SpaceOps-2023, ID # 110

THE BACK UP PAYLOAD TO THE MOON MISSIONS : THE DESIGN AND THE REQUIREMENTS OF RAMS ARCHITECTURE

Jamel Metmati

[a] *Department of Cyber:* djamel.metmati@thalesgroup.com

Abstract

The missions to the Moon and the LunaNet networks requires back up procedures for crew in Space with payload ready to go rendez-vous to the issue between Earth and the Moon. The design of the payload should include a rocket on back up at each times a launch is done. The purpose is to get a specific spacecraft which would be able to carry logistics with docking. Second, the spacecraft shall be able to transport astronauts with enough power to go on Earth for the reentry or to dock with the Space station on Earth orbit. Third, the spacecraft shall be able to transport the components for Lunar Gateway. The design of the solution can be unique on one spacecraft with all the functions for the back up and the transportation. Then, the operational concept can be divided in several subsystem with specific embedded module link with the purpose of the missions. The goal being to be fast in case of problem as to be flexible to plan a routine mission in Space. The requirements of this design need to combine the facilities of several compagnies from several launching site. The building of new Space port should provide the capacities of back up spacecraft and the right timing to support any issues of the missions in Space. And the safety management will give the final assets of the architecture of the back up system.

Keywords : RAMs, Moon, LunaNet, payload

1-Introduction

The objectives of this work is to present the need to plan backup module to ensure the continuity of the missions on the Moon.

2-Methods

2.1-Lunar route from Space port

The feasibility studies exist which describe different combinations of mission types, mission architectures, spacecraft architectures and propulsion types to get to the Moon[1]. These choices are based on the science requirements, launch vehicle capability, launch date and the launch sites. To find the possible payload(s) deliverable for a lunar mission [2], this study :

- Identifies mission architectures of interest
- Identifies mission constraints from a launch from the UK and associated assumptions
- Assesses a sample of the architectures through first principles to broadly understand capabilities
- Refines and validates these results using ASTOS as a case study to identify the payload options
- Given these results, discusses the types of payloads that could be delivered to the Moon taken account the example from the UK.

The lunar mission types that could be considered are: a lunar flyby, a lunar orbiter, or a mission to the lunar surface. Each of the mission types could be achieved with different architecture and propulsion options. A spacecraft could be placed around the Moon choosing one of the two different mission architecture types: direct trans-lunar injection from launch, or through delivery to an intermediate parking orbit around Earth.
The two options considered in the analysis were:
1) launch vehicle upper stage performing the trans-lunar injection burn,
2) a separate propulsion module to perform the trans-lunar injection burn and lunar capture/circularisation. In the instance of a separate propulsion module, several propulsion types could be considered, including chemical, ionic, electrical propulsion depending on the mission constraints.
The first principles to assess initial feasibility of a lunar mission launched from a high latitude launch site, several aspects of the mission design should be assessed using geometry and orbital mechanics.

3-Discussion

3.1 UK example

Access to space from the UK is a key objective in the UK's National Space Strategy. Several spaceports have been proposed and are being developed throughout the UK which will enable orbital launch from the UK.

The UK is becoming a major player in the European small satellite launch market by 2030, primarily serving high-inclination orbits. Capability beyond LEO, for example to the Moon, could be foreseeable as an additional mission offering from the UK.

The analysis suggests that the direct insertion using the LV upper stage from the UK sites is inefficient and would lead to very low/negligible payload mass, ~20 kg including propellant. In further analysis a coasting arc should be considered – given the results in, performing the TLI manoeuvre at an appropriate declination reduces the flight path angle required and thus increases the efficiency of the orbit raising manoeuvre – minimising the delta-V, the propellant requirements and thus increasing the maximum possible payload mass.

A LEO parking orbit of ~250 km around the Earth, followed by a TLI manoeuvre to achieve a lunar orbit, delivering payload of 150 – 170 kg around a lunar orbit of 1000 km. This could be considered a feasible payload mass for a lunar mission – for example, the CAPSTONE mission is a lunar mission flying a 12U CubeSat weighing around 25 kg into a novel orbit around the Moon. Depending on the target orbit, a specified amount of propellant for AOCS should also be carried, reducing the payload mass slightly – further analysis should also take this into account. Some indicative station-keeping delta-V requirements for certain target orbits are discussed in.

The second mission type considered is a lunar flyby which is a less attractive option to perform science as it would limit the time that a spacecraft would spend around the Moon, but an option that may be plausible considering the constraints around the high altitude launch sites and the available launch vehicle capabilities.

In this scenario, the direct insertion would also be an option for smaller satellites (i.e., CubeSats). The parking orbit option considered above. One of the benefits of the flyby, if designed to have a free return to Earth, is that the data could be transmitted back to ground closer to Earth, mitigating communication constraints especially with small satellites.

The third mission type, lander is optimistic with the constraints discussed earlier and therefore has been eliminated from this study. However, the option is highlighted as it has the highest capacity to yield lunar science and exploration, as well as provide support to international programmes such as Artemis. If launch vehicle capabilities are increased in the future, or there is UK access to a different launch site (lower latitude/equatorial), this may become a more feasible

3.2-The RAMS architecture

LunaNet is defined as a telecommunications network capable of supporting human exploration and scientific missions to the Moon [3]. The first building blocks of the telecommunications system will be nodes for lunar deployment and the first permanent installations. The features of this network combine a set of interoperable systems with government and commercial partners. And the aim of the system is to support the Artemis III, Artemis IV and commercial missions involved in the IOC and EOC phase.

The structure of the LunaNet network is a first in human space exploration as it lays the foundation for interplanetary communications for the presence of human civilisation outside Earth. The LunaNet design encompasses all systems providing time, navigation, and communications services to users around the Moon and to Earth. In other words, the network equipment will be located both in lunar orbit and on the surface of the Moon. For the lunar segment, a specific chain is envisaged for which an interface could be implemented to the ground segments of the Earth.

A relay system between the two segments is being studied in which the exchane cinfiguration would be based on a private link. To establish the link between the two segments, the LunaNet will be built through a combination of LunaNet access providers who will themselves be service providers. The interfaces between the segments can be divided into several categories. The first includes the physical interfaces and protocols between a user and a provider. The second concerns the interfaces between different access providers.

The declination of interfaces is then divided into a series of connections involving typologies of interfaces: linkage between the lunar and terrestrial system, linkage between lunar surface users, linkage between surface users and those in lunar and terrestrial orbit, linkage between service providers according to linkage use cases. Permanent data transmission is achieved through a communication in space and a link from the lunar ground. Users will be able to establish communications through these two channels according to known standards and protocols. Thus, the

Internet protocol could join the Bundle protocol in the Consultative Committee on Space Data Standards, the Advanced Orbiting Systems, and the IETF.

This Space Internet is based on three space telecommunication characteristics: real time, time shifting, and service messages. The applications supporting this transmission chain are related to alerts, position navigation times and service acquisition. Thus, the LunaSAR service corresponds to the Search and Rescue signal of the navigation satellite constellations in Earth orbit. This service offers the ability to monitor the distress signal from any equipment and infrastructure on the Moon. Other services include space weather monitoring and the use of optical and radio links for measurement missions from Earth.

Together this creates an inter-planetary architecture in which Earth-Moon telecommunication use X, Ka, or optical bands to connect to relay nodes inlunar orbit. These nodes, connected to each other with a complementary band[5] communicate with spacecraft in lunar orbit and entities on the surface of the Moon. The existing ground stations will transmit and receive the lunar signal from the constellation of navigation satellites. This means that terrestrial infrastructures will have to be able to supervise and monitor the state of the network by taking into account new parameters. These include the ability to manage integrated architectures with different systems and protocols, to understand the effect of the space environment on signal processing, to ensure signal availability within acceptable performance times for crews in orbit and on the lunar surface.

The design of the networks to the Moon out from radio communication as known in the Apollo Mission supports the future activities on its surface. The primary topics could be " to perform field geology with humans and robots at sites across the Moon, to find and retrieve samples and return them to Earth, to deploy and operate a global network of geophysical stations, to deploy and operate a global network of space weather stations, to measure biological and physiological effects of the lunar environment, to prepare, build and operate an international astrophysical observatory on the lunar far side, to search for potential resources and characterise their properties, demonstrating production of oxygen, metals and other products from local resources and eventually using them". It shall added the capacity to ensure the communication test beds on the Moon surface and the building of small modules to be able to stay couples of days with the use of solar panel on the surface. The design of the networks should provide the way to send and to receive data from Earth. The datasets shall be useful for the primary components on the Moon surface. Moreover, it will give the support to monitor on remote the assets in case of failure or damage. The last point is also the means to provide a backup communication solution to ensure the safety and the security of the missions. Others purpose could be useful thanks to the design of these networks. The antena field with the architecture is a potential tool of detection against the astroid detection. The quantum antena being the capacity to detect the electromagntic field of the Earth should be able to record the unexpected particles move in the vacuum. The overview of the design can be illustrated by th Lunar Pathfinder. It will be launched by NASA in 2024, using the Commercial Lunar Payload Service (CLPS) programme. With a store and forward architecture, a proximity link allowing for two simultaneous links with lunar missions in S-band and UHF, and backup link to Earth in X-band, a data-relay satellite will be able to solve both direct line of sight and performance limitation due to distance between the Earth and the Moon. In addition, an ESA GNSS receiver capable of detecting weak signals coming from the Earth GNSS infrastructure (GPS and Galileo) will be hosted onboard Lunar Pathfinder, demonstrating GNSS's potential role in Lunar navigation and other services like Search on Rescue.

3.3 Manage the distance

According to the Moon's environment and the features of installation, the applicability of RAMs methodology for people and materials shall take account the requirement of the distances. The feed back of the operational mission will be useful for the RAMs model to the Moon. And the infrastructure already existing could be completed by first with the information and communication system able to make data transfer with high speed to be near to the real-time and to manage the anomalies at the distance. The term anomaly refers to unintended or off-nominal function of vehicle systems with consequences that can range from benign to life-threatening. Anomalies that require urgent response are those that affect critical subsystems, deplete essential resources, and/or involve uncertainty, meaning there is no set procedure in place for response, causal analysis is required, and short-times-to-effect for unwanted consequences are possible

The NASA Mission Control Center (MCC) manages the combined state of the mission, vehicle, and crew. MCC staff monitor and analyze mission data, identify trends of concern, diagnose and respond to vehicle anomalies, and oversee effective execution of actions [4]. The ISS over the past few years, showing an average of 1.7 vehicle anomalies per year requiring urgent attention and diagnosis. Even with the best engineering processes in place, vehicle anomalies will continue to occur throughout the duration of a mission [5]. In the Moon context, the hardware software interaction analysis should be managed through the long-duration missions taken account several assets in Space. To consider the Earth-independent, the Moon's mission shall integrate in the RAMs framework the artificial intelligence to support the crew in data visualization for the systems and the equipments. As they must act with a safety model, it considers to anticipate the behaviour expected in terms of data. The equipments can be advanced sensors, sensor fusion for diagnosis and repair robots at the distance for the software components. And the advanced maintainability standards concepts which could be applied for routine operations and conditions requiring critical repairs. The predictibility of the operations become the key parameters for the RAMs life on the Moon missions [6]. In each component of the system and the sub-system, the simulation provide the level of functionalities with the data expected for the operations planned. The same approach is applicable for the crew. In the relationship with the HSIA, the model expected shows the bricks to aid the crews to understand the context, the errors, the failures, the anomalies. The point is to maintain the network link in Space with the different ground to provide data for the management of the system. The RAMs approach should also considered to be completed by the C-SOC to operate the security and the safety of these data.

3- Conclusion:

The back up payload to the Moon missions is linked with the space exploration. The Chang'e and the Artemis missions demonstrate the need to support the highway to the Moon. It takes the introduction of the backup payload ready to go on orbit from Space port on Earth.

References

Reference to a journal publication:

[1] Doggett, William et al. "Architecture Options for Creation of a Persistent Platform Orbital Testbed," AIAA 2020-4130. ASCEND 2020. November 2020

[2] Kutter, Bernard F. and Sowers, George F. "Cislunar1000: Transportation supporting a self-sustaining Space Economy," AIAA 2016-5491. AIAA SPACE 2016. September 2016.

Reference to a conference/congress paper:

[3] M.F. Montaruli, G. Purpura, R. Cipollone, A. De Vittori, L. Facchini, P. Di Lizia, M. Massari, M. Peroni, A. Panico, A. Cecchini, M. Rigamonti, A software suite for orbit determination in Space Surveillance and Tracking applications, 9th European Conference for Aeronautics and Aerospace Sciences (EUCASS) proceedings, Lille, France, June 2022

[4] Lidtke, Aleksander A., et al. "Processing two-line element sets to facilitate re-entry prediction of spent rocket bodies from geostationary transfer orbit." 6th International Conference on Astrodynamics Tools and Techniques. 2016.

Reference to a book:

[5] External Payloads Proposer's Guide to the International Space Station, NASA SSP 51071 Baseline
Commercial Orbital Transportation Services: A New Era in Spaceflight, NASA/SP-2014-617
Kutter, Bernard F. and Sowers, George F. "Cislunar1000: Transportation supporting a self-sustaining Space Economy," AIAA 2016-5491. AIAA SPACE 2016. September 2016.

Reference to a website:

[6] NASA website, August 4, 2022, "Commercial Destinations in Low Earth Orbit (LEO),
URL: https://www.nasa.gov/leo-economy/commercialdestinations-in-low-earth-orbit, (accessed 17.08.22).