INTERNATIONAL
ASTRONAUTICAL
FEDERATION

IAF HIGHLIGHTS 2021

Connecting @ll Space People

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Abbreviations

3G	Geography, Generation, Gender
AAS	American Astronautical Society
ADR	Active Debris Removal
AEB	Brazilian Space Agency
AI	Artificial Intelligence
AIAA	American Institute of Aeronautics and Astronautics
ASE	Association of Space Explorers
ASI	Italian Space Agency
BEC	Bose-Einstein Condensate
CSSC	IAF Commercial Spaceflight Safety Committee
CLPS	Commercial Lunar Payload Services
CNES	Centre National d'Études Spatiales
CONFERS	Consortium for Execution of Rendezvous and Servicing Operations
CRTS	The Royal Centre for Remote Sensing
CSA	Canadian Space Agency
DART	Double Asteroid Redirect Test
DLR	German Aerospace Center
EDRS	European Data Relay System
EEAS	European External Action Service
ELSA-d	End-of-Life Services by Astroscale-demonstration
EOL	End of Life
ERMC	IAF Enterprise Risk Management Committee
ESA	European Space Agency
EU	European Union
FAA	Federal Aviation Administration
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GGPEN	Angola's National Space Programme Management Office
GISTDA	Geo-Informatics and Space Technology Development Agency
GLEC	IAF Global Conference on Space for Emerging Countries
GLEX	IAF Global Space Exploration Conference
GNSS	Global Navigation Satellite System
GRSCE-FO	Gravity Recovery and Climate Experiment Follow-on
GSFC	NASA's Goddard Space Flight Center
GTOC	Global Trajectory Optimization Competition
HAC	IAF Honours and Awards Committee
IAC	International Astronautical Congress
IAF	International Astronautical Federation
IAF GNF	IAF Global Networking Forum
IAWN	International Asteroid Warning Network
ICAO	International Civil Aviation Organization
IDEA	International Platform for Diversity, Equality and Astronautics
IISL	International Institute of Space Law
ILRS	International Lunar Research Station
IRC	IAF Industry Relations Committee
ISEB	International Space Education Board
ISECG	International Space Exploration Coordination Group
ISF	International Space Forum
ISRO	Indian Space Research Organisation
ISS	International Space Station
ISU	International Space University
ISZ	International Student Zone
ITACCUS	IAF Committee for the Cultural Utilisation of Space
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
KMTC	IAF Knowledge Management Technical Committee
LEAP	Lunar Exploration Accelerator Programme
LTS	Long Term Sustainability
MARSIS	Mars Advanced Radar for Subsurface and Ionosphere Sounding
MBRSC	Mohammed Bin Rashid Space Centre
MEV	Mission Extension Vehicle
MoP	Members of Parliaments
MOU	Memorandum of Understanding
MS	Member States
NASA	National Aeronautics and Space Administration
NEO	Near-Earth Objects
NEOSM	Near-Earth Object Surveillance Mission
NESDIS	National Environmental Satellite, Data, and Information Service
NGO	Non-Governmental Organization
NOAA	US National Oceanic and Atmospheric Administration
NRHO	Near Rectilinear Halo Orbits
OSAM	On-Orbit Servicing, Assembly, and Manufacturing
PDC	Planetary Defense Conference
PNT	Positioning/Navigation/Timing
PPP	Public-Private-Partnership
PRS	Public Regulated Service
ROSCOSMOS	State Space Corporation ROSCOSMOS
RPO	Rendezvous and Proximity Operations
SANSA	South African National Space Agency
SATC	IAF Space Astronomy Technical Committee
SCAN	IAF Space Communications and Navigation Committee
SEOC	IAF Space Education and Outreach Committee
SGAC	Space Generation Advisory Council
SHC	IAF Space Habitats Committee
SLS	Space Launch System
SST	Space Surveillance and Tracking
STC	IAF Space Transportation Committee
STM	Space Traffic Management
TC	Technical Committee
ToR	Terms of Reference
TUA	Turkish Space Agency
UAE	United Arab Emirates
UAESA	UAE Space Agency
UCLA	University of California, Los Angeles
UN	United Nations
UNCOPUOS	United Nations Committee on the Peaceful Uses of Outer Space
UNOOSA	United Nations Office for Outer Space Affairs
USA	United States of America
VP	Vice President
WD-YPP	IAF Workforce Development-Young Professionals Programme Committee
WoAA	Women of Aeronautics and Astronautics

Welcome Message

Following a very challenging year 2020 with many postponed events, 2021 provided a more optimistic outlook and more opportunities for travel and meetings in person. It was wonderful to finally be able to gather the whole space community and to meet and discuss in person at the different IAF events. The first in person conference since the start of the pandemic was GLEX 2021 in the Russian Federation, followed by IAC 2021 in the United Arab Emirates. Both conferences were successfully organized with a great international participation! In this IAF Highlights 2021 you will be able to read more about the many interesting sessions and panels held at these events.

GLEX 2021 was hosted by ROSCOSMOS in the beautiful city of Saint Petersburg from 14 – 18 June 2021. More than 800 attendees from 34 countries gathered for the conference and another 1500 participants connected remotely. GLEX 2021 provided an important platform to exchange knowledge on the advancements in Space Exploration and was also the occasion to celebrate the 60th anniversary of Yuri Gagarin's spaceflight.

In October, the 72nd International Astronautical Congress gathered more than 5 000 delegates from 110 countries in Dubai! IAC 2021 was organized together with the Mohammed Bin Rashid Space Centre (MBRSC) under the theme '*Inspire, Innovate and Discover for the Benefit of Humankind*'. As usual the IAC was packed with plenty of interesting events involving many space stakeholder communities. Even though we are getting more skilled to work in a virtual environment, we know it can never fully replace face to face meetings that offer global networking and multi-stakeholder attendance.

In these demanding times, we hope that the situation in 2022 will further improve worldwide and allow us to meet in person, for GLEC 2022 in Quito, Ecuador and the IAC 2022 in Paris, France!

Pascale Ehrenfreund

President,
International Astronautical Federation (IAF)

IAF 2021

Events Overview

IAF General Assembly Report 2021

The International Astronautical Federation General Assembly has gathered during the International Astronautical Congress, (IAC 2021) in Dubai, United Arab Emirates, in two sessions (Monday, 25 October 2021, and Friday, 29 October 2021). Several important decisions have been taken.

2021 Elections of IAF Officers

The Incoming President and four new Vice Presidents have been elected by the General Assembly:

Clay MOWRY, Chief Revenue Officer at Voyager Space Holdings, United States, has been elected as IAF Incoming President.

Lisa CAMPBELL, President, Canadian Space Agency (CSA), Canada, has been appointed as IAF VP for Agency Relations and Global Membership Development.

Steven EISENHART, Senior Vice President, Space Foundation, United States, has been appointed as IAF VP for IAF Global Networking Forum (IAF GNF).

Davide PETRILLO, Executive Director, Space Generation Advisory Council (SGAC), Austria, has been appointed as IAF VP for Education and Workforce Development.

Lionel SUCHET, Chief Operating Officer, Centre National d'Études Spatiales (CNES), France, has been appointed as IAF VP for Technical Activities.

Selection of Host City for IAC 2024

The IAF General Assembly at its second session on 25 October 2021, selected Milan, Italy, as Host City for IAC 2024. The Hosting Organization is the Italian Association of Aeronautics and Astronautics (A.I.D.A.A.), an IAF founding member since 1951.

IAF Finance

The IAF has also approved the **final accounts 2020 and Auditor's Statement 2020**, the **revised budget and preliminary accounts 2021** and the **Proposed Budget 2022.**

New IAF Members

The IAF General Assembly also approved the applications of **50 new Member Organizations**. With this, the IAF Membership comprises **433 Member Organizations** from **72 countries**, bringing two new countries in the Federation Members' community, Egypt and Angola, re-confirming IAF's position as a truly global Federation.

The New IAF Members are:

Organization	Category	Region	Country
AAKA SPACE STUDIO CORP	Space Industry	North America	Canada
ALE Co., Ltd.	Space Industry	Asia	Japan
Angolan National Space Program Management Office (GGPEN)	Space Agency/Space Office	Africa	Angola
Asia-Pacific Space Cooperation Organization (APSCO)	Space Agency/Space Office	Asia	China
Astralintu Space Technologies	Space Industry	Latin America	Ecuador
Astrax, Inc.	Space Industry	Asia	Japan
Beijing Minospace Technologies Co., Ltd	Space Industry	Asia	China
C-Astra Technologies	Space Industry	North America	United States
Center for Space Technology and Research (CSTAR)	University	North America	United States
Centre for the development of Industrial Technology (CDTI)	Space Agency/Space Office	Europe	Spain
COMSPOC Corp.	Space Industry	North America	United States
DcubeD (Deployables Cubed GmbH)	Space Industry	Europe	Germany
Dragonfly Aerospace Pty (Ltd)	Space Industry	Africa	South Africa
Egyptian Space Agency	Space Agency/Space Office	Africa	Egypt
EngineRoom.io Pty Ltd	Space Industry	Oceania	Australia
European Space Foundation	Association and Professional Society	Europe	Poland
Fachhochschule Wiener Neustadt GmbH	University	Europe	Austria
Felix & Paul Studios	Space Industry	North America	Canada
Global Defence for Industrial Transformation	Space Industry	North America	United States
Gokmen Space and Aviation Training Center (GUHEM)	Space Museums	Asia	Turkey
Hebrew University of Jerusalem	University	Asia	Israel
INNOSPACE Co. Ltd.	Space Industry	Asia	South Korea
Institut d'Estudis Espacials de Catalunya	R&D Organization	Europe	Spain
Institute of Mechanics, Chinese Academy of Sciences	R&D Organization	Asia	China
Karman Project	Association and Professional Society	Europe	Germany
Keldysh Research Center	R&D Organization	Europe	Russian Federation
MicroDrive Space Ltd.	Space Industry	Asia	China
Mudd Law	Space Industry	North America	United States
NanoAvionika UAB (NanoAvionics LLC)	Space Industry	Europe	Lithuania
National Space Science Agency (NSSA)	Space Agency/Space Office	Asia	Bahrain
NeutronStar Systems UG (hb)	Space Industry	Europe	Germany
Office for Space Technology & Industry, Singapore	Space Agency/Space Office	Asia	Singapore
Pacific West Data Pty Ltd - Trading as ACME SpaceTek	R&D Organization	Oceania	Australia
Portugal Space Agency	Space Agency/Space Office	Europe	Portugal
Reaction Engines	Space Industry	Europe	United Kingdom
Saint Petersburg State University of Aerospace Instrumentation	University	Europe	Russian Federation
Saudi Space Commission (SSC)	Space Agency/Space Office	Asia	Saudi Arabia
Shaanxi XingYi Space technologies Co. Ltd.	Space Industry	Asia	China
Simera Sense	Space Industry	Europe	Belgium
Slovak Investment and Trade Development Agency (SARIO) - Slovak Space Office	Space Agency/Space Office	Europe	Slovakia
Spade	Space Industry	Space Industry	France
Spartan Space	Space Industry	Europe	France
Starburst Aerospace Ltd	Space Industry	Asia	Israel
Stardust Technologies Inc.	Space Industry	North America	Canada
Teaching Science and Technology, Inc (TSTI)	Space Industry	North America	United States
Tensor Tech CO., LTD.	Space Industry	Asia	Taiwan
The University of Winnipeg	University	North America	Canada
Turkish Space Agency (TUA)	Space Agency/Space Office	Asia	Turkey
University of Strathclyde	University	Europe	United Kingdom
Voyager Space Holdings	Space Industry	North America	United States

GLEX 2021
GLOBAL SPACE EXPLORATION CONFERENCE

IAF Global Space Exploration Conference

14-18 June 2021 | Saint Petersburg, Russian Federation


GLEX 2021
14-18 JUNE 2021
Saint Petersburg


ROSCOSMOS
14-18 JUNE 2021
Saint Petersburg
GLEX 2021

GLEX 2021

Opening Ceremony

After a challenging year brought on by the global pandemic, the third Global Space Exploration Conference kicked off in style with speeches by high-level representatives from Russia and the President and Executive Director of the International Astronautical Federation.

The global pandemic has made the past year extremely challenging for everyone, but the world's space sector showed remarkable resilience during this unprecedented hardship. The International Astronautical Federation's third Global Space Exploration Conference was originally scheduled to be held in St. Petersburg in June, 2020. But the dangerous conditions created by the COVID-19 pandemic made it impossible to safely host the conference and the IAF made the decision in April 2020 to postpone the event until the following year. GLEX 2021 was a unique experience that blended in-person and online events. This hybrid format allowed scientists, technologists, industry-leaders, and government representatives to come together to discuss the most pressing issues in space exploration.

"This is indeed a crucial moment in the history of space exploration, both for the important event that we celebrate this year, the 60th anniversary of humankind's first spaceflight, but also for the outstanding achievements that the space community accomplished in the past year and months," said IAF President, Pascale Ehrenfreund, during her opening remarks. "We all know the importance of space exploration: it helps us to address fundamental questions about our place in the universe and the history of our solar system. And most importantly, through addressing the challenges related to human space exploration, we expand technology for the benefit of our citizens on Earth."

GLEX 2021 occurred on the 60th anniversary of Yuri Gagarin's spaceflight, an auspicious occasion now that several national space agencies have plans to launch crewed missions to the moon and commercial launch companies are beginning to launch astronauts into low Earth orbit. To commemorate the occasion, IAF President, Pascale Ehrenfreund awarded ROSCOSMOS with the IAF's special award, which was accepted on behalf of the agency by its Director General Dmitry Rogozin, who used the opportunity to underscore the importance of international cooperation in space.

"The award signifies the importance of the efforts that are aimed at strengthening international cooperation and mutual support in outer space, which is important for all of us," Rogozin said. "For those who are ready to rush forward into outer space, this kind of support is an essential factor to promote the expansion of mankind into outer space."

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Rogozin dedicated GLEX 2021 to “all the pioneers that paved the way to outer space and all the designers and engineers that created the spacecraft and took those risks.” His remarks were followed by a welcome message from Alexander Beglov, the Governor of St. Petersburg, who discussed the rich history of space exploration in the city, where Russian engineers started working on a rocket engine 100 years ago, and its continuing role in building Russia’s burgeoning space industry.

Ivan Abramov, the Deputy Chairman of the Federation Council of the Federal Assembly, spoke about the importance of space exploration to his home region in Russia’s far East. This is the location of the Vostochny Cosmodrome, a sister spaceport to Russia’s Baikonur cosmodrome, that is located about 8 000 kilometers away from Moscow. Abramov said the region welcomes the space industry and now employs thousands of scientists and engineers working at the spaceport. “The space industry has always been a driver that promoted scientific advancements and we saw the fruits of these advancements in our homes later on,” Abramov said.

Denis Kravchenko, Deputy of the State Duma of The Federal Assembly, also highlighted the importance of the space industry for driving science and technology advancements as well as the benefits of increased cooperation in space exploration between the private and public sectors. “The coronavirus pandemic and the economic downturn has been a significant challenge for the entire humankind,” Kravchenko said. “But we need to review this as a window of opportunities to enhance our capabilities and to scale up. I am sure that we will find new opportunities for cooperation that would enable us to make further steps towards continuing space exploration.”

The GLEX opening ceremony concluded with a message from two cosmonauts on board of the ISS, who sent their greetings and welcome addresses to several international ministers, including Rashad Nabiyev, Minister of Transport, communications and high technologies of the Republic of Azerbaijan, the location of the 2023 International Astronautical Congress. ■

GLEX 2021

Plenaries

60th Anniversary of Gagarin's Flight

GLEX 2021 took place on the 60th anniversary of Yuri Gagarin's historic spaceflight. To commemorate this occasion, more than 15 cosmonauts and astronauts took the stage for the first plenary to discuss Yuri's legacy and what this historic spaceflight meant to them.

On April 12, 1961, a 27-year old pilot from the Soviet Union forever changed the world when he became the first human to fly to space. Yuri Gagarin's historic spaceflight opened the door to the cosmos and a new frontier for human exploration. To commemorate this historic event, 18 astronauts and cosmonauts gathered for the first GLEX plenary to discuss Yuri's legacy and what this historic flight meant to them.

The session opened with introductory remarks from Austrian Astronaut Franz Viehbock, who moderated the session, and pointed to ways that Gagarin's flight changed our perspective on all manner of terrestrial affairs. "He was the first to go into space and look back down on our planet,"Viehbock said. "He saw the beauty of our planet and he talked about protecting our environment and living here in peace. This message from Yuri Gagarin is more than ever valid."

Jean-Loup Chrétien, a French Astronaut and CEO of Tietronix Europe, described starting in the French Air Force Academy two years before Gagarin's flight with dreams of becoming a fighter pilot. But the impact of Gagarin's flight changed his life and after witnessing that historic moment he decided to become a cosmonaut. Sergey Krikalev, a Russian Cosmonaut and Executive Director for Human Space Flights at ROSCOSMOS, also acknowledged Gagarin's impact on his decision to work in the space sector. "I still remember 1961 and I was thinking about what to study and what to do, then mankind was in outer space and there was science fiction available," Krikalev said.

German Astronaut Ulf Merbold emphasized the importance of pioneering explorers like Gagarin in advancing the state of scientific knowledge. "Without him, we would not have been able to go into space and perform scientific work," Merbold said. "I think for that reason his name will be in the history books for eternity." American Astronaut Mike Baker highlighted the incredible progress in space exploration that we've made since Gagarin's flight, noting that there have now been 566 people who have spent a total of 29 000 person days, or 77 total years, in space.

Alexander Alexandrov, Cosmonaut and General Directors council, S.P. Korolev Rocket and Space Corporation Energia, recalled his experience as an engineer working on the cosmonaut lunar programme at Star City where he would get to work alongside Yuri Gagarin who was head of the pilot's programme. "Yuri was an excellent person, he

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was always smiling," said Alexandrov. "He is a role model for all of us and we will look up to him when we teach the next generation."

UAE Astronaut Hazzaa Al Mansoori is one of those next generation of astronauts who was inspired by Gagarin's historic flight. As the first astronaut from his country, he said his mission is to inspire the youth in his country to pursue spaceflight much like Gagarin inspired him. "He ignited that spark I carried with me in my life to become the first Emirati astronaut," Al Mansoori said. "He's young, he's committed, and anyone can do it. We have a young generation with the strength to say we can also be an astronaut." This point was also emphasized by Oleg Kotov, Cosmonaut and Deputy Director for science at the Institute for Biomedical Problems of the Russian Academy of Sciences (IBMPRAS), who said the next generation will be looking at the first people to go to space as an inspiration for future exploration.

Canadian Astronaut and former Governor General Julie Payette recalled her time working in Russia on the International Space Station and finding a plaque that had a quote from Gagarin about how you can not see borders from space, only one world shared by us all. Payette said a copy of this plaque still hangs in her home as a reminder of the importance of working together to advance knowledge and continue exploring space.

Jean-François Clervoy, a French Astronaut and the Founder of AirZeroG, remembered learning a song written about Gagarin when he was learning Russian and said he convinced his crew to sing that song with him once they were in space on a resupply mission to Mir. He recited the song for the GLEX audience and the whole crowd clapped in rhythm.

Romanian Astronaut Dumitru-Dorin Prunariu recalled listening to a radio broadcast as a child that was interrupted by the broadcaster to announce Gagarin's flight into outer space. "I remember myself staying behind the skirts of my mother and listening to what my neighbors said," Prunariu recalled. "No one would believe that 20 years after his flight, I would become the Gagarin of Romania." He told the audience that he carried Gagarin's image of a united Earth with him into space with the goal of continuing Gagarin's dream of using spaceflight to make the world a better place.

Reinhold Ewald, a German Astronaut and Professor of astronautics at the University of Stuttgart, recalled his career working in control centers with all the support personnel who make human spaceflight possible. Although few of them would ever go to space, they were there supporting the vision and dream of human spaceflight in the spirit of Gagarin, who continues to inspire men and women working all different positions in the space sector.

The session concluded with a speech from Andy Turnage, the Executive Director of the Association of Space Explorers (ASE), who unveiled a universal insignia for all astronauts to wear into space and carry on Gagarin's legacy of unity in exploration and on Earth.

High-Level Space Leaders

In the first of two panels, high-level space leaders from around the world came together to discuss their current and future space exploration initiatives. The five leaders who spoke during this session especially focused on their lunar exploration plans as well as their hopes for further international cooperation in low Earth orbit and planetary missions.

The plenary opened with Dimitry Rogozin, Director General of ROSCOSMOS, who described Russia's plans to launch a crewed mission to the Moon. The missions will begin with an uncrewed launch called Luna 25 perhaps as soon as this year. He highlighted Russia's plans to cooperate with China on later lunar missions in 2026 and 2027 to explore the moon's south pole. Rogozin remarked on the young age of the programme's engineers and underscored the importance of maintaining a robust space exploration programme to pass knowledge from one generation to another. "Space technologies live as long as the people who made these technologies live," said Rogozin. "If you do not establish a tradition of handing over the knowledge from the older generation to the younger one, you will have a gap and have to make everything from scratch again."

Yanhua Wu, the Vice Administrator of the China National Space Agency Administration (CNSA) spoke about the country's work on its space station, which he said should finish construction by 2022. China is also developing plans for lunar exploration in cooperation with Russia and other national partners. Wu announced China's intention to publish a roadmap for an international lunar research station that will be open for international cooperation with other agencies. "We will try to follow the principles of openness and sharing," Wu said. "Win-win cooperation was the purpose of strengthening communication with other nations and to jointly advance progress in space science as well as social and economic development."

Simonetta Di Pippo, Director of the United Nations Office for Outer Space Affairs (UNOOSA), acknowledged that the UN is seeing an increasing demand for international partnerships and applauded these efforts. But she underscored the need for these commitments to abide by legal frameworks that guide behavior in space, which must be further

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developed through a multilateral effort to address the challenges and opportunities of more countries working in space. “A bright future is ahead of us in space exploration, but it must be one driven by responsibility and sustainability,” she said.

Hiroshi Yamakawa, President of the Japan Aerospace Exploration Agency (JAXA), highlighted the results from the country’s ambitious Hayabusa-II mission to collect samples from an asteroid as well as Japan’s contributions to the NASA-led Artemis lunar mission. In addition to providing life support missions for the Artemis lunar gateway, Yamakawa said that Japan intends to launch the world’s smallest spacecraft to ever land on the moon by the end of the year as well as an uncrewed rover to explore water resources around the lunar South Pole. Yamakawa also touched on current and future planetary exploration initiatives such as the Venus Climate Orbiter and a 2029 mission to return samples from the Martian moon, Phobos.

K. Sivan, Chairman of the Indian Space Research Organisation (ISRO), celebrated the data returned from the Chandrayaan-2 lunar orbiter, which was launched in 2019 and continues to study the moon’s atmosphere from orbit. He also highlighted ISRO’s plans to launch a mission to Mars, as well as the country’s second mission to Venus, which are currently under development. Finally, he said the country plans to demonstrate a crewed mission to orbit by the 75th anniversary of India’s independence in 2022 or 2023.

Grzegorz Wrochna, President of the Polish Space Agency (POLSA), described his agency’s contributions to the European Space Agency and the country’s interest in developing scientific instruments, Earth observation satellites, and telecommunications technology for space applications. He highlighted Poland’s growing number of space businesses and the country’s ambition to build its own satellite constellation. “We do not have a very extensive space heritage, but we have very ambitious plans,” Wrochna said. “And of course we count on international cooperation.”

High-Level Space Leaders

In the second of two panels, high-level space leaders from around the world came together to discuss their current and future space exploration initiatives. The seven leaders who spoke during this session especially focused on their lunar exploration plans as well as the need for clear regulatory frameworks to enable cooperation for the future of space exploration.

The second plenary for high-level space leaders opened with remarks from Dmitry Rogozin, the Director General of ROSCOSMOS, who focused on the need for clear regulatory frameworks to enable the next phase of space exploration and how the regulatory environment is changing as more countries engage in deep space exploration. A key aspect of the future of space exploration is managing the thousands of space objects that will be launched in the coming years both by national space agencies and private companies. He called for increased cooperation in monitoring the space environment to prevent collisions, which pose a threat to all spacefaring nations. Rogozin also highlighted the need for a regulatory framework around using in-space resources, which will be key to establishing long term crewed habitats on and around the Moon.

"Russia believes that states must adopt any laws and regulations because space is our common heritage and belongs to everyone," Rogozin said. "We consider the United Nations a suitable venue to discuss these issues because we consider it necessary to address some of these issues in a bilateral and multilateral format."

Bill Nelson, the Administrator for NASA, called in remotely and discussed both the agency's focus on using space assets to monitor climate change as well as the upcoming Artemis lunar missions. Nelson highlighted the importance of having a broad and diverse coalition of national space agencies and private companies involved with the return of crewed missions to the Moon. He said that space exploration is a reminder that Earth is one planet and it is critical that everyone works together to achieve common goals. "Having participated in a space shuttle flight, I was struck looking out the window by what I saw," Nelson said. "I did not see political divisions, religious divisions, or racial divisions, what I saw is that we're all in this together. Even countries that have differences, we can cooperate in space."

Josef Aschbacher, Director General of the European Space Agency (ESA), had only started his position a few months before GLEX, but he said these first few days at the helm of the agency have defined Europe's goals in space for the coming years. He spoke about the ESA's commitment to using space assets for planetary protection in the context of climate change as well as the European Union's ambitions for space exploration. For example, the ESA is working with NASA on their Mars sample return missions as well as serving as a critical partner developing technologies for the Artemis lunar gateway. "Europe wants to continue working with the major space powers to really help explore our universe and our solar system in order to really make sure that we will understand what is happening around us and where we come from," Aschbacher said. "These are very central questions of humankind in general."

Lisa Campbell, President of the Canadian Space Agency (CSA), said that Canada is "all in on space exploration." She says the Canadian Space Agency has set its sights on the Moon and is leveraging its expertise in robotic arms to enable the Artemis lunar gateway mission. The agency is also developing a lunar rover that it hopes to land on the Moon within five years and is also contributing to international Mars missions, including the sample return mission. "All of these missions are setting the foundation that will enable future human exploration and recommend a quick plan for humanity's exploration into deep space will continue to spur innovation and create new technologies that have applications here on Earth," Campbell said.

> "Europe wants to continue working with the major space powers to really help explore our universe and our solar system in order to really make sure that we will understand what is happening around us and where we come from"

Plenary 2B

Salem Al Marri, Assistant Director General for Science and Technology and Astronaut Program Manager at Mohammed Bin Rashid Space Centre (MBRSC), gave an update on the Emirati space programme, which successfully launched its first probe to Mars last year. He pointed to the HOPE Mars mission as a shining example of international cooperation and what can be accomplished when national space agencies work together. Al Marri also discussed the United Arab Emirates' plans to explore the Moon by building a rover that may launch next year, as well as the country's growing astronaut programme, which currently has four astronauts training at NASA's Johnson Space Center. "International collaboration is a big part of making space a success, especially when you're looking at small countries," Al Marri said.

Christian Hauglie-Hanssen, Director General of the Norwegian Space Agency (NOSA), spoke about how his agency is contributing to ESA's exploration goals as well as further developing its own space industry within the country. He focused on the importance of communicating the value of space exploration to politicians, who ultimately decide how to allocate funding to exploration programmes. A key part of this, he said, is to highlight the role that space places in the commercial and industrial sectors that develop the technologies that enable deep space missions. Even small countries have specialized niches where they can make big contributions to space exploration, and Hauglie-Hanssen recommended focusing on these specialized talents. "As a small country, we need to demonstrate that our contribution provides a real difference," he said. "This is the only way that we can become an important player in big programmes. And progress within exploration must be fed back into the non space sectors, thereby providing technology competitiveness also in other fields."

Giorgio Saccoccia, the President of the Italian Space Agency (ASI), also focused on international collaboration and spoke about how the ASI's contribution to the International Space Station provided a roadmap for contributing to the human exploration of the Moon. He said ASI is discussing possible contributions to the Artemis programme for shelters and telecommunications systems, while also contributing to the European goals of developing robotics for the exploration of Mars. "Exploration is the field which reflects the DNA of ASI which is prone to international collaboration," he said. "Exploration is the field of space applications that is most able to implement this attitude."

Going Forward to the Moon

Space industry leaders from Germany, the United States, Italy, the UAE, and Russia met to discuss the technologies they are developing to enable crewed lunar exploration in the coming years. Each panelist discussed the unique contribution made by their company and country to future lunar exploration, ranging from technologies for extracting oxygen from lunar regolith to developing habitation modules that will be able to host crews for weeks at a time in lunar orbit.

The world is preparing to return humans to the lunar surface in just a few years and this ambitious programme is fundamentally built on international collaboration and partnerships with space industry leaders. During the third GLEX plenary, leadership from ROSCOSMOS and high-level executives from space companies representing four countries met to discuss how they are developing new technologies to enable humanity's next "great leap."

The session opened with remarks from the plenary moderator Alain Bories, Senior Vice President of Business Development and Political Affairs for OHB System AG, who described the 2020s as "the decade of the Moon." As Bories pointed out, the new push for lunar exploration has given rise to "new technologies, new partnerships, and new business models," which were discussed in depth throughout the session.

Vincenzo Giorgio, President of Institutional Marketing & Sales at Thales Alenia Space and CEO of ALTEC S.p.A. in Italy, described how the company has leveraged decades of experience in low Earth orbit, especially on the ISS, to develop systems that will enable lunar exploration. He described how the company is working on three axes with regard to lunar exploration. First, Thales Alenia was tapped as the prime contractor for the international habitation module on the lunar gateway. Second, they are working on the HALO program, the module where astronauts will work when they visit the lunar gateway. And finally, Thales Alenia is working on developing surface operation technologies, particularly around mobility and communication.

Salem Al Marri, Assistant Director General for Science and Technology and Astronaut Program Manager at Mohammed Bin Rashid Space Centre (MBRSC), discussed how the UAE is excited about pursuing lunar exploration as a stepping stone for its long term ambitions to put humans on Mars. He described the UAE's Rashid rover, which will explore the lunar surface and will be the country's first spacecraft to land on another celestial body. Al Marri said the country's objective is to launch the rover by next year and then launch a second rover that carries more instruments by 2025.

Andreas Lindenthal, the Head of Business Operations Space Systems, Head of Spacecraft Equipment, and Head of Space Systems at Airbus Defence and Space in Germany— as well as an IAF Vice President in charge of the IAF Global Networking Forum— described his vision of a "self-sustaining lunar ecosystem for the benefit of society at large." Lindenthal discussed the numerous opportunities that the lunar research programme created for European industry, including developing the technologies for a permanent lunar transfer capability for Europe to get down to the Moon and technologies that enable astronauts to live offworld. In particular, he pointed to the development of ROXY, a technology that can extract oxygen from lunar regolith.

Kyle Acierno, the CEO of ispace technologies US, described how the company is developing HAKUTO, the first privately financed mission to another planetary body. The mission is scheduled to launch next summer and will involve international collaboration with both national space agencies and other private companies— including companies that do not typically work in aerospace. "This was very important to us to build a bridge between the space community and the non-space community," Acierno said. "As we grow as a sector, it is going to be very important for us to continue to bring in non-space companies and I am very happy that for this first mission we have been able to do that."

Sergey Krikalev, the Executive Director for Human Space Flights at ROSCOSMOS, discussed how the agency decided to work on both robotic and human missions on the lunar surface. "In Russia, we have had a long discussion about whether we should study the Moon by automated vehicles or do we need to send people," Krikalev said. "Finally the decision was made that we should not oppose human and robotic exploration, it should complement each other." Krikalev described Russia's plan to send three automated landers to the Moon while Russia continues to develop its crewed landing capabilities. Ultimately, Krikalev said, the Moon is a stepping stone for Russia to fly deeper into the solar system.

Lutz Bertling, a Member of the Executive Board of OHB SE and Chief Strategy and Development Officer & Chief Digital Officer OHB Group, called in remotely to the panel to offer his insights about the future of lunar development and OHB's involvement in the new push for lunar exploration. "Clearly, within the decades to come, the lunar ecosystem can be expected to be developed," Bertling said. "Our founder has always had a special devotion to the Moon and in fact was the first to send a privately funded mission to the Moon's orbit." For the next phase of lunar exploration, Bertling said OHB has partnered with Thales Alenia Space to develop refueling systems for the Lunar Gateway's ESPIRT module and is continuing to work on the robotic technologies that will enable lunar surface access for the European space community.

Human Roads to Outer Space:
Real and Imaginary Dangers

Space medicine experts from China, Russia, Greece, and Germany met to discuss the health hazards faced by crews headed to deep space. The panel covered many different medical challenges that will be faced by future deep space explorers, including radiation exposure, challenges with body heat, and preventative medicine.

Outer space is a dangerous place for human explorers, but not all dangers are created equal. The fourth GLEX plenary brought medical experts from Greece, Russia, Germany, and China together to discuss the real and imaginary dangers of future human space exploration missions. The panel was moderated by Anatoli Petrukovich, the Director of the Space Research Institute at the Russian Academy of Sciences, who facilitated a wide-ranging discussion about what we should really be concerned about when planning future human missions into deep space.

Bingxian Luo, an Associate Professor at the National Space Science Center in the Chinese Academy of Sciences, opened the session with his thoughts on the dangers of radiation exposure in deep space. Without the protection of Earth's magnetosphere, crews in deep space are exposed to elevated levels of cosmic and solar radiation that can create increased risk of cancer. Solar radiation varies with the solar cycle and Luo's presented preliminary research that was aimed at determining a crew's radiation exposure during a three year mission to Mars depending on when they launched in the solar cycle.

Ioannis Daglis, President of the Hellenic Space Center in Greece, discussed the multifaceted nature of human medicine in space, particularly when it comes to the risks of genetic mutations that can lead to cancer as a result of exposure to ionizing radiation. "The risks are related to both technical infrastructure and our own bodies," Daglis said. "Both are very important because if the infrastructure fails then this will have an impact on the health of astronauts. By quantifying the hazards and estimating the risks, we can design appropriate shielding." The challenge is that cancers are a complicated disease and it can be difficult to predict the specific threshold radiation dose that can cause certain types of cancer to develop from DNA mutations. Daglis suggested using robotic spacecraft to alert crewed missions of an increase in radiation levels during a solar event so they can take precautionary measures.

Vladimir Kalegaev, Head of the Laboratory of Space Research at Moscow State University, was the panels third and final speaker on radiation issues. He described how Earth's magnetosphere protects humans from solar radiation and generates radiation belts. A thorough understanding of the way Earth's magnetosphere interacts with solar and cosmic radiation could be a key method for determining how to keep astronauts safe on long duration space missions to Mars.

Oleg Orlov, Director of the Institute for Biomedical Problems of the Russian Academy of Sciences, discussed the many unknowns of human health during long duration space flight. A key question, said Orlov, is whether preventative measures should be used all the time because we still do not know the extent to which the human body can adapt to long duration space missions. Given these unknowns, he suggested that as we prepare for long duration missions to the Moon and Mars, "we should absolutely change the

principles of medical support for these missions because they cannot be organized on the basis of our experience in low Earth orbit."

Hanns-Christian Gunga, the Deputy Director at the Institute of Physiology in Germany's Center for Space Medicine and Extreme Environments, focused on the well-known problem of fluid shift that occurs during spaceflight and related issues. When astronauts are exposed to micro-gravity for long periods of time, fluids tend to pool in the upper body. A related issue is the problem of heat exchange. In space, humans tend to have a hard time getting rid of heat from their body, which becomes especially noticeable during exercise. In some cases, astronaut body temperatures rose to nearly 40 degrees, which Gunga said could be approaching dangerous levels. The effect is that the body is in a state that looks similar to a fever or an infection during long term space flight.

> "We should absolutely change the principles of medical support for these missions because they cannot be organized on the basis of our experience in low Earth orbit"

It will be necessary to get a better understanding of human physiology in space before human crews set out for long duration missions to the Moon or Mars. But the work of the panelists who presented during this plenary, as well as their colleagues, are laying the foundation for a more robust approach to space medicine.

ISECG:
Exploring Together – Opportunities, Challenges

The final GLEX 2021 plenary focused on the opportunities and challenges of cooperation in deep space exploration. The panel featured high-level representatives from six national space programmes who discussed their experiences and hopes for the future in terms of collaboration on shared exploration goals.

The fifth and final GLEX 2021 plenary focused on the opportunities and challenges of cooperating on deep space exploration, as well as the role that the International Space Exploration Coordination Group (ISECG) can play in engaging emerging space agencies. The panel was moderated by IAF President Pascale Ehrenfreund and featured Salem Al Marri, the Assistant Director General for Science and Technology and Astronaut Program Manager, Mohammed Bin Rashid Space Centre; Christian Lange, the ISECG Chair and Director of Space Exploration Planning, Coordination and Advanced Concepts at the Canadian Space Agency; Gwanghyeok Ju, ISECG Emerging Space Agencies Working Group Co-Chair and Principal Researcher at Space Exploration Research Division in the Korea Aerospace Research Institute; Anthony Murfett, the Deputy Head of the Australian Space Agency; Salvador Landeros, the Director General of the Mexican Space Agency; and Grzegorz Wrochna, the President of the Polish Space Agency.

Ehrenfreund opened the session by describing the role of the ISECG, which was created in 2007 to coordinate space exploration activities between national space agencies. The ISECG regularly produces global exploration roadmaps, the most recent of which was released in 2018 with a supplement report on lunar surface exploration released last year. As a sign of the rapidly growing space sector, when the ISECG released its most recent global exploration roadmap in 2018, there were only 15 member agencies; today, there are 26.

Lange provided a detailed overview of ISECG since its founding and described the evolution of its goals. “The key was really to present a vision for robotic and human

space exploration and focusing on destinations in the solar system where we may one day work and live," Lange said. "In 2007 that still sounded like science fiction but with recent developments, things have changed and become a lot more real now."

Ju offered the perspective of the ISECG's emerging space agency working group, which consists of 30 members from 12 state agencies. "Our initial focus is on information sharing on each agency's activities to identify common interests and areas for potential collaboration," Ju said. "We are planning to collect new ideas and messages to promote collaboration between the emerging and established space agencies, and also come together with the private sector."

Al Marri discussed the two primary challenges that are typically faced by smaller countries and emerging space agencies when it comes to space exploration. First is the problem of a sufficient budget. He said that can be partly solved with cheaper solutions, such as sending scientific payloads to the Moon on commercial missions. But the more important challenge, he said, is securing the political will in smaller countries that are not used to spending money on space exploration. "When you look at space exploration, everyone in this room knows what the benefits are," Al Marri said. "But communicating that to political leaders who will be supporting these programmes in the long term is a key factor."

> "In 2007 that still sounded like science fiction but with recent developments, things have changed and become a lot more real now"

Landeros offerened an overview of the Mexican Space Agency's plans for deep space exploration as well as the challenges associated with being such a young space agency. Landeros described the agency's collaboration with the National Autonomous Mexican University, the largest public university in the country, which is developing tools to demonstrate the feasibility of building structures on planetary surfaces using robotic swarms. He said one of the biggest challenges for the agency is finding overlap between Mexico's national goals and those of other space agencies that create opportunities for collaboration, which requires the support of ISECG as well as the space agencies themselves.

Murfett discussed the challenges associated with defining a new space agency's role in international exploration. "When we established the Australian space agency in 2018, we had to ask: What is Australia's role in space?" Murfett said. The first thing the agency did was release a civil space strategy that highlighted Australia's strengths, both as a signal to its domestic industries as well as potential international partners. Murfett said the key was looking for Australia's strengths in other sectors, such as mining and asset management, and finding ways to translate those robust skill sets into the space sector.

Wrochna identified three key ideas on the role of emerging agencies in international collaboration. First, emerging space agencies can take advantage of low cost, mass produced components to build satellites that carry useful payloads on board but are not prohibitively expensive to make. Second, he said it is key for the agency to work with industry, which can provide important technologies and scientific insights to enable an emerging agency to accomplish its goal. Finally, Wrochna said the agency can focus on integration by being the connecting layer among many disparate actors that brings their work together to create a mission, rather than the agency trying to do it all on its own in-house. "It is a different story with large missions, where we have to rely on international cooperation," he said. "But here comes the role of the ISECG to facilitate this bridging process if we want to connect our science and our industry to some long term goals." ■

GLEX 2021

Highlight Lectures

HLL

Space Transportation System of Human Mars Exploration

Xiaojun Wang, the President of China Academy of Launch Vehicle Technology and IAF Vice President, gave a talk discussing concepts for space transportation systems that would enable the human exploration of Mars.

President of China Academy of Launch Vehicle Technology and IAF Vice President Xiaojun Wang outlined the preliminary results of an International Academy of Astronautics study that examined space transport systems for the human exploration of Mars. Now that China has successfully sent its first orbiter, lander and rover to the Red Planet, it is national space agency and space industry leaders are beginning to turn their sights to the crewed exploration of Mars. One of the biggest challenges with crewed exploration is developing a space transportation system that can get the crew to Mars and back safely.

Wang began his presentation with an overview of the Tianwen-1 mission, which entered into Mars orbit in February and landed on the surface in May. The unique Tianwen-1 mission was a combination of an orbiter, lander, and rover, the first time that all three spacecraft have been combined into a single mission. The lander carried six scientific payloads to study the surface conditions around the landing site.

Compared with the robotic exploration of Mars, Wang said that the human exploration of Mars is "of greater significance in the exploration for extraterrestrial life." Humans are better equipped to search for elusive signs of ancient life, which may be very rare on the surface if they exist at all. Wang outlined an overarching mission architecture that could enable a human mission to the Martian surface. There are a number of tradeoffs that will have to be made for the mission, including when and where it is launched, the type of propulsion used, and how long the mission will last, all of which will affect the amount of time that humans are in transit.

Next, Wang outlined a development roadmap. It begins with robotic exploration that will scout and characterize potential landing sites as well begin initial construction activities involving in-situ resources. The next stage involves humans orbiting Mars and eventually doing short trips to the surface.

This stage may also include the initial construction of a Mars base. Once these preliminary phases are complete, it will lay the foundation for routine missions to Mars and the development of large scale Earth to Mars transportation fleets.

Finally, Wang introduced the system design of his proposed transportation system. In Wang's vision, there are four different stages of the mission architecture— the Earth ascent stage, the Earth space ferry, the Earth-Mars transfer, and Mars space. The Earth space stage would consist of seven heavy launch vehicles and one human launch vehicle, all of which use chemical propulsion and would carry all the space systems needed for the mission. The Earth ferry stage would use an electric or nuclear-electric propulsion system and would be responsible for the Earth-Mars cargo and crew transfer. The Earth-Mars transfer stage would use nuclear-thermal propulsion and consist of a Mars ascent-descent vehicle, a Mars lander, a deep space habitat, and a crewed spacecraft. Finally, the Mars space phase would use chemical propulsion to deliver crew and cargo to the surface of the Red Planet.

It is an ambitious proposal and Wang acknowledged that there were many key technology challenges. These include advanced propulsion technologies like a nuclear-thermal engine, precision guidance and control technologies, robust interplanetary communication technologies, and the design of lightweight thermal protection structures. But despite these challenges, Wang is optimistic that the design architecture is feasible and worth pursuing.

"Mars exploration is of great significance to human beings," Wang said. "It is an important way for human beings to get out of the cradle of the Earth, explore the origin of life and expand our living space. We are willing to join hands with our counterparts all over the world to realize the dream of mankind going to deep space and walking on Mars."

UAE National Space Program

During the second GLEX Highlight Lecture, Adnan Al Rais, the Senior Director of the Remote Sensing Department and the Program Manager of Mars 2117 at the Mohammed Bin Rashid Space Centre (MBRSC) discussed the United Arab Emirates' National Space Program including the UAE astronaut program and the country's ambitions on Mars.

Mars has had a busy year. Three independent missions have recently arrived at the Red Planet, including NASA's Perseverance Mars Rover, China's Tianwen-1 probe, and the United Arab Emirates' HOPE orbiter, which represented the country's first deep space mission. For the second GLEX Highlight Lecture, Adnan Al Rais the Senior Director of the Remote Sensing Department and the Program Manager of Mars 2117 at the Mohammed Bin Rashid Space Centre, discussed how the country will build on the HOPE mission to expand its Mars presence and continue to build its space exploration programs.

Al Rais began by detailing the four pillars of the UAE Space Program before going into detail about how the country is pursuing each of its four main space goals. The first pillar is the UAE satellite development program, which started in 2006. The program grew out of a Technology Know-How Transfer program with South Korea that resulted in the development of the UAE's first satellite that launched in 2009 and a second satellite in 2013. After that, Al Rais said the UAE was able to develop its first satellite entirely independently, which was developed for Earth monitoring. Since then, the UAE has continued to develop its satellite development capabilities including an emissions monitoring satellite launched earlier this year and another high-resolution Earth monitoring satellite currently under development.

The second pillar is the Emirates Mars mission and continued Martian exploration. The HOPE satellite arrived in Mars orbit in February and was developed through an international collaboration with American universities and NASA. The goal of the HOPE mission is to study the Martian atmosphere and develop a holistic picture of its day and night variations. Al Rais provided some examples of the data that is being collected by the HOPE orbiter and said the UAE will make the data available for study by the international space community.

The third pillar is Mars 2117. This is the name of the UAE's 100 year vision to build a human settlement on Mars. The Mars 2117 program is built around a roadmap that outlines the key steps that will enable the country to reach this ambitious goal, including science and technology development, education, building a national space ecosystem of universities, research institutions, and industry, and international collaboration. "We developed our strategy so that it is in alignment with a global exploration roadmap," Al Rais said. "There are gaps in the global exploration roadmap in terms of technology and science and we are focusing on contributing to the overall implementation of the roadmap."

The fourth pillar is the UAE astronauts program. The UAE launched its first astronaut to the ISS in 2019 and has continued to recruit more Emiratis into its astronaut corps, including its first female astronaut. Al Rais said that currently two of the UAE's astronauts are training with NASA at the Johnson Space Center in Texas in preparation for upcoming spaceflights. The UAE astronaut program is a critical piece of its Mars 2117 mission, which will use human flights to the Moon as a gateway to the Red Planet. Al Rias concluded the session by underscoring the importance of international collaboration in the UAE's space program and invited other countries to work with the UAE to further their space exploration goals together.

"We have partners from different parts of the world and international collaboration is an integral part of all of our programs," Al Rais said. "We're going to continue doing that with all of our programs. We work with everyone and we have since day one." ■

GLEX 2021

IAF Global Networking Forum (IAF GNF)

Global Networking Forum
Meet. Share. Connect.

Tuesday
26 October 2021

Tuesday's IAF Global Networking Forum sessions covered many different aspects of the robotic and human exploration of the Moon and Mars. The day began with an overview of the science and exploration achievements of NASA's new Perseverance rover, whose mission includes demonstrating key technologies for a human Mars mission. Later in the day, representatives from the ESA, NASA, and several commercial exploration partners discussed various technologies ranging from habitat architecture to communication systems that will enable humans to live and work on the lunar surface as a stepping stone toward the Red Planet.

Perseverance, Ingenuity, Mars Science and Exploration

During Tuesday's first GLEX 2021 IAF GNF session, IAF President Pascale Ehrenfreund was joined by four scientists involved with the Perseverance mission to discuss the future of Mars science and exploration. The session began with a comment from Lori Glaze, Director of NASA's planetary science division, who highlighted three main goals for the rover: understanding the 4-billion year history of the rover's landing site, studying the crater for signs that it had the conditions for life, and preparing for human Mars exploration with technology demonstrations and experiments.

Matt Wallace, the Perseverance Project Manager, described the immense challenges involved with setting a car-sized rover down safely on the surface of Mars and the amazing results from Ingenuity, the rover's rotorcraft companion, which became the first aircraft to ever take flight on another planet. Ken Wilford, the Perseverance deputy project science, and Veronica Peinado Gonzalez, the MEDA Operations Engineer, discussed many of the instruments on the rover that are key to its scientific programme, including SHERLOC, PIXL, and MEDA, which help the rover characterize and map its local environment.

The session concluded with Sandra Siljeström, Research Scientist at the RISE-Research Institutes of Sweden, who gave an overview of the planned mission to collect samples cached by the Mars rover and return them to Earth. The sample return mission is a critical aspect of determining whether life existed on Mars because it allows scientists to analyze the samples with more sensitive machines on Earth.

Lunar Surface Infrastructure

Tuesday's second IAF GNF Session was on lunar infrastructure, which is a critical part of the International Artemis program led by NASA. During a session led by Maria Antonietta Perino and Eleonora Zeminiani, who are involved in human exploration initiatives at Thales Alenia Space in Italy, representatives from the ESA, NASA, and several commercial contractors including LIQUIFER Systems, Thales Alenia Space, Boeing, and Blue Origin discussed how they are contributing to the creation of lunar infrastructure, including payload delivery, orbital habitats, and basecamp construction.

The International Space Station (ISS) has provided a lot of insights into what is needed to live and work in space, but the panelists all highlighted that leaving low Earth orbit comes with many new challenges. In order to live and work in cislunar space, it is necessary to protect crew members from dangerous radiation and develop technologies that enable in situ resource utilization to reduce the amount of material that must be imported to the Moon from Earth. This is especially critical for life support infrastructure, including lunar habitats and resources like breathable oxygen. It will also be necessary to establish a robust communications infrastructure to expand lunar surface operations beyond missions that require line of sight communications with the Earth.

But as John Connolly of NASA's Human Systems Landing Program pointed out, the development of lunar infrastructure is about more than the Moon. It is a proving ground for testing the technologies that humans will eventually need to live on Mars. Many of the same technologies that will enable a permanent human presence on and around the Moon will provide the foundation for Martian exploration.

Enabling Science and Exploration

For Tuesday's final IAF GNF session, IAF President Pascale Ehrenfreund moderated a discussion between Lisa May and Kerry Timmons, two representatives from the Lockheed Martin Corporation. May is the Chief Technologist for commercial and civil space programmes and Timmons is the systems engineering design and integration senior manager for Orion, and both women emphasized the importance of enabling science and exploration on the Moon and beyond through their work on next-generation spacecraft systems.

Timmons opened the session with an update on the development of Orion, the spacecraft that will carry astronauts to the Moon in 2024 as part of the Artemis program. But before the astronauts arrive, Orion will embark on a series of demonstration missions. Artemis I is expected to launch later this year on an uncrewed mission around the Moon and back to Earth that will last for around a month and carry several technology demonstration payloads. Timmons said this would be followed by a crewed Artemis II mission that will carry humans around the Moon and back to Earth before culminating with a lunar surface landing with Artemis III.

May discussed key technologies that will enable humans to live and work on the moon, such as mobility, power, and communication systems. Each of these systems is critical to establishing a permanent human presence on the moon and will enable unprecedented advances in lunar science. But as both Timmons and May pointed out, the moon is just the beginning. The same technologies that enable lunar science and exploration will also allow humanity to make its next great leap to Mars. Although that mission is still a decade away, Timmons and May discussed how Lockheed Martin is already preparing for the mission by creating a Mars Basecamp roadmap to develop key technologies that will enable a crewed expedition to the Red Planet.

Wednesday
27 October 2021

The second day of IAF Global Networking Forum was packed full of diverse discussions on topics including forecasting space habitability, international lunar research stations, and building a sustainable lunar economy. The day also featured a panel with astronauts and cosmonauts from around the world, who spoke about their experiences in spaceflight and what to expect for the future of human space exploration.

Forecasting Space Habitability

The first IAF GNF session of the day was focused on forecasting space habitability. The session was moderated by Justin Walsh, an Associate Professor of art history and archaeology at Chapman University and Jean-François Clervoy, an Astronaut and the Founder of AirZeroG. Its featured speakers included Andrea Boyd, the Deputy Lead of Astronaut Operations and EUROCOM at the European Astronaut Centre; Octave de Gaulle the Director of the Spade Agency; Sandra Häuplik-Meusburger, a Senior lecturer at TU Wien's Institute for Architecture and Design in Austria; Sergey Krikalev the Executive Director for Human Space Flights at ROSCOSMOS; Julie Patarin-Jossec, a Lecturer at Saint Petersburg State University; and Ashley Shew, an Associate Professor of Science, Technology, and Society at the Virginia Polytechnic Institute and State University.

For the past 20 years, there has been a continuous human presence on the International Space Station and the speakers on the panel expected the number of humans living and working in space to significantly grow in the future. This will require reimagining what it means to live in space and moving beyond a habitat paradigm defined primarily by survival to one that is more inclusive of a broad range of human activity. Patarin-Jossec discussed how the cultural values can shape the design of a space habitat and Shew made a strong case for opening space exploration for disabled astronauts. De Gaulle discussed how he saw living conditions in space evolving toward comfort and Häuplik-Meusburger discussed the need to accommodate different values such as privacy in the design of future space architecture. Krikalev gave an astronaut's perspective on what it is like to live in space and Boyd discussed how to make operations less constraining for astronauts living in space.

IAF/ASE Astronauts Panel

The second IAF GNF session of the day was an Association of Space Explorers panel featuring 10 astronauts and cosmonauts from around the world. The panel was moderated by Reinhold Ewald, an Astronaut and Professor of astronautics at the University of Stuttgart, and Oleg Kotov, a Cosmonaut and Deputy Director for Science at the Institute for Biomedical Problems of the Russian Academy of Sciences. They fielded questions to a panel of astronauts from seven different countries: Franz Viehbock from Austria, Julie Payette from Canada, Ulf Merbold from Germany, Jean-François Clervoy from France, Sergey Krikalev and Aleksandr Skvortsov from Russia, Mike Baker from the United States, and Hazzaa Al Mansoori from the United Arab Emirates.

Clervoy began the session by speaking about the importance of zero G training for astronauts prior to going to space. Kotov also underscored the role of space analogs on the ground for preparing astronauts for long duration stays in orbit. Al Mansoori discussed how the first human spaceflight for the UAE was a major factor in inspiring the scientists and engineers that the country needs to execute on its long term vision for space exploration, including sending humans to Mars within 100 years. Krikalev discussed how control of space operations has changed now that private astronauts are beginning to fly to space and the need for implementing rules established in the past to govern these spaceflights. Baker also discussed how astronauts on the ISS handled spaceflight participants and discussed the need for establishing dedicated tourist destinations like space hotels that are an alternative to the ISS. Payette offered her advice on how to become an astronaut and Viehbock highlighted the importance of astronautics in inspiring the next generation of space explorers, scientists, and engineers.

International Lunar Research Station (ILRS)

For the third IAF GNF panel of the day, Sergey Saveliev, the Deputy Director General for International Cooperation for ROSCOSMOS, moderated a discussion between Viktor Voron, the Head of Division of the Department of Automatic Space Complexes and Systems at ROSCOSMOS, Zhaoyu Pei, the Deputy Director of China National Space Administration's Lunar Exploration and Space Engineering Center, and Yanhua Wu, the Vice Administrator of the China National Space Administration, who outlined a roadmap for the creation of the International Research Lunar Station.

In March, Russia and China signed an intergovernmental memorandum of understanding to work on an international lunar research station. The roadmap presented by the speakers during the GLEX panel was the result of months of discussions following that MOU. The goal of the ILRS is to create a space station with sophisticated experimental research facilities that are open to countries around the world who want to do research in lunar orbit. The speakers discussed the technical details of building the station, including the launch services required and the various modules that will be included on the station. The station will be constructed in two stages, the first lasting from 2026 to 2030 and the second from 2031 to 2035.

Towards a Sustainable Moon Economy

The fourth IAF GNF session of the day was organized by Airbus and Air Liquide on the topic of building a sustainable lunar economy. The session was moderated by Pierre-Alexis Joumel, the Director International & New Business, Space Systems at Airbus Defence and Space, and included Bertrand Baratte, the Space Market Director at Air Liquide; Joerg Kreisel, the CEO of JKIC; Sergey Krikalev, Cosmonaut and Executive Director for Human Space Flights at ROSCOSMOS; Bob Lamboray, a Policy Officer at the Luxembourg Space Agency; and Luigi Scatteia, the Space Practice Leader at PwC Advisory.

Multiple national agencies are planning to return to the Moon with the intention of establishing a permanent human presence, but this exciting development requires the development of a sustainable lunar economy. The speakers during this session outlined their vision for the role of the commercial space sector in this process. The group focused on key technologies that will enable a lunar economy such as in-situ resource utilization and on-orbit refueling, as well as steps that government and commercial actors can take together to support the development of a lunar economy.

Kreisel opened the panel by describing the current state of the lunar economy and his vision for how it may develop over the next decade. Scatteia underscored the critical role that government demand will play in laying the foundation for a lunar economy, which will foster the development of key technologies such as those that will enable the use of lunar resources for human exploration. Lamboray offered a government perspective and suggested that it will be necessary for many different governmental and commercial entities to be involved in order to create the demand that would foster a sustainable lunar economy. Baratte highlighted the role that the moon can play in further developing the cislunar economy by enabling more efficient access to space due to its low gravity environment. He described five key pillars that will be necessary to consolidate complex value chains to create a sustainable economy on and around the moon. Krikalev pointed to the government's role in advancing science that can lead to new technologies that enable space exploration, but may not yet be profitable for commercial industry.

Explore as One

The fifth IAF GNF panel of the day featured three representatives from NASA who spoke with IAF President Pascale Ehrenfreund on the topic of exploring as one. The NASA representatives included Kathryn Lueders, the associate administrator of the human exploration and operations mission directorate, James Reuter, the associate administrator for the space technology mission directorate, and Thomas Zurbuchen, the associate administrator for the science mission directorate.

The session highlighted the fundamental role of international cooperation, as well as industry and government collaboration in advancing ambitious space exploration missions. Zurbuchen discussed the incredible scientific advancements we can expect in the next chapter of space exploration, especially an increased human presence on and around the moon. These scientific advances provide the foundation for further human exploration in deep space, both on the moon and eventually, on Mars. Reuter discussed how his directorate is focused on understanding the deep space environment and developing technologies that will enable astronauts to explore new regions of deep space. Lueders spoke about how operations on the lunar surface will pave the way for the first human mission to Mars, which will require new technologies and mission architectures. The moon will serve as a critical proving ground for building the skills that will be necessary to send astronauts to the Red Planet and bring them safely back home again. All of the speakers acknowledged the large role that international collaboration in terms of science, technology, and policy will play in this next chapter of exploration.

Habitats, Extreme Analogues, Research, Training, Culture and Arts for Space Exploration (Heart-Case)

The final IAF GNF session of the day was on the topic of Habitats, Extreme Analogues, Research, Training, Culture and Arts for Space Exploration, a project by the IAF's Committee for the Cultural Utilisation of Space. The session was moderated by Bernard Foing, the Executive Director, International Lunar Exploration Working Group and the chair of the IAF ITACCUS committee. He fielded questions to several speakers involved with the project, including Jean-François Clervoy, an Astronaut and the Founder of AirZeroG; Agata Kołodziejczyk, the Director of Scientific Projects at the Analog Astronaut Training Center; Oleg Orlov, the Director of the Institute for Biomedical Problems of the Russian Academy of Sciences; Ioana Roxana Perrier, a Professor Space, Science and Physics at the IPSA Air and Space Engineering School; Henk Rogers, the CEO of the Blue Planet Foundation and the Chair of PISCES & HI-SEAS; and Anna Sitnikova, the Curator, Manager and the Deputy-Chair of the Moon Gallery Foundation.

The panelists discussed the many research projects occurring at space analogs around the world, including a Mars analog habitat on the side of a volcano in Hawaii. Known as HI-SEAS, this space analog has hosted several months-long missions for NASA and continues to host a variety of analog space explorers ranging from astronaut candidates to artists. The group discussed the various psychological and social issues that can come up during long duration space flights and how space analog habitats can help astronauts prepare for these situations. The speakers also detailed how they created scientific experiments for use in these analog research environments that can be translated into knowledge and research pathways that would be useful for actual space missions. But it is not all about science. Sitnikova also discussed her plans for creating the moon gallery, a collection of artworks that will be deployed on the exterior of a lunar lander and the importance of art in fostering collaboration in space exploration.

Thursday
28 October 2021

The third day of the IAF Global Networking Forum at GLEX 2021 covered a wide array of topics that included insight into China's Chang'e-5 lunar sample return mission, Europe's ambitions in deep space exploration, a media panel, and an overview of the 2021 International Astronautical Congress in Dubai.

Design and Implementation of Chang'e-5 Robotic Sample Return Mission

For the first IAF GNF session, IAF Executive Director Christian Feichtinger facilitated a discussion with Jing Peng, the Deputy Chief Designer of the Spacecraft System of the 3rd Phase of China's Lunar Exploration Program at Academy of Space Technology, who called in remotely from China to provide a detailed overview of the country's Chang'e 5 sample return mission.

The Chang'e-5 lander touched down on the moon on December 1, 2020 and returned approximately 2 kg of lunar regolith sample to Earth two weeks later. Peng outlined the key technical features of the mission, as well as the challenges that the team had to overcome to make it possible. In addition to the sophisticated flight profile of the Chang'e probe, Peng highlighted the automatic samping technologies, lunar ascent, the sample transfer on lunar orbit, and the high-speed re-entry into Earth's atmosphere as the most challenging aspects of the mission.

Global Exploration at a Cross Road: The Role of Europe

The second IAF GNF session of the day was on the topic of the role of Europe in the future of space exploration and was moderated by Pierre-Alexis Joumel, the Director International & New Business, Space Systems, Airbus Defence and Space in Germany. Joumel spoke with Silvio Sandrone, the Vice President New Programmes, Space Exploration, Airbus Defence and Space GmbH; Volker Schmid, the Mission Leader of Cosmic Kiss at the Deutsches Zentrum für Luftund Raumfahrt e.V.; and Stefaan De Mey is a Senior Strategy Officer of the Directorate of Human Spaceflight and Robotic Exploration Programs of the European Space Agency, who each offered their perspectives on the unique strengths of Europe in the global space sector.

De Mey discussed how ESA is working with industry stakeholders and its member states to create a long term space exploration strategy for the European Union. He said that the goal of ESA is to have "more European-led capabilities" and "more autonomous missions" to complement the cooperative work that is already occurring in LEO, cislunar space, and on Mars. Schmid offered Germany's view on the future of European exploration and highlighted the country's interest in further exploring on the lunar surface with robotics. Sandrone gave a perspective from European industry, which he said is particularly interested in advancing Europe's capabilities in a number of key exploration technology domains such as launch vehicles, navigation, and communication. "There is no predefined role for Europe or any other space nation," Sandrone said. "We do it because we want to be able to do certain things without asking anybody's permission and because we are a better partner when we are capable of being an equal partner."

TUA Space Program

The third IAF GNF panel of the day was hosted by IAF Executive Director Christian Feichtinger in conversation with Serdar Hüseyin Yildirim, the President of the Turkish Space Agency. TUA just applied for IAF membership and is expected to become the latest space agency to join the IAF family. On this special occasion, Yildirim provided an in-depth overview of the TUA space exploration program and the 10 main goals of Turkey's National Space Program.

Yildirim said one of the most important goals of Turkey's 10 year space programme is the country's moon mission, which will involve soft-landing a rover on the lunar surface. Yildirim says TUA expects to complete the mission within eight years. He also highlighted TUA's focus on developing a hybrid rocket engine, which has already undergone hundreds of static and flight tests. TUA is also working on consolidating its satellite manufacturing capabilities in order to expand the number and types of satellites that are built in the country.

Media Panel

For the fourth IAF GNF session of the day, Remco Timmermans, the Founder of SpaceSide, moderated a discussion between several journalists about the role that media can play in communicating complex technical subjects and the importance of space exploration to the general public. Timmermans was joined by Anastasia Medvedeva, a Journalist at Russia Today, Stephen Cole, a Journalist at CGTN Europe, Maxim Pyadushkin, a Journalist at Aviation Week, and Leif Lønsmann, a former Journalist and current Educator and Science Communicator.

The panelists discussed the challenges and opportunities for journalists and others in media in shaping public opinion around space exploration, as well as steps the space industry can take to become more accessible to the media and spread their message. The speakers all acknowledged the power and importance of social media in shaping perceptions of the space industry, but also rejected the idea that social media has undermined the importance of traditional media. As the industry prepares to launch humans to the Moon and eventually to Mars, the speakers said that it will be critical for journalists to connect what is happening in space to the benefits on Earth, which helps everyday people make a connection to the space industry.

Next Stop — IAC 2021 in Dubai

The final IAF GNF session of GLEX 2021 was a look to the future and what's in store at the 2021 International Astronautical Congress in Dubai, UAE. IAF President, Pascale Ehrenfreund, IAF Executive Director Chrisitian Feichtinger, Adnan Al Rais, the Senior Director, Remote Sensing Department and Program Manager of Mars 2117 at Mohammed Bin Rashid Space Centre, and Salem Al Marri, the Assistant Director General for Science and Technology and Astronaut Program Manager at the Mohammed Bin Rashid Space Centre discussed what visitors can expect and why hosting the annual IAC in Dubai is such an important opportunity for the United Arab Emirates.

"The IAC is the one time of the year where all global space actors come together," said Ehrenfreund. "The event attracts several thousand participants each year and covers all space sector topics. It offers everybody the latest space information, and also the developments in academia and industry."

The IAC in Dubai will be the first time the conference is hosted in an Arab country and Ehrenfreund highlighted the eminent speakers and guests who will be in attendance, including astronauts from around the world. Al Marri and Al Rais discussed the safety precautions that will be in place due to the pandemic and several of the highlights the city has to offer. ■

GLEX 2021
Closing Ceremony

After four days of discussions about the past, present, and future of space exploration, the GLEX 2021 closing ceremony celebrated yet another successful conference with speeches from the IAF President, representatives from ROSCOSMOS, and members of the GLEX 2021 International Programme committee.

The third Global Space Exploration Conference occurred nearly a year later than planned due to the global pandemic, but the wait was well worth it. IAF Executive Director, Christian Feichtinger was joined by IAF President, Pascale Ehrenfreund, as well as representatives from ROSCOSMOS and the GLEX 2021 International Programme committee to offer closing remarks following four days of phenomenal discussions about the past, present, and future of space exploration.

Ehrenfreund opened the closing ceremony by giving a word of thanks to the more than 800 attendees who came to GLEX in person representing more than 30 countries, plus the more than 1300 attendees who tuned in online from over 100 countries. She also thanked all the speakers who participated in the programme, which she said represents the growing community of space explorers.

"As the conference ends, I believe we all have the same feeling that people are persistently exploring the dream of space exploration and we see that these dreams are actually becoming reality," Ehrenfreund said. "We have seen so many new results of recent space missions, we have seen all the very interesting and diverse plans for the next decades in international cooperation, we have seen the plans of emerging space nations, and the plans of new space agencies. I think this is what it is all about."

Sergey Krikalev, the GLEX 2021 IPC Co-Chair and Executive Director for Human Space Flights, ROSCOSMOS, spoke to the historic and unique nature of the conference. "This conference has been interesting, and not only from the point of view of their scientific reports that have been delivered," Krikalev said. "It was great after a long period of time to see everybody and to communicate in a live offline format. I think GLEX will remain a part of the history of St. Petersburg because such a large number of cosmonauts and astronauts attended this conference and this city has never witnessed such a large number before."

Christian Sallaberger, GLEX 2021 IPC Co-Chair, President and CEO of Canadensys Aerospace Corporation, called in remotely to extend his thanks and well-wishes from Canada. Although he was not able to attend in person due to

pandemic travel restrictions, Sallaberger was there in spirit. "I've had to participate remotely this week and there have been many others in our international community who have done that," he said. "We wish we were there physically with you to participate in all the side discussions that happen at IAF events. We look forward to getting together physically in Dubai for the International Astronautical Congress."

The closing ceremony concluded with Ehrenfreund bestowing the awards for the best technical presentations given during GLEX 2021. The three winners were selected from a pool of more than 250 scientists and 12 finalists for their presentations on the legal framework for Mars exploration, gravity assists around Venus, and Space Bakery, a food production system for Mars habitats. ■

> "As the conference ends, I believe we all have the same feeling that people are persistently exploring the dream of space exploration and we see that these dreams are actually becoming reality"

International Astronautical Congress

25-29 October 2021 | Dubai, United Arab Emirates


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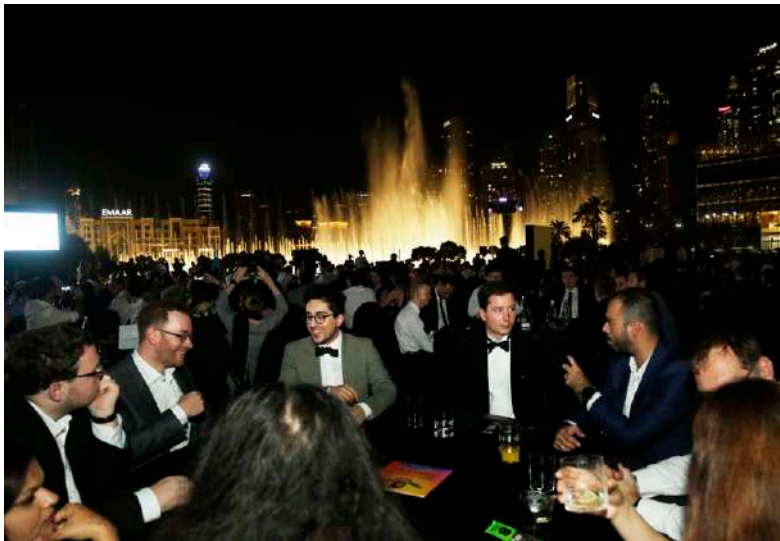


IAC 2021
Opening Ceremony

In the huge Sheikh Rashid hall of the Dubai International Convention and Exhibition Centre, the local children sang the United Arab Emirates' national anthem to start the opening ceremony of the 72nd International Astronautical Congress.

The International Astronautical Federation President, Pascale Ehrenfreund, welcomed the participants to the first ever IAC held in an Arab country. She said it was great to finally seeing everyone in Dubai and how the last two years had been very challenging. Ehrenfreund described 2021 as a year of accomplishments for the space community. She referred to NASA's Perseverance Rover; China's first Mars mission; the launch of China's Tiangong space station; SpaceX's Crew 2 Dragon mission; ROSCOSMOS launching private cosmonauts to the International Space Station; Virgin Galactic and Blue Origins successes, and the UAE's Hope probe studying the Red planet's atmosphere.

Mohammed Bin Rashid Space Centre Chairman, H.E. Hamad Obaid Al Mansoori, spoke of the UAE being the fifth country to send a probe successfully to Mars and how space would help empower the youth. Al Mansoori said that the 50-year-old nation of UAE had the dream of space from the beginning thanks to the country's founder, Sheikh Zayed Bin Sultan Al Nahyan. Al Mansoori talked of the need to invest in people and how growing crops would bring a year of prosperity but developing people would deliver 100 years of prosperity. The UAE has been building its knowledge base to help the country. Through global strategic partnership it has set the foundations for growing generations of scientists and engineers and innovators to assure UAE developments in the space sector.

After Al Mansoori, the opening ceremony turned to awards and the winner of the IAF Excellence in International Cooperation Award was Jean-Yves Le Gall, former President of the Centre National d'Etudes Spatiales (CNES) and former IAF President, he is now an IAF Honorary Ambassador. Le Gall was awarded the IAF Excellence in International Cooperation Award because he always found a way of convincing politicians that space needs international cooperation. The IAF World Space Award was given to the Japan Aerospace Exploration Agency (JAXA) Hayabusa2 team. The IAF World Space Award recognizes a person or a team who have made an exceptional impact on the world's space activities. The JAXA President, Hiroshi Yamakawa, and Hayabusa2 Project Manager, Yuichi Tsuda, received the award. Hayabusa2 has more than 300 researchers and space agency staff involved in the mission. Yamakawa and Tsuda said the mission was a perfect success, reaching the asteroid and delivering four rovers to its surface and achieving two landings at two sites to obtain separate samples. Three objects also orbited the asteroid to carry out studies. Yamakawa said Hayabusa2 was also a success for international cooperation and that it brought back 4.5 grams of sample material and is a precious stepping-stone for humanity's wisdom. Bringing the opening ceremony to a close, UAE astronauts spoke about what drove them to become astronauts and how the country's space programme would benefit all. ■

IAC 2021

Plenaries

PE

Heads of Agencies

The first plenary of IAC 2021 brought together leaders from seven of the world's top space agencies in a wide-ranging discussion moderated by IAF President, Pascale Ehrenfreund and IAF Executive Director, Christian Feichtinger. Each agency gave updates on its current activities and plans for the future while highlighting the importance of international cooperation in space exploration.

It has been a busy year for space agencies around the world. Over the past 12 months, two national space agencies have begun the robotic exploration of another planet for the first time, hatched plans for new astronaut programmes, launched astronauts on private rockets, and successfully completed the first flight on another planet. During the first plenary of IAC 2021, the head of the China National Space Administration (CNSA), Japan Aerospace Exploration Agency (JAXA), Indian Space Research Organisation (ISRO), ROSCOSMOS, the National Aeronautics and Space Administration (NASA), the Canadian Space Agency (CSA), and the European Space Agency (ESA) came together to provide updates on their national space exploration programmes and plans for the future in a discussion led by IAF President, Pascale Ehrenfreund and IAF Executive Director, Christian Feichtinger.

Director General of ROSCOSMOS, Dmitry Rogozin, began the discussion of two key accomplishments of the Russian Space Agency. First, it launched a multifunctional research laboratory to the ISS, which docked in July and was the first module of its size to be added to the space station in more than 20 years. Rogozin also described the agency's plan to launch a second module in November, which will mark the completion of the Russian segment of the ISS. Looking to the future, he highlighted Russia's plans to launch a robotic mission to the Moon in 2022, which will be the country's first return to the lunar surface in 46 years.

NASA Deputy Administrator, Pam Melroy, highlighted the agency's work with SpaceX to certify its Crew Dragon capsule and the successful launch of 10 astronauts to the ISS, marking the United States' return to crewed flight for the first time in a decade. Melroy also discussed the launch of NASA's ninth LandSat satellite, which provides climate data and Earth Observation. She also highlighted the work of the Perseverance rover on Mars, which is currently in the process of collecting samples that will be returned to Earth next decade to be analyzed for signs of ancient microbial life. The next big mission for NASA, Melroy said, is the launch of the James Webb Space Telescope in December, which will revolutionize the search for Earth-like exoplanets and reveal the earliest periods of the universe.

Director General of the European Space Agency, Josef Aschbacher, also discussed the James Webb Space Telescope and ESA's role in its development and launch to orbit. The next major mission for ESA is JUICE, which will explore Jupiter and three of its icy moons—Ganymede, Callisto,

and Europa—in detail after it launches at the end of next year. He discussed collaborations with ROSCOSMOS on the Rosalind Franklin Mars rover launching next year as well as the results from the BepiColombo mission ESA launched in collaboration with JAXA. Finally, Aschbacher outlined the ESA's space ambitions as determined by the agency's 2025 agenda, which will determine the continent's space exploration priorities over the next decade.

Lisa Campbell, the President of the Canadian Space Agency, discussed CSA's work on space robotics, particularly its success using CanadaArm and its robot, Dexter, to autonomously connect to an anchor point on the station this past summer. This maneuver typically requires input from human controllers on the ground and demonstrates the remarkable advancements in autonomous space robotics that Canada has pioneered. Campbell described how a new CanadaArm will be used on the Artemis lunar gateway and the agency's plans to send an astronaut on the Artemis 2 mission. In the near future, Campbell said that CSA also plans to land a rover on the moon and is working to develop promising lunar exploration technologies through collaborations with Canadian companies.

Hiroshi Yamakawa, the President of JAXA, celebrate the successful sample return from Hayabusa2, its mission to an asteroid orbiting between Earth and Mars. Hayabusa2 is currently on an extended mission to a second asteroid after swinging by Earth to jettison its asteroid regolith, which is currently being prepared for study by an international community of scientists. Yamakawa also discussed the agency's newest navigation satellite, which will be

launched on an H-IIA rocket in the near future, as well as Japan's human spaceflight programme and plans for lunar exploration, both crewed and robotic, as a participant in NASA's Artemis programme. Yamakawa concluded with a description of the agency's new flagship launch vehicle, the H-III, which it expects to launch by next year.

K. Sivan, Chairman of ISRO, provided an update on India's space activities, with a particular focus on the agency's human spaceflight initiatives. He discussed the important role of space, and especially satellite technologies, in the development of India's economy and highlighted the agency's work to support a robust private space sector in the country. The panel concluded with a video from Kejian Zhang, the Administrator of CNSA, who described China's future space plan and how it will inspire the next space generation and spur innovation in the country's commercial space sector.

Expeditions 60/61 Reunion

The second plenary of IAC 2021 brought together astronauts and cosmonauts from the United States, the Russian Federation, and the United Arab Emirates to discuss their experience participating in the Expeditions 60 and 61 on the International Space Station.

On September 25, 2019, Hazza Al Mansoori made history when he arrived at the International Space Station and became the first Emirati astronaut. After a career flying F-16 fighter jets in the UAE Air Force and months of astronaut training at the Yuri Gagarin Cosmonaut Training Center in Star City, Russia. Al Mansoori spent eight days on the ISS conducting experiments created by students in the UAE and filmed the first ever tour of the ISS recorded in Arabic. Al Mansoori arrived at a busy time on the ISS and was one of nine crew members on the station. During the second plenary of IAC 2021, many of the crew members that participated in the Expedition 60/61 reunited to discuss the experience.

The session began with remarks from Salem Al Marri, the Deputy Director General and CEO of the Mohammed Bin Rashid Space Centre, who provided an overview of the birth of the space sector in the UAE. Al Marri described how a discussion with Sergey Krikalev, the Executive Director for Human Space Flights at ROSCOSMOS, laid the foundation for the UAE's crewed space programme. In addition to ROSCOSMOS, Al Marri detailed the UAE's relationship with national space agencies around the world including NASA, JAXA, and ESA, and underscored the importance of international cooperation to realize the UAE's space ambitions.

Krikalev spoke about how when he first met with Al Marri it was "not clear how serious and how long lasting" the UAE's human spaceflight programme would be or whether it would just end up being another tourist mission. But he said as the conversations advanced, it was clear the UAE was serious about creating an astronaut corps and building a robust human spaceflight programme. After several discussions, Krikalev said ROSCOSMOS committed to helping with astronaut training and facilitating the UAE's entry into the world of human spaceflight.

Throughout the rest of the plenary, the astronauts who participated in Expeditions 60/61 described their experience and how the unique mission came to be. Al Mansoori spoke about the privilege of being the first UAE astronaut and being able to represent his country on the ISS. NASA Astronaut Nick Hague and ROSCOMOS Cosmonaut Alexey Ovchinin described how a mishap on a Soyuz rocket in October 2018 pushed the date for the expedition back.

NASA Astronaut Jessica Meir related her experience flying to space with Al Mansoori and ROSCOSMOS cosmonaut Oleg Skripochka. During that flight to the ISS, Skripochka was the only one who had previously been to space before. Meir said that when the rocket entered the microgravity environment, she "looked over at Hazza and both of our eyes were as big as I've ever seen them. We shared that moment as rookies and it was very special for us knowing that we had both made our dreams come true."

During Expeditions 60/61, NASA Astronaut Christina Koch claimed the record for the longest continuous stay in space with 320 days. She discussed that experience during the conference and what it was like to return to Earth just a few weeks before the world went into lockdown for COVID-19. "For me it was almost like moving from one type of isolation into another, except I actually had a lot more freedom than I had had in the past year when I was in space," Koch said.

UAE Astronaut Sultan Saif Alneyadi, who was part of the first batch of astronauts selected by the country and the backup to Al Mansoori, rounded out the session by describing his duties as a backup astronaut and gave some advice to future recruits to UAE's human spaceflight program. "I would emphasize patience," Alneyadi said. "They need to feed their curiosity with knowledge, feel the responsibility of this new program, and hopefully they will be very successful astronauts in the future."

Small Satellites Solving Climate Challenges

During the third plenary of IAC 2021, representatives from Blue Origin, DLR, Planet, and NASA met to discuss how small satellites are being used to solve climate challenges. The group gave examples of how small satellites are used to monitor environmental changes and provide new perspectives on climate change that empower leaders on Earth to make data-driven policy decisions.

Earlier this year, the Intergovernmental Panel on Climate Change issued a new climate report that the UN Secretary-General António Guterres described as "code red" for humanity. The report called for immediate and decisive action to curb rising global temperatures and keep them below 1.5 degrees Celsius relative to pre-industrial levels. To make that happen, policymakers on the ground will rely on space systems to monitor key environmental variables and collect the information they need to make data-informed decisions.

Satellites have always been an important tool to help us understand our planet and now the proliferation of small satellites in Earth orbit have given us unprecedented insights into how our environment is changing across multiple scales. During the third plenary of IAC 2021, Clay Mowry the Vice President of Global Sales, Marketing & Customer Experience at Blue Origin led a discussion with representatives from DLR, Planet, and NASA about how small satellites are helping solve our most pressing climate issues.

Anke Kaysser Pyzalla, the Chair of the Executive Board at Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), started the conversation by detailing how the German space agency is using small satellites to complement larger satellite missions and detailing the benefits they provide over larger satellites. She pointed to the role of small satellites for regional climate monitoring as a particularly important use case because small satellites can be deployed more rapidly to study particular parts of the world at a low cost.

Karen St. Germain, the Director for Earth Science at NASA, talked about the agency's fleet of 23 earth monitoring satellites that are monitoring everything from the atmosphere to the oceans to Earth's landmasses. She said that NASA's satellites were instrumental in revealing the extent of climate change on a global level and agreed with Pyzalla that studying how climate change affects the Earth at a regional level is the next frontier of Earth observation where small satellites can play a big role in providing the data to build robust regional climate models.

Robbie Schingler, the Co-Founder and Chief Strategy Officer at Planet, brought an industry perspective to the conversation and talked about how his company has developed an expertise in mass manufacturing small Earth observation satellites that has enabled them to image the entire planet in high resolution every day. Schingler also acknowledged that private space companies can not solve the climate challenges we face on Earth on their own and underscored the importance of collaboration between industry and national space agencies to solve our climate challenges.

Mars 2020: First Step Towards Mars Sample Return

On February 18, NASA's Mars 2020 rover arrived on the surface of the Red Planet and it has been scouting for signs of ancient microbial life ever since. During the 4th Plenary of IAC 2021, leaders from NASA and ESA robotic explorations programmes discussed how Mars 2020 is laying the foundation for the first sample return mission from another planet. They explained the cutting-edge sensors on the rover that are used to select the samples and why the return mission is an important dry run for the first crewed Mars mission.

In February of this year, NASA's Mars 2020 was lowered into the Jezero Crater from beneath a skycrane after a 6-month journey from Earth. The car-sized rover came loaded with sophisticated instruments specially designed to aid in the rover's search for ancient microbial life. NASA's previous rovers Spirit and Opportunity furnished data that suggested water existed on Mars in the deep past and its Curiosity rover found evidence that there were ancient habitable environments. Still, direct evidence of ancient Martian life remained elusive.

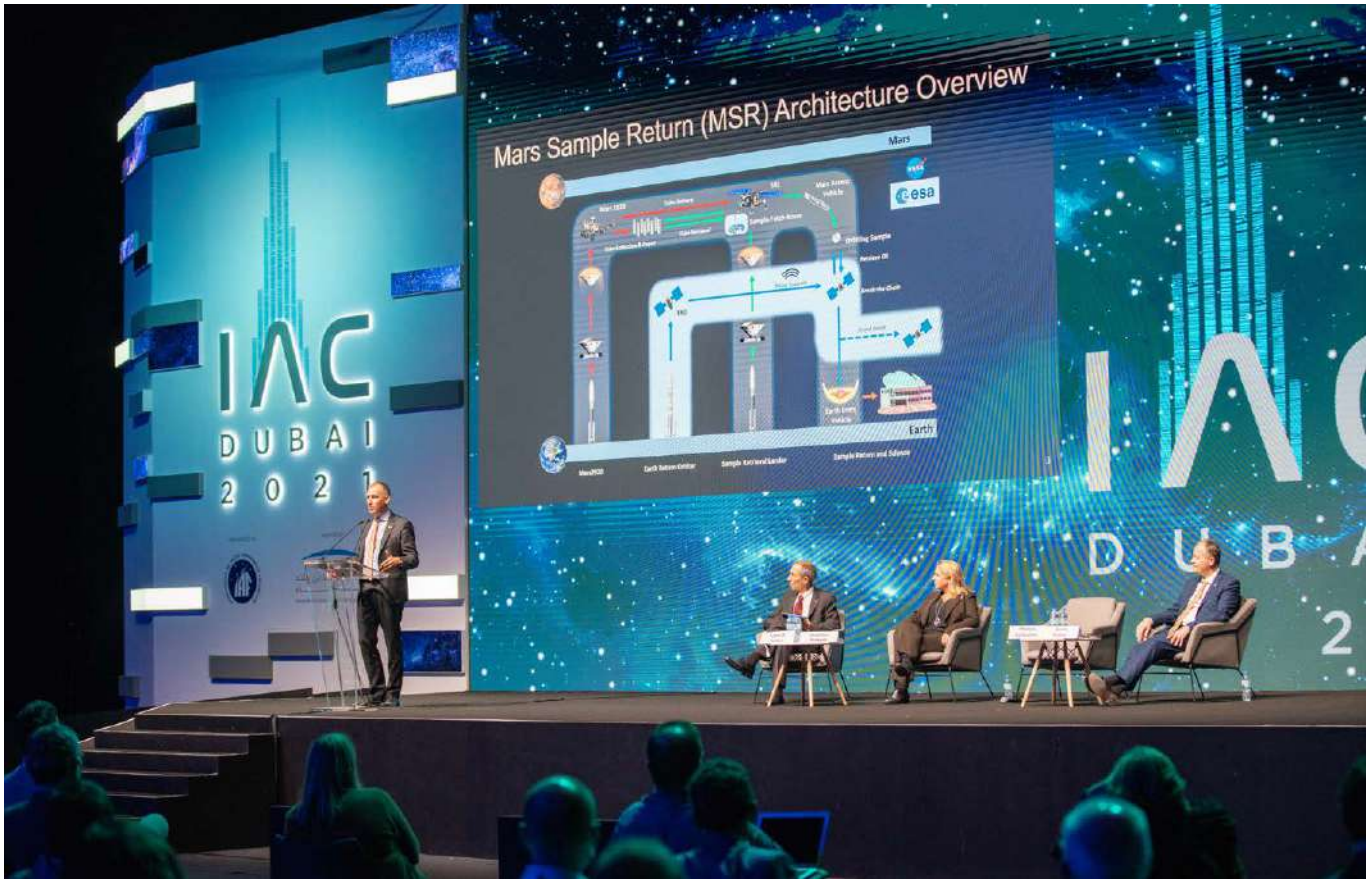
Mars 2020 is our best hope of finding evidence of ancient microbial extraterrestrial life. Jennifer Trosper, NASA's Mars 2020 Project Manager, explained how many of the instruments on the rover are designed to identify promising samples that may reveal the presence of ancient microbial life. PIXEL and SHERLOC, for example, are built to make sub-millimeter measurements of soil that divulges its chemistry and mineralogy. If a sample has a compelling chemistry, the rover seals it in a sample vessel in a process that Trosper described as the "most complex robotic thing we've ever sent to another planet."

Mars 2020 will only collect a few dozen samples, so it is important that it selects sample sites that are likely to have the biggest scientific payoff. "We want to bring back important rocks and we know from the history of geology how hard it is to find the rocks that tell us the important history of our own planet," said Thomas Zurbuchen, the Associate Administrator for the Science Mission Directorate at NASA. In this sense, he said, the instruments carried by the Mars 2020 rover are important not just for identifying important samples, but providing the geological context in which those samples were found.

But determining whether the samples collected by the Mars 2020 rover will have to wait until they are returned to Earth in the next decade. NASA's Mars rover will cache its samples on the surface of Mars until they can be retrieved by the Mars Sample Return mission. This joint NASA and ESA mission will consist of two elements: a lander that will collect the samples and launch them into Mars orbit, and a spacecraft to capture the samples in Mars orbit and return them to Earth. Once they are back on Earth's surface, the samples can be analyzed with machines far more sensitive than those on the Mars 2020 rover for signs of life.

The European Space Agency will play a critical role in retrieving the Mars 2020 samples and bringing them back to Earth. It is developing a Martian Dune Buggy designed to be able to traverse the Jezero crater faster than any previous rover to collect the cached samples, as well as the massive Earth Return Orbiter that will collect the samples in Mars orbit and bring them back to Earth. David Parker, ESA's Director of Human and Robotic Exploration, said that the agency and its industry partners have already done a lot of design work on this unique spacecraft and expect the first hardware, its computer system, to be delivered next year.

Ultimately, Parker said, the sample return mission is a step toward an even larger goal of putting boot prints on the Red Planet. "You can view the sample return mission as a dry run of eventual human exploration," Parker said. "So while it has this incredible scientific potential, it is also part of humanity's exploration of our solar system"



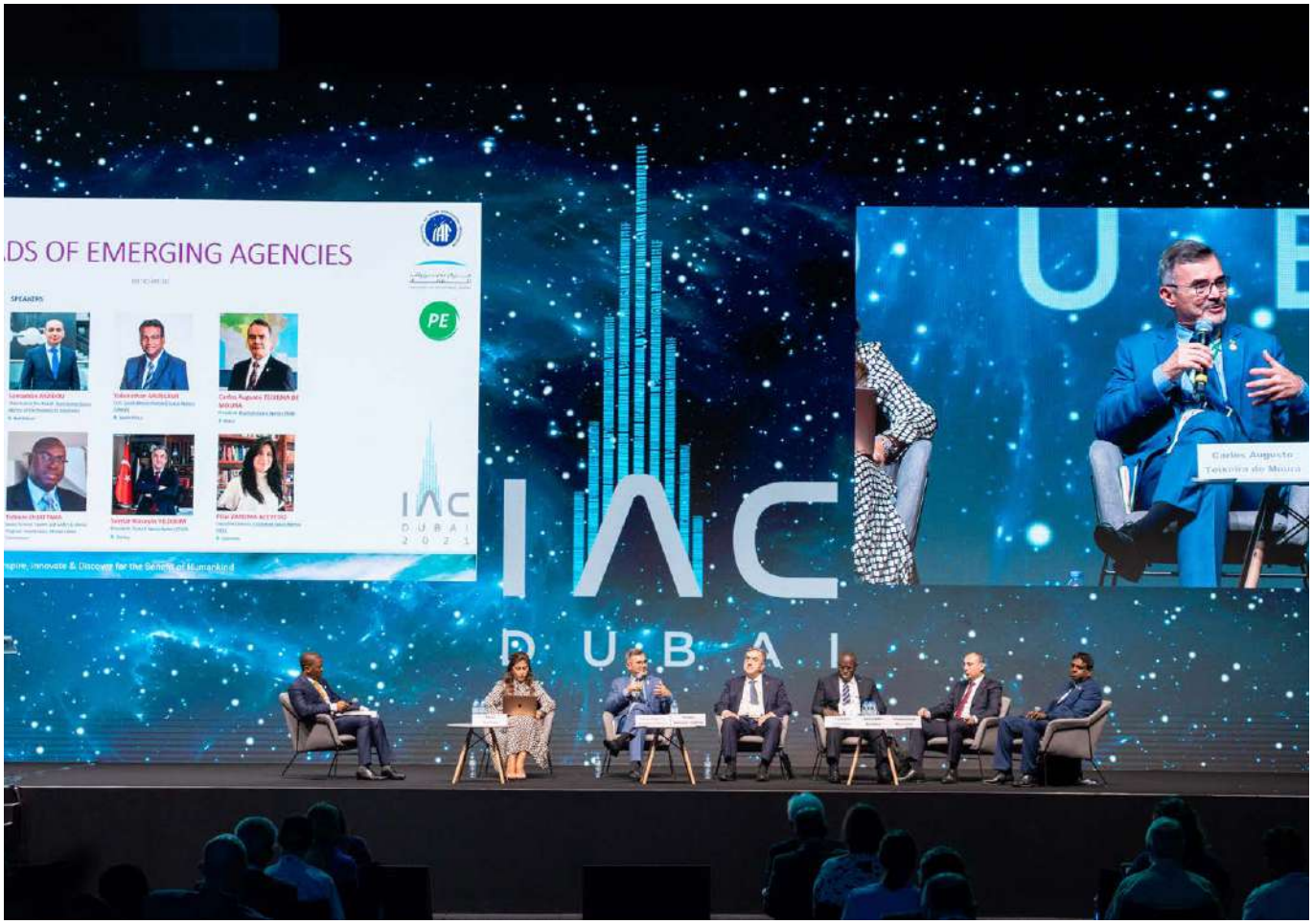
Heads of Emerging Agencies

Representatives from six emerging space agencies came together to discuss how their countries are leveraging space technology to further national education, agriculture, science, engineering, and financial goals. The conversation was led by Ntoshane Mohlamonyane of the South African National Space Agency (SANSA) and included input from representatives of Azerbaijan, South Africa, Brazil, Turkey, Colombia, and many others.

The rapidly falling costs of space access has made the final frontier more accessible than ever. During the 5th plenary session of IAC 2021, Ntoshane Mohlamonyane, the Strategic Manager to the CEO at the South African National Space Agency led a conversation between the heads of six emerging space agencies, who discussed how they are using space technologies to further national goals.

The conversation began with Pilar Zamora Acevedo, the Executive Director of the Colombian Space Agency (AEC), who described how the AEC is using space technology to advance five national projects: agricultural productivity, STEM education, internet access, satellite imaging for geospatial intelligence, and sustainability. Acevedo highlighted GreenSat, which will teach the next generation of Colombian space engineers how to build CubeSat constellations that will advance the country's sustainability initiatives.

Carlos Augusto Teixeira de Moura, the President of the Brazilian Space Agency (AEB), discussed the country's long history in space and focused particularly on its collaboration with other major spacefaring nations such as the United States, China, and Germany. Teixeira de Moura outlined how building a space industry can help Brazil solve many challenges simultaneously ranging from environmental challenges to defense issues. He acknowledged that Brazil is unable to provide all the services it needs for building a robust space economy, which is why the country has focused on establishing relationships with other emerging space actors that can benefit both parties.



Plenary 5

Serdar Hüseyin Yildirim, the President of the Turkish Space Agency (TUA), described the National Space Program of Turkey, which was unveiled earlier this year and outlines the roadmap for the country's space ambitions. The 10-year program has 13 main objectives that will help establish Turkey as a capable space actor, including a robotic Moon mission, a regional positional system, and the establishment of a spaceport. Yildirim emphasized that Turkey seeks to use its space program to build and strengthen partnerships around the world and the importance of collaboration for achieving important commercial, scientific, and engineering breakthroughs.

Tidiane Ouattara, the Space Science Expert and GMES at the African Union Commission, spoke about how space exploration is a key part of the sustainable development agenda for the African Union, which consists of 55 countries across the continent. He particularly emphasized the importance of space assets in connecting Africa and delivering telecommunication services, which will help grow the African market both on and off the planet. He described Africa as the "new El Dorado for the space business" and discussed how countries from Egypt to Nigeria are participating in the new space economy.

Samaddin Asadov, the Chairman of the Board of the Azerbaijan Space Agency, spoke of Azerbaijan's ambitions to grow from an emerging space agency to a regional player and how the country has taken strides toward this goal over the past decade. Asadov highlighted the agency's work in space situational awareness, a capacity it is building in partnership with commercial entities and academia. In particular, he singled out the importance of engaging with students at local universities through events like hackathons to cultivate the necessary skills to build a space industry in the country.

Finally, Valanathan Munsami, the CEO of the South African National Space Agency (SANSA), described several of the country's major space initiatives, such as its new space weather center that will provide information on space weather to all flights into and out of Africa. At the same time, South Africa is expanding its satellite ground station footprint as part of the Digital Africa Initiative and through an agreement with JPL to explore the possibility of adding a fourth Deep Space Network station in South Africa to aid upcoming missions to the moon and Mars. Munsami briefly highlighted several other initiatives including a new satellite design center and a sounding rocket launched by South African students that broke the continent's altitude record.

The world's emerging space agencies have never been busier working on ambitious projects. A key theme of the plenary was the importance of international collaboration, which empowers countries to accomplish more in space by combining complementary strengths while building new capabilities. Moreover, each speaker demonstrated how space exploration can support other critical national initiatives ranging from education and defense to sustainability and telecommunications.

Innovative Space Solutions for Search and Rescue and Life Saving Applications

The 6th plenary panel of IAC 2021 featured a discussion between representatives from ESA and national space agencies in Europe about new space solutions for assisting with search and rescue and other life saving applications. The speakers gave an overview of the past, present, and future of space-based safety systems and how they have saved tens of thousands of lives over the years.

Satellites in Earth orbit help save hundreds of lives every year by providing the critical data links that enable search and rescue missions in some of the most remote regions on the planet. Satellites monitor for emergency beacons that point to people in distress and direct emergency personnel where they need to go. During the 6th plenary of IAC 2021, Jörg Hahn, Head of Galileo G1 System Engineering Service at the European Space Agency (ESA), and Xavier Maufroid, Head of Sector Galileo Implementation at the European Commission, led a conversation with representatives from ESA, the Italian Space Agency, the International Cospas-Sarsat programme, and the Centre National d'Etudes Spatiales (CNES) about the current state of space-based rescue technologies and what to expect in the future.

Steven Lett, the Head of International Cospas-Sarsat Programme Secretariat, led the conversation with a description of Cospas-Sarsat, a 40-year old organization that claims responsibility for saving nearly 54,000 thousand lives. Lett said that in 2020 alone, the satellite system assisted in the rescue of 2,000 people across nearly 1,000 incidents. Lett discussed the history of the organization and how it uses emergency beacons to locate lost persons on the ocean and in the wilderness.

Arnaud Carlier, the Head of Department for Telecom, Ground Stations and Alert Systems at CNES, spoke about the European contribution to space-based search and rescue assets, particularly the payloads on the Galileo positioning satellites that localize real time emergency

beacons. In the near future, Carlier said that European space systems will be able to transmit to people in distress to let them know their signal has been received by a person in the control center. Another new system under development by the European Commission will enable Galileo satellites to inform people on the ground that there are hazardous situations such as forest fires or earthquakes, even when all ground-based communication systems are down.

Paul Verhoef, the Director of Navigation at the European Space Agency, discussed the critical role of international collaboration in the use of space assets for search and rescue. He particularly homed in on the importance of the interoperability of technologies from around the world with space-based assets. "If you buy something in one country, it needs to be able to be used around the world," Verhoef said. This means collaborating to develop shared

standards and protocols to allow emergency responders to contact the relevant authorities anywhere on the planet during a rescue mission.

Francesco Longo, the Head of the Earth Observation Division at the Italian Space Agency rounded out the conversation by discussing how future space-based safety systems will provide important additional data to rescue teams such as the status of the victims, the local weather, or the situation on the sea, which will enable a more safe and effective rescue effort. This, he said, will involve solving a number of problems, such as the availability of real-time Earth observation data to rescuers on the ground. He said this will become particularly important as climate change leads to more extreme weather events, but the rapid progress in space technologies, especially Earth observation systems, have the promise to make life on the surface safer than ever before.

Next Generation Impact on Social Responsibility In Space

The final plenary of IAC 2021 gathered representatives from the International Institute of Air and Space Law, the Space and Sustainability Initiative, and the Global Expert Group on Sustainable Lunar Activities to discuss how the next generation can shape social responsibility beyond Earth.

The final plenary of IAC 2021 showcased the work of four young professionals and students from around the world who were selected through a competitive process to discuss their work at IAC. The panel was moderated by Tanja Masson-Zwaan, the Assistant Professor and Deputy Director of the International Institute of Air and Space Law, who led a wide-ranging discussion about the next generation's role in shaping social responsibility in space.

Andrew Swackhamer, a Research Assistant at CU Boulder's Space & Sustainability Initiative, led the panel by discussing the growing challenges of orbital debris. "Just like we're facing a climate crisis here on Earth, we're also facing growing concerns about a buildup of orbital debris and increased congestion in near Earth space," Swackhamer said. He discussed his engagements with experts in orbital debris, satellite operators and other stakeholders to improve the debris situation in Earth orbit and issued a call to remedy this issue before we loose access to space entirely.

Giuliana Rotola, an Implementation Support Officer at the Global Expert Group on Sustainable Lunar Activities in Italy, discussed the issue of satellite constellations and their impact on scientist's ability to observe the night sky. She also touched upon the need for increasing democratization in space and how to make space exploration more inclusive and diverse. She discussed the tradeoffs involved with satellite constellations and spoke about how it is incumbent on the next generation to have a shared vision of our future in space and to work together to make that vision a reality.

Ruvimbo Samanga, a Space Law & Policy Analyst from Zimbabwe, discussed how her experience working in the space sector in Africa has taught her about the meaning of social responsibility and how it can be achieved through outreach and awareness that inspires the next generation to get involved in space development. As part of this effort, Samanga has partnered with the director Kelly Polaski to create a documentary about women in space and raise awareness about the crucial role that women have played in building the modern space sector. She concluded by discussing how her startup, Agrispace, is using satellite data to empower African farmers and reduce food insecurity on the continent as a method for improving social responsibility in space.

Molly MacEachen, a Research Associate, Space & Sustainability Initiative at CU Boulder, wrapped up the panel with a discussion about the impact of the commercial space sector on space exploration and the world more generally. She described her work creating an advisory working group that discusses issues like whose responsibility it is to prevent satellite collisions and how commercial space actors can work together to improve the orbital commons for everyone. She said that students are critical to the work that she and Swackhamer are doing at ISS and that they are united in their mission to "train the next generation of space leaders to create a more sustainable future of space." ■

IAC 2021

Highlight Lectures & Late Breaking News

HLL

LBN

The Osiris-Rex Sample Return Mission – The Value of Planning Ahead and Adaptability

Last Autumn, NASA's OSIRIS-REx spacecraft successfully collected a large sample of regolith from asteroid Bennu. During this Highlight Lecture, two members of the OSIRIS-REx team discussed the importance of the asteroid sample return mission and the challenges involved with sending a spacecraft to an asteroid and back.

Astronomers estimate that there are more than 1 million asteroids doing laps around our solar system. As of today, around 800,000 asteroids have been positively identified. A small fraction of these are potentially hazardous, which means their orbital trajectory creates the risk of a collision with Earth. One of the most hazardous asteroids is known as Bennu, a roughly 500-meter-wide near-Earth object shaped like a spinning top in an orbit very similar to Earth's own. Although the probability of an impact with Bennu in the near future is small, scientists are understandably anxious to learn more about it and similar asteroids to better understand the collision risk and mitigation strategies.

In 2016, NASA launched OSIRIS-REx, its third New Horizons mission, on a United Launch Alliance Atlas V rocket toward Bennu. After nearly two full years of cruising through deep space, the spacecraft reached the asteroid in late 2018 and spent the next year-and-a-half preparing to briefly touch down on its surface and collect the largest asteroid sample in the history of space exploration. During the first Highlight Lecture of IAC 2021, two members of the OSIRIS-REx team discussed the goals of the mission and the challenges involved with collecting asteroid regolith and returning it to Earth.

The OSIRIS-REx spacecraft was built by the Lockheed Martin Corporation to meet the demanding specifications of an international team of scientists led by NASA and the University of Arizona's Lunar and Planetary Laboratory. In addition to its role in providing more data for planetary defense, the OSIRIS-REx mission had several other scientific goals.

Scientists believe that Bennu was formed in the first 10 million years of the solar system's formation, which makes it about 4.5 billion years old. The hope is that the sample collected by the spacecraft will provide a window on to the early solar system and may shed light on the origin of life and water in our cosmic neighborhood. Another goal of the mission was to identify the chemical composition of the asteroid and identify any valuable resources on its surface for possible extraction in the future.

Fulfilling all these goals meant that the OSIRIS-REx team could not just grab any sample from the surface. "You want to grab something that actually matters," said David Murrow the Senior Manager of Strategy and Business Development Deep Space Exploration at the Lockheed Martin Corporation. "So we had to look for the science value of what we saw."

> “We started to get concerned about these specks of sample floating around. As it turned out, we got so much sample that some of the larger rocks jammed open the mylar flaps”

After several months in orbit around the asteroid, the OSIRIS-REx team identified four promising sample collection spots and eventually narrowed it down to one called Nightingale. Last October, the OSIRIS-REx briefly touched the surface of the asteroid in the Nightingale crater and used a blast of nitrogen gas to blow a sample into the spacecraft’s collection arm. “I remember sitting there waiting for the data to process when we were downlinking these images,” said Anjani Polit, the Mission Implementation Senior System Engineer of the OSIRIS-REx Science Planning Team at the University of Arizona. “We started to get concerned about these specks of sample floating around. As it turned out, we got so much sample that some of the larger rocks jammed open the mylar flaps.”

The OSIRIS-REx team estimates that the spacecraft managed to collect at least 60 grams of asteroid regolith at Bennu and possibly as much as a kilogram. This is by far the largest sample ever collected from an asteroid, but the mission team would not know exactly how much asteroid material it collected until the spacecraft returns it to Earth in 2023. Until then, Polit and her colleagues are busy sifting through the data collected by the spacecraft that is already shedding light on its composition and history.

Twenty Years of Saving Lives From Space;
How Space Agencies Are Contributing To Relief Efforts Through The "International Charter Space and Major Disasters"

During the second highlight lecture of IAC 2021, leaders from the European Space Agency, the French Space Agency CNES, and the Canadian Space Agency came together to reflect on the importance of the International Charter Space and Major Disasters for saving lives on Earth. The discussion was moderated by the IAF's Earth Observations Committee Chair and celebrated the 20th anniversary of this unique humanitarian initiative.

Just a few months into the new millennium, leaders from the European Space Agency and the French Space Agency CNES initiated the International Charter Space and Major Disasters, a first-of-its-kind non-binding agreement between spacefaring nations to voluntarily provide satellite data to assist in relief efforts in the wake of major disasters. Today, the Charter has 17 members and has been activated more than 700 times to assist relief efforts in more than 120 countries over the past 20 years.

The International Charter Space and Major Disasters is a visceral reminder of the important role that space exploration plays in improving life on the surface. The second highlight lecture of IAC 2021 celebrated the 20th anniversary of this unique humanitarian initiative with a discussion between Lisa Campbell, the President of the Canadian Space Agency, Philippe Baptiste, the President of CNES, and Josef Aschbacher, the Director General of ESA that was moderated by the IAF's Earth Observations Committee chair Harry Cikanek.

Aschbacher opened the discussion by outlining the capabilities of the space assets contributing to the charter and the types of disasters they provide assistance with. Over the past 20 years, the 61 satellites that currently participate in the programme have assisted relief efforts for everything from flooding and fires to the search for missing aircraft like Malaysia Airlines Flight 370 and disease outbreaks like Ebola. "The charter really has been a huge success," Aschbacher said.

Baptiste described the genesis of the charter in the 1990s and how the charter provides assistance to first responders on the ground. In addition to high resolution imagery, Baptiste said satellites also provide critical data from non-optical sensors that helps to further contextualize the situation on the ground. He celebrated the growing number of countries that participate in the charter as authorized users of the data and said seven new countries are scheduled to join in 2022. "The charter is very important to explain that space is not only for science and for business, it is also for people on a daily basis," Baptiste said.

Campbell concluded the highlight lecture by discussing why Canada decided to become one of its first members back in 2000 and how the Canadian Space Agency continues to contribute to the effort today. Campbell noted that the CSA has provided over 22,000 images as a participant in the Charter and detailed how it has improved Canada's ability to respond to natural disasters. "This is the real beauty of space, collaborating on numerous fronts, transcending national borders and innovating to harness the power of technology to improve life on Earth," Campbell said. But she also pointed out that the number of charter activations has been increasing and was about 38% higher in 2020 than the average number of activations since 2007. So while the International Charter Space and Major Disasters improves our ability to respond to a changing climate, it also underscores the urgent necessity of mitigating the inputs that result in a higher level of natural disasters.

IAF World Space Award:
Accomplishments of The Hayabusa2 Mission: Sample Return From C-Type Asteroid Ryugu

In December 2020, JAXA's Hayabusa2 returned a 5.4 gram sample collected from asteroid Ryugu near the end of its six-year primary mission. The pristine asteroid samples collected by Hayabusa2 contain clues about the formation of the early solar system and will also help scientists understand how to protect Earth from a possible asteroid impact in the future. In recognition of this accomplishment, Hayabusa2 Project Manager Yuichi Tsuda accepted this year's IAF World Space Award from IAF President Pascale Ehrenfreund on behalf of JAXA's Hayabusa2 team.

On 5th December 2020, a capsule the size of a dinner plate descended under a parachute over the Australian outback. Inside the capsule was 5.4 grams of pristine material collected from asteroid Ryugu, a rocky body rich in organics that is circling the sun between Earth and Mars. This was the largest asteroid sample ever returned to Earth and the culmination of the Japanese Aerospace Exploration Agency's primary Hayabusa2 mission. Scientists around the world have been waiting to study the Hayabusa2 sample for years to see what it will reveal about the origins of the solar system and its implications for planetary protection.

In recognition of the Hayabusa2 team's incredible accomplishment, IAF President Pascale Ehrenfreund presented JAXA's Hayabusa2 Project Manager Yuichi Tsuda with the 2021 IAF World Space Award. "The Hayabusa team has greatly contributed to the advancement of robotic interplanetary sample return through a series of flawless operational accomplishments made possible by sophisticated technologies," Ehrenfreund said.

Tsuda detailed the incredible challenges the Hayabusa2 team faced during the mission and how JAXA's scientists and engineers had to improvise once the spacecraft arrived

> “The biggest headache for us was the many, many boulders all over the surface, (...) This forced us to change our strategy for landing operations”

at the asteroid. Hayabusa2 was launched in 2014 and did not arrive at asteroid Ryugu until mid-2018. Over the next year-and-a-half, Tsuda said Hayabusa2 circled the asteroid doing “many challenging operations” in preparation for its two descents to the surface to collect a sample.

Ryugu was a challenging target for many reasons. It is large (about twice the size of the asteroid visited by NASA’s OSIRIS-REx mission), it has a long rotation (nearly eight hours), it is very dark (only about a 2% reflectance), and, as the JAXA team discovered when Hayabusa2 arrived at the asteroid, its surface was littered with boulders. “The biggest headache for us was the many, many boulders all over the surface,” said Tsuda. “This forced us to change our strategy for landing operations.”

In order to avoid the boulders during its sample collection maneuvers, the Hayabusa2 team had to improve the spacecraft’s landing operations from a 50 meter accuracy to a 1 meter accuracy. To better understand the environment, Hayabusa2 deployed three rovers to the surface of the asteroid. One of the rovers, called MASCOT, was built by the German Aerospace Center in collaboration with CNES to study the composition of the asteroid. The other rovers consisted of two twin cylindrical rovers known as HIBOU and OWL, plus the MINERVA-II-2 rover that made measurements in orbit around the asteroid.

After much planning and assistance from the rovers sending images and data from the asteroid’s surface, Hayabusa2 successfully collected two samples from asteroid Ryugu. The first sample was collected from the asteroid’s surface. The second sample was collected from beneath the surface after Hayabusa2 created a crater by shooting a 2 kilogram copper projectile at the asteroid.

Hayabusa2 was a follow-on mission to JAXA’s original Hayabusa mission, which became the first mission to return a sample from an asteroid more than a decade ago. The success of both of these missions has changed our understanding of asteroids and other rocky bodies in our solar system while providing a glimpse into its origins. These missions paved the way for many other sample return missions, including NASA’s OSIRIS-REx and the Mars sample return mission.

“Now we are in the era of bringing samples back to Earth for direct analysis,” said Tsuda. “It is a really effective way of doing space science. It is very difficult, but it is an interesting and exciting way of doing these space missions.” ■

Late Breaking News:
New Perspective - NS-18 Astronaut Chris Boshuizen

The Late Breaking News event of IAC 2021 brought together Clay Mowry, the former Vice President of Global Sales, Marketing, and Customer Experience at Blue Origin, and Chris Boshuizen, a partner at DCVC, to discuss Boshuizen's experience as an astronaut on the second crewed launch of Blue Origin's New Shepard rocket.

Chris Boshuizen has been a space advocate for most of his career. As a cofounder of Planet Labs, he helped revolutionize Earth observation with a fleet of small satellites that image the entire planet in high resolution each day. This past October, Boshuizen continued his space advocacy work as one of four passengers to fly on Blue Origin's second crewed New Shepard flight. During the sole Late Breaking News session at IAC 2021, Boshuizen spoke with Clay Mowry, the Vice President of Global Sales, Marketing, and Customer Experience at Blue Origin, about his experience and how seeing the Earth from space shifted his perspective.

Boshuizen began his talk by discussing his conviction that there is a "revolution that's about to begin in human spaceflight" and how his participation in Blue Origin's New Shepard launch traced its origins to his work as a volunteer at past International Astronautical Congresses. Boshuizen had worked as a volunteer at IAC for years before he founded Planet, which eventually led him to be connected to researchers at NASA's Ames Research Center, where he experimented with the idea of putting a phone in space and sending pictures back to Earth.

After some initial successful tests with the phone in a vacuum chamber, on a high altitude balloon, and eventually in orbit, Boshuizen realized that this could be the foundation for a low cost Earth imaging satellite. He left NASA and spent the next several years building what would become Planet Labs from a garage in California. Since then, Boshuizen described the incredible progress that has been made in the commercial space sector, with dozens of new launch companies and hundreds of satellite companies and other space actors. The pinnacle of the new space economy, he said, is private human spaceflight, which is just breaking open a new era of crewed exploration.

Boshuizen described his experience of going to space with a crew that included William Shatner of Star Trek. In addition to microgravity gymnastics and taking in the view, Boshuizen said he had an unexpected experience when the rocket reached its apogee. He found that he had gone suddenly blind. "I could not see anything," he said. "I am looking out the window kind of confused. My brain was overloaded."

When Boshuizen came back to Earth, he learned that his experience, while not exactly common, is not unusual for astronauts either. "It is a strange experience to be temporarily blinded by seeing something that's so strange," he said. Despite the temporary blindness, Boshuizen said he was deeply moved by what he saw above the Karman line. Although he was just one of only 600-odd people to have seen the Earth from such heights in all of human history, Boshuizen concluded that it was only a matter of time until the rest of us will have the opportunity to experience it as well and fulfill his lifelong dream of making "pace travel as easy as catching the bus." ■

> "It is a strange experience to be temporarily blinded by seeing something that's so strange"

IAC 2021

IAF Global Networking Forum (IAF GNF)

Global Networking Forum
Meet. Share. Connect.

Monday
25 October 2021

Monday's IAF GNF sessions focused on opportunities and challenges for a responsible space sector, as well as a session dedicated to the importance of open data for Earth system science.

As more spacefaring nations are born each year, it become more important than ever for space actors to establish norms for operation and commit to fostering a responsible space sector. The first two sessions of Monday's Global Networking forums at IAC 2021 focused on challenges and opportunities for extending the rule of law to outer space.

The first GNF session focused on space law for new space actors and featured leaders from both governments and NGOs including the United Nations Office for Outer Space Affairs, the government of Luxembourg, South Africa's Department Science and Innovation, the Chilean Air Force, and the International Institute of Space Law. The session began with a video message from the Japanese Minister of Foreign Affairs, who spoke about the importance of working together to establish frameworks that allow countries to responsibly operate in outer space. A common theme explored by all speakers throughout the GNF session was the idea that even if there is no national sovereignty in outer space, it is important to establish international treaties and behavioral norms that ensures that the global space commons can be used by all in the future.

The second IAF GNF session focused specifically on future challenges for a responsible space sector. It featured representatives from the ArianeGroup, Thales Alenia Space Italia, AVIO, SME4Space, and the European Space Agency, who discussed how European space actors set their priorities and coordinate to solve challenges between themselves. The session offered a balance of public and private perspectives that both acknowledged the progress that has been made in terms of public-private collaboration in establishing operational frameworks for space activities as well as the challenges that the sector has faced. One of the main challenges voiced by the participants was the need for private actors to rapidly reduce their carbon emissions while continuing to meet the needs of the wide space industry.

The third and final IAF GNF session on Monday brought together two leaders from NASA to discuss the importance of open data for supporting Earth system science. Thomas

Zurbuchen, NASA's Associate Administrator for the Science Mission Directorate, discussed the agency's new initiative to build a foundation for open source science and data that can reveal high impact actions to preserve our planet. The discussion really highlighted how making data available to a broad community of scientists and engineers opens up new possibilities for exploration and discovery that will be key to advancement both on our planet and beyond.

Tuesday
26 October 2021

Tuesday's IAF GNF sessions covered a wide variety of topics focused on the future of Earth orbit, cislunar space, and lunar operations. Panelists discussed laser communications, human space exploration, servicing satellites, mega-constellations, and more, painting a vivid portrait of the exciting space developments we can expect around Earth in the coming years.

Earth orbit and the moon are about to get busy. Rapidly increasing levels of commercial activity and ambitious national exploration programs have laid the foundation for a burgeoning offworld economy featuring humans and robots working together to write the next chapter of space history. During Tuesday's GNF Sessions at IAC 2021, panelists from governments, private industry, and NGOs came together to discuss many of the most exciting developments on and around Earth and the moon over the next few years.

The first GNF session featured four speakers from the Lockheed Martin Corporation, who detailed how the company is powering the next giant leap to the moon. A main focus of the conversation was how lessons learned from human spaceflight in low Earth orbit laid the foundation for the crew modules that will carry humans to lunar orbit and eventually to the lunar surface through NASA's Artemis program. The speakers also discussed key innovations in power generation and communications technology that are empowering the next generation of lunar explorers to return to the moon for long duration missions.

In the next IAF GNF session, IAF President Pascale Ehrenfreund moderated a panel of executives from the private space sector to discuss how they are building the commercial future of low Earth orbit. The session featured representatives Redwire, Sierra Space, Blue Origin, and Boeing, who each offered their unique perspective on the economic prospects beyond Earth. The speakers touched on topics ranging from the usefulness of the ISS for fostering commercial projects, the need to push forward R&D on in-space manufacturing, and how the research being conducted by industry and microgravity can improve life on Earth by improving the quality of agriculture and medicine.

During the third GNF session of the day, Simonetta Di Pippo, Director of the United Nations Office for Outer

Space Affairs (UNOOSA), and Andreas Hammer, the Senior Vice President of Exploration at Airbus Defence and Space, announced the winner of the contest to secure a free flight on the Bartolomeo platform aboard the ISS. The winner was the Clean Cam Project, a conception of three different agencies from Africa representing Egypt, Kenya, and Uganda, that will use a remote sensing camera to monitor water and climate change.

As satellite mega-constellations move from science fiction to science fact, it is become increasingly clear that the space industry needs to have clear guidance on the regulations governing their creation to ensure that all stakeholders can benefit from low Earth orbit. During the fourth GNF session, leaders from the Summit Space Corporation, Arianespace, RUAG Space, Amazon Web Services, Voyager Space Holdings Inc., and Sheppard Mullin discussed different pathways to regulation that will enable commercial innovation while prioritizing the sustainability of space operations.

The fifth IAF GNF session of the day featured speakers from NASA, Astroscale, ClearSpace, and D-Orbit, who discussed the concept of on-orbit servicing and why it is key to a growing space economy. While on-orbit servicing has been used in the past to repair flagship space assets like the Hubble Space Telescope, until very recently it remained prohibitively expensive and remained uncommon. Yet as the speakers during this session revealed, the technologies now exist to make on-orbit servicing a reality. All speakers were in agreement that the ability to repair satellites in space will drive down costs, which is key to quickening the arrival of a robust extra-terrestrial economy.

The next IAF GNF session of the day featured Steve Krein, the Vice President of Civil and Commercial Satellites Tactical Space Systems Division at the Northrop Grumman Corporation. Krein's talk discussed the details of Northrop Grumman's HALO module that will provide a habitat for crews in lunar orbit. He discussed the differences between the next generation crew modules used for deep space exploration and the capabilities of the ISS, and how the requirements for those missions have pushed the limits of what's possible for crewed exploration.

The final IAF GNF session of the day featured two representatives from Mynaric, who made the case for laser communication as the backbone of future satellite constellations around Earth. The duo argued that laser links are the best way to move large quantities of data between satellites and between satellites and ground stations. The ability to move more data around in space has the potential to dramatically drive down the cost of satellite communications but requires overcoming some key technological challenges.

Wednesday
27 October 2021

Wednesday's IAF GNF sessions covered a range of topics in various forums. The first session of the day was a fireside chat on the topics of surveillance, habitat, and security, and featured an impressive array of speakers offering diverse perspectives on these important topics for the space industry. Later sessions covered space startups, a pitching competition, the cloud, and Europe's crewed spaceflight ambitions.

Wednesday's IAF GNF sessions kicked off with a unique French fireside chat on the topics of surveillance, habitat, and security. The discussions brought together leaders from government and industry players around the world, and featured opening and closing remarks from the French ambassador to the UAE and the Commander of the French Space Command. The first fireside chat featured representatives from Unseenlabs and Share My Space, who spoke about collecting data on seafaring vessels from space and how satellite fleets can employ safe navigation solutions. The second fireside chat featured the CEOs of Interstellar Lab and Spartan Space, who discussed the future of sustainable habitats both on Earth and in space. The final fireside chat brought together representatives from Sodern, Magellium, and Cailabs who covered various facets of space security including optronics, earth observation, and free space optical communication.

During the second IAF GNF of the day, the Executive Director of the UAE space agency gave an opening address for a panel that forecasted that the next decade would belong to the space start-up companies. The panel featured representatives from Bexperience.nl, the European Space Agency, the UAE Space Agency, Stemrad, and the Andy Thomas Foundation, who each spoke about the various ways that startups are using space to shape the economy on Earth and beyond. The topics covered included novel ideas like using cosmic rays to detect water leaks to more conventional new space activities such as extracting information from satellite imagery. The session showcased the incredible variety of commercial activity led by startups in the new space sector.

In a fitting follow up to the second IAF GNF, the next session was a pitch competition that allowed space startups to advocate for their business to the UAE Space Agency. The pitch competition featured judges from the UAE Space Agency, Group 42, and Gothams, who fielded pitches from three startups working on very different space issues. The startups were focused on building a backbone of a global sustainable water management system, a CubeSat designer and manufacturer, and a system to use AI to analyze

satellite imagery. It was a tough choice for the judges who could only pick one winner, but a great sign of how the next generation of entrepreneurs is pushing the space industry to new heights.

The fourth IAF GNF session of the day focused on Europe's ambitions for human spaceflight. It brought together speakers from the European Space Agency, AirZeroG, ArianeGroup, and the Indian Space Research Organisation, who looked at the challenges and opportunities of a stand-alone European human spaceflight program. The speakers were in agreement that Europe should invest more in crewed spaceflight opportunities so it does not fall behind its peers and can be a larger participant in the next chapter of human spaceflight. They highlighted many programs under development by the European member states, ESA, and private industry that will lay the foundation for a more robust astronautics program on the continent and compliment already existing programs such as ESA's work on various modules for the Artemis Lunar Gateway.

During the next IAF GNF session, NASA Deputy Administrator Pam Melroy gave a speech on the importance of inclusiveness and working together for the future of space exploration. Melroy underscored how the incredible growth in the space industry over the past decade was the result of many decades of hard work previously and a close collaboration between industry, academia, and national space agencies. She pointed to the success of companies like SpaceX as examples of the types of what can happen through these collaborations and the positive effects, they can have on the broader space sector by lowering barriers to the cosmos.

In the final IAF GNF session of the day, AWS Satellite Solutions Lead Bill Carlin delivered remarks on how the cloud can bridge the data gap between Earth and space. Carlin spoke about the collaboration between AWS and the Mohammed Bin Rashid Space Centre to apply cloud-enabled solutions to satellite missions. In particular, he detailed how cloud solutions are transforming the way that satellites are controlled, eliminating the need for proprietary ground networks and instead using a global network of shared dishes and data centers to lower the barrier to satellite technology.









Thursday
28 October 2021

Thursday's IAF GNF sessions were focused on the moon. Speakers from industry and national space agencies came together to discuss how they are collaborating to power a lunar economy and both crewed and robotic lunar exploration.

The first IAF GNF session on Thursday focused on how national space agencies and industry actors are building the lunar ecosystem today. Representatives from the Mohammed Bin Rashid Space Centre, Air Liquide, Centre National d'Etudes Spatiales, ispace Europe, and Airbus Defense and Space all offered their perspective on the state of lunar development and how their organization is contributing to this effort. The panel touched on a variety of economic development opportunities ranging from transportation to the moon to in-situ resource utilization.

Space exploration has proven to be a major economic boon to spacefaring nations and as the cost of space access falls it has created an abundance of business opportunities in emerging space nations. During the second IAF GNF session, speakers from Azercosmos Space Agency of the Republic of Azerbaijan offered their perspective on how space exploration has created economic opportunity in their country. They particularly highlighted the satellite industry as a fruitful business for emerging space nations given its role in a variety of sectors ranging from telecommunications to geospatial imaging. They also discussed various methods for building a robust national space economy by fostering human capital and spoke about their successes in hosting competitions and hackathons.

Many of the world's national space agencies have committed to returning to the lunar surface this decade with both crewed and robotic missions. During Thursday's third IAF GNF session, speakers from Thales Alenia Space Italia, the Lockheed Martin Corporation, NASA, Boeing, the European Space Agency, Blue Origin, and LIQUIFER Systems Group discussed how they are building a sustainable lunar infrastructure that will enable long duration missions to the lunar surface. The conversation ranged from the construction of crew habitats and putting communication satellites in orbit around the moon to how to safely and efficiently deliver cargo to the lunar surface. The session underscored the tremendous engineering challenges that come with returning to the moon and how some of the world's brightest minds are thinking about solutions.

The fourth IAF GNF returned to a familiar theme from this year's IAC: space startups. Young space companies have fundamentally changed the industry over the past few decades, but this session focused on how the investment landscape changed over the past year in particular. It featured speakers from Fondazione E. Amaldi, Italian Space Agency (ASI), the European Space Agency (ESA), and Bryce Space and Technology who offered their insights on the state of space startups in Europe and abroad. The panel

discussed how government agencies can create startup friendly environments and frameworks for cooperation that can spur more investment in fledgling space companies. Multiple speakers offered insights from Italy's experience investing in space startups in particular and the lessons that can be learned from the country's success in fostering a robust national space sector.

The next IAF GNF provided an introduction to Moonlight, a project spearheaded by the European Space Agency to establish a robust communication system between the Earth and the moon. The session featured speakers from the European Space Agency, Telespazio, Astrobotic, ispace Europe, Surrey Satellite Technology, and OHB, who all offered their perspective on the best way to reduce the communication burden for future lunar missions. The idea is to create a shared telecommunications network that will reduce the need for every new mission to the moon to have to carry its own navigation and telecommunication system. All the panelists agreed that the Moonlight project has the opportunity to dramatically lower the cost of lunar missions while improving reliability of Earth-moon communication.

Thursday's sixth IAF GNF featured participants in Horizon 2061, an initiative designed to foster long term thinking around our planetary exploration goals. The conversation featured speakers from Institut de Recherche en Astrophysique et Planétologie, Johns Hopkins Applied Physics Laboratory, EuroMoonMars, and Thales Alenia Space Italia, who all offered their vision of the deep future of space exploration. A central theme of the discussion was the importance of long term thinking and clearly articulating our biggest goals for the far future. Without initiatives like 2061 taking the long view, the speakers argued, it will be difficult to successfully execute on the most ambitious crewed and robotic exploration missions.

The final IAF GNF session of the day focused on sustainable lunar activities. It featured a panel with representatives from the Moon Village Association, the Egyptian Space Agency, Redwire, the Romanian Space Agency, and the University of Luxembourg who offered a balanced mix of views on the subject through a governmental, industry, and academic lens. The session focused on the legal framework for ensuring that humanity's return to the moon is accomplished in a way that is fair and transparent without undermining innovation through over-regulation. The session participants agreed that it is crucial that these decisions are made now before the possibility of conflict and to create certainty for all stakeholders about acceptable actions on and around the moon.

Friday
29 October 2021

The final day of IAF GNF sessions for IAC 2021 covered three diverse and important topics for the space industry. The first session of the day was an introduction to the deep space food movement, which was followed by panels on the accessibility of space and the role of media in promoting space activities.

As the world space industry prepares for the next great leap in human space exploration beginning with private rides to orbit and eventually new human habitats on and around the moon, it has raised a pressing question: How will the astronauts eat? The first GNF session on Friday was an introduction to the Deep Space Food Challenge, a competition run by NASA designed to rethink our culinary future beyond Earth.

The session brought together speakers from the Methuselah Foundation, NASA Centennial's Allied Organization, Infinite Area, the European Space Agency, EuroMoonMars, Starlab Oasis, Martha Stewart Living, and the UN International Fund for Agricultural Development, who offered their perspectives on why it was necessary to change the way astronauts eat. The session began with an overview of NASA's Deep Space Food Challenge, which attracted 250 teams from around the world who submitted their own proposals for novel food systems. The challenge is ongoing and is about to enter its second phase, and the speakers were optimistic that the result of the competition will not only help astronauts be nutritionally health on long duration space missions, but that the food systems themselves will be key enablers of those missions.

The second session of the day was focused on space accessibility and was specially organized through a collaboration between the International Astronautical Federation (IAF) and the Association of Space Explorers (ASE). It featured speakers from Canadensys Aerospace Corporation, the UAE

astronaut corps, DCVC, Institute for Biomedical Problems of the Russian Academy of Sciences, ROSCOSMOS, the European Space Agency, and NASA who examined the way that the barriers to crewed space exploration have fallen and the work that still needs to be done to open up space to more people. Many of the participants in the session were astronauts or spaceflight participants, and they shared their experiences and the responsibilities that come with space travel.

The final GNF panel of IAC 2021 was a roundtable on the role of media in promoting space activities. It featured several members of the press with representatives from SpaceSide OÜ, SpaceNews, The National, Space in Africa, and others who discussed the vital role that communicators and journalists play in helping everyday people and industry insiders alike connect with the latest developments in space exploration. The panel discussed how the nature of space media is changing due to the advent of social media and debated the role of the media as space advocates versus just providing the facts. The speakers all emphasized the importance of humanizing space by not just focusing on the incredible technology in the space but the people behind those technologies. In conclusion, the group also offered some suggestions on how participants in the space industry can improve communications and ensure that the media is able to do its job of bringing the stars down to Earth for their audiences. ■

IAC 2021

Special Sessions

SpS

Monday
25 October 2021

Monday saw the Special Sessions cover two very different topics, learning about the importance of infrastructure to space exploration and two missions that will help humankind one day, if needed, deflect an asteroid that could destroy civilization. There were three infrastructure games organized by LightBridge Strategic Consulting's co-founders Kevin Barry and Eduardo Pineda. The games were designed to raise the players' awareness about the economic merits of space infrastructure, specifically on launch and transportation infrastructure needed for the development of a space-based economy.

The first game involved moving water from one bucket to another using small plastic cups and a hose. The cups represented a rocket's small payload and the hose represented infrastructure. Deep space exploration and colonisation was reflected in the fact that for the extended distance three cups were needed to move one cup onward and then another three to reach final bucket. One team had cups and the second had the hose. In the first round the hose took longer, but the hose team in the next round won. This was because eventually the hose, infrastructure, provided more payload to the colonies.

The second game introduced economics. Everyone was given $10 and we sold them cups at $5 each, which represented rocket payload space, or they could buy the hose for $100. This saw one group come together as a team of 10 to buy the hose while some individuals only bought cups. One individual was able to tripe their original capital and have $30 by the end of the game delivering payload, water, but the hose team eventually made $150 because of the hose's greater capacity. But everyone in the hose team made less money individually. The hose, which represented infrastructure, saw less profit, but more people would have benefited. In the third game, teams had to build towers and the infrastructure team began $100 in debt but could buy blocks for $2 each while the rocket team had no debt, but each block was $4. The goal was to build the tallest tower and more towers and at the end of a round, a team

would be paid based on the height and number of towers. The infrastructure team won by a small margin indicating that for a larger Earth-Moon-Mars economy infrastructure would ultimately deliver a more productive multiplanetary economy. The second part of Monday's Special Session was about the NASA Double Asteroid Redirection Test (DART) and European Space Agency Hera missions that will perform the first asteroid deflection test using a kinetic impactor. DART and Hera are both going to the binary asteroid system of Didymos, an 800-metre average asteroid, the mother, and its small moon, Dimorphos, which is 163 metres in size. DART launches in November 2024 and it will go to the small Moon and use a kinetic impact to determine what effect a small impact can have and if it can stop an incoming threat. "We have studied other technologies, nuclear, but this one sems to be the most effective. Dimorphos orbits at a 12-hour period. The goal is to model the effectiveness of the impact and its effect on the momentum," said GMV Aerospace & Defence space systems and robotics Executive Director, Mariella Graziano. The European Space Agency's mission Hera will be launched in October 2024 and will arrive at the binary asteroid system in 2026. Hera will have two cubesats, Juventas and Milani. Hera is the first mission to characterise the asteroids' dimensions and is the first time that a soundings of the asteroids' internal structure will be studied. It will also study the crater left behind by DART's kinetic impact.

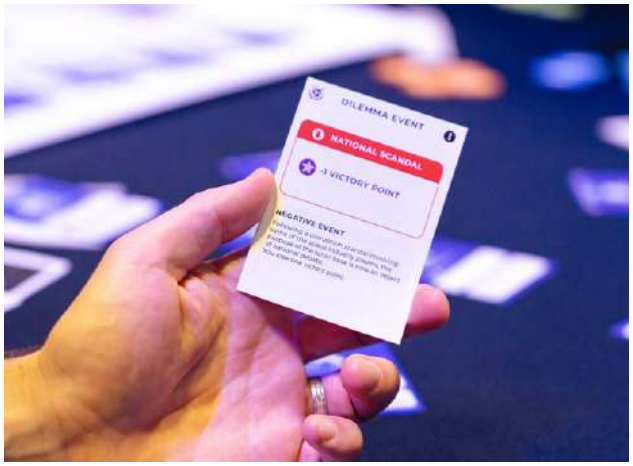
Tuesday
26 October 2021

The first part of the Tuesday Special Session was a workshop on nanosatellite mission design with Open Cosmos, a mission design company. Mission design can be just a mouse click away with modern software and Space Generation Advisory Council (SGAC) partner, Open Cosmos, provided an insight into nanosat mission planning using its software. Open Cosmos can help with constellation design, satellite manufacturing and testing, launch, satellite commissioning and operations, and insurance and compliance.

First and foremost, Open Cosmos is a mission designer, SGAC national coordinator for Angola, Marco Romero explained. Regional Partnership manager for SGAC, Manuel Ntumba pointed out that the missions for nanosats can be varied, from remote sensing to wider Earth observation, all of which can be used to monitor climate change, ecological events. Open Cosmos Academy ambassador Isaac Garcia reminded the audience that that space environment is harsh, it is radioactive, it is very demanding for the nanosatellite.

The second part of the Tuesday Special Session was about the impact of satellite constellations on ground-based astronomy. European Space Agency ARTES Programme Assistant Contracts Officer, Charlotte Nassey and International Astronautical Federation technical committee on space traffic management member explained that SpaceX Starlink satellites had been seen with the naked eye as satellites have become a more reliable business more and more are being used. “We have realised there is a downside. This issue will require all the actors to cooperate to mitigate this,” Nassey said. Association Ephemerides Astronomer Fatoumata Kebe explained that the stress from the constellations’ impact can be mitigated, but it takes a while and one night of observation costs 50,000 euros. Telescopes are based in deserts to avoid humanity, but the constellations can interfere with the radio telescopes at any time. “We started work on this two years ago and we intend to work with industry to preserve the astronomical studies and to protect the sky,” Kebe said.

The third part of the day was about rethinking the sustainability and inclusiveness of space exploration through the design of space habitats. Saint Petersburg State University lecturer Julie Patarin-Jossec pointed out that space habitats design up to now have reflected the people who have dominated the space industry and the designs have not include the needs of other types of people. indigenous geographer Deondre Smiles spoke via pre-recorded video and said that just because there are no indigenous peoples in outer space does not mean we should colonise it; which means more anthropogenic change outside the Earth. The final part of the day was about gaming conflict and cooperation scenarios in lunar development. There is a risk of unnecessary duplication of resources on the Moon and there are many missions planned from now until 2030 which may lead to increased tension on Earth if something goes wrong on the surface, especially with human missions. With a red and a blue team, the two teams ultimately competed and did not cooperate after difficult early negotiations. The Red team won by one point due to a favourable geopolitical event back on Earth.



Wednesday
27 October 2021

The Wednesday Special Session began with the International Astronautical Federation initiative on space traffic management. The session heard that the IAF, International Institute of Space Law (IISL) and International Academy of Astronautics (IAA) have agreed a memorandum of understanding for a technical committee to look at space traffic. The work began by identifying an initial list of 23 topics, IAF Space Traffic Management Committee chair Christophe Bonnal said and nine were selected based on the levels of interest. Small groups were then dedicated to each topic and 10-15 pages were produced, including an executive summary, by each topic team. The IAF, IAA and IISL are working together to produce a final document which will be a synthesis of all the working groups' reports. The second part of the Wednesday Special Session was about viewing the health of the oceans from space. Earth's Oceans, cover greater than 70% of Earth's surface and are critical to climate, weather, transportation, food, ecosystem health, biodiversity, and security.

Satellites provide unique, critical information for understanding how Oceans are responding and, in some cases, forcing climate change, and the many other factors critical to humankind. Centre National d'Etudes Spatiales' Head of Earth Science Selma Cherchali explained that in November 2022 a NASA, CNES, United Kingdom Space Agency, satellite mission, Surface Water and Ocean Topography, will be launched. She added that in last 30 years no single agency has built a system that can monitor the entire planet and its oceans. Agencies need to work together to identify solutions to challenge of monitoring world's environment.

The third part of the Wednesday Special Session leapt to geosynchronous orbit with a independent proposal for a geostationary orbit space station. The station would be 100 times further from the surface of the Earth than the International Space Station at a distance of 36,000 kilometres. Called Gateway Earth and proposed for the 22nd century, the speakers for this session were from Scotland, the United States, the Netherlands and Slovenia.

International Lunar Exploration Working Group Executive Director Bernard Foing, from the Netherlands, said that Gateway Earth could be used as a factory to manufacture interplanetary vehicles that could not be launched from Earth. The station could also be a refuelling station for reusable tugs that move spacecraft from one orbit to another. Science and tourism were also proposed uses for the station.

The final part of the Wednesday Special Session was the findings of a community think tank activity on the topic of in-space Servicing, Manufacturing, Assembly, Robotics, and Transportation or SMART. Justin Kugler explained that the space Smart think tank was a volunteer organization of industry and academic experts. It is seen as a "pre-competitive phase," study examining how different groups could work together on technology and policy to move SMART forward. The goal is to create a space-based supply chain, an eco-system of capabilities in low Earth orbit that can also increase space science, support cislunar exploration, spur space commercialisation and protect space assets. Growing the space economy, increasing space collaboration were two of the common themes that ranged from new combinations of capabilities, persistent platforms, automation, robotics that can host visiting payloads and able to carry out more than one single mission.

Thursday
28 October 2021

The first part of the Thursday Special Session examined the potential clashes between space law, commerce, antitrust and ethics. International Institute of Space Law (IISL) Executive Secretary, Diane Howard, said the growth of the space economy ecosystem will see novel activities and combinations of activities previously conducted separately which may have legal implications. NASA Chief Economist Alexander MacDonald spoke via pre-recorded video about partnerships and lessons learned from International Space Station. He said that there would be a need for multilateral dialogue for the next phase of lunar development. He added that it was a difficult path but it has been done before with the creation of the Outer Space treaty. Federal Aviation Administration (FAA) Office of Commercial Space Transportation Director of Research and Program Manager for the FAA Center of Excellence for Commercial Space Transportation, Ken Davidian, said that different industries are emerging at different rates. In his view, these nascent industries to be allowed to grow and make mistakes and produce products and then the law should be created to protect the public.

The second part of the session heard about the United Arab Emirates' Mars Mission (EMM). The audience heard from Mohammed Bin Rashid Space Centre (MBRSC) EMM Instrument Science Engineer (EMIRS), Fatma Lootah; MBRSC EMIRS Khalid Badri; MBRSC Lower Atmosphere EMM Science Data Analyst, Noora Al Mheiri, and MBRSC EMM Science Data Center Lead, Omran Al-Hammadi. The EMM Hope spacecraft was launched on 20 July 2020 and was captured by Mars' gravity on 9 February 2021. The science phase of the mission began on 23 May, and this lasts for two years. Lootah explained that Hope is studying the Martian atmosphere and that the uniqueness of Hope is its global geographic coverage and the full image of the atmosphere it can provide. Al-Hammadi explained the mission's data management explained and how third parties could use the science data centre to download data for analysis.

The third part of the Thursday Special Session was about Amazon Web Services (AWS) and how AWS can enable developers, data scientists and organizations to acquire, process and analyze all the data from the growing number of commercial satellite constellations for Earth Observation, together with the proliferation of cubesats, nanosats and even chipsats. The audience heard about how AWS has a standard workflow for geospatial analytics. This includes data from Amazon's satellites, public satellites and third party data. Satellite data can be stored as TIFF or GeoTIFF or metadata such as XML. The analytics includes traditional processes using physics-based models and data distribution. Distribution can be as a data set or as a visualisation or another method.

The final part of the Special Session was about the results of a study funded by NASA's Human physics division and carried out by Johns Hopkins University Applied Physics Laboratory. This report into a "pragmatic interstellar probe" is to be published by the second week of December. It is a multigenerational mission begun by one generation and completed by a future generation because the proposed launch date is 2036 and the flight time of the spacecraft will be more than 50 years.

Friday
29 October 2021

Friday Special Session began with a demonstration of data processing using artificial intelligence (AI) and satellite data for ocean farming applications. The world is asking, how can food security be improved, and ocean farms are one answer. However, they face several threats such as ocean acidification and harmful algal blooms. Ocean farms may themselves have a negative environmental impact if they are not carefully managed. In the demonstration, AI algorithms combined Earth Observation and navigation information with in-situ data for the sustainable development of ocean farming. The second part of the session focused on advancing disability inclusion in space for the benefit of science. Space policies for disabled astronauts to space education for blind students were examined. The session provided an exciting look at the future of disability inclusion in space. Non-profit disability in science advocate SciAccess Executive Director, Anna Voelker told the audience that 26% of the US population has some sort of disability and that 10% of engineers have a disability and 2% of doctoral graduates have a disability. Voelker explained that surveys had found that US firms with accessible workplaces have higher revenue. She showed educational tools for bind people including 3D printed models of star constellations and talked about how sound could be used to represent data to help inform the blind. SciAccess runs an annual virtual conference about access to science for people with disability.

The third part of the day was about virtual assistants (VA) and how they can interface with humans in a human way while storing a lot of information and potentially reason autonomously, supporting decision-making processes. VisionSpace Technologies is developing VA for information retrieval tasks, its Chief Technology Officer Tiago Nogueira, explained. For the Lunar Gateway, a planned space station around the Moon, and the exploration of Mars, humans and robots will work together. A VA will be needed to facilitate the interactions between astronauts and robots, maybe a rover. Natural language processing will be needed. Texas A&M University Graduate Research Assistant, Antoni Virós i Martin, is developing a VA and his first step was to find out what engineers need. The VA can give advice on, for example, what launch site for what orbit. Other examples were simulation analysis and in-space emergency responses, finding a solution to a problem without relying on mission control. The Friday Special Session ended with the topic of regional cooperation. United Nations Office for Outer Space Affairs (UNOOSA) Associate Space Law Officer, Yukiko Okumura encourages and supports government departments working together to draw up space laws to enable them to participate in international programmes. This UN effort to encourage the adoption of space law is funded by Chile, Belgium, Luxembourg, Kyushu Institute of tech and Secure world foundation. Keio University Law School Professor of Law, Setsuko Aoki spoke of the Asia-Pacific Regional Space Agency Forum (APRSAF) which has existed since 1993 promoting the peaceful uses of outer space. Sharing best practice in space law and policies, Australia, India, Indonesia, Malaysia, Korea, Vietnam and the Philippines participate. United Arab Emirates Space Agency Executive of Space Activities Licensing, Hamda Al Hosani, spoke of UAE space legislation and how March 2019 saw the national space strategy published with six goals and 16 programmes. That year also saw space sector legislation. University of Nebraska-Lincoln College of Law Professor of Space Law, Frans Von Der Dunk, said that for the United States international space cooperation is a matter of policy, not law. He cited the Artemis Accords which he said are for cooperation and that 12 states, and or space agencies had signed them. ■

Special Sessions

IAF IDEA “3G” Diversity Day

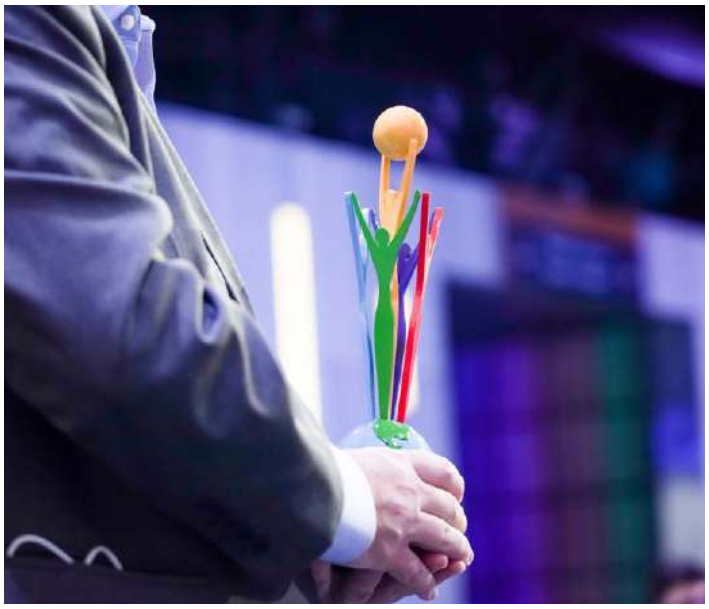
The International Astronautical Federation’s International Platform for Diversity and Equality in Astronautics (IDEA) breakfast and lunch were held on Wednesday 27 October at the 72nd International Astronautical Congress.

IAF IDEA "3G"

The 3G (Gender, Geography, Generation) Diversity Breakfast sponsored by NASA Jet Propulsion Laboratory (JPL) saw JPL's Interim director, Larry James, given the Excellence in 3G Diversity Award. James said: "Your career is only limited by your imagination and if everyone can accomplish that then we have succeeded with our 3G programme. We want everyone to have voice to get to the solutions." He spoke of JPL having different groups representing the different types of "employee resource groups," which had names like, 'Spectrum' and 'AAC equality California' and 'Mental wellbeing in indigenous communities'. He explained that when he in the 1980s first led a team as a young captain, he was responsible for a small team of 10-15 officers in the GPS satellite development. It was at that point that he recognised the strength of a diverse team, which included young ladies, young lieutenants, people from parts of the United States he had never been too. Hearing the various viewpoints, James understood that there was

strength in diversity. At the IDEA "3G" Luncheon on the same day, IAF President, Pascale Ehrenfreund welcomed people and spoke of the idea of "3G" being able to unite people and how important cooperation was. Ehrenfreund thanked the sponsor, Jacobs. Jayne Dale, Jacobs' Space Campaign Lead for the EMEA region spoke about how technological change is more far reaching than it has ever been and how organizations are strengthened when they include diversity principles. Space was challenging our perceptions and as individuals we are more connected now than we have ever been, she said. "I can see we are breaking through our national boundaries simply by seeing how astronauts cooperate on the ISS," Dale said. IAF Vice President for Honours and Awards, Anthony Tsougranis was there as part of the award ceremony of the luncheon. He said that human dignity means respecting all human beings irrespective of each of the 3Gs and that equal opportunity meant everyone has the same opportunities regardless of the 3Gs or their disability status.

For Tsougranis, smart solutions mean the many different experience are considered so organizations can come up with better solutions, and he added that JPL has bult a strategy to support diversity. Larry James, JPL interim director, spoke at the luncheon following his earlier Excellence in "3G" Diversity Award. He said he knew there was a lot of "stiff competition" for the award. The Luncheon also saw the Excellence in "3G" diversity award for teams and projects awarded and it was awarded to the Earth and planetary imaging academic team at Israel's Ben Gurion University. Shimrit Maman-Tirosh, Research Associate and Laboratory Director, accepted the award. Maman-Tirosh said: "Diversity means variety and with a variety of ideas the best idea will come to the front. With a variety of experience, the team is richer and more productive. It is the responsibility of all, irrespective of "3G", to act jointly to use all available space technology to confront climate change." ■



11th IAF International Meeting for Members of Parliaments

The 11th IAF International Meeting for Members of Parliaments met at the 72nd International Astronautical Congress with the theme of Space Solutions for the Benefit of Society.

The President of the International Astronautical Federation, Pascale Ehrenfreund opened the meeting by presenting the goal of the event and its history. She was followed in her welcome remarks by the speaker of the Federal National Council of UAE, H.E. Saqr Ghobash, welcomed the fellow representatives as Guest of Honour of the Event. His Excellency pointed out that humanity is facing a fourth industrial revolution where nations are realizing they need innovation and space access for their future. Dominique Tillmans, Chair of the Event and IAF VP for Parliamentarian and Ministerial Relations and User Communities, presented the main goal of the meeting explaining how the platform need to become a beacon for the Parliamentarians, "*the place to be*", where MoP are called to be the main actors of by presenting the benefits that space brough or might bring within their country with the idea that "*what is possible in your country should be possible in mine too*".

The Emirates were also represented Salem AlQubaisi, Director General of the UAE Space Agency, who welcomed the participants highlighting that the IAC 2021 was the first congress ever hosted in an Arab Country. He continued by outlining the country's plans to launch a probe to Jupiter and the asteroid belt in 2028, making the UAE only the fourth country to send such a mission. The lessons learned from UAE's Hope mission to Mars would help the country's space industry and future missions: "Hope will produce gigabytes of information during the mission all of which will be given to the global community".

The Host of the IAC 2021, the Mohammed Bin Rashid Space Centre (MBRSC), was represented by its Director General, Yousef Al Shaibani. He stressed on the importance of partnership and cooperation for the future of the world and emphasized that, in future, space exploration would become more global. Concerning the internal projects for UAE he said that "The UAE's focus for the next period is getting the private sector and start-ups more involved in space".

The welcome remarks were concluded by Sophie Primas, President of the Economic Affairs Commission of the French Senate, who invited her fellow Parliamentarians to join her in Paris for the 12th IAF international meeting of Members of Parliament which will be held in conjunction with the IAC 2022.

To better deepen the discussion about the solutions that space applications and technologies can bring to societies the meeting was divided in three different sessions, each focusing on one specific topic and characterized by both the intervention of an expert of the field and multiple presentation from the attending Members of Parliaments.

The first session, focusing on Space Solutions for Health & Emergency was introduced and moderated by Joseph Aschbacher, the Director General of the European Space Agency. After the introduction of the topic by the moderator, which focused on the international cooperation to supports states hit by major disasters, several national representatives gave detailed information about their countries internal and international efforts.

Sérgio Freitas De Almeida, Vice Minister of the Brazilian Ministry of Science, Technology and Innovations focused on the country efforts in spreading the benefits that space technologies can grant to societies.

One of the French representatives who attended this year's meeting, Bastien Lachaud, Member of the French Parliament, presented the various ways in which space can serve the management of health with a presentation titled "Towards a planification of space services for public health".

Greece was represented on site by Christina Giannopapa, Advisor to the Secretary General of the Greek Ministry of Telecommunications and Post, which gave an interesting presentation on "Space as an enabler for the Digital Transformation".

The focus then moved to Poland with the intervention of Jakub Ryzenko, Expert of the Space Group of the Polish Parliament, represented in Dubai by Bogusław Wontor, Chairman of the Group, Paweł Poncyljusz, Vice Chairman, and Zbigniew Girzyński. The presentation introduced to the audience the efforts of the country toward the development of a "Systematic approach for use of satellite data for crisis management in Poland".

The second session of the day was introduced and moderated by a young researcher from the MBRSC Lab, one of the most innovative branches of the Mohammed Bin Rashid Space Centre (MBRSC) which gave a fresh look to the topic of the session "*Space Solutions for Mobility*".

Belgium, home country of the IAF VP for Parliamentarian and Ministerial Relations and User Communities and Co-Chair of the meeting, former senator Dominique Tilmans was represented both by Michel De Maegd Member of the country's Parliament, and Steven Coenegrachts, representative of the Belgium Senate.

De Maegd focused on the most recent innovations brought by the management of mobility by drones, "*How drones will make our mobility better*", while Coenegrachts gave a presentation titled "*Opportunities for public transport using space technology*"

The final session of the day, "*Space Solutions for Public Services*", was moderated and introduced by the President of the Italian Space Agency, Giorgio Saccoccia, and saw the participation of several countries to the debate thanks to the interventions of multiple representatives.

The Parliament of Azerbaijan, attending the event for the first time, was represented by Vugar Bayramov, Member of Committee on Economic Policy, Industry and Entrepreneurship. While a longstanding supporter of the meeting, the Parliament of Estonia, was represented by Andrei Korobeinik, Head of the Space Support Group and of the delegation, who gave a presentation titled "*Estonian AI applications based on space data – an outlook on our public and private sector*", Raivo Tamm, Member of the Parliament, Paul Liias, Head of Space, Economic Development Departement, and Madis Vooras Head of the Estonian Space Office - Enterprise Estonia.

Sophie Primas, President of the Economic Affairs Commission, Senate of France, took the floor once again to give a short presentation on "*Precision in agriculture: space at the service of the transformation of agricultural practices*". Followed by Zeynep Yildiz, Member of the Turkish Parliament, who focused on "*HES Code (Life fits into Home)*".

Ukraine participated to the event with two members of Parliament, Dmitry Natalukha, who presented on "*How parliaments and state agencies can cooperate to use space programs for a public good?*", and Alona Shkrum.

Finally, the African continent was represented at the meeting thanks to Mahama Ouedraogo, Head of the AU Commission for Education, Science, Technology and Innovation (ESTI) of the African Union, whose intervention concluded the last session.

The meeting was further enriched by questions and interventions from other attending representatives, such as the President of the Austrian National Council, Wolfgang Sobotka, who was accompanied by Andreas Liebmann, Austrian Ambassador Extraordinary and Plenipotentiary to the UAE; Marcos Pontes Brazilian Minister of Science, Technology and Innovations; Claude Raynal, Sénateur de la Haute-Garonne, France; and Roberta Pinotti, President of the Defence Commission of the Italian Senate.

In addition, the various national delegations of the UAE Federal National Council attended the meeting in its entirety, and welcomed the foreign delegations.

The closing remarks were given by Sara Mohammad Amin Ahmad Mohammad Falaknaz, Members of the UAE Federal National Council.

After a short networking lunchthe meeting's programme continued with a short press conference, where the Minister Marcos Pontes and Vice-Minister Sérgio Freitas De Almeida - Brazil, Zeynep Yildiz Turkey, Dmitry Natalukha – Ukraine, and the IAF VP Dominique Tilmans answered the questions from the press and the audience.

The MoPs meeting included, on Monday, MoPs's participation in the IAC 2021 Opening Day, where they were invited as Guests of Honor, and on Tuesday a guided tour of World Expo 2020, organized by the host. ■

IAC Hosts Summit - Eighth Session

Incoming IAF President and Blue Origin Vice President for Sales, Marketing & Customer Experience, Clay Mowry, chaired the IAC Host Summit of the 72nd International Astronautical Congress. He said that he was pleased there were five bidders for holding the IAC in 2024. Mowry talked about how recent years had seen a "huge resurgence in space, investment in space, growing interest, almost on a daily basis."

What is important is sustainability of space and how to benefit life here on Earth. He announced that IAF would accept 50 new members at this IAC making the Federation more than 430 member organizations. He noted that the growth was in companies and research and development institutions, for example. Mowry spoke of the impact COVID-19 had had for Blue Origin and how manufacturing was able to continue with health protocols, such as mask wearing.

During the Pandemic, Blue Origin had hired more than 1,000 people, Mowry added. IAF Executive Director, Christian Feichtinger, told the Summit how IAF had been resilient in dealing with the COVID-19 crisis. "We always put the mission first and be true to the motto, connecting the space community", he explained. He defined resilience as meaning protecting the IAF's financial performance. With the spread of COVID-19 around the world in early 2020, the IAF Spring Meetings last year was the first time the Federation members met virtually. "At the beginning it sounded quite weird [a virtual meeting] and it took some quite intensive discussions in the bureau and finally the bureau took the decision to go for that [for IAC 2020]," Feichtinger said. The 71st IAC, the CyberSpace edition, was a success with more than ten of thousands of views of live sessions and technical presentations, far greater than with a normal Congress, but the important missing part was the in-person networking.

IAC Hosts Summit

For the Global Space Exploration Conference 2021, which took place in St. Petersburg in the Russian Federation from 14-18 June, it was an in-person event with hybrid elements. It saw more than 2,000 registrants with 866 in-person registrants and a further 1,503 virtual registrants. Half of the 866 were from outside the Russian Federation. Feichtinger said that the decision was taken not to make the 72nd IAC a hybrid event to encourage people to attend and there were more than 4,000 registrants with more than 50% of them below the age of 35. The activity that led to that decision started with weekly teleconferences from February, March 2020, Mohammed Bin Rashid Space Centre Deputy Director General and Chief Executive Officer, Saleem Al Marri, told the Summit. "When we saw Expo 2020 was being delayed to 2021, the government decided it was hard to have large events," said Al Marri. There were lots of discussions about the IAC being hybrid or reduced in number, but then the Dubai Emirate decided to open up in the summer 2020 and that saw the hotel traffic return to normal. This turn of events led to the May announcement that IAC 2021 was going ahead, Al Marri explained. The good news has been that while 2,000 registrants were planned for, the 72nd IAC had more than double that and up to 15 Arab nations participated. ■

IAC 2021
Closing Ceremony

The IAF Executive Director, Christian Feichtinger, opened the closing ceremony, recounting the week's activities of the 72nd International Astronautical Congress. The IAF President Pascale Ehrenfreund joined Feichtinger on stage and underlined the great success of the IAC. She preceded by thanking everyone involved in the congress and expressed her gratitude to all the volunteers, speakers, and delegates.

Ehrenfreund welcomed on stage the incoming IAF President, Clay Mowry, who will take over at the closing ceremony of the 73rd IAC, to be held in Paris in September 2021. They were then joined by the four newly elected IAF Vice Presidents: the Canadian Space Agency's President, Lisa Campbell, the Chief Operating Officer of the Centre National d'Etudes Spatiales, Lionel Suchet, the Space Foundation's Senior Vice President of Strategic and International Affairs, Steve Eisenhart, and Space Generation Advisory Council (SGAC)'s Executive Director Davide Petrillo.

Outgoing Vice Presidents were also invited on stage to be thanked for their service. On this occasion the IAF President announced the new IAF Honorary Ambassador Programme, which will be composed of the 2021 outgoing IAF VPs and the IAF Past President, Jean-Yves Le Gall. "Once again, I want to thank all of you and the entire IAF community, it is you that make the IAC so interesting and alive without you this wonderful project would not be possible" concluded Pascale Ehrenfreund.

MBRSC Deputy Director General and Chief Executive Officer, Saleem Al Marri, addressed the audience expressing his stance on the closing event "We are humbled by the support and comments over the past week. As one of the first in-person events we had to move fast, and it needs strong partnerships and cooperation. This is a strong message that in-person meetings are back and thank you for coming to Dubai. Thank you to all our sponsors and our leaders here in UAE".

The IAF Executive Director, Christian Feichtinger, brought this part of the closing ceremony to an end by thanking the UAE and the Mohammed Bin Rashid Space Centre team, and presented the IAC 2021 Highlights Video.

The second portion of the closing ceremony was dedicated to the IAF Awards. Anthony Tsougranis, IAF VP for Honours and Awards proceeded to recall the various awards bestowed during the week and then moved forward to announcing the winner of the Frank J. Malina Astronautics Medal, Filippo Graziani, Senior Professor of Astrodynamics, University of Roma "La Sapienza" and long-standing participant of the IAC "I am very honoured

to receive this award from the IAF. I remember the first IAF conference I participated in 1975 in Lisbon". The Ceremony continued with the announcements of the finalists of the Luigi G. Napolitano award, and the winner, Federica Angeletti. Anthony Tsougranis then announced the 2021 awardees who have been included in the IAF Hall of Fame: Alexander Degtyarev, General Director - General Designer of the Yuzhnoye State Design Office, Guirong Min, Chief Scientist and former President of the China Academy of Space Technology (CAST), and Matsuo Hiroki, President of the Japanese Society for Promotion of Space Sciences.

The IAC 2021 was the first in person conference since the beginning of the pandemic, after inviting on stage the winners of the 2021 IAF Young Space Leaders Recognition Programme, the IAF VP took the occasion to call on stage the awardees of the 2020 IAF YSL. Both groups were warmly welcomed by the public.

The ceremony followed with the announcement of the 2021 IAF Emerging Space Leaders and all Student Competition awardees.

After a final warm round of applause for all the winners, Christian Feichtinger moved to the final portion of the ceremony, he highlighted the outstanding success of the event recalling that "This IAC confirms the will of our community to come together and 5,000 delegates from more than 110 countries decided to join us here in Dubai and another 1,500 joined for the public day." Feichtinger called on stage the IAC 2021 Organizing team together with Lionel Suchet, Chairman of the IAC 2022 Local Organizing Committee, for the traditional handover of the IAF Flag.

The IAF President, Pascale Ehrenfreund, closed the ceremony and the Congress by thanking everyone and wishing the attendees to enjoy the city of Dubai. "Thank you all for participating. I'll see you all at the IAC 2022 in Paris," she added. ■

IAF Astrodynamics Committee

Introduction

The IAF Astrodynamics Committee was established more than four decades ago and is currently made up of about 30 members. The Astrodynamics Symposium, coordinated by the Committee and conducted at annually IAC, is an international forum for recent advancements in the areas of guidance, navigation & control, mission design, optimization and operations, orbital and attitude dynamics.

Summary

In the area of Guidance, Navigation & Control (GNC), theoretical as well as applied contributions have appeared in the domains of landing and in-orbit maintenance. As in various other scientific fields, there is a confirmed trend in the research to investigate the benefit of artificial intelligence (neural networks) for the definition of open-loop guidance (also on-board). In parallel, more realistic modelling of the equipment used in GNC (in particular, pulse thrusters) continue to be investigated in terms of impact versus a more simple approach. Two main recurrent themes are:

- autonomy: shift of the guidance & control planning and computations from the ground station to the on-board computer,
- GNC techniques: machine learning, reinforcement learning, potential function, sliding-mode control,

whereas the main applications are:

- reconnaissance and landing on small bodies: autonomous reconnaissance, trajectory optimization, landmark navigation,
- formation flight and swarms: decentralized control of swarms, reconfiguration control, optimal collision avoidance,
- orbital debris: uncertainty propagation, collision prediction, debris removal,
- Earth-Moon system: data-driven model predictive control, low-thrust station keeping and attitude control in Halo orbit.

In the context of mission design, operations and optimization, emphasis is on lunar missions, including satellites in NRHOs and deployment of microsatellite constellations. Missions to the Martian moons have gained interest, most likely in response to the role that Phobos and Deimos have been assigned in support to the Mars exploration program in the areas of telecommunications, radiation protection and infrastructure for transportation and operations. Trajectories to the asteroids and the outer solar system are also in the focus of recent research. From the methodology point of view, multi-objective trajectory optimization approaches have been developed which address system and operations uncertainty (even severe). The use of neural networks and tree-search like heuristics is more and more common.

The main topics and applications in the context of orbital dynamics can be summarized as follow:

- Multi-body dynamics: uncertainty prediction, data-driven analysis and identification of dynamical structures, optimal orbit transfers between invariant manifolds, Keplerian map theory for third-body effects, adiabatic invariant theory applied to capture dynamics,
- Earth orbit dynamics: efficient orbit propagation methods, deorbiting with the use of solar radiation pressure and J_2 perturbation,
- Orbit dynamics in the Earth-Sun system: formation flying control using solar radiation pressure,
- Orbit dynamics in the Earth-Moon system: machine learning for orbit predictions, ballistic escape using lobe dynamics.

Studies in the area of attitude dynamics have developed along traditional as well as highly-challenging paths, such as with magnetic control and control moment gyros. Novel techniques are being investigated, including visual serving based on tracking features identified in onboard captured images. Artificial intelligence techniques are a trend also for attitude control. The a-posteriori analysis of some attitude-related issues during the re-entry of Hayabusa-2 is remarkable and intriguing as all actual operation results can be.

The Breakwell Lecture – Prof. Martin Lara (Universidad de la Rioja, Logroño, Spain)

Prof. Martin Lara from Universidad de la Rioja, Logroño, Spain (in the photo with Prof. Daniel Scheeres and Prof. Anna Guerman) received the Breakwell Award from the International Astronautical Federation for his dedication and outstanding research on perturbation methods. Prof. Lara gave a keynote speech on the application of perturbation methods to Quasi Satellite Orbits and Libration Point Orbits.

Highlights

- Autonomy: shift of the orbital and attitude guidance & control planning and computations from the ground station to the on-board computer,
- GNC techniques: machine learning, reinforcement learning, potential function, sliding-mode control,
- Multi-body dynamics: decentralized control of swarms, reconfiguration control in formation flying
- Interplanetary missions: to the Moon, Mars with optimal orbit transfers between invariant manifolds and the four-body problem technique

Future outlook

- In the year ahead, astrodynamics techniques will enable and enhance a significant number of missions beyond Earth orbit. The Artemis 1 mission will carry several CubeSat payloads of interest, including NASA's LunaH-Map and Lunar Ice Cube missions, which will use ion propulsion to achieve Lunar orbit; NASA's NEA Scout mission, which will solar sail to an asteroid; JAXA's OMOTENASHI mission, which will test landing technologies at the Moon; JAXA's EQUULEUS mission, which will use low-energy-orbit techniques to enter into an orbit around the Earth-Moon L2 Lagrange point. Other lunar missions of note include NASA's IM-1 launch of the CLPS lunar lander, which includes navigation demonstration technologies; NASA's CAPSTONE mission, which will place a spacecraft into a near-rectilinear halo orbit (NRHO) near the Moon; the Russian Space Agency's Luna 25 (lunar lander) mission; Korea Pathfinder Lunar Orbiter (KPLO), the first Korean mission to the Moon; NASA's Prime 1 and Peregrine Mission 1 lunar landers; JAXA's Smart Lander for Investigating Moon (SLIM) lunar lander.
- Further out, the NASA/ESA/CSA James Webb Space Telescope will enter into a halo orbit around the Earth-Sun L2 Lagrange point. NASA's Double Asteroid Redirection Test (DART) mission will deliberately crash a space probe into the double asteroid Didymos to test whether the kinetic effect of a spacecraft impact can successfully deflect an asteroid on a collision course with Earth. NASA's Psyche mission will use ion propulsion to reach its namesake asteroid. A secondary payload on that launch are the twin Janus smallsats which will reach and investigate binary asteroids and their dynamics. ESA's ExoMars 2022 mission comprises a European rover, Rosalind Franklin, and a Russian surface platform, Kazachok. ESA's JUpiter ICy moons Explorer (JUICE) will launch and begin its interplanetary journey to the Jovian system.
- After a successful mission to Mars (Emirates Mars Probe) and the on-going development of the Rashid lunar rover (Emirates Lunar Mission, 2022), the United Arab Emirates (this year's IAC hosts) have announced their next space exploration project: a flyby mission to Venus with an estimated launch date in 2028 that will target an object of the Main Asteroid Belt to which it will release a lander.
- Finally, the 11th edition of the Global Trajectory Optimisation Competition, GTOC 11, was hosted in 2021 by the joint team National University of Defense Technology - Xi'an Satellite Control Center. This competition plans to organize a workshop for competitors to present their solutions in late 2021, and a special GTOC 11 issue in the journal *Acta Astronautica* in 2022.

Committee activities

The Politecnico di Milano (Milan, Italy) will host the 11th International Workshop on Satellite Constellations & Formation Flight (IWSCFF, June 7-10, 2022, https://iwcff-2022.polimi.it/). The event will gather experts from science, mathematics and engineering from research institutions, universities and industries to discuss recent advances in the field of astrodynamics applied to satellite constellations, formation flight and proximity operations.

- From 7 to 9 June 2022, the International Academy of Astronautics (IAA) in partnership with RUDN University (Moscow, Russia) and the American Astronautical Society (AAS) will host the IAA-AAS SciTech Forum 2022 including two conferences: the 4th IAA-AAS Conference on Space Flight Mechanics and the 4th IAA-AAS Conference on Space Structures and Materials. (https://iaaspace.org/event/iaa-aas-scitech-forum-2022/)
- The honorary Breakwell Lecture will be held also during the Astrodynamics Symposium of the 73rd International Astronautical Congress (Paris, 2022). The speaker will be announced in the coming months.
- A Joint Special Session is being proposed in collaboration with the Materials & Structures Committee for IAC 2023 on the topic of attitude dynamics and control of complex flexible structures.

IAF Commercial Spaceflight Safety Committee Brief (CSSC)

Fostering Safe Commercial Access To Space

Introduction

The present brief has been prepared to provide an outlook of the major areas onto which the CSSC focused over the year.

Summary

Spaceports: In Europe there is high interest in Spaceports Development and in general in the new Space Economy. This was in particular remarked during the Conference 'Mediterranean Aerospace Matching', held in Grottaglie in September 2021; this site was designated in 2018 by the Italian Minister of Infrastructures and Transportation as the future spaceport for suborbital flights. The 2nd National conference of Space Geopolitics was held in Caserta, Italy in October 2021, with the participation of the Italian Space Agency (ASI) and reps from different organizations, including ALTEC. In the regulatory area, following the European Concept for Higher Airspace Operations (ECHO) an EU- driven initiative, a working group for High Altitude Operations and Access to Space led by the Italian Civil Aviation Authority (ENAC) was established to start drafting its national regulatory framework covering suborbital flights, air-launch and reentry activities.

Japan has four spaceports in development: Hokkaido, Kii, Oita and Okinawa. Oita Spaceport is based on a commercial aviation airport from which All Nippon Airways (ANA) has signed an agreement with Virgin Orbit to operate the air-launched rocket carrier Launcher One.

Debris Removal: Japan has now five commercial space debris mitigation companies, namely Astroscale (ADR/magnet), Ale (Electrical Tether), Axelspace (Membrane structure), Skyperfect/JSAT(Laser) as well as KHI (ADR/robot).

Suborbital and Orbital Spaceflight: The UK and Italy are pursuing initiatives for direct access to space from their respective territories. In the UK, the Government has published its Space Industry Regulations in July 2020, aiming at Commercial Launches from Scotland from 2023 onwards. In Italy, ALTEC is coordinating suborbital spaceflight capabilities, aiming at carrying out Ground Segment and Operations activities. This is targeting markets such as space tourism, microgravity science, and astronauts/pilots training. Other European countries (i.a. the Netherlands through the DAWN company currently testing rocket-powered drones from New Zealand) are also interested in developing infrastructures for vertical and horizontal operations.

Flight and Ground Facilities: In Italy, the SpaceLand group is accelerating the development of ad-hoc-designed ground and flight facilities to fulfill the need of low-cost, user-friendly low-gravity and zero-gravity environments in support to microgravity STEMM (Science, Technology, Engineering, Math, Medicine). Operations are predicted to start from mid-2022 onwards.

Space Transportation Companies In Japan: there are seven commercial space transportation companies in Japan including Honda which newly announced in September 2021 a small launcher development. Interstellar Technologies have already gotten into suborbital launch service. Planned operations are manned and unmanned by horizontal, vertical, sea and air launch.

Highlights

US New Safety Regulations: New launch and reentry safety regulations (Part 450) issued by the US Federal Aviation Administration's Office of Commercial Space Transportation (FAA-AST) went into effect in 2021. Part 450 regulations may be useful to countries that are considering new national frameworks for commercial space transportation, including hosting U.S. vehicles in their country that would be licensed by the FAA. In parallel, the FAA through its Center of Excellence continues pushing medical guidelines both for Crew Members and for Spaceflight Participants (SFP).

Commercial Space Technologies: In Japan, initiatives are focusing on a pulse-destination engine development, next-gen composite high-pressure tanks and Artificial Intelligence-driven operations. The Space Liner Association (SLA) was established in Japan in May 2021 to develop reusable space vehicles for human suborbital spaceflight, LEO space tourism, and P2P space flight. SLJ is the platform formed by users, operators and manufacturers to encourage LEO and beyond space economic activities under Private-Public Partnerships (PPP).

Ground & Flight Segments: 1) Spaceports: design of the first set of SpaceLand Centers is ongoing, configured as prototypes of Mars Habitats, showcasing novel Near-Zero-Energy-Building (NZEB) and In-Situ-Resources-Utilization (ISRU) technologies, construction methods and mixed materials; such multi-facilities will be open to both users and the general public, with three target locations in Switzerland, Mauritius and central-eastern Asia 2) Flight: following on a License granted to SpaceLand by the US-Government for Spaceport development studies in Africa, an exclusive agreement has been signed with US partners to support the above mentioned projects with a novel large aircraft accessible to SpaceLand affiliates and partners for long-duration parabolic flights.

IAASS Establishes A Space Safety Institute (SSI) as an independent safety verificator for New Space, checking compliance with relevant Industry Standards using a "Safety Case" approach.

Safety and Psychology: When safety is at stake, it is not only a question of technical advances, psychology is also an important question, especially concerning the evaluation of risks. With this point of view, the flight of SpaceX in outer space with only "amateur" astronauts is an important milestone; For some, it shows that non-professional astronauts could be considered as "payload" or "passengers" rather than an integrated component of the safety of the system, what shall impact future designs.

Future outlook

Point to Point (P2P) Transportation: From the perspective of the Global Spaceport Alliance, one of the most interesting projects in the coming years will be the effort to accomplish point-to-point transportation through space. Multiple companies are looking at developing similar systems. Successfully achieving this type of capability will require partnerships between government, industry, and academia, and will involve not only advances in engineering and technology, but also work in policy, law, regulations, customs and security, flight and ground operations, market analysis, and economics. We believe that the IAF Commercial Spaceflight Safety Committee could play an important role in helping to bring about these transformational capabilities.

Japan is establishing and developing its hydrogen network both for ground and space transportation.

Regulatory and Legal: An adequate and harmonized regulatory framework has to be developed and refined. Exchange of information among participating countries has to be fostered.

Access to Low-Cost Facilities: SpaceLand Flight and Ground segments aims to help planetary exploration industry and low-G / microgravity STEM stakeholders in all continents, facilitating access to low-cost facilities for hand-on R&D, Education and Test programs.

Committee activities

The CSSC will focus on fostering the interactions and mutual knowledge of the committee participants. An intensive effort shall be performed in attracting more papers stimulating the sharing of information and discussing among a diverse community the various challenges of common interest. Primary focus has to be put on how Safety affects the various activities and processes. Focus on Space Traffic Management (STM) will also be given by the Committee.

IAF Committee on Integrated Applications

Introduction

Space systems are more and more involved in the delivery of global utilitarian services to end-users. The concept of Integrated Applications encompasses the simultaneous use of basic space services and technologies. The IAF Committee on Integrated Applications focuses on various aspects of integrated applications, which combine different space systems (Earth observation, navigation, telecommunications, etc) with airborne and ground-based systems, in addition to other technologies as big data, analytics, IOT, 5G and others to deliver solutions responding to users' needs.

The applications exploit the synergies between different data sources to provide the right information at the right time to the right user in a cost-effective manner and deliver the data to users in a readily usable form. The objective of the Committee is to enable the development of end-to-end solutions by connecting the user communities that are driving toward end-to-end solutions with those that are developing enabling technologies for integrated applications. Other aspects pertinent to the committee are the commercial satellite applications including the commercial space and space culture, the commercial space model for public users and some case analysis of satellite commercial applications.

Summary

Key topics addressed are the specific systems, tools and technologies in support of integrated applications solving the various issues associated with applications development, the kind of data to be collected, how are data collected and how the data are integrated and distributed to address key user needs.

Highlights

Emerging technologies, such as Machine Learning, Artificial Intelligence, Internet of Things, and other advanced technologies are rapidly revolutionizing and reshaping infrastructure and global-local economies. Leveraging these new transformative developments and understanding their disruptive potential with respect to technology, shifting demographics and global connectivity is essential for space technologies.

Possible topics include: ground-truthing of data collected from space platforms; innovative, low-cost tools for data

distribution and access that focus on the space segment; new ways of distributing integrated data products; data fusion and visualization tools; managing integrated applications programmes and public outreach efforts to connect the public to these applications.

Examples of case studies of particular interest include end-to-end solutions, case studies, proof-of-concept applications and current projects that aim to provide innovative user-driven solutions and applications that combine ground- and space-based data sources with models to address specific user requirements.

These examples can cover a variety of domains, like disaster/crisis monitoring and management, energy, food security, space situational awareness, transportation, health, etc. The user needs, the structure of the user communities, the value chain, the business case and the sustainability of the solutions are among the many aspects that can be considered. Examples of projects with established partnerships and fluent working relationships between space and non-space stakeholders are also discussed.

Future outlook

The concept of digitizing and connecting everything forms the basis of how the Fourth Industrial Revolution, Industry 4.0, is influencing and impacting the world. Emerging technologies, as Machine learning, Artificial Intelligence, Internet of Things, and other advanced technologies are rapidly revolutionizing and reshaping infrastructure and global-local economies. Leveraging these new transformations and understanding their disruption potential with respect to technology, shifting demographics and global connectivity is essential for the space technologies.

The ability of satellite technology to provide ubiquitous and increasingly fast connectivity to billions of people globally is at the core of the Fourth Industrial Revolution. Connectivity is not the only element in the Fourth Industrial Revolution that can be harnessed by the satellite industry. Innovative technologies will open the door to new opportunities incorporating multiple disciplines and industries to create new markets and growth. New business models (eg. the impact of AI on satellite data processing) and the evolving economic/trade landscape, for example related to the autonomous technologies, will lower barriers to entrepreneurs with new ideas to access the markets. Space systems are more and more involved in the delivery of global utilitarian services to end-users.

Committee activities

The plan for spring next year is to undertake a global Air Quality project. The project has already started in Los Angeles funded by NASA. The aim is to integrate data from many other cities around the globe as part of a global effort to use satellite data and ground data to provide predictive analytics using machine learning. See more at http://airquality.lacity.org.

Next year's proposal from the Committee is to organize a special session workshop on "Space Applications for Social Justice". Environmental justice (air quality), food justice (food insecurity), and digital justice (cybersecurity), and educational justice (African school support).

IAF Committee on Planetary Defense and Near-Earth Objects (NEOs)

Introduction

Planetary defense is the term used to encompass all the capabilities needed to detect and warn of potential asteroid or comet impacts with Earth, and to prevent and mitigate their possible effects.

A Near-Earth object (NEO) is an asteroid or comet whose orbit brings it within about 50 million kilometers of Earth's orbit.

The primary objective of the IAF Technical Committee (TC) on Planetary Defense and Near-Earth Objects (NEOs) is to raise awareness among the global space community, in particular the IAC audience, about the ongoing work within the planetary defense community and to get more people, especially students and young professionals, interested and actively participating in the field.

Summary

The biennial IAA Planetary Defense Conference was held in April this year, hosted by the United Nations Office of Outer Space Affairs (UNOOSA). Over 700 individuals from 50 countries attended the virtual event. Highlights of the conference included a realistic but fictitious Asteroid Threat Exercise, as well as a panel that featured representatives of seven national space agencies, demonstrating awareness and support of planetary defense activities. A primary outcome of the conference was unanimous attendee support for an International Year of Planetary Defense (IYOPD) similar to like the 2009 International Year of Astronomy. The 2029 close passage of asteroid Apophis is a natural opportunity to hold the event, raise awareness about the hazard, demystify the topic, and connect current and future communities.

Highlights

Recent highlights include the two asteroid sample return missions. JAXA's Hayabusa2 mission to asteroid Ryugu yielded 5.4 grams of material when it returned the sample on 5 December 2020, while NASA's OSIRIS-REx took a sample from asteroid Bennu on 20 October 2020, which is expected back on Earth on 24 September 2023. While primarily science missions, knowledge about the physical properties and composition of asteroids is critical for designing and implementing a deflection mission when needed. In fact, scientists were surprised by the size of the crater that was created when Hayabusa2 fired a small projectile into the surface on the asteroid in order to take a subsurface sample, as it was bigger than expected, proving that there is still much to learn about asteroids and their characteristics.

Future outlook

On 24 November 2021, the launch period for NASA's Double Asteroid Redirect Test (DART) spacecraft will open. DART will journey to the non-hazardous, binary asteroid system Didymos to demonstrate the viability of the kinetic impactor – an asteroid deflection technology that works by colliding a spacecraft into an asteroid to give it a push years before it would impact Earth in order to move it sufficiently out of the way. In this case, DART will hit Didymos' moon, Dimorphos, on 2 October 2022 and will allow scientists to compare the actual outcome with the expected one. Two years later, ESA's Hera mission will launch to the same binary asteroid system to measure in detail the effect the impact had on Dimorphos after it arrives in December 2026.

Figure 1- left: sample site on Bennu, right: sample from Ryugu

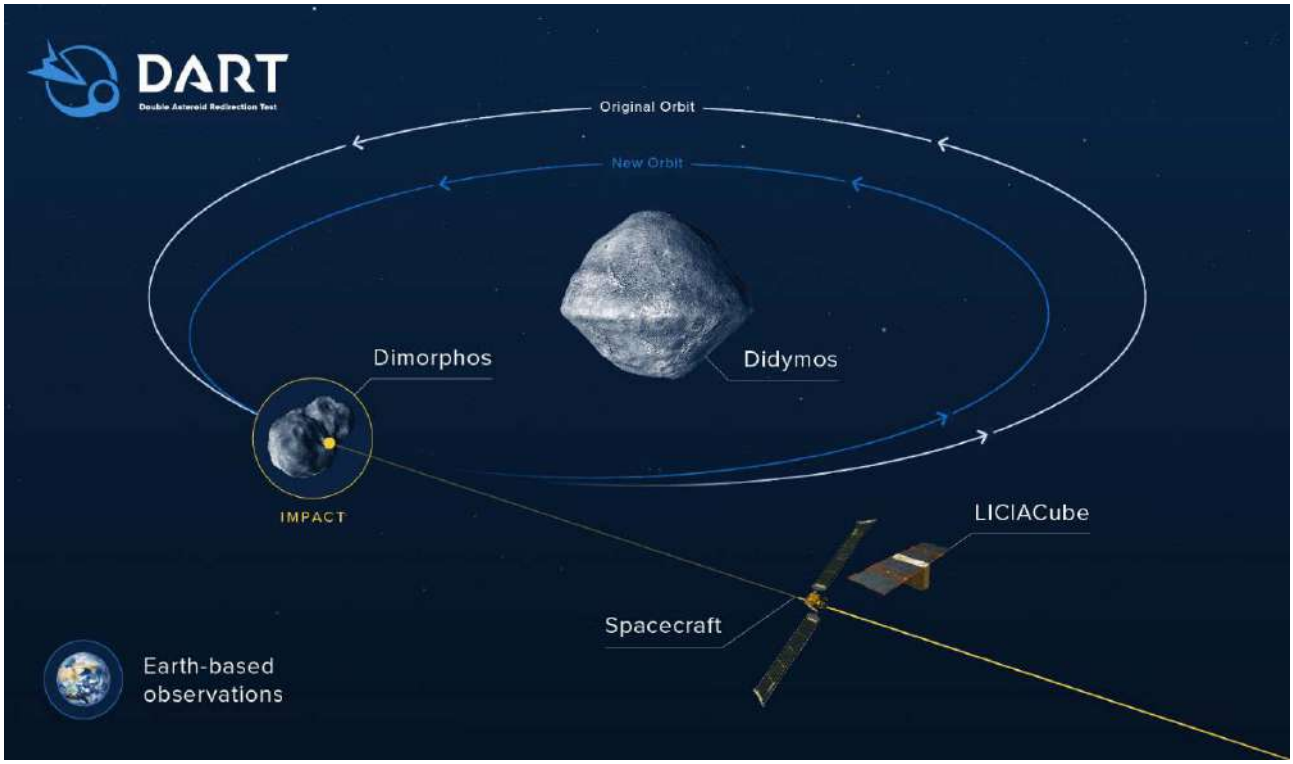


Figure 2- DART kinetic impactor schematic

As we can only deflect what we know, finding objects before "they find us" is of paramount importance. NASA plans to launch an infrared space telescope called NEO Surveyor in 2026 that is dedicated to finding asteroids that are potentially hazardous to Earth. In combination with the ground-based Vera C. Rubin Observatory, which is expected to start observing in 2022/2023, an exponential increase in the number of asteroid discoveries is expected, reducing the uncertainty of asteroid impacts with Earth.

Committee activities

The committee has been renamed to stress its focus on planetary defense and to help clarify the topics covered as the committee will have for the first time a dedicated technical session at the IAC 2022. After successful Special Sessions in 2019 and 2021, the committee intends to continue submitting quality proposals for the IAC programme.

IAF Earth Observations Committee (EO)

Introduction

Earth Observations has entered an era of high importance on international political and social agendas due to the twin threats of global climate change and biodiversity reduction. They have also demonstrated their business value for a wide variety of commercially important applications and are attracting new business from both established industry and entrepreneurial firms across all points of the value chain. These developments are underpinned by dramatic advancements in technologies, business models, and science. They result in providing accelerating value to society as threats and impact along with opportunities to provide actionable information for societal decisions all increase. The most noteworthy developments from June 2021 through November 2021 are highlighted.

Summary

Capella Space announced it will begin installing optical terminals on its SAR imaging satellites to increase volume and speed of data delivery. The US National Reconnaissance Office released a request for bids for commercial imagery from US providers. PlanetIQ Launched its Global Navigation and Occultation Satellite (GNOMES-2) on June 30th and is raising money to build out a 20-satellite constellation. IceEye officially joined the Copernicus Earth Observation Program after winning a contract to provide data from its SAR satellites. Planet unveiled its Pelican Earth-imaging satellites and infusing SAR data from Sentinel 1 in its Planet Fusion Monitoring Project. The 38th Institute of China Electronics Technology Group (CETC) announced it is partnering with Spacety to construct an C and X band SAR constellation of 96 satellites launched into various orbits. Tomorrow.io won a contract from the US Air Force to support a planned constellation of 32 weather satellites with a 1-hour revisit time. NASA's Landsat 9 was launched on September 27th. South Korea announced the Satrec Initiative to build a constellation of high-resolution Earth observation satellites. EUMETSAT made its first commercial data acquisition. NASA and ESA signed a cooperation agreement on climate science cooperation.

Highlights

The major breakthroughs in the field are primarily coming as a result of industry and Agency application of new technologies developed in other industries and supported by Agency technology programs to adapt them to Space application. Two primary technologies to highlight are optical communications allowing satellite to satellite links that enable reduced data latency, and Machine Learning / Artificial Intelligence which is greatly expanding utility and efficiency of analyzing and producing value added information products from earth observations.

Future outlook

The main focus in the following years will be three-fold. First, the major driver from society will be climate change monitoring and mitigation, along with associated improvement in weather, ocean, and land forecasting on all time scales. Second, is value added commercial applications across a wide variety of industries that need precision earth information, and third is security spanning national defense, illegal activity, and major societal issues such as disease, famine, oppression etc. We are seeing the emergence of many developing constellations to address these three topics and many more being announced. The World's Spacefaring Agencies are also obtaining increased resources to expand their science and public benefit observations and applications.

Committee activities

The Earth Observations committee had a very successful IAC 2021 in Dubai with its six technical sessions and one interactive presentations' session. For the third year in a row, a presenter in the EO IP session won the award for top IP presentation in the B Category on Applications and Operations. Highlights included a session dedicated to celebrating 20 years of one of the most noteworthy international collaborations: The Disaster Charter. Several prominent members of the Charter Agencies provided presentations on past successes, status and future plans.

The committee plans to combine the papers along with a summary of the Disaster Charter Highlight Lecture into a special section of Acta Astronautica.

The committee also elected new Officers and reconfirmed members per IAF rules and updated its announcements in the call for papers for IAC 2022 to highlight Green House Gas Monitoring and elicit papers addressing the emerging transformation technologies of Machine Learning and Commercial Ground Services, cloud networking and data analytics. The EOC is working closely with GEOSS to foster new partnerships with Young Professionals, offer a new slate of Plenary and Special Session proposals and other cooperative activities.

Highlight Lecture by the Heads of the Three Founding Agencies – ESA, CNES and CSA at IAC 2021 Celebrating the 20th Anniversary of the Disaster Charter

IAF Enterprise Risk Management (ERM) Committee

Pushing the Boundaries of Risks for a Successful Organization

Introduction/Summary

In 2021 the ERM committee has held two meetings, at the IAF Spring session (virtual) and IAC (F2F/virtual). **A focus on how to assess opportunities linked to every risk were at the core of the discussions this year, especially considering the ongoing pandemic and its impact on Space activities throughout the world.** The major developments and trends that have shaped the year in our ERM field are the relationship between opportunity and risk management.

Highlights

Linking Sustainability of an organization with its risk management process, especially of interest for Risk and Corporate Social Responsibility Officers. Other themes that have been tackled relate to space debris and to the monitoring and prevention of risks especially considering the developments of space traffic management regulations.

Future outlook

In the next year the focus will be on building resilience after having faced risks such as the pandemic and in several areas, such as:

1. automation of risk surveillance, to ensure "full coverage" of risks identification
2. cybersecurity risks and associated regulatory framework
3. risk management in new space technology assets
4. STM for the future in the time of ever increasing constellations
5. strategies for risk management and lessons learned from industries and institutions outside the Space world

Committee activities

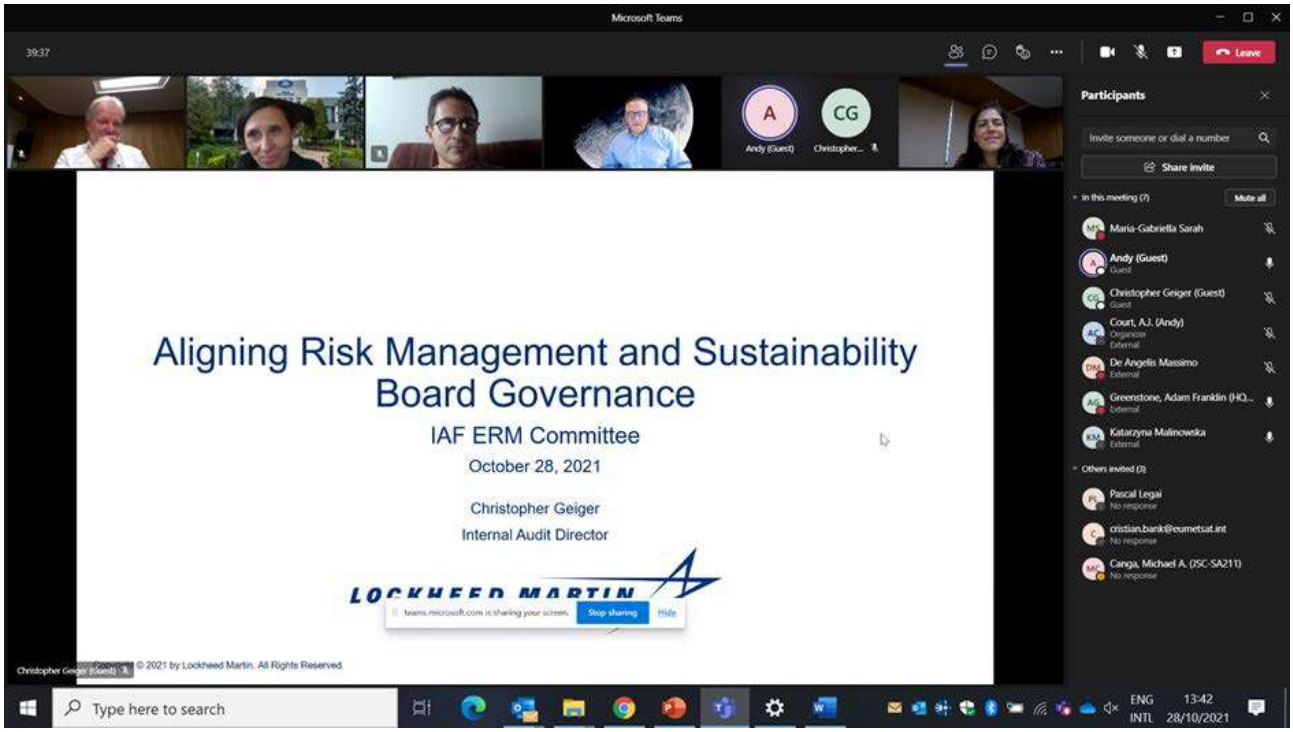
The focus was on analyzing the role played by a robust Risk Management system post COVID-19 pandemic and draw some lessons learned. How were the Risk Managers solicited during and after the pandemic and what was their involvement in the business continuity plan?

The ERM committee has held two meetings this year.

- The first meeting took place during the Spring IAF meetings (cyber edition) in March 2021 and every member was able to report on their business continuity plans within their organizations.
- The second meeting was during the IAC 2021 hybrid-edition (half of the participants online and half were in the room at the Dubai World Trade Center) with a keynote speech from Christopher Geiger, (Lockheed Martin) - internal audit Director-on integrating enterprise risk management and sustainability processes.

At the Dubai meeting the members and officers of the committee were renewed for another three-year term. Christopher Geiger (Lockheed Martin) and Nancy Wolfson (Disrupting Space) were also elected as new members committee. Two experts were also nominated: Antonio Carlo from NATO and Francesca Casamassima from Deloitte, both specialists in cybersecurity, an area of interest for the ERM committee.

Apart from the IAF Spring Meetings and IAC in 2022, the committee will also plan intermediate meetings early in 2022 to agree plans for sessions at the IAC, and before the IAC in Paris to review the program at the Congress.



IAF Global Earth Observation System of Systems (GEOSS) Subcommittee

Introduction

The Global Earth Observing System of Systems has entered an era of high importance on international political and business agendas due to the twin threats of global climate change and biodiversity reduction, and due to the tremendous shift in cost vs benefit profile of commercial and public / private partnership applications. The most noteworthy developments in partnerships, applications, GEOSS cooperation from May 2021 through November 2021 are highlighted. The IAF GEOSS Subcommittee promotes cooperation between space agencies and Earth focused organizations to address the changing climate, its impact on biota, and applications for sustainable development. The Subcommittee coordinates between the IAF and many of these organizations like the Group on Earth Observations (GEO), and works to highlight the latest advances in Satellite based Earth science to the IAC by conducting highlight lectures, plenary events and special sessions at the Congresses.

Summary

Dramatic advancements in technologies, business models, and science are providing the opportunity provide accelerating value to society as threats and impact along with opportunities to provide actionable information for societal and business decisions all increase. Satellite based earth observations are having more and more impact on applications that address environmental conditions, human activity, protection of the environment, and climate change mitigation.

Highlights

The biggest event of the year in Earth science was COP 26 in Glasgow Scotland. The Group on Earth Observations (GEO) community presented through the negotiations, side events and engagements outside the official COP26 events over the two weeks to promote the role of Earth observations in providing actionable information for climate adaptation and mitigation. NOAA highlighted using space assts for monitoring and described the importance of in situ measurements.

GEO week starts in Nov 22, 2021. GEO is a partnership of more than 100 national governments and in excess of 100 Participating Organizations that envisions a future where decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth observations. GEOSS provides the linkage between GEO and the IAF.

There is a major celebration planned for July 2022 to honor the 50th Anniversary of the launch of the first Landsat mission. At the same time, plans are underway to celebrate the 30th Anniversary of the launch of the first spacecraft dedicated to measuring sea surface height and the continuous measurements since that date. Sentinel 6 Michael Freilich was the recent member of this continuous chain of spacecraft.

Key present and upcoming events are as follows:

- November 2, 2021, U.K. Pavilion COP-26, WGIC, GEO and Climate Trace discuss GHG Monitoring from Space Report (virtual)
- October 24-27, 2022, Pecora-22, Denver, Colorado (see attached Hold-the-Date and Call-for-Abstracts)
- October 26, 2022, Landsat 50th Celebration at Pecora Conference
- November 14-18, 2022, ISRSE-39, Hanoi, Vietnam

Future outlook

Public private partnerships both in observations (such as for greenhouse gas monitoring) and in applications (such as machine learning, data access, services) are coming to fruition and are expected to make major contributions that go beyond the traditional Government provided services and commercially offered services. One example is the Carbon Plume Mapper effort within the USA.

Committee activities

GEOSS conducted several major activities during the IAC in Dubai including a Highlight Lecture celebrating the 20th Anniversary of the Disaster Charter (speakers included the heads of the three founding agencies - ESA, CNES, CSA), a Special Session on monitoring Ocean's health from Space to coincide with the UN Decade of Ocean Science (speakers include Heads of Earth science in several leading space agencies), an IAF Global Networking Forum session in conjunction with Young Professionals on Tuesday night at the Congress, and further discussion to support greater integration with GEO, Emerging Countries, and development of a new three year partnership with YPP. The GEOSS is identifying several new themes for events for the next IAC in Paris. GEOSS also supported GEO management by organizing and supporting a meeting of MENA members and GEO management at the IAC.

The committee also elected new Officers and reconfirmed members per IAF rules, and updated its announcements in the call for papers for IAC 2022 to highlight Green House Gas Monitoring. The GEOSS Subcommittee is working closely with the IAF SEOC Committee to foster new partnerships with Young Professionals, offer a new slate of Plenary and Special Session proposals and other cooperative activities. The GEOSS SC is shown below while meeting in Dubai.

IAF Knowledge Management Technical Committee (KMTC)

Introduction

Working on complex space missions requires virtual teaming, learning lessons, sharing knowledge between generations, and developing deep expertise within an organization. The IAF Knowledge Management Technical Committee (KMTC) recognizes the importance of Knowledge Management to conduct space activities, and the mutual benefit of sharing experiences, best practices, promoting individual, team, organizational excellence, and new techniques with knowledge officers, managers, human resources actors, in space agencies, industries, universities and professional societies throughout the world.

In this age of big data, analytics, artificial intelligence, Internet of Things (IOT) and others, knowledge management can enhance the power of big data and help decision makers in today competitive economy. Digital transformation and innovations have changed how employees' access and share the knowledge and therefore KM processes need to adapt to the new environment in supporting and helping the users in how they collaborate and interact with the knowledge daily.

Summary

Key topics addressed by the Committee are strategies and tools for the sharing of the knowledge to develop new projects, the impact of the culture and the internal social network in driving innovation and creating new knowledge, processes, and technologies that organizations are using to sustain, energize and invigorate their ability to learn, innovate, and share knowledge. Examples of case studies of particular interest include successful projects and innovations in the application of knowledge management, grounded research in knowledge and risk management, methods that allow data, information, or knowledge exchange within or amongst organizations in support of actual programmes and capturing engineering knowledge and information in computer models.

Highlights

The COVID-19 pandemic has had a profound and lasting impact on organizations. Industries have been forced to reassess their entire business model, assessing new ways to use advanced technology tools, pushing digitalization and automation to drive productivity. The pandemic has also shaped a new working life/environment with a combination of remote and on-site working, i.e a *hybrid working model,* in which some employees are on premises, while others work from home. In many organizations, employees working remotely were struggling and unable to access needed documents and information stored on local area networks, not knowing where to find answers, without colleague interaction, and struggling to remain on task without the structure of face-to-face meetings.

Terms such as digitalization, smart working, New Work or Work 4.0 have become in use. The changes that have taken place following the pandemic, e.g. virtual meetings, are all examples of "new work" having an enormous influence on organizations and are likely to remain. The forced digital transformation helped accelerate the appreciation of digital workplace concepts like remote work, people-centred processes and experience, and the value proposition of good KM practices. However, this has posed new challenges for collaboration and sharing knowledge virtually.

With the explosion of workforce conversations on digital collaboration tools, knowledge is flowing dynamically across the digital communication channels that have become the medium of new working relationships. This implies that the organizations' approaches to knowledge management need to consider how emerging technologies, such as Artificial Intelligence, can support problem-solving and help workers innovate and uncover new insights. For example, AI technologies can take a contextualized information and push it to the organization's teams and systems, allowing the knowledge to flow through the workforce, and asking questions and seeking answers became more an electronic experience.

Future outlook

The development of digital technologies has triggered substantial changes in the collaborative learning approaches and infrastructure, thus promoting an integrative approach to the areas of big data, knowledge management and innovation. This has taken a key role during the pandemic and the changes are likely to remain. With the radical diffusion of artificial intelligence, a new data-knowledge ecosystem has emerged where knowledge artifacts and human and social entities interact through new business models and applications powered by numerous new technologies, cloud computing and others.

The sharing of knowledge has become even more essential as COVID-19 has scattered staff among homes and different work sites. The digital technology enables knowledge to be transferred, with platforms and tools helping dispersed teams stay connected. However, the technology alone is not enough to harvest the value of knowledge management. It is necessary to shift the focus from knowledge capture to knowledge creation and transfer, and promote a knowledge-sharing culture together with the digital tools and platforms.

According to several recent statistics, it is expected that the post-COVID-19 workplace will retain the hybrid on-site and remote presence. Therefore, the organizations will require new ways of driving more effective collaboration across the remote teams of employees.

The emphasis of knowledge management until recently was on search and findability and expertise location.

The pandemic has forced companies to operate in a virtual world leading to an acceleration in the evolution of the toolbox of knowledge management toward the digital workplace. Knowledge management has not changed direction, in the sense that we all continue to do things that we were doing before, but the balance has shifted toward the creation of digital communities and digital workplace.

Committee activities

The plan for early summer next year is to organize a Knowledge Management Virtual Event, possibly held in CNES, Paris. The topics are Collaboration platform, Digital transformation, Digital community of practice, Public-private partnerships, Data protection and sharing. The challenge to be addressed is how companies use products of space, i.e. ontologies.

IAF Materials and Structures Committee

Recent trends and achievements in high-performance, lightweight and innovative materials and structures for space applications.

Summary

As the whole space sector, the field of materials and structures is undergoing constant evolution and advancements. In particular over the last 12 months, an increasing trend towards further miniaturization of satellites and launchers has been observed. This is mainly driven by a large number of startups and private entities venturing into the commercial space market, for which SmallSats and MicroLaunchers significantly lower the entry barrier in terms of cost, schedule and risk. Another ongoing trend has been the increased use of lightweight design and optimization via computational approaches. Continuous advancements in the field of computational methods, readily available computational resources and novel manufacturing techniques enable the use of advanced designs even for most challenging, multidisciplinary space applications. The advancement of additive manufacturing techniques furthermore enables the utilization of custom-tailored composites and engineered materials in order to maximize the performance of future materials and structures in an unprecedented manner.

Highlights

One of the highlights in the field of materials and structures is the unlimited possibilities enabled by serial additive manufacturing. While additive manufacturing techniques do not only provide almost unlimited geometrical design freedom, they also greatly reduce the complexity, cost and schedule of space systems by minimizing the number of parts and enhancing their capabilities by design. This, for example, enables multi-scale optimization and manufacturing of, for example, ultra-lightweight structures consisting of optimized macro geometries and tailored lattices on a meso level. Combined with smart materials and deployables, such innovative concepts and designs are currently being investigated for upcoming robotic landers and rovers. All of these new developments have been widely presented and discussed in this year's IAF Materials and Structures symposium confirming their high importance to the space community.

Future outlook

Looking ahead, several topics in the field of materials and structures are on the horizon and about to drastically change some of the design and manufacturing approaches of classical space systems. From a technological point of view, the topic of in-space manufacturing is expected to open up unparalleled possibilities with respect to a sustained human space exploration. To enable off-Earth manufacturing, innovative additive manufacturing techniques are combined with in-situ resource utilization, which providing the fundamental ingredients from a materials perspective. In-space manufacturing is also of high importance for upcoming exploration missions to Moon and Mars and will therefore be heavily investigated and matured in the near future.

Another very promising but yet underdeveloped field is structural health monitoring. Understanding the health status of structures and systems while in use, unlocks unprecedented opportunities in terms of operation, prediction and design optimization of space systems. Only with the availability of increased computational power on-board of spacecraft (i.e. edge computing), real-time processing of structural health data of a satellite is possible. This revolutionary technology will enable significant autonomy and smartness of future space systems.

Finally, the paradigm of design-to-cost will gain more and more importance throughout all subsystems of a spacecraft. Therefore, the design and manufacturing of future space structures and materials will increasingly be driven by cost, schedule and the potential for large-scale serial production, especially for large-scale commercial space applications.

Committee activities

For next year, the committee plans to reorganize some sessions of its symposium to better respond to new developments taking place in the field of space technologies, materials and structures.

IAF Space Astronomy Technical Committee (SATC)

Introduction/Summary

Ground and Space Astronomy synergy has recently permitted a phase of remarkable discovery and growth. Public recognition is the several Nobel physics prizes gained in (observational) cosmology, exoplanets, gravitational waves, X-ray astronomy, and astrophysical neutrinos. Although the field of astrophysics is vast, the the IAF Space Astronomy Technical Committee (SATC) concentrates its work in the area of space astronomy and in particular, serve as a forum for the exchange of information and interaction between the scientific community, space industry, and space agencies involved in the preparation and the future development of new astronomy missions. Therefore, the SATC action covers the very early phases of mission conception before missions are proposed to the Agencies for assessment. As such, the SATC role comes up-front and is largely complementary to the current work that the Agencies achieve. Its principal intended role is to enable or improve the emergence of new science mission concept.

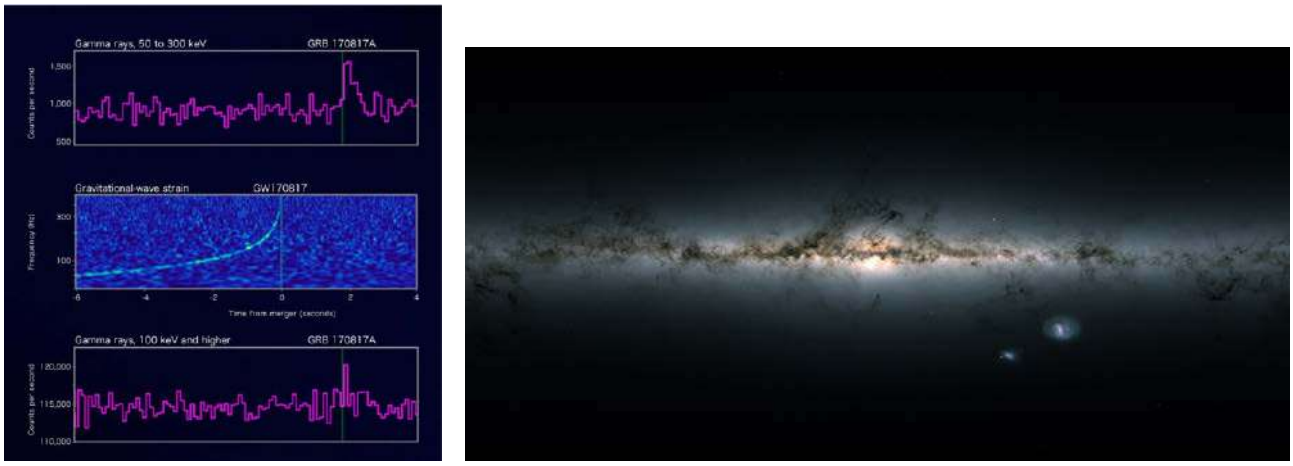
Highlights

Astronomy is currently in a phase of remarkable discovery and growth. A public recognition of this impact are the Nobel physics prizes in 2021, Giorgio Parisi, *"for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales";* Roger Penrose, Reinhard Genzel and Andrea Ghez *"for the discovery of a supermassive compact object at the centre of our galaxy"* in 2020; Jim Peebles - cosmology, Michel Mayor and Didier Queloz – exoplanets in 2019; Rainer Weiss, Kip Thorne and Barry Barish in 2017– gravitational waves; Saul Perlmutter, Brian Schmidt and Adam Reiss in 20211 – observational cosmology; John Mather and George Smootin 2006 – observational cosmology, Riccardo Giacconi – X-ray astronomy, and Ray Davis Jr and Masatoshi Koshiba – astrophysical neutrinos in 2002. The impressive range of progress is manifest. Just few examples among others:

- **Gravitational waves and Astrophysical counterpart search of BH-BH Mergers**
- **NS-NS Mergers: first Gravitational Wave counterpart detection**

On August 17, 2017, after a long quest, Fermi and INTEGRAL detected a short γ-ray burst (GRB 170817A) linked to GW70817 caused by the merger of two neutron stars. The time lag (1.7 s) between the GW event and the prompt γ-ray observation after 120My travel time, imposed constraints on the difference between the speeds of light and gravity, placed new bounds on the violation of Lorentz invariance, and presented a new test of the equivalence principle. The observations also constrained the size and bulk Lorentz factor of the γ-ray emitting region. To date, this observation remains the only firm detection of the so-called Kilonova generated by the NS-NS merging process with spill-over of nuclear dense matter.

- **Protoplanetary disks and exoplanets**
- **Fast Radio Bursts**
- **GRB detected at TeV**
- **Origins of a Cosmic Neutrino**
- **Gaia**
- **Asteroseismology**



Joint, multi-messenger, detection of GW170817 and GRB 170817A (left) and Gaia's view of the sky. Credit: Abbott et al. 2017, ApJ 848, L13 and ESA/Gaia/DPAC, CC BY-SA 3.0 IGO.

Future outlook

The increasing size and complexity of large space-based observatory missions place a growing emphasis on international collaboration. The increasing range of joint missions involving space agencies in Europe (ESA), United States (NASA), Japan (JAXA), the Russian Federation (RKA) and China (CNSA), India (ISRO), and more recently, the United Arab Emirates (UAESA), and others. The Astronomy and Astrophysics Decadal Survey (US: Astro2020) and the ESA Cosmic Vision (EU) outline a comprehensive research strategy and vision for a transformative science at the frontiers of astronomy and astrophysics in the next decades. Similar plans, though at a lower level, are on-going under other major national space agencies mentioned before. In particular, large scale flagship missions like the Athena X-ray Observatory, LISA GW explorer, the Jupiter icy moons Explorer (juice) (ESA), NASA technological studies for LUVOIR, Nancy Roman Space Telescope (NASA), and medium size missions like Euclid, PLATO, and TESS, and Starburst are already operative, approved, or in the realization phase. This impressive fleet of space observatories will be complemented during this decade by large-scale ground based facilities like TMT, ELT (ESO), SKA, CTA, and others, spanning from radio to optical/IR to high energy gamma rays. The new observational window opened by the GW interferometers and Neutrino detectors are under upgrade and optimized to be inter-operative with other ground-based infrastructure and space-based missions.

Committee activities

The main SATC activity for the current year have been focused on:

1. Long-term analysis of the technical, scientific and programmatic areas of space astronomy. Serve as a *forum for exchange of information and interaction between the scientific community, space industry and agencies* involved in the preparation and future development of new astronomy missions. Particular emphasis is on technological breakthroughs for future space applications (e.g. space cryogenics systems, cubesat constellations, space-ground synergy).
2. Of particular importance are the recent developments and actions to preserve the "Dark Sky" against the optical and radio interference between 1.000-10.000 small-sat for TLC and ground and space astronomical observatories. The strong interaction with STM-TC26 Committee has been finalized during the Dubai IAC2021 meeting with cross participation of members of TC23 and TC26 meetings. As such, the SATC role will be complementary to the current work carried out by the Agencies, industries, Academia and space and ground-based stakeholders;
3. Organization of the A7 symposium at IAC 2021 and IAC 2022, for the discussion and publication of ideas and relevant results and issues to the impact and needs of future astronomical missions.

Provide a point of contact for national and international bodies

The Action plan foresee: IAC 2021 sessions with active participation (done), IAU Las Palma UNOOSA, ISSI Forum 2021 (done), participation to "Ground and Space Astronomy: Challenges and Synergies", November 2021, to COSPAR 2022 (Athens) and 2023 Space science with small satellites (Singapore), IAU Busan 2022 etc.

IAF Space Communications and Navigation Committee (SCAN)

Introduction

The IAF Space Communications and Navigation Committee (SCAN) addresses all aspects of space-based systems, services, applications, and technologies for fixed, broadcast, high-throughput, and mobile communication services as well as position determination, navigation and timing services.

Summary

Space-based communication and space-based navigation continue to be significant drivers for new applications and new technology.

The satellite communications market was estimated to be worth $62.19 billion in 2019 and is predicted to grow by about 9.2 % in the period from 2020 to 2027. There is still a high need of very high throughput satellites (VHTS) and a growing capacity need for Internet of Things (IoT) services.

The international Global Navigation Satellite Systems (GNSS) infrastructure continues to expand, with global [Beidou (China), Galileo (EU), GLONASS (Russia), GPS (USA)] as well as the regional [EGNOS (EU), IRNSS (India), QZSS (Japan), WAAS (USA)] systems. The economic benefit of GPS alone has been estimated at $1.4 Trillion (2017$) since it went operational in 1995. The impact of the loss of GPS is estimated at $1 billion per day.

Highlights

In 2020 about 22 commercial communication satellites were ordered to be manufactured: six by Space Systems Loral (US), four by Northrop Grumman (US), two by Boeing Satellite Systems (US), six by Airbus Defense and Space (F), three by Thales Alenia Space (F), and one by China Great Wall Industries (CGWIC).

As of 5 Nov 2021, six commercial communication satellite manufacturing orders have been placed: two for Maxar (US), two for Airbus Defense and Space (F), one for Thales Alenia Space (F) and one micro-GEO for Astranis (US).

SpaceLink, a US company formed by Australia's Electro Optic Systems (EOS) in 2020, awarded a contract to OHB System AG (Germany) to manufacture four satellites for its commercial space data relay constellation. SpaceLink plans to establish a relay network in medium Earth orbit to connect commercial and government satellites with customer mission operations centers. This is a remarkable move. Until now, all data relay networks have been established in geostationary orbits.

SpaceLink won a contract to demonstrate a 10 Gbit/s optical communication service for the ISS. SpaceLink plans to provide data-relay services in K_a-band at about 600 Mbit/s (as currently provided by TDRSS), and in the optical domain for 1 to 10 Gbit/s data rate with its now contracted MEO data relay constellation.

In the area of mega-constellations, 2021 saw a substantial increase of the constellation sizes of OneWeb and Starlink. From July 2021 until October 2021 OneWeb has launched 240 satellites using four launchers. Starlink launched 51 spacecrafts in September 2021.

On 20 January 2021, the European Commission signed a contract with Airbus and Thales for the second generation of Galileo satellites. These new satellites, due to be launched in 2024, will have the latest in highly innovative technologies (e.g., digitally configurable antennas, inter-satellite links, new atomic clock technologies, use of fully electric propulsion systems), that will allow these satellites to improve the accuracy of Galileo as well as the robustness and resilience of its signal.

In March 2021, EGNOS, the European Geostationary Navigation Overlay Service, celebrated 10 years of operation. This European regional navigation system provides services primarily to airlines, and provides an accuracy and integrity improvement to all GNSS service providers. EGNOS, like the US-based Wide Area Augmentation System (WAAS), can pinpoint positions to within 1.5 m! Such accuracy facilitates automated landing of aircraft thus allowing operations in the worst visibility conditions.

RUAG Space signed an agreement in October 2021 with the UAE's Mohammed Bin Rashid Space Centre (MBRSC) to deliver their LEORIX space-based GNSS receivers. These latest receivers allow satellite operators to locate their satellites with unprecedented accuracy. RUAG's LEORIX, GEORIX, and PODRIX line of products leverage the latest in technology development from the European Space Agency and with 80 receivers already on order, space operations will be getting increasingly more reliable – something that is of the utmost importance as the issue of space debris continues to haunt those that are on the operational front lines.

The US Global Positioning System launched the fifth GPS III satellite, nicknamed Neil Armstrong, on 17 June 2021, and it is now operational. The five operational GPS III satellites, manufactured by Lockheed Martin, are an integral part of the GPS constellation, and continue to advance the capabilities of GPS, with a 15-year design life, 3X better accuracy, and a new internationally coordinated signal, L1C.

The Japanese Quasi-Zenith Satellite System (QZSS) launched its first successor satellite, QZS-1R, on 26 October 2021. It has a 15-year design life, and replaces QZS-1 (Michibiki-1). QZSS began service in 2018 with four satellites. The Japan Aerospace Exploration Agency (JAXA) plans to have seven satellites launched by 2023.

Future outlook

The first ViaSat-3 VHTS satellite launch, originally foreseen for 2021, has been moved to 2022 at the earliest, due to the effects of COVID-19. ViaSart-3 is the highest capacity geostationary satellite system under development in the world, providing a capacity of more than one Terrabit/s ($=10^{12}$ bit/s) with one satellite. The ViaSat-3 Americas satellite must be brought into use (BIU) by 31 December 2021 OR it must receive a waiver from the FCC's deployment milestone. The originally planned launch date was 29 March 2021 and operational service was expected by 31 December 2021. The launch date has now shifted to 2022.

The success of EGNOS and WAAS to airlines has attracted the attention of those wishing to operate unmanned drones in the same commercial airspace. As the number of remotely piloted vehicles quickly outpace the number of commercial aircraft, safety-of-life services is seen as essential to safely managing the skies.

Committee activities

The SCAN committee had a very active year. The IAC 2021 symposium was organized, abstracts evaluated and selected, and sessions conducted in Dubai. This was the first use of a restructure of the symposium session descriptions, which now has several sessions with the same name but shown as Part 1, Part 2, etc. The new structure required more coordination between session chairs, but also allowed grouping of specific topics into each session, for more cohesive discussion. The committee will continue with this approach for a few more years, to further evaluate the benefits versus effort. As a result of pandemic-related absents in Dubai, substitute session chairs were arranged to support all nine sessions that the committee sponsors.

In addition to organizing and running the B2 symposium, the SCAN committee Terms of Reference was updated. The previous version from 2005 did not include space-based navigation. This has been added, the overall ToR updated, and it now conforms to the new IAF template.

Virtual meetings were held in March 2021 and October 2021. Elections were conducted for Chair and Vice-Chair. All affiliations and contact information were updated in the SCAN committee roster. Reviewing the roster for inactivity (no committee participation for more than three years), several "members" and one "friend" were removed. Four new members and one expert were added. All other members were re-elected. After two years of successful virtual meetings, the committee is exploring the opportunity to conduct more frequent virtual meetings to improve cohesion of all activities. The goal is to conduct meetings quarterly, adding virtual meetings in winter and summer, with in-person meetings at the IAF Spring Meetings and the annual IAC.

IAF Space Education and Outreach Committee (SEOC)

Introduction

The IAF Space Education and Outreach Committee (SEOC) promotes the development and delivery of quality learning and outreach opportunities for students, educators, and members of the IAF so that space, science, and technology become better known and are more accessible to the global community. We also help recognize activities by students and educators at the IAC through our competitions and Honours and Awards programme.

Highlights

New approaches to outreach and science communication within the space sector are growing, particularly with engagements involving artists and strong emphasis in the use of social media. As part of these initiatives, mentorship focused programs are also on the rise, the IAF Launchpad Mentorship Programme and SGAC's Mentorship Programme being among the successful ones. Outside of the IAF and its partners, several industrial mentorship programs have been developed in the US and Canada to help students enter the industry in an easier manner. The implications of these trends on the work of the committee is one of the focuses of the committee's 2022 activities.

Future outlook

SEOC welcomed its new leadership this month, and the new vice-chairs are currently scoping their vision for the next three years. In the meantime, we are continuing preparations for the 73rd IAC, which will be held in Paris in 2022. Our call for papers for the Space Education and Outreach Symposium and the Student Competition have been updated with lessons learned from this year's IAC and are now available online. SEOC also plans to continue its honours and awards programme, contributions to the Next Generation Plenary and mentorship programmes at the IAF.

One of the trends that the committee is interested in exploring and bringing into its programmes include the rise of novel science communication techniques through arts and social media. These trends, while somewhat covered by our technical symposia, could be engaged within the context of other platforms within the IAF. In addition, we have observed that most speakers at SEOC activities are scientists and engineers that are active in education; K-12 educators and teachers have not engaged with the committee as much. SEOC wishes to engage with these communities more, either by inviting them as keynote speakers at the IAC, or as part of special sessions and other online activities to be planned in the coming year.

Committee activities

The SEOC worked throughout 2021 to plan for excellent support to the 72nd International Astronautical Congress (IAC), where we hosted two symposia:

- The Space Education and Outreach Symposium (E1) showcased over 90 papers (selected from over 180 submissions) in 10 sessions around various topics in space education and outreach, workforce development and culture
- The 29th Student Competition Symposium (E2) showcased 45 papers from around the world in four sessions, one of which was broadcast online as part of the Global Technical Symposium

While both symposia were impacted by the uncertainties of the COVID-19 pandemic, the end result was comparable to past years.

SEOC Honours and Awards continued its great work this year, by awarding the following three titles:

- The Frank J. Malina Astronautics Medal was awarded to Filippo Graziani, President of the Italian company Group of Astrodynamics for the Use of Space Systems (G.A.U.S.S. srl), and Senior Professor of Astrodynamics at University of Roma "La Sapienza". This award recognizes an educator who has demonstrated excellence in taking the fullest advantage of the resources available to him/her to promote the student of astronautics and

related space sciences. Professor Graziani was also a keynote speaker at the SEOC E1 Symposium.
- The Luigi G. Napolitano Award was awarded to Federica Angeletti, School of Aerospace Engineering (SIA), Sapienza University of Rome. This award is presented annually to a young scientist (below 30 years of age) who contributed significantly to the advancement of aerospace sciences and presents a paper on this contribution at the IAC.
- The IAF Student Awards were presented to Sam Bunka, Hugo Lévy, Harika Pothina, Nadia Weronika Brzostowicz and Jaroslav Hruby. These awards recognize the best papers presented by students at the IAC in the undergraduate, graduate and student team categories.

SEOC members contributed to the selection of the IAF Emerging space Leaders Grantees and the IAF Young Space Leaders Award programme as well. We are happy to see two SEOC members and contributors (Kat Robinson and Elizabeth Barrios) among the awardees of the YSL this year.

SEOC members (alongside the IAF WD-YPP and other committees) also supported the Next Generation Plenary (NGP) program as steering committee members. The NGP this year focused on Next Generation Impact on Social Responsibility in Space and was a great success, while the program also planned an additional plenary this year focused on the role of space in combating climate change.

Throughout 2021, SEOC also supported other initiatives, such as the IAF Abstract Mentor Programme and IAF Launchpad Mentorship programme, with SEOC members acting as mentors in both programmes. We also revamped its webpage this year, providing a broad description of its activities and highlighting the new procedure for joining the committee in a clear manner. We have also created a new means for those interested to reach out to SEOC vice chairs directly, and have updated our terms of reference to reflect new definitions and election procedures used by the committee.

IAF Space Habitats Committee (SHC)

Introduction

The IAF Space Habitats Committee (SHC) aims, in cooperation with other IAF committees and symposia, to foster interest in the importance of building an international and interdisciplinary understanding of the issues and stakes raised by future space habitats (e.g., settlements on celestial bodies and orbital infrastructures). Besides diversity in terms of generation and geography, the SHC gathers one of the most diverse interdisciplinary teams of experts among IAF members (engineers, architects, designers, crewmembers, social scientists, policymakers and space explorers) to consider the various dimensions of space habitation for innovative and inclusive initiatives.

Summary

Plans are continuously under development for future lunar and Martian exploration, which include, within the current decade, habitats concepts for Moon missions – e.g., the circumlunar station "Gateway" and some landers concepts –, all designed for scientific missions performed by professional crews. Newly developed spacecrafts which will serve as habitats in the coming years include the Orion capsule and the Chinese space station.

Meanwhile, we also observe fast-growing development of private missions involving a wide range of habitation configurations, such as:

- The Crew Dragon capsule in autonomous flight for four people for three days;
- After ten years without non space professionals on board, the ISS is currently serving again as habitat for private residents, benefiting from recent additions to the station such as the Russian Nauka module launched during the Summer 2021 (a Russian film crew and a Japanese crew using a Soyuz, an international private crew and an American film crew launching on SpaceX's Crew Dragon);
- Private crews orbiting the Earth with the Blue Origin's New Shepard;
- NASA and Axiom Space have also signed an order for the first private astronaut mission to the International Space Station to take place no earlier than January 2022;
- The massive and voluminous StarShip will take nine private passengers around the Moon within a few years, while private space stations will become operational.

These missions present a variety of configurations in terms of crew size, crew qualification, training, available volume, duration of the mission, type of mission and tasks. This implies mobilization of multiple actors involved in the design, engineering, operatibility, training concepts and space analogs, all related to habitability, including also universities where teaching space architecture and design evolves accordingly fast.

Highlights

Habitat design requirements include the design integration of technology for life support, designing for strict limitations in habitable volume, while providing maximum safety and strategies for future expansions and optimizations for

possible variables in mission objectives. Complying with such needs also pushes the technological and scientific advancements on Earth challenges related to the design of sustainable living environments on Earth. Lessons learned from more than 20 years of permanent human presence on board the ISS constitute a strong contribution to further space habitability development. Future habitats beyond LEO will also need to address the problem of radiation protection of the crew. The past years have seen the development and exhibition of various ways to address the issues raised by future long-duration spaceflights, either professional or private, including via inflatable and modulable structures. Analog missions around the world, either commissioned and organized by space agencies or private actors, are more than ever important to test and analyze different habitability options.

Future outlook

Until recently, humans in space were mostly professional astronauts and cosmonauts, from STEM, pilot or military backgrounds whose missions are determined by scientific and technological experiments. However, the commercial sector is now transporting civilians to space and space habitats will also increasingly include commercial astronauts and cosmonauts, as illustrated by the 'Summary' section. This raises questions on the status of civilians in space (including the rights and obligations of those civilians and appropriate governance mechanisms) and consequent updates in space law, but furthermore on the definition and design of space habitats in terms of life quality beyond the safety and operational aspects of professional crews' flights. Another important aspect of space habitats in the near future, especially for orbital habitats, will be the organization of their end of life considering space debris management.

Committee activities

The SHC held its elections for the 2021-2024 term during its IAC meeting in Dubai (29 October 2021). New members have been voted on in addition to several 'observers' interested in joining the Committee in the future, and Chair (Julie Patarin-Jossec) and Vice Chairs (Olga Bannova and Sandra Häuplik-Meusburger) have been elected. In terms of scientific and political dialogue related to space habitats, SHC members have actively contributed to the IAC 2021 in Dubai either via technical papers and the organization of symposia, the participation in, and organization of Special Sessions, the participation in GNFs, and the participation in plenary events like astronaut panels. Some SHC members have also been actively part of the exhibition, for instance presenting prototypes of surface space habitats for future analog, Moon and Mars missions.

Several new projects have been discussed among SHC members for the coming year, including:

- The creation of a working group/task force on governance issues related to space habitats (introduced by E. Tepper), to further discuss new governance models better suited to future space habitats than the ISS' framework, including regarding the increasing commercial and long-term nature of human spaceflight.
- The organization of a dedicated session for SHC members' presentations as part of the 'Mars to Earth' 2022 conference (January 2022), organized by the Mars Planet organization (part of SHC membership).
- The organization of joint session(s) for the IAC 2022 in Paris with symposia in space architecture, space and society and system engineering –– in addition to a keynote lecture in space architecture and eventual Special Sessions and/ or GNFs.
- The development of a new technical session for the IAC 2023 in Baku.
- The creation of an analog habitats group within the SHC to further work on analog-based habitability solutions, completing analog space habitats projects in partnerships with the UNOOSA.
- The development of a partnership with Padova University which, for its eighth centenary celebrations, will designate May 2022 as 'Space Month'.
- The organization of (side) events during the IAF Spring Meetings in March 2022 around space habitats.
- The discussion, and eventually the creation, of a hybrid architectural investigation of the concept of an 'orbital university' reflecting on what would be minimum necessary requirements for a habitat people would want to live in space.
- A collective and long-term reflection on best practices and processes benefiting an increasingly diverse membership, including (but not limited to) forms of participation in SHC and IAF activities for marginalized space actors (NGO representatives, artists, etc.).

All these initiatives are aimed to be undertaken by, or open to, members, experts and friends from a wide range of disciplines representing the multidisciplinary expertise of the IAF Space Habitats Committee. New memberships allow, and will allow in the coming year, new partnerships completing the above-mentioned projects.

IAF Space Transportation Committee

Introduction

The objective of the IAF Space Transportation Committee is to address worldwide space transportation solutions and innovations. In particular the goals are:

- To foster understanding and cooperation amongst space business academicians and practitioners, through the creation, diffusion, and adoption of new knowledge and lessons learned
- To build a world-wide network of communication and relationships
- To encourage, promote, and assist the development of newer members of the space community through IAC participation

The corresponding activities are devoted to different types of space transportation missions, systems (launch vehicle system and/or the propulsion stages, expendable or reusable, manned or unmanned) and to their safety and support operations.

Summary

The major highlight in 2021 was the achievements in commercial human space transportation with successful flights of Virgin Galactic, Blue Origin and SpaceX.

Another interesting development is the race between tenths of companies related to the development of a cheap launch service based on a small launch vehicle with a high launch rate.

Highlights

Horizon 2020

Air-breathing hypersonic vehicle concepts may act both as first stage of future reusable two stage to orbit vehicles, able to take-off and land horizontally, and as high-speed civil passengers transport aircraft. Within the framework of the Horizon 2020 Project STRATOFLY (Stratospheric Flying Opportunities for High-Speed Propulsion Concepts), significant results have been achieved at mission, system and subsystems level for a vehicle concept that flies at Mach 8 at 35 km of altitude exploiting liquid hydrogen as propellant. At mission and system level the following achievements can be highlighted:

- Complete aero-propulsive characterization for all speed regimes through high-fidelity simulations for wave rider configurations
- Enhancement of the scientific understanding of atmospheric processes has revealed that the higher is the stratospheric altitude of the water vapour emissions, the longer is the perturbation lifetime of the emitted water vapour, thus resulting in higher climate impact
- Jet-noise test campaigns coupled with high-fidelity simulations have allowed to get reliable acoustic data to make observations about the noise mechanism and to derive an adapted semi-empirical noise prediction tool for the nozzle o fair-breathing high-speed engines. Strategies for noise reduction potentials have thus been defined.

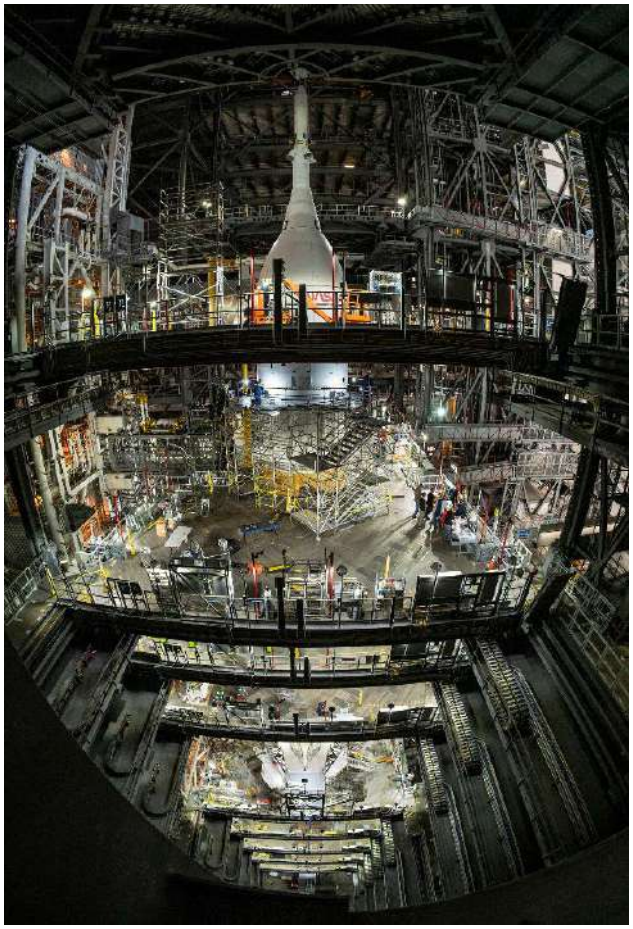
At subsystems level the following achievements can be highlighted:

- Redesign of the dual mode ramjet combustor guarantees a reduction of the 80% in NOx levels emissions in cruise at Mach 8, with respect to the initial baseline
- Validation of LES high-fidelity models of high-speed combustion through combustion test campaign
- Performance assessment of the multidisciplinary and multi-functional Thermal and Energy Management System that exploits liquid hydrogen for multiple integrated purposes: heat rejection, thermal control (as coolant mean of heat exchangers) and high electric power generation through turbine expansion for on-board subsystems

NASA Update

NASA's Commercial Crew Program safely returned their second crew from the International Space Station after 199 days in orbit in November 2021. The next crewed launch, Crew-3, is preparing for launch aboard a SpaceX Crew Dragon in November.

NASA has completed stacking of the Artemis I Space Launch System rocket and Orion spacecraft in the Vehicle Assembly Building (VAB) at the Kennedy Space Center in Florida. The ground team also recently completed their Underway Recovery Test 9 (URT-9) certifying that NASA's Landing and Recovery team is ready for the Artemis I recovery. A series of tests are now underway in the VAB before the wet dress rehearsal in January and a targeted launch in February 2022. This first test flight paves the way for NASA's first crewed flight of Orion and the SLS, planned for 2024 on Artemis II.



A view of the fully stacked Orion and SLS in the Vehicle Assembly Building

Newest Development of China's Space Transportation

Chang'e-5 has accomplished China's first Lunar sample return mission. Chang'e-5's mission profile is very similar to Apollo program, although it is unmanned. The probe is consisted of an Ascender, a lander, a return capsule and an orbiter. The Ascender/Lander combination is similar to Apollo's Lunar Module and return capsule/Orbiter is similar to CSM. During the mission, the world's first unmanned Lunar orbit rendezvous and docking with an orbiter was conducted.

After a test launch in 2020, China used its Long March-5B rocket to take its space station into orbit. This version is the world's only one and a half stage launch vehicle in service. It has four boosters with two YF-100 kerosene/liquid oxygen engines each. The total thrust of the boosters are more than 960 tons. It took Tianhe-1 core module of China's space station to a 41.5 degree inclined orbit. The core module is the first of the world that adopted hall effect engines to raise its orbit.

China tested its new launch vehicle, Long March-8 on 22 December 2020. This launch vehicle has a similar first stage like Long March-7 but with only two boosters. The second stage of this rocked is a derivative of the third stage of Long March-3A, which uses liquid hydrogen/liquid oxygen engines. Long March-8 rocket is developed for commercial market and hope to test recover and reusable technologies in the future.

U.S. Navy divers from Explosive Ordnance Disposal (EOD) Expeditionary Support Unit 1, attach tending lines to a mock Orion capsule during Day 2 of Underway Recovery Test 9 (URT-9) aboard the USS John P. Murtha. During the weeklong test, NASA's Landing and Recovery team completed their final mission certification ahead of Artemis I.

After a failure on its maiden flight of Long March-7A in March 2020, the second flight was a success in March 2021. The rocked is based on Long March-7, which is a two and a half stage mid-sized launch vehicle. Long March-7A added a third stage, which is based on the third stage of Long March-3A. With this improvement, the GTO capability can reach to seven tons.

Beijing Interstellar Glory Co. Ltd, which is the first private company in China that achieved an orbital launch in 2019, suffered two failures in its second and third orbital launch attempt. Galactic Energy, another private company accomplished its first orbital launch in November 2020. Both company's launchers are small four-stage solid-rocket boosters.

Future outlook

As an outlook into the future, it will be interesting to see in the next years, which company will be able to successfully develop, qualify and operate a small launch vehicle out of the many currently running projects.

Also, one must watch carefully how the commercial human space flight will develop after the first successful missions this year into low earth orbit with a short visit to a space station respectively into suborbital altitude.

Finally, 2022 will hopefully mark the return to human lunar missions with the first flight of the SLS launch vehicle and the Orion spacecraft.

Committee activities

Two new activities are planned by the IAF Space Transportation Committee up to the next committee meeting in March 2022:

- To organize a virtual session on small launch vehicles latest developments
- To propose special sessions and keynotes for the IAC 2022 in Paris. For example, a special session on the climate impact of future launchers (either reusable or not), imagining a higher launch rate for large constellations

IAF Technical Committee on Space Traffic Management (STM)

Introduction

The IAF Technical Committee on Space Traffic Management aims at providing a contribution to the joint Reference Paper prepared together with IISL and IAA, following the MOU signed between the three organizations in Bremen in 2018, with the objective to "develop comprehensive approaches and proposals for STM to be addressed to decision-makers on national and international level"

Summary

The work of the Committee has been initially subdivided into 29 thematic Working Groups. The first phase of the work, led in 2021, focused on the first nine subjects; the second phase, started in Dubai in October 2021, added five subjects. One additional one has been merged with existing one, four have been postponed probably to end of 2022, and four are not yet started, but could turn out to be merged with ongoing topics.

The following table describes the Working Groups currently ongoing.

	1st Phase	2nd Phase	~~Merged~~	Postponed	Not yet started
1	Terminology - Common understanding and Definitions				
2.1	Improving the knowledge - New technical means of space objects monitoring				
2.2	Improving the knowledge - Improve trackability and identification of small objects				
2.3	Improving the knowledge - Data fusion - Merging of information - Shared catalog				
2.4	Improving the knowledge - Improvement of orbital data precision and accuracy				
2.5	Improving the knowledge - Improvement of the UN registration				
~~2.6~~	~~Improving the knowledge - Shared Catalog (merged with 2.3)~~				
2.7	Improving the knowledge - Hazards associated with reentry				
3.1	Space capacity management				
3.2	Management of RF interferences				
3.3	Improvement of the collision avoidance process				
3.4.1	Future operations - Spacetugs, IOS, IOM, IOR				
3.4.2	Future operations - Large constellations				
3.4.3	Future operations - Sub-orbital activities				
3.4.4	Future operations - Ground support activities such as spaceports				
3.4.5	Future operations - Transits through airspace				
3.4.6	Future operations - Impact of constellations on Astronomical observations				
3.5	Future operations - Preparation of future activities				
3.6	Future operations - Traffic from orbit to Moon (and Mars)				
4.1	Technical regulations - Current references				
4.2	Technical regulations - New activities				
4.3	Technical regulations - Effective compliance to Technical Regulations				
5	Outreach				

The aim of each Working Group is to provide a 10 pages report + Annexes + one page Executive Summary. The collection of all these inputs, merged by the coordinators, completed by a couple of pages introduction, will constitute the Final Report, expected for IAC 2022 in Paris.

The work of TC26 is structured following the dedicated web zone on the IAF website https://iafastro.directory/iac/folder/tc/spacetraffic/#file.5090.

Highlights

The Technical Committee currently regroups 134 Members, Friends, Experts, coming from 24 different countries, following very well the 3G motto from IAF, Gender, Generation, Geography.

Each Working Group followed its own agenda, meeting regularly to prepare their draft Final Report for IAC 2021. The nine initial Working Groups have globally been very efficient and in line with the objective planning. A general review of the progress has been done on Oct. 24th in Dubai, followed by a Special Session on Oct. 26th, recalling the general frame of the effort, presenting the progress of each Working Groups and recalling the perspectives for the following periods. This progress can be seen on the dedicated page set in place by IAF secretariat: Space Traffic Management Committee (iafastro.org)

Future outlook

As explained, five new Working Groups have been kicked-off in Dubai, involving 54 members, each WG being co-chaired by two coordinators. We currently witness the setting in place of these groups, the first meetings, and can be very optimistic on the progress that should take place in the coming six months. We expect all the draft Reports by May 2022, followed by general merging and polishing of the complete file, cross-read, comments, amendments… and final issue by September 2022 under a form which is still TBD (White Paper; Special Publication…).

One point nevertheless remains open and source of worry: the progress made by the "parallel" entities involved in the MOU (IAA and IISL) is unknown, and we hope their contributions will arrive in due time for the finalization of the common report.

Committee activities

The IAF TC26 Coordinators, Darren Mc Knight and Christophe Bonnal, the TC Secretary Serge Plattard, and the IAA-IISL Liaison Officer Didier Alary wish to warmly thank the IAF secretariat for the wonderful job done in assisting our Technical Committee; thanks to this support, we are very confident in the success of the initiative.

THE INTERNATIONAL ASTRONAUTICAL FEDERATION

Connecting @ll Space People

WHO WE ARE

Founded in 1951, the International Astronautical Federation (IAF) is the world's leading space advocacy body with over 433 members from 72 countries including all leading space agencies, space companies, industries, research institutions, universities, societies, associations, institutes and museums worldwide.

Following its motto *"Connecting @ll Space People"* and its vision of *"a space-faring world cooperating for the benefit of humanity"*, the Federation advances knowledge about space, supporting the development and application of space assets by promoting global cooperation. As organizer of the annual International Astronautical Congress (IAC) as well as other thematic conferences and workshops, the IAF actively encourages the development of space activities for peaceful purposes and supports the dissemination of scientific and technical information related to space.

WHAT WE DO

- **Promoting cooperation**
- **Advancing international development**
- **Sharing knowledge**
- **Recognizing achievements**
- **Preparing the workforce of tomorrow**
- **Raising awareness**

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Membership in the IAF is open to all companies and organizations working in space-related fields.

If you are interested in becoming a member, please complete the "Application for IAF Membership" form (which can be found on our website: http://www.iafastro.org/membership) and send it together with your company's by-law, statutes and any other requested material to the IAF Secretariat.

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The IAF Secretariat

The IAF Secretariat is a small dynamic team based in Paris, France. We work hard every day with unwavering enthusiasm to ensure a smooth coordination and management of all IAF activities and events.

The IAF Alliance Programme is open to all IAF Members and aims to deepen the involvement of IAF Members in the Federation, enhance the prominence and visibility of their role within the Federation, complement the traditional sponsorship opportunities with strategic long-term partnerships, assure the sustainability of IAF operations in the interest of its Members; further improve the quality of the Federation's activities, and strengthen the Federation by fortifying the one-to-one relationships with its Members.

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