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Towards the International Lunar Decade

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Abstract

In November, 2014 the participants of the conference "Next Giant Leap: Leveraging Lunar Assets for Sustainable Pathways to Space" issued the International Lunar Decade (ILD) Declaration. The central premises of ILD are: 1. The inspiration for ILD is the International Geophysical Year 1957-8 that marked the first global effort to understand the Earth. ILD is proposed as framework for international cooperation towards permanent presence of humankind on the Moon and beyond. Initially proposed by COSPAR to start on the 50th anniversary of IGY in 2007, global conditions were not favorable. Now, with many countries planning missions to the Moon the decade of 2020-2030 would be appropriate to work towards the strategic goal of making possible permanent presence on the Moon. 2. Economic use of lunar resources is a precondition for sustainable research and commercial activities on the Moon. There is speculation about lunar water and asteroid resources, but no business case for use of space resources has so far been offered. Markets for space resources do not exist. Technologies to mine and process space resources need to be developed. Even the legal right to use space resources within existing space law is uncertain. Recent developments suggest that a business case for lunar resources can emerge over the next few years. Space-Based Solar Power (SBSP) can bother accelerate lunar development while creating markets for the use of lunar resources to meet needs on Earth. Recent designs of SBSP promise electrical costs competitive with other alternatives with zero CO2 emissions. An early application with commercial potential could be a Lunar Power Utility that could lower costs and speed up lunar development. Lunar water is another promising resource. Low cost launch from the lunar surface is key to realizing the economic potential of lunar resources. Additionally, the issue of rights to use lunar resources, particularly as commercial products, remain to be addressed.

The ILD provides an open framework to coordinate space exploration and space science research involving national space agencies, research centers, and universities with activities undertaken by international organizations including the International Council for Science, COSPAR, UN COPUOS, and various commercial and private organizations. Similar to IGY national research organizations would initiate their own projects within the general ILD framework.

The Moon Village Association provides a structure to link between lunar exploration and research and commercial developments into a mutually augmenting whole. Moon Village is a bottom-up, open, evolutionary concept for development on the Moon and in cislunar space by an international community including scientific research, business and cultural interests, as well as space agencies and international organizations. Moon Village, however, does not address the policies required to enable use of lunar resources or to engage the global research community, the UN, and other international organizations such as the International Council for Science, which coordinated the IGY. Moon Village and other developments can benefit from the framework for strategically directed international cooperation from 2020 to 2030 provided by the ILD to: develop internationally accepted policies for use of space resources, foster innovation and the development of enabling technologies and infrastructure aimed at driving down the costs of activities in cislunar space and on the Moon, and facilitate the creation of markets for space resources. Adoption of the ILD framework by the International Council for Science (ICSU) and UN COPUOS, as well as by ISECG and other forums for international cooperation in outer space can lead to greater progress in the 2020-2030. The ultimate purpose of ILD is to maximize the international benefits of lunar exploration and development. Key to this is to engage the public globally, particularly students and young people.

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EarthMoonMars Village Update 2018

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Abstract

We give an update of Moon Village (MV) and EarthMoonMars activities, with emphasis on events that took place in 2017-2018. The Moon Village is an open concept proposed with the goal of a sustainable human and robotic presence on the lunar surface as an ensemble where multiple users can carry out multiple activities. [1-3]

1. EarthMoonMars Village

Multiple goals of the Moon Village include planetary science, life sciences, astronomy, fundamental re-search, resources utilisation, human spaceflight, peaceful cooperation, economical development, inspiration, training & capacity building.

How did the Moon Village start? ESA director gen-eral has revitalized and enhanced the original concept of MoonVillage discussed in the last decade. Space exploration builds on international collaboration. COSPAR and its ILEWG International Lunar Explora-tion Working Group (created in 1994) have fostered collaboration between lunar missions [4-8]. A flotilla of lunar orbiters has flown in the last international lunar decade (SMART-1, Kaguya, Chang'Eal1 &2, Chandrayaan-1, LCROSS, LRO, GRAIL, LADEE). Chinese Chang'E 3 lander and Yutu rover. Upcoming other landers from 2018 (GLXP, Chang'E 4 & 5, SLIM, Luna , LRP) will constitute a Robotic Village on the Moon.

:Moon Village Workshops were held at ESA centres in 2015-2016 at ESTEC or EAC/DLR were reported [45,28-36]. A MoonVillage ESA interdirectorate group organized meetings and seminars, EuroMoonMars workshops were held with senior experts as well as Young ESA professionals to discuss general topics and specific issues (habitat design, technology, science and precursor missions; public and stakeholder engagement) .Dedicated ESA studies were started on mission scenarios (GO et al), building blocks (DB,ML), 3D Manufacturing & ISRU (LP, NA, MG).A number of MoonVillage talks and/or interactive jam sessions conducted at International workshops and symposia in 2016 have been reported [45, 16-27]. In 2017-2018, Moon Village Workshops MVWS or sessions were also conducted at international symposia or in collaboration with specific universities or institutes (we give here events, and initials of main co-organisers listed in acknowledgements*):

-WdeKooning Acad. Arts Rotterdam: King of Moon (NV)
-ISU Strasbourg MVWS & design projects 6 March 2017
-ISAE Supaero Toulouse MVWS & design 7 March (SDM)
- ESTEC PMAS simulation workshop 16-18 March (SH)
- Paris SGAC European meeting 24-25 March (HG)
- London Ontario SW Uni Exploration day 4-5 April(JC)
-McGill Montreal Moon Village workshop 6-7 April (VF)
-Stuttgart Architecture Moon Village Projects April-August
- Cannes Innov. Centre/O'Sol MVWS 5-6 May (PS, EGB)
- Stuttgart Architecture MVWS / projects ESTEC 8-9 May
- Munich Airbus/ESA MVWS 31 May (P-A J, LF)
-Stuttgart Architecture MVWS & projects review 30 May
- Seoul KICT MVWS 1-2 June (TSL, BF)
- Paris Obs. Astronomy from Moon 21 June (JS, BF,AD)
- Salon du Bourget Air & Space 22-23 June MV WS
- Torino SGAC MVWS 29 -30 June (HG)
- Etna ROBEX DLR campaign 29 Jun- 2 July (AW, MW)
- LunAres Base installation expeditions (AK, AL)
- LunAres Base PMAS campaign (SH, AK)
- LunAres Base LunEx1 campaign (AK, MH)
- LunAres Base IcAres campaign (AK, CH)
- Budapest MVWS 31 Oct (TP)
-VU Amsterdam/ESTEC Planetary design 9 Nov-11 Dec

Moon Village talks at 2017 international events

- Global Space Congress Abu Dhabi UAE 30 Jan-1 Feb
- UN COPUOS Action team on Exploration 5-7 Feb 2017
- UN COSPAR explo workshop Vienna 25 April, 22 May
- European Lunar Symposium & New Views of Moon , Muenster 2-4 May (HH, CN)
- ISDC ST Louis (with ESA DG J. Woerner) 1-2 June
- GLEX Global Exploration Conf Beijing 6-8 June
- Concordia U Montreal MVWS 11-12 Aug (M-P B.)
- Global Hands on Universe , Bowling Green 16-17 Aug
- Nashville Adventure Sci Center, Eclipse 19-21 Aug (JI)
- EPSC European Planetary Science Congress Riga, Moon Village Science, Explo. Technology Foresight 18-21 Sep
- Adelaide Australia IAC Intl Astronautical Congress A3 exploration symposium & plenaries 25-29 Sept
- Hawaii International Moon Base Alliance 1-4 Oct (HR)
- Columbia, LEAG Lunar Expl. Analysis Group 10-11 oct

- Bremen Space Tech 24-26 Oct
- ISU MVA MVWS 19-21 Nov (GR, CW, JM, AK)
-ESLAB ESTEC Extreme Habitable Worlds 4-8 Dec (ESN)
- MoonVillage Global Science Opera (performance over 15 countries including ESTEC event) 13 Dec (O. B.-O.)

EarthMoonMars events 2018
- Amsterdam Waag Society, Out of Cradle workshop (MT)
- Tokyo 2-4 March Exploration Forum ESF
- The Hague 12 March Intl Women Moon Village WS
- Houston LPSC 18-23 March
- Paris 26 March SGAC Space Generation workshop
- Paris 27-29 March IAF Spring meetings
- Vienna 9-13 April EGU European Geosciences Union
- The Hague 16 April KABK Art, design & MV WS
- ESTEC 19-20 April EuroMoonMars WS & simulations
- Lausanne 23-25 April EOFL Exploration 2061 WS
- Washington DC 7-9 May Humans to Mars Summit
- Toulouse 14-16 May European Lunar Symposium
- Pasadena/LA SpaceTech & ISDC 22=27 May
- Big Island Hawaii MoonMars Field Research 29-31 May
- Vienna 16-20 Jine Unispace 50+
- The Hague Pulchri 19 May-9 Jun Art & MoonMars WS
- Delft/ESEC/Leiden ISU SSP 25 June-
- Pasadena 15-21 July COSPAR & ICEUM13
- Berlin 17-21 Sept EPSC (many MoonMars sessions)
- Bremen 1-5 Oct IAC Int'l Astronautical Congress
- Moscow 8-12 Oct 9M-S3 symposium
- Amsterdam 15 Nov VU Humanities & Space
- Hainan China 4-7 Dec ILOA Galaxy Forum

Perspectives for MoonVillage: A number of Moon-Village activities are planned. "The Moon Village will rely both on automatic, robotic and human-tendered structures to achieve sustainable moon surface operations serving multiple purposes on an open-architecture basis."

Acknowledgements

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Lunar electrical power utility: Key to lunar development

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Abstract

The global acceptance of the International Lunar Decade (ILD) will enable infrastructure projects like the lunar electrical power utility [1] to be constructed ahead of the emergence of demand for the electrical power. Availability of electrical power has been a primary driver of economic development. One example: The Tennessee Valley Authority (TVA), was launched by an act of the U.S. Congress in 1933, resulting in hydropower plants being built throughout the Tennessee Valley to provide power to seven southeastern US states. Future demand was hard to forecast insofar as the region had been largely without electrical power. TVA built the dams and industry emerged in the region to use the generated power. In WWII aluminum production was located in the region as well as a significant share of the Manhattan project that required huge amounts of electrical power.

Important uses of electrical power on the Moon include power for ISRU to process lunar regolith and other lunar materials into products including oxygen, metals, silicon for solar cells, basalt fiber, and other uses. The ready availability of electrical could double the productivity of rovers and other equipment on the lunar surface by enabling operating during the two weeks of lunar night without requiring large-scale power storage. A highly promising use of electrical power could be to make possible low-cost launch from the lunar surface using one of several options that require significant electrical power including beam launch, rail-gun derived electromagnetic launch and others. Low-cost launch from the lunar surface in turn would enable vastly increased use of lunar materials enabling the construction of large-scale facilities in outer space that otherwise would be impossibly expensive if launched from Earth. Even launched from the Moon with conventional technology would be impractical.

Our power generating approach of choice is space-based solar power (SBSP) as proposed by NASA researcher Jim Schier [2]. In Schier's concept two SBSP systems in halo orbits about the Moon could cover the entire surface of the Moon.

Given that the system with two satellites is financed and firmly in the forward plan with sufficient power generating capacity to power rovers, pilot ISRU production operations, and experiments with low-cost launch from the Moon, then such equipment could be designed to receive the power from the SBSP system. Standards could emerge for power-beaming and receiving equipment contributing to moderate and lower costs. Avoiding the cost of landing equipment with sufficiently large battery systems to power equipment through the lunar night would further contribute to declining costs.

Utilities serving customers on Earth have developed financing mechanisms for projects that require a decade or more to start generating electricity and selling power to rate paying customers. The lunar power utility could be seen as analogous to such terrestrial utilities. It is plausible that a consortium of utilities could find such a project of considerable interest. First, it would attract favorable public attention establishing them as technology leaders. Second, the development and the piloting of the technology in lunar applications can position the utilities to apply similar technologies to meet needs of customers on Earth.

Government guarantees, and risk management instruments are likely to be required to encourage private investment in such a venture. But such arrangements are not uncommon.

We argue that the lunar power utility should be an early project in the development of lunar industries fulfilling the vision of “Build it, and they will come!

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Creating music from astronomical/planetary data: Herschel/PACS data sonification of Haumea

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Abstract

Science and technology can be used to create and develop artistic expressions and styles and produce artworks, and also arts can be used to underlying or communicate physical properties, processes or relations. By developing a program code to sonificate scientific data (converting data into sound signals), and using thermal light-curves of a sample of Transneptunian objects (TNOs) observed by the Herschel Space Observatory [1], we generated musical material. We elaborated an audio CD with musical pieces integrating them, the musical pieces were performed in different events (installation and concerts). The project engages the public, promotes astronomy, planetology, and arts, underlies physical characteristics of TNOs, presents data in different aesthetically ways, and uses a new basis for musical composition.

1. Introduction

Transneptunian objects (TNOs) are very cold and remote objects beyond Neptune, their physical properties are largely unexplored and their thermal properties are difficult to measure. Their studies can help us to understand the Solar System and its formation [2]. In the framework of the large program "*TNOs are Cool: A survey of the trans-Neptunian region*" [3] Herschel measured the thermal flux of about 140 TNOs and carried out time series observations of few ones.

It is a standard procedure to convert data into visual representations (plots, figures) by which qualitative patterns/relations are evaluated/underlined by simply looking at it. Less common is converting data into sound and listening for patterns. Here we apply sonification to scientific data and incorporate the output audio signals into musical pieces to recognizing and interpreting observed (heard) patterns in a different way and producing artworks.

2. Observations and data Sonification

As an example, one of the most remarkable TNOs is the dwarf planet Haumea, Herschel/ Photoconductor Array Camera and Spectrometer (PACS) [4] measured its thermal light-curve [5]. Fig. 1 shows a clear detection of a light-curve at 100 µm. We developed a program in *SuperCollider*[1] to sonificate the light-curve: transposition to aural domain to generate an amplitude envelope, generation of rhythmic impulses, and generation of material for musical notation (Fig. 2), in written notation for instruments, soundfiles for electronic composition, algorithms and data for real time audio and video synthesis.

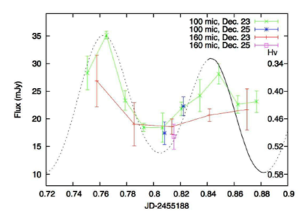

Figure 1: Thermal light-curve of Haumea at 100 µm (green) and 160 µm (red), fluxes vs. a function of fractional date.

Figure 2: Example of Chord instrumentations corresponding to Haumea light intensities

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3. Deliverables

We incorporated the set of sounds and musical material into nine musical compositions and elaborated the audio CD “signals from the cool”[2] (Fig. 3) by Neuklang Future. The musical piece “Cool Tune (2016)” formed part of the floating light sculpture installation “Rosalie”[3] at SCHAUWERK Sindelfingen, Germany (Fig. 4). The musical ensemble “Polytheistic Ensemble”[4] performed the live music in events like concerts (Fig. 5).

Figure 3: Audio CD “signals from the cool”. Photo credit: Miriam Rengel.

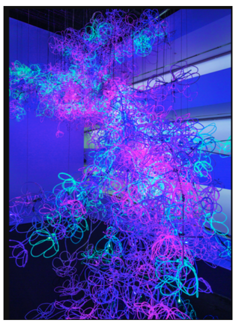

Figure 4: Rosalie exhibited at SCHAUWERK Sindelfingen, Germany, during13 March 2016–07 January 2018. It was accompanied by the sound installation “Cool Tune“ (2016) by M. Ockert. Photo credit: Wolf-Dieter Gericke, ©rosalie.

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Figure 5: Tour Concert “signals from the cool” by Polytheistic Ensemble, 10 June 2016, Karlsruhe. Photo credit: Miriam Rengel.

4. Summary and Conclusions

Our project explores and offers a way to evaluate qualitative patters from astronomical/planetary data by converting them into sounds, and integrating it into musical material. The project engages the public, promotes astronomy, planetology, and arts, underlies physical characteristics of TNOs, presents data in different aesthetically ways, and uses a new basis for musical composition.

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Herschel is an ESA space observatory with science instruments provided by European-led Principal Investigator consortia and with important participation from NASA. The Herschel spacecraft was designed, built, tested, and launched under a contract to ESA managed by the Herschel/Planck Project team by an industrial consortium under the overall responsibility of the prime contractor Thales Alenia Space (Cannes), and including Astrium (Friedrichshafen) responsible for the payload module and for system testing at spacecraft level, Thales Alenia Space (Turin) responsible for the service module, and Astrium (Toulouse) responsible for the telescope, with in excess of a hundred subcontractors. “signals from the cool” was supported by Innovationsgutschein C für Unternehmen der Kultur- und Kreativitätswirtschaft and Initiative Musik GmbH with project funds from the Federal Government Commissioner for Culture and Media.

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Self Deployable Origami for MoonMars Architecture

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Abstract

We give an update on the development of self deployable origami for MoonMars architecture. On the 19th and 20th of April 2018, the International Lunar Exploration Working Group (ILEWG) and ESA-ESTEC held the annual *EuroMoonMars* Workshop. On the second day of the workshop, a field test of our first prototype was carried out during Lunar Analogue simulations.

1. Self deployable origami for MoonMars architecture

Textiles can play a transformative role in future space architecture. Textile origami offers high performance external layer for extraterrestrial architecture. Origami structures facilitate kinetic transformation and can be unfolded into a myriad of different shapes due to their structural flexibility. They are lightweight. They can be easily deployed by embedding inflatable or hardware spine. Robotic pulling force could be an alternative compact support. Faceted origami surface helps avoiding harmful close to perpendicular confrontations with external particles. Embedded in textile solar panelling can alter direction following the sun and gathering more energy from this renewable source. Transparent vs. blind facets can alter direction allowing light and climate control. An added value of origami inspired structure as an external membrane for a Moon Village or a space station unit is its sustainability. Such structures can be re-used in different shapes and sizes as a solution for flexible spatial usage. Therefore, they enable spaces to stay functional for longer and fulfill their potential when requirements change. Space enhanced by such structures is temporal and alive as it transforms redefining itself in resonance to human and environmental factors. Extraterrestrial origami brings together technique, science and art.

1.1 Current status

Our first prototype was deployed and tested to extreme conditions on the 20th of April – origami structure as a gateway and sub-system between the exo-habitat, airlock system and exo-laboratory at EuroMoonMars2018 simulation.

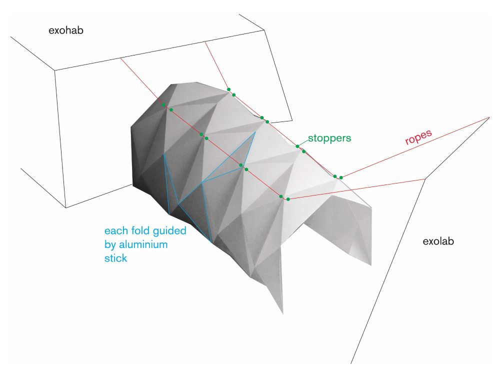

Figure 1 - origami structure drawing

Figure 2 - origami structure for MoonMars architecture prototype

1.2 Current challenge

The current challenge is finding optimal combinations of deploy systems and origami patterns. Through tentative model making and prototyping we can discover the most suitable combination allowing the most compact fold and lightweight, energy efficient deploy mechanism.

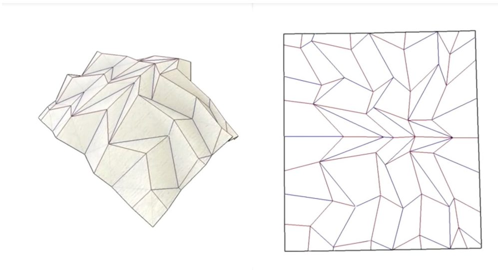

Figure 3 - software allows us to sculpt or generate complex origami forms while altering the crease pattern of the model

1.3 Perspectives

In collaboration with textile architect Studio Samira Boon we can implement origami structure into the digital weaving process. We're creating and digitalizing various origami patterns for MoonMars architectural applications. As the next milestone in our development process, we're planning to design a self deployable origami habitat.

Figure 4 - Studio Samira Boon – woven self supported origami dome from a single sheet of fabric

Acknowledgements

As a part of EuroMoonMars 2018 team we thank ILEWG for supporting our activities. We thank ESA/ESTEC for providing field test opportunities and technical expertise. We would like to acknowledge the analogue astronauts who participated in our field tests: Maria Grulich, Ilaria Cinelli, Yulia Akisheva, Bram de Winter and Jocelino Rodrigues, Daniel Michalik, Mark Ijzerman, Isa Andersson.

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A possibility to teach planetary and space science by increasing enthusiasm: the school year of 2018-2019 covers as 50 years anniversary of the preparations to lunar landing in 1969 July by NASA.

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Abstract: We propose a historical project method in order to help teaching planetary and space science in high school by remembering the main events of Apollo mission preparations for the first lunar landing, 50 years ago.

Introduction: During the 1968-1969 school year term (10 months from September to July) final steps were organized and accomplished at NASA for the lunar landing of Apollo-11 in July, 1969. The EPSC conference begins at the starting days of the school year term 50 years later. This gives an occasion to refresh the memory about this historical event. At the same time the comparisons between the todays technologies and those in the past can be examined in the classes. The 50 years anniversary is an excellent occasion to increase the enthusiasm of students in space science and recent years of efforts in planetary science and space travel technologies. Therefore we overview the 5 successful Apollo flights during that period and attache some points of discussion for teachers on the teaching at the specific missions.

The main events in 1968-1969 school term for the Apollo program.

Apollo 7: In October 1968 (bw. 11 and 22.). EARTH ORBIT. The first crew (3 astronauts) after Apollo 1 disaster. They used the new (re-planned) Apollo cabin in Earth orbit. This Earth orbital test flight proved that the new Apollo cabin is ready for the next steps. For teachers it is an occasion to tell and show how the Apollo 1 disaster caused a feedback in the program, but resulted in a less risk cabin atmosphere by application of nitrogene together with oxigene instead of the earlier free oxigene atmosphere.

Apollo 8. In December 1968 (bw. 21 and 27.). LUNAR ORBIT. The second 3 astronauts crew carried out a flight first farther than Earth orbit: they went to Lunar orbit and circled the Moon 10 times. The astronauts greeted the Christmas of 1968 from lunar orbit. For teachers it is an occasion to tell about the specific orbit the astronauts used to and back on this lunar mission. (the 8 shaped orbit).

Apollo 9. In March 1969 (bw. 3 and 13). EARTH ORBIT. The crew tested the systems of Lunar module, Command and Service modules. It was the first use in flight of the Lunar module. The necessary docking maneuvers and simulations of some lunar landing maneuvers were carried out in a low Earth orbit. The teachers can explain the most important docking steps during the Apollo missions.

Apollo 10. In May 1969 (bw. 18 and 26). LUNAR ORBIT. The crew tested all maneuvers and all the systems of Lunar module, Command and Service modules on lunar orbit. During the maneuver of descending the astronauts approached the lunar surface for 15 kilometers height, but did not land on it. This mission was the final preparation to the historical lunar landing of the next Apollo mission. Teachers have the occasion to tell episodes about the selection of the landing sites, some historical aspects of lunar stratigraphy – compared with that of the Earth.

Apollo 11. In July 1969 (bw. 16 and 24). LUNAR ORBIT, LUNAR LANDING. The crew accomplished a historical flight with first manned landing on the Moon. The astronauts settled the first man-transported basis of measuring instruments, collected samples and returned to the Earth for the first time. After almost a 1 year of studies the first Lunar Science Conference had been organized in Houston. Next year the 50th Lunar and Planetary Science Conference will celebrate this historical scientific event, too. For teachers two main scientific topics are comfortable to explain: The role of lunar samples returned, and the garden of instruments settled on the Moon (Apollo Lunar Surface Instrumental Package – ALSEP)

The 4 main rock types were first collected: basalts (high Ti-basalts), anorthosites, breccias, and the lunar soil.
The most important instruments were: seismic (active and passive) thermal, solar wind (low and middle energy range), magnetometer. They can also be compared to those instruments on Surveyor missions.

Summary: Teaching through the Apollo historical events is an excellent opportunity for the next school year. The way space technology and science reached this historical goal gives useful aims and examples to teachers and students in order to increase their enthusiasm in advancing their studies in space science, especially lunar science. In the next years this program can be extended to the subsequent Apollo missions and their results, too. May we offer cooperation to others schools all over the world to join our program.

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Astrojots: Explaining space and its exploration with cartoons

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Abstract

Astrojots is a web-based project for which the author - an active planetary scientist - creates cartoon strips to explain aspects of planetary science and exploration, space science, and astronomy. The aim of the strips is to be informative and engaging, with a good sprinkling of humour!

Astrojots cartoons are not exclusively targeted at school pupils; the intended audience is as wide as possible, and for all ages. The cartoon strips are created under a Creative Commons licence, allowing them to be freely printed and distributed, as long as they are not amended and that their source is identified. The strips are released every few weeks, and the usual format is suitable for printing on A4 paper for further free distribution by educators. The level of detail covered in the strips varies – sometimes very basic topics are addressed, suitable for pre-High School children, while other strips cover more advanced fields.

On social media, Astrojots can be followed on Twitter at

@astrojots

and on Facebook at

www.facebook.com/astrojots/

The project website is

www.astrojots.com

The project is complemented by public talks and school visits in the UK, related space data sonification activities, and a parallel Welsh-language project –

www.gofota.cymru

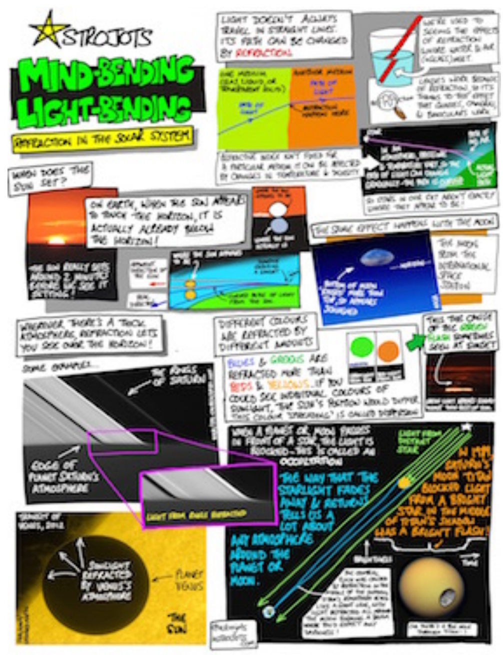

Figure 1: An example Astrojots strip.

Acknowledgements

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Ecosystem design and engineering: Key to permanent return to the Moon

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Abstract

The overall goal of the International Lunar Decade (ILD) is to enable permanent return to the Moon through cooperative international activities initiated during the 2020-2030 timeframe. The ILD open framework enables international cooperation to take place to achieve this objective through activities proposed by research organizations, space agencies, firms, NGOs and individuals. The intent of the ILD is to maximize international benefits of lunar exploration and development.

Multiple barriers exist to permanent return to the Moon. The ILD framework is intended to enable international cooperation to address these barriers by fostering knowledge sharing and the development of standards and similar approaches that can reduce costs and entry barriers for new participants. A looming barrier to permanent return to the Moon and long duration space missions is inadequate knowledge of ecosystem designs that could be sustainable and self-renewing using in situ materials for the engineering of soils. A significant cost of ISS operations has been regular resupply of the astronauts living on the space station. Such resupply to the Moon or to cislunar space facilities like the Deep Space Gateway would be prohibitive.

What is proposed within the framework of the ILD is a global program in ecosystem design and engineering that can utilize the highly varied in situ materials to design and engineer sustainable ecosystems with the potential for self-renewal. The knowledge and technologies developed through this program would have immediate application to address urgent problems on Earth as well as assuring the possibility of permanent human presence beyond the Earth.

Climate change is imposing rapid, and often disruptive changes to ecosystems destroying habitats, diminishing biodiversity, and affecting the food security of millions of people. Ecosystem design and engineering knowledge and capabilities are urgently needed on Earth, but this knowledge can also assure the possibility of permanent human presence beyond the Earth.,

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Economic impact of the International Lunar Decade

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Abstract

The overall goal of the International Lunar Decade (ILD) is to enable permanent return to the Moon through cooperative international activities initiated during the 2020-2030 timeframe. Presently announced projects by NASA, ESA, China, Japan, India and others represent an investment of more than $40 billion in lunar exploration projects. Given a global commitment to achieve permanent return to the Moon public investment would grow and numerous opportunities will emerge for private investment. It can be expected that a significant share of such investment could be in the form of public - private partnerships but as major barriers to permanent operations on the Moon are addressed numerous commercial opportunities will emerge. Such opportunities can be significantly multiplied through creation of funding instruments such as a lunar investment fund. The greater assurance and lower risk associated with a global program like ILD is also likely to motivate significant increases in private investment. Such investment will be further encouraged by cost reductions made through the deployment of infrastructure that lowers costs and risks for participants.Of particular value we see an energy infrastructure designed to encourage ISRU and other projects that require energy supplies at predictable and declining costs. For example many ISRU projects require both reliable, moderately price electrical power and low cost launch from the lunar surface. The availability of electricity can enable electromagnetic or beam launch not requiring volatiles and that could see declining costs in coming decades.

Total investment in lunar exploration and development is likely to top $100 billion in the 2020-2030 decade with greater returns on investment emerging as the decade proceeds. If there are credible prospects of the availability of low cost launch from the Moon and of electrical power when and where needed on the lunar surface as could be provided by an electrical power utility, then numerous projects could start to become economically feasible serving satellite markets in Earth orbit as well as rocket launch using lunar basalt fiber for thermal barrier shields enabling upper stage return to Earth as proposed by Michael Turner [1].

In this paper we will present scenarios of lunar development and forecast economic impact for outer space markets as well as on economic prospects for the spacefaring countries involved. We will also address the issue of a policy framework for use of lunar materials.

Notes

[1] Michael Turner proposal for lunar basalt fiber production - https://sites.google.com/view/kelah/services?authuser=0

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Fluid Bodies: from the Celestial to the Subatomic

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Abstract

The artworks of Evelina Domnitch and Dmitry Gelfand explore exotic fluid phenomena, from sonoluminescence to the hexagonal jet stream on Saturn's north pole. Pushing the very thresholds of observability, their endeavours raise questions as to what can and cannot be ultimately perceived and comprehended about physical reality. The duo will discuss their 20-year trajectory, culminating in a recent collaboration with the 2017 Nobel Prize winner, LIGO (Laser Interferometer Gravitational Wave Observatory).

1.Figures

Figure 1: Emissions of sonoluminescence in *Camera Lucida: Sonochemical Observatory.*

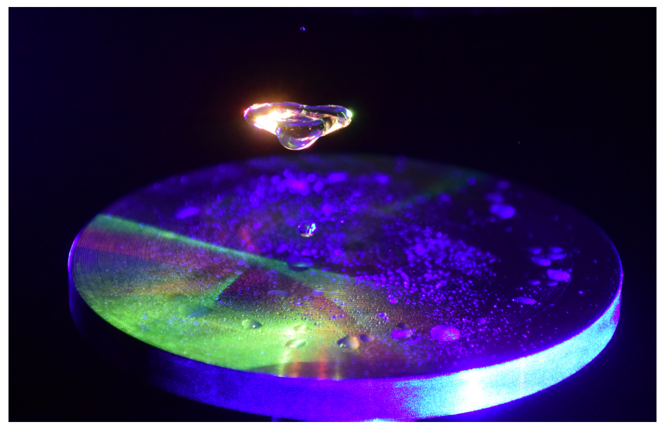

Figure 2: In the performance of *Force Field,* acoustically levitated water droplets evoke astrophysical dynamics.

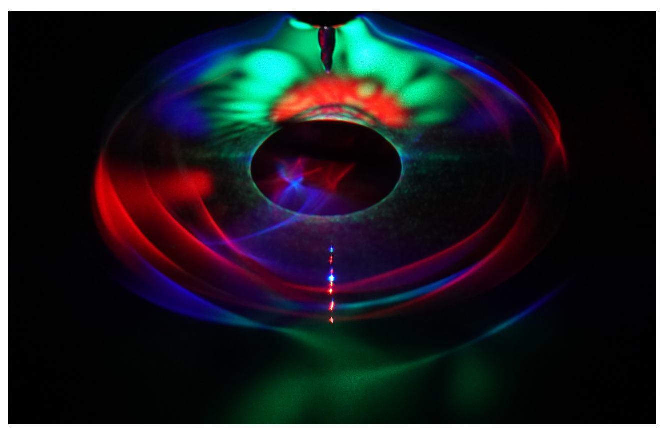

Figure 3: A hydrodynamic black hole analogue in the LIGO collaboration, *Orbihedron.*

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Pop Culture and Planetary Studies

A. M. James B. Foing[1,2,4] [1]ESA-ESTEC, [2]ILEWG, [3]KABK The Hague, [4]VU Amsterdam

Abstract

We examine the role of man in space through the lens of pop culture. From the earliest incarnation of science fiction through the modern-day blockbuster what role does planetary exploration play in building the myths and dreams of the future?

1. The Power of Public Perception and the Shared Dream.

Human beings have been preparing for our journey to the stars from the earliest stories told by the fire under the infinite sky. By the time the space race had begun, the public psyche was groomed through science fiction and fantasy (see fig1&2), story and myth, to not only believe that we as humans could go to space but that we should. Once viewed through the religious lens, these stories transformed in the early eighteenth century through literature. The popularity of these stories created a sense of ownership in technology for the everyman. We do not fully understand why certain ideas are popular but we can recognize when they are and examine the importance those ideas play in moving society. Would John F. Kennedy's famous speech declaring that we choose to go to the moon have had the same impact if the population had not been steeped in books and movies demanding mans rightful place amongst the stars?

Fig.1 - Fantasy and Science fiction Pulp cover

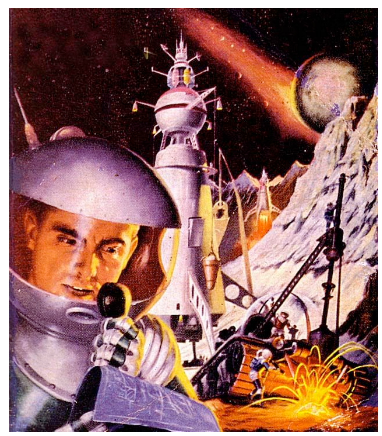
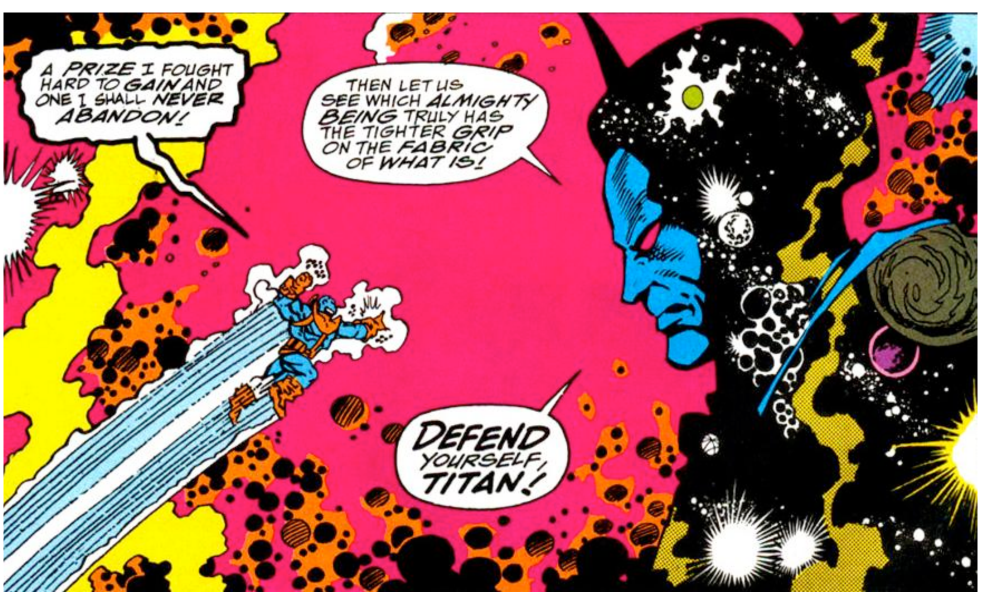


Fig.1 - Marvels Infinity Gauntlet comic book



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Global Science Operas: Moon Village (2017), Oceans & Climate (2018)

O. Ben-Horin[1], B. Foing[2,3,4] , J. Robberstadt[1], G. vd Sanden[2,3,4] & GSO Team
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Introduction: The GSO vision is to produce annual Global Science Opera productions during which a global community will explore interwoven science, art and technology within a creative and democratic inquiry process. We shall report the worldwide highlights of GSO 2017 Moon Village, which collaborated with the European Commission's H2020 initiative "Developing an Engaging Science Classroom (CREATIONs)" as a flagship implementation of that project, and provided a research focus for the Norwegian Research Council's project "iSCOPE".

Fig. 1: poster & partners for GSO Moon Village

GSO Moon Village; Based on scientific inspiration from B. Foing (ESTEC/ILEWG/VU Amsterdam), the opera "Moon Village" has been created by schools, universities and art institutions. The 27 countries in all the inhabited continents were: Argentina, Australia, Belgium, Brazil, Canada, Chile, China, Cyprus, England, France, Germany, Greece, Holland, Ireland, Italy, Japan, Kenya, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, USA, Wales and Zambia.

The opera included live streaming and events from many sites worldwide including from European Space Agency's Technology Centre (ESTEC) in Holland. The opera "Moon Village" is about human society on the future Moon Village. The opera begins in the year 2040. 100 persons (scientists, artists, farmers, teachers, engineers) live on the Moon Village. Two of them are expecting a child: Sofia is the first child born in space. Soon, more children are born on the Moon. Robi the Robot is their nanny. Gravity plans to make life difficult for them. As the children grow, they explore Space. When they learn about the troubles on Earth, some of them (including Bernard, Sofia's boyfriend) decide to return back to Earth. Sofia and the others who stayed on the Moon are sad. They grow even more curious about the Space around them. They need a school on the Moon! They study the Earth more carefully. Finally, Sofia leads Moonchildren to declare independence from Earth. For this, they will need to trick Gravity by using creative knowledge.

GSO 2018 Oceans & Climate: We shall also give latest news and artistic examples about GSO 2018 Oceans Climate that is currently in preparation with worldwide performance planned in September 2018.

Credits: We thank participants in GSO Moon Village (2017) GSO Oceans & Climate (2018)
http://globalscienceopera.com/

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From Westworld to Moon World on Grindhouse Radio

M. James[7], Claire Unabia[5,6,7], B. Foing[1,2,4,7] , BrimStone[7], Steve Zambo[7], Kim Adragna [7] , and sometimes Thomas[7], [1]ESA-ESTEC, [2]ILEWG, [3]KABK The Hague, [4]VU Amsterdam, [5]Westworld, [6]HBO, [7] Grindhouse radio

Abstract

A national radio broadcast featuring space scientist Bernard Foing, Westworld actress Claire Unabia and artist Matthew James discussing the possibilities of space travel and habitation with Brimstone and the cast of Grindhouse radio.

1. Space outreach radio program

Scientist Bernard Foing embarks on journey to enlighten the cast of US national radio program Grindhouse radio about past, present and future endeavors to space, the moon and beyond.

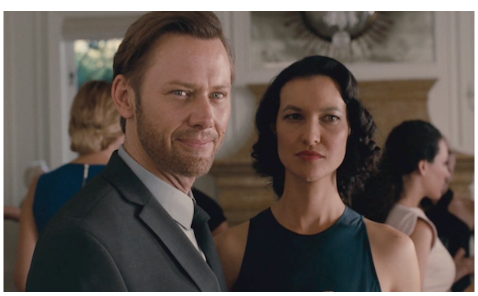

Figure 1 - Claire Unabia on Westworld Se2 Ep 2

Figure 2 - Recording Broadcast

1.1 Current status

The radio program was recorded on May 14, 2018 for broadcast on May 17 2018. It can be listened to internationally on iTunes and Iheart radio.

Figure 3 - Recording Broadcast

2.What is Grindhouse Radio?

Grind house radio is quite simply a show for everyone, from a group of not-so "normal" people. The Grindhouse Radio offers listeners their weekly pop culture fix of current news and events, comics, music, geeky gadgetry, sports and movies seamlessly blended into a two hour format. A no holds barred, madhouse of mythological proportions, GHR aims to be the public's weekly fix for pop-culture, nerdisms and all around

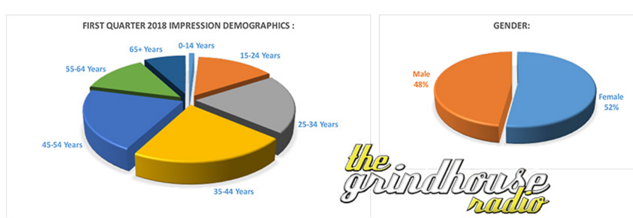

Figure 4 - Grindhouse Radio key demographics

oddball topics that relate to media and celebrities! Grindhouse Radio is currently syndicated on seventeen networks, most prominently iHeartRadio with a weekly listenership of between 3.5 - 4 million worldwide. The show can also be found here on TheGrindhouseRadio.com as well as on Brimstone's Official Website. We are always in growth mode in terms of additions being brought into our Syndicate (syndicated networks) which will be continuing throughout the year.

Brimstone has had a successful and rewarding career spanning well over three decades; participating in numerous entertainment fields boasting a list of titles including professional wrestler, radio host, actor, voice actor, author, musician, philanthropist, food critic, horror model, and comic book/animated/children's book/video game hero. He's been called a Renaissance man by many, but more accurately described as a well seasoned entertainer and entertainment entrepreneur.

Figure 5 - Cast of Grindhouse radio

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thegrindhouseradio.com

matthewhjames.com

www.hbo.com/westworld

reference of recording broadcast on May 17, 2018

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Mapping Synergies: Sustainable Development Goals and Research & Technology in Space Architecture and Human Spaceflight

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Abstract

Space has been an essential tool driving innovation beneficial for humankind, for over 50 years. The 2030 UN Agenda, with a more specific focus on sustainability is a reminder to critically consider the beneficial aspects of Space exploration for Earth. The emphasized focus on sustainability within the 17 Sustainable Development Goals leads to examine how the full range of space technologies can contribute to achieve these ambitious goals.

Space habitats, extraterrestrial or in orbit, are highly innovative environments that require a high degree of autonomy from Earth. The more extended the planned mission becomes, the higher the degree of autonomy, and need for a qualitative and sustainable habitats. Virtually all space environments for long-term habitation of spacecrafts or other extraterrestrial modules and structures need a high efficiency in terms of cost, energy and resource utilization. These requirements and limited resource-availability do not need to harm or undermine the manufacturing and operation of extraterrestrial habitats, or manned missions. Enabling such undertakings leads to a number of technological developments and innovative solutions in, for example: in-situ resource utilization, advanced life support systems, energy utilization, resource mining, habitat structures, material technology and advanced plant growth systems.

Investments made into these advanced space applications enable spin-offs and technology transfers that provide the opportunity to bring new technologies and applications to Earth. These could contribute towards a greener Earth and the fulfilment of the 2030 Agenda with the targeted Sustainable Development Goals. However, there is room for improvement through this multiplier effect, by defining synergies and supporting global partnerships.

We will present a review, summarizing the research & technology development in space architecture and human spaceflight, within the framework of the Sustainable Development Goals. Three particular developments are evaluated in the framework of environmental sciences, 1) in-situ resource utilization, 2) advanced life support systems and 3) energy utilization. This research draws upon primary research to identify synergies and coupling with known environmental challenges within our terrestrial and non-terrestrial systems. This research aims to highlight those developments that could function as transfer-technologies, which could be significant to work towards the United Nations 2030 Agenda for Sustainable Development.

Acknowledgements

The authors would like to thank ILEWG, the International Lunar Exploration Working Group for their support.

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