
**Focus Group Discussion Meeting on the Future of STEAM for Space**
**MIT, Cambridge October 28, 2019**

The focus group meeting was organized and chaired under the auspices of the International Academy of Astronautics by Prof. Dr. Liya Regel (Chair, IAA Study Group "STEAM for Space") with the essential help of the office of Prof. Dr. Wesley Harris (NAE, IAA), AeroAstro Department at MIT.

The Focus Group meeting brought together the fresh eyes of representatives from different organizations and countries. It showed the way to create novel approaches to advance STEAM for Space, and to make important steps in recognizing the importance of STEAM for education in general.

Participants and guests received a special invitation for the one-day meeting, including a campus and lab tour, impressive poster presentations on research by MIT AeroAstro Department graduate students, and more.

**Discussion topics included:**

STEAM for Space and Creative Arts

STEAM for Space: A New Model for Education

STEAM Principals in Space Project Design

STEAM for Space and Human-Systems Integration

STEAM and Creative Performances During Short or Long Space Flight Missions

STEM/STEAM for Space and Innovation

STEAM for Moon/Mars, as a Model for the Restricted Workplace Compared to the Open Society on Earth

**Dr. Jean-Michel Contant, IAA Secretary General** presented an outstanding lecture on "The International Academy of Astronautics and STEAM for Space". He gave an overview of the impressive history, the present status, and expectations for the future of the Academy. He presented exceptional data for the years of life of the Academy. Dr. Contant described the achievements and the goals of the Academy Sections, their Study Groups, meetings around the world, publications, and space projects around the world led by renowned space scientists, engineers, space law experts and historians. It was a most informative and outstanding presentation.

**Prof. Dr. Liya Regel,** Distinguished Research Professor, Clarkson University, NY, USA and the Chair of the IAA Study Group "STEM/STEAM for Space. Grand Challenges." In her opening lecture she described the role, goals, strategic plan, and opportunities for the Study Group from its beginning up to recent days. She noted that, so far, the elite body of the IAA is the only international organization with a study group focused on STEAM for Space, which began in 2014. Since then the Academy selectively appointed members from different countries and organizations from six continents to the SG to provide their essential knowledge, experience and leadership to reach the goals: identify sources for relevant expert information from the space countries and their national academies, companies, organizations and professionals in STEAM education for space research; and generate recommendations to advance this essential endeavor.

Dr. Regel invited the audience to consider the classical curriculum of ancient Greece and Rome that was organized into the trivium: rhetoric, logic, grammar; and the quadrivium: arithmetic, geometry, astronomy, music. She referred to the polymath genius, Leonardo da Vinci: scientist, mathematician, engineer, inventor, anatomist, painter, sculptor, architect, botanist, musician and writer, all in one human. His dreams of space flight and inventions still live with his amazing sketches, flight models, paintings, sculptures, and more. Dr. Regel pointed out that STEM/STEAM was born with Leonardo de Vinci; he was the first "STEAMIST." Regel shared with the audience her new acronyms, STEMIST and STEAMIST, to denote educators, professionals, and advocates for STEM and STEAM education worldwide.

And, of course, another STEAMIST was Gustav Eiffel. In 1889, he completed his magnificent beautiful tower using his knowledge of science, technology, engineering, art, and mathematics. And as Dr. Regel said a few years ago: "Where does the tower point? To space! It reminds us of a rocket on its launch pad." The Eifel Tower -- a perfect illustration of the symbiosis of the STEAM subjects.

She also presented a few illustrations of the paintings of Kazimir Malevich, from the era of the supremacism in the early part of the last century. Some of his paintings remind us of planes and spacecrafts. She showed some famous paintings by Soviet-Russian cosmonaut Aleksey Leonov, who was the first human to conduct a spacewalk; and some of those by astronaut Alan Bean, an aeronautical engineer and Apollo 12 crew member who walked on the Moon. After he retired from NASA he became a full-time artist, and left behind exceptional paintings.

Dr. Regel raised the following questions to foster discussion:

Did painting stimulate Leonardo da Vinci's creation of new devices?

Did the arts play a role in Eiffel's design of his beautiful tower?

Did Jules Verne's novels inspire future developments in submarines and space flight?

Did movies stimulate technological innovations? Consider "Woman in the Moon," a silent science fiction film that premiered 15 October 1929 at the UFA-Palast am Zoo Cinema in Berlin to an audience of 2,000. This was the first movie to dramatize space travel as a realistic possibility. One of those in that audience was Albert Einstein. Is there a connection between Einstein's General Relativity and the first sci-fi movie?

Did playing the violin help Einstein in his quest to understand the Universe?

Which type of art is most likely to lead to creative leaders in space activities? Why?

What is the best way to incorporate art in nurturing such leaders for space?

What difficulties are there in accomplishing this?

How can we overcome these difficulties?

Can engaging in creative arts outside of a person's job stimulate creativity on the job in the space industry?

How can we help our students and future employers to recognize the benefits of artistic endeavors outside of the classroom and the workplace?

What are some examples where the creative arts led to development of new technologies?

The SpaceX mission to send painters and poets to the moon could have world-changing ramifications. And herewith: News for all STEAMISTS - STEMISTS for Space: the first private lunar mission, SpaceX, plans to send artists to orbit the moon. The "Dear Moon" project is backed by Japanese billionaire Yusaku Maezawa, who intends to take six to eight artists with a range of backgrounds, from literature to dancing to architecture.

Dr. Regel said that STEAM through the lens of the creative arts will make all the difference in the world. The next generation of leaders for space can be brought to a new level of excellence by pioneering new methods of teaching that combine disciplines that have been isolated from one another under traditional educational models.
And that we all need to continue to generate benefits for society through STEAM for ALL education around the world, but especially for FUTURE SPACE LEADERS of TOMORROW.

Following are selected highlights of presentations at the Focus Group meeting at MIT.

**Dr. Guy Andre Boy,** *Professor of Centrale Supélec, Paris Saclay University, and ESTIA Institute of Technology, France*, introduced his view of the importance of Human-Systems Integration (HSI) as a Technique and an Art. HSI is grounded on the co-construction of Technology, Organizations and People's activities and jobs. HSI also requires the association of physics, cognitive engineering and arts. Physics provides the necessary knowledge, rules and constraints that an engineer needs to build a system that works. Cognitive engineering provides knowledge, rules and constraints that are necessary to safely, efficiently and comfortably use a system. However, neither physics nor cognitive engineering provide insights or methods that support creativity. Consequently, arts should be integrated into STEM education and practice to make STEAM (with "A" for *Arts*).

Dr. Boy said that visualization supports integration by making abstract constructs more tangible and facilitates effective learning. He mentioned that during the design of what became NASA Space Exploration Vehicle (SEV), "we worked with artists and cartoonists, who helped us visualize possible scenarios. They first drew cartoons that were displayed around a room and developed animations. We not only used them as tangible visualizations of our concepts, but also as mediating representations that integrated multiple participants views." He also described his experience on the ISU Space Studies Program 2012 in which his team carried out a project on "what space can contribute to global STEM education," which clearly anticipated the shift from STEM to STEAM. He commented that "space leaders of tomorrow should physically, cognitively and creatively investigate a specific planet, that is Earth, in addition to the other ones. He observed that HSI is both a technique and an art, and qualifies for being a STEAM discipline.

**Mrs. Kaori Sasaki,** *Director, Space Education Center, JAXA, Japan*, described one of the leading efforts in science education and STEM education in Japan -- the Super Science High-School (SSH) that was started in 2002. This program encourages high school students to study science, technology and mathematics by collaborating with universities and research institutes. In 2019, over 200 out of 6,600 high schools in Japan have been designated for this program with supplementary budgets. While SSH was being implemented at these schools, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) announced a new course of study in 2016 in response to global educational trends. It rearranges the qualities and the abilities to be fostered and requires the improvement of the classes from the viewpoint of "in-depth study by thinking for students themselves through discussion." The new course of study shows that elementary school students learn about logical thinking through program coding, which will be a compulsory subject beginning in 2020. There are few teaching materials for programming education in schools. There are private after-schools in some big cities to learn program coding for school students.

STEM and STEAM were discussed particularly in the context of higher education in Japan. There is no official statement from MEXT on STEAM. However, related elements

are almost on board, so, the discussion by experts on STEM/STEAM will accelerate soon.

JAXA has been developing STEAM materials since the Space Education Center (SEC) was established in 2005. In the field of informal education, SEC provides support to the Young Astronauts Club (YAC), Space Schools for Families (SSF), and Cosmic College for their activities. YAC and Cosmic College mainly target primary school children. SSF aims at families (parents and children of K-2). “We aim to improve children’s scientific minds from their childhood.”

Recently, JAXA developed program coding and robot learning materials in collaboration with a private company that provides after-school activities. This is called "Hayabusa 2 touchdown." In 2019, asteroid explorer “Hayabusa 2” made two touchdowns to the asteroid Ryugu. Children are highly interested in the outcome of space activities. At the beginning of the activity, a video message from JAXA researchers describe the mission to the students. Four students constitute a group and play the roles of commanders and programmers. In the process of communication and program coding for safe touchdown to Ryugu, they overcome miscommunication and get to know about computational thinking. This program was used in after-school classes nationwide as well as in some formal school classes.

Another affordable example is the program coding materials with Scratch on satellites which was developed by the JAXA Earth Observation Research Center (EORC) and the Space Education Center. It has been incorporated in formal school classes in grades 4 and 5.

As mentioned, discussions on STEAM education have just begun in Japan. It has not yet penetrated the education scene widely. Informal education, such as science museums and NPO initiatives, provide various opportunities for hands-on activities, but these are concentrated in big cities. Some elementary school teachers feel unable to teach a program coding class. Some teachers who heard about STEM feel a burden to teach it. As a space agency, JAXA can contribute taking a lead in driving STEAM education in Japan.

**Dr. Oleg Ventskovsky,** *Director of the Brussels-based European Representation of the Yuzhnoye Design Office, a leading Ukrainian space company*, started by showing a short video presenting Chesley Bonestell’s Moon passages accompanied with the “Fly me to the Moon” song by Doris Day. He reminded us about the outstanding role Bonestell and his art played in encouraging thousands of young people to choose STEM-associated careers, in particular to become space professionals, and in inspiring the US space program.

Dr. Ventskovsky went on by pointing out a very special, in his view, instrument for STEAM education – the game of chess. The game is widely acknowledged as having elements of art, science and sport. He believes that cultivating chess among primary and secondary scholars can help improve their concentration, develop logical and

critical thinking, and promote creative problem solving and other useful qualities. He said that “this has been proven, in particular, thanks to some initiatives by the Kasparov Chess Foundation. For example, beginning in 2011 the Ministry of Education of Armenia made chess a part of primary school curriculum for children over the age of 6. Their example is going to be followed in several other countries.” He also mentioned an American movie “Queen of Katwe” (2016) about a Ugandan girl from a slum becoming a chess master and thus improving her own and her family’s life, as a possible role model.

Finally, Dr. Ventskovsky, emphasized that the Moon Village Association (MVA) has included STEAM high on its agenda. (He is a member of the Board of Directors of MVA, an International NGO whose goal is to provide a permanent global informal forum for governments, industry, academia, the public and other stakeholders interested in the development of a Moon Village.) One of MVA’s institutional members, Planet Zebunar, developed a similarly-named augmented reality app combining in a very creative and funny way the latest online and offline technologies to engage children in STEAM. Another interesting example - “Space Architecture Design Studio” at the Vienna Technical University (summer semester 2018) was organized by Dr. Sandra Haeplik-Meusburger, an individual member of MVA. During the semester, 13 projects of potential habitats and of research stations on the Moon were implemented by architecture students under the guidance of space experts with very impressive results.

**Mr. Amal Khatri,** *Executive Director at South African National Space Agency (SANSA*), introduced how active SANSA is involved in the development of human capital, in particular through SANSA’s Science Advancement role, and in STEM to support the future of Space in emerging countries. This impressive effort exposes young learners to activities within the space industry, seeking to encourage future generations to take up careers that are based in the fields of science, technology, engineering, mathematics and innovation (STEMI).

Emerging countries face several social challenges that have a broader impact on our youth. Engaging with underprivileged schools, vulnerable students and youngsters not normally exposed to the advantages of pursuing STEMI careers, will increase the diversity of students pursing STEMI fields and widen the available workforce. This is a great opportunity to close the gender gap through exposure to the sciences at an early age in preparing the next generation of women in STEM. In the same breath we need to be aware that STEM in the 4$^{th}$ industrial revolution needs to start introducing students to a new way of working. Moreover, we as a society are faced with serious challenges like climate change and the environment, which lead to sustainable development goals.

Mr. Kharti pointed out that research has shown that currently there is a gap in developing the right capability and more importantly the capacity to support the future Space Program. He said “as emerging countries, we are all developing our own program to meet user requirements from our stakeholders. This eventually leads to a space industry which drives the economy and creates new knowledge to address the sustainable development goals and drive our own space economy. Imagine a future where we consciously protect our planet by installing a value system that will allow us to

have a better understanding of who we are and how we engage with our environment. The world is moving a drastic pace. Technology is evolving at a rapid rate. To give you an idea it took over 64 years for air travel to reach 50 million people. Electricity reached 50 million people in 46 years. Yet even today in some emerging countries we don't have electricity. Is this because we are investing money in areas that matter less? Or are we not conscious of our roles in society? WeChat reached 50 million people in 1 year. This rapid growth of the internet is largely the factor driving this change. The question is can we predict what will happen in the next 10 year and are we preparing our youth adequately for this new chapter?

STEM is starting to bridge the ethnic and gender Gap. Much more needs to be done to close this gap. STEM is allowing our economies to grow by creating a knowledge economy to now take them to the next level. STEM in emerging countries in particular has sparked interest in careers.

The youth of today need to be exposed to a broader STEM program in engineering technology by engineering our youth to make better decisions about our planet.
Mr. Kharti said "we are all living in an interconnected society. Opportunity now exists to create a global revolution in using science with a conscience." He kindly shared with the audience his short and interesting ppt presentation.

**Prof. Mg. Alejandro J. Román M.,** *General Director of Aerospace Development and Execution of the Space Agency of Paraguay,* described the implementation of project-based learning using Space-based applications to strengthen and improve STEM/STEAM education in Paraguay. He showed the audience his impressive short ppt presentation. He noted that the PISA-D Report of December 2018, in which Paraguay had the last position in mathematics and science, is a socio-economic time-bomb in a country of 7 million people with more than 60% of the population under 35 years of age. The problem of this country's weakness in STEM/STEAM education is even worse considering that there are more than one million students in the schools with poor results. This situation is receiving considerable attention from the government and public opinion.

However, taking the necessary actions, combined with this demographic bonus, will transform the country's productivity matrix and provide new opportunities to current and future generations. We aim to inspire students' interest in STEM content at an earlier age, with a proactive approach that can ensure students are on track through high school to complete the needed competencies for adequate preparation to enter STEM degree programs at institutions of higher education.

The proposed solution is to urgently improve technical education, especially in STEM/STEAM, using Project-Based Learning (PBL). PBL has a proven record as a teaching tool. It is also well known that constructivism learning theory suggests that students learn better by actively participating in the learning process. In order to involve them in this participatory learning process, the interaction in a classroom becomes very critical to ensure inclusiveness of quality education and benefit all aspects of society,

stimulating, inspiring and giving the adequate skills to the youngest generations. With the incorporation of Arts, it complements the integral formation of students.

The Paraguayan Space Agency is developing a coordinated initiative with the Paraguayan Ministry of Education and Science and other actors to strengthen STEM/STEAM education and to encourage competitions in the use of space science and technology like High Altitude Balloon Missions, CanSats, and, later CubeSats and Small Rockets, with a combination of these using Space Technologies that are fundamental parts of their subsystems. In the next phase we can also incorporate satellite image processing as a tool for learning, e.g. geography and environmental awareness. This has proved to be successful in other countries. In Paraguay we have had very good results with other STEM disciplines like robotics and computer video game programming, in which our students have won competitions at the international level for 5 years. The goal is to have the same results in space-related project competitions in less than 5 years.

Space-based applications and systems are playing a major role in improving STEM education in Paraguay with project-based learning using High Altitude Balloons, CanSats, CubeSat, Small Rockets, and Satellite image processing in High Schools and in Universities. We will comprehensively analyze the results of this work.

The value of new technologies in relation to teaching is highly accepted. Its incorporation in teaching practices becomes indispensable to generate innovative proposals and improve student learning, promote more integral and inclusive STEM/STEAM education system. This will guarantee that all young people, regardless of their socioeconomic condition, will reach at least a minimum level of education, performance, well-being and commitment. These are necessary for them to participate in a space society and be prepared with twenty first century skills in order to ensure their competitiveness in this era of globalization, especially in the science and technology sector.

Finally, Prof. Roman said “We will help achieve Sustainable Development Goals, especially in SDG4, to ensure inclusive and equitable quality education. Space-technology project-based learning will provide the tools to accomplish this goal and, moreover, to inspire and improve opportunities for the youngest generations. “

**Dr. Herie de Vries,** *Visiting Scholar at Yale University, New Haven, Connecticut, USA,* She introduced her research on “Creative Performance in the Extreme Human Environment of Space.” Future deep space missions, for example to Mars, have no direct contact with earth. Astronauts might need to engage more on their own creative skills to survive. Therefore, the need to understand creative performance in extreme human environments will increase. Within the domain of creativity, generally optimal environments for creative performance are being studied. Environments in space differ and there are psychological consequences. Within a multivariate theory of creativity, the environment, as a contributing factor, determines creative potential.

This again impacts related psychological, and social-emotional factors. Existing research focusses on moderate environments. Thus, there is a gap in research on how more extreme human environments like space, might contribute or impact creative potential. This might impact creativity in different domains, such as scientific, artistic and musical creativity as well.

The focus on extreme environments will not only enhance our understanding of fostering and developing creative skills in the environment of space, but can also be transferred and applied to other extreme human environments. She substantiates this new research area with a focus on cultural, cognitive psychological, and social-emotional issues.

Examples of creativity and space-related issues, are, for example 1) temperatures of the space environment, 2) the circadian rhythm in space, 3) overwhelming emotions and the “sense of wonder? in space, 4) astronaut’s collaborative creativity and conflict resolution in confined spaces, 5) effect of isolation on mood during long duration flights.

Insights on human creative potential in space can be used in multiple situations. Examples are accidents when mine workers are trapped underground (e.g., in San Jose, Chile in 2010), when people are trapped in a cave (e.g., in Tham Luang, Thailand, in 2018), or in war zones. Relatively less, but still extreme, environments could be experienced in education in classrooms, by individual students, minorities such as immigrants, and low social-economic background students. Finally, natural disasters already today create human extreme environments on earth. By investigating creative potential in space, we might add to insights into how creativity can be unleashed and fostered in space and other extreme human environments, and anywhere where creative skills are needed.

**The Focus Group meeting was adjourned with continuing discussion during a tour of laboratories and the MIT campus tour.**

**Participants and special guests concluded that this was a successful and friendly meeting which will lead to fruitful collaborations on STEM/STEAM for Space Leaders of Tomorrow, and beyond.**

**Graduate students presenting their posters. MIT AeroAstro Department, October 28, 2019**

**Some participants waiting for lab and campus tour.**
**October 28, 2019, MIT, Cambridge, USA**