17th International Conference on Space Operations, Dubai, United Arab Emirates, 6 - 10 March 2023.

SpaceOps-2023, ID # 114

THE USING OF INTERNATIONAL SPACE STATION FOR THE DEEP SPACE

Jamel Metmati

Department Cyber : djamel.metmati@thalesgroup.com

Abstract

The International Space Station is going to finish its life cycle soon. In the same way, the missions to the Moon are ongoing with the Artemis missions and the design of Mars landing continues its process. As the Moon shall be a test bed for Mars mission, the International Space Station owns a function to limit the cost to show the behaviour of Space habitational in Deep Space. It means the Space should be thought as the materials on Earth as circular economy. Planned for 2031, the end of the International Space Station with some debris in the ocean could be bypassed by another methodology with some sprints. First, the delays provide the possibility to plan the reuse and the recycling of the station. The target should be the Moon, Mars, and the Deep Space. For each main objectives, the subjects will be linked with the components of the Station useful to be tested or to be exploited by the ground or Space segment. The components concern at the same time the modules, the solar panel, the communication and information system, the laboratory, and the robots on board. The other ingredient should be added like the motors. Within of these topics, the test beds should be planned and proposed about the energy, the backup communication and habitational to the Moon, the Deep Space test bed for Space missions. At last, the requirement of this reuse should be the basis of New Space approach including the activity management in Space by usual.

Keywords : Deep Space, Exploration, Space station

Acronyms :
DsD: Deep Space Gateway
IT: Information Technology
NRHO: Near Rectilinear Halo Orbit
PFM: Program Financial Management
QM: Quality Manual
SCO: Strategic Communications Office
SL: Senior Leadership
WI: Work Instruction

1-Introduction

The objectives of the work is to demonstrate how to exploit the International Space Station to improve the Space exploration.

2-Methods

2.1 The ISS design for Deep Space

The purpose is to establish a consistent method for making network inside and outside the Deep Space Station close to the Moon at the Langrange point L1/L2. The intent is to promote decision making providing a global view of what can be done in Space. The scope of this white paper is to list the topics for the Space network in the Deep for the futur Gateway Station orbiting around the Moon.

The actions that shall be performed by process participants for each Nations having the capability to provide module service close to IIS Station with Spacecraft additionnal for the Lunar surface. The goals should be the exploration of the ground for the ressources like water, the Helium 3, the new technologies development for the industries on the Earth from the ressources : energy, biomedical, robotics, cyber [1].

The engineer rules for the design Deep Space Station concerns the building of service module for exploration E-M1 and E-M2. The work of the astronauts on board in the Station with the Deep Space Station habitat. The road map which should be taken into account are : the end of service between 2024-2028 linked with some Roskosmos module and the OPSEK, the building the Deep Space Gateway on the Low Orbit in the same IIS process management including the deep space requirements, the building of the Deep Space Gateway, by the docking of service module, on the Lunar Orbit or towards at the Lagrange points, the test the Deep Space Station on the Deep Space Orbit without crew inside, except the sensors or robots, the sending of a mission to check the outside structure of Deep Space Station.

The requirements of Deep Space for a Station orbiting ainclude the new events of lunar environnement : gravitation, radiation storm, dust from solar system, safety and security management far away from Earth. It seems to be the intent location for the DsD will be near rectilinear Halo Orbit (NRHO) in cislunar space. This choice would combine low cost and effective. The point that it should be point out is the deep space requirements for the DsD. The Lunar requirements concerns as much the moon landing as full back to the Gateway Station. Above all, the lunar gravity and the radiation must be supported by human with a long period on the ground. Mission operations can be supported by the current infrastructure with some control center as a relay in Space and forward control center in low orbit around the Earth. This center has the capabilities to communicatte with the Gateway Station to coordonate its operation without the constraints of the atmosphere.

The IIS properties station, in more, there are specific modules linked with the distance with Earth and the contact with the Lunar surface. The magnetic field is the point for the Deep Space Station for the Earth magnetic field protects the Spacecraft against the radiation from the Sun and from the deep space. Unlike the Earth orbit, the Lunar orbit is strongely exposed to these radiations. For example, the astronauts in the IIS Station already sustained the radiations from Space 60 % in more than usually. It means that the astronauts living a long time inside the Deep Space Station should have a local protection. The module magnetic will be proced by multiple couchs : create a local magnetic field thanks to the structure from the Spacecraft, get a new suit using the local electricity from the human body, transmit an artificial field by signal from the Earth orbit . the micro-meteor impact against the station would be avoided if an electromagnetic force surrounds the Spacecraft.

The List of laboratory testing in Deep Space Station shall integrate the components following : high quality fiber optics experience, electric power propulsion, 3D printers testing on Space, 4G netwok testing between the Moon, Gateway Station and the Earth, cyber-cognitive testing with the Earth distance, radioprotection human body, solar power testing to the Earth via the laser, solar power testing to the moon via the laser, lense testing to the moon for energy, vegetables culture in the laboratory, probe detector for the asteroid, observation to the deep space, Magnetism Earth testing [3].

4-Discussion

4.1 The bed test Space Station in Deep Space concept

The Station Deep Space concept defines the capacity to launch and to manage the assets potentially habitable outer the protection of Van Halen belt [2]. At the moment, only probes and robots are in the Deep Space give the test bed of how to design and to protect the materials in Deep Space. The International Station planned to the Moon would be the first step to built a vessel able to move outer the Moon. The Apollon mission gave the lessons learnt to manage it from Earth. On the condition that Mars exploration the second steps for Space countries, the bed tests outer the Moon are needed. The costs to realize the test require a Spacecraft close to the requirements of a vessel.

The Artemis I gives the proof of concept with Orion Module far away from the Moon, further the Apollo missions. The test concerns the crew, the Spacecraft, and the telecommunication. With the end of the International Space Station, instead to push the components on the Earth's atmosphere, the project would be to use the Station as the laboraty to notice through sensors, the effects of the Deep Space on a futur crew on board.
Space resources will be important for both future lunar, and future Mars missions, with the former providing an opportunity to test and develop technologies for the latter. For future crewed Mars missions, space resources can be considered across four categories : Transportation, Agriculture, Habitation, Manufacturing. The Transportation category considers space resources to help both in transportation between planets / orbital bases, such as through the processing of local water for spacecraft fuel, as well as local transport on planets. The Agriculture category encompasses all space resource agricultural activity, for which extensive challenges currently exist, where technological development in plant design and growth facilities is required to ensure that space agriculture can be low-input, low-waste growth and processing. The Habitation category encompasses space resource use for habitation, such as the use of lunar regolith for habitation, and similarly the Manufacturing category considers the role of space resources in all aspects of manufacturing, including local tool development, and the development of pharmaceuticals. The modules useful to be tested shall taken account of these categories. The design thinking should include in more the module existing the engines and the hardening of the materials against the radiations. Before the end of the International Space Station, the recommendations for Deep Space travel could be added inside to test the behaviour of the vessel. Some studies propose the requirements for Mars mission for crew management and the Spacecraft itself. Several topics were proposed as the medical management of the crew in Space : module biohazard, cooling, storage, the follow of the trajectory of spacecraft, the ability to jettison and decompression of vehicle, the pressure suit containment, the injuries.
The second point is the food management to provide enough nutrient for a crew. The primary is to test autonomous life support in deep space postion with camera on board how the system works. To reproduce conditions found on Earth whilst maximizing growing space, a novel solution, increasingly used on Earth, is proposed: vertical farming. This will be our main method of growing crops and farming insects. The benefits of this technique include condensed growth areas, efficient use of resources, and optimization of environmental conditions. The concept integrates two technologies: Rotofarm and the carousel from Urban Crop Solutions.
It will provide crops with an environment that simulates Earth's gravity and the sun's diurnal cycle. The spiral vertical farm consists of a central column, surrounded by light of different intensities. A -like spiral rotates the crops. This simulates normal gravity and directs the plants towards the light. Crop nutrients and water, stored inside the column, are released in a controlled fashion. Two substrates will be used: treated regolith and hydroponic solutions. Mojave Mars stimulant (MMS-1), a substitute for Martian regolith, has been demonstrated to be a good medium to grow lettuce species, when combined with vegetal compost. It can be extrapolated that the same will be true for various other species of plants. Hydroponic growing systems use mineral nutrient solutions to cultivate plants outside of a soil environment. This is typically achieved via Nutrient Film Technique (NFT), composed of a narrow water stream with key nutrients circulating through channels housing the plant roots.
Crop management can be automated using sensors that track important soil properties such as soil gas, moisture, temperature, nutrients, pH, and pollutants. Wireless sensor networks (WSN) that analyze these soil conditions can monitor overall crop health. These sensors can then be connected to local computers, with automation of feedback loop tasks such as humidity and temperature control of various sections of the biodomes. Companies such as Libelium already offer commercial off-theshelf sensors and such smart agriculture system.
bioprinting, a technology used on the ISS, can also provide another source of protein. Bioprinting uses genetically modified cell cultures grown in bioreactors. The end product has properties, such as color, flavor, aroma, texture, and palatability, similar to conventional meat. Cultivated meat is already being produced on Earth, by such companies as Aleph Farms. Cultured meat is currently deficient in some essential elements such as iron and vitamin B12, which will need to be supplemented, for example with biosynthetic microbial fermentation. Adding Yeast cultures such as Yarrowia lipolytic yeast strains can further provide Omega-3 essential fatty acids. Ultimately, the challenge will be to scale everything up to provide all of the above for a group of 100 people
The thrid point is the protection against the radiation. In order to mitigate the effects of the rays, the agricultural laboratory should be added with the capacity to monitor at the distance the cultures. The laboratory shall be enough autonomous to show the workflow of maturation cycle from the plants useful. The secondary effect will be to notice the way to produce the oxygen thanks to the laboratory. And the first study for the Moon shall be used to the International Space Station. The circular workflow could completed a cycle to limit the radiations. Radiation Settlers will be exposed to cosmic radiation, initially during the transport phase to the planet, but also while travelling in Deep Space. Long-term radiation damage to human cells has several disastrous results, such as cancer, organ

damage, bone loss, weakening of the cell structure, arterial thickening, and in extreme cases Deoxyribonucleic acid (DNA) damage. While the primary method of radiation protection is ensured by shielding, consumption of certain foods has been demonstrated to reduce the potential side effects of radiation exposure. The most notable radiation-protective foods are micro-algae and other chlorophyll-containing plants such as chlorella. They can inhibit radiations and the metabolic activation of many carcinogens. Cruciferous vegetables that contain substances called Dithiolthiones and 3,3-diindolylmethane (DIM) have also been shown to have antioxidant and anti-radiation properties, and could also be considered. Fibers play an important role in the prevention of stomach and colon cancers, and have been shown to improve the microbiome, which has an important impact on longevity and health. All of the above shall be incorporated into the settler's diet.

The fourth concerns the energy requirements. Two energy sources will be required: solar and nuclear. NASA estimates that six humans on a 500 days mission on Mars will consume approximately 40 kW of power, which would require approximately 400 tons of solar panels. Current solar panels are operated at 30% efficiency and would therefore not be sufficient. The nuclear technology has already been used in deep space missions, with different Radioisotope Thermoelectric Generators (RTGs). Promising technologies in development are those demonstrated in the NASA 'Kilopower' project, a nuclear fission reactor which could provide 10 kW for 10 years.

The fifth requirement could incorporate crew considering the case of the risk is taken to test the presence of persons in the Deep Space far away from the trajectory known for Spacecraft with people. The training should incorporate more exercises to practice communication equipment failures, navigate misunderstandings, and appreciate different perspectives. This should include elements of pressure and stress similar to what the crew might experience during the mission. This will vary based on mission criteria (e.g., internal/external environment, duration, crew size, workload). Prior to the mission, mindset training should be provided. The crew should then be required to endure a series of mental toughness challenges mapped to the mission criteria.

4.2 The information and communication in Deep Space

Additionally, to improve analog mission objectives and continue the efforts for interplanetary human space flight, methodologies must be put in place to allow the collection of lessons learned to build an effective curriculum [4]. This requirement need to connect a backup payload module able back on Earth.

The test bed for the Deep Space Station needs the information and communication system to follow the behaviour of the station. The Deep Space Network and the GNSS constellation provide the parameters useful to be applied to ensure the communication and the access to the module at distance. For deep space missions, the design requirements of the communication systems must be characterized by optimum intelligence, high data rate, and perfect interconnection in an inter-satellite link (ISL) network or between a spacecraft and point of interest on the lunar or Earth's surfaces. Integrating human factors into the system design of the communication systems ensures secure and effective uplink of commands and downlink of mission data. Considering communications between the Earth and spacecraft, optical communication has proven to be the best technique compared to classical radio frequency bands. Based on optical tests performed by NASA, lunar laser communication demonstration has proven an error-free data upload rate of 20 Mbps and a record-breaking Moon to Earth download rate of 622 Mbps. For communication between the Gateway, spacecraft in lunar orbit, and lunar surface infrastructures, S (2.0/2.2 GHz), K/Ka (23/26GHz) and Ku (37/40) bands networks can be utilized to achieve effective communication. To optimize the spacecraft communication network, it is highly recommended the use of reconfigurable space-grade transceiver models such as software-defined radios (SDR), with high signal sensitivity, scalability, modular design, programmability, and software remote reconfigurability onboard the spacecraft that support evolution over time based on mission requirements and channel conditions [5]. The C&DH subsystem is the brain of the spacecraft responsible for controlling the spacecraft and managing data flows within the spacecraft and data transmitted to or received from other systems. Interaction of humans with the C&DH is very critical as failure to integrate human factors and capabilities may lead to system and mission failure. The electronic procedures developed for Orion efficiently step the crew through planned tasks and reduce crew workload by highlighting various telemetry on a display format or queuing up commands. Astronauts must therefore be highly trained and oriented with all system functionalities so that they will be able to make quick and informed decisions based on displayed data, be it anomalies or faults. Through well-built crew interfaces, the safety of astronauts is guaranteed through monitoring and warning indicators and efficiency and performance.

Conclusion:
The use of ISS in Deep Space should be the first steps to test Space exploration on the Moon and on Mars. The tests will be complet to improve the methodology to extend the human presence in the solar system.

References
Reference to a journal publication:
[1] CYBEX: the cybersecurity information exchange framework (x.1500). Rutkowski, A., Kadobayashi, Y., Furey, I., Rajnovic, D., Martin, R., Takahashi, T., Schultz, C., Reid, G., Schudel, G., Hird, M., Adegbite, S. ACM SIGCOMM Computer Communication Review, Volume 40 Issue 5, 2010.

Reference to a conference/congress paper:
[2] Peter Suedfelda, Phyllis J. Johnsonb , Jelena Brcicc, Personal Values Before and After Long-Duration Spaceflight 73rd International Astronautical Congress (IAC), Paris, France. 18-22 September 2022. Page 1 of 3.
[3] Dana R. Levinac , Jon Stellerad, Arian Andersone , Jay Lemerybe, Ben D. Easterbe, David C. Hilmersbcg , Kris R. Lehnhardtbcf, Enabling Human Space Exploration Missions Through Progressively Earth Independent Medical Operations, 73rd International Astronautical Congress (IAC), Paris, France, 18-22 September 2022.
[4] Matthew Weinzierl. "Space, the Final Economic Frontier". In: *Journal of Economic Perspectives* 32.2 (May 2018), pp. 173–192.

Reference to a website:
[5] ETSI. *ETSI TS 102 606 V1.1.1 Digital Video Broadcasting (DVB); Generic Stream Encapsulation (GSE); Part 1: Protocol*. DVB BlueBook. Dec. 2013. url: https://www.dvb.org/resources/public/standards/a116 1_gse_specification.pdf.