DRAPER®

Version 1.0

Artemis-7

Payload Users Guide

Introduction

This Payload Users Guide (PUG) provides an overview of the currently planned Artemis-7 missions and the resources that the Artemis-7 lander provides to integrated payloads for those missions.

Additionally, the PUG provides a description for how the payload providers will work with the Artemis-7 lander team integrating and operating each payload.

Definitions

Organizational

The Payload Provider will primarily interface with the Lander team through the following personnel.

Payload Systems Engineer. The main technical point of contact for the payload providers will be the Payload Systems Engineer (PSE). The PSE will work with the payload provider to generate all documentation required to interface the Payload with the Lander. The PSE also will support all Payload/Lander reviews, including the PSR and TRR. Additionally, the PSE will support any requested participation or attendance in the Payload design reviews.

Mission Assurance Manager. For the CLPS program, the Mission Assurance Manager (MAM) will define all mission assurance requirements for the lander and ensure those requirements are properly flowed down to all partners and suppliers. The MAM will identify any of these mission assurance requirements that are also applicable to the payload and will document those in the Payload Requirements Document.

Mission Systems Engineer. The Mission Systems Engineer (MSE) oversees all systems engineering activities for an Artemis-7 mission. All PSEs report to the MSE, and the MSE ensures that there are no operational conflicts among the payloads.

Program Manager. A Program Manager (PM) is assigned to each Artemis-7 mission and oversees the work done by the MAM and the MSE. The PM is also responsible for contracts, integrated schedule management, and other programmatic and business functions.

Documentation

The following documents will be generated for each payload by the Artemis-7 lander team. Any additional documentation required to be delivered by the Artemis-7 lander team or the payload provider will be assessed on a payload-by-payload basis.

Payload Integration Assessment Report. An initial payload integration assessment provides a preliminary assessment of compliance of a payload with the Artemis-7 lander and an identification of any gaps to be addressed. This assessment is used as an input to the creation of the *Payload Management Plan*.

Payload Requirements Document. Payload requirements will be derived from the Artemis-7 lander requirements and will define all requirements for the payload, including mission assurance and environmental test requirements as well as all necessary analyses required to be completed by the payload provider(s).

Payload-to-Lander Interface Control Document. Clear documentation of the interfaces is achieved during the early part of the program to ensure that the Artemis-7 team (the host) and the payload teams have a common understanding, supporting correct integration and function of the payloads when integrated to the lander. The *Payload-to-Lander Interface Control Document* will define the environmental, mechanical, Field of View (FoV), thermal, and electrical interfaces between the lander and the payload. At no time shall any test, functional or environmental, expose the payload to environments, signals, or other conditions that exceed the limits specified in the interface control documents. This ICD will also define data formats for passing data and commands between the lander and payload. Operational interfaces and conops details for each payload will be captured in the *Payload Operations Plan.*

Payload Operations Plan. The *Payload Operations Plan* will define the concept of operations of the payload and the operations interfaces with the lander. The *Payload Operations Plan* also will define the interface between the payload provider and payload operations, including the definition for how payload operations will receive command requests, how data will be distributed to the Payload Provider, and any data security needs.

Payload Management Plan. *The Payload Management Plan* (PMP) will define all the activities that will occur to support the integration of the payload with the Artemis-7 lander. This includes any necessary payload design reviews and required attendance by the PSE, regularly scheduled programmatic or technical interchange meetings, and any additional design documentation from the payload provider(s) required by the Artemis-7 team.

Payload Integration & Test Procedures. Prior to delivery of the payload to the Artemis-7 team, the I&T team, in conjunction with the payload teams, develop the required integration and test procedures for each payload. The Artemis-7 team manages and maintains these I&T procedures. They give the detailed step-by-step procedures for integration and test activities that involve the payload hardware, including a description of the activity or test objective, the required equipment and personnel, environmental conditions for the activity or test, and any steps to ensure equipment and personnel safety.

Reviews

The Lander reviews that the Payload Providers are expected to support are listed below. Additional design review support will be defined for each Payload and detailed in the Payload Management Plan.

Payload Pre-Ship Review (PSR). The Pre-Ship Review (PSR) will occur prior to the delivery of the payload for integration with the Artemis-7 lander. The payload provider will demonstrate compliance of the payload to the *Payload to Lander ICD Document* and the *Payload Requirements Document*. Additionally, the *Payload Integration & Test Procedures Document* also will be assessed for sufficient maturity in order to minimize the time from payload delivery to the start of payload integration.

Payload Pre-Integration Review. The Payload Pre-Integration Review (PIR) will occur prior to the integration of the payload with the Artemis-7 lander. The PIR will verify that all documentation, facilities, hardware, and personnel that are required for integration are available and ready to support Payload integration activities. The PSE can represent the payload provider at this review, and payload providers can attend if desired or required by the *Payload Management Plan*.

Payload Post Integration Review (PoIR). The Payload Post Integration Review (PoIR) will occur following the integration of the payload with the Artemis-7 lander. The PoIR will verify the results of the payload acceptance and payload integration activities and that all required integration and test procedures are completed and results reviewed. Any anomalies and discrepancies encountered during the integration and tests will also be reviewed.

Test Readiness Review (TRR). A Test Readiness Review (TRR) will be conducted following the completion of all Payload integration activities and just prior to Integrated Environmental Testing. The TRR will review the configuration of the integrated Artemis-7 Lander under test and verify that the test facility, personnel, and test procedures are ready to execute testing activities.

Operational Readiness Review (ORR). An Operational Readiness Review (ORR) will be conducted following the completion of Integrated Environmental Testing. This review will confirm that all procedures for operating the Artemis-7 Lander and the integrated Payloads, along with all ground support hardware and software, personnel, and documentation, are available and ready.

Flight Readiness Review (FRR). The Flight Readiness Review (FRR) will be conducted to verify the lander is ready for launch campaign and flight. This review will confirm that all tests have been completed, the lander system (ground and space segment) has passed all tests, all the results have been reviewed and accepted, all anomalies have been resolved, procedures required at the launch site are in place, all the support and test equipment required at the launch site is available and ready for shipping, and the required shipping and any export documentation and clearances are in place.

AM-1 Mission Architecture

The Artemis-7 mission is summarized in Figure 1 and is broken into 7 major events, for a total flight duration of two to six weeks, depending on the lunar phase at launch. Artemis-7 uses a spacecraft that is propelled by a combination of bipropellant propulsion for orbital and landing maneuvers, and powered by solar energy for instruments and customer payload operations.

In flight, Artemis-7 will be operated real-time and with time-tagged commands from the ground to execute certain maneuvers and functions; in situations where real-time/manual commanding is not possible or necessary, the spacecraft will be autonomously operated.

Event	Nominal Timeline *(Days)*
Launch	L+0
Perigee Raising Maneuver	L+4
Trans-Lunar Injection	L+8
Trajectory Correction Maneuver	L+9 or L+10
Lunar Orbit Insertion	L+15
Deorbit & Landing	L+(16–42)
Lunar Surface Operation	7–14 days since landing

Launch Orbit	
Apogee	320,000±20,000 km (3σ)
Perigee	200±20 km (3σ)
Inclination	28.5±0.1 deg (3σ)
Period	8 days

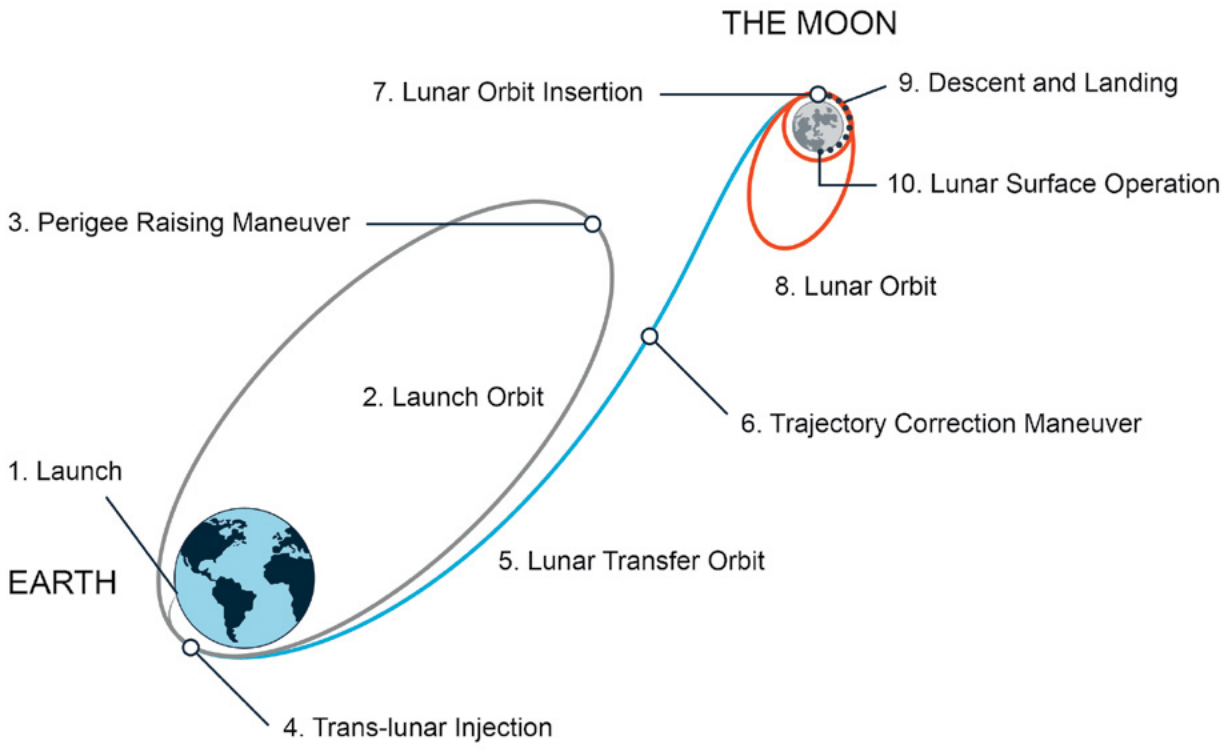

Figure 1 – AM-1 Mission Architecture and Event Table

Mission Overview

LAUNCH

The AM-1 mission will launch on a commercial rideshare opportunity, saving cost as a secondary payload, on a proven launch vehicle. The spacecraft will be separated 32 minutes after launch at an altitude of 200km with launch orbit conditions, shown in Figure 1, resulting in a super-synchronous orbit with a 320,000km apogee altitude.

PERIGEE RAISING & TRANS-LUNAR INJECTION

Starting at separation, Artemis-7 will perform sun pointing attitude control, system checkup, and a small test maneuver to raise perigee and to fix any launch dispersion if necessary. The trans-lunar injection will happen 8 days after launch, followed by a trajectory correction maneuver to target a specific perilune point at lunar arrival.

Artemis-7 approaches the Moon ≈14 days after launch and performs a lunar orbit insertion to put it into a 100×6000km lunar orbit, followed by a subsequent maneuver to circularize it into a 100×100km low-lunar orbit. At the lunar orbiting phase, Artemis-7 begins its observation of the Moon and prepares for the landing sequence.

During cruise, the focus is to maintain a nominal operating state with sufficient resources available for the spacecraft to operate safely. While certain maneuvers require precise timing, no other operation beyond housekeeping is planned.

SITE SELECTION

The Artemis-7 lander is designed to land at any predefined location meeting the following constraints:

(1) No local slopes >15°.

(2) No local hazards (rocks, boulders, etc.) > 30cm high.

(3) No areas without solar illumination during the landing phase.

Our initial mission is currently designed to land at Lacus Mortis (44.96°N, 25.61°E). Future missions are undergoing mission design and site selection and we welcome input.

LANDING, TIMELINE AND APPROACH

Landing operations will be initiated at low lunar orbit to ensure a proper status check before the landing sequence starts. Landing preparations include system check, battery recharge activities, and guidance, navigation and control mode to landing. A final go/no-go ground operational procedure will occur before command uplink to initiate the landing sequence.

The landing sequence starts with the execution of a deorbiting maneuver to reduce the perilune prior to the braking maneuver. When in range, the radar and rangefinder sensors provide relative velocities and distance measurements with respect to the lunar surface.

These magnitudes will be introduced into the control function to adjust thruster actuation and guarantee safe touchdown.

The Artemis-7 lander senses an altitude of 3m (± 0.5m) above the surface and commands thrusters off to initiate a controlled free-fall, soft landing that meets the following constraints:

(1) Maximum vertical velocity <2.3 m/s.

(2) Maximum horizontal velocity <0.3 m/s.

(3) Maximum angular rate <2 deg/s about all axes.

Missions may include active precision landing, hazard detection, and avoidance technology developed by Draper. Precision landing can be achieved within 5m, target-relative, or 100m, inertial-relative. Different precision landing requirements may be able to be achieved if needed.

Landed Operations

Once on the surface, the propulsion system passivates to avoid any additional heating related to the lunar surface environment. Connection is then established with the high-gain antenna to prepare for payload operation/deployment. Payload deployment will be commanded from the ground in accordance with mission-specific requirements. Once the payloads are deployed, the lander acts as a data relay and provides onboard storage for larger amounts of data if necessary.

Depending on local sunrise time of the target landing site, Artemis-7 will spend up to 7 hours on battery recharging, then begin surface operations. The surface phase lasts from touchdown to battery depletion after the start of the lunar night. Optionally, the operations team will command the overwriting of all lander memory banks, and trigger a safe reboot if it is determined necessary for safety or security reasons to avoid any further commanding and exploitation of the lander.

Payload Accommodations

Utilities

MASS

The total payload delivery mass to the lunar surface for each mission is defined in Table 1:

Table 1 – Mass

Mission	Total Mass
AM-1	16 kg
AM-2	30 kg

POWER

The total power and battery capacity per operating case for each mission are defined in Table 2 – Power:

Table 2 – Power

Mission	Operating Case	Total Load w/o Payloads	Total System Capacity	Capacity Available for Payloads
		W / Wh		
AM-1	Cruise	227.70 W	359.70 W	132 W
	Maneuver	397.65 W / Max 198.83 Wh	N/A / 545.42 Wh	307.63 Wh
	Low-Lunar Orbit	202.87 W / 161.74 Wh	Min Orbit-Avg 207.39 W / 545.42 Wh	344.72 Wh
	Braking & Landing	Max 764.36 W / 408.56 Wh	N/A / 545.42 Wh	87.89 Wh
	Surface Operations	116.80 W	Avg 219 W, Max 358 W	Avg 102.20 W, Max 241.20 W

The Artemis-7 lander will provide the harness from the lander to the payload. Connectors at the payload should be selected to comply with the connector requirements defined in the Payload Requirements Document. We can support all common power interfaces.

VOLUME

Payloads may be integrated onto the Artemis-7 lander in one or both of the two payload bays, one or both of the two avionics bays, or on the external surface of the lander as seen in Figure 2. When integrating payloads into these volumes, the FoV requirements necessary for each payload will be accommodated.

The figures represent the nominal volumes that payloads may occupy in the respective locations of the Artemis-7 lander. The Artemis-7 team will investigate accommodating any payloads that may exceed these volumes.

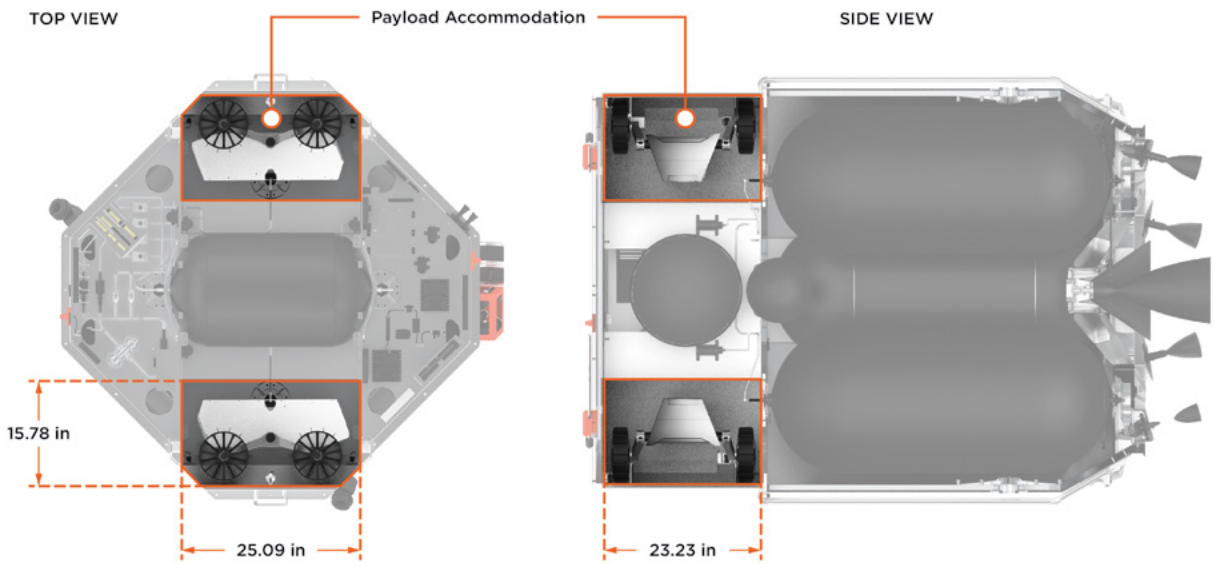

Figure 2 – Artemis-7 Lander Payload accommodations and volume

MECHANICAL INTERFACE AND MOUNTING

The Artemis-7 Lander will provide mounting hardware in the correct orientation and location for each payload that will meet payload FoV requirements in the payload mounting location. Mounting hardware will be custom developed for each payload and will be captured in the Payload ICD. We are happy to work with the payload provider to meet their payload mounting needs.

Fastener hardware and fastener installation will comply with the appropriate requirements defined in the Payload Requirements Document.

COMMUNICATIONS

The total daily data uplink and data downlink capabilities to the Lunar surface for each mission are defined in Table 3 – Communications.

Table 3 – Communications

Mission Phase	Mission Phase	Uplink Bit Rate	Downlink Bit Rate
AM-1	Launch Orbit	2 kbps	2 kbps
	Lunar Transfer	2 kbps	2 kbps
	Moon Surface	2 kbps	1.6 Mbps as Max.

During periods where no communications link can be established with the ground, data transferred to the lander from the payload will be stored onboard the lander for later downlink.

The Artemis-7 lander will provide the harness from the lander to the payload. Connectors at the payload should be selected to comply with the connector requirements defined in the *Payload Requirements Document*. We can support USB, Ethernet and Serial (RS-422 &RS-232) communications.

DATA

A distributed payload interface board will provide data and power interfaces to the payload(s). The board will be configured to provide the appropriate interface(s) and protocols to communicate commands and data with the payload(s). The interface will be defined in the Payload-to-Lander Interface Control Document and Payload Operations Plan documents. Payload data storage is provided primarily in the payload interface board via 4GiB rad-hard, space qualified NAND Flash memory, and additional storage may be co-located with the spacecraft bus telemetry stored in the CDH board. A payload interface application will be developed for each payload module, which will store instrumentation data from the payload for later playback. The payload interface application will provide a timestamp to all payload data using the onboard computer fault-tolerant timekeeping capabilities. This timestamp will have a precision of 15µs and an absolute accuracy of <1s.

Payload Integration Activities

The nominal payload integration schedule described below is outlined in Table 4 and may be tailored for each payload. Detailed definitions of the organizational staff, documentation, and reviews required to support payload integration with the Artemis-7 lander is provided in the Definitions section.

Payload Integration Schedule

An initial assessment for each payload to be integrated with Artemis-7 will be performed at the identification of the integration opportunity between the payload and an Artemis-7 lander mission. A PSE will be assigned to perform this assessment and will continue to work with the payload provider over the life of the program, including payload development, physical integration, launch, and operations.

The output of this initial assessment is the Payload Integration Assessment Report, which will include a preliminary assessment of compliance of the payload with the Artemis-7 lander interfaces and will identify and document all of the gaps to be addressed. The PSE also will develop the Payload Management Plan, which will identify all necessary payload design reviews, regular meetings with the payload provider, and any additional documentation to be provided by the payload provider during mission development. The PSE will work with the payload provider to develop the Payload to Lander Interface Control Document and the Payload Operations Plan as described above. The PSE will work with the Artemis-7 lander MSE and MAM to develop the Payload Requirements Document, which will capture all payload requirements derived from the lander requirements documentation.

If multiple payloads are being hosted on a single Atemis-7 lander, the MSE will coordinate with the PSE(s) to ensure there are sufficient resources for operations of all payloads and that there are no resource utilization or interface conflicts among the payloads.

Prior to delivery of the payload for integration, the payload provider is expected to have completed a Pre-Ship Review (PSR). The PSR will demonstrate payload compliance with the Payload to Lander Interface Control Document, as well as the requirements in the Payload Requirements Document. The Payload Integration & Test Procedures Document developed by the Artemis-7 PSE also will be reviewed at this time. In order to support early payload data integration to Artemis-7 lander's data interface, an emulator will be provided to each payload provider for data interface development and test. This activity will be supported by the PSE and is expected to take place prior to PSR.

All payloads will be delivered to the lander integration facility for integration into the Artemis-7 lander. Prior to integration, a Payload Pre Integration Review will be held for each payload, which is followed by a Post Integration Review after all activities for an individual payload are complete. Following the integration of all payloads on the Artemis-7 lander, a Test Readiness Review will be conducted prior to integrated environmental testing. All environmental testing of the lander will be performed at a partner facility and overseen by the Artemis-7 team.

Prior to delivery for launch vehicle integration, an Operational Readiness Review will occur that will include all the relevant payload providers. Following the ORR and prior to delivery for launch vehicle integration, end-to-end testing will be conducted that will include the Payload Provider operations assets.

For activities following the delivery of the Artemis-7 Lander for Launch Vehicle integration, the payload provider's role in the Flight Readiness Review (FRR) will be defined in the Payload Management Plan.

Table 4 – Payload Integration Schedule

Integration Activity	Activity Timeline
Payload Integration Assessment Report	Initial identification of integration opportunity
Payload Management Plan	Defined at the initial payload integration assessment
Payload Requirements Document	Defined at the initial payload integration assessment
Payload-to-Lander Interface Control Document	Defined at the initial payload integration assessment
Payload Operations Plan	Defined at the initial payload integration assessment
Payload Pre-Ship Review	Prior to delivery for integration
Payload Integration & Test Procedures Document	Payload Pre-Ship Review
Payload Delivery	At least 1 month prior to integrated environmental testing
Payload Pre-Integration Review	At Payload Delivery
Payload integration Start	At least 1 month prior to integrated environmental testing
Test Readiness Review	Completion of integration activities
Start Integrated Environmental Testing	Completion of TRR, at least 2 months prior to delivery to launch site
Operation Readiness Review	Completion of Integrated Environmental Testing, within 1 month of delivery to launch site
End-to-End Testing	Within 1 month of delivery to launch site
Flight Readiness Review	Prior to delivery to launch site

Payload Operations

The Payload Operations Center (POC), see Figure 3 – Payload Operations, will provide all payload operations services for all payloads. Payload providers will provide commands to the POC, which then interfaces with the Lander Mission Operations Center to coordinate all payload commanding and payload data distribution. Additionally, the Artemis-7 team can perform payload operations as a service and simply distribute payload data to the payload provider. All interfaces between the payload provider and the POC will be captured in the *Payload Operations Plan* which also will define all operational constraints between the payload and the lander. As part of planning for payload integration with Artemis-7, the data security requirements for each payload will be defined and operations tailored in order to meet those requirements. The POC will be capable of handling unique payload encryption needs for payload operations on Artemis-7.

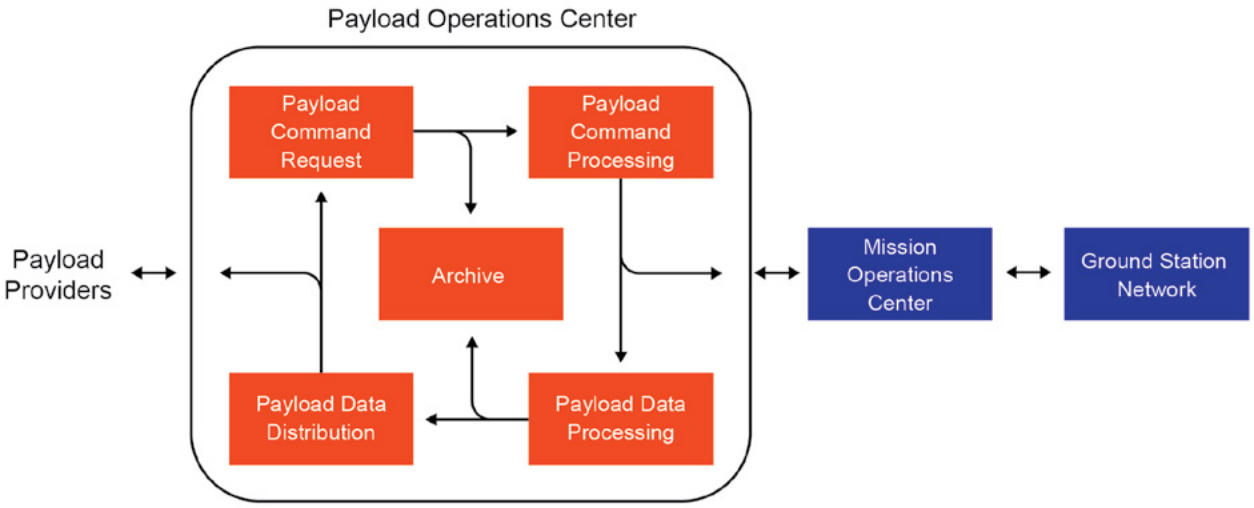

Figure 3 – Payload Operations

Partners

Commercial Lunar Payload Services (CLPS) Team

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GENERAL ATOMICS

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