RIDESHARE PAYLOAD USER'S GUIDE

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1.0 INTRODUCTION

1.1 USER'S GUIDE PURPOSE

Sierra Space provides low-cost rideshare opportunities for unpressurized external payloads in low Earth orbit (LEO) aboard the Dream Chaser Cargo System (DCCS). The DCCS, developed for NASA's Commercial Resupply Services 2 (CRS-2) Program, carries pressurized and unpressurized cargo to the International Space Station (ISS) After separation from the ISS, the Dream Chaser® spacecraft returns to Earth using a lifting-body design and wings provide a gentle, low-g entry profile and a runway landing to protect sensitive cargo.

The Payload User's Guide (PUG) is a comprehensive manual that outlines the standards and guidelines for evaluating payload compatibility with the DCCS. The PUG comprehensively covers the suite of integration, operations, and management protocols that underpin efficient payload delivery, deployment, and disposal for the DCCS.

Upon payload selection, Sierra Space engages closely with developers to produce dedicated Interface Control Documents (ICD) to document and verify payload-to-vehicle interface requirements, ensuring seamless integration for successful space missions.

1.2 COMPANY DESCRIPTION

Sierra Space is a leading commercial space company at the forefront of innovation and the commercialization of space in the Orbital Age®, building an end-to-end business and technology platform in space to benefit life on Earth. With more than 30 years and 500 missions of space flight heritage, the company is reinventing both space transportation with Dream Chaser®, the world's only commercial spaceplane, and the future of space destinations with the company's inflatable and expandable space station technology. Using commercial business models, the company is also delivering orbital services to commercial, DoD and national security organizations, expanding production capacity to meet the needs of constellation programs. In addition, Sierra Space builds a host of systems and subsystems across solar power, mechanics and motion control, environmental control, life support, propulsion and thermal control, offering myriad space-as-a-service solutions for the new space economy.

Figure 1-1: LEO Space Station Concept Using LIFE Habitats

1.3 RIDESHARE DESCRIPTION

The Dream Chaser Rideshare Program leverages the DCCS to provide microgravity opportunities for unpressurized, external payloads. The DCCS can accommodate unpressurized payloads in up to three locations per mission. The DCCS consists of the Dream Chaser DC-100 spaceplane and the Shooting Star® Cargo Module. The integrated spacecraft launches on United Launch Alliance's Vulcan Centaur out of Cape Canaveral Space Force Station, adjacent to NASA's Kennedy Space Center (KSC).

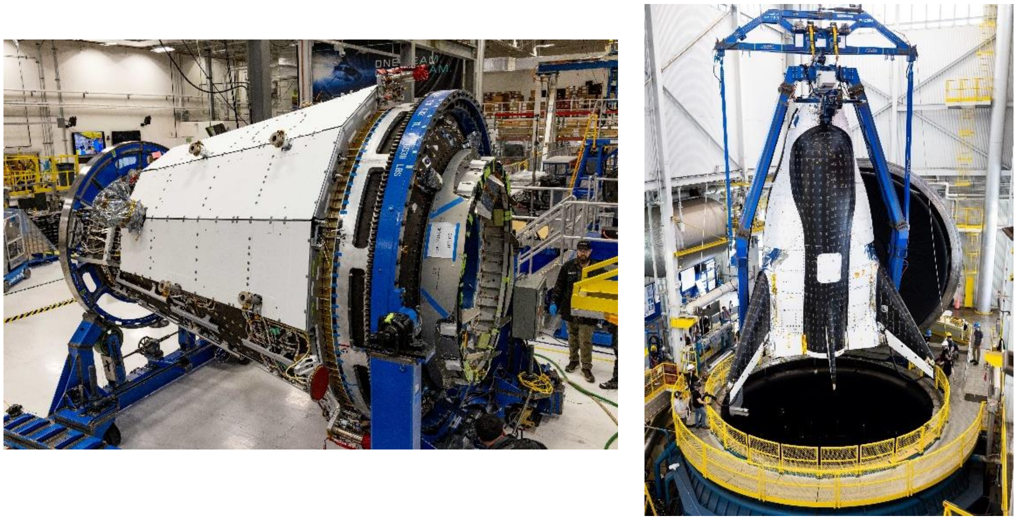

Figure 1-2: Shooting Star (left) and DC-100 (right)

Once on-orbit, the DCCS initiates a rendezvous with the ISS for cargo delivery. Following berthed operations, the DCCS demates. After payload deployment and a deorbit burn, Shooting Star is jettisoned to be burned up during atmospheric entry, while the Dream Chaser lands at Space Florida's storied Launch & Landing Facility (LLF) adjacent to Kennedy Space Center. An overview of the Concept of Operations is provided in *Figure 1-3*.

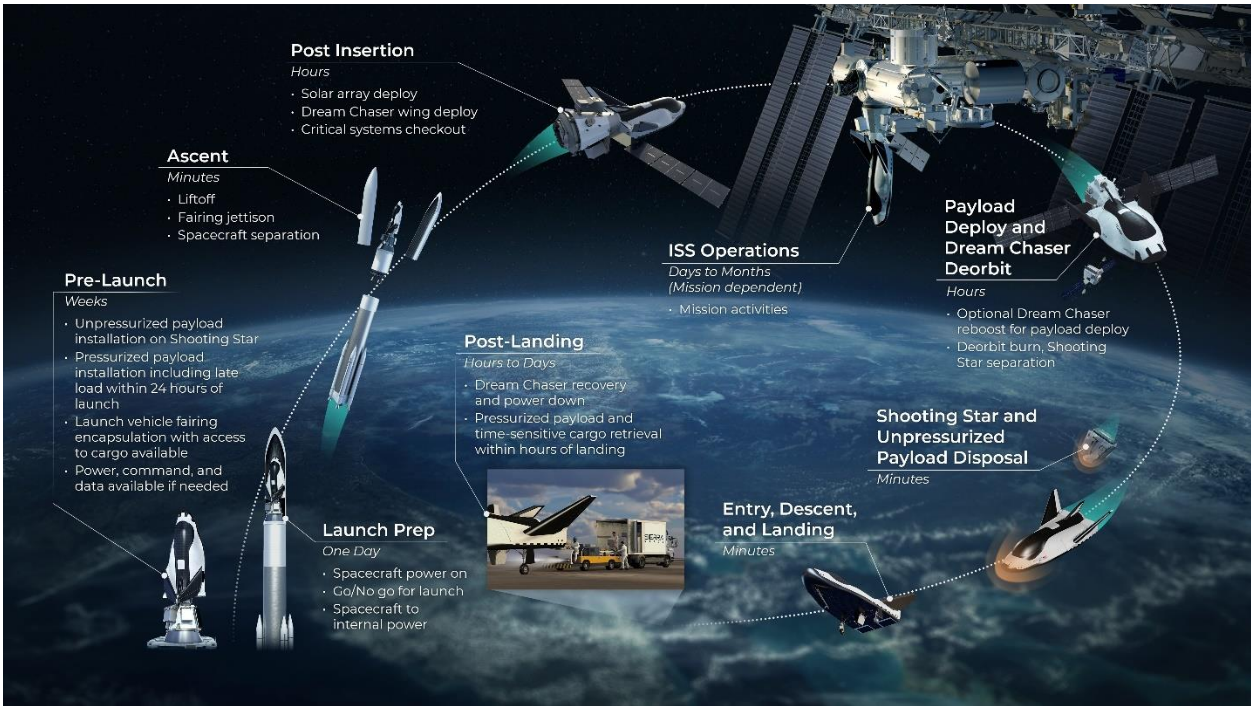

Figure 1-3: Mission Concept of Operations

1.4 DREAM CHASER CARGO SYSTEM (DCCS) OVERVIEW

1.4.1 DREAM CHASER DC-100

The cargo variant of the Dream Chaser spaceplane, the DC-100, is a lifting body with a pressurized cabin that uses a thruster Reaction Control System for spaceflight and aerodynamic control for atmospheric flight. It is the primary element of the DCCS and supports pressurized cargo upmass and downmass, including pressurized powered payloads. The DC-100 stores all consumables for the Dream Chaser and Shooting Star, provides energy storage and distribution, and houses flight computers. The DC-100 is reused for each mission. The Shooting Star and DC-100 are connected through a metallic structural adapter that supports routing of atmosphere, cooling fluid, power, and data.

Figure 1-4: DC-100

1.4.2 SHOOTING STAR CARGO MODULE

Shooting Star is a module that attaches to the aft end of the DC-100. The Shooting Star supports delivery of pressurized and unpressurized cargo to ISS, and disposal of pressurized and unpressurized cargo from ISS. The module contains solar arrays for power generation and the mechanism for mating with ISS. The Shooting Star separates from the DC-100 during deorbit for a destructive reentry.

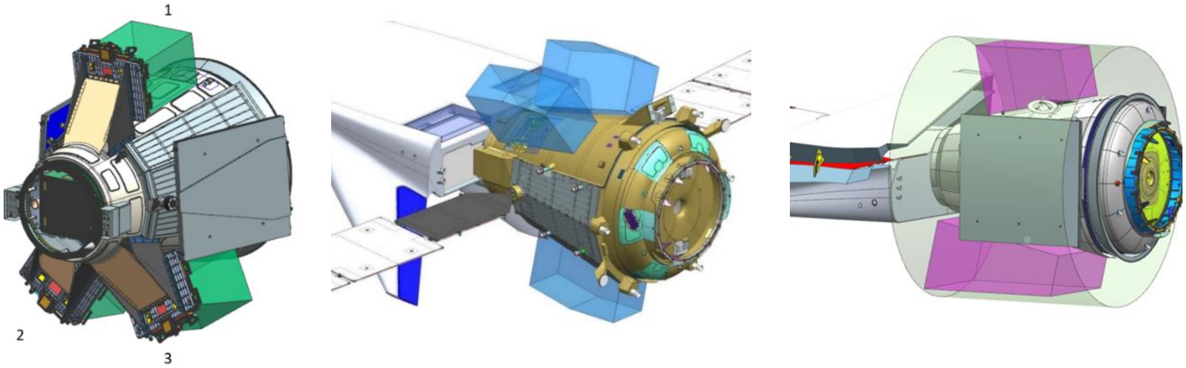

Figure 1-5: Shooting Star

1.4.3 VEHICLE COORDINATE SYSTEM

The DCCS uses an X-Y-Z coordinate frame, with the +X aligned with the vehicle long axis and +Z towards the upper dorsal. The vehicle is also divided into a right and left side, as shown in *Figure 1-6: Vehicle Coordinate System*. Additional coordinate frames may be defined with reference to the payload interface for specific missions.

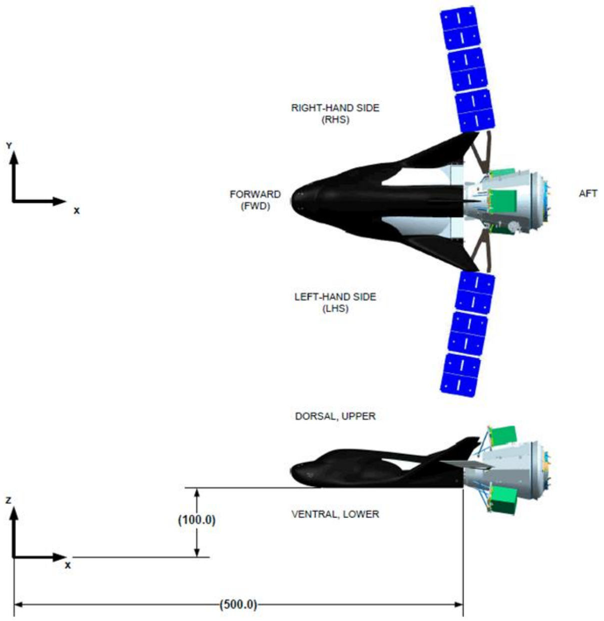

Figure 1-6: Vehicle Coordinate System

Notes:

1. X points positive toward aft and parallel to the Ventral, Lower

2. Y points positive toward starboard (Right-hand side) and perpendicular to the plane of symmetry

3. Z points positive toward the vertical tail and completes the right-hand system

4. Dimensions (100.0 and 500.0) are in inches.

1.4.4 VULCAN CENTAUR LAUNCH VEHICLE (LV)

The DCCS launches from Cape Canaveral Space Force Station on a United Launch Alliance (ULA) Vulcan Centaur rocket. ULA performs spacecraft encapsulation and integration with the LV adapter, provides unpressurized cargo access at the Vertical Integration Facility (VIF), supports late cargo loading at the VIF and pad, and executes launch operations. The integrated spacecraft is encapsulated in a 5.4 m payload fairing on the Vulcan LV.

Figure 1-7: ULA Vulcan Centaur Rocket

1.5 MISSION ASSURANCE AND RELIABILITY

The DCCS meets strict safety requirements to ensure mission success and risk mitigation. This program improves upon the history of the Space Shuttle program and its many successes and challenges.

As a lifting body reentry vehicle, the DCCS is capable of low-g re-entry and runway landing, offering a new envelope for load and time sensitive payloads with nearly immediate access to pressurized payloads after landing. The DCCS also provides late loading capability for certain pressurized payloads prior to launch.

2.0 PERFORMANCE

2.1 LAUNCH SITE

Vulcan launch operations occur at the launch pad at SLC-41. The launch pad includes a launch deck, the rail system from the VIF to the pad for transport of the Vulcan Launch Platform (VLP), VLP hard points and tie downs, launch exhaust duct, and a pad water suppression system. ULA provides the infrastructure to support DCCS during launch countdown operations, including providing power, data, cooling, and purge services. Sierra Space has late unpressurized cargo access capability if access to a payload on the Shooting Star is needed within L-8 and L-6 days.

2.2 MISSION PROFILE

The mission launches from KSC into an inclination of 51.65°. The spacecraft performs orbital maneuvers to raise orbit altitude over the next two days, with timing dependent on the location of the ISS. After a stay at the ISS of up to 75 days, the spacecraft can optionally increase its orbit altitude up to 450 km for payload deployments. Afterward, the spacecraft decreases to a deorbit altitude of 420 km. The table below provides more information on the mission profile.

Table 2-1. Orbit Profile

Orbit Altitude Profile	Inclination	Expected Duration
333 km (LV Separation)	51.65°	3 to 12 hours
333 to 420 km	51.65°	Up to 2 days
420 km (ISS)	51.65°	Up to 75 days
420 to 450 km*	51.65°	Up to 1 day
420 km (Deorbit)	51.65°	Up to 1 day
**Optional for deployments, circular and elliptical orbits available*		

2.3 AVAILABLE INJECTION ORBITS

Deployed payloads are nominally released after the spacecraft unberths from the ISS. Contact Sierra Space about deployment at other points in the mission profile. Additional information can be provided for defined missions as needed.

2.4 CARGO CAPABILITY

Table 2-2. contains the Shooting Star unpressurized cargo upmass and downmass capabilities. Unpressurized cargo volumes vary by interface and can be found in *Section 3.0.*

Table 2-2. *Shooting Star Capability*			
Capability	**Cargo Type**	**Maximum Mass (lbs) [kg]**	**Maximum Volume (CTBE)**
Upmass	Unpressurized	3,306 [1,500]	Interface Dependent
Downmass	Unpressurized (disposal)	3,306 [1,500]	Interface Dependent

2.5 PAYLOAD INTERFACE CAPABILITIES SUMMARY

Table 2-3 showcases a summary of all the offered payload interface specifications. Each option is described in more detail in *Section 3.0*.

<table>
<tr><th colspan="6">Table 2-3. Payload Interfaces Summary</th></tr>
<tr><th>Interface Type</th><th>Volume Envelope* (Inches)</th><th>Mass Capability (Kg)</th><th>Power² (Watts)</th><th>Data</th><th>Supported Satellite Class</th></tr>
<tr><td>Flush Mount</td><td>83 x 44 x 58 x 41 (L x W x H1 x H2)</td><td>500</td><td rowspan="4">100 W average power

333 W peak power for up to 2 cumulative hours</td><td rowspan="4">10/100 Base-TX Ethernet</td><td>Up to ESPA Grande</td></tr>
<tr><td>90° Standoff</td><td>48 x 56 x 44 x 38 (L x W x H1 x H2)</td><td>500</td><td>Up to ESPA Grande</td></tr>
<tr><td>QwkSep 15</td><td>83 x 44 x 58 x 41 (L x W x H1 x H2)</td><td>430</td><td>ESPA Class</td></tr>
<tr><td>QwkSep 24</td><td>83 x 44 x 58 x 41 (L x W x H1 x H2)</td><td>500</td><td>ESPA Grande Class</td></tr>
<tr><td colspan="6">Notes:
1. Separation System volume envelopes include separation ring with a 2” height
2. Custom power options available, as described in Section 4.2</td></tr>
</table>

2.6 PAYLOAD SEPARATION

2.6.1 ATTITUDE AND ACCURACY

DCCS offers 6-axis attitude control for payload deployments. Payload separation attitude will be determined by Sierra Space. Pointing accuracies of up to ±1 deg/second are available during separation.

2.6.2 RATES AND VELOCITY

All payloads must separate through an axis perpendicular to the separation ring. The separation event must target a minimum separation velocity of 1 ft/s (0.3 m/s). Payload customers are required to provide a complete recontact analysis to ensure no segments of the payload will contact the DCCS during separation.

During deployment, vehicle rates of less than ± 1 deg/second are expected.

2.6.3 PAYLOAD MANEUVERS AND DEPLOYMENTS

Payloads must delay attitude maneuvers or deployment of appendages for 300 seconds post-separation event. This delay ensures clean separation and no re-contact with the DCCS. All appendage deployments within twelve hours must be communicated to Sierra Space with a separate keep out zone for the new appendage.

Payloads must delay orbital maneuvers and secondary payload deployments at least five days post separation from DCCS.

It is the Customer's responsibility to pre-coordinate orbital maneuvers or the secondary deployment of Payload Constituents with the 18th Space Control Squadron (SPCS), submit estimated trajectories for screening to the 18th SPCS, and demonstrate to Sierra Space that coordination with the 18th SPCS has been completed.

Figure 2-1: External Payloads on the Shooting Star

3.0 MECHANICAL INTERFACES

The DCCS accommodates unpressurized cargo in up to three locations on the Shooting Star ranging in size and mass, depending on the mission-specific manifest and interface type. Each location can accommodate multiple payloads depending on payload size. Sierra Space can provide various types of mechanical interfaces depending on the needs of the payload developer.

3.1 MOUNTING LOCATIONS

The Shooting Star can be arranged to support several different configurations of payloads using three locations. Locations 1, 2, and 3 are shown in *Figure 3-1*.

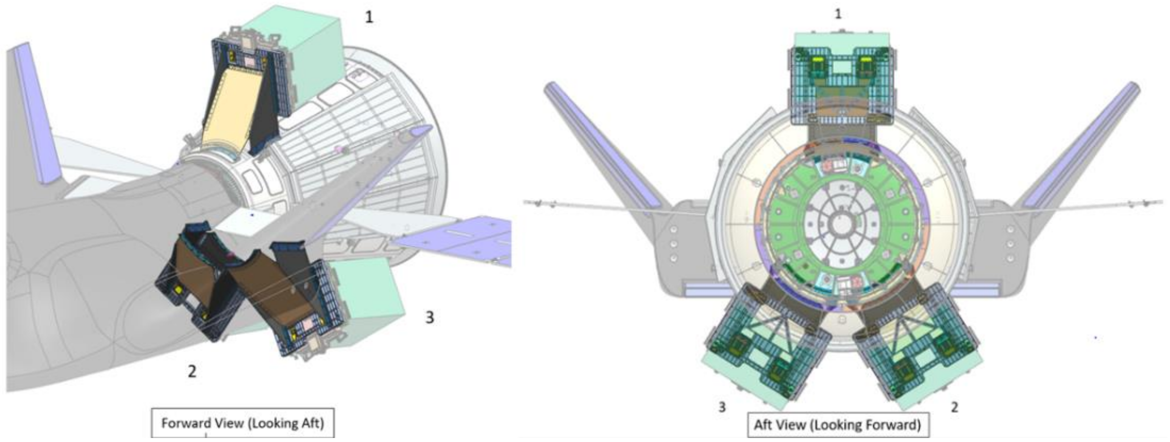

Figure 3-1: Shooting Star External Mounting Locations 1, 2, and 3

3.2 MOUNTING PLATE

Sierra Space provides a mounting plate in two different size options for unpressurized payloads in cargo locations 1, 2, or 3. The mounting plate can attach flush to adapter plates on the Shooting Star, as shown in *Figure 3-2: Mounting Plates on the Shooting Star***.** This plate option measures approximately 84" x 44" and can accommodate one or multiple payloads up to 500kg.

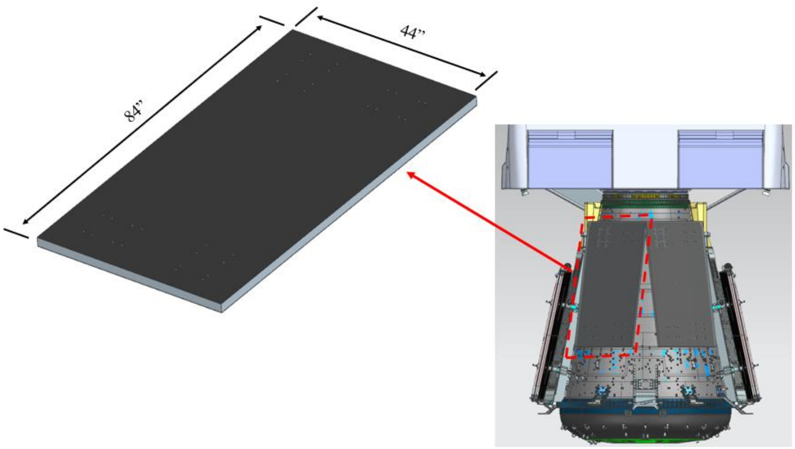

Figure 3-2: Mounting Plates on the Shooting Star

Sierra Space can also provide a 55" x 43" mounting plate that attaches to a 90° standoff, offering payloads an alternative viewing angle as shown in *Figure 3-3: Mounting Plate on 90° Standoff.* This plate orientation can also accommodate payloads up to 500kg.

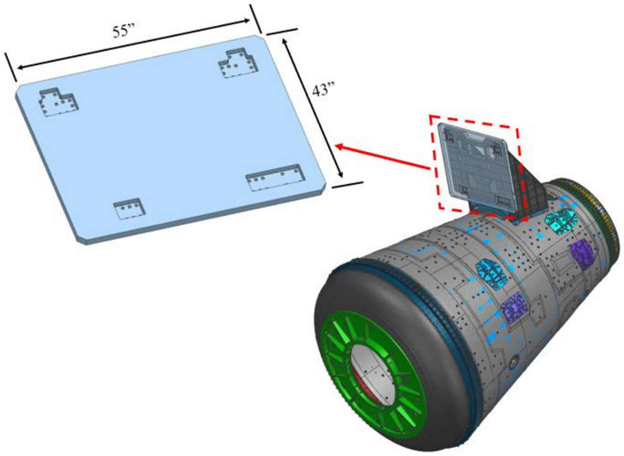

Figure 3-3: Mounting Plate on 90° Standoff

3.2.1 VOLUME ENVELOPE

The available volume envelope for the flush mounting plate is listed in *Table 3-1* and shown in *Figure 3-4*.

Table 3-1. Volume Envelope Dimensions for Mounting Plate Interface

Length (inches)	Width (inches)	Height 1 (inches)	Height 2 (inches)
83	44	58	41

Notes

- *Dimensions account for offset for structural adapter plate interface to Shooting Star*
- *Length is forward to aft*
- *Width is port to starboard*
- *Height is off surface of Shooting Star*

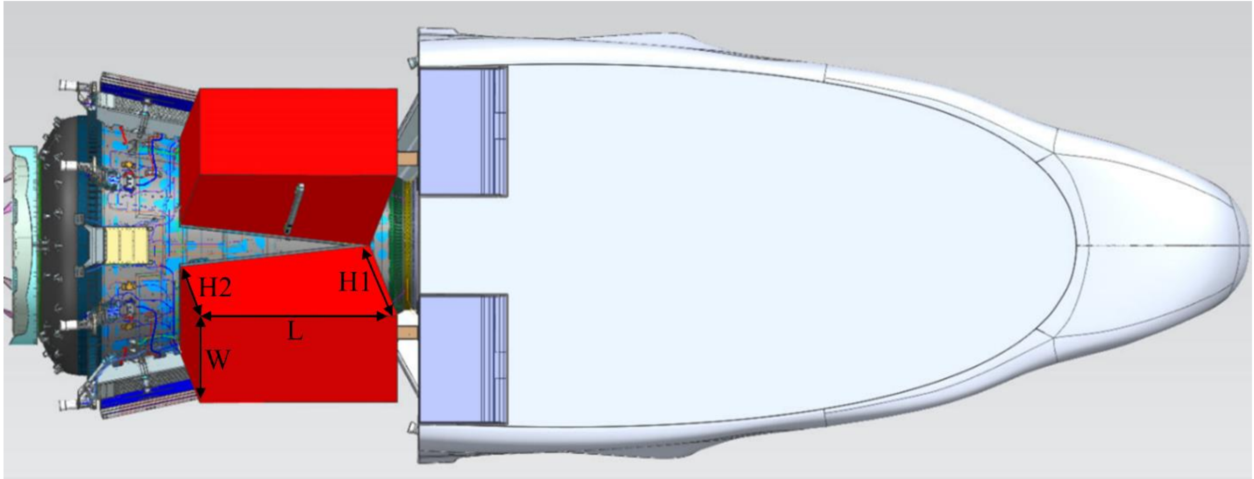

Figure 3-4: Volume Available in Locations 2 and 3 on the Shooting Star Using Mounting Plate

The available volume envelope for the mounting plate angled on the 90° standoff is listed in *Table 3-2* and shown in *Figure 3-5*: Volume Available in Locations 2 and 3 on the Shooting Star Using Mounting Plate on 90° Standoff .

Table 3-2. Volume Envelope Dimensions for Standoff Mounting Plate Interface			
Length (inches)	**Width (inches)**	**Height 1 (inches)**	**Height 2 (inches)**
48	56	44	38

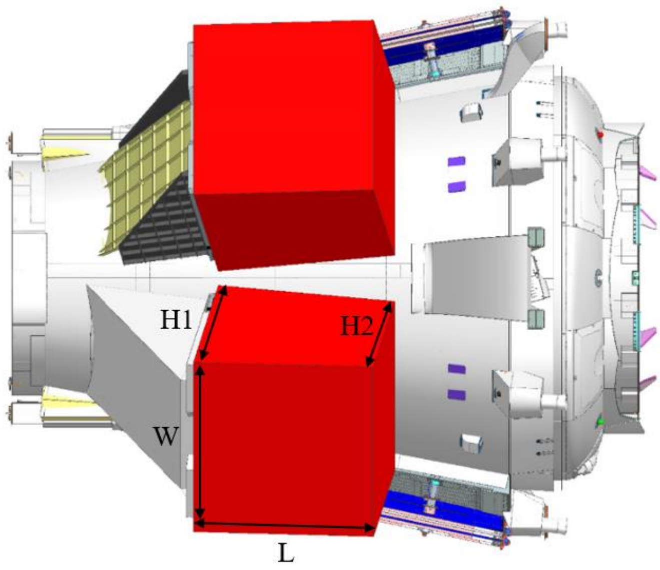

Figure 3-5: Volume Available in Locations 2 and 3 on the Shooting Star Using Mounting Plate on 90° Standoff

3.3 SEPARATION SYSTEMS

In addition to mounting plates for fixed payloads, Sierra Space provides several robust separation systems for simple payload deployment. Customers may also contact Sierra Space about use of alternative separation systems.

3.3.1 QWKSEP 15 LOW-PROFILE SEPARATION SYSTEM (LPSS)

Sierra Space's QwkSep® 15 Low-Profile Separation System (LPSS) provides a low-shock solution to small satellite separation in an extremely low profile. The system has a 15-inch satellite interface launch configuration (orthogonal to thrust axis). The interface rings have integrated adjustable kick off springs, pass-through separation connectors and redundant telemetry indication of positive separation. The system is released with a mini, low-shock Clamp Band Opening Device (CBOD). This design configuration has heritage in more than 100 successful flight releases.

The CBOD features redundant circuits driven by a typical pyrotechnic firing pulse. Based on our space-qualified Fast-Acting Shockless Separation Nut (FASSN) technology, the CBOD restrains the band tension bolts with a double helix, flywheel nut. The back drive torque of the high lead, band tension bolts is reacted through the CBOD by the latched flywheel nut. A pyro-compatible pulse releases the flywheel nut, which spins up and ejects the tension bolts. The strain energy in the band is converted to rotational energy in the flywheel nut allowing the two mating halves to separate with extremely low shock.

Figure 3-6: QwkSep 15 Low-Profile Separation System (LPSS)

3.3.1.1 SPECIFICATIONS

Table 3-3. QwkSep 15 LPSS Specifications

	U.S.	**SI**
Mechanical		
Payload Capability	948 lbm, with 20-inch center of gravity (CG) Offset height above ESPA interface	430 kg (508 mm CG height)
Quasi-static Environment	8.5 gs axial and lateral dynamic loading simultaneously	

Table 3-3.	*QwkSep 15 LPSS Specifications*	
	U.S.	**SI**
Random Vibration Environment	Qualified to NASA *General Environmental Verification Specification* (GEVS) levels for large (400+lbm) payloads (5.6 Grms)	
Stiffness Axial: Moment:	2.15E6 lb/in 9.62E7 in·lb/rad	3.76E4 Nm 1.09E7 Nm/rad
Envelope Dimensions	Ø15 BCD x 2.1-inch max stack height	Ø381 BCD x 53.3 mm
Mass, Flyaway	4.0 lbm max	1.8 kg max
Redundancy	Full electrical	
Source Shock	Pyro: 1,000 gs from 1 kHz to 2 kHz near actuator Non-pyro option: 100 gs max from 10 Hz to 10 kHz	
Kick-off Rate (separation velocity)	1 ft/s min	0.3 m/s min

Table 3-3.	***QwkSep 15 LPSS Specifications***	
	U.S.	**SI**
Electrical		
Release Signal	Pyro: NASA Standard Initiator (NSI)-firing pulse Non-pyro option: 3.5 amps for 50 ms (typical)	
Separation Telemetry	Redundant loop-back circuits indicate positive separation	Ø381 BCD x 53.3 mm
Release Time	50 ms max	
Thermal		
Operating Temperature Range	Pyro: -90 °F to +219 °F Non-pyro option: -85 °F to +167 °F	
Special Tools	Sierra Space band loading tool; Sierra Space spring compression tools	
Time Required for Reset	~ 2 hours	
Note: This data is for information only and subject to change. Contact Sierra Space for design data.		

3.3.2 QWKSEP 24 LOW-PROFILE SEPARATION SYSTEM (LPSS)

Sierra Space's QwkSep® 24 Low-Profile Separation System (LPSS) provides a low-shock solution to small satellite separation in an extremely low profile. The system has a 24-inch satellite interface launch configuration (orthogonal to thrust axis). The interface rings have integrated adjustable kick off springs, pass-through separation connectors and redundant telemetry indication of positive separation. The system is released with a mini, low-shock clamp band opening device (CBOD). This design configuration has heritage in more than 100 successful flight releases.

The CBOD features redundant circuits driven by a typical pyrotechnic firing pulse. Based on our space-qualified Fast-Acting Shockless Separation Nut (FASSN) technology, the CBOD restrains the band tension bolts with a double helix, flywheel nut. The back drive torque of the high lead, band tension bolts is reacted through the CBOD by the latched flywheel nut. A pyro-compatible pulse releases the flywheel nut, which spins up and ejects the tension bolts. The strain energy in the band is converted to rotational energy in the flywheel nut allowing the two mating halves to separate with extremely low shock.

Figure 3-7: QwkSep 24 Low-Profile Separation System

3.3.2.1 SPECIFICATIONS

Table 3-4. QwkSep 24 LPSS Specifications		
	U.S.	**SI**
Mechanical		
Payload Capability	1102 lbm with 20-inch center of gravity (CG)	500 kg
Quasi-static Environment	8.5 gs axial and lateral dynamic loading simultaneously	
Random Vibration Environment	Qualified to NASA *General Environmental Verification Specification* (GEVS) levels for large (400+lbm) payloads (5.6 Grms)	
Stiffness Axial: Moment:	6.23E6 lb/in 4.45E8 lb·in/rad	1.09E3 Nm 5.03E7 Nm/rad
Envelope Dimensions	Ø24 BCD x 2.1-inch max stack height	Ø610 BCD x 53.3 mm
Mass, Flyaway	5.0 lbm max	2.3 kg max
Redundancy	Full electrical	
Source Shock	Pyro: 1,000 gs from 1 kHz to 2 kHz near actuator Non-pyro option: 100 gs max from 10 Hz to 10 kHz	

Table 3-4. QwkSep 24 LPSS Specifications		
	U.S.	**SI**
Kick-off Rate (separation velocity)	1 ft/s min	0.3 m/s min
Electrical		
Release Signal	Pyro: NASA Standard Initiator (NSI)-firing pulse Non-pyro option: 3.5 amps for 50 ms (typical)	
Separation Telemetry	Redundant loop-back circuits indicate positive separation	
Release Time	50 ms max	
Thermal		
Operating Temperature Range	Pyro: -90 °F to +219 °F Non-pyro option: -85 °F to +167 °F	Pyro: -68 °C to +104 °C Non-pyro option: -65 °C to +75 °C
Reset		
Special Tools	Sierra Space band loading tool; Sierra Space spring compression tools	
Time Required for Reset	~ 2 hours	
Note: This data is for information only and subject to change. Contact Sierra Space for design data.		

3.3.3 SEPARATION SYSTEM INTERFACE TO THE SHOOTING STAR

Both the QwkSep 15 and QwkSep 24 separation systems interface to the Shooting Star via the mounting plate previously described in *Section 0*, with the plate oriented flush to the Shooting Star. Each plate can support multiple separation systems depending on customer needs. *Figure 3-8* depicts the mounting plate with several separation systems per plate. Contact Sierra Space if additional deployment orientations are desired.

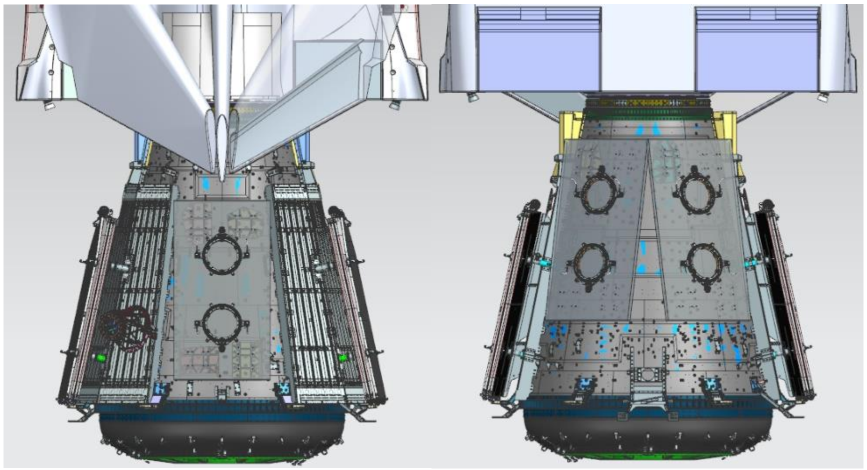

Figure 3-8: Mounting Plate in Multiple Locations with Separation System Interfaces

3.3.4 SEPARATION SYSTEM VOLUME ENVELOPES

The volume envelope for separation system payloads is the same as that listed in *Table 3-1*, with a reduced 2" in height due to the height of the separation system.

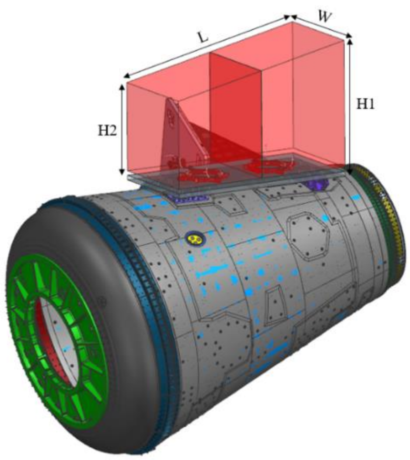

Figure 3-9: Separation System Volume Interface

4.0 ELECTRICAL POWER AND DATA INTERFACES

4.1 STANDARD OFFERING INTERFACE

The DCCS provides a nominal 120 VDC of electrical power to the payload interface as a standard service. Each unpressurized payload can draw up to 100 W average power, with a 333 W peak power level for no more than 2 cumulative hours. This power draw can be negotiated on a mission-specific basis depending on the other payloads manifested. A total of 300 W nominal is available for all the unpressurized payloads. The harness interface is worked during the ICD development process.

4.2 CUSTOM OFFERING

The DCCS can provide other ranges of electrical power and signals if needed by the payload developer, as shown below.

Table 4-1. Payload Interface Signal Options (Power/Analog/Discrete)

Type	Excitation	Receive Input Data Current/Voltage	Notes	Quantity Channels Available
Analog - RTD (2-wire)	1 mA	0-5 V		8
Analog - Differential Voltage (4-wire)	10V	0-109 mV	50mA limit for 10V excitation	5
Analog - Differential Voltage (4-wire)	24V	0-5 V	150mA limit for 24V excitation	1
Analog - Current (2-wire)	24V	0-55 mA		2
Discrete - Input	N/A	0V/5V	Internal 5V pullup	8

Table 4-1. Payload Interface Signal Options (Power/Analog/Discrete)				
Type	**Excitation**	**Receive Input Data Current/Voltage**	**Notes**	**Quantity Channels Available**
Discrete - Output	0V/5V	N/A		8
Power Channels	22-32V	N/A	5A limit per channel Voltage dictated by vehicle bus/SOC	12

4.3 DATA AND COMMUNICATION

4.3.1 STANDARD OFFERING

The DCCS vehicle provides an Ethernet data connection (ANSI/IEEE-STD-802.3, Institute of Electrical and Electronic Engineers (IEEE) Standard for Ethernet, 10/100 BASE TX Ethernet) for each unpressurized cargo location to transfer cargo Health & Status (H&S) data using Ethernet protocols. The payload should provide data output at a frequency of 1 Hz if ethernet based H&S data is desired.

The DCCS vehicle provides H&S data packets prior to launch and ending with removal of the cargo with frequencies that meet or exceed the following rates:

- While unpressurized cargo is installed on the DCCS post launch and not mated to ISS, Sierra Space provides one data packet per unpressurized cargo item at a rate of no less than once per minute.
- While unpressurized cargo is installed on the DCCS and mated to ISS and Ethernet connection established, Sierra Space provides one data packet per unpressurized cargo item to ISS at a rate of no less than once per second (1 Hz).

4.3.2 CUSTOM OFFERING

If requested, the DCCS provides commanding capability to each unpressurized cargo location via six discrete interfaces and additional telemetry is provided via six analog interfaces. The harness and signal interfaces and characteristics are established during the ICD development process, examples are shown in *Table 4-1.* The DCCS can also provide additional data storage depending on customer needs.

5.0 LOADS AND ENVIRONMENTS

The below sections offer insight into the launch environments for unpressurized cargo on DCCS. Once manifested, the exact environments and unique details will be worked via the ICD development process.

5.1 LAUNCH ACCELERATION LOADS

While on the launch vehicle, the payload will experience a range of axial and lateral accelerations. Axial acceleration is driven by launch vehicle thrust and drag profiles; lateral acceleration is primarily driven by wind gusts, engine dynamics, and other short-duration events.

Launch acceleration loads are dependent on the payload mass and mechanical interface type. Final load factors will be determined during the ICD process, but in general payloads can expect loads within the bounds shown in *Table 5-1. Payload Launch Acceleration Loads*.

Table 5-1. Payload Launch Acceleration Loads

Payload Mass (kg)	Axial (DCCS X) (g)	Lateral RSS (DCCS Y/Z) (g)
0-500	+/- 8.2	5.5

Reference Frame Notes:

1. *X: The launch axis of the vehicle. Positive x-axis extends from the nose toward the tail and parallel to the belly of the payload vehicle.*
2. *Y/Z: Lateral factors are applied at every 15 degrees azimuthally normal to the X direction.*
3. *All components of accelerations are applied simultaneously.*

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5.2 RANDOM VIBRATION

Payloads can expect vibration environments within the bounds shown in *Table 5-2* and *Table 5-3*. Provided loads do not contain a qualification factor. Since Sierra Space can fly multiple payload configurations, structural models will be included in the CLA results for final payload responses.

Table 5-2. Random Vibration Environment for Launch (Normal)

Frequency (Hz)	**Unpressurized Cargo Launch Vibration MPE – All Events – Normal/Vehicle Axial [g²/Hz]**
20	0.04
100	0.04
120	0.075
180	0.075
250	0.005
400	0.005
500	0.002
2,000	0.002
Gravity Root-Mean-Square (GRMS)	3.82
Duration	60 sec/axis

Table 5-3. Random Vibration Environment for Launch (Lateral)	
Frequency **(Hz)**	**Unpressurized Cargo Launch Vibration MPE – All Events – Lateral Axes** **[g²/Hz]**
20	0.01
40	0.01
50	0.03
90	0.03
100	0.05
130	0.05
150	0.03
300	0.002
2,000	0.002
GRMS	3
Duration	60 sec/axis

5.3 SHOCK

Shock events include launch vehicle stage separations, fairing separation, spacecraft separation, Solar Array deployment, and Shooting Star separation. Payloads can expect shock environments within the bounds shown in *Figure 5-1: Shock Environment*.

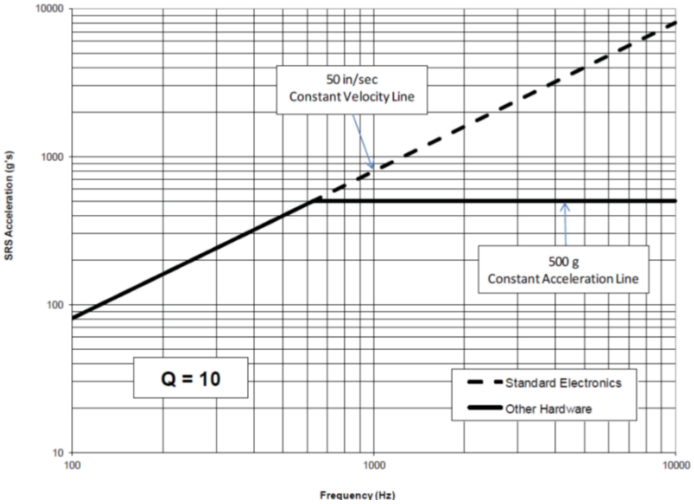

Figure 5-1: Shock Environment

5.4 ACOUSTIC ENVIRONMENT

While on the launch vehicle during ascent, the payload will be subjected to a varying acoustic environment. Levels are highest near liftoff and during transonic flight.

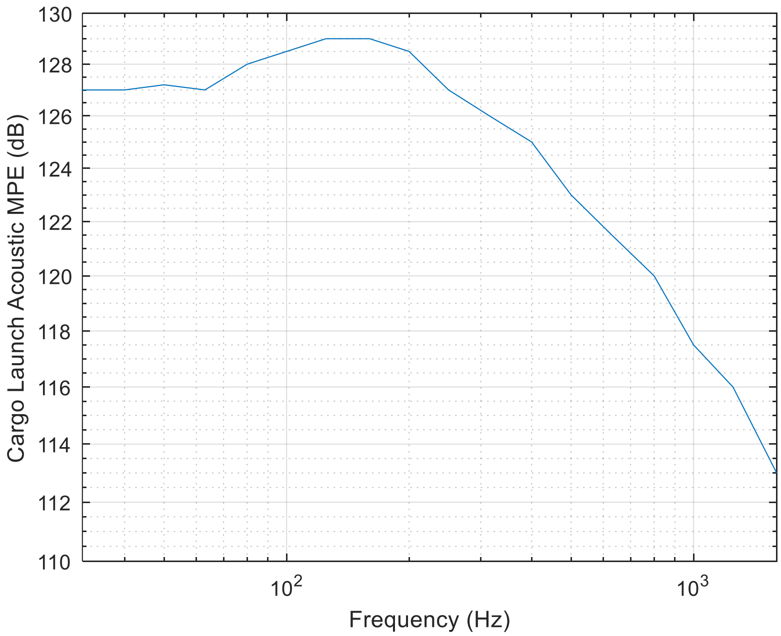

Figure 5-2: Acoustic Environment

5.5 PRESSURE DECAY

While on the launch vehicle during ascent, the pressure withing the payload fairing will slowly decrease as altitude increases. The payload should expect a maximum ambient pressure decay rate of 1.2 psi/s.

5.6 MICROGRAVITY QUALITY

Maneuvers on-orbit will cause a linear acceleration in any axis no greater than 0.04 g. Constant disturbances to virbo-acousitc acceleration limits from the payload between 10 – 300 Hz must be less than 0.1 mico-g.

5.7 THERMAL

Unpressured cargo externally mounted on the Shooting Star can be exposed to direct sun and deep space throughout the mission profile. The thermal environment is dependent on the payload's location on the Shooting Star. The bounding, worst-case parameters for thermal analysis should be qualified within -140 °F (-95.6 °C) to +220 °F (104.4 °C).

These values should be used as a reference to ensure the payload can be placed at any Shooting Star location and operate during all attitudes and beta angles. In reality, the mission profile may not be as extreme and DCCS can adjust its flight profile for better payload temperature regulation, if needed. 120V power is available for heaters to keep payload components within thermal limits as needed.

5.8 EMI/EMC SUSCEPTIBILITY

Payloads that have safety-critical circuits are required to comply with susceptibility requirements via testing. These requirements will be provided during the ICD development process. The safety-critical determination is via analysis. If the payload is determined not to have any safety-critical circuits, then susceptibility testing is not required. Safety-critical circuits are defined as:

- Circuits whose loss of function due to electromagnetic effects (EME) could result in a critical (loss of hardware function resulting in inability to complete the mission, e.g. loss of mission) or catastrophic hazard (loss of an uncrewed vehicle prior to completing its primary mission) or,

- Circuits whose malfunction or degradation of performance because of EME that could result in a critical or catastrophic hazard or,

- Circuits that control inhibits whose loss due to EME could result in critical or catastrophic hazards. This includes impacts on upstream DCCS vehicle power and hardware channelized to that power path.

6.0 MISSION INTEGRATION AND SERVICES

6.1 MISSION MANAGEMENT

Sierra Space provides each payload with a single technical point of contact from initial manifesting through launch. Your Mission Manager is responsible for coordinating mission integration analysis and documentation deliverables, planning integration meetings and reports, conducting mission-unique design reviews, and coordinating all integration and test activities associated with the mission.

The Mission Manager leads a mission team who will periodically be called on to answer payload questions or support requirements development. This team is shown in *Figure 6-1: Mission Management Team Organization*.

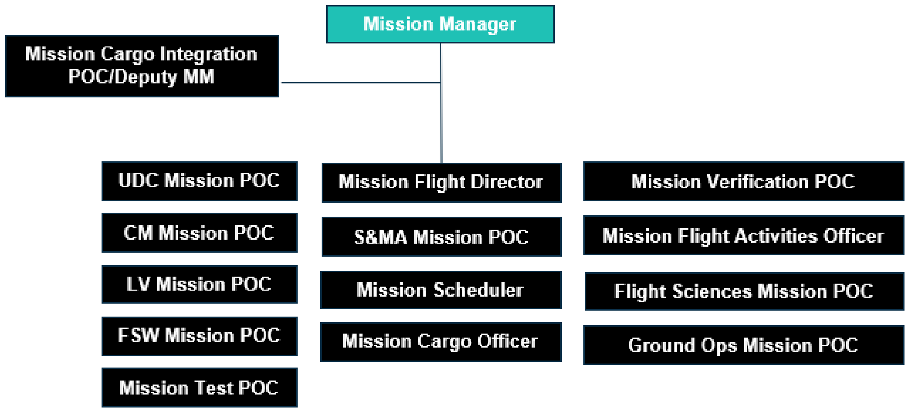

Figure 6-1: Mission Management Team Organization

The Mission Manager and mission integration team will work with the customer to create a payload to Shooting Star ICD and determine all required evidence for verification. Following signature approval of the ICD, Sierra Space maintains configuration control of the document.

6.1.1 MISSION AND PAYLOAD INTEGRATION PROCESS

Once a payload is manifested and an interface type is selected, Sierra Space provides a payload questionnaire and a mission interface requirements document (IRD). The IRD defines all payload to vehicle interfaces, assumptions, requirements, and proposed verification methods.

Requirement applicability from the IRD and any unique payload requirements will form the payload-specific ICD. Once signed, the ICD will serve as the main interface document between the payload and Sierra Space. The payload will be required to provide verification evidence as specified in the ICD.

A series of mission integration meetings, deliverables, and decision points are executed to successfully manage missions and ensure compatibility of cargo with the DCCS interfaces. These meetings are used to manage the design, development, qualification, testing, and integration of mission-unique requirements. Mission-specific hardware and software development status is tracked, and issues are resolved through this integration review process. *Table 6-1. Mission Integration Events* presents an overview of major DCCS mission integration reviews. All events in the below table represent a nominal mission integration process. Changes/updates can be accommodated as needed.

Table 6-1. Mission Integration Events

Event	Date	Purpose and Key Products
Integration Kickoff Initial Payload Data Delivery	L-20 months	Payload provides preliminary (Preliminary Design Review (PDR) or best available) data and any mission unique services needed. Sierra Space provides IRD and payload questionnaire
Vehicle Baseline Review (VBR)	NLT L-18 months	NASA mission required milestone. Establishes and formalizes the baseline vehicle and specific configuration for the mission. Unpress cargo configuration and preliminary data presented.
Payload Data Delivery	L-16 months	Payload provides Critical Design Review (CDR)-fidelity thermal, CAD, structural models and re-entry data to Sierra Space. Will be used in mission analysis cycles to determine mission performance and requirements compliance.
Draft ICD	L-14 months	First draft of ICD completion date, includes results from payload questionnaire and IRD applicability
Mission Integration Review (MIR)	NLT L-12 months	NASA mission required milestone. Provides program with a current mission integration status

Table 6-1. Mission Integration Events

Event	Date	Purpose and Key Products
Final ICD	L-10 months	ICD finalized and signed by this point. ICD verification closure starts.
Unpressurized Integration Review (UIR)	L-10 months	Demonstrates readiness to receive and integrate unpressurized payloads. Reviews results of unpressurized cargo analysis.
Payload Data Delivery	L-8 months	Payloads provide Phase III safety data and any model/data updates for second mission analysis cycle
Flight Operations Review (FOR)	L-6 months	Program review of all baseline integrated operations products, including flight design/dynamics products, timelines, procedures, and flight rules.
Cargo Integration Review (CIR)	NLT L-3 months	NASA required mission milestone. Demonstrates Sierra Space readiness to receive and integrate cargo at L-30 days.
Payload Installation	L-60-40 days	Payload installed on cargo module and tested for power/data connections
Flight Readiness Review (FRR)	L-4 days	Final review of flight readiness prior to launch of all missions
Launch Vehicle Readiness Review (LRR)	L-2d	LV provider leads review to ensure all critical items needed for launch are ready, vehicle systems verified, actions closed or resolved, Range and launch site readiness, tracking and data resource readiness, open work status and closeout plans identified, and mission risks documented.
Post-Mission Review	End of Mission (EOM) +30 days	Assesses mission success after return of cargo and completion of mission.

6.1.2 CUSTOMER DELIVERABLES

The following are the expected deliverables from the payload customers.

Table 6-2. Pre-Mission Key Integration Deliverables

Deliverable	Deliverable Description
Payload Safety Data	Payload information to support creation of FAI submittals, requirements tailoring and launch operations planning. Includes hazard analyses and reports, vehicle break-up models, and detailed design/test information
Payload Models	CAD, thermal, and structural models for requirement compatibility and verification analysis
ICD Information	Provide needed data for the payload specific ICD. This includes items like mass, orbits, pinouts for electrical interfaces, IP addresses, unique/non standard services, mechanical drawings, etc. Payload developer is required to sign ICD and approve to the verification methods.
Environmental test plans and reports	Payload provider's approach to qualification and acceptance testing, including general test philosophy, testing to be performed, objectives, test configuration, methods and schedule. Specific qualification and acceptance test data may be required prior to launch to demonstrate compatibility Sierra Space and NASA requirements.
Launch site operations plans and procedures	Describes all aspects of mission activities to be performed at each ground processing location. Ground installation and GSE procedures/design. Interface testing procedures. Hazardous procedures must be approved.

7.0 OPERATIONS

7.1 PRE-LAUNCH OPERATIONS

7.1.1 DCCS PROCESSING

The DCCS is integrated at KSC. Unpressurized payloads are handed over at the Space Systems Processing Facility (SSPF) at least 60-35 days before launch for installation on the Shooting Star within the SSPF while the vehicle is in a horizontal orientation.

The payload provider is responsible for payload transportation, final checkouts, and services prior to handover at KSC.

Following stand-alone activities, the DC-100 and Shooting Star are rotated vertically, stacked, and transported to another facility for checkouts and fueling operations, followed by encapsulation in the LV fairing.

The integrated spacecraft is transported to the LV facilities for hoist and mate to the LV. Within this facility, access by Sierra Space personnel is available for external payloads for final payload operations such as removing Remove Before Flight items between L-8 and L-5 days.

7.1.2 PRE-LAUNCH SERVICES

Table 7-1 shows the services available to unpressurized payloads after installation on the Shooting Star.

Table 7-1. Resources Available to External Payloads

Resource	Nominal	During Critical Operations*
Power	300 W 120 Vdc; Provided via ground power resource to support operations as needed	None
Data	When powered, health and status data are available once per day; limited to 0.1 Hz post-encapsulation	None
Temperature	Pre-VIF: 60 °F (15.56 °C) to 80 °F (26.67 °C) VIF and after: 50 °F (10°C) to 80 °F (26.67 °C)	50 °F (10.0 °C) to 89 °F (31.6 °C)

Table 7-1. Resources Available to External Payloads		
Resource	**Nominal**	**During Critical Operations***
Humidity Control	Pre-VIF: 25% to 75% relative humidity VIF and after: 0% to 75% relative humidity	0% to 75% relative humidity
Air Purge	Provided if needed pre-encapsulation and then continuous 5K class post-encapsulation. At L-4 hours, switches to 5k class GN2.	During Astrotech transport, 100K purge During VIF transport, 5K purge During hoist, visibly clean maintained
Physical Access	Payload can be accessed prior to transport to Astrotech Access inside the launch vehicle fairing can be provided between L-8 and L-5 days	None
***** *Critical operations include 1 day transport to Astrotech, higher priority testing activities, 1 day transport to VIF, 1 hour hoist onto LV, and 1 hour rollout to the launch pad.*		

7.1.3 CLEANLINESS

During ground processing, Sierra Space maintains unpressurized cargo in accordance with visibly clean sensitive cleanliness requirements as specified in SN-C-0005, *Space Shuttle Contamination Control Requirement*.

All operations are conducted in a certified 100K cleanroom environment.

7.2 PAD OPERATIONS

Rollout of the LV to the pad is typically conducted the day before launch. The DCCS is powered on at the pad and remains powered for the mission. Within an hour of launch, the DCCS seamlessly transitions to internal power and the launch team supported by the launch provider at KSC and the DCCS flight control team in Colorado provides the Go for Launch. In the event of a launch scrub, the next launch attempts are typically targeted at 24 to 48 hours after the previous attempt.

7.3 LAUNCH AND POST-INSERTION

The LV provider performs launch operations. Once the launch vehicle fairing is jettisoned on ascent, the unpressurized payload is exposed to the space environment. The ascent duration is less than 30 minutes. Once separated from the LV and checkouts are complete (within a few hours of launch), the DCCS enters orbit operations. Checkouts are complete prior to the first of a series of phasing burns to reach ISS orbit. Potential mission activities include but are not limited to Earth or space observation while maintaining FOV attitudes and payload-level activities.

Payload commanding is executed by the Dream Chaser Mission Control Center (DC-MCC). Depending on the payload and operation, data from the DC-MCC can be available to payload providers real-time at the DC-MCC or downlinked and securely sent to the provider's operating location within 24 hours.

7.4 ISS RENDEZVOUS AND PROXIMITY OPERATIONS (RPO)

The integrated rendezvous phase begins when common communication for visiting vehicles (C2V2) is established at approximately 30 km from ISS. Upon authority to proceed (ATP) commands from the DC-MCC, the DCCS executes a series of onboard-calculated rendezvous burns. The DCCS approaches and enters the approach ellipsoid, where the proximity operations phase begins. The DCCS autonomously approaches ISS along the R-Bar with stops at planned hold points. Once reaching the capture volume, NASA uses the Space Station Remote Manipulator System (SSRMS) to grapple and berth the DCCS to the ISS at either the Node 1 Nadir or Node 2 Nadir location.

7.5 ISS ATTACHED OPERATIONS

While berthed to ISS, the Dream Chaser is located at the Node 1 or Node 2 Nadir port with the Shooting Star end pointed zenith and top of the spacecraft pointed into the velocity vector (see *Figure 7-1)*. Visibility in each direction is estimated in *Table 7-2* and detailed Field of Views (FOV) can be provided with more analysis.

As needed, unpressurized payloads are available for transfer to any of the ISS external platforms throughout the mission. Transfer to ISS platforms requires pre-coordination with NASA. DCCS unpressurized cargo is transferred using the SSRMS or SPDM, controlled by the ISS flight control team. Sierra Space coordinates with the ISS team to operate DCCS camera systems and DCCS-based FSE mechanisms.

Downmass unpressurized cargo mounts to the exterior of the Shooting Star for deployment or disposal.

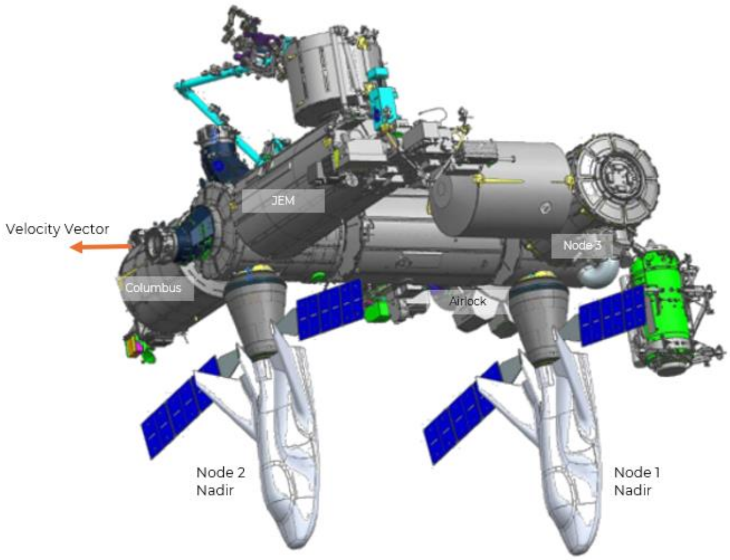

Figure 7-1: DCCS Berthing Locations on ISS

Table 7-2.	***DCCS External Payload FOV During Berthed Operations***	
Direction Relative to VV	**Node 1 Nadir FOV**	**Node 2 Nadir FOV**
Starboard	Partially Obstructed	Partially Obstructed
Port	Partially Obstructed	Partially Obstructed
Aft	Limited FOV	Limited FOV
Zenith	Obstructed by ISS structure	Obstructed by ISS structure
Forward	Partially Obstructed	Partially Obstructed
Nadir	Partially Obstructed	Partially Obstructed

7.6 ISS UNBERTH AND DEPARTURE OPERATIONS

Prior to leaving ISS, the Sierra Space flight control team performs a series of entry-critical systems checkouts to verify the DCCS is ready for departure. NASA grapples the DCCS with the SSRMS and uses the SSRMS to maneuver and release the DCCS. The DCCS performs a departure burn to safely exit the ISS vicinity.

7.7 PAYLOAD DEPLOYMENT

For missions including payload deployments, the DCCS performs additional maneuvers, as needed, to reach the deployment orbit. This may include orbits higher than the ISS altitude, as provided in *Section 2.2 Mission Profile*. Pre-mission coordination between Sierra Space and the payload developer will determine the optimal location and DCCS attitude for deploying payloads along the orbit. The DC-MCC will initiate the deployment sequence which will command the Sierra Space deployment mechanism to release the payload at the required location. Back-up opportunities are planned in the mission profile in the case of a deployment waive-off.

7.8 DEORBIT

At the end of the mission, the DC-MCC prepares the DCCS for deorbit. The Shooting Star is depressurized, and final checkouts are performed for entry activities. Flight control personnel monitor the landing criteria including weather and provide a Go for Deorbit. The DCCS performs all subsequent operations autonomously until wheels stop on the runway, lasting about 1 hour. After the deorbit burn, the Shooting Star detaches from the DC-100 and proceeds along its disposal trajectory over the Pacific Ocean. This disposal profile provides safe, broad open ocean disposal of the jettisoned Shooting Star and the unpressurized cargo that meet the FAA Part 450 reentry criteria. Payload developers are required to submit data to support payload disposal analysis prior to launch. The Dream Chaser continues to a runway landing at the KSC LLF.

If a deorbit waive-off occurs, Sierra Space will communicate any change in operations with the payload providers. The next deorbit attempt can be as soon as 90 minutes following the previous attempt or wait until the next day.

7.9 MISSION CONTROL

The state-of-the-art DC-MCC monitors and commands the DCCS from power on at the launch pad through post-mission operations. Real-time monitoring services are available for payload providers within DC-MCC facilities, if needed for part or all of the mission.

Figure 7-2: DC-MCC Facility

8.0 SAFETY

8.1 SAFETY REQUIREMENTS

All payloads flying on DCCS require a hazardous assessment to prove the payload does not create hazards. The payload shall not require critical commands or monitoring of a hazardous function. Additional safety requirements and standards will be developed for each mission given their dependency on mission parameters such as orbit, vehicle configuration, and other payloads. This flexibility in safety requirements affords scientists and investigators a wider variety of possible onboard experiments.

The payload shall meet the requirements of *Dream Chaser Cargo System AFSPCMAN 91-710[T] Tailoring Document* in the design and operations of their payload and ground equipment. In addition, customers must provide a Ground Safety Checklist (KSC 50-341, *Ground Safety Checklist*) for SSPF operations. All hazardous operations (ordnances, pressurized systems, lifting toxic materials, high-power RF/lasers) require procedures that are approved by both Sierra Space and the launch range prior to execution.

If a customer has an idea for an experiment that has previously been prohibited on other vehicles for safety reasons, please reach out to Sierra Space to discuss options to fly on DCCS.

8.2 HAZARD ASSESSMENT

A hazard assessment shall be conducted per MIL-STD-882 or a Sierra Space approved alternative that meets the same intent. Payload providers are required to support the integrated assessment for hazardous mission conops. For standard service, rideshare payloads should not require any hazard controls from the DCCS. Payload-specific issues can be assessed on a case-by-case basis. Finally, the information needed for ISS Safety Review Panel (ISRP) Phase III approval will be required for rideshare missions.

8.3 WAIVERS

For systems and operations that do not meet safety requirements but are believed to be acceptable for ground operations and launch, a waiver is produced for approval by the launch range safety authority. Waivers are considered a last resort and should not be considered a standard practice.

9.0 FACILITIES

Ground systems facilities are based in Louisville, CO, at KSC, Cape Canaveral Space Force Station (CCSFS), and Titusville, FL. The Florida facilities support DCCS ground operations from launch through landing and include the SSPF, ASO, VIF, Space Launch Complex-41 (SLC-41) launch pad, and LLF. *Figure 9-1: Overview Map of KSC and CCFS Facilities Used for the DCCS* provides an overview map of the KSC and CCSFS facilities used for the DCCS.

Figure 9-1: Overview Map of KSC and CCFS Facilities Used for the DCCS

9.1 LOUISVILLE, CO

The DC-100 and Shooting Star are individually assembled and functionally tested at Sierra Space's facility in Louisville, CO. Once horizontal integrated testing is complete, the DC-100 and Shooting Star are shipped to environmental testing before being sent to the SSPF for horizontal processing. A new Shooting Star is manufactured, environmentally tested, and delivered to the SSPF for each subsequent mission.

9.2 SPACE SYSTEMS PROCESSING FACILITY (SSPF)

DCCS pre-launch and post-mission processing activities occur at the SSPF at KSC. Sierra Space uses two adjacent footprints and an additional footprint for overflow in the class 100K clean-level SSPF high bay for DC-100 and Shooting Star processing. The SSPF provides unique science and hardware laboratory capabilities for pressurized and unpressurized cargo processing pre-handover.

Figure 9-2: NASA/KSC Space Systems Processing Facility (SSPF)

9.3 ASTROTECH SPACE OPERATIONS (ASO)

The DC-100 propellant loading and encapsulation facility is the ASO Building 9 Spacecraft Processing Facility in Titusville, FL. ASO provides a class 100K clean room high bay and encapsulation bay with dedicated control rooms for spacecraft processing and 5-meter payload fairing (PLF) encapsulation.

Figure 9-3: Astrotech Space Operations Spacecraft Processing Facility

9.4 VERTICAL INTEGRATION FACILITY (VIF)

The encapsulated spacecraft is transported by ULA to the VIF located at SLC-41.

Figure 9-4: Encapsulated Spacecraft

After arrival at the VIF, the encapsulated spacecraft is hoisted on to the top of the launch vehicle.

Figure 9-5: Spacecraft During Hoist Operations

ULA leads spacecraft and Vulcan integration activities. The VIF provides conditioned air and power supplied through ground interfaces to support spacecraft operations and monitoring. Platforms in the VIF provide access for pressurized cargo installation and access to unpressurized cargo. Platforms in the VIF and within the fairing provide unpressurized cargo access starting at L-8 days until L-5 days, for activities such as remove before flight (RBF)/inspect before flight (IBF).

Figure 9-6: ULA Vertical Integration Facility (VIF)

9.5 SPACE LAUNCH COMPLEX 41 (SLC-41) LAUNCH PAD

Vulcan launch operations occur at the launch pad at SLC-41. The launch pad includes a launch deck, the rail system from the VIF to the pad for transport of the Vulcan Launch Platform (VLP), VLP hard points and tie downs, launch exhaust duct, and pad water suppression system. ULA provides the infrastructure to support DCCS during launch countdown operations, including providing power, data, cooling, and purge services.

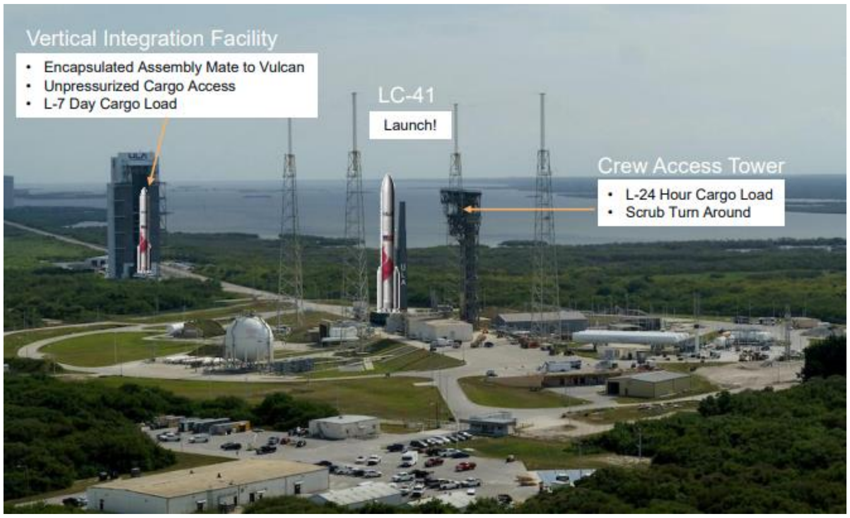

Figure 9-7: SLC-41 Launch Pad

9.6 LAUNCH AND LANDING FACILITY (LLF)

The LLF at KSC is the landing site for DCCS missions. The LLF is a 15,000-ft long x 300-ft wide runway. A convoy staging area is provided at the LLF for the DC-100 landing and recovery team and associated GSE. The LLF is where time-critical cargo (R+3/6 hour pressurized cargo) is unloaded and handed over to NASA for rapid return. Sierra Space interfaces directly with the NASA team to complete handover. The NASA cargo team follows their standard flow, receiving cargo from the NASA team working in Florida.

Figure 9-8: Launch and Landing Facility (LLF)

9.7 MISSION CONTROL CENTER (MCC)

The DCCS flight control team supports flight operations from the DC-MCC. There are two certified DC-MCCs geographically located in separate facilities, one in the Taylor facility in Louisville, CO, and the other in the Control Room 9 (CR9) at KSC. The DC-MCC in Louisville, CO is the primary flight control room, with CR9 serving as a fully capable backup. Both facilities are connected to a dual fault-tolerant wide area network (WAN), supporting DCCS control and monitoring through all mission phases.

Figure 9-9: Dream Chaser Mission Control Center in the Taylor Facility in Louisville, CO

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