IAF SPACE EXPLORATION SYMPOSIUM (A3)
Moon Exploration – Part 3 (2C)

Author: Mr. Nick Gollins
European Space Agency (ESA-ESTEC), The Netherlands, nick.gollins@esa.int

Dr. Markus Landgraf
European Space Agency (ESA), The Netherlands, Markus.Landgraf@esa.int

MAXIMISING "RISK VERSUS REWARD" IN LUNAR EXPLORATION MISSION PLANNING

Abstract

The international roadmap of lunar exploration is currently developing at a rapid rate, with a wide variety of missions being planned by space agencies across the world. These include small commercial landers, sample return missions, and the fast-tracked "boots on the ground" Artemis programme of NASA. The end-goal of the roadmap is clear, with a view to increase the sustainability of lunar exploration and increase the frequency and duration of both robotic and crewed missions in preparation for future Mars exploration. As such, over the coming decades, the scale of lunar missions will vary greatly. Due to a low ratio between the payload mass-to-surface and the equivalent mass-to-LEO of lunar missions, a topic of debate during the planning of missions of any scale is the optimisation of the mission architecture. The lower complexity missions with fewer vehicles and systems involved produce inefficient delivery of mass to the Moon's surface. Adding complexity in the form of additional transfer stages and/or interactions with other systems can improve the reward, at the cost of added mission risk. Furthermore, making mission elements reusable can drive down mission costs, and thus improving efficiency, due to the need for fewer hardware developments and launches. However, a reusable mission element will experience many mission-critical operations during its lifetime and is therefore subject to the same risk-to-reward trade-offs.

Firstly, by considering a number of example mission scenarios, this paper presents a method to assess different architectures based on their payload delivery capabilities ("reward") and the risks involved in the operation of such architectures. This assessment is carried out by identifying a description of the mission payload capability as a function of operational risk. Secondly, the results of this method will be examined across a range of mission scales with the objective to provide an assessment of the optimal mission architecture as a function of mission scale. Finally, in the case of missions incorporating reusability, the evolution of the assessment versus system lifetime will also be investigated.

In light of previous internal work, this paper quantitatively demonstrates the opinion that the diminishing returns of utilising more than one transfer stage between high (specifically near-rectilinear halo orbit) and low lunar orbit do not justify the additional introduced complexity. It also shows how the effectiveness of reusable mission elements evolves with the intended lifetime of the systems.