.; Lindner, R.; Wurz, P.; **Ehrenfreund, P.**: Laser Ablation Ionization Mass Spectrometry: A space prototype system for in situ Sulphur isotope fractionation analysis on planetary surfaces, 2021, Front. Astron. Space Sci., 8, 726373, 1-12, doi: 10.3389/fspas.2021.726373

Roy, A.; Surendra, V.S.; Ambresh, M.; Sahu, D.; Meka, J.K.; Ramachandran, R.; Samarth, P.; Pavithraa, S.; Jayaram, V.; **Hill, H.**; Cami, J.; Rajasekhar, B.N.; Janardhan, P.; Bhardwaj, A.; Mason, N.J.; Sivaraman, B.: Shock Processing of Amorphous Carbon Nanodust. Accepted for publication in Advances in Space Research (June 27, 2022)

Sawyers, L. ; Anderson, C. ; Boyd, M.J. ; Hessel V., **Wotring, V.** ; et al. : Astropharmacy: Pushing the boundaries of the pharmacists' role for sustainable space exploration, 2022. Res Social Adm Pharm. 12:S1551-7411(22)00034-1. doi: 10.1016/j.sapharm.2022.02.002, PMID: 35183459

Schwendner, P.; Riedo, A.; Melton, D. J.; Horvath, P.; Lindner, R.; **Ehrenfreund, P.**; Beblo-Vranesevic, K.; Rettberg, P.; Rabbow, E.; Westall, F.; Moissl-Eichinger, C.; Garcia-Descalzo, L.; Gomez, F.; Amils, R.; Marteinsson, V.; Walter, N.; Cockell, C.S.: Microbial degradation of amino acids as a potential biosignature, 2022, Front. Astron. Space Sci., 9, 781542, 1-10, DOIi: 10.3389/fspas.2022.781542

Schwander, L.; Ligterink, N.F.W.; Kipfer, K.A.; Lukmanov, R.; Grimaudo, V.; Tulej, M.; de Koning, C.P.; Keresztes, P.; Gruchola, S.N.; Boeren, N.J.; **Ehrenfreund, P.**; Wurz, P.; Riedo, A. : Correlation network analysis for amino acid identification in soil samples with the ORIGIN space-protoype instrument, 2022, Front. Astron. Space Sci., 9, 909193, 1-12, DOI: 10.3389/fspas.2022.909193

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Van Camp, C. and **Peeters, W**.: A World without Satellite Data as a Result of a Global Cyberattack, 2022, Space Policy 59, 101458, DOI: 10.1016/j.spacepol.2021.101458

Winnard, A. ; Caplan, N. ; Bruce-Martin, C. ; Swain, P.; Velho, R.; Meroni, R.; **Wotring, V.** ; Damann, V. ; Weber, T.; Evetts, S.; Laws, J.: Developing, Implementing, and Applying Novel Techniques During Systematic Reviews of Primary Space Medicine Data. Aerosp Med Hum Perform. 2021 Aug 1;92(8):681-688. DOI: 10.3357/AMHP.5803.2021.PMID: 34503621

ANNEX 2.2 Reviews

Dello Russo, C. ; Bandiera, T. ; Monici, M. ; Surdo, L. ; Yip, V.L.M. ; **Wotring V,** Morbidelli L. : Phyiological adaptations affecting drug pharmacokinetics in space: what do we really know? A critical review of the literature. Br J Pharmacol. 2022; 179:2538–2557. DOI: 10.1111/bph.15822

Pavez Loriè, E. ; Baatout, S. ; Choukér, A. ; Buchheim, J.-.I ; Baselet, B.; Dello Russo, C.; **Wotring V.**, Monici, M.; Morbidelli, L.; Gagliardi, D.; Stingl, J.C.; Surdo, L.; Lai Ming Yip, V.: The Future of Personalized Medicine in Space: From Observations to Countermeasures, 2021, Front. Bioeng. Biotechnol. 9:739747, DOI: 10.3389/fbioe.2021.739747

ANNEX 2.3 Systematic reviews

Swain, P.; Laws, J.M.; De Martino, E.; **Wotring, V.**; Caplan, N.; Winnard, A.: Effectiveness of exercise countermeasures for the prevention of musculoskeletal deconditioning in simulated hypogravity: A systematic review, 2021, Acta Astronautica, Volume 185, Pages 236-243. DOI: 10.1016/j.actaastro.2021.05.005.

ANNEX 2.4 Proceedings

Gonzáles, E.; **Goldman, B**.; Zapatero Osorio, M.R.; et al.: Studying brown dwarf dust cloud distribution through polarization, Cool Stars 21, Toulouse, France, July 4–9, 2022.

Ignjatović Stupar, D.; Chabrol, G.R.; Cutard, T.; Lecler, S.; Brendle, J.: Selective Laser Melting of various lunar soil simulants, E-MRS 2022 Spring Meet. Conf., Strasbourg, France, May 2022a.

Ignjatović Stupar, D.; Chabrol, G.R.; Baraze, A.R.I.; Lecler, S.; et al.: Selective laser sintering (SLS) of various lunar soil simulants for Moon base manufacturing: experimental results and numerical modelling, SPIE, Strasbourg, France, April, 2022b

Ignjatović Stupar, D.; Rošer, J.; Vižintin, G.: Space Mining and Consequences in Chasing Rare Earth Elements on Other Celestial Bodies, 8th Int. Conf. Min. Environ. Prot., Vrnjačka Banja, Serbia, 2021.

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Ignjatović Stupar, D.; Chabrol, G.R.; Baraze, A.R.I.; Lecler S., et al.: Feasibility of Additive Manufacturing Processes for Lunar Soil Simulants, 14th Int. Sci. Conf. MMA 2021 Flex. Technol., Novi Sad, Serbia, 2021. ISBN 978-86-6022-364-9

Peeters, W.: Is Newspace really so new? 2021, ROOM, Summer 28, 72.

Peeters, W., Is NewSpace a paradigm shift? 2022a, Aerospace Europe Bulletin (CEAS, January 2022), 16.

Peeters, W., Evolution of the Space Economy: Government Space to Commercial Space and New Space, 2022b, Astropolitics, DOI: 10.1080/14777622.2021.1984001.

Roy, A.; Surendra, V.S.; Meka, J.K.; …, **Hill, H.**; et al. Minerals in the ISM are Made in an Instant. Online symposium on Meteoroids, Meteors, Meteorites: Messenger from space (MetMeSS-2021), 29-30 November 2021.

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Smart, R. L.; Bucciarelli, B.; Jones, H. R. A.; Marocco, F.; Andrei, A. H.; **Goldman, B.**; et al.: Parallaxes of Southern Extremely Cool objects, VizieR On-line Data Catalog: J/MNRAS/481/3548, DOI: 10.1093/mnras/sty2520

ANNEX 3: Research Lunches

The Research lunch series continued in its third year. The purpose of the series is to discuss the research conducted on the Central Campus; learn from our visitors and Strasbourg col- leagues about their research and think about possible collaborations; present to and educate our master's students about what work researchers do and what topics are most promising. The MSS students are invited to join as audience or speaker on a voluntary basis.

The health situation allowed us to invite some ISU and local researchers to present in person in the Pioneer Hall, while we continued to take advantage of remote connections to listen to distant researchers. We sought to achieve a balance between the ISU disciplines, speaker gender (50% of female speakers) and geographic distribution (although time zone considerations led to an under-representation of Asia).

Because of the complexity related to the sanitary conditions and overall MSS workload, we ended the season earlier to allow the students to concentrate on the preparation of their individual and team reports, with seven lunches organized over the academic year.

We anticipate changing the schedule in the next academic year to adjust to the needs of the MSS students.

Calendar of sessions during the academic year:

- 8 February: Vincent Tatischeff (IJCLab, Université Paris-Saclay): Gamma-Ray Burst Polarimetry with a CubeSat mission
- 31 January: Nana Ama Browne Klutse (Univ. of Ghana): The role of scenarios in climate change mitigation and adaptation in Africa
- 14 January: Caoimhe Rooney (NASA Ames): Head in the clouds: mathematical modeling cloudy exoplanets
- 26 November: Adam Russell (ESO): ESO Instrumentation
- 3 November: Sarah Goubet and Vincent Sionneau (WaterShed Monitoring): Water quality monitoring and prediction
- 15 September: Giovannni Fazio (Harvard & Smithsonian): Viewing the Universe in Infrared Light: The Spitzer Space Telescope
- 29 September: Ruthanne Huising (EM Lyon Business School): Ethics in Innovation

ANNEX 4: Useful Links

ISU Website

ISU Library

Student Projects

Job Center

Photo Gallery

ISU Twitter account

ISU Facebook page

ISU LinkedIn page

ISU Youtube channel