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Spacecraft/Payload Integration & Evolution Element,
Space Launch System Program
Marshall Space Flight Center AL 35812

Space Launch System (SLS) Block 1B Secondary Payloads: ESPA-Type and 27U Cubesat Potential Accommodations

WHITEPAPER

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The following are excerpts from the Space Launch System (SLS) Mission Planner's Guide (ESD 30000 Rev. A, 12/19/18). It is available publicly at https://ntrs.nasa.gov/search.jsp?R=20170005323. *Questions may be sent via email to:* *nasa-slspayloads@mail.nasa.gov*

1.0 Lunar Vicinity

For typical SLS Block 1B missions to cislunar destinations (e.g., Lunar Gateway), the SLS Exploration Upper Stage (EUS) will perform a Trans Lunar Injection (TLI) burn to enable Orion to insert into a Near Rectilinear Halo Orbit (NRHO), shown in Figure 1. Primary Payload (PPL), Co-manifested Payload (CPL), and Secondary Payload (SPL) operations begin after Orion has separated from the EUS/USA. Depending on mission requirements, this separation can occur approximately five to eight hours from launch. Following separation from Orion, EUS will continue onto a heliocentric disposal trajectory. Deployment of any SPLs may occur during this period as shown as notionally represented Figure 2.

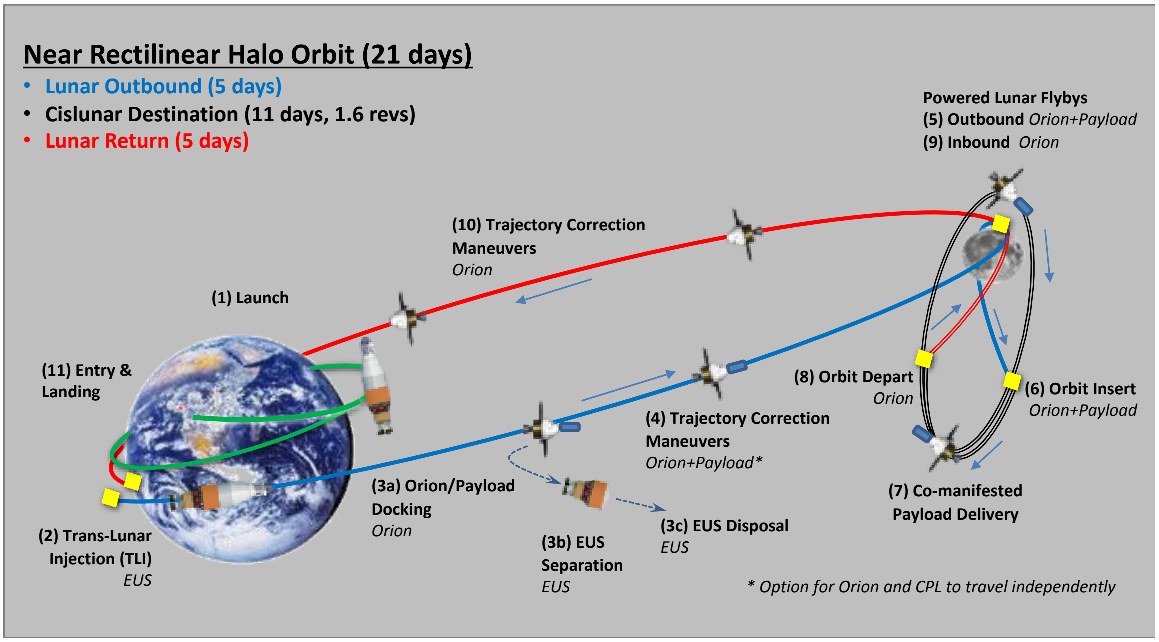

Figure 1. SLS Block 1B Near Rectilinear Halo Orbit (NRHO) Trajectory

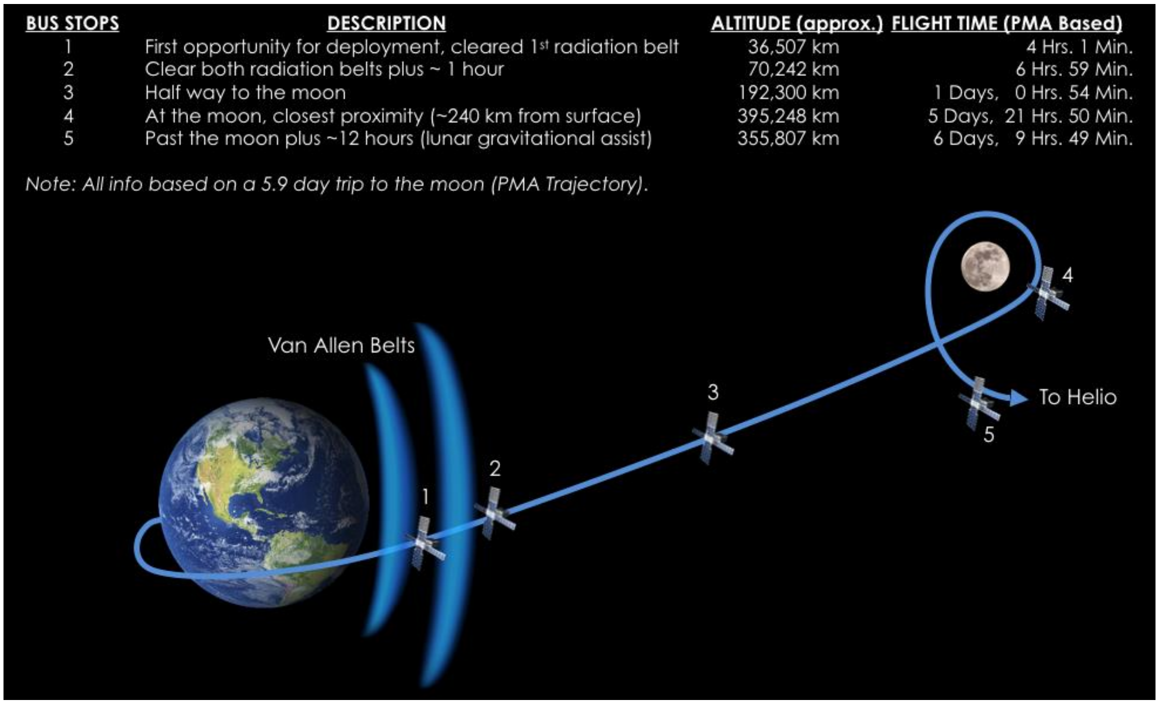

Figure 2. Representative Secondary Payload Jettison "Bus Stops"

2.0 SLS Environments

This section describes the SLS Block 1B environments to which a spacecraft or payload will be exposed, both during ground processing and in flight.

2.1 Structural Loads

Spacecraft/payload accelerations are estimates from ongoing SLS analysis. Dynamic excitations, occurring predominantly during liftoff and transonic periods of SLS flights, are superimposed on steady-state accelerations from specific mission trajectory analyses to produce combined accelerations that should be used in payload structural design. The combined payload accelerations are a function of launch vehicle characteristics as well as payload dynamic characteristics and mass properties. Representative design load factors for SLS Block 1B payloads are shown in Table 1.

Table 1. Block 1B Payload Component Load Factors Due to Low Frequency Loads

Flight Phases	Vehicle Axial	Vehicle Lateral and Radial
Liftoff through Ascent/Boost	+0.6, -3.5g	±3.0g
Ascent/Core through In-Space	-4.1g	±0.5g

2.2 Thermal Environments

The SLS Block 1B environmental temperature for payloads installed on the Payload Adapter (PLA) located within the SLS Universal Stage Adapter (USA) is shown in Table 2. Radiation sink temperatures for the USA with a surface emissivity of 0.77 are documented in Table 3 for the USA conical section and Table 4 for the USA barrel section.

Table 2. Block 1B CPL-to-PLA Interface Temperatures

Mission Phase	Min (Deg. F)	Max (Deg. F)
Rollout	30	106
On-Pad Unfueled	53	103
On-Pad Fueled	34	101
Launch to Core Stage Separation	28	89
Core Stage Separation to SECO1	19	90
SECO1 to ORION Separation	-92	92
ORION Separation to USA Jettison	-106	86

Table 3. Block 1B USA Cone Radiation Sink Temperature

Mission Phase	Min (Deg. F)	Max (Deg. F)
Rollout	30	105
On-Pad Unfueled	50	104
On-Pad Fueled	44	103
Launch to Core Stage Separation	42	131
Core Stage Separation to SECO1	52	131
SECO1 to ORION Separation	-64	127
ORION Separation to USA Jettison	-110	79

Table 4. Block 1B USA Barrel Radiation Sink Temperature

Mission Phase	Min (Deg. F)	Max (Deg. F)
Rollout	30	104
On-Pad Unfueled	50	103
On-Pad Fueled	44	102
Launch to Core Stage Separation	43	111
Core Stage Separation to SECO1	47	111
SECO1 to ORION Separation	-72	105
ORION Separation to USA Jettison	-112	71

2.3 Internal Acoustics

The payload internal acoustic environment is considered equivalent for both the SLS Block 1B crew (USA) and cargo (Payload Faring-PLF) configurations. These acoustic environments for PPL, CPL and SPL are defined in Table 5.

Table 5. Block 1B USA/PLF Internal Acoustics Environment, 95/50, 60% Fill Effect

1/3-Octave Band Center Frequency (Hz)	Sound Pressure Level (dB re: 20 µPa)
20	118.7
25	122.6
31.5	128.2
40	134.8
50	135.4
63	135.2
80	134.8
100	134.6
125	132.5
160	132.9
200	132.5
250	132.5
315	132.5
400	130.5
500	128.5
630	126.0
800	124.0
1000	122.0
1250	120.2
1600	117.8
2000	116.0
2500	114.5
3150	112.5
4000	111.0
5000	109.0
6300	107.0
8000	105.5
10000	103.5
Overall Sound Pressure Level	144.7

3.0 SLS Contamination and Cleanliness

Launch vehicle hardware that comes into contact with the spacecraft/payload's environment is designed and manufactured according to strict contamination control requirements and guidelines. Ground operations at the launch site have been designed to ensure a clean environment for the spacecraft/payload. Cleanliness requirements for each spacecraft/payload will be evaluated on a case-by-case basis. All SLS payloads will follow specified contamination control procedures to prevent particle release and minimize Foreign Object Debris to ensure mission safety and success.

Cleanliness levels will be categorized as “generally” or “visibly” clean, to meet a wide range of cleanliness needs. A “generally” clean level ensures that parts are free of manufacturing residue, dirt, oil, grease, processing debris and any other extraneous contamination. This generally clean level should be assigned to hardware that is not sensitive to contamination and can be easily and quickly cleaned.

“Visibly” clean hardware will meet the requirements of the generally clean level and will be cleaned and qualitatively verified to be free of all particulate and non-particulate material visible to the normal eye. Hardware cleaned to this level will be continuously protected using heat-sealed double bagging until the hardware is integrated or assembled into the next level of assembly in a clean-room environment. If the item is too large in size or weight, the visibly clean surfaces shall be prepackaged to cover all exposed critical surfaces.

The first level is Standard, which will have an incident light level greater or equal to 500 lm/m2 with an inspection distance of 5 to 10 feet (1.5 to 3 m). The next level, Sensitive, will have the same incident light level as Standard, but with a closer inspection distance of 2 to 4 feet (0.6 to 1.2 m).

4.0 SLS Block 1B Spacecraft/Payload Interfaces

Figure 3 provides nominal SLS Block 1B Integrated Spacecraft/Payload Element (ISPE) details; the ISPE includes all equipment between the SLS EUS and Orion for the crew configuration and all equipment above the SLS EUS for the cargo configuration. Note: the SPL shown in Figure 3 is representative of a SPL volume (6U to 27U) mounted to the PLA.

An option also exists to fly multiple, larger than 27U SPLs mounted in a manner similar to the Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA) mounted on or above the SLS PLA. This approach can provide additional deployment flexibility and efficiency for larger SPLs as well as accommodate an entire payload ring (in addition to a CPL) or even stacked rings (replacing a CPL entirely).

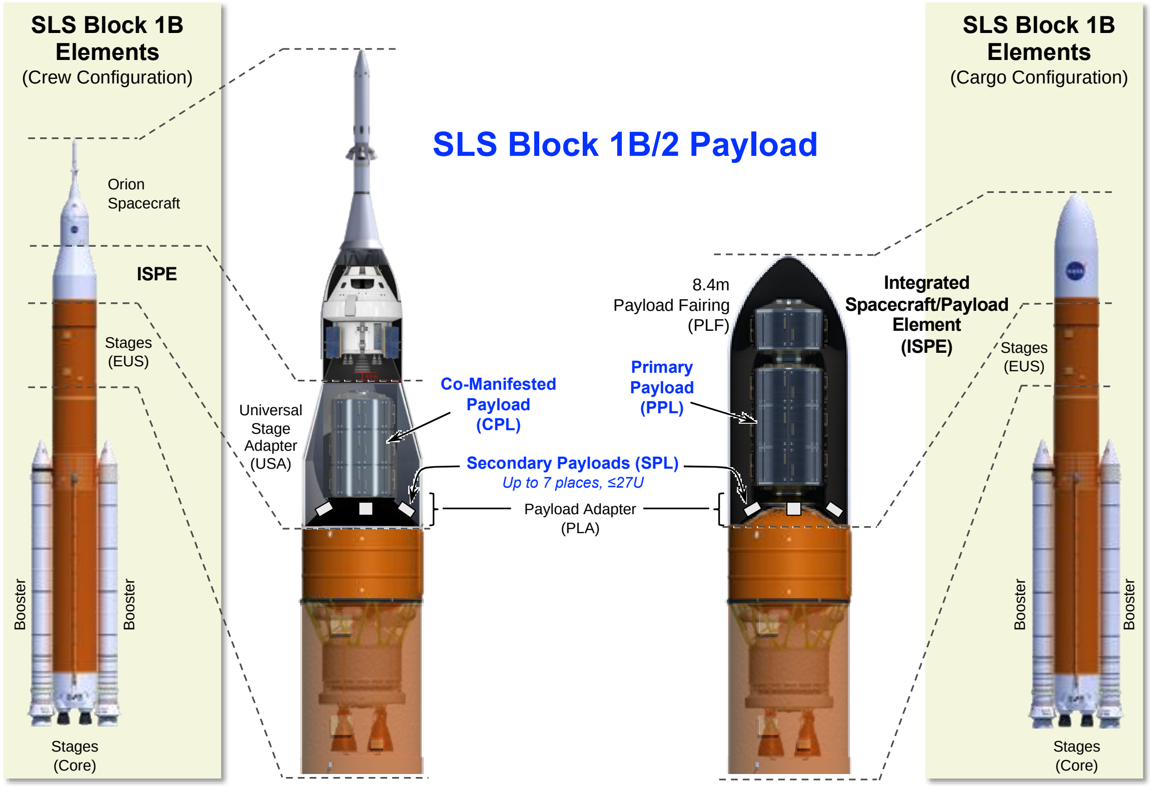

Figure 3. SLS Block 1B Integrated Spacecraft/Payload Element (ISPE)

4.1 Accommodations for SPL CubeSats

The Block 1B SLS PLA can accommodate SPLs, based on availability of excess capacity after accommodating CPL for crewed missions and PPL for cargo missions. In general, SPL accommodations range from 6U (unit) to 27U class CubeSats. SPL interface to the Block 1B PLA via the Secondary Payload Deployment System (SPDS). The SPDS provides a standard SPL interface via a commercial off-the shelf (COTS) dispenser, dispenser/SPL support structure, Avionics Unit and cable harnesses for deployment signal and access to battery charging via the upper stage (provided by KSC ground services). Once Orion has separated from the EUS or the PLF separated from the EUS, and the EUS has completed its disposal burn, SPLs can begin to be deployed. The Dispenser provides environmental interfaces for thermal, bonding/grounding, electromagnetic compatibility, venting, shock, and random vibration and load conditions.

The SLS Block 1B will accommodate the SPDS via "insets" on the PLA as shown in Figure 4.

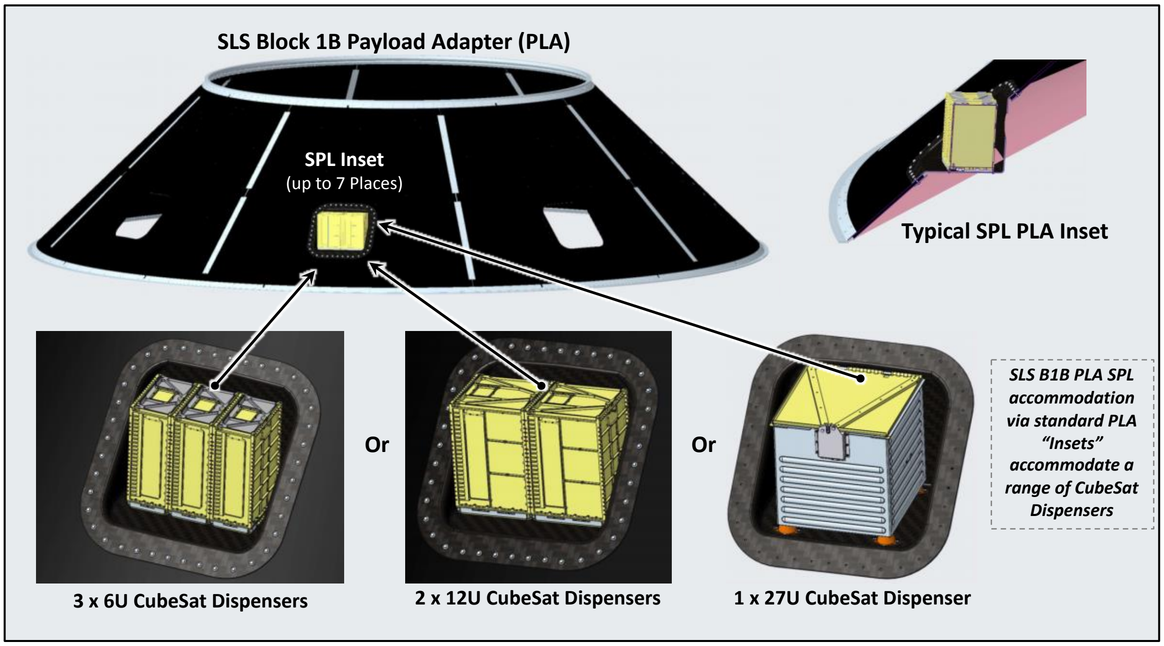

Figure 4. Range of PLA Mounted Accommodations for SPL

4.1.1 SPL CubeSat Mechanical Interfaces

The primary structural interface for an SPL is to an SLS-specified COTS dispenser. This dispenser provides the SPL a means for SLS integration, protection during launch and ascent, and deployment from the SLS. The SPDS can accommodate a 6U, 12U and up to 27U dispenser; the SPL must stay within allowed physical provisions for its associated dispenser. The SLS Block 1B Payload Adapter (PLA) can physically accommodate up to 21 (for 6Us or less for other sizes) SPLs.

Physical provisions include the dimensional orientation of the payload inside the dispenser; maximum allowable dimensions, volume and mass; and the CG envelope. Figure 5 depicts the SPL dimensional orientation. Table 6 provides the dimensions, volume and mass numbers for both 6U, 12U and 27U dispensers. Figure 6 provides the payload CG datum within the dispenser. Table 7 provides the CG envelope numbers for 6U, 12U and 27U dispensers. Based on the maximum allowable payload mass for a 6U dispenser (Table 6), an ejection rate of 3.9+/-0.2 feet/sec (1.2+/- 0.06 m/sec) is anticipated. Spring rates for 12U and 27U CubeSats has not been determined but should be comparable to a 6U.

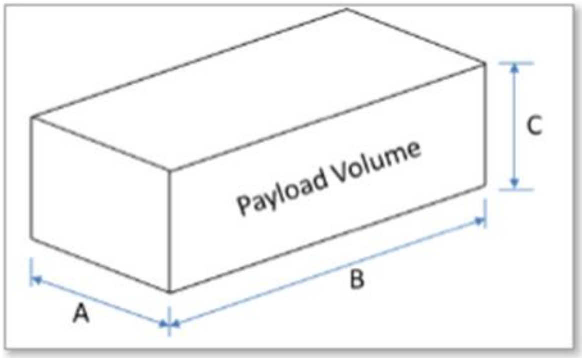

Figure 5. Secondary Payload (SPL) Envelope Dimensional Depiction

Table 6. Secondary Payload (SPL) Maximum Dimensions

Size	A		B		C		Volume		Mass	
	in	mm	in	mm	in	mm	in^3	mm^3	lbm	kg
6U	9.41	239.00	14.41	366.00	4.45	113.00	603.41	9,884,562	30.86	14.00
12U	9.41	239.00	14.41	366.00	8.90	226.00	1206.82	19,769,124	44.73	20.29
27U	13.90	353.00	14.41	366.00	13.35	339.00	2,673.99	43,798,122	54.0	119.0

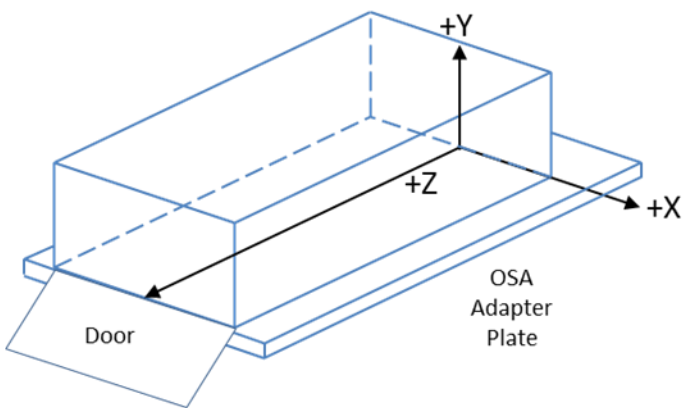

Figure 6. SPL Center of Gravity (CG) Envelope within Dispenser

Table 7. SPL Center of Gravity (CG) Envelope

Parameters	Units	6U		12U		27U	
		Min.	Max.	Min.	Max.	Min.	Max.
Center of Mass, X	in (mm)	-1.50 (-38)	+1.50 (+38)	-1.57 (-40)	+1.57 (+40)	-2.36 (-60)	+2.36 (+60)
Center of Mass, Y	in (mm)	+0 (+0)	+5.00 (+127)	+2.17 (+55)	+4.92 (+125)	+3.94 (+100)	+7.09 (+180)
Center of Mass, Z	in (mm)	+6.00 (+152)	+9.50 (+241)	+5.24 (+133)	+9.17 (+233)	+5.14 (+133)	+9.17 (+233)

The integrated SPL/dispenser unit will interface with SLS for structural support (Block 1B PLA) during launch and early flight phases. The SPDS will provide the cable connectors and wire types that interface the integrated dispensers with the PLA support brackets. The integrated SPL/dispenser unit must be within the allowed mass and CG provisions of the PLA. Mass margin provisions for vibration isolation, thermal protection, etc. are an option and must be discussed with the SPIE office. The combined SPL/dispenser unit CG envelope is the same as shown in Table 7. The integrated SPL/dispenser unit will contribute to the combined loads as part of the encapsulated payload. These loads will be analyzed as part of flight/mission planning.

4.1.2 SPL CubeSat Electrical Interfaces

In general, there is no capability for battery charging to SPLs, during VAB operations, or at the pad. Generally, the last opportunity for users to charge SPL batteries will be in standalone KSC facilities prior to vehicle stacking. SPL battery charging in the VAB via a drag on cable may be possible on a case-by-case basis as requested by the user. SPLs must remain powered off from handover to EGS at KSC until post-deployment from the SLS upper stage.

Representative SPDS Avionics Unit interface connections are depicted in Figure 7 (representative sine it reflects a SLS Block 1 layout for up to 17 Dispensers). Only SPL systems using Lithium-ion 18650 rechargeable batteries can be charged at KSC prior to launch. SPLs will be delivered to KSC and inhibited from performing any functions until 15 seconds after deployment to minimize risk of hazardous operations during integration, launch and post-deployment.

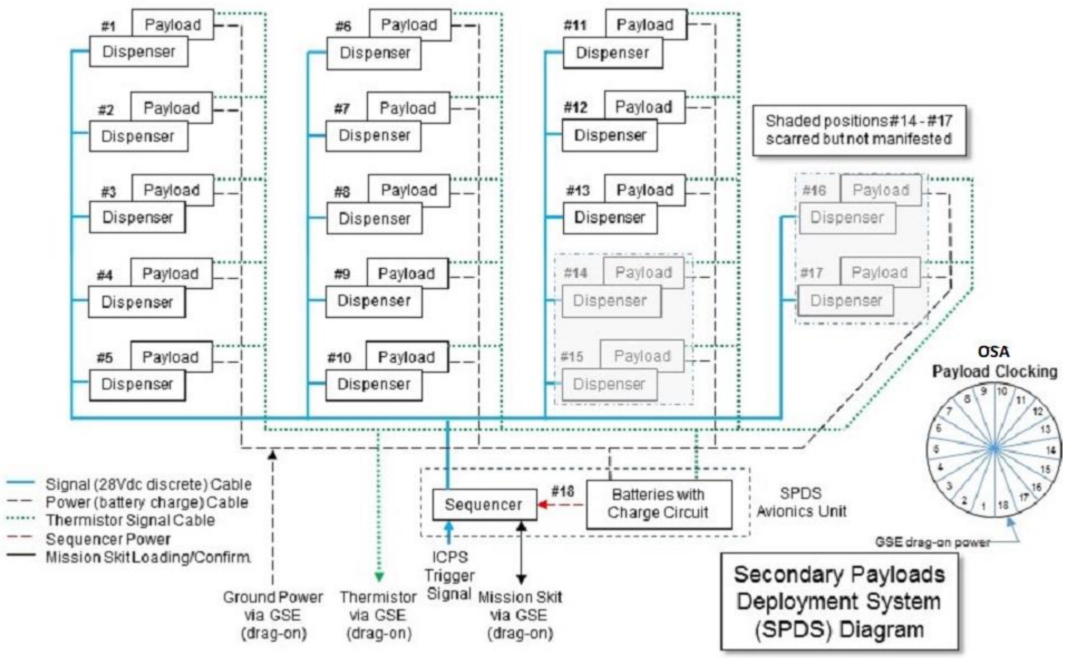

Figure 7. Representative SPDS Avionics Unit SPL Interface (Block 1)

The AU has a battery life of up to 10 days after activation of the sequencer on-orbit. The sequencer activation is delayed until post-TLI and near completion of the upper stage disposal maneuver. SPLs using rechargeable batteries should be designed to support a launch no less than 180 days (nominal) after the last recharge. Approximately five minutes after the upper stage end-of-mission is complete (within eight hours from launch), the SPLs

4.2 Accommodations for ESPA-Type SPL

Similar to Expendable Launch Vehicles (ELV), SLS PLAs can accommodate an ESPA-Type ring underneath the PPL or CPL depending on launch available vehicle performance and payload height within the USA or PLF. Alternatively, ESPA-Type Ports can be provided as part of the PLA in place of a ring depending on mission requirements.

4.2.1 SPL ESPA-Type Mechanical Interfaces

SLS PLAs have a standard EUS interface diameter of 8400 mm with the current baseline PLA having an ELV-like 4394 mm diameter ring for the upper payload interface. While there is a PLA concept that offers a payload interface diameter of 1575 mm compatible with existing ESPA designs, it is anticipated that future SLS PPL or CPL will more likely require interface diameters of 4394 mm and larger.

Figure 8 shows a range of 4 ESPA-Type accommodation concepts currently being evaluated by SLS: PLA EPSA Ports, ESPA Port Shelf, ESPA Port Ring, and ESPA (Standard or Grande). It is envisioned that either 15” (257 to 450 kg capability) and/or 24” (700 kg capability) ESPA Ports could be accommodated depending on mission needs. With a 7500 mm diameter internal static envelope available within either the SLS USA or PLF versus a standard ESPA 1575 mm diameter, different accommodation configurations will be possible. Detail on Standard and Grande ESPA payload interfaces can be found in Moog's ESPA User's Guide at this link: https://www.moog.com/products/spacecraft-payload-interfaces.html.

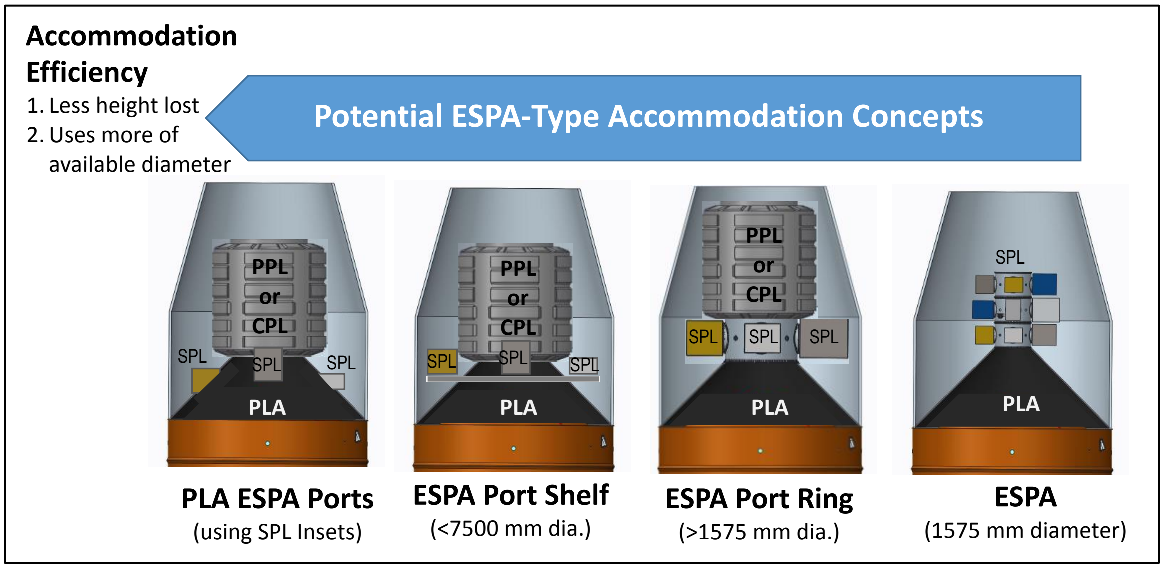

Figure 8. SLS ESPA-Type Accommodation Concepts (crew configuration shown)

4.2.2 SPL ESPA-Type Electrical Interfaces

ESPA Port separation systems are available as Commercial Off the Shelf (COTS) items. It is anticipated that an adaptation of the SPDS Avionics Unit described in 4.1.2 could support ESPA Port payload deployment in a manner similar to that provided to CubeSat Dispensers post Orion or PLF separation from the EUS.

5.0 Spacecraft/Payload Integration Documentation and Process

The products listed in this section define required spacecraft/payload services, interfaces and analysis to support all phases of the integration process. Based on the complexity of a specific spacecraft/payload, additional information may be required.

5.1 Payload Integration Agreement (PIA)

The PIA, or an equivalent programmatic agreement, establishes and implements all management and programmatic integration requirements between the spacecraft/payload and SLS. The PIA defines SLS and the spacecraft/payload roles and responsibilities, interfaces, standard services, any non-standard services, deliverable exchanges and the overall schedule for successful integration and launch. The PIA is developed by the PIM and coordinated with the spacecraft/payload, with revisions negotiated and agreed to by all parties as needed. SPIE will work with ESD, ESG and the spacecraft/payload early in the development process to develop a draft PIA using the spacecraft/payload IRD or equivalent document; all parties will agree to a draft of the document prior to formal manifesting. When ESD manifests the spacecraft/payload on SLS, the PIA will be baselined. Baselining the PIA formally starts the SLS-spacecraft/payload integration process.

5.2 Payload Unique Interface Control Document (ICD)

The SLS payload unique ICD defines the interface and requirements between SLS and EGS, and the spacecraft/payload for a specific mission. The ICD is the agreed upon design solution that controls and defines each side of an interface (SLS or spacecraft/payload) for hardware, GSE, software and environment compatibility. The SPIM (Secondary Payload Integration Manager) develops ICD in coordination with the spacecraft/payload. As part of this payload unique ICD, a verification plan will provide one-to-one mapping of spacecraft/payload requirements to a particular compliance method for all phases of operations (e.g., ground processing, lift-off, in-flight, SLS separation events). The verification plan provides instructions and guidelines to verify safety and interface compatibility of the as-built SLS vehicle and spacecraft/payload hardware and software. The success criteria and methods of verification will be in the form of Detailed Verification Objectives (DVO), outlining the type or proof required for closeout (e.g., test, analysis, demonstration, inspection, similarity, and/or validation of records).

5.3 Payload Unique Safety Requirements Document (SRD)

A SLS safety representative establishes the safety policy and requirements applicable to SLS spacecraft/payload for a specific mission in the payload unique SRD. Its typical scope starts at payload delivery at the launch site and continues through ascent until end of the Orion mission or until upper stage disposal. For the ground processing phase, the payloads must also comply with identified ground processing hazard requirements as identified in this document. Verification results of these payload ground and flight processing/operations hazards will be reviewed at the relevant phase Payload Safety Reviews.

5.4 Payload Safety Reviews (PSRs)

PSRs will be phased over time and require information to perform analysis efforts that include, but are not limited to, payload handling and physical processing hazards, RF interference, ascent hazard, debris characteristics for input to unique range safety data, joint loads and environments, payload recontact analysis (nominal mission scenarios), etc. The spacecraft/payload will be required to participate in these and support data requests from the Payload Safety Review Panel (PSRP). Flight and ground safety requirements will be documented in the SRD and will form the basis of verification according to the corresponding hazard.

6.0 Provided Items to the Payloads

Items to be provided to the payload developers are:

- A flight dispenser shall be provided to each payload on a reimbursable basis by the project office.
- The project office will make available a non-flight dispenser for up to 2 payload fit checks.
- The project office will provide flight 18650 battery cells to the payloads for those wishing to have their batteries charges in the OSA prior to stacking of the vehicle. Said payloads will also need to meet the earlier mentioned battery/circuit protection requirements. Payloads wishing to use their own batteries must meet JSC 20793 Rev. C.