User’s Guide for
NASA Commercial Lunar Payload Services (CLPS)
Deep Space Systems Small Lunar Lander

This document is consistent with NASA Request for Proposal (RFP), Solicitation No. 80HQTR18R0011R, Commercial Lunar Payload Services (CLPS).

This User’s Guide reflects our best estimates as of the date it is published.

Note that DSS has also proposed a Medium Class Lander with and without a Mobility option. There is a separate User’s Guide for the Medium Class Lander.

Please go to the Deep Space Systems website for the latest versions of the CLPS User’s Guides: https://www.deepspaceystems.com/

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Deep Space Systems Small Lunar Lander
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REVISION HISTORY

A revision history will be provided in future releases. This is the initial release of the DSS CLPS Small Lunar Lander User’s Guide, therefore there is no revision history.

1.0 Introduction

1.1 User’s Guide Description

The DSS Small Lunar was designed specifically in response to NASA Request for Proposal (RFP), Solicitation No. 80HQTR18R0011R, Commercial Lunar Payload Services (CLPS), to Commercial Lunar Payload Services Task Order #2 Request for Task Plan – Lunar Surface Transportation.

Designed to cost-effectively accommodate a multitude of small payloads, our single stage, monopropellant SLL is sized for launch as a secondary payload on an ESPA ring, maximizing launch opportunities and minimizing cost. In response to the CLPS Task Order 2 RFTP and similar future RFTPs, DSS is offering a baseline mission and system capability that supports NASA-defined payloads including a NASA Laser Reflector as well as commercial payloads. The DSS Lander is shown in Figure 1-1 with a suited astronaut for scale.

Figure 1-1 DSS Small Lunar Lander
1.1.1 Commercial Delivery Services

DSS offers commercial lunar payload delivery services featuring pole to pole global access and platform avionics and power systems that survive lunar night via hibernation mode. The DSS Small Lunar Lander does NOT include the option for a 4 wheel drive, 4 wheel steering mobility package or rotary percussive drill with sample acquisition, these capabilities are found exclusively on the DSS CLPS Medium Class Lander (for more information please see https://www.deepspacesystems.com).

Pricing for commercial payload delivery for the DSS CLPS Small Lunar Lander (SLL) services depends on factors including:

- Landing location (compatibility with other payloads)
- Payload mass, volume, power and data resource consumption
- Integration and accommodation complexity
- Operational complexity

For instance, the NASA Laser Reflector is a small, lightweight, passive payload that requires no electrical interfaces, thermal control, data or operations. It is simply a target for orbital and Earth based lasers. Cremains and mementos are examples of simple and relatively inexpensive payloads. In contrast, an instrument that has complex modes of operation, deployments, requires extensive ground testing, special accommodations such as cruise and surface thermal control, and data intensive command and telemetry interaction will be more expensive. A deployable rover using 802.11n relay communications would be an example of a more complex and expensive commercial payload.

Dedicated commercial missions, with no NASA Government payloads, are possible if a full commercial payload manifest can be realized. Otherwise, NASA furnished payloads will have priority and will govern landing site selection. A complete dedicated SLL mission to the site of your choosing, with your supplied payload(s), ordered by the end of 2020, for launch prior to Dec 2023, can be purchased for a firm fixed price.

Commercial Delivery Services pricing for individual payload delivery or other DSS products or services is available upon request.

1.1.2 Government Delivery Services

The Commercial Lunar Payload Services (CLPS) program is managed by the NASA Johnson Space Center for NASA’s Science Mission Directorate (SMD). NASA payloads are also expected to include Technology Demonstration Payloads wholly or partly funded by the NASA Space Technology Mission Directorate (STMD), and Human Exploration precursor payloads funded by the NASA Human Exploration and Operations Mission Directorate (HEOMD). For missions with NASA payloads, the NASA furnished payloads will have priority over commercial payloads in terms of landing site selection and SLL resources and services.
1.1.3 Payload Development Services

Deep Space Systems will design, develop, test, integrate and/or operate your payload if desired. Our team is very experienced with high performance sensor, data, and mechanical systems, and will design, build, test and integrate your payload if desired.

Payload Development Services pricing is available upon request.

1.1.4 Mission Data Products and Services

The Deep Space Systems Small Lunar Lander standard equipment includes an Ultra High Definition, Binocular, VR360 Camera System that includes 2 DSS WRA50X cameras and 5 DSS WLA 50x cameras.

This high-performance camera system is capable of taking 12 megapixel still frame images (WRA50X), including continuous time lapse images throughout flight or 4K video at 30 frames per second (fps). Two of the WLA50X cameras have fish eye lenses and opposite mounting locations providing Virtual Reality (VR), time lapse or single frame imaging, or 4K/30 fps video or 1080P/120 fps video (slow motion video).

DSS will be collecting time-lapse, binocular, VR 360, high resolution imagery and video products throughout flight and surface operations. Simulations of these image products can be provided upon request. DSS is open to adding additional cameras or generating custom data products to suit customer needs.

High resolution imaging from our two 5 megapixel global shutter WRA50X optical navigation cameras will also be recorded and will be available for downlink.

Mission Data Products and Services pricing is available upon request.

1.2 Payload Integration Overview

The Small Lunar Lander (SLL) payload integration plan starts with the development of all interface requirements. These include mounting, workspace, physical volume, fields of view, mass, stability, optical properties, electrical, software, command & telemetry, data rate, data volume, channelization, application IDs, downlink budgets, power profiles, operational sequences, protocol, autonomy, contingencies, safe mode interfaces, dependencies, modes, states, time synchronization, valid state transitions, contamination control, thermal management approach and space environments.

In addition to these standard interface requirements, most payloads have unique interface requirements such as limited life items. We will identify and refine these requirements early in the development process through face-to-face Technical Interchange Meetings (TIMs) with the payload teams very early in the development process. We will work with each payload provider to ensure their documentation and analysis fully supports the process of defining, baselining, and controlling these interface requirements in Interface Control Documents (ICDs). This information can be provided to DSS through payload specifications, drawings, analyses, design definition documents, test results and verification reports.
An overview of major schedule milestones is provided in Table 1-1. Note that MSP stands for Mission, System and Payload and that certain Internal Design Reviews include Payload integration topics.

DSS understands that payloads can vary dramatically in terms of complexity, cost and risk posture. Therefore the number and content of required Payload documentation products, the scope of the Payload Interface Document, and the level of formality in the Payload Contract and Internal and External Reviews will be tailored to be appropriate to the Payload type and the Payload Customer.

Early draft iterations of the ICDs are shared with the payload providers through virtual collaborative team rooms. Formal draft ICDs will be made available and summaries presented at the Payload Integration Plan Review (P/L IPR). Final ICDs are released and made available at the Payload Integration Readiness Review (P/L IRR) and Internal Design Review-3 (IDR-3).

Because payload accommodation is more than interface definition, we have established a dedicated payload accommodation team whose primary role throughout mission development and execution will be to ensure a successful mission. The team’s objective is to drive out payload specific interface requirements that may not be common to other payloads. We accomplish this through open and continuous communication with payload teams throughout the mission life cycle, using TIMs, collaborative team rooms, and less formal phone calls and emails. This process also captures the level of sensitivity of specific requirements. Thermal stability, for example, is a typical requirement, but is far more important for a thermal spectrometer.

The verification and validation of payload integration with the complete flight system is accomplished through a series of risk reduction events. These include document reviews, a traveling Payload Suitcase, real-time hardware-in-the-loop simulation (FlatSat), faster-than-real-time software-in-the-loop simulation (SoftSim), functional and performance testing, integrated payload testing, and many rounds of mission/system testing on the spacecraft.

The DSS Payload Suitcase tester performs early validation of avionics, software and firmware compatibility between the spacecraft and payloads. This test suite is a full FSW-in-the-loop simulation of the spacecraft with enough Command and Data Handling (C&DH) interfaces and Electrical Power (EPS) interfaces to accommodate any given payload. It is portable by design, allowing it to travel to each of the payload provider’s facilities to validate interfaces in their labs and specific test environments early in the development process. DSS provides flight/ground payload command and data interface and data management HW and SW for payloads. SW encryption will be employed to ensure that recorded and transmitted data is secure and that commands cannot be ghosted.

DSS maintains 3D CAD models and visualizations of spacecraft and payloads systems and static envelopes including fields of view, fields of regard, keep out zones, and any dynamic envelopes such as cover deployment, articulation, separation, etc. These models document thermal and optical fields of view, dynamic or time dependent
envelopes, potential interferences, predicted clearances, and margins. The models are not only integral to the payload integration process, but also critical in support of mission operations.

DSS has the engineering analysis tools, expertise, and experience to support payload integration through dynamics, coupled loads, and shock transmission analyses, along with integrated thermal modeling tied to operational states and environments with steady-state and time varying conditions. We employ mission/system models that are directly coupled with the FSW and mission design environments (STK SOLIS) to compute and predict interrelated conditions from mission sequences such as power balance, heat rejection, and shadowing. This integrated vehicle performance tool-suite also captures resources such as power generation, energy balance, downlink bandwidth at planned downlink rates, data storage, and processing throughput for onboard computing such as compression and memory scrubbing.

Real-time hardware-in-the-loop simulation, and faster-than-real-time software-in-the-loop SoftSim simulation systems support analysis, verification, and validation of payload systems. These are coupled with dynamic scene generation to visually monitor the modeled state of the spacecraft and payload systems and to examine the scene from any perspective.

Our Payload Accommodation Engineers (PAEs) participate in payload provider design reviews as requested by NASA or the payload providers, serving as advocates for payloads throughout the spacecraft implementation process. PAEs participate in spacecraft requirements and design development and all design trades, ensuring payload requirements are given primary consideration throughout the development process. If a payload provider discovers new or changing interface requirements during their development process, the PAE representing their payload ensures that the spacecraft team accommodates these requirements to the greatest extent practical.

Our PAEs work with payload providers to write the procedures for interfacing the payloads to the spacecraft. Our standard set of payload interface tests include “Safe to Mate” (a non-powered pin-to-pin checkout to ensure proper channelization of signals and power interfaces), “Power Distribution” (a powered interface check incorporating break out boxes to verify signal quality), and “Initial Power Turn-On” (verifying each payload powers up correctly and starts communicating to the spacecraft after break out boxes are removed and the payload has been fully physically integrated onto the spacecraft).

Standard payload tests include Integrated Payload Aliveness (IPA), Integrated Payload Functional (IPF), Integrated Payload Performance (IPP), and Mission/System Tests (MSTs) as described in Section 3. As part of these tests, DSS accommodates payload specific calibration targets, sources and/or electrical support equipment as defined in the ICDs. See Section 3 for the comprehensive description of Post-Integration Payload Testing.

After completing integration, the payload teams participate in spacecraft system level testing, including mission scenario testing. The payload teams also take part in spacecraft environmental testing, including separation/shock, thermal vacuum, vibro-acoustics, and EMI/EMC.
The Payload Accommodation Engineer role will continue during launch vehicle integration and launch site processing. Throughout the process, PAEs keep their payload teams up-to-date on scheduling and logistical status.

A high level schedule is shown in Figure 1-2 Example Critical Path Analysis and Schedule Margin, which highlights our schedule risk management methodology. Note that the schedule includes 3 periods of unencumbered margin, each lasting 2 months. Due to the complexity of the spacecraft, the mission, payloads and the logistics and constraints associated with being a Ride Share secondary payload, it is necessary to plan for and maintain these explicit period of schedule margin. This margin can also help accommodate any unforeseen schedule impacts to Payload development and integration. The first 2 months of margin is relative to the start of Assembly, Test and Launch Operations (ATLO), where Payload Integration can begin. The second margin period is relative to the start of spacecraft/payload integrated environmental testing. The final 2 months of margin precedes the date at which the integrated system must be shipped to KSC to meet the launch vehicle integration timeline.

A high level summary of payload milestones is provided in Figure 1-3 SLL Payload Integration Milestones, with milestone names, acronyms and descriptions summarized in Table 1-1: Milestones and Associated Products, Demonstrations, and/or Reviews.

This approach to schedule risk management is shown with Payload Milestones emphasized in Figure 1-4 Small Lunar Lander Generic Schedule and Milestones.
Figure 1-3  SLL Payload Integration Milestones

Table 1-1: Milestones and Associated Products, Demonstrations, and/or Reviews

<table>
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<th>Milestone</th>
<th>Description</th>
<th>Product Completions, Internal Deliveries, Demonstrations, and/or Reviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSP-SRR</td>
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<td>Internal Integration Review #2</td>
<td>Mission System Test End to End Demo, Env Test Readiness Review</td>
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<td>Internal Integration Review #3</td>
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<td>Internal Integration Review #4</td>
<td>Mission Dress Rehearsal 2, Completion of Payload Verification</td>
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<td>Internal Integration Review #5</td>
<td>P/L Integ Readiness Review, Primary Structure Static Load Test, Launch Service Review</td>
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<td>MSP FRR, Environmental Testing % Complete, Mission Dress Rehearsal 3</td>
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<td>Mission, System and Payload</td>
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Deep Space Systems Small Lunar Lander
Figure 1-4 Small Lunar Lander Generic Schedule and Milestones
2.0 Mission and System Description

An example mission design is provided based on the DSS proposal for NASA CLPS Task Order #2. There are many possible variations on this reference mission that may be employed based on overall mission objectives. Some of these variations are discussed in subsequent subsections.

The reference mission describes two SLLs launched as secondary payloads on a single launch landing on the North and South Poles of the Moon. This reference mission is intended to illustrate the options and flexibility inherent in our mission and system design, not to establish limitations. The two reference NASA payloads and landing sites are also shown for illustration and do not represent NASA’s actual payload assignments, science priorities or landing site priorities.

The following five Figures describe the reference mission and system architecture.

Figure 2-1 shows example NASA payloads distributed between two Small Lunar Landers, one targeted for the Lunar North Pole, the other to the South Pole.

Figure 2-2 describes two initial landing sites and payload compliments consistent with NASA’s CLPS Task Order #2 competition, including the scientific context and key knowledge gaps that the reference science instruments are intended to address.

Figure 2-3 identifies key elements of the of the DSS Small Lunar Lander system designed to fulfill payload delivery, science instrument operations, and data return objectives.

Figure 2-4 presents the mission design by mission phase, illustrating the sequence of events from Launch Operations through the completion of Lunar Surface Operations, discussing both the mission characteristics and SLL design features that enable the mission.

Finally, Figure 2-5 identifies the subsystems and component layout on the spacecraft. The spacecraft main deck provides a common, reconfigurable work space for spacecraft and Payload components and harness. “FlatSat” is a term often used to describe a hardware testbed that arranges all of the spacecraft avionics on a table for the purpose of testing and instrumentation. The DSS SLL main deck is effectively already in a FlatSat configuration making test and integration configurations much more similar to flight, and supporting our overall test like you fly, and fly like you test philosophy.
Example NASA Payloads

Small Lunar Lander – 1
Lunar North Pole: 71.5°N, 38° E, in the crater Arnold E
A - Laser Retro-Reflector Array (LRA)
B - Linear Energy Transfer Spectrometer (LETS)
C - Near Infrared Volatile Spectrometer System (NIRVSS)
D - Neutron Measurements at the Lunar Surface (ANS-LUN)

Small Lunar Lander - 2 (Optional)
Lunar South Pole: 84.4°S, 39.4°E, “Malapert Plateau”
A - Laser Retro-Reflector Array (LRA)
B - Ion-Trap Mass Spectrometer for Lunar Surface Volatiles (PITMS)
C - Neutron Spectrometer System (NSS)
D - Neutron Spectrometer System (NSS)Landers (SEAL)

Figure 2-1: DSS CLPS Task Order #2 Small Lunar Lander Reference Mission Payloads
Figure 2-2: DSS CLPS Task Order #2 Small Lunar Lander Reference Mission Payloads and Landing Sites
Figure 2-3: DSS CLPS Task Order #2 Small Lunar Lander Reference System Design

- **Launch Vehicle Integration**: DSS and Spaceflight Industries expertise in general payload and secondary payload LV integration
- **Experienced Systems Integrators**: DSS personnel that have performed key system integration leadership roles on many NASA and other space missions
- **Interplanetary Mission Operations Expertise**: Experienced mission operations team (SEI, DSS, AS) having flown many space missions, including Mars orbiter and lander missions
- **Existing Software Infrastructure**: ASI provided MAX flight software (currently flying on 26 missions) for vehicle software, ground software, and payload commanding
- **Launch Vehicle Flexibility**: ESA Grande class design maximizes launch options (>35 commercial CTO launches per year forecasted) while minimizing launch costs
- **State-of-the-Art Camera System**: DSS provided camera system based on NASA Orion camera system for vision navigation and general imagery
- **Compact Design**: Lander fits within ESPA Grande Launch Volume, standard ground and air freight shipping containers and forklift pallets
- **Monopropellant Design**: Simplicity and reliability of monopropellant propulsion system and flight proven engines minimizes development risks
- **Propellant Tank Expertise**: Propellant tank provided by Northrop Grumman ATK - world leader in space propellant tanks, based on heritage tank design, with a PMT design provided by world-renowned PMT designer to provide continuous propellant supply through coast and landing operations
- **Blowdown Simplicity**: Monopropellant operations in blowdown, while augmented with a single operation pressurant system for ease of operation and reliability
- **Proven Propulsion System Integrator**: Aerojet Rocketdyne has integrated over 200 propulsion systems
- **Functional Structural Design**: Simplified component and payload deck allowing ease of integration and tailored inserts for payload needs
- **Dedicated Payload Volume**: Designated payload volumes for ease of payload integration and dock configurability from mission to mission
- **Polar Region Power Collection**: 2.0 m² of solar array area tailored for power collection in polar regions
- **Landing Stabilization**: Landing legs (fixed) and deployable outrigger legs designed to support landing loads even if deployment fails
- **Lightweight Avionics**: DSS designed NASA Orion heritage avionics - flight-critical flight computer and tailored microcontrollers with rapid reboot capability, payload flexibility, and ease of prototyping
Launch Operations

Mission Characteristics:
- Duration: 11.9 hrs
- Start: Launch from Cape Canaveral or Kennedy Space Center
- Destination: Geosynchronous Transfer (GTO) Super Synchronous Orbit

Key SL Design Features:
- Range safety fault tolerant design to critical hazards
- Flexible launch trajectory with daily opportunities
- Tank flexibility for propellant loading consistent with insertion orbit
- Lander activation by breakwires upon TV separation
- 150 kg of margin to 200 kg ESA Grand Limit

Lunar Transfer Phase

Mission Characteristics:
- Duration: 42 days
- Start: GTO Insertion
- Destination: Low Lunar Orbit (LLO) 100 km circular
- Phasing burns from GTO to final Lunar orbit insertion at elliptic crossing (demonstrated by Spawls, planned by our SEE teammates)

Key SL Design Features:
- High thrust to weight main engines to minimize gravity gradient losses
- Batteries sized for transit eclipses (Earth or Moon) of up to 3 hrs in duration (current Orion limitation)
- Solar inertial attitude with roll degree of freedom for comms closure
- Daily comm passes and navigation updates
- Radiation tolerant avionics design for Van Allen belt transits
- 2.0 m² of solar array to tolerate any LLO beta angle

Descent and Landing Operations

Mission Characteristics:
- Duration: 63 min
- Start: LLO 100 km circular
- Destination: Landing sites tailored for science objectives, lighting conditions, comm, and landing conditions
  - Baseline: North Polar Region — Arnold Crater
  - Optional Lander: South Polar Region — Malapert Plains
- Decel burn to target ~24km altitude braking start
- Braking phase — Removal of most horizontal dv
- Approach phase — Targeting of landing site
- Landing phase — Hazard avoidance and deceleration to constant velocity for touchdown

Key SL Design Features:
- High thrust to weight main engines to minimize gravity gradient losses
- Symmetric main engine configuration for 6-4-2 engine configurations and tailored thrust
- Descent control engine (MR-10K) for altitude and acceleration control
- Vision nav camera and laser altimeters to aid nav state and enable precision landing
- Horizontal velocity and hazard avoidance software

Lunar Surface Operations

Mission Characteristics:
- Duration: 8.6 Earth days
- Start: Touchdown
- Nominal operations end: Sunset at local landing location
- Polar landing sites for science and human exploration objectives
- Landing before noon to maximize payload operations

Key SL Design Features:
- Landing with Earth and Sun out primary axis
- Medium gain antenna pointed to Earth for payload and imagery data transfer, low gain antenna backup
- Twice daily comm passes for data downlink and commanding
- Data storage and downlink bandwidth for continuous payload operations
- Arrays sized for continuous payload operations throughout nominal surface stay time
- Lander designed for hibernation through lunar night

Figure 2-4: DSS CLPS Task Order #2 Small Lunar Lander Reference Mission Design
Figure 2-5 DSS Small Lunar Lander Subsystems Description
2.1 Launch Operations

DSS has baselined a GTO supersynch orbit drop off, and the SLL design is flexible on the specific GTO apogee that the primary payload prefers. According to the FAA’s 2018 Annual Compendium of Commercial Space Transportation, there are over 15 GTO commercial missions forecasted each year during the span of the 10-year CLPS program. Based on current launch vehicle capabilities, most of these launches have excess mass/volume launch capacity, and they could accommodate one or more SLLs. This GTO baseline offers ample launch opportunities for multiple SLL missions to various locations on the Lunar surface. The SLL lunar transfer trajectory from GTO to LLO builds upon the successful transfers demonstrated by the NASA LADEE spacecraft and SpaceIL Beresheet lander with the assistance of our SEE and Spaceflight teammates.

The SLL reference mission design utilizes a GTO insertion and cis-lunar phasing loop trajectory similar to the plan used for transfer by the SpaceIL Beresheet probe. As with Beresheet, the insertion GTO is “supersynchronous” with an Apogee altitude of 68,000 km. The SLL mission profile allows for a launch on any day, with the DSS CLPS mission choosing the RAAN/Launch time for each day. SEE has studied these trajectories for 18 months of daily launch opportunities to characterize the variability in required delta velocity (dV), which is accounted for in the SLL dV budget. For a nominal case, the spacecraft spends 4 revolutions in this initial orbit to allow for Orbit determination and spacecraft checkout. Small Apogee Maneuvers (AM) may also be necessary if lunar perturbations on the launch day cause low perigees. This insertion orbit necessarily has its apogee on the equatorial plane, and the line of apsides also in the lunar orbit plane. Once the orbital plane and line of apsides orientation is established by the launch, the spacecraft then uses phasing orbits to adjust the altitude and timing at apogee to match those of the Moon when it crosses the Earth’s equatorial plane.

The DSS SLL is designed to accommodate different launch vehicle injections to provide the most flexibility in planning missions for payload customers. Depending on the injection selected, DSS SLL is capable of various Lunar transfer types pending desired mission payload mass as described in the following section.

2.2 Lunar Transfer Options

The DSS SLL is sized to perform all of the following transfer cases below. For methods that require less delta V propellant can be traded for additional payload mass, as described in Section 2.5.

During coast operations the SLL primarily operates with its solar array side pointed toward the sun, with an off-pointing angle chosen to optimize thermal conditions. The vehicle selects a roll angle about the pointing vector to provide continuous communication coverage. The battery system of the SLL is sized to accommodate up to 3 hours of transitory eclipses that can often occur with cislunar transfers. The solar arrays of the SLL are sized by the LLO higher eclipse fractions and can operate in LLO without any beta angle constraints.
2.2.1 Indirect Lunar Transfer

The SLL Indirect lunar transfer trajectory from GTO to LLO builds upon the successful transfers demonstrated by the NASA LADEE spacecraft and SpaceIL Beresheet lander with the assistance of our SEE and Spaceflight teammates. After the first four revolutions in the insertion GTO.

For the Design Reference Mission (DRM) the SLL executes Phasing Maneuvers (PM) into two subsequent phasing orbits: the first phasing orbit with 132,000 km apogee (2.1 day period) and the second with a 290,000 km Apogee (6.7 day period). The SLL spends four revolutions in the first phasing orbit and 2 revolutions in the second phasing orbit. The size and number of revolutions used for this DRM are tailored to the launch date but are adjustable to accommodate a different amount of phasing time for alternate launch dates. This allows great flexibility in the launch date, while still targeting the same lunar arrival conditions. After the phasing orbits are complete the spacecraft is raised to an orbit that matches lunar distance at apogee. This orbit (~11 day period) allows for precision orbit determination prior to Lunar Orbit Insertion (LOI) and provides multiple opportunities for trajectory correction maneuvers.

The final leg of the cislunar portion of the trajectory is similar to a direct transfer, with multiple opportunities for Trajectory Correction Maneuvers (TCMs) prior to LOI. The targeted periapsis altitude is 250 km, and the lunar orbit inclination was chosen to place the parking orbit plane over the landing site. The SLL mission uses a multi-phase LOI with 3 maneuvers, placing the SLL into a 12-hour orbit, 6-hour orbit, and then a 100 km circular orbit ready for landing. Both Northern and Southern approaches are available for LOI depending on landing site requirements with insignificant dV costs. This flexibility is utilized within this DRM to send one lander to the North Pole region and the other to the South Pole, while maintaining favorable lighting conditions for both.

2.2.2 Direct Lunar Transfer

The DSS SLL is also designed to accommodate a Trans Lunar Injection (TLI) drop-off from a Launch Vehicle. Such launches are less common but save significant lander delta V that can be translated into approximately 30 kg of extra landed payload mass. With the relatively small mass and ESPA size of the SLL, one or more landers could accompany many TLI bound launches. Once separated from the LV after injection, the SLL would complete the 3-4 day trip to insertion into the desired Lunar Orbit.

2.2.3 Low-Energy Lunar Transfer

The DSS SLL can fly low-energy lunar transfers, such as a Weak Stability Boundary (WSB) trajectory, to increase the payload mass of the system. These trajectories have successfully demonstrated (JAXA Hiten in 1991, NASA GRAIL in 2011-2012) reductions in required delta V. However, these missions have increased transfer durations of up to 5 months. The DSS SLL and supporting operations team can support these mission durations if needed to increase payload mass. A representative WSB trajectory is illustrated in Figure 2-6.
2.3 Lunar Orbit Operations Options

2.3.1 Lunar Orbit Payload Delivery Options

The DSS SLL is capable of delivering payloads to various lunar orbits either on a dedicated mission or en route to a lunar landing mission. The payload mass capabilities of various configurations are found in Section 2.5. Orbital payloads of various sizes can be accommodated. Cubesat dispensers from 1 to 16U would be standard services, and custom payload deployments (with the deployment system either as a service or provided by the payload) are both possible. Multiple delivery deployments are also possible in either a phased single orbit or multiple orbits. Without a landing attempt, the DSS SLL contains significant propellant margins for lunar orbit station keeping or transfers between delivery orbits.
2.3.2 Lunar Orbit Mission Examples

The DSS SLL is designed for long duration deep space operation with its storable monopropellant design, solar array power, and thermal design. This design, combined with the ability to deliver one or multiple payloads to lunar orbit, enable various mission scenarios with the SLL as the base platform. The DSS SLL has been studied as the basis for various Lunar orbital missions ranging from a far side communications relay for surface operations to deployment of multiple CubeSats flying in formation. Figure 2-8 illustrates a mission where the SLL delivers up to ten 6U ground penetrating radar CubeSats in formation, with the SLL then serving as the telecommunications relay for the CubeSats to Earth. This and other lunar orbital missions are within the capability of the current SLL design.

![Diagram of DSS SLL Representative Ground Penetrating Radar Mission](image)

**Figure 2-8: DSS SLL Representative Ground Penetrating Radar Mission**

2.3.3 Option for Multiple Landers per Launch

The DSS SLL is mounted as a secondary payload on an ESPA ring and may thus be launched as a single vehicle on a single mission, as multiple vehicles on a single mission (such as a Lunar Geophysical Network), or as multiple vehicles on multiple missions. This unique mission flexibility is illustrated in Figure 2-9 Possible Multiple Vehicle Launch Configurations.
2.4 Descent and Landing

The descent and landing sequence major phases are summarized below:

- **Deorbit burn** – Main engines burn to lower Perilune to braking starting altitude
- **Braking** – Remove most horizontal velocity with 6 MR-107S Engine burn at 100% duty cycle, MR-106L control
- **Approach** – Target landing site with 4 MR-107S Engine burn at 100% duty cycle, MR-106L control
- **Landing** – Constant velocity landing achieved with 2 MR-107S at appropriate duty cycle, MR-106L attitude control

The following sections identify key aspects of the DSS SLL descent and landing system and performance.

2.4.1 Performance Optimized Landing

After insertion into the appropriate Low Lunar Orbit (LLO) direction and inclination, the SLL waits a designated number of orbits for the appropriate lighting at the designated landing site. The sites and timing of our example DRM were chosen to provide a lunar morning landing for surface stay duration, but they were also chosen to provide a lit lunar surface throughout the descent and landing profile for visual navigation. In addition, the descent orbits were chosen to optimize Earth communications and visual navigation angles through the profile. The SLL flies descent such that one of the two vision navigation cameras are always pointed toward the lit lunar surface for imagery. While the entire descent and landing sequence is automated, the orbits and vehicle attitude are chosen such that one of the Low Gain Antennas (LGAs) are pointed toward Earth throughout the landing sequence for continuous communications.
Prior to descent radio navigation provides the orbit state knowledge, supplemented by the visual navigation system which identifies known features from orbit using the SURF (Speeded Up Robust Features) algorithm. This algorithm was demonstrated on DSS flight-like hardware from existing lunar imagery, as shown in Error! Reference source not found.. A de-orbit burn initiates descent and landing.

![Figure 2-10 The Camera View (left) is Matched to a Geo-Referenced Image](image)

### 2.4.2 Precision Landing at a Specific Site

The primary landing site was chosen to accommodate a 3-sigma conservative landing ellipse of 20 km in length (in-track). However, the SLL performs a precision landing to a designated spot within the ellipse. The 3-sigma ellipse was preserved to increase the likelihood of mission success. Once the primary landing demonstrates a successful precision landing in Arnold crater, the precise landing site of the second optional lander on Malapert Plateau can be more aggressively chosen to maximize science return at the South Pole. This provides a near immediate return on the precision landing demonstration for the CLPS program.

During braking phase (~24 km altitude start) all six descent main engines fire at 100% duty cycle while the descent control thrusters are differentially pulsed from a 50% duty cycle for additional acceleration capability and attitude control. Visual navigation uses the Oriented FAST and rotated BRIEF (ORB) algorithm to estimate velocity. Altitude is initially based on the propagated navigation, and then starting at about 10 km altitude is directly measured using the long-range laser altimeter. The ORB algorithm has been demonstrated at 8 updates per second using DSS flight-like cameras and vision navigation processor by imaging existing lunar video data as shown in Figure 2-11.
2.4.3 Landing Approach and Hazard Avoidance Methods

During approach phase (~2.5 km altitude) two of the main engines are shut off to achieve the acceleration level required to track the Approach phase guide slope while the control engines are differentially pulsed from a guidance-determined command bias based on the acceleration required. This phase continues to use the ORB and SURF algorithms to update the terrain-relative state knowledge. A particle filter algorithm also processes the laser altimeter data compared to the Digital Elevation Map (DEM) to provide an independent horizontal position measurement in addition to the measured altitude. Altimetry is handed off from the long-range to the short-range altimeter at an altitude between 100m and 50m. Toward the end of the approach phase, adjustments to the touchdown location are made based on hazard avoidance detection via a combination of image segmentation and Haar-like feature detection, as shown in Figure 2-12. Horizontal velocity is nulled based on data from the ORB algorithm leading into the landing phase.

2.4.4 Landing Orientation and Attitude

During landing phase (10 m altitude) two more main engines are shut off leaving two main engines pulsed at a variable duty cycle to balance gravity and achieve the 0.5 m/s fixed velocity touchdown target. The control engines are on-pulsed during landing for
attitude control. Engine shutdown is based on both propagated altitude and contact acceleration measurement.

A high-fidelity simulation including the full MAX (Modular, Autonomous, eXtendible) Flight Software (FSW) and guidance add-on module has been used to show the SLL design can safely deliver payloads to the lunar surface as shown in Figure 2-13.

![Figure 2-13: A Detailed Descent Simulation Implements Existing and Proven Guidance Techniques with MAX Flight Software, Demonstrating Successful Landing with Ample Margin](image)

2.5 Payload Mass Performance Options and Considerations

2.5.1 Landed Payload Mass Capability vs. Transfer Options

The DSS SLL has been designed to accommodate different launch options and injections depending on payload needs, as described in Section 2.2. Depending on launch option, the maximum landed payload mass capability is:

- 20 kg - Injection to Geo Transfer Orbit (Task Order 2 Baseline)
- 50 kg – Trans Lunar Injection
- 70 kg – Weak Stability Boundary Injection

The maximum payload mass accounts for NASA and commercial payloads and is relatively independent of landing site due to the trajectory design and insertion orbits.

2.5.2 Orbital Payload Mass Capability

The DSS SLL as designed can deliver significant payload masses to various Lunar orbits, making it an efficient Lunar orbit delivery system on an ESPA class launch.
Minor modifications of the SLL can further optimize the overall payload mass and packaging. The practical limit on orbital payloads is ultimately constrained by volume, not mass, based on the ESPA Grande Launch Envelope, but even in the most conservative case of a GTO injection, the orbital payload mass could be more than 120 kg (much greater than the 92.6 kg payload mass of Lunar Reconnaissance Orbiter (LRO). This payload capacity would be applicable for any of the following delivery orbits:

- Circular orbits of various altitudes and inclinations
- Any of the identified Stable frozen orbits (e.g. LRO)
- Highly elliptical polar scouting orbits with low perilune

Example configurations of orbital payload packaging onto the DSS SLL are illustrated in Figure 2-14.

![Figure 2-14: DSS SLL Orbital Delivery Configuration Examples](image)

### 2.5.3 Mixed Orbital and Landed Payload Capability

The DSS SLL is also capable of delivering both orbital and landed payloads on the same mission. As an example, the SLL can deliver:

- 25 kg of Landed Payload Mass (GTO Supersynchronous Injection)
  
  **AND**
  
  - 40 kg of Orbital Payload Mass (Trans Lunar Injection)
  
  **OR**
  
  - 75 kg of Orbital Payload Mass (Weak Stability Boundary Injection)
The orbital payload masses quoted are deployed mass, as the vehicle is accounting for the deployment system mass estimates. An example of a mixed orbital and landed payload mission configuration is illustrated in Figure 2-15.

![Figure 2-15: SLL Landed Configuration of a Mixed Orbital and Surface Payload Mission](image)

2.5.4 Landing Site and Landing Approach Selection

The DSS SLL is designed for landing sites above 45 degrees latitude - in particular, for polar landing sites where accessible volatiles may be found. For the Task Order 2 (TO2) reference, two locations were selected by the DSS science team, both of geologic and In-Situ Resource Utilization (ISRU) interests. Both are on the near side, where a continuous view of the Earth within the beam width of our medium gain antenna eliminates the need for relay satellites. Locations recommended in the NASA payload proposals (RFTP Appendix B) also shaped the final landing site selections.

With precision landing, the DSS SLL is designed to land in a broad range of landing sites based on the objectives of a particular mission. Based on the site selected by the customer or DSS science team, the mission is designed to accommodate a Lunar morning landing at that site to preserve a majority of a lunar day for lighted operations. The landing approach is selected to provide favorable lighting conditions for the vision based navigation throughout the descent profile. The attitude and approach direction is also selected to provide continuous line of site communications with Earth during this critical mission phase. Final landing attitude is selected to provide power generation over the majority of the lunar day, and to provide higher rate communications with Earth for Payload and imagery data transfers. For far side lunar sites, a comm relay would be required, and could be provided by a DSS SLL remaining in Lunar orbit (Section 2.3).
2.6 Flight Operations

2.6.1 Mission Operations Center

The Mission Operations Center (MOC), see Figure 2-16, is located at the facility of DSS teammate ASI. The MOC is already in operation supporting multiple small satellites through the use of remote ground stations and a roof-mounted UHF antenna. For the DSS SLL mission, the MOC will be tied into the Swedish Space Corp. (SSC) global commercial multi-mission ground station network. During ATLO, the MOC can also serve as a Test Control Center (TCC) producing a “Test Like You Fly” environment. A portion of this MOC infrastructure will be duplicated at the DSS facility to provide a backup command and telemetry capability during the mission, and to make space available for co-located payload support personnel if desired. When the spacecraft is ready for system-level environmental testing, the Mechanical Ground Support Equipment (MGSE) transports the spacecraft to and from environmental test facilities, DSS and the launch site in a fully assembled flight configuration, except for the solar array which will be shipped separately in a custom shipping container.

![Figure 2-16: ASI's Mission Operations Center is Currently Operational](image)

At the launch site, the Ground Data System (GDS) allows secure sharing of critical GDS products (i.e., procedures, scripts, commands, and telemetry) across all test and flight environments. Using the same GDS and infrastructure for both ATLO and Mission Operations enables a small integrated team to support the program with continuity of staffing throughout the program. It also fulfills the philosophy of “Test Like You Fly – Fly Like You Test” to minimize risk incurred by other programs that have separate test and operations teams and tools. At the launch site, the spacecraft is powered up for the last time before launch, and health and status of all spacecraft and payload hardware is...
verified to be ready for launching in a powered-off configuration.

### 2.6.2 Flight Operations Process

While the majority of the personnel, tools and processes transition seamlessly from ATLO to flight operations, orbit determination and navigation are functions that require additional specialized tools and personnel. DSS has teamed with world class experts from Space Exploration Engineering (SEE) with over 30 years of experience in lunar trajectory design and navigation. Using the Orbit Determination (OD) system the team members were in charge of navigation for NASA’s IBEX and LADEE missions, and also supported SpaceIL’s Beresheet mission.

![Diagram showing Flight Dynamics System integration](image)

**Figure 2-17: FDS Tools Used for Orbit Determination are Integrated with Sim & FSW**

Figure 2-17 shows how the Flight Dynamics System (FDS) is integrated into the tools framework that has been used through integration and testing. The FDS was developed at L3 Applied Defense Solutions (ADS) in cooperation with the SEE team to bridge the gap between analysis tools and the critical automation and database facilities necessary to record inputs and outputs from flight dynamics processes during operations. The FDS uses the Commercial Off-the-Shelf (COTS) Satellite Toolkit (STK) and Orbit Determination Toolkit (ODTK) from Analytical Graphics Inc. (AGI), both of which have been used for multiple operational cislunar and lunar missions.

### 2.6.3 Navigation

Our navigation strategy from launch through Lunar Orbit Insertion until handoff to the lander uses coherent Doppler and 2-way range radiometric tracking. Ground station angle information will also be processed as needed to support initial orbit determination. A coherent X-band Doppler system provides range and range rate tracking using a flight
proven X-band transponder fully compatible with commercial and Deep Space Network (DSN) ground networks. Our Orbit Determination (OD) algorithms use an extended Kalman filter and a fixed interval smoother, and the force models include atmospheric drag, solar radiation pressure, and gravity 3rd body effects from the Sun and planets, as well as the latest high-order spherical harmonic models of the Earth and Moon. During final approach and landing the navigation is aided by on-board vision navigation as described in Section 2.4.

2.6.4 Maneuver Planning and Execution

The team uses the same trajectory design, maneuver planning, execution, monitoring, and recovery techniques and algorithms they have developed and used for many missions, which include the lunar and cis-lunar missions Clementine, WMAP, IBEX, LCROSS, LADEE, and SpaceIL. The high-fidelity numerical orbit propagation models are matched to the orbit determination models, and include the environmental forces from solar radiation pressure, atmospheric drag, 3rd body gravity from the Sun and planets, and the latest high-order spherical harmonics gravity models of the Earth and Moon. The entire end-to-end trajectory is numerically integrated prior to launch based on the predicted launch vehicle burn out vectors. The multiple cis-lunar maneuvers are numerically targeted together to achieve Lunar Orbit Insertion (LOI) targets that meet mission constraints in terms of perilune altitude and with a Lunar inclination that causes the desired flyover of the landing site.

The numerical targeting algorithms use differential correction and optimization based on numerical partial derivatives, which are especially important to account for the nonlinearities in the satellite-Earth-Moon-Sun four-body system dynamics. The LOI and other Lunar orbit maneuvers are usually targeted individually to achieve orbital desired elements, with verification that in combination with subsequent maneuvers the orbit will meet all requirements. As the mission progresses and propulsion system values are updated, the maneuvers are modeled as finite burns by numerically integrating the trajectory through the maneuver accounting for multiple thruster firings, with attitude, thrust, and mass-flow-rate updated as a function of time, temperature, and pressure. During maneuver execution for maneuvers that are in view, or directly after for those performed out of the line-of-sight, the spacecraft attitude and propulsion system telemetry is monitored and compared with pre-maneuver predictions. When post-maneuver tracking data becomes available the maneuver is reconstructed and then calibrated by comparing to pre-maneuver predictions. The FDS also computes corrections to the effective thrust efficiency, duration, and thrust-vector pointing, which the flight dynamics team reviews with the satellite engineers to improve future maneuver execution precision.

2.7 Surface Operations

2.7.1 Payload Surface Operations

Once the SLL senses positive confirmation of touchdown on the lunar surface (through a combination of acceleration, propagated state, and altimeter readings) it
terminates active thruster control. The SLL executes preplanned communication contacts to downlink data and upload new sequencing and commanding as needed.

On the surface, the payloads can be operated continuously during the primary surface mission, which is calculated to be a minimum of 8.6 Earth days for the TO2 missions. Daily communications passes are scheduled twice per day, allowing downlink of all stored science data and uplink of command sequences, including real time commanding if needed. Payload and spacecraft data are recorded and then downlinked during the communications passes. The data rate through the medium gain antenna is sufficient to downlink video data recorded by DSS cameras during descent and landing with the excess data volume not needed for the payloads.

2.7.2 Lunar Night Operations

The surface operations continue until a detailed analysis of the Arnold E crater Azimuth-Elevation (Az-El) masking determines that the sun will set behind local mountains to the West. When the sun dips below the lunar horizon at the end of the primary mission duration, the spacecraft will operate on battery power for a short duration and then begin an orderly shutdown process that will remove power from all loads, including the payloads. The last part of the process disconnects the batteries to preserve them for the next lunar day, and then the vehicle will continue to cool down to reach ambient lunar night temperature.

Although survival at that temperature is not guaranteed, experience leads us to expect that when the sun reaches the solar panels on the following lunar day, the vehicle is capable of operating again. Recent DSS testing has shown that lithium ion batteries can survive being hard-frozen in an open-circuit state without measurable degradation, if they are warmed back to the operating range before attempting charging. The power system is designed to operate from solar array power with the batteries offline, while powering battery heaters to bring the batteries back up to charging temperatures. Once warm, the batteries can be connected, and larger loads can be turned on. After wake-up, the spacecraft will initialize communication with ground stations so that the spacecraft clock can be set to the correct time, and then surface operations, including payload operations, can resume.
3.0 Definition of Environments

3.1 Preflight Environments

3.1.1 Storage
The SSL and scientific payloads are securely stored in our controlled, single entry point facility. Access to labs, including the payload bench checkout area, is restricted via cypher locks on all doors. Payload teams will control access to this bench checkout area from payload arrival through payload integration onto the spacecraft. This area will have ESD, contamination, temperature, and humidity controls and any additional controls required as defined in the spacecraft and payload ICDs.

3.1.2 Integration
The Payload integration includes activities from bench top testing, through mechanical integration, electrical integration, mission/system testing, environmental testing, through transportation to KSC, launch vehicle integration and launch. The spacecraft will have multiple lifting, mounting, transportation and work fixtures including a turnover and rotation fixture to facilitate assembly and integration onto the Launch Vehicle.

3.1.3 Transportation
Our SLL is small enough to be shipped in an environmental roadable shipping container to any US launch site. Key features of this cost-effective proven container include temperature control tolerance of ±3 °C, fully redundant electrical heating and compressor cooling, data logging functionality, and battery autonomy of over 100 hours.

3.2 Launch through Separation Do No Harm Environments

3.2.1 Acoustic Environment
During flight, the spacecraft will be subjected to a varying acoustic environment. Levels are highest at lift off and during transonic flight, due to aerodynamic excitation. As reference, Figure 3-1 shows the maximum predicted acoustic environment. As such, it does not include margin for qualification or acceptance testing.
3.2.2 Vibration

Quasi-Static Loads
The quasi-static ESPA satellite design load factors for the SSL and its components are reported below in Table 3-1.

Table 3-1: Quasi-static load factors from ESPA Mass Acceleration Curve

<table>
<thead>
<tr>
<th>Acceleration, g</th>
<th>Axial</th>
<th>Lateral</th>
<th>Vector Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5</td>
<td>5.6</td>
<td></td>
<td>8.6</td>
</tr>
</tbody>
</table>

The values reported may be updated, if necessary, with the results of a coupled loads analysis.

Sinusoidal Vibration
Maximum predicted sinusoidal vibration levels are shown in Figure 3-2 and Figure 3-3. Results of coupled loads analysis will be used to modify these levels, if necessary.
Figure 3-2: Maximum axial equivalent sine environment

Figure 3-3: Maximum lateral equivalent sine environment
3.2.3 Shock

The DSS SSL will be subjected to shock events during launch injection originating from the launch vehicle, such as fairing release and separation. Reference shock environments are reported below in Table 3-2. As the exact launch configuration is matured, the environments may be updated to reflect the distance and number of joints over which the shocks will travel and dissipate.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>SRS (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>10,000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

3.2.4 Thermal

The natural environments for flight and surface operations are described in the SLS SPEC 159 Cross Program Design Specification for Natural Environments (DSNE). See Section 3.3.1 for more information. Payload environments will strongly depend on mounting location, mounting method (thermally grounded vs thermally isolated), local thermal optical properties, the use of multilayer insulation (MLI), and the degree to which the local MLI treatment is connected to the overall spacecraft-level MLI enclosure.

The thermal control system will include both active and passive thermal control methods. The spacecraft thermal design will provide a temperature margin of 11°C to acceptance temperatures and 16°C to protoflight temperatures as shown in Figure 3-4 Temperature Margin Relative to Flight Allowable Operational Limits. This figure shows an example component that will be Protoflight tested to +80° and -40° in operation. The actual operational and non-operational protoflight or qualification levels of spacecraft component hardware and payload hardware will vary, but the wider these ranges the easier the integration and testing will be, and the lower the mass and heater power.

Some spacecraft components will be drivers for overall thermal control, including the batteries and the hydrazine tanks, lines and valves. These components must be kept above freezing and well below the upper limits that electronics can be easily qualified to.
The thermal design strategy for spacecraft and payload components is to design and select qualified components with as generous an operational range and non-operational range as practical. The non-operational range is used to size closed loop heater circuits for “survival” conditions. When activated and operational, payload steady state temperature should be sufficient to raise the temperature to the minimum Flight Allowable temperature. If this is not the case, either the payload or spacecraft will have to provide an operational heater to cover this cold case. The SLL will have spare heater channels that can be allocated as negotiated in the Payload ICD.

The active thermal system will use heaters in a closed loop (SW) system to maintain various components within their specified temperature ranges. Heaters will be sized such that the maximum duty cycle is less than 80% at the minimum voltage and the watt density is less than 5 W/in² at the maximum voltage.

The passive thermal control system will use MLI blankets and various surface coatings on radiative surfaces. These coatings include tapes, paints, and material finishes such as anodizing, as necessary. Avionics will reject their heat with a combination of a heat spreader and high emissivity surface finishes that will radiate to the environment under the MLI and/or to space.

Payloads will be provided a combination of active and passive thermal control to maintain them within their operating temperature ranges as specified in the RFTP. Payloads are generally mounted under the MLI blanket, except where necessary for viewing constraints. Additional thermal control will be done through the application of standard thermal design techniques, such as heaters, mounting interfaces, radiative environments, and thermal coatings as deemed necessary by detailed thermal analysis.

The overall spacecraft MLI enclosure is illustrated in Figure 3-5 Baseline MLI.
Enclosure. This enclosure includes the propellant tank, the majority of the propellant lines, pressurization system, the batteries, most flight avionics, and can include payload components as well.

This MLI enclosure volume can be expanded or modified by adding protrusions or windows as shown in Figure 3-6 MLI Enclosure with Example Payload Doghouse. It is possible to design in velcro doors or patches to help support access to the payloads during integrated testing with the MLI enclosure fully installed. Any modification to the Baseline envelope necessary to support payload integration or operations will be specified in the Payload ICD.

Figure 3-5 Baseline MLI Enclosure

Figure 3-6 MLI Enclosure with Example Payload Doghouse

Thermal analysis for all phases of the mission (transfer, orbit, descent, landing and surface ops) will be performed using the industry standard thermal analysis tool, Thermal Desktop. Each mission is expected to have unique mission/system design and analysis characteristics. An integrated thermal model of the lander and its payloads will be used to size heaters, size the avionics spreader plate, size windows or radiators, and
predict payload mounting temperatures based on hot and cold driving design conditions.

A simplified model response for example hot and cold conditions is depicted in Figure 3-7 Integrated Spacecraft and Payload Thermal Modeling.

![Figure 3-7 Integrated Spacecraft and Payload Thermal Modeling](image)

### 3.2.5 Pressure Change and Venting

All payloads will be required to show that void spaces are filled or are appropriately vented. Trapped gas at atmospheric pressure can rupture its containment in a vacuum. The rate of depressurization during launch can be up to 6.20 kPa/s (0.9 psi/s), therefore venting pathways must be designed to accommodate this rate of pressure change.

### 3.2.6 Contamination Control

Launch system typically limit contamination depositions from all launch system sources onto Payload surfaces to a molecular thickness of 150 Angstroms and a particle obscuration of 1.0%, from the start of Spacecraft encapsulation operations through the post-separation phase in which the launch vehicle may be performing a separation maneuver. Our DSS-PL-003 DSS Contamination Control Plan can be provided for use or reference by the Payload Team upon request.

Launch system ascent contamination sources are unique to the selected Launch Vehicle but can include molecular outgassing, non-volatile residue redistribution (NVR), particle redistribution, payload fairing separation effects, booster and staging separation effects, spacecraft motorized Lightband separation effects, launch vehicle separation/collision avoidance maneuver (CAM).

Up through Launch Vehicle Integration, cleanliness levels are maintained to Visibly Clean. Contamination-critical hardware surfaces are cleaned and inspected to Visibly Clean Level 2 (free of all particulate and molecular contaminants visible to the unaided eye at a distance of 15.2-45.7 cm (6-18 in.) with a minimum illumination of 1,076 lumen/m²). Hardware cleaned to this criterion is protected to maintain this level of cleanliness through shipping, launch vehicle integration and encapsulation. DSS and service providers can support better levels of cleanliness if required and included in the Payload ICD and Launch Contracts.
If requested, Tape Lift Sampling, Ultraviolet Light Inspection, or Customer Provided Witness Plates can be employed if specified in the Payload ICD.

Additional anti-static covers or other Remove-Before-Flight devices provided by the Customer or DSS can be used based on instructions in the Payload ICD.

3.2.7 Foreign Object Debris Control

DSS provides Foreign Object Debris (FOD) mitigation throughout integration, test, transportation and launch vehicle encapsulation. Our internal controls are documented in DSS-TR-002 Foreign Object Damage (FOD) Training. This training is mandatory for all personnel involved in spacecraft, payload and launch vehicle integration.

3.2.8 Electromagnetic Compatibility During Launch

During launch, the spacecraft and payloads will be powered off in order to ensure electromagnetic compatibility with the launch vehicle and range.

3.3 Trans-Lunar through Lunar Surface Flight Environments

The NASA Marshall Space Flight Center (MSFC) develops and maintains Space Environment Definition Documents applicable to CLPS mission and system design for lunar spacecraft and payload teams. These documents, which are described below, are used as references and as a resource by Deep Space Systems and are the basis of analysis and design for spacecraft systems and payload accommodations.

3.3.1 Design Specification for Natural Environments (DSNE)

MSFC/EV44 developed and maintains SLS SPEC 159 Cross Program Design Specification for Natural Environments (DSNE).

The DSNE was initially developed for the Constellation Program and has sections in development for lunar surface environment definitions. The next update will contain all surface environments currently found in NASA/TM 2016 218229 Natural Environments Definition for Design (NEDD) (see next section).

Baselined for SLS, Orion, Gateway, Human Landing Systems and exploration EVA Systems Rev. F includes 15 year lifetime radiation dose environments for Gateway orbit. Rev. G will include lunar surface environments and newly released Meteoroid Engineering Model (MEM 3).

The DSNE is publicly available here:
https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20190027643.pdf Rev. F

The DSNE includes lunar natural environment descriptions including sections on the following topic areas:

➢ Radiation Total Dose
➢ Radiation Single Event Effects
➢ Plasma Charging
➢ Meteoroids and Orbital Debris
➢ Earth Gravitational Field
➢ Lunar Gravitational Field
➢ Thermal Environment for In Space Hardware
  ➢ Includes lunar albedo and infrared emission
➢ Solar Illumination Environment for In Space Hardware
  ➢ Solar spectrum, including lunar eclipses
➢ In Space Neutral Atmosphere (Thermosphere) density
➢ Geomagnetic Fields (In Work)
➢ Lunar Surface Geological Environment
  ➢ Global crater and rock size distributions, slope distributions
  ➢ Considering adding site dependent data for Design Reference Sites/Missions
➢ Lunar Regolith Properties
  ➢ Mechanics properties, regolith composition, particle size and shape
➢ Lunar Dust
  ➢ Size and composition
  ➢ Electrostatic dust lofting
➢ Lunar Regolith Electrical and Photoelectric Properties
  ➢ Bulk conductivity (noon and cryogenic temperatures), dielectric constant, photoelectric emission of lunar fines, secondary electron emission bulk material
➢ Optical properties
  ➢ Absorption and reflection at visible, lidar and radio wavelengths
➢ Lunar
  ➢ Thermal Environment
    ➢ Specific heat (bulk material), thermal conductivity (bulk material), surface temperature extremes, subsurface temperature, albedo and infrared emission
➢ Lunar Radiation Environment for avionics and materials
  ➢ Surface ionizing radiation, neutrons (may not be an issue for hardware)
  ➢ Crew dose environment is responsibility of JSC/Space Radiation Analysis Group
➢ Lunar Surface Plasma Environment
  ➢ Electron and ion temperatures, densities, fluxes
  ➢ Cis lunar (solar wind, lunar wake, and magnetotail) and Surface
➢ Lunar Ejecta Environment
  ➢ Flux, particle size, density and speed distributions
  ➢ Meteoroid Environment Office has provided primary impactor particle flux
  ➢ Collaborating with Lawrence Livermore (M. Syal) to leverage the hypervelocity impact modeling capability (SPHERAL) to generate ejecta size, speed, and direction distributions
➢ Lunar Illumination
Rather than repeat those natural environment descriptions in this User’s Guide, DSS refers payload teams to the DSNE as an authoritative source for mission and system design information.

3.3.2 Natural Environments Definition for Design (NEDD)

The NASA Marshall Space Flight Center EV44 developed NASA/TM 2016 218229 Natural Environments Definition for Design (NEDD) which contains the lunar surface environments originally developed for the Constellation Program and is now being updated for Artemis.

The NEDD is publicly available here:

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170003920.pdf

The NEDD will be referenced as an authoritative source for mission and system design information for the Lunar Surface until such time as those relevant sections are incorporated into the DSNE.

3.3.3 Vacuum and Outgassing

Outgassing of volatile or non-volatile materials or residues is a major concern for the optical and thermal performance of the spacecraft and payload systems.

All Payloads will be required to describe the materials and processes used in the as-delivered payload. A Material Identification Usage List (MIUL) may be required, and if so, will be specified in the Payload ICD. Upon request, DSS will provide a list of known materials and processes to avoid and some standard materials and processes that may commonly be used for applications such as adhesives, tapes, and polymeric (for bonding, staking, conformal coating, etc.).

Venting of trapped gasses during launch vehicle ascent is discussed in the previous section 3.2.5.

3.4 Payload Compatibility Test Requirements

Payload testing expectations and requirements will vary from payload to payload. For every payload the Payload ICD will be the governing document that will specify specific tests, test methods, test conditions and test levels specifically applicable to that payload. General test expectations and requirements are discussed in the following sections.

NASA provides a comprehensive set of standards which if followed ensure adequacy of Payload testing prior to and after delivery for spacecraft integration. NASA-STD-7002B Payload Test Requirements includes:

- Payload Test Requirements Matrix (Protoflight Program)
- Mechanical Tests
- Strength
- Sinusoidal Vibration
- Random Vibration and Acoustics
- Shock (Mechanical and Pyro)
- Modal Survey
- Pressure Profile
- Mechanical Function

- Thermal Tests
  - Thermal Vacuum and Ambient Pressure Thermal Cycle
  - Thermal Balance
  - Bakeout
  - Leak Test for Sealed Components

- EMI/EMC Tests
- Functional Tests
  - Electrical Interface
  - Comprehensive Performance
  - Failure-Free Performance
  - End-to-End Compatibility Tests and Mission Simulations
  - Life Test Program
  - Mass Properties Verification
  - Alignment

- Protolflight vs. Prototype Approaches

Following NASA-STD-7002B Payload Test Requirements is an excellent approach to help ensure mission success, however it can be expensive. DSS will not dictate what level of mission success a payload team should conform to, or what deviations or waivers are acceptable risk for achieving mission objectives, but we must apply Do No Harm principles at a minimum to ensure that the payload cannot do harm to the spacecraft, other payloads or the launch systems.

### 3.4.1 Do No Harm Criteria

Payloads on the DSS SLL must pass an independent Spacecraft Safety and Range Safety Review. The Spacecraft Safety Review is an internal review that includes analysis of system level environmental testing. Failure to pass either of these reviews will result in the removal of the Payload prior to launch.

“Do No Harm” is a key philosophy and mantra of the Air Force Range Safety Officer. The burden of proof is on Deep Space Systems and the Payload Teams to prove that all aspects of our system are ready for flight and cannot damage the launch vehicle, the launch pad or launch infrastructure, injure personnel working at the launch site, or in any way endanger the Space Coast population.

Underwriters for the companies insuring the mission, the primary payload, and associated launch facilities and equipment, have a fiducial responsibility to ensure that our SSL system does not represent a significant risk to their interests.
3.4.2 Passive Inert Payloads

Depending on the nature and heritage of the passive payload, there may be no pre-delivery test requirements. It is possible that Passive, Inert Payloads may be integrated for launch after system level environmental testing has been completed, where visual inspection and analysis support Do No Harm principles.

Using pre-approved materials compatibility, cleanliness and encapsulation and mounting methods will help ensure a painless integration process.

DSS encourages the use of 3rd party integrators to help ensure that mementos, keepsakes, and treasures are properly handled, documented and prepared for integration.

3.4.3 Basic Active Payloads

Payloads that accept power and undergo any kind of mode or state change are considered active, and are subject to pre-delivery verification, which may include verification by testing if inspection, analysis and/or demonstration methods are not considered adequate:

➢ Electromagnetic Interference / Electromagnetic Compatibility (may be deferred to spacecraft system level testing)
➢ Shock
➢ Dynamics (Vibration and/or Acoustic)
➢ Thermal Vacuum
➢ Bake Out (required for all payloads, and may be performed as a service by DSS)
➢ Functional testing using a DSS-provided Payload Suitcase or via integrated testing in the DSS CLPS hardware in the loop testbed

Previous test data from identical or similar payload systems may be sufficient to avoid potentially expensive and time-consuming payload environmental testing prior to instrument deliveries. Do No Harm principles will govern DSS in our approach to specifying test requirements in the Payload ICD and our acceptance of payload hardware for integration onto the spacecraft.

3.4.4 Complex Payloads

Complex payloads may include payloads with:

➢ unique measurement sensitivities (e.g. magnetic cleanliness or UV detectors)
➢ deployments, articulation, or work space keep outs
➢ unique electrical or RF interfaces
➢ high dependence on spacecraft resources
➢ mass
➢ power
➢ volume
➢ data storage
➢ data uplink or downlink rate or volume
➢ thermal interface conditions
➢ onboard processing (compression, encryption, filtering, data management, etc.)
➢ unique environment sensitivities (e.g. thermal, solar, dust)

In addition to the test methods described above in the Basic Active Payloads section, additional testing of Complex Payloads may be required by DSS or requested by the Payload Team. This might require extra test steps, special test equipment, unique test configurations, additional integrated testing in laboratory conditions or on the spacecraft. Examples include:

➢ Payload Performance Testing, particularly if this requires payload-specific MGSE or Electrical Ground Support Equipment (EGSE)
➢ Deployment, articulation or other mechanical/mechanisms integrated testing
➢ RF functionality and/or performance testing for spacecraft 802.11N WiFi or 802.11ad WiGig interfaces
➢ Ground based payload calibration on the spacecraft

3.4.5 Qualification

Standard aerospace practice is to qualify space flight hardware with dedicated qualification units, which are tested well beyond maximum expected flight environments, and to then perform Acceptance Testing on separate Flight Units. This is an excellent practice but due to expense is not required or expected.

3.4.6 Protoflight

Protoflight test levels are below qualification levels and durations but establish margin against the maximum expected flight environments of the actual flight hardware. It is fairly standard for a new NASA science payload to deliver an Engineering Development Unit (EDU) for integration into a spacecraft hardware testbed, and to do Protoflight testing on the flight unit prior to delivery and integration.

3.4.7 Flight Acceptance

Established payloads which have previously been qualified, either by dedicated Qualification Testing or by Protoqual or Protoflight testing of a prior flight unit, may be Acceptance tested at levels modestly above the maximum expected flight environments to demonstrate flight readiness. Testing at Flight Acceptance or Protoflight levels is strongly encouraged for all active payloads.

3.5 Integrated Spacecraft Test Program

When payloads are delivered for system integration, DSS will provide resources to accommodate payload standalone testing prior to spacecraft integration. Specific accommodations will be as defined in the ICD, and will include a test bench area capable of supporting payload electrical and mechanical support equipment and any payload-specific needs.

Our Payload Accommodation Engineers (PAEs) will produce the procedures used to interface the payloads to the spacecraft with inputs from the payload providers. The
high level flow of payload integration testing is shown in Figure 3-8  Payload Integration High Level Test Flow.

Prior to mechanical installation fit checks can help ensure interface compatibility. “Electrical Bonding Measurements” and “Power and Ground Isolation Measurements” are also performed as a part of electrical integration. Our standard set of payload interface tests include:

- “Safe to Mate”, a non-powered pin-to-pin checkout to ensure proper channelization of signals and power interfaces;
- “Power Distribution”, a powered interface check which incorporates break-out boxes to verify inrush characteristics, steady state current, signal characteristics and quality; timing and other characteristics.
- “Initial Power Turn-On”, as a part of Spacecraft Powered Testing, this a verification that each payload powers up correctly and starts communicating to the spacecraft after break-out boxes are removed and the payload has been physically integrated onto the spacecraft (including all flight mates);
- “Functional Electrical Test”, a validation that the payload is operating as expected via review of payload telemetry as the payloads are put through each of their different modes; and
- “Payload-Unique Performance Tests”, accommodated as required by each payload team. As part of these tests, DSS will accommodate payload-specific targets, sources, and/or electrical support equipment as defined in the ICDs.

Standard payload tests include Integrated Payload Aliveness (IPA), Integrated Payload Functional (IPF), Integrated Payload Performance (IPP), and Mission/System Tests (MSTs) as described in Section 7 Payload Processing, Launch and Flight Operations. As part of these tests, DSS accommodates payload specific calibration targets, sources and/or electrical support equipment as defined in the ICDs.
After payloads complete their specific interface tests, payload representatives are encouraged (at the discretion of the payload team) to take part in all spacecraft system-level tests, including spacecraft functional and mission scenario testing. The payloads will participate in all spacecraft environmental testing, including thermal vacuum, vibro-acoustics, and EMC/EMI compatibility as shown in Figure 3-9 Integrated Environmental Test Flow.

**Figure 3-9 Integrated Environmental Test Flow**

### 3.5.1 System Launch Dynamics

The vibration and acoustics levels experienced during launch are driving test conditions. Vibration and/or Acoustics testing will be performed at the system level depending on the launch vehicle chosen and the driving environments. System Dynamics testing will be performed at a local test facility such as Ball Aerospace. This will require packing and shipping the integrated spacecraft in its “Envirotainer”.

### 3.5.2 System Shock

Separation from the Launch Vehicle is usually a defining environmental test case. A system level shock test may be performed on a test fixture such as an impulse table. This testing will generally be accomplished in the same configuration as the System Launch Dynamics test.

### 3.5.3 System In-Flight Thermal Vacuum

System level In Flight Thermal Vacuum testing uses cold plates cooled with liquid nitrogen as well as electrically heated hot plates to represent cold and hot sinks inside the vacuum chamber. Although these are not direct analogs of cold space or solar heating, these cold and hot conditions are the basis for test cases that validate thermal models of deep space flight conditions. The models predict the response both for deep space and for the conditions created in the chamber, allowing model correlation to actual test results. This test also allows the active thermal control system, consisting of
closed loop heaters, and passive thermal control systems such as multilayer insulation to be tested. This test requires a significant amount of planning and preparation, and consists of 24/7 testing that will last more than a week.

Transient response simulating maneuvers, attitude changes, and lunar orbit conditions will be performed, as well as steady state hot and cold cases planned to demonstrate predicted response relative to expected flight environments. Payloads requiring deployments in flight or in orbit may be tested with the addition of special fixturing if negotiated and included in the Payload ICD.

Complex instruments or temperature sensitive payloads should plan on supporting this test and being on call around the clock.

3.5.4 System Surface Thermal Vacuum

System level Surface Thermal Vacuum Testing may require a reconfiguration or different thermal vacuum chamber from the above In-Flight test configuration in order to better simulate the post landed environments, with a potentially very hot lunar surface and the sun slowly tracking in an arc through the airless sky. This test has not been designed yet and will strongly depend on the landing site chosen for the mission.

This test may include surface deployments (e.g. mini rover), articulation (e.g. robotic arm), or active mechanical systems (e.g. drill) with the addition of special fixturing if negotiated and included in the Payload ICD.

3.5.5 System EMI/EMC

System level Electromagnetic Interference and Electromagnetic Compatibility (EMI/EMC) will be performed to ensure the conducted and radiated emissions from our flight system do not interfere with sensitive radio receivers, serial interface transceivers, sensors, or other electronics on the integrated spacecraft, and that payloads and spacecraft systems are not susceptible to magnetic field emissions that may be encountered during test, launch or flight operations.

Active payloads that adhere to spaceflight industry standard practices for grounding and shielding should be compatible with the DSS Small Lunar Lander and the Launch Services provider.

Any special payload requirements for magnetic “cleanliness” such at that required for a magnetometer boom will need to be carefully evaluated and may not be compatible with the spacecraft or other payloads.

3.5.6 Mission/System Testing

Standard mission/system testing that involve active payload testing include Integrated Payload Aliveness (IPA), Integrated Payload Functional (IPF), Integrated Payload Performance (IPP), and Mission/System Tests (MSTs) as shown in Figure 3-9 Integrated Environmental Test Flow. As part of these tests, DSS can accommodate payload specific calibration targets, sources and/or electrical support equipment as specifically negotiated and defined in the Payload ICD. A brief description of these test types is provided below:

- Integrated Payload Aliveness (IPA) – An abbreviated test that establishes command and telemetry are working with a few simple commands and telemetry
responses but does not cycle through payload functions. This test is done before and after any significant test configuration changes or vehicle moves, or major test events to establish basic functionality.

- **Integrated Payload Functional (IPF)** – A test designed to exercise all payload interfaces and functions to ensure all interfaces and payload internal systems are operational. This test, or a version of it, may be run repeatedly in system tests such as EMI/EMC to assess functionality over a range of test conditions or test cases.

- **Integrated Payload Performance (IPP)** – The Integrated Payload Performance Test operates each payload in a flight-like way, with simultaneous or overlapping operation consistent with flight and surface operations. If specified in the Payload ICD, this test may include payload MGSE (e.g. targets, covers) or EGSE (e.g. lights, stimulation, data sources).

- **Mission/System Tests (MSTs)** – Mission/System Tests use actual Flight Sequences and Flight Parameters in a spacecraft in the loop test of flight mission phases including:
  - Separation and Initialization
  - Cruise Flight
  - Trajectory Correction Maneuver
  - Lunar Orbit Insertion
  - Coasting Orbital Operations
  - Orbital Payload Deployment Operations
  - Remote Sensing Orbital Operations
  - Communication Relay Orbital Operations
  - Deorbit and Coast
  - Braking, Pitch Over and Landing
  - Surface Operations Day N

### 3.5.7 Mission Dress Rehearsal

After Payload Integration a series of Mission Dress Rehearsals will help prepare the Spacecraft and Payload Teams for Launch, Cis-Lunar Operations, Landing and Surface Operations. Using the Spacecraft or the Hardware-In-the-Loop (HWIL) testbed, various mission phases will be simulated with real time command and telemetry, and with data products and ground communications between DSS and the Payload Teams conducted with exactly the same systems that will be used for the mission.

The involvement of the Payload Teams and formality of these tests will depend on the nature of the Payload. For NASA science instrument payloads it is expected that operations personnel would participate just as they would for flight.
4.0 Mission and System Integration

Clear and open written and verbal communication are key to any successful mission. The DSS team will appoint a Payload Accommodation Engineer (PAE) for each payload who will develop the Payload ICD, coordinate integration and testing in the testbed and on the spacecraft and will continue support during launch vehicle integration and launch site processing. Throughout the process, PAEs keep their payload teams up-to-date on scheduling and logistical status.

For Payload Teams it is critical that the Payload ICD be a complete description of what is expected and serve as a Statement of Work (SOW) for any non-standard items. The PAE will control the Payload ICD, and will instantiate it with standard services such that any services, analysis, material, logistics, additional testing, etc. that would result in technical, cost, schedule, or personnel impacts are identified, coordinated and priced into the Payload Services Contract.

4.1 Mission and System Integration

Unless the Payload Customer is purchasing more than half the system capacity, the landing site, which will drive mission planning and analysis will be selected by committee or the majority Payload Customer.

The Spacecraft System will be tailored and adapted to serve the mission, with mechanical interfaces (e.g. composite panel inserts), stiffeners, flight harness, multi-layer insulation (MLI) and other details implemented in accordance with mission needs.

It is vital to the success of the mission for each Payload Team to clearly communicate their ideal Concept of Operations (CONOPS) early and to work closely with the DSS PAE to get this captured in the Payload ICD, where it can be translated into mechanical, electrical, software, and documentation product designs, test plans, test procedures, and other flight products. Although this is not strictly a first come, first served paradigm, it will certainly be to the benefit of the payloads with the earliest and clearest definition of their design and CONOPS. Since there will likely be differences of opinion, priority, and flight readiness between payloads, there will likely need to be coordination, compromise, and negotiation between Payload Teams. Any conflicts that arise will be immediately raised and remedied as quickly as possible by DSS. Any irreconcilable differences may be referred to 3rd party arbitration.

4.1.1 Deep Space Systems Responsibilities

Deep Space Systems is responsible for the Small Lunar Lander design, manufacture, integration, checkout, launch, and flight operations from launch vehicle separation through the end of the lunar surface mission. This work will take place at the Deep Space Systems headquarters in Littleton Colorado, and test facilities in the Denver/Boulder area, and at the Kennedy Space Center. DSS is responsible for the performance and products of key teammates including Advanced Solutions Inc (flight and ground software systems) and Space Exploration Engineering (mission and trajectory planning and analysis). DSS is responsible for interfacing with the NASA CLPS Program Office.

DSS is also responsible for cultivating commercial lunar payload opportunities and integrating those with NASA CLPS opportunities.
4.1.2 NASA Responsibilities

The NASA Commercial Lunar Payload Services (CLPS) Program Office is responsible for selecting NASA Payloads for flight, developing Task Orders for NASA CLPS Payload Deliveries, selecting CLPS contractors for specific payload delivery services, and supporting the CLPS Payload Teams.

4.1.3 Launch Services Provider Responsibilities

Deep Space Systems will select launch service providers on a mission by mission basis based on the overall best value given mission requirements and constraints. The Launch Service Provider may be a company such as United Launch Alliance or SpaceX, or a Launch Services Broker such as Spaceflight Industries.

The Launch Services Provider is responsible for fulfilling the requirements in the Launch Services Agreement, within the negotiated Terms and Conditions of the Contract. This includes items specified in the appropriate Launch Vehicle User’s Guide.

Generally, this will include the design, manufacture, integration, checkout, and launch of the launch vehicle.

4.1.4 Payload Responsibilities

Each Payload Team is responsible for the design, manufacture, integration, checkout, and operation of their payload. The Payload ICD will define all products that the Payload Team is required to deliver to DSS to support integration, test and flight operation. The Payload Teams are expected to physically or virtually support key integration and test events.

4.1.5 Management and Integration

DSS will appoint a Payload Accommodation Engineer (PAE) for each payload and will have an open door policy for Payload concerns to be brought to the attention of the DSS CLPS Mission Manager and/or Program Manager.

DSS will provide external Management and Integration interfaces to NASA, the Launch Services Provider, and other Commercial Lunar Payload Services Customers.

Technical integration for a specific mission is the responsibility of the DSS Mission/System Design Lead for that mission. The Mission/System Design Lead focuses on engineering integration of the mission, selected landing site, payload compliment, overall CONOPS, and the design, integration, test and flight processes and products necessary to realize the mission. The Mission/System Design Lead has final technical review and approval of all Payload ICDs, and is responsible for tracking of action items, and coordination of technical requirements across engineering disciplines and external interfaces.

4.1.6 Oversight, Insight and Reviews

For NASA Payloads provided by the CLPS Program, DSS will support NASA oversight and insight provided to the CLPS Program Office based on a set of external reviews:
The schedule of these meetings will be tailored to the overall mission schedule, with the MSP-SRR and P/L-IPR occurring relatively early, the P/L-IRR near the mid point, the MSP-FRR and MSP-LRR in the final quarter of the schedule and the Mission End at the conclusion of surface operations.

DSS encourages each Payload Team to include DSS membership on major external reviews and possibly on peer reviews to help ensure successful integration.

### 4.1.7 Payload Interface Control Document

The Payload Interface Control Document (ICD) is the most important governing document for each Payload Team. The DSS PAE controls the contents, revisions and release of the Payload ICD and must get Engineering and Program approvals for any changes that have cost or schedule impacts.

The ICD will be a controlling document and will also identify the electronic location of other controlling engineering and documentation including:

- Computer Aided Design (CAD) Model Files
- Thermal Desktop Model Specifications
- Test Plans
- Test Procedures
- Test and Verification Data
- Other important analysis, design, test and integration soft products

Any non-standard services, fixtures, provisions, consumables, activities, analysis, customization, adaptations, travel, analysis, reports, test events, etc. must be captured in the Payload ICD and approved by engineering and programmatic review by both the Payload Team and DSS.

An outline of the Payload ICD is provided below in Table 4-1 Draft Payload Interface Control Document Table of Contents (scope will be tailored based on payload complexity):
Table 4-1 Draft Payload Interface Control Document Table of Contents

0. Applicable Documents
1.0 Introduction
   1.1 Purpose and Scope
   1.2 Acronyms
   1.3 Payload Description
2.0 Spacecraft Systems and Services
   2.1 Command and Data Handling
   2.2 Flight Software, Sequence and Parameters
   2.3 Communications
   2.4 Electrical Power System
   2.5 Attitude Determination and Control
   2.6 Position Knowledge
   2.7 Structure
   2.8 Active and Passive Thermal Control
   2.8 Propulsion
3.0 Interfaces
   3.1 Mechanical Interfaces
      3.1.1 Structural Interface
      3.1.2 Analysis and Testing
      3.1.3 Grounding and Harness Accommodation
      3.1.4 Thermal
   3.2 Electrical Interfaces
      3.2.1 Physical Layer
      3.2.2 Data Link Layer
      3.2.3 Network Layer
      3.2.4 Connectors
4.0 Command and Telemetry Dictionary
   4.1 Spacecraft to Ground
   4.2 Payload to Spacecraft
5.0 Flight Rules and Constraints
6.0 System Integration and Test Plan
7.0 Appendix I: Electronic File Links for CAD and Mechanical Systems
8.0 Appendix II: Electronic File Links for Electrical Systems
9.0 Appendix III: Electronic File Links to Transportation, Handling, Logistics, Mechanical Integration, Electrical Integration, and Test Procedures

4.1.8 Payload End Item Documentation

For NASA Payloads developed and delivered by NASA Centers or NASA contractors, the Payload End Item Documentation required by NASA should be sufficient for DSS and the Launch Services Provider. In general Payload End Item Documentation should include:

- “as-designed/as-built” (ADAB) record of Payload assembly
- contractual compliance
• traceability and revision levels of all deliverables
• Summary of test records
• anomaly records

4.1.9 Payload Aggregation

Payloads may be aggregated for ease of installation and testing. Passive payloads are candidates for aggregation into a single container or package that provides simpler interfaces, handling and integration.

DSS encourages the use of 3rd party integrators to help ensure that mementos, keep sakes, and treasures are properly handled, documented and prepared for integration and are aggregated into cost effective collections.

4.2 Mission and System Analysis

The Launch Services Provider and the Air Force Range Safety Office will require certain technical documentation, analysis and reports from Deep Space Systems, and some inputs from the Payload Teams may be required to support these obligations.

4.2.1 Coupled Loads Analysis

DSS will provide Coupled Loads inputs to the Launch Services Provider as necessary to support launch integration. This will include a dynamical model of the DSS Small Lunar Lander and its payloads. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.2 Thermal Analyses

DSS will provide Thermal Analysis inputs to the Launch Services Provider as necessary to support launch integration. This may include a Thermal Desktop model of the DSS Small Lunar Lander and its payloads. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.3 Venting Analysis and Flow Impingement Velocities

DSS will provide an analysis of Venting and Flow Impingement Velocities to the Launch Services Provider as necessary to support launch integration. This will include a dynamical model of the DSS Small Lunar Lander and its payloads. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.4 Critical Clearance Analysis

DSS will provide a Critical Clearance Analysis to the Launch Services Provider as necessary to support launch integration. This will include a model of the DSS Small Lunar Lander and its payloads static and dynamic envelopes. Information provided in the Payload ICDs and collected during system level testing should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.5 Spacecraft/LV Separation Analysis

DSS will support Spacecraft/LV Separation Analysis by the Launch Services Provider as necessary to support launch integration. This will include a model of the
DSS Small Lunar Lander and its payloads. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.6 Spacecraft Post Separation Analysis

DSS will perform analysis and testing of post separation tip off rates, conditions and attitudes, and active control spacecraft rate damping and initialization, and will support Spacecraft/LV Separation Analysis to ensure recontact or collision are avoided. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.7 Pyroshock Analysis

DSS will support Spacecraft/LV Launch event and Separation Analysis by the Launch Services Provider as necessary to support pyroshock analysis. This will ensure that our specified shock spectrum bounds expected flight conditions including launch vehicle fairing separation and staging. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.8 Acoustic Analysis

DSS will support Spacecraft/LV Launch Analysis by the Launch Services Provider as necessary to support Acoustics analysis. This will ensure that our specified acoustics spectrum bounds expected flight conditions including launch vehicle launch pad reflections and maximum dynamic pressure conditions during ascent. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.9 Launch Vehicle Induced Interface Vibration

DSS will support Spacecraft/LV Launch Analysis by the Launch Services Provider as necessary to support launch vibration analysis. This will ensure that our specified vibration spectrum bounds expected flight conditions including launch vehicle launch conditions during ascent and possible excitation from the SLL pulse mode thrusters. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.10 Electromagnetic Interference/Electromagnetic Compatibility Analysis

DSS will support Spacecraft/LV EMI/EMC by the Launch Services Provider as necessary to support pre-launch and post-launch conditions. This will ensure that specified EMI/EMC test levels are correct. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical inputs.

4.2.11 Contamination Analysis

DSS will provide inputs for Spacecraft/LV Contamination Analysis by the Launch Services Provider as necessary to support the launch approval process. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.12 RF Link Compatibility and Telemetry Coverage Analysis (Flight)

DSS will perform RF Link Compatibility and Telemetry Coverage Analysis of the flight system under worst case initialization and acquisition conditions to ensure flight
system response and telecom modes and operating states are optimized for initial acquisition of signal.

4.2.13 RF Link Compatibility and Telemetry Coverage Analysis (Ground)

DSS will perform RF Link Compatibility and Telemetry Coverage Analysis of the ground system remote stations under worst case initialization and acquisition conditions to ensure ground system response and telecom modes and operating states are optimized for initial acquisition of signal.

4.2.14 Performance Analysis

DSS will perform integrated vehicle Performance Analysis and testing prior to flight and throughout flight to ensure that critical performance measures including propellant consumption, dead bands, power, active thermal control, passive thermal response, RF link margins, delta V, battery state of charge, and flight computer speed, storage and data transfer metrics are all within expected values. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical inputs.

4.2.15 Stability and Control Analysis

DSS will perform integrated vehicle Stability and Control Analysis and testing prior to flight and throughout flight to ensure that changes in Center of Gravity (CG) as propellant is expelled and imparts expected loads on the internal slosh baffles in the Propellant Management Device (PMD). Settling burns on the small Attitude Control Thrusters are performed as a part of pre-positioning propellant prior to Main Engine Burns. Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical inputs.

4.2.16 Mass Properties

DSS will support Spacecraft/LV Launch Mass Properties Analysis by the Launch Services Provider as necessary to support launch vibration analysis. This will ensure that our specified vibration spectrum bounds expected flight conditions including launch vehicle launch conditions during ascent and possible excitation from the SLL pulse mode thrusters.

DSS will also perform Mass Properties Analysis for mission phases leading up to lunar landing including dynamic conditions associated with the movement and settling of propellant.

Information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical model inputs.

4.2.17 Trajectory Analysis and Design

DSS will perform integrated Trajectory Analysis and Design prior to flight and throughout flight to a precision landing at our target landing site as well as any in flight or in orbit payload events including CubeSat or subsatellite deployment.

4.2.18 Guidance Analysis

DSS will perform Guidance Analysis prior to flight and throughout flight to assess and update our ability to make a precision landing at our target landing site as well as
any targeted maneuvers along the way including trajectory correction and orbital maneuvers. SLL guidance dispersion analysis, and monte carlo simulations, demonstrate that guidance algorithms are insensitive to 3-sigma dispersions by showing that guidance software correctly compensates for these dispersions.

4.2.19 Launch/Landing Window Analysis

DSS will analyze predicted Launch Vehicle Injection dispersions across the launch window and is prepared to perform dynamic mission and trajectory re-planning based on as-executed or off-nominal injection results. To the extent that off nominal conditions drive significant changes to landing site selection or landing site conditions such as local solar time at touchdown, DSS will work closely with payload teams to re-plan and prepare for flight and surface operations.

4.2.20 Flight Safety Analyses and Data

DSS will support Spacecraft/LV Flight Safety Analyses and Data Deliveries by the Launch Services Provider as necessary to support Air Force Range Safety requirements to achieve both Preliminary Flight Plan Approval (PFPA) and Final Flight Plan Approval (FFPA). This may include some involvement by the Payload Team, however we anticipate that information provided in the Payload ICDs should be sufficient for DSS to develop and deliver the required technical inputs.

4.3 Mission and System Safety

4.3.1 Range and Launch Vehicle Requirements

The Launch Services Provider must adhere to a strict regime and requirements in order to gain approval to launch at Cape Canaveral Air Force Station (CCAFS). Both the Launch Vehicle and the Spacecraft design and ground operations must comply with applicable launch site Range Safety regulations, United States Air Force (USAF) requirements concerning explosives safety, and U.S. consensus safety standards. Both the Launch Vehicle and the Spacecraft must comply with applicable facility safety policies during spacecraft processing and integration. DSS must comply with applicable facility safety policies and procedures when using spacecraft processing facilities operated by Spaceport Systems International (SSI), Astrotech Space Operations Inc. (ASO), NASA, SpaceX, or the USAF.

Mission-unique Spacecraft designs and ground processing operations are documented in the Missile System Prelaunch Safety Package (MSPSP) or Safety Assessment Report (SAR). DSS will develop the Spacecraft MSPSP/SAR to describe the Spaceflight system, document potential hazards associated with ground processing operations at the Range (e.g., pressurized systems, propellant systems, propulsion system, ordnance control systems, toxic and hazardous materials, Spacecraft access requirements, RF testing, ionizing and non-ionizing sources hazard controls, battery charging, etc., and associated MGSE, EGSE and operations), and define the means by which each hazard is mitigated to an acceptable level of risk. In particular, DSS will need to provide a Spacecraft Propellant Leak Contingency Plan (PLCP).

Range Safety regulations specify the format and contents of the MSPSP/SAR. The CCAFS Range Safety organization regularly update their safety requirements documents. DSS and the Launch Services Provider will work together to make sure
that applicable policies and procedures are followed and that this process is as transparent to Payload Teams as possible.

4.3.2 Mission Success and Safety Process

The Launch Services Provider selected by DSS for the mission will be the driver for the launch through separation portion of the mission. DSS will follow and support that process which generally consists of:

- Mission Orientation – basic flight system descriptions, timelines, schedules, future deliverable/receivable products, and special topics
- Spacecraft/Launch Vehicle System Safety Assessments and Reports - many of these are identified in Section 4.2
- Launch License – application to the FAA by the Launch Vehicle Provider
- Spacecraft Procedures – prelaunch activities including fueling and pressurants, battery maintenance, etc. requiring Range and Facility approvals
- Flight Design and Range Safety – includes launch vehicle and spacecraft breakup analysis, requires Range approval

DSS will lead Mission Success and Safety analysis for pre-launch integration and post separation mission phases. This will include:

- Payload Orientation - basic flight, test and ground system descriptions, timelines, schedules, future deliverable/receivable products, and special topics
- P/L-IPR - Payload Integration Plan Review
- P/L-IRR - P/L Integration Readiness Review

Policies

4.3.3 Launch Readiness

Generally, missions must proceed based on the overall readiness of the spacecraft, launch vehicle and payloads. Individual Payload ICDs and Contracts will govern whether launch will proceed without a payload if payload readiness fails to be adequate during development, integration or system testing. If the spacecraft system or other DSS-provided systems including the Ground Systems fail to be ready for flight, the Individual Payload ICDs and Contracts will govern the outcome and potential remedies.

4.3.4 Launch Scheduling

Launch scheduling can be complicated by weather or Range Safety factors beyond the control of DSS and the Launch Services Provider. Generally, the Launch Services contract provides for remedies that could include a delayed or rescheduled launch. Delays or cancelation by the primary Ride Share Customer could require rescheduling with a new Ride Share arrangement.

4.3.5 Government vs Commercial Prioritization

The NASA Commercial Payload Services (CLPS) program will have priority over commercial payloads due to their anchor tenant status. DSS will pursue all-commercial payload options, but unless commercial payloads make up the majority of the mission by mass and revenue, the NASA CLPS payloads and NASA’s Science Mission
Directorate priority objectives will drive mission CONOPS, spacecraft resource allocation, operations and landing site selection.

4.3.6 Government Specific Policies

NASA and US Government payloads will follow their own policies, but since DSS is providing commercial payload services, those policies do not govern DSS or commercial payloads except where specifically called out in this document (e.g. Range Safety requirements) or in the CLPS Task Order Contract, or in Payload ICDs, or the Payload Contracts. Generally, DSS has the right to include whatever payloads, mission modifications, system modifications, branding, non-payload data distribution, marketing, licensing, fee for service, or other revenue generating methods that we see fit.

4.3.7 Commercial Specific Policies

Logos and branding are treated as commodities and services and are not authorized unless specifically negotiated in the Payload ICD and Payload Contract. DSS will price the inclusion of logos, branding, spacecraft provided imaging, and other unique commercial advertising or revenue generation business opportunities on a case by case basis, but generally in proportion to size, mass, and other expended resources and risk.

DSS encourages innovation and creativity for generating interest and revenue associated with payloads, mission operations, public engagement, media participation, education, and outreach. Please bring your ideas to DSS mission and program management. We are in this business for fun and profit.
5.0  Payload Accommodations
5.1  Mechanical Interfaces
5.1.1  CubeSat Mechanical Interfaces

The DSS Small Lunar Lander is designed to support standard CubeSat interfaces and dispensers from companies such as Tyvak, ISIS, Rocket Lab, and Planetary Systems. Information on CubeSats can be found at http://www.cubesat.org/.

CubeSats may be deployed In-Flight, In-Orbit or on the Lunar Surface. Possible CubeSat configurations and mounting locations are shown in Figure 5-1 Example SLL Orbital Configuration CubeSat Mounting Locations and Figure 5-2 Example SLL Surface Configuration CubeSat Mounting Locations.

**DSS Small Lunar Lander in Orbital Delivery Configuration**

![CubeSat Mounting Locations](image)

**Figure 5-1** Example SLL Orbital Configuration CubeSat Mounting Locations
Figure 5-2 Example SLL Surface Configuration CubeSat Mounting Locations
5.1.2 Standard Static Envelope Accommodations

The standard volumes available for orbital or surface payloads are illustrated below in Figure 5-3 Standard Volumes Available to Payloads.

![Figure 5-3 Standard Volumes Available to Payloads](image)

5.1.3 Non-Standard Static Envelope Accommodations

Depending on size, mass and other relevant payload characteristics, other mounting locations may be available, including on the lower deck, upper deck, struts, solar array or a custom-built platform or bracket. Please contact DSS for ideas or questions about other locations and applications.

5.1.4 Dynamic Envelope Accommodations

Deployments, articulation, or other types of work space that is needed after launch that falls outside the static envelope are possible and are handled on a case by case basis. Please contact DSS for ideas or questions about other dynamic envelope options and applications.
5.1.5 Optional Mobility System
DSS will develop a Surface Mobility System to customer specifications upon request. Please contact DSS for additional information and pricing.

5.1.6 Optional Robotic Manipulator System
DSS will develop a Robotic Manipulator System to customer specifications upon request. Please contact DSS for additional information and pricing.

5.1.7 Optional Subsurface Drill System
DSS will develop a Subsurface Drill System to customer specifications upon request. Please contact DSS for additional information and pricing.

5.1.8 Custom Payload Options
DSS will develop Custom Payload Options to customer specifications upon request. These might include imaging systems, mechanisms, electronics, harness, sensors systems, or entire payloads. Please contact DSS for additional information and pricing.

5.2 Electrical Interfaces
5.2.1 CubeSat Electrical Interfaces
The DSS Small Lunar Lander is designed to support standard CubeSat interfaces and dispensers from companies such as Tyvak, ISIS, Rocket Lab, and Planetary Systems. Information on CubeSats can be found at http://www.cubesat.org/. Non-standard interfaces and functionality can be accommodated on a case by case basis as negotiated and described in the Payload ICD.

5.2.2 Standard Power Interfaces—+4V, +12V, +28V.
The CLPS lander has 3 primary power busses which are preferred for power transfer. They are tied to Li-Ion batteries with 1, 3, and 7 Li-Ion cells in series for the nominal 4V, 12V, and 28V busses, respectively. The Min, Max, and nominal voltages for each of the busses is given in Table 5-1

<table>
<thead>
<tr>
<th>Bus Voltage (V)</th>
<th>Nominal</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>4V</td>
<td>4.1</td>
<td>3</td>
<td>4.2</td>
</tr>
<tr>
<td>12V</td>
<td>12.3</td>
<td>9</td>
<td>12.6</td>
</tr>
<tr>
<td>28V</td>
<td>28.7</td>
<td>21</td>
<td>29.4</td>
</tr>
</tbody>
</table>

Each payload power feed has current and voltage telemetry which can be provided in the payload data, software-settable over-current protection, and a controlled rise time of 200 microseconds to limit in-rush currents. Current limits during and after initial turn-on are negotiable. The number and type of power feeds are negotiable.

Total power available for the sum of all payloads is 150W during lunar transfer and surface operations. A smaller amount of power is also available during low lunar orbit operations for survival heaters and limited-duration operations.
5.2.3 Non-Standard Power Interfaces

Non-standard power interfaces, including regulated power at voltages and currents to be negotiated, can be accommodated on a case by case basis as negotiated and described in the Payload ICD.

5.2.4 Standard Command and Data Interfaces

The physical interface for standard command and data is a bi-directional RS-422 standard over shielded, controlled-impedance harness. The preferred data format for commands and telemetry is:

- Universal Asynchronous Receiver-Transmitter (UART) with baud rate evenly divisible by 1200 baud, up to 4915200 bits/second.
- Packet framing by idle line detection
- Up to 128 kBytes (1048576 bits) per packet
- Packet format with a simple header and Application Process Identifier (APID) which defines the packet type and length: (16 bit APID, data with length per APID definition, and a 16 bit Cyclic Redundancy Check (CRC).

Other RS-422 or Low Voltage Differential Signaling (LVDS) based C&DH interface formats are supported, including a synchronous serial interface (clock/data or clock/data/frame), a UART with a separate packet framing signal. 802.11 wireless interfaces are described in 5.3.6.

5.2.5 Non-Standard Command and Data Interfaces

SpaceWire or Ethernet can be supported at additional cost, with interface electronics power consumption coming from the payload allocations.

5.2.6 Standard Flight Instrumentation

The spacecraft provides telemetry for payload power switch current and voltage. These measurements will be sent to the ground as part of spacecraft engineering telemetry and can be sent to the payload over on-board serial.

5.2.7 Standard Payload Heater Zone

One temperature sensor and one 28V heater channel are included with each powered payload service. The heater channel supports heaters up to 3 Amps and can be controlled via spacecraft thermal control software according to the temperature sensor and a software-settable setpoint or turned on or off by ground command. If not used for a heater, this channel can be used by the payload for other purposes.

The temperature sensor is monitored by the spacecraft after spacecraft separation even when the payload is powered off and is typically telemetered back to Earth as part of the spacecraft engineering health and status. The temperature measurement can also be sent to the payload over the on-board serial interface.

Additional heater zones are available and negotiable.
5.3 Computation, Data Storage and Transmission Interfaces

5.3.1 Spacecraft Provided Payload Processor

The DSS small lander provides a dedicated payload processor which hosts the serial interfaces to all the payloads. This processor has approx. 2.5 times the computational power of a RAD750. Software for payload data processing can be hosted on this computer on a case by case basis as negotiated and described in the Payload ICD.

5.3.2 Spacecraft Provided Payload Data Storage

The standard service provides data storage sufficient to buffer payload downlink data. Additional on-board data storage for payload data processing can be accommodated on a case by case basis as negotiated and described in the Payload ICD.

5.3.3 High Integrity, High Security Data Transmission

The spacecraft will use AES 128 encryption (or equivalent) in the radio at the link layer during communications with Telemetry, Tracking, and Command (TT&C) stations. Encryption keys will be loaded prior to flight and used to encrypt every packet sent and received over the main command and telemetry link. All payload data will be encrypted and stored locally (on-board the satellites) using AES-256 and transmitted in this format. All facilities with direct access to the spacecraft will employ multiple layers of physical protection for security. All spacecraft and payload data will pass through cloud-based web-services managed by DSS prior to delivery to the payload teams. ASI has similar experience through their partner company, Astro Digital, in protecting Earth imagery data via a NOAA-approved Data Protection Plan.

5.3.4 Spacecraft Provided Camera System

The DSS small lander has seven high-resolution visible light cameras in a variety of locations for situational awareness and vision navigation. The locations, fields of view and pointing of the cameras for payload purposes, as well as additional cameras, can be accommodated on a case by case basis as negotiated and described in the Payload ICD.

The camera system records 4K video at 30 frames on up to five cameras simultaneously. These cameras can be configured to provide a Virtual Reality (VR) 360 coverage, and/or to provide stereo vision recording. DSS is interested in providing cinematic quality video throughout the mission, including time lapse photography, and welcomes input and involvement from organizations that can utilize or enhance the image system products that we create and return to Earth.

5.3.5 Spacecraft Provided LoRa Radio System

Some payload applications can benefit from a communications capability that combines long range (~ 100 Km line of sight), ultra-low power (< 1 mW average power) and a small form factor (~1 sq inch, < 10 grams). DSS has extensive experience with this technology and can provide it on a case by case basis as negotiated and described in the Payload ICD.
5.3.6 Spacecraft Provided 802.11 WiFi Radio System

802.11 WiFi is available on a case by case basis as negotiated and described in the Payload ICD. DSS has experience qualifying 802.11a, b, n, and 802.11ad (WiGig) hardware for space applications.

5.4 Ground and Test Interfaces

5.4.1 Spacecraft Electrical Interface Simulator

Our early integration process includes traveling with a “Payload Suitcase test set” to Payload providers facilities to support risk reduction activities including electrical interface, software and firmware compatibility checks. The Payload Suitcase is utilized by payload providers to facilitate the development and maturation of their payload-specific software, mission science planning and script development.

5.4.2 Spacecraft Mission Simulation

A key capability used from the beginning of hardware-in-the-loop (HWIL) testing is the On-Board Dynamic Simulation System (ODySSy). ODySSy is a full-featured spacecraft simulation built directly into the flight code that can model all aspects of the Attitude Determination and Control System (ADCS) subsystem, as well as other subsystems, to form a closed-loop environment around the flight software as shown in Figure 5-4. ODySSy is configurable as an all-digital or simulation on a per-component basis. Simulation models of payloads will be incorporated into the mission simulation, with increasing fidelity reflecting increasing maturity of the payload hardware and software.

5.4.3 Spacecraft Hardware in the Loop TestBed

The Spacecraft Hardware-In-the-Loop (HWIL) testbed is a complete avionics system with each interface supported both electrically and with flight software. As components and payloads arrive (EDU and flight), they are checked out in the HWIL testbed prior to installation on the flight vehicle. All hardware and software interfaces will be verified using the HWIL testbed prior to ATLO start. Establishing and maintaining the HWIL
testbed early in the program with all interfaces operating will ensure a smooth transition to formal qualification reducing the overall risk at each step of the program.

5.4.4 Spacecraft Fit Check Mockup

One method of helping to ensure mechanical interface compatibility is to exchange interface templates, mass models or mockups to use in pre-integration fit check exercises. DSS will build a spacecraft mockup with a composite main deck that can be used for fit checks and can accept flight type fastener inserts (“spools”). Although CAD modeling will also be used extensively for compatibility analysis, the mockup will be a valuable tool for planning work and visualizing and validating harness paths and potential access restrictions.

5.4.5 Custom Ground and Test Interface Options

DSS personnel have worked with many science instrument teams and understand that payload integrators may have special needs that may require special test equipment, special red tag (remove before flight) or green tag (install before flight) items and/or access needs, or the use of non-flight interfaces. DSS will strive to support special ground and test interface options. These should be identified as soon as possible and documented in the Payload ICD in order to assure a smooth integration and test experience.

5.5 Commemorative Flight Experience Package

5.5.1 In Flight Videos and Image Library

Digital media including images and videos will be distributed along with a link to a publicly accessible Library of images, videos and documents that tell the story of the Mission and the people involved. This may include documentation of the design, development, integration, test, launch, and flight operations of the mission, including press kits, edited and produced video, and unprocessed and archive data. Any material in this collection will be included only based on signed releases of non-copyrighted material.

Copyrighted and exclusive content will not be publicly accessible.

5.5.2 Flight Experience Kit

Your Flight Experience Kit will include, photos, press packages, T-shirts, hats as well as mementos such as stickers, pins, and models. Those who are able to travel to the Kennedy Space Center will be invited to Pre-Launch and Post-Launch dinner parties and will have the option to be bussed to a launch viewing area with snacks and drinks provided on the day of launch.
6.0 Payload Envelopes and Work Spaces

6.1 Payload Envelopes

6.1.1 Launch Payload Dynamic Envelope

The DSS SLL has "saddle bag" mounting locations on the +Y and -Y sides of the spacecraft. The standard payload envelopes applicable to both locations on the SLL are shown in Figure 6-1 Standard Payload Saddlebag Dynamic Envelopes.

Figure 6-1 Standard Payload Saddlebag Dynamic Envelopes

These dimensions define the dynamic envelopes for mounted payloads and any payload harness, brackets or other provisions necessary to support the payload through
the dynamics of launch. These envelopes generally account for whatever vibration displacement may take place during launch. Some of these enveloping dimensions may be re-negotiated based on coordination with the spacecraft and/or launch vehicle analysts. Additional volumes on the lower side of the main deck, on the solar arrays, on the struts, the tank skirt, or other unoccupied volumes are possible and questions regarding productive use of these volumes are welcome. Any exception to these standard envelopes must be coordinated and included in the approved Payload ICD.

6.1.2 Storage and Transportation

For convenience and safety, all users should assume that storage and transportation envelopes are the same as the Launch envelopes specified above. If a cover or other special equipment such as a purge is required for storage and/or transportation and does not fit within the launch dynamic envelope, it must be carefully coordinated and called out in the Payload ICD.

6.1.3 In Flight and In Orbit

For simplicity and safety, all users should assume that In-Flight and In Orbit envelopes are the same as the Launch envelopes specified above. If a deployment, cover removal, door, or other post launch configuration change is required that extends beyond the launch dynamic envelope, it must be carefully coordinated and called out in the Payload ICD.

CubeSats will mounted in such a way that their deployment mechanisms and swept volumes for deployment are planned in advance and are therefore known exceptions to the launch dynamic environment restriction.

DSS has preferred CubeSat Dispenser suppliers and prefers to provide the Dispenser as a service, but we will work with Payload Teams to ensure that Dispensers selected by the Payload Team are properly integrated.

6.1.4 Landing and Surface

Due to the critical nature of landing, no active payload reconfigurations are allowed after lunar orbit operations. Payloads may be operated throughout descent and landing as long as they do not result in changes of mass, moment of inertia, or dynamic response. Static envelopes established in orbit will remain in effect through landing.

Surface operations may involve deployments (e.g. mini rovers), articulation (e.g. robotic actuators), or near surface alteration (e.g. drills and tailings), therefore it is expected that envelopes will change.

6.2 Payload Fields of View and Workspace

DSS will work with each Payload Team to establish fields of view, stay out zones, and/or work space envelopes as appropriate. If applicable, these will be documented in each individual Payload ICD.

6.2.1 Storage and Transportation

Generally during storage and transportation, static and storage envelopes will apply, and workspace and field of view provisions will not apply.
6.2.2 Launch

Generally during launch processing, static and storage envelopes will apply, and workspace and field of view provisions will not apply.

6.2.3 In Flight

In Flight payload optical and thermal fields of view, stay out zones, and/or workspace envelopes shall be as specified in the Payload ICD. In Flight operation and/or checkout will be supported as specified in the Payload ICD.

6.2.4 In Orbit

Orbital operations may come with some special constraints or operational considerations relative to power dissipation, changing thermal fields of view, spacecraft attitudes, and the natural environments depending on lunar orbital characteristics. In Orbit payload optical and thermal fields of view, stay out zones, and/or work space envelopes shall be as specified in the Payload ICD. In Orbit operation and/or checkout will be supported as specified in the Payload ICD.

6.2.5 On Surface

Surface operations should be expected to vary by latitude, site characteristics and local solar time. For instance, operation in mountain valleys or deep craters will affect the local horizon, decreasing the view to space and increasing local surface temperatures.

DSS will work closely with Payload Teams that have surface operations workspace requirements to understand static and dynamic envelopes, swept volumes, fields of view, fields of regard, and potential sensitivity to lunar dust. Complex interactions between Payloads are possible and will be analyzed and simulated to help ensure trouble free lunar surface operations. Depending on the complexity of the workspace requirements, the Payload ICD may need to include extra modeling and simulation requirements, or EDU hardware used in a testbed environment.

6.2.6 Surface Mobility

DSS can accommodate deployable ramps or other types of mechanisms to support the deployment of a free roving payload. Tethered or wireless connections to the SLL can be coordinated as well. The DSS SLL provides 802.11N connectivity as a standard service. DSS can provide a mobile surface rover as well if desired.
7.0 Payload Processing, Launch and Flight Operations

An overview of spacecraft and payload processing from assembly and integration through integrated environmental testing and launch operations is shown in Figure 7-1.

In the left of the figure, major lander subassemblies are provided by DSS and our approved supply chain including propellant tank from Northrup Grumman Innovation Systems. The main composite deck panel, struts, tank skirt, and mechanical interfaces are shipped to our teammate Aerojet Rocketdyne in Redmond Washington where propulsion components including valves, filters, and engines are integrated onto the deck, the tank is mounted to the struts, the system is welded together, and proof pressure testing is performed before shipment back to DSS.

Meanwhile, at the DSS Facility in Littleton Colorado, the flight avionics including Command and Data Handling (C&DH), Electrical Power System (EPS), Camera Systems, Telecommunications System, and Guidance, Navigation and Control (GN&C) are being integrated onto a FlatSat table that mimics the main deck. This FlatSat configuration is also very similar to the FlatSat Hardware-In-The-Loop (HWIL) Testbed that will be a permanent test asset used to test out Payload EDU hardware in Mission/System level tests prior to Flight Payload Deliveries.

Once the integrated propulsion system is delivered by Aerojet Rocketdyne, the Assembly Test and Launch Operations (ATLO) phase of the program begins. The tested and fully operational flight avionics are transferred onto the main deck and the systems is ready for Payload Integration.

For Payload teams that would like to get an early start on Payload Electrical Checkout, DSS will provide a “Payload Suitcase” and a test engineer to support electrical checkout. This helps ensure interface compatibility when EDU and/or Flight hardware is delivered. The Payload Suitcase has every type of standard electrical interface offered on the SLL in sufficient quantity to interface to any single payload. With this portable test system voltages, signal characteristics, pin outs, timing, FPGA programming, protocols, and other relevant interface functionality and performance can be validated in advance of integration into the FlatSat or Spacecraft.

Once the fully assembled spacecraft has been checked out and undergone Mission System Test (MSTs) with the Payloads using flight sequences and flight parameters it is ready for system level environmental testing, which will take place at the Ball Aerospace test facilities in Boulder CO, a short drive from Littleton. Environmental Testing will include Launch Vibro-Acoustics, Separation Shock, Thermal Vacuum and EMI/EMC with Payloads operated in a flight like way for Thermal Vacuum and EMI/EMC.

Shipping of the integrated spacecraft to and from Boulder will use air ride trucking, and subsequent shipment to the Kennedy Space Center will be via standard air cargo. Both methods will use a commercial “Envirotainer” to maintain temperature and humidity levels in transit and to record environmental data throughout transit and storage.
Figure 7-1: Overview of Spacecraft and Payload Integration Through Launch Operations
7.1 Deep Space Systems Payload Integration Facilities

Payload integration and environmental testing will take place at the Deep Space Systems facility in Littleton, Colorado. Once environmental testing is complete the integrated lander system will be shipped to the Kennedy Space Center for Launch Vehicle integration and launch.

7.1.1 DSS Littleton Colorado Facility.

The Deep Space Systems Facility is located at 8100 Shaffer Parkway, Littleton, CO 80127 as shown in the following Figures showing the southwest Denver Metro Map in Figure 7-2, the local street map in Figure 7-3, and the building aerial view and entrance in Figure 7-4.

![Figure 7-2: DSS is located in beautiful Littleton Colorado in the Denver Metro Area](image)

DSS is able to accommodate payload teams of 3 to 5 personnel in the 8100 Shaffer Parkway location and some nearby office space that can be used if multiple teams are present at the same time. Depending on the size of the payload team, the degree of NASA participation, and the number of payload teams present, DSS will assign shifts and accommodations in coordination with our customer’s needs and the overall integration plan. Generally, the goal will be to integrate one payload at a time, but powered on electrical testing and mechanical integration activities must often be interwoven.

A building floor plan and work area illustration is provided in Figure 7-5: DSS Facility
at 8100 Shaffer Parkway in Little Colorado.

For system environmental testing, the integrated lander system will be packed in an “Envirotainer” and shipped via truck to nearby Boulder, Colorado for Dynamics, Thermal Vacuum and EMI/EMC testing. Payload team participation in these tests will be limited due to constraints of the Ball Aerospace facilities. Round trip time to and from Ball Aerospace in Boulder to the DSS facility in Littleton is about 1.5 hours in good weather.

![Figure 7-3: DSS location, on 8100 Shaffer Parkway, is near by many Hotels and Restaurants](image)

DSS can provide recommendations for travel and logistics upon request.
Figure 7-4: Visitor entrance to the DSS Facility is on the west side of the building
Figure 7-5: DSS Facility at 8100 Shaffer Parkway in Little Colorado

New DSS Facility
8100 Shaffer Parkway
Littleton, CO 80127
19,000 sqft current total
Lease with option to buy an additional 17,000 sqft
Move Completed in Sept 2018

Option on Additional 17,000 sqft

Office Space
High Bay

Deep Space Systems Small Lunar Lander

8/30/2019

DSS SLL User's Guide
7.1.2 Shipping and Receiving

DSS prefers that shipments be accomplished with bonded and licensed carriers with formal tracking and insurance provided prior to delivery.

Once all payloads have been integrated, the integrated lander system is transported to and from system environmental testing at Ball Aerospace in Boulder, Colorado and to the Kennedy Space Center in an “Envirotainer” as standard air freight. The “Envirotainer” is pictured below in Figure 7-6: Integrated Lander System Shipping.

![Envirotainer Image]

**Figure 7-6: Integrated Lander System Shipping**

7.1.3 Non-Standard or Hand Delivery

DSS will accept non-standard or hand delivery of payloads when this method is coordinated with the DSS team and specified in the Payload ICD.

7.1.4 DSS Cleanroom

DSS provides a 10,000 Class Clean Room to support payload integration and testing as shown in Figure 7-7 DSS 10,000 Class Clean Room.
Cleanliness levels are always maintained to Visibly Clean. Contamination-critical hardware surfaces are cleaned and inspected to Visibly Clean Level 2 (free of all particulate and molecular contaminants visible to the unaided eye at a distance of 15.2-45.7 cm (6-18 in.) with a minimum illumination of 1,076 lumen/m²). Hardware cleaned to this criterion is protected to maintain this level of cleanliness through shipping, launch vehicle integration and encapsulation.

If requested, Tape Lift Sampling, Ultraviolet Light Inspection, or Customer Provided Witness Plates can be employed if specified in the Payload ICD.

Additional anti-static covers or other Remove-Before-Flight devices provided by the Customer or DSS can be used based on instructions in the Payload ICD.

**Clean Room 1 — Class 10,000**

- Temperature 23.8 ±2.8 °C (75 ±5 °F)
- Relative Humidity 50 ±10%
- Usable Floor Space 11.0 x 7.3 m (36 x 24 ft)
- Ceiling Height 4.8 m (16 ft)
- Crane Type - Bridge Crane
- Capacity 1.0 tonne
- Crane Hook Height 4.3 m (14.0 ft)
• Roll-Up Door Size (w x h) 3.0 x 3.6 m 10 x 12 ft
• Available Commodities: Compressed Air, Dry Nitrogen, Vacuum
• Clean Room suits, masks, gloves, booties, and ESD wrist bands are provided

7.1.5 Payload Team Accommodations

The Payload team, consisting of US citizens or Permanent Residents (Green Card Holders), is provided one common room with:

• 4 Desks and 4 swivel chairs
• Whiteboard
• 42” or larger monitor for video conferencing
• Wireless 802.11AC connectivity to the internet behind a firewall
• 120V AC power and power strips
• Mini Fridge and access to shared kitchen
• Access to Conference Rooms if scheduled
• Access to Rest Rooms

Non-US Citizens associated with the Payload Team may visit but must be escorted at all times by a DSS employee, and only when pre-coordinated with the DSS Team or as specified in the Payload ICD.

Generally, it is the responsibility of the Payload Team to bring their own laptops, personal electronics, payload-unique supplies, Payload Mechanical Ground Support Equipment (MGSE), Payload Electrical Ground Support Equipment (EGSE), and to arrange their own travel, hotel accommodations, meals and incidentals.

Storage for shipping containers will be provided in a warehouse class environment.

Our bonded storage area with environmental controls can be used for sensitive or high value equipment if specified in the Payload ICD.

7.1.6 Non-Standard Payload Accommodations

Payload accommodations, materials, logistics, or services not specifically listed above can be provided as negotiated and coordinated by inclusion in the Payload ICD. Requests for accommodation that are outside of standard accommodations and the Payload ICD should be brought up your DSS Payload Accommodation Engineer as soon as the need is identified and may result in additional cost.

7.2 Launch Site Integration

The DSS Small Lunar Lander is a secondary or RideShare Payload mounted to a standard 24” ESPA Grande port. The ESPA Ring may be accommodated by a variety of Launch Vehicles including the SpaceX Falcon, ULA Atlas 4/Atlas 5, NG Omega, Blue Origin New Glenn, and other future launch systems.

DSS will arrange for the launch vehicle and launch integration services.
In general, SLL Lander Payload Teams will NOT be required to support launch vehicle integration and/or launch operations. Like most missions in this class, our Small Lunar Lander system is designed for “Ship and Shoot” operations. Payload team members and associates are encouraged to travel to KSC to witness the launch, but any accommodations at the launch site required to be fulfilled by DSS must be specified in the Payload ICD.

7.2.1 Astrotech Integration Facility

Depending on the launch service selected, DSS SLL integration may take place at the Astrotech facility at KSC. Information about this facility can be found at their website:

http://www.astrotechspaceoperations.com/

7.2.2 Restrictions on Launch Site Integration

Any post-shipment and pre-launch activities required by the Payload Teams such as Remove-Before-Flight (red tag) or Install-Before-Flight (green tag) items will be performed by the DSS launch team as specified in the Payload ICD.

Any need for Payload Team participation must be identified in the Payload ICD. All launch vehicle and payload processing and integration facilities at KSC will be restricted to US citizens or Green Card Holders.

7.2.3 Launch Site Delivery

Delivery of SLL payloads to the launch site is only allowed for passive payloads that have no electronics, and as specified in the Payload ICD. Mass simulators are required for all such payloads to be used in system level environmental testing.

7.2.4 Late and Non-Standard Payload Accommodations

Late delivery of SLL payloads to the launch site is strongly discouraged, and in general will not be accepted. Exceptions must be coordinated with DSS Mission Managers. For instance, if adequate simulators or EDUs are provided for system level environmental testing, and late installation is carefully coordinated, an exception may be granted. Such exceptions will result in additional cost.

7.2.5 Do No Harm Screening and De-Integration

Payloads on the DSS SLL must pass an independent Spacecraft Safety and Range Safety Review. The Spacecraft Safety Review is an internal review that includes analysis of system level environmental testing. Failure to pass either of these reviews will result in the removal of the Payload prior to launch.

“Do No Harm” is a key philosophy and mantra of the Air Force Range Safety Officer. The burden of proof is on Deep Space Systems and the Payload Teams to prove that all aspects of our system are ready for flight and cannot damage the launch vehicle, the launch pad or launch infrastructure, injure personnel working at the launch site, or in any way endanger the Space Coast population.

Underwriters for the companies insuring the mission, the primary payload, and associated launch facilities and equipment, have a fiducial responsibility to ensure that
our SSL system does not represent a significant risk to their interests.

7.2.6 Mass Simulators
Mass simulators are required in the event that a SLL payload needs to be removed prior to launch for any reason. The mass simulator must closely match the mass and moment of inertia properties of the Payload. The mass simulators are provided by the Payload Team unless otherwise specified in the Payload ICD.

7.3 Countdown and Launch

7.3.1 Pre-Launch Activities
DSS personnel will attend every launch.

7.3.2 Customer Accommodations
Customers are expected to make their own arrangements for travel to KSC, hotels accommodations, meals and other incidental expenses as desired. Customers and guests should be advised that launch delays are not uncommon, and sometimes result in multiple scrubs or even cancelation.

7.3.3 Pre-Launch Activities
DSS will host a pre-launch party at a local restaurant suitable for guests of any age. Some pre-launch gifts will be distributed including T-shirts and hats.

7.3.4 Day of Launch Activities
DSS will also arrange for transportation to a launch viewing area. Customers and guests should be advised that the launch may take place at any time of the day or night.

7.3.5 Post-Launch Activities
DSS will host a post-launch party at a local restaurant suitable for guests of any age. Digital media including images and videos will be distributed, as well as mementos such as stickers, pins, and models.
8.0 Other Capabilities

Deep Space Systems was selected by NASA for the CLPS Program based on the Midsize Lander which is summarized in Figure 8-1 Summary of the DSS Midsize Lander.

Task Order 2 did not require a lander with these capabilities, therefore the Small Lunar Lander was proposed for the initial mission.

8.1 DSS Midsize Lander

The DSS Midsize Lander provides the option to land directly on wheels, with the addition of a mobility package, or on conventional landing gear. The mobility package includes 4 wheel drive, 4 wheel electronic Ackerman steering, and independent suspension. The foot print and ground clearance are very similar to the Lunar Roving Vehicle (LRV) developed for the Apollo program and flown on Apollo 15, 16 and 17, which had a design top speed of 13 km/h (8 mph), but was actually driven at up to 18.0 km/h (11.2 mph) by Gene Cernan on Apollo 17.

When equipped with a 1 meter depth rotary percussive drill and mobility package, the vehicle can move quickly over most terrain when driven remotely by an Earth based driver with a ~3.0 second speed of light time delay. The mobility system is equipped with an autonomous safety system that brings the vehicle to a stop if predicted driving parameters are exceeded. Earth based vision systems take in the same video and image streams as are presented to the driver, and based on the driver's driving commands for throttle, steering and braking develops real-time predictions of the response of the vehicle. These predictions prevent overly aggressive commands from being sent, and provide an envelope to assess measured behavior as predicted versus experienced on the remote vehicle. Lander sensors including accelerometers, gyros, wheel position, torque, temperatures, and other sensor measurements, are analyzed on board for safety limit violations that would result in a “safe mode stop”.

The vehicle configuration shown in Figure 8 1 Summary of the DSS Midsize Lander was specifically developed for lunar polar volatile exploration and the ability to circumnavigate the polar region, remaining in sunlight through the long lunar day by staying near noon local solar time. This is known as the Magellan Traverse, and several feasible routes have been proposed which would either require a relay communications satellite for far side operations, or an autonomous driving system based on terrain recognition and onboard path planning and hazard avoidance.

The Midsize Lander can deploy standard CubeSats in orbit or on the surface of the Moon, and therefore can emplace its own communications relay capability. With the addition of a robotic arm the Midsize Lander can emplace payloads on the surface, collect and transport samples, and manipulate items as needed. Without the mobility option the landing gear pads are equipped with an abrasion tool and two nitrogen gas driven sample delivery systems, one that delivers fine particles and one that delivers sieved rocklets to payloads on the body of the lander.

Like the DSS Small Lunar Lander, the Midsize Lander is designed to survive multiple Lunar nights by employing a hibernation mode.
Deep Space Systems Midsize Lander

**Payload Summary**
- **Mass:** up to 100 kg
- **Volume:** 3.36 m³
- **Power:** 400 W (all mission phases)
- **Comm:** 1-10 Mbps downlink
- **Destination:** High Latitude Sites
- **Landing:** DSS Midsize Lander

**Payload Volumes**
- Upper Cargo: 0.9 m³
- 2X Cargo Overflow: 0.26 m³
- 2X Cargo: 0.85 m³
- 4X Lower Cargo: 0.06 m³

**Standard Payload Features:**
- Multiple Data Interfaces
  - < 1 Mbps: UART serial over RS-422, RS-485, LVDS
  - > 1 Mbps: 10/100/1000 Ethernet, SPI over LVDS
  - Available: SPI, I2C, USB, Spacewire, MIPI CSI, Quad-SPI, I2S, 1553, Wi-Fi, CAN, low-voltage discretes, high-voltage discretes, and RS-422 differential discretes, heater control
- Multiple Power Interfaces:
  - Preferred: 28V
  - Available: 12V, 5V, or selectable voltage above/below 28V
- **Data Storage:** 1000 GB (1 TB)
- **Payload Survival Heaters** (two wire system)
- **HiRes Camera Package** (6 VisCams)
- **Orbital/Surface Cubesat Deployment** (1U to 27U)

**Special Lunar Science Features:**
- Surface Roving Operations (up to 3 km/hr)
- 1 m Rotary Percussive Drill
  - Sample Delivery to Payloads
- Propulsive Hop Mobility (up to 4 km)
- Lunar Night Survivability
- Easy Access to Surface

**More Options and Services:**
- 6 DOF Robotic Arm and Appendages
- Mast Mounted Payloads
- Auxiliary Solar Panels
- High Capacity Battery (60 Ahr)
- Up to 6 TB of Data Storage
- UHF Data Relay to Orbit (>128 Kbps 2 way)
- Payload Dedicated i5 Computer
- WiFi and/or WiGig Surface Radio Systems
- Custom Camera System
- Complete Payload Design, Development, Test and Integration Service
- Orbital Cubesat Deployment (1U to 6U)
- Surface Cubesat Deployment (1U to 16U)

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Figure 8-1 Summary of the DSS Midsize Lander
Small Lunar Lander Enhancements and Future Missions

DSS welcomes input and ideas for evolving the capabilities of the Small Lunar Lander, and for identifying mission concepts that the current or evolved vehicle is capable of performing.

We believe that this small, simple, low cost system is ideal for a variety of missions that could not be accomplished with a larger, more complex, and/or expensive lander system. These potential Mission applications include:

- Emplacement of a global lunar seismic network
  - “Lunar Geophysical Network—This mission consists of several identical landers distributed across the lunar surface, each carrying instrumentation for geophysical studies.”

- Direct propulsive entry into a Lunar “Skylight”
  - Potential entrance to a lunar lava tube that may provide underground radiation shielding for human habitats
  - The ability to fly over and land next to a Skylight, study it extensively, and to then actually take off and land inside the Skylight providing the most cost-effective method of obtaining ground truth on these structures

- Direct investigation of multiple highly localized and unique features such as “Magnetic Swirls”
  - Lunar swirls correspond to highly local regions of relatively high magnetic field strength, where each swirl is associated with a magnetic anomaly, but not every magnetic anomaly features a swirl.

Note that several small directed missions to enigmatic features such as Lunar Polar Volatiles reservoirs, Lunar Skylights and/or Magnetic Swirls could also help emplace the seismometer network required to achieve the decal survey objective of a Lunar Geophysical Network.

Lunar Sample Return

The DSS Midsize Lander has sufficient performance and precision to deliver a Sample Return Ascent Vehicle to the proximity of a lunar roving vehicle for sample transfer and return to Earth of samples totaling ~0.3 kg.

Lunar In-Situ Resource Utilization

The DSS Midsize Lander has sufficient performance to deliver In-Situ Resource Utilization (ISRU) experiments over 100 kg in mass.
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tr>
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<td>One Pulse Per Second</td>
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<td>3D</td>
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<td>ACS</td>
<td>Attitude Control System</td>
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<td>SV</td>
<td>Space Vehicle</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
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<tr>
<td>---------</td>
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<tr>
<td>SW</td>
<td>Software</td>
</tr>
<tr>
<td>SWaP</td>
<td>Size, Weight, and Power</td>
</tr>
<tr>
<td>SWIR</td>
<td>Short Wavelength Infrared</td>
</tr>
<tr>
<td>TBR</td>
<td>To Be Resolved, Revised, or Reviewed</td>
</tr>
<tr>
<td>TCM</td>
<td>Trajectory Correction Maneuver</td>
</tr>
<tr>
<td>TCS</td>
<td>Thermal Control System</td>
</tr>
<tr>
<td>TDI</td>
<td>Time-Delayed Integration</td>
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<tr>
<td>TEC</td>
<td>Thermal Electric Cooler</td>
</tr>
<tr>
<td>TFM</td>
<td>Telemetry Formatter</td>
</tr>
<tr>
<td>TIM</td>
<td>Technical Interchange Meetings</td>
</tr>
<tr>
<td>TiNi</td>
<td>Titanium Nickle</td>
</tr>
<tr>
<td>TLI</td>
<td>Trans Lunar Injection</td>
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<tr>
<td>TLYF</td>
<td>Test Like You Fly</td>
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<tr>
<td>TO</td>
<td>Task Order</td>
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<tr>
<td>TO2</td>
<td>Task Order 2</td>
</tr>
<tr>
<td>TRL</td>
<td>Technology Readiness Level</td>
</tr>
<tr>
<td>TRR</td>
<td>Test Readiness Review</td>
</tr>
<tr>
<td>TT&amp;C</td>
<td>Telemetry, Tracking, and Command</td>
</tr>
<tr>
<td>TVAC</td>
<td>Thermal Vacuum</td>
</tr>
<tr>
<td>UART</td>
<td>Universal Asynchronous Receiver-Transmitter</td>
</tr>
<tr>
<td>USAF</td>
<td>United States Air Force</td>
</tr>
<tr>
<td>USG</td>
<td>United States Government</td>
</tr>
<tr>
<td>UV</td>
<td>Ultraviolet</td>
</tr>
<tr>
<td>VDC</td>
<td>Volts Direct Current</td>
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<tr>
<td>Vis</td>
<td>Visible</td>
</tr>
<tr>
<td>VNIR</td>
<td>Visible-Near Infrared</td>
</tr>
<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>WAS</td>
<td>Wide Area Surveillance</td>
</tr>
<tr>
<td>WBS</td>
<td>Work Breakdown Structure</td>
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<tr>
<td>WG</td>
<td>Working Group</td>
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<tr>
<td>WOSB</td>
<td>Women-Owned Small Business</td>
</tr>
<tr>
<td>WSB</td>
<td>Weak Stability Boundary</td>
</tr>
<tr>
<td>X-Band</td>
<td>Frequency band designation for radio region of the electromagnetic spectrum set at approximately 7.0 to 11.2 GHz</td>
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Appendix A  RESERVED (Mission/System History)
Appendix B  Quality Management System

1. Introduction

Deep Space Systems Inc. (DSS) has established a Quality Management System (QMS) and manages processes in accordance with AS9100D (Note: Where AS9100 is read, it is to be understood AS9100D).

Established in 2001, DSS is an award-winning Woman Owned Small Business located in Littleton, Colorado. DSS expertise is in the design, development, integration, test, launch and operation of human and robotic exploration spacecraft.

DSS was founded in 2001 by Steve Bailey after Lockheed Martin was awarded the Mars Reconnaissance Orbiter (MRO) project by the Jet Propulsion Lab. Steve, a veteran of the Mars Surveyor Program, joined the MRO proposal team as a 1099 contractor and played a key role in the proposal, developing the unique aerobraking-centric MRO spacecraft configuration concept and making other significant contributions to the proposal. After JPL awarded the contract to Lockheed Martin, Deep Space Systems was born, and Steve supported the MRO program through launch with roles including Testbed Integration Lead and Payload Integration Engineer for the HiRISE, CTX and MARCI cameras, as well as acting Spacecraft System Design Lead when Tim Halbrook was called to active duty after the 9/11 terrorist attacks.

In 2004 Michelle Bailey bought the controlling interest in Deep Space Systems and took over long term planning and day to day operations of the company as Chief Executive Officer, with Steve as President and a new business partner, Karl Lauffer, as Vice President. As a Woman Owned Small Business, DSS grew steadily based on support for Lockheed Martin’s proposal teams in successfully bidding and winning new business including Mars Phoenix, OSIRIS-Rex, GOES-R and Orion, and in providing highly skilled individuals for niche positions in those and other projects including Mars Odyssey, Stardust-NExT, GRAIL, JUNO, MAVEN, and InSight.

Since its formation, Deep Space Systems has been committed to helping make NASA successful in developing and successfully executing complex robotic and human exploration missions and providing high quality hardware, software and engineering support to our customers.

The DSS website is located at www.deepspace systems.com.

DSS has always applied high quality standards to its processes and operations and continues its dedication in maintaining high levels of quality and integrity in communicating with people inside and outside of its business operation.

Deep Space Systems is located at 8100 Shaffer Parkway #130, Littleton, CO 80127. This facility supports DSS headquarters, management, engineering, design, development, manufacturing, assembly, qualification and acceptance testing of hardware.
2. DSS Philosophy and Governing Policies

DSS QUALITY POLICY

A singular focus on human and robotic exploration including 100% mission success of our products, outstanding people and loyalty to our customers are the defining characteristics of Deep Space Systems and its employees.

2.1. Scope

DSS’s quality management system applies to all processes within all functional areas of DSS’s business operation. The DSS work scope includes engineering services support to our customers as well as the design, build, integration and test of hardware components for aerospace applications. This includes but is not limited to camera systems, mechanical systems and avionics for aerospace applications.

DSS has developed a Code of Business Ethics and Conduct, located on the employee portal of the DSS website (www.deepspacesystems.com), that states: “The success of our business is dependent on the trust and confidence we earn from our customers, our co-workers, subcontractors, and employees. We gain credibility by adhering to our commitments, displaying honesty and integrity and reaching company goals solely through honorable conduct. It is easy to say what we must do, but the proof is in our actions. Ultimately, we will be judged on what we do. ”

2.2. Exclusion

DSS takes no exclusions to AS9100.
3. Context of the Organization

3.1. Understanding the Organization and its Context

DSS monitors customer objectives and any changes in fiscal, regulatory, market or schedule to determine how it impacts the organization, skill sets, resource needs and ability to perform at the highest levels. DSS utilizes customer feedback on existing programs and how we are doing and what changes need to be made to ensure we are giving the best service or product.

3.2. Understanding the Needs and Expectations of Interested Parties

DSS is constantly working with our customers to understand the needs and objectives for their products and services. In addition, DSS is also working to secure new customers that would benefit from our products and services. The ability to show customers our commitment to AS9100 through the successful utilization of our QMS is very important to showing customers our operating capabilities and potential for new work.

3.3. Determining the Scope of the Quality Management System

DSS reviews the QMS scope to consider how our existing or potential customers are served and make appropriate changes to reflect the changes in customer priorities and objectives. The QMS is the standard we use to provide products and services which lead to total mission success, on time and schedule.

3.4. Quality Management System and Its Processes

The primary purpose of the quality manual and QMS procedures is to describe and document the quality management system in place at DSS and to define all the QMS processes in use within DSS. This manual is issued under the authority of the top management and the most current version is located on the employee portal of the DSS website and in an internal SharePoint Library.

Copies of the manual are controlled by means as described below. Uncontrolled copies may be distributed as requested and are identified as “Uncontrolled”. It is meant to be used by employees as the primary source of official DSS quality policies. This manual is accessible to customers, regulatory authorities, and third parties that wish to verify DSS’s quality management system. Externally distributed copies will be uncontrolled and not subject to revision unless otherwise agreed.

Additional procedures and work instructions have been developed to further clarify specific instructions for the execution of these procedures. Where subordinate documents are referenced, they are shown in bold italics.

The Management Representative is responsible for control and distribution of this manual and all other controlled documentation within the quality management system. The latest revision of this document is located on the DSS intranet. Users shall verify the latest revision before use. Contact the Management Representative for questions related to this manual.

Organizational roles and responsibilities for each contract are discussed in Section 4.3 of this document and specifically defined in that contract Program Management.
Plan. The DSS organization chart, which resides on the employee portal of the DSS website, is also used to determine the reporting structure for each layer of the organization.

Risks and opportunities for DSS are discussed in Sections 5.1 and 7.1.1 of this document.

Documented procedures established for the QMS may be found in Appendix B: Master Procedures List.

Interaction between processes of the QMS may be found in Appendix A: Advanced Processes and Applicable AS9100 Clauses.

DSS has established, documented, implemented, and maintains a quality management system and continually improves its effectiveness in accordance with the requirements of AS9100. Furthermore, DSS’s QMS addresses customer and applicable statutory and regulatory management system requirements. DSS currently has two lines of business: technical services and the Hardware contracts with several customers. The breakdown of these contracts are shown in the organization chart which is on the employee portal of the DSS website under Employee Resources.

### 3.4.1 Technical Services

Technical services contracts provide DSS engineering expertise to customers. DSS has outstanding engineering capabilities that companies need on site to support their engineering staff. Based on customer requirements defined in the Statement of Work (SOW) task descriptions, DSS hires employees using the process defined in Section 6.0 of this document. These employees are located on site at the prime contractor facility, given subcontractor badges for entry and exit to the customer facility, take all necessary on-site training required by the customer, report to customer managers for daily duties as defined in the SOW task descriptions and are given desks, computers and all necessary tools to perform their job by the customer management.

The DSS management is responsible for the employee’s timekeeping, insurance, payroll, and any other items associated with DSS employment. The DSS employee has access to the employee portal on the DSS website where they can access their timesheet and training on how to use the timesheet application, employee resource information, employee rights and all AS9100 QMS information.

### 3.4.2 Hardware Contracts

Additionally, DSS has hardware contracts to build space hardware for government and commercial customers, which are documented in the organization chart which is on the employee portal of the DSS website under Employee Resources. The remainder of this document is associated with the QMS for that program and any other hardware programs that may follow.

DSS has;
- Determined the processes needed for the quality management system and their applications throughout the organization as shown in Figure 3-1
- Determined the sequence and interaction of these processes as shown in Figure 3-1
• Determined criteria and methods needed to ensure that both the operation and control of these processes are effective,
• Ensured the availability of resources and information necessary to support the operation and monitoring of these processes,
• Monitored, measured, where applicable, and analyzed these processes,
• Implemented actions necessary to achieve planned results and continual improvement of these processes.

These processes, their sequence and interaction (including any outsourced processes) are shown in Figure 3-1.

Figure 3-1. DSS Quality Management System
4. Leadership

4.1. Leadership and Commitment

4.1.1. General

DSS’s leadership is committed to the ongoing maintenance and improvement of the quality management system. The DSS management team provides communication to the team through email or all hands meetings to ensure that the team understands the importance of meeting the customer requirements and any applicable statutory and regulatory requirements. To ensure this, management focuses on deploying practical steps that concretely support the quality policy.

- **Establishment of a Quality Policy**: DSS has developed this DSS Management System that establishes the corporate quality policy for all employees to follow. This policy is documented in this Management System document and the associated plans, procedures and training that have been developed and placed on the employee portal of the DSS website for all team members to review, understand and follow. The DSS Management has identified the Quality objectives and they are shown in Appendix D of this document.

- **Customer Focus**: DSS communicates the importance of meeting customer, regulatory and statutory requirements through employee orientation (ref 6.2) and by providing documentation of requirements and workmanship criteria (ref 7.5.1.1 and 6.5). The Contract Review process ensures that customer requirements are captured and reviewed before acceptance (ref 7.2.2). In addition, the DSS Management will perform Management Reviews on the Quality System at regular intervals, as defined in Section 8.3.

- **Employee Involvement**: All employees are empowered to submit requests for corrective or preventive action to affect change and improve DSS and its processes and their own experience at DSS (ref 9.0). All employees are empowered to stop production when nonconformities are encountered (ref 9.2)

- **Management**: DSS aims to ensure that management makes decisions based on facts, data, risks, opportunities and evidence. To do this, management has established quality objectives (ref 5.2). The internal audit process relies on the recording of verifiable data as a means of driving corrective and preventive actions as well as improvement efforts (ref 8.2, 9.2, 9.3). By conducting periodic management reviews of the quality system, management ensures the overall effectiveness of the quality system (ref 8.3). The **DSS-PROC-003 Problem Reporting and Corrective Action** procedure ensures that action is taken if planned results are not achieved.

- **Employee Resources and Workplace**: DSS strives to provide the best employee resources to our customers based on their needs and job descriptions. DSS ensures the work environment, facilities and atmosphere are satisfactory to employees through management’s understanding and review of resource requirements (ref 8.3) and through ongoing communication with employees regarding the workplace (ref 6.4)
4.1.2. Customer Focus

DSS shall ensure that customer requirements and any applicable statutory and regulatory requirements are understood and are met with the aim of enhancing customer satisfaction.

DSS shall ensure that the risks and opportunities associated with product conformity and on-time delivery performance are measured and that appropriate action is taken if planned results are not or will not be achieved.

The entire staff of DSS recognizes the importance of maintaining customer satisfaction and its importance to the continued growth and stability of the company.

4.2. Policy

4.2.1. Establishing the Quality Policy

The quality policy has been developed and approved by DSS management. This policy and relevant procedures are available to all employees. The policy is reviewed regularly to ensure its distribution and the ongoing overall awareness of it by employees. During management review, the quality policy is reviewed for continual suitability. The quality policy is contained inside the quality manual that is controlled according to the DSS-PROC-004 Document Change and Control Process procedure. The quality policy may also be issued as a stand-alone document; in this occurrence it is uncontrolled if printed.

4.2.2. Communicating the Quality Policy

DSS provides regular team meetings, DSS website, emails and social events to ensure the QMS is properly communicated to the team. This includes our emphasis on ethics, mission success, importance of safety in the workplace and of our products. The management team is constantly determining better ways to provide continual communication to the team.

4.3. Organizational Roles, Responsibilities and Authorities

The DSS organization chart which resides on the employee portal of the DSS website, defines the basic management structure of DSS. In all cases, the appropriate person has been granted both the responsibility and authority for the duties of their position, which are further defined within position specific job descriptions. A program manager is defined for each specific product level program at DSS.

Project management is a process designed to ensure customer requirements are met. During project management, managers plan and manage product realization in a structured and controlled manner. Resource needs and schedule constraints are considered and adjusted as needed. Appropriate actions are taken to mitigate risks as they are determined. These processes are further defined in sections 5.1, 7.1.1, 7.1.2, and 7.5.1.

The Management Representative identified in the Organization chart is responsible for ensuring the proper implementation of the quality system, as well as, for overseeing the maintenance of the system, reporting on its effectiveness during management
review, and discussion of matters relating to the quality management system with customers, registrars and other concerned parties.

The Management Representative is responsible for facilitation of these policies and procedures and works with the Safety and Mission Assurance Manager (S&MA). The S&MA manager has the responsibility and authority to resolve matters relative to quality in products, processes and service from internal and external sources. S&MA may suspend internal and external processes and/or shipments that do not meet requirements until appropriate correction is implemented on an expedited, high priority basis.

The S&MA Manager reports directly to the Chief Executive Officer (CEO) and has unrestricted access to top management. Inspectors and auditors report directly to the S&MA Manager. In addition, the Management Representative, who also reports to the CEO, ensures the promotion of awareness of customer requirements throughout the organization.

5. Planning

5.1. Actions to Address Risks and Opportunities

As DSS reviews the QMS and how it is working for the company, certain considerations are evaluated. These considerations include the organization and the ability to perform the functions required by our customers, whether in technical services or development of products. Also, DSS is in tune to the customers wishes and needs and how that might influence the changes in the DSS QMS. DSS looks at the risks and opportunities that any change in customer objectives, schedule, funding as well as the company growth and changing employee competencies. DSS updates the QMS to ensure that the company is always seeking ways to improve, provide the best product and service and to prevent any undesirable circumstances that would impact our achievement of mission success.

5.2. Quality Objectives and Planning to Achieve Them

Top management has established the quality objectives for the entire organization of DSS; these objectives apply to all DSS personnel. Appendix D defines all of the quality objectives currently in place.

This quality system was planned. Its documented policies and procedures were reviewed prior to implementation. Management ensures the QMS is maintained when changes to the QMS are planned and implemented. Subsequent major changes that may affect the performance, quality or reliability of the product will be identified, reviewed and approved and the QMS documentation will be updated.

The QMS documentation acts as the overall quality plan for DSS. As required, specific quality processes may be developed for individual products; these plans include the information given above. In such cases, the appropriate department manager (with support from the Safety and Mission Assurance Manager) has overall responsibility for the development of quality plans.
5.3. Planning of Changes

As the need to change the quality management system arises, DSS evaluates the changes required and the potential impacts to the organization and company culture. DSS ensures that the main focus of providing the best product and services to customers is maintained or improved. DSS will provide the appropriate resources and allocate the appropriate organization roles and responsibilities to ensure the change is made promptly and efficiently.
6. Support

6.1. Resources

6.1.1. General

During management review, DSS’s management determines and provides the resources needed to implement and maintain the quality management system and continually improve its effectiveness. Resources needed to enhance customer satisfaction by meeting customer requirements are also determined and provided.

6.1.2. People

All DSS employees shall be competent on the basis of appropriate education, training, skills, and experience. The DSS hiring and on-boarding process is defined in DSS-PROC-007 Hiring and Onboarding Process.

Deep Space Systems (DSS) developed an Affirmative Action Plan (AAP) (DSS-PL-010) with good faith for the purpose of promoting equality of opportunity. DSS seeks to increase the recruitment of qualified women and/or minorities and hereby adopts the following nondiscriminatory pledge and the AAP.

“The recruitment, selection, employment, and training of apprentices during their apprenticeship, shall be without discrimination because of race, color, religion, national origin, sex or gender identity. DSS will take affirmative action to provide equal opportunity and will operate as required under Title 29 of the Code of Federal Regulations, part 30.”

6.1.3. Infrastructure

DSS has determined and provides and maintains the basic infrastructure needed to achieve conformity to product requirements. Infrastructure requirements are regularly reviewed during management review and include the review of:

- Building(s), workspace, and associated utilities,
- Process equipment (both hardware and software), and
- Supporting services (such as transportation, communication or information systems)

Specifically, DSS has established a production facility with the necessary environmental controls for factors including temperature, humidity, lighting, and cleanliness. Facilities undergo routine preventive maintenance by skilled maintenance personnel.

DSS’s ITAR compliant Sharepoint is configuration controlled using a username and password entry for each employee. The data is backed up to the Microsoft Cloud which is also configuration controlled. DSS-TR-007 SharePoint Training is available for all employees who will be using SharePoint.

The DSS production and engineering facilities have controlled access via door locks accessible only to employees.
6.1.4 Environment for the Operation of Processes

DSS has determined and manages the work environment, including noise, temperature, humidity, and lighting, needed to achieve conformity to product requirements. The work environment is periodically reviewed during internal audits and work environment-related resource requirements are regularly reviewed during management review.

6.1.5 Monitoring and Measuring Resources

DSS plans and implements the monitoring, measuring, analysis and improvement processes needed:

- To demonstrate conformity to product requirements,
- To ensure conformity of the quality management system, and
- To continually improve the effectiveness of the quality management system.

This includes determination of applicable methods, including statistical techniques, and the extent of their use.

DSS monitors and measures the characteristics of the product to verify that product requirements are met. This is carried out at appropriate stages of the product realization process in accordance with the planned arrangements. Evidence of conformity with the acceptance criteria will be maintained.

Measurement requirements will include:

- Criteria for acceptance and/or rejection,
- Where in the sequence measurement and testing operation are performed,
- Required records of the measurement results and at minimum indication of acceptance or rejection, and
- Any specific measurement instruments required and any specific instructions associated with their use.

When critical items, including key characteristics, have been identified DSS ensures they are monitored and controlled in accordance with established processes. When DSS uses sampling inspection as a means of product acceptance, the sampling plan is justified on the basis of recognized statistical principles and appropriate use. Product is not to be released until it has been inspected or otherwise verified as conforming to specified requirements.

Records indicate the person(s) authorizing release of product for delivery to customer.

Where required to demonstrate product qualification DSS ensures that records provide evidence that the product meets the defined requirements. Product release and delivery will not proceed until all the planned arrangements have been satisfactorily completed, unless otherwise approved by a relevant authority, and where applicable by the customer. DSS ensures that all documents required by the contract / order to
accompany the product are present at delivery and are protected against loss or deterioration.

If DSS determines that the validity of previous measurement results has adversely affected hardware because the measurement equipment is out of calibration or not working properly, appropriate action will be taken such as recalibration of measuring equipment, repair of equipment or replacement as necessary. Once the measuring equipment has been returned to a valid operational state, the affected hardware will be re-measured as appropriate to ensure proper results are shown.

6.1.6. Organizational Knowledge

DSS’s management regularly reviews the knowledge, capabilities and skill needs of the organization against those available. In any instance where there is a gap between needs and capability, the functional manager will take the necessary steps to acquire needed knowledge, capabilities and/or skills. This may include training and skills development for existing employees, or the use of consultants or other outside expertise.

6.2. Competence

For full-time, part-time, and temporary employees, DSS

1. Has determined the necessary competence for personnel performing work affecting conformity to product requirements,

2. Where applicable, provides training or takes other actions to achieve the necessary competence,

3. Evaluates the effectiveness of this training,

4. Ensures personnel are aware of the relevance and importance of their activities and how they contribute to the achievement of the quality objectives, and,

5. Maintains appropriate records of education, training, skills and experience.

Necessary competencies are spelled out within job descriptions which are maintained for all positions. New hires are selected based upon whether they meet the needs described in these job descriptions. New and existing personnel are provided with orientation and any necessary training in order to meet the requirements of their given position. One important aspect of the new employee training is the orientation into the timecard system. Each DSS employee is given training on the system which is called Tsheets (DSS-TR-003 How to use Tsheets Training).

DSS management will provide International Traffic in Arms Regulations (ITAR) training per DSS-TR-004 ITAR Training to all employees that require training as part of their job responsibilities.

For issues related to on job performance, DSS will react to both customer and internal complaints of employee job performance using the following procedures:

- **DSS-PROC-011 Employee Review and Corrective Action Following Customer Complaint**
• **DSS-PROC-012 Employee Review and Corrective Action Following Internal Complaint**

The DSS current organization chart is located on the employee portal of the DSS website under Employee Resources.

**6.3. Awareness**

DSS has informed the DSS staff of the QMS and its importance to the success of the organization, our products, services and reputation. Each member of the company understands how their work impacts the mission success of the technical services or product development for our customers. DSS continually strives to maintain product safety and the importance of adhering to the ethics of the company.

**6.4. Communication**

Top management shall ensure that appropriate communication processes (such as communication boards and company meetings) are established within the organization and that communication takes place regarding the effectiveness of the quality management system.

**6.5. Documented Information**

**6.5.1. General**

DSS maintains all required documentation to effectively sustain its quality management system. Management is responsible for implementation of procedures and records in their areas as required by the quality management system.

**6.5.2. Creating and Updating**

The quality system documentation is comprised of a hierarchy of documents as shown in Figure 6-1 that flow from AS9100 and this quality manual. Procedures support and enhance the primary mandates of DSS’s company philosophy and quality policy as defined in section 2. Quality objectives may be found in Appendix D of this document.
DSS maintains a secure intranet that allows authorized users to access documents as needed throughout DSS’s organization. Obsolete documents are identified as such and stored separately to prevent unintended use.

Documents and records determined to be necessary for effective planning, operation, and control of processes, unless otherwise directed by the customer requirements are as follows:

- Customer Contract / Purchase Order
- Engineering Data
- Acceptance and Qualification Data Packages
- Inspection Records
- Government specifications
- Vendor / Seller Specifications
The extent of the QMS documentation is appropriate for the size of the DSS organization, its activities, the complexity, and interaction of the quality processes.

DSS will develop specific plans and procedures as necessary for each individual program. These include technical plans as well as test plans and procedures for each piece of hardware that will be delivered to the customer. These plans and procedures are located on the DSS configuration controlled Sharepoint site. The specific locations for documents that are referenced in this document and used throughout DSS are found on the employee portal of the DSS website. DSS employees log into the employee portal using a login name and password that allows them access to DSS plans, procedures, training and employee resources

6.5.3 Control of Documented Information

Documents are controlled so that the information on them is accessible, legible and suitably maintained. Documents are reviewed and approved prior to release and only the latest revisions are available to users. Previous revisions are segregated and retained electronically in a folder labeled “obsolete”. The controls for documents are defined in the **DSS-PROC-004 Document Change and Control Process**. Documents are retained on the configuration controlled Sharepoint.

Records are controlled to provide evidence of conformity to requirements. Records that are subject to control are maintained according to the **DSS-PROC-006 Control of Records** and DSS's customer contract Terms and Conditions.
7. Operation

7.1. Operational Planning and Control

In planning the processes for product realization, management has ensured that the processes are consistent with the requirements of the other processes within the quality system.

Planning includes the following:

- Quality objectives and requirements for the product;
- The need to establish processes and documents, and to provide resources specific to ensuring on time delivery of the product based on the program schedule;
- Required verification, validation, monitoring, measurement, inspection, and test activities specific to the product and the criteria for product acceptance;
- Records needed to provide evidence that the realization processes and resulting product meet requirements;
- Configuration management appropriate to the product;
- Resources to support the use and maintenance of the product.

The output of the planning is the acceptance or qualification data packages for each product, related drawings, inspection packages, operator check sheets, and specifications that show dimensions, characteristics, tolerances, and any key characteristic identified by DSS or the customer. Likewise, these instructions define any processes, documents or resource requirements specific to the product.

7.1.1. Operational Risk Management

Risk management is essential in meeting customer requirements. Managers, or their delegates, communicate with customers, obtaining information that may not be stated in contracts or purchase orders. The information obtained is used in risk management.

Management is responsible for risk management and taking action to mitigate risks. Factors such as labor, equipment, material, scheduling, and outside processing are identified throughout contract review, purchasing, planning, production, and inspection processes. Documents are created or revised, and meetings are held as needed to address and communicate risks that have been identified. Internal preventive and corrective action is closely integrated into risk management. As risks are identified these actions may be used to mitigate/resolve risks.

Prior to acceptance of contract or purchase order, relevant risk criteria are assessed to identify risk and determine feasibility. Criteria may include but are not limited to:

- Engineering data (e.g., drawings, models, specifications, etc.) are made available,
- Customer supplied quality requirements and/or vendor manual,
- Configuration plan,
• Quantity and delivery schedule,
• Requirements for customer approved suppliers,
• Lead time and cost for raw material and/or hardware items,
• Lead time and cost for outside processing (e.g., calibration, plating, etc.),
• Cost of any non-recurring charges, if any,
• Labor hours and skill,
• Equipment (e.g., tooling, fixtures, and resources),
• Inspection and test plans,
• Any special requirements and expectations not stated in request.

If any of the above criteria cannot be resolved, or causes unease to trained personnel, then the order is considered “high risk”.

On “high risk” orders:
• Top management investigates, confirms, and documents any risk associated with the order.
• If the decision to accept risk is made, the appropriate personnel will be notified and the mitigation process will continue.

7.1.2. Configuration Management

Configuration management includes planning, identification, change control, status accounting, and auditing. Configuration audits are conducted during internal audits. Contracts for new products and changes to existing products are processed in accordance with section 7.2.2.

Part configuration is provided in the customer’s engineering specifications. A configuration management plan (DSS-PL-002) is created for the DSS hardware program to ensure the products are controlled properly. When the product requirements change, the manufacturing plan is revised and appropriate personnel are informed of the change. This process is further defined in section 7.5.

Configuration is controlled through verification during manufacturing. Evidence of verification is recorded within the acceptance data packages for each product delivered to the customer as defined in section 6.1.5.

7.1.3. Product Safety

DSS considers safety and quality our priority—from the staff to the equipment, creating exceptional, high-quality products in a controlled environment is our touchstone. Above all else, safety is paramount, be it the safety of the employees or the safety of the hardware, a safe and regulated environment is an effective and efficient environment. To ensure a safe workplace, DSS hired a safety coordinator to maintain OSHA compliancy, immediately address any safety issues that may arise, ensure facility conditions are conducive to the temperature, humidity, and security specifications set forth by our clients, as well as promoting the health and well-being of
the staff. By maintaining a safe, controlled environment that maintains temperature, humidity, and security parameters, DSS ensures that the individuals in the laboratories and machine shops can operate at peak performance and ensure that the project materials are utilized in the most efficient manner to prevent errors, breakage, and waste. However, safety is not solely the responsibility of the safety coordinator; safety is also the responsibility of all employees. By utilizing a thorough training regimen, (Which includes, but is not limited to, Electrostatic Discharge (ESD) safety training, Machine Shop Safety training, soldering training, chemical safety training, and material inspection training,) the DSS staff is empowered to engineer, manufacture, and produce high-quality and high-precision products. From the machining of raw materials to completion of the electronics build while maintaining ESD integrity of the product, the processes of inspection, documentation, and implementation of procedure safeguard the quality of the final product. Thorough inspection of the components ensures that only quality materials are selected for integration, painstaking documentation tracks the life of the components from raw material to finished product, and meticulous implementation of procedure ensures that the finish product is constructed to meet all contract specifications in a uniform and reliable manner. At DSS, exceptional, high-quality products are created by our expert technicians because the safety and quality of our staff and our final product is our priority.

7.1.4. Prevention of Counterfeit Parts

Deep Space Systems will apply a risk-based approach to prevention, detection, and mitigation of Counterfeit Work and has developed a process documented in \textit{DSS-PROC-017 Counterfeit Parts Process} located on the DSS website. In addition, DSS-TR-005 Counterfeit Parts Training was developed for DSS employees.

7.2. Requirements for Products and Services

7.2.1. Customer Communication

DSS determines and implements effective arrangements for communicating with customers in relation to:

- Product information,
- Inquiries, contracts or order handling including amendments
- Customer feedback, including customer complaints.
- Employee Review and Corrective Action based on customer complaint (\textit{DSS-PROC-011 Employee Review and Corrective Action Following Customer Complaint Process})

7.2.2. Determining the Requirements for Products and Services

DSS captures all contractual and special requirements, monitoring and measurement requirements, applicable statutory or regulatory requirements, and/or any necessary, unstated requirements as part of the contract review process.

7.2.3. Review of the Requirements for Products and Services

Once contractual and special requirements are captured, and risks determined, they are reviewed against previous contract or order requirements and differences are
resolved. Relevant documents are changed as requirements change, as defined in section 6.5.1. DSS determines their capability to meet customer requirements before acceptance of the order. In addition, any applicable statutory and regulatory requirements that pertain to the DSS products and services are reviewed and an approach to meeting these requirements is defined and presented to the customer at the initial review prior to beginning work.

Where the customer provides no documented statement of requirement, the customer requirements shall be confirmed by requesting customer approval of quote or by feedback through electronic communications or phone (“or phone” is for non-aerospace parts only).

Prior to the beginning of contract work, DSS will coordinate a review with the customer to present the approach to meeting all requirements necessary to successfully complete the contract. At this review any issues, clarifications, concerns are discussed to ensure all parties understand clearly the work ahead, risks and schedule of the program.

7.2.4. Changes to Requirements for Products and Services

Where product requirements are changed after work has begun, DSS shall ensure that relevant documents are amended and that relevant personnel are made aware of the changes.

7.3. Design and Development of Products and Services

7.3.1. General

DSS has a company culture that establishes, implements and maintains its design and development process that enables the successful delivery of quality hardware and/or services that meets the customer’s needs.

7.3.2. Design and Development Planning

Prior to the design and development stage of any program, DSS ensures that the customer, statutory and regulatory requirements are understood by the team, processes are in place, and how the design will be built, tested and verified. The team discusses the design objectives with the customer to validate that the right thing will be built at the right cost and on time. The customer SOW contains the required reviews necessary for the design to be checked to make sure we are on the right course.

7.3.3. Design and Development Inputs

DSS performs a review of customer, statutory and regulatory requirements prior to the initiation of the design and development phase of any program. The development portion of a contract allows the DSS team to ensure that design requirements are met, procedures are developed and validated and testing performed. During the build and test phase of the program, the DSS team will build the appropriate hardware and perform the required functional, performance and environmental testing as specified in the contract. Any recommended modifications to the design based on build, integration and test results are communicated to the customer during team meetings or design reviews to gain approval to change the design.
7.3.4 Design and Development Controls

DSS develops test plans and procedures for each type of test to be performed: functional, performance, and environmental. The test reports include the success criteria of the test based on the requirements. The results of all testing are documented in test reports which will also include variances, flags and/or discrepancies. These test reports are delivered to the customer as part of the contract deliverables. The test reports and all associated documentation are used by the customer to ensure that DSS deliverables meet the requirements imposed upon them during the contract.

New DSS test personnel are given training on test engineering prior to being allowed to perform any testing on flight or qualification hardware. This training is found in DSS-TR-006 Test Engineering Training Course.

Customer reviews such as Preliminary Design Review (PDR), Critical Design Review (CDR), Manufacturing Readiness Review (MRR) and Test Readiness Reviews (TRR) are used as decision points by the program customer to determine if the progression to the next stage of the design, build or test process should be authorized. The customer provides the authorization for DSS to proceed to the next stage upon successful completion of the reviews.

7.3.5 Design and Development Outputs

At the completion of the design and development process, prior to entering into the manufacturing and build process, DSS utilizes customer reviews and peer reviews to validate the design meets the customer’s requirements. This includes review of the requirements set, processes are in place for entry into the next phase and the customer approves of the design in the critical design reviews. Per SOW, DSS provides objective evidence of the design through schematics, drawings, technical analyses, plans and procedures for the customer to review and provide comment on.

At the completion of the design and development process, prior to entering into the manufacturing and build process, DSS utilizes customer reviews and peer reviews to validate the design meets the customer’s input requirements. This includes:

- Review of the requirements set and show that the design meets the requirements
- The DSS process and procedures in place are adequate to meet the provision of the products or services defined by the contract
- All equipment necessary to provide monitoring and measuring of the hardware are in working order and have been properly calibrated
- Show that the products or services meet the customer’s intended purpose and are safe and proper
- Define and document the critical items and their characteristics associated with the customer deliverables and any actions that need to be taken for these during the contract
- Processes are in place for entry into the next phase and the customer approves of the design in the critical design reviews

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Deep Space Systems Lunar Lander
• Per SOW, DSS provides objective evidence that is stored at DSS of the design through schematics, drawings, technical analyses, plans and procedures for the customer to review and provide comment on

• Proper management and technical reviews are held internally and with the customer to ensure all design data is reviewed and approved by the proper authorizing personnel prior to release of the products to begin the build phase of the program

7.3.6. Design and Development Changes

DSS management is in communication with the customer periodically through team meetings, reviews and meetings with the customer subcontracts administrator to assess how DSS is performing with respect to the contract. DSS management communicates contract performance achievements and shortfalls to the team to begin corrective action to fix any problems as necessary.

DSS retains all documentation that is required by the contract or SOW on the ITAR compliant, configuration controlled SharePoint site. All customer Subcontract Data Requirements List (SDRL) documents are delivered to the customer per the SOW. The documentation pertains to:

• Design and development data and all associated changes
• Presentation packages from customer reviews (PDR, CDR, MRR, TRR, etc) including all results of actions, changes, etc.
• Authorization of all approved changes
• Actions taken to prevent adverse impacts

7.4. Control of Externally Provided Processes, Products and Services

7.4.1. General

DSS ensures purchased products or services conform to specified purchase requirements as defined in the purchase order and referenced documents. The controls applied to the supplier and to the purchased product or service vary, dependent on the effect of the purchased product or service.

Purchasing is a process within the DSS QMS. DSS accepts responsibility for the conformity of products that are purchased from suppliers including product from sources defined by the customer. DSS does not use customer verification as evidence of effective control of quality by the supplier. However, DSS does accept responsibility for the conformity of Products or Material (e.g., castings, circuit cards and electronic parts) provided by the customer.

Supplier selection and Evaluation is defined in DSS-PROC-005 Supplier Evaluation and Purchasing Process. The purchasing process ensures DSS manages risk when selecting and using suppliers and only purchases materials and services from suppliers that have undergone evaluation and approval.

7.4.2. Type and Extent of Control

Purchase orders are used to transmit DSS’s requirements to suppliers.
Purchase orders include statements in our “terms & conditions” section concerning the following items, when and where we require these items:

- Requirements for approval of product, procedures, processes and equipment,
- Quality management system requirements,
- Drawing and/or specifications (or other technical data) and applicable revision,
- Requirements for design, test, examination, inspection, and related instructions for acceptance,
- Requirements for test specimens, design approval, inspection/verification, investigation or auditing,
- Requirements for supplier notification to DSS of nonconforming product, requirements for the supplier to notify DSS of changes in product and/or process definition and, where required, obtain organizational approval for nonconforming product disposition, requirements for the supplier to flow down applicable requirements,
- Records retention requirements, and
- Right of access by DSS, our customer, and regulatory authorities to all facilities involved in the order and to all applicable records.

When any of these items are required by DSS, the required items are clearly stated on the first page of the Purchase Order. DSS ensures adequacy of specified purchase requirements before communicating them to the supplier.

**7.4.3 Information for External Providers**

When planning to temporarily transfer work DSS defines the process to control and validate the quality of work per the customer requirements and/or the vendor check sheet.

- The outsourced service provider must be an approved, evaluated supplier according to the requirements of section 7.4,
- The supplier is required to notify DSS of any process changes, any nonconformity, or other issues,
- The supplier will be subject to the corrective action system, as defined in section 9.2.
- Work must be conducted on the article(s) according to any specification listed on the purchase order.

This process is controlled through purchasing and resultant receiving documentation. Product and quality requirements are flowed down in purchase orders as described in section 7.4.

DSS has established receiving inspection and/or other activities necessary to ensure purchased product meets specified purchase requirements. Receiving inspection uses certificates of conformity, test reports, and/or visual and dimensional inspection to verify
product conformity. Without exception, purchased product or material shall not be used or processed until it has been properly received. DSS does not delegate inspection to suppliers.

Where specified by contract, DSS’s customer shall be afforded the right to verify at the suppliers’ premises or at DSS’s premises that subcontracted product conforms to specified requirements. Verification by the customer shall not be used by DSS as evidence of effective control of conformity by the supplier and shall not absolve DSS of the responsibility to supply acceptable product, nor shall it preclude subsequent rejection by the customer.

7.5. Production and Service Provision

7.5.1. Control of Production and Service Provision

DSS plans and carries out production under controlled conditions. Controlled conditions include, as applicable:

- The availability of information that describes the characteristics of the product,
- The availability of work instructions as necessary,
- The use of suitable equipment
- The availability and use of monitoring and measuring equipment,
- The implementation of monitoring and measuring,
- The implementation of product release and delivery,
- Accountability for all products during production (e.g., parts quantities, split orders, nonconforming product),
- Evidence that all production and inspection/verification operations have been completed as planned, or as otherwise documented and authorized,
- Provision for the prevention, detection, and removal of foreign objects (DSS-PL-003 Contamination Control Plan Section 8.0)
- Electrostatic Discharge Control as detailed in DSS-PL-006 ESD Plan,
- Monitoring and control of utilities and supplies such as water, compressed air, electricity and chemical products to the extent they affect conformity to product requirements, and
- Criteria for workmanship (e.g., de-burr or blending – smoothing out steps), specified in the clearest practical way (e.g., written standards, representative samples, or illustrations).

Planning Considers, as applicable,

- Establishing, implementing and maintaining appropriate processes to manage critical items, including process controls where key characteristics have been identified,
- Designing, manufacturing and using tooling to measure variable data,
• Identifying in-process inspection/verification points when adequate verification of conformance cannot be performed at later stages of realization, and

• Special processes (ref 7.5.1.4).

7.5.1.1. Production Process Verification

DSS provides for the inspection, verification and documentation of representative item from the first production run of a new part or assembly or following any subsequent change that invalidates the previous first article inspection result.

7.5.1.2. Control of Production Process Changes

CEO, President, Program Manager, and S&MA Manager have the authority to approve changes to production processes. To ensure product conformity, DSS shall validate production processes, equipment, tools, setup and software programs prior to production or after changes have been made through first piece inspection at each operation. All production process changes are documented and stored on Sharepoint.

7.5.1.3. Control of Production Equipment, Tools and Software Programs

Production equipment, tools and software programs used to automate and control / monitor product realization processes will be validated prior to release to production and will be maintained. Production equipment shall be maintained in accordance with established preventive maintenance plans and shall be logged.

Holding fixtures (vises, jaws, etc.), when not in use shall be stored indoors. They shall be lubricated and inspected as necessary before use.

7.5.1.4. Validation of Processes for Production (Special Processes)

Validation demonstrates the ability of these processes to achieve planned results.

DSS shall specify arrangements for these processes including, as applicable

• Defined criteria for review and approval of the processes,

• Approval of equipment and qualification of personnel,

• Use of specific methods and procedures,

• Requirements for records (ref 6.5.3),

• Revalidation

7.5.1.5. Control of Monitoring and Measuring Equipment

DSS determines the monitoring and measurement to be undertaken and the monitoring and measuring equipment needed to provide evidence of conformity of product in accordance with DSS-PROC-008 Calibration of Company Owned Equipment Process.

7.5.2. Identification and Traceability

Product is identified by suitable means throughout product realization.

DSS shall maintain the identification of the configuration of the product in order to identify any differences between the actual configuration and the agreed configuration.
Product status with respect to monitoring and measuring requirements is identified; nonconforming parts are identified (and segregated) in accordance with DSS-PROC-003 Problem Reporting and Corrective Action procedure.

Where traceability is a requirement, DSS controls and records the unique identification of the product according to the level of traceability required by contract, regulatory, or other established requirements.

DSS system provides for:

- Identification to be maintained throughout the product life;
- All the products manufactured from the same batch of raw material or from the same manufactured batch to be traced, as well as the destination (delivery, scrap) of all products of the same batch;
- For an assembly, the identity of its components and those of the next higher assembly to be traced;
- For a given product, a sequential record of its production (manufacture, assembly, inspection) to be retrieved.

7.5.3. Property Belonging to Customers or External Providers

DSS exercises care with customer property while it is in DSS’s control or use. DSS shall identify, verify, protect and safeguard customer property provided for use or incorporation into the product as defined in DSS-PROC-001 Receipt and Processing of Customer and Supplier Material.

Customer property may include intellectual property and personal data.

7.5.4. Preservation

DSS preserves the product during internal processing and delivery to the intended destination in order to maintain conformity to requirements. As applicable, preservation includes identification, handling, packaging, storage and protection. Preservation also applies to the constituent parts of the product.

Preservation of product also includes, where applicable in accordance with product specifications and applicable statutory and regulatory requirements provisions for:

- Cleaning,
- Prevention, detection, and removal of foreign objects,
- Special handling for sensitive products,
- Marking and labeling including safety warnings,
- Shelf life control and stock rotation,
- Special handling for hazardous materials.

7.5.5. Post-Delivery Activities

Post-delivery activities for each program is defined in the Contract/Statement of Work between each customer and DSS.
7.5.6. Control of Changes

DSS reviews and controls all changes requested for production or services and determines if they are necessary to ensure conformity of requirements. DSS management has identified the personnel on the program with the authority to approve any changes to the production or services processes, equipment, tools or software.

DSS retains all documentation on Sharepoint of approved changes, associated approval authority, and any action arising from the review of the changes.

7.6. Release of Products and Services

At the completion of the build, integration and test of each product, there are deliverables that accompany the product delivery to the customer. These products include the acceptance or qualification data packages which include:

- In Process Traveler (IPT) containing the build log, manufacturing process steps completed and signed off
- Imagery of hardware at each step of the process
- Non-Conformance paperwork
- Test plans and procedures (filled out for each successfully completed test)
- Verification Matrix
- Drawings, schematics and analyses
- Hardware Shipping Log documenting the hardware part number, authorization to deliver and signature of official releasing the hardware to the customer

7.7. Control of Nonconforming Outputs

DSS ensures that product which does not conform to product requirements is identified and controlled to prevent its unintended use or delivery. The responsibilities, authorities, and controls for controlling nonconforming product are defined in DSS-PROC-003 Problem Reporting and Corrective Action Process.
8. Performance Evaluation


8.1.1. General

DSS shall apply suitable methods for monitoring and, where applicable, measurement of the quality management system processes. The core QMS processes are shown in Figure 8-1.

These methods demonstrate the ability of the processes to achieve planned results. When planned results are not achieved, correction and corrective action is taken, as appropriate.

In the event of process nonconformity, DSS:

- Takes appropriate action to correct the nonconforming process,
- Evaluates whether the process nonconformity has resulted in product nonconformity,
Determines if the process nonconformity is limited to a specific case or whether it could have affected other processes or products, and

Identifies and controls any nonconforming product.

8.1.2. Customer Satisfaction

As one of the measurements of the performance of the quality management system, DSS monitors information relating to customer perception as to whether the organization has met customer requirements.

The method for obtaining and using this information is determined.

DSS collects feedback from customers using one or more of the following methods to monitor and measure customer satisfaction:

- Corrective action requests
- Customer complaints
- Customer provided performance data
- On-time delivery
- Product conformity

DSS has developed and implemented a plan for customer satisfaction improvement that addresses deficiencies identified by the above evaluations and assesses the effectiveness of the results. See 8.3 Management Review.

8.1.3. Analysis and Evaluation

DSS determines, collects and analyzes appropriate data to demonstrate the suitability and effectiveness of the quality management system and to evaluate where continual improvement of the effectiveness of the quality management system can be made. This includes data generated as a result of monitoring and from other relevant sources.

- The analysis of data provides information relating to:
- Customer satisfaction (ref 8.1.2),
- Conformity to product requirements (ref 6.1.5)
- Characteristics and trends of processes and products including opportunities for preventive action (ref 8.1.1), and
- Suppliers (ref 7.4).

8.2. Internal Audit

DSS conducts internal audits at planned intervals to determine whether the quality management system:

- Conforms to the planned arrangements, to the requirements of AS9100 and to the quality management system requirements established by DSS, and
- Is effectively implemented and maintained.
Internal audits are performed in accordance with **DSS-PROC-002 Internal Self-Assessment Audit**.

DSS maintains the authority to outsource the internal auditing process to a certified third party auditor.

### 8.3. Management Review

#### 8.3.1. General

Top management shall review the QMS, at quarterly intervals, to ensure its continuing suitability, adequacy and effectiveness. This review shall include assessing opportunities for improvement and the need for changes to the QMS, including the quality policy and objectives.

#### 8.3.2. Management Review Inputs

Items that will appear on the agenda will include:

a. Action items assigned in last management review meeting
b. Changes in external or internal issues relevant to the QMS
c. Information on performance and effectiveness of QMS including trends in:
   a. Customer satisfaction and feedback (Technical Services and/or Hardware Contracts)
   b. Extent to which quality objectives have been met
   c. Non Conformance Status (Process and Hardware)
   d. Non conformities and Corrective Actions Taken Since Last Review
   e. Monitoring and measurement results
   f. Internal and External audit results
   g. External provider performance
   h. On time delivery performance
   i. Resource Needs (Technical Services Contracts/Hardware Contracts)
   j. Effectiveness of actions taken to address risks and opportunities
   k. Opportunities for improvement

#### 8.3.3. Management Review Outputs

The following items will appear in the meeting minutes:

- Opportunities for improvement
- Any need for changes to QMS
- Resource needs
- Risks Identified
9. Improvement

9.1. General

DSS continuously take actions to improve all aspects of the company and implement those changes in a concise and effective manner. This includes improving the QMS as appropriate, evaluating and changing processes, working with employees to provide improvement through education, and or training and working with management to be more efficient in the dealings with employees and customers.

9.2. Nonconformity and Corrective Action

DSS takes action to eliminate the cause(s) of nonconformities in order to prevent recurrence in accordance with DSS-PROC-003 Problem Reporting and Corrective Action procedure. Corrective actions are appropriate to the effects of the nonconformities encountered.

DSS determines action to eliminate the causes of potential nonconformities in order to prevent their occurrence in accordance with DSS-PROC-003 Problem Reporting and Corrective Action Process. Preventive actions are appropriate to the effects of the potential problems.

DSS tracks any hardware returns from our customers via Return Material Authorization (RMA) forms and an RMA tracking matrix located on Sharepoint. In addition, any hardware that needs to be returned to a supplier for rework will be tracked on a Return Material Authorization form for the supplier and tracked on the RMA tracking matrix.

The DSS-PROC-018 GIDEP procedure provides guidance associated with the receipt, issuance, and investigation of Government-Industry Data Exchange Program (GIDEP) alerts or other customer received problem notifications. GIDEP alerts and customer problem notifications are used to communicate suspected or known systemic parts, materials, and processes (PMP) and software concerns. GIDEP alerts and customer problem notifications are used to communicate issues across government and industry.

9.3. Continual Improvement

DSS continually improves the effectiveness of the quality management system through the use of the quality policy, quality objectives, audit results, analysis of data, corrective and preventive action and management review.

DSS monitors the implementation of improvement activities and evaluates the effectiveness of the results.

DSS monitors the implementation of improvement activities and evaluates the effectiveness of the results. The evaluation of this effectiveness will be lessons learned, resolution of problems or non-conformances, customer feedback, audit results and discussions with employees on their interaction with the improvement process.
## Subappendix A: Advanced Processes and Applicable AS9100 Clauses

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### Subappendix B: Master Procedure, Plan and Training List

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<td>Local Post Solder Cleaning</td>
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<td>Aqueous Cleaning Procedure – Aqueous Flux Off</td>
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<td>DSS-PROC-540</td>
<td>Rosin Pre-Coat Cleaning Procedure</td>
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<td>DSS-PROC-550</td>
<td>Ionograph Verification Procedure</td>
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<td>DSS-PROC-560</td>
<td>Acetone Cleaning Procedure</td>
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<td>DSS-QMS-001</td>
<td>DSS Management System</td>
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<td>DSS-PL-001</td>
<td>DSS Camera System Program Management Plan</td>
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<td>DSS-PL-002</td>
<td>DSS Configuration Management Plan</td>
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<td>DSS-PL-003</td>
<td>DSS Contamination Control Plan</td>
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<td>DSS-PL-004</td>
<td>DSS Materials and Processes (M&amp;P) Plan</td>
<td>8.1.3, 8.5.1</td>
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<td>DSS-PL-006</td>
<td>DSS Electrostatic Discharge (ESD) Plan</td>
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<td>DSS-PL-007</td>
<td>DSS Manufacturing Plan</td>
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<td>DSS-PL-008</td>
<td>DSS Safety and Mission Assurance Plan</td>
<td>8.1.3, 8.1.4, 8.5, 10.2</td>
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<td>DSS-PL-009</td>
<td>Material Handling Plan</td>
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<td>DSS-PL-010</td>
<td>Affirmative Action Plan</td>
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<td>DSS-PL-011</td>
<td>OCI Mitigation Plan</td>
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<td>DSS-TR-001</td>
<td>Electrostatic Discharge (ESD) Training</td>
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<td>DSS-TR-002</td>
<td>Foreign Object Damage (FOD) Training</td>
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<td>DSS-TR-003</td>
<td>How to Use Tsheets Training</td>
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<td>DSS-TR-004</td>
<td>International Traffic in Arms Regulations (ITAR) Training</td>
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<td>DSS-TR-005</td>
<td>Counterfeit Parts Training</td>
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<td>DSS-TR-006</td>
<td>Test Engineering Training Course</td>
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<td>DSS-TR-007</td>
<td>DSS SharePoint Training</td>
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Subappendix C: Outsourced Processes

The following processes are outsourced and controlled as indicated:

- Calibration: Only approved calibration labs are used according to **DSS-PROC-008 Calibration of Company Owned Equipment Process**. Certificates must provide evidence of standard traceability to NIST and must meet all requirements of section 7.5.1.5 of this quality manual.
- Plating / Coating
- Firmware updates of embedded electronics
### Subappendix D: Quality Objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Objective Target</th>
<th>Measurement Method</th>
<th>Core Process</th>
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<tbody>
<tr>
<td><strong>Pre-Production Phase of Program</strong></td>
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<tr>
<td>Requirements Definition</td>
<td>Component Specification Baselined</td>
<td>Specification Released with no TBD/TBRs</td>
<td>Core Process 1 Requirements Definition</td>
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<tr>
<td>Design Completion</td>
<td>Design Baselined for Production</td>
<td>Successful completion of CDR with design solution baselined</td>
<td>Core Process 5 Design and Development</td>
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<tr>
<td><strong>Production Phase of Program</strong></td>
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<tr>
<td>End Item On-time Delivery</td>
<td>Meet program schedule milestones</td>
<td>Schedule reviewed with customer regularly during contract period</td>
<td>Core Process 2 Planning and Control</td>
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<tr>
<td>Flight Hardware Returns to DSS for Rework</td>
<td>Less than 10% of total deliveries</td>
<td>Number of Material Return Authorizations to DSS</td>
<td>Core Process 6 Production</td>
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<tr>
<td>Purchasing</td>
<td>Supplier on time delivery</td>
<td>Performance reviewed at Management Reviews</td>
<td>Core Process 4 Purchasing</td>
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<tr>
<td>Flight Hardware Returns to Supplier for Rework</td>
<td>Less than 10% of total deliveries</td>
<td>Number of Hardware Return Authorizations to Suppliers</td>
<td>Core Process 6 Production</td>
</tr>
<tr>
<td><strong>Engineering Services Support to Customer</strong></td>
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<tr>
<td>100% Engineering Personnel Satisfaction</td>
<td>0 complaints from customer</td>
<td>Engineering services personnel customer review</td>
<td>Core Process 3 Customer Support</td>
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<tr>
<td><strong>DSS Management and Support Processes</strong></td>
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<tr>
<td>Maintain AS9100 certification</td>
<td>Maintain AS9100 certification at specified periods</td>
<td>Certification</td>
<td>Management Processes</td>
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User’s Guide for
NASA Commercial Lunar Payload Services (CLPS)
Deep Space Systems Lunar Lander