



SLS Dual Use Upper Stage (DUUS) Opportunities

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Objective

- **Provide an overview of SLS DUUS type capability requirements to provide context for possible International Partner collaboration**
- **DUUS Overview Approach**
 - DUUS Capability
 - DUUS Generic Requirements
 - DUUS Development Timeframe
 - Typical SLS/DUUS Design Reference Mission
 - DUUS Description Overview
 - Primary Structure, Exploded View
 - Cryogenic Fluid Management
 - Main Propulsion System
 - Electrical Power System
 - Thermal Control System



DUUS Significantly Enhances Exploration Capability

- **Current SLS Block 1 configuration delivers ~90t to LEO and ~25t to Trans Lunar Injection (TLI)**
- **Addition of a DUUS would greatly increase exploration mission capture and performance margin for cis-Lunar and Near Earth System exploration campaigns**
- **Exploration Mission Capability Provided by a DUUS**
 - Low Earth Orbit Mission Class
 - **LEO delivery capability, 105 – 130t delivery**
 - Stage life/duration, 10 min – 5 hours
 - Destination Injection Mission Class
 - **Trans-Lunar, 40 – 50t delivery**
 - **Trans-Mars, 25 – 35t delivery**
 - Stage life/duration, 5 hours
 - Cis-Lunar Mission Class
 - **EM-L2 or Low Lunar Orbit, 30 – 35t delivery**
 - Stage life/duration, 5 days

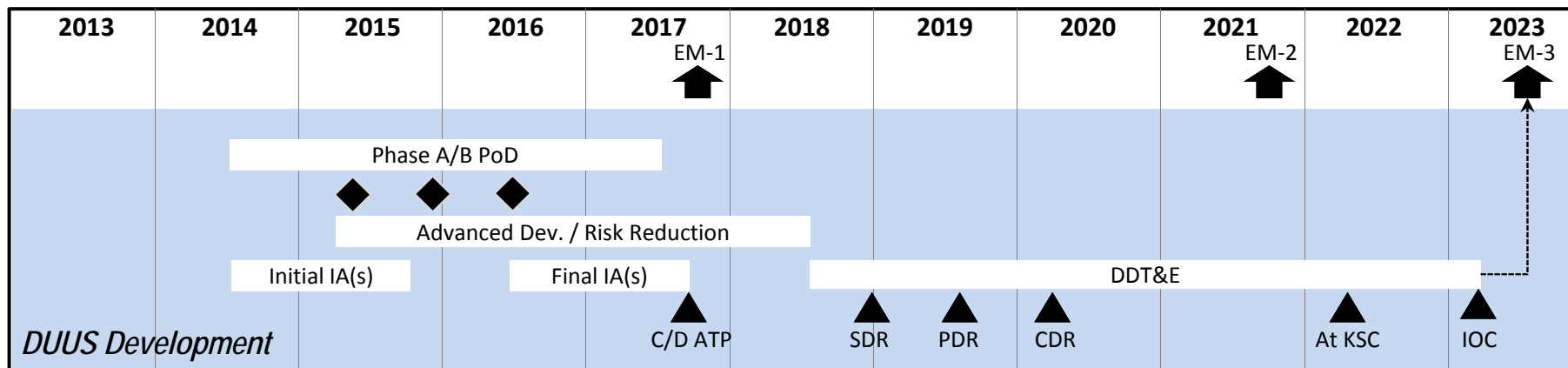


Generic Mission/Stage/Engine Requirements

- **Stage provides multiple propulsion functionality**
 - Ascent burn (to range of LEO)
 - Trans-Destination Injection Burn (from LEO to Destination)
 - Insertion (Braking) Burn at Destination
- **Stage design considerations (Usable Propellant Mass Fraction is a Priority)**
 - Minimal Dry Mass
 - Minimal and Efficient Functionality
 - Maximum Usable Propellant
- **Stage description guidelines**
 - 130t Propellant Load (Oxygen / Hydrogen)
 - 100-120K lb Total Thrust Class
 - 8.4m maximum diameter
 - 8.4m H₂ Tank / 5m O₂ Tank (5.5m and 6.4m O₂ Tank Options)
 - 18.3m maximum height
- **Engine description guidelines**
 - 500-700s maximum single engine burn
 - 1100-1300s total mission burn time for single engine
 - 2-3 mission starts
 - 30 to 60K lb thrust per engine; 462 - 465 sec I_{sp}
 - Throttle TBD
 - Extendable Nozzle Option



DUUS Development Timeframe





Typical Lunar Surface DRM Profile

DUUS provides the propulsive capability to deliver payloads from SLS Core separation to Low Lunar Orbit

US MECO/Orbital Insertion

Time to MECO = ~1100 sec
Perigee alt = 130.00 nmi
Apogee alt = 130.00 nmi
Inclination = 28.50°
Injected mass = 257869 lb
US prop burned = 100000 lbs

Lunar Orbit Insertion (LOI)

Perilune alt = 100 km
Apolune alt = 100 km
dv = 3031.5 ft/s (924 m/s)
LOI burn time = ~160 sec

Payload Separation

US Disposal

dv = 49.2 ft/s (15 m/s)
RCS maneuver
Dispose to Surface

UpperStage (US) Ignition

Time of ignition = ~480 sec

Trans Lunar Injection (TLI)

Perigee alt = 130.00 nmi
Apogee alt = 130.00 nmi
Inclination = 28.50°
dv = 10761.15 ft/s (3280 m/s)
TLI burn time = ~570 sec

Core Burnout/US Separation

Time of burnout = ~470 sec

Core Throttle Down

Time of throttle down = ~460 sec

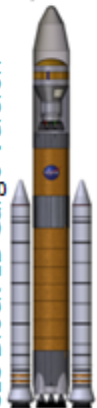
Shroud/LAS Jettison

Time of jettison = ~330 sec

Booster Jettison

Time of jettison = ~130 sec

SLS Block 1B Cargo Version



Liftoff

Booster Splashdown

Core Splashdown

LEO Loiter

Perigee alt = 130.00 nmi
Apogee alt = 130.00 nmi
Inclination = 28.50°
3 hour Loiter
Solar Array Deployment
System Check / Trajectory Verification

Mid Course Correction

dv = 114.83 ft/s (35 m/s)
RCS maneuver

5 day Lunar Coast

- ◆ **DUUS provides control authority for payload**
 - MPCV has command override authority
- ◆ **RCS performs course correction maneuvers and stage disposal**
- ◆ **Assumptions:**
 - Velocity vector orientation during LEO loiter
 - Solar inertial orientation during Lunar transit
 - No power sharing capability
 - Passive thermal control of propellants



Typical Mission Campaign Requirements

Design Reference Mission Description and Phasing	Payload Mass (t)	DUUS Mission Duration	Primary Propulsion System Burns	Delta V (m/s)
Tactical / Lunar Vicinity	25 t	5 hr	2	2900 - 3100
Strategic Class Exploration	20 - 30 t	5 hr / 5 days	2 / 3	3300 - 4500
Architectural Class Exploration	25 - 32+ t	5 hr / 5 days / 50+ days	2 / 3	3300 - 4700
Low Lunar Orbit Delivery	25 - 30 t	5 days	3	4300 - 4500

* All numerical values are representative approximations and not to be used for actual mission design.



DUUS Description Overview (Notional)

Structures System:

- Aluminum Primary Structure
- Composites are an Opportunity
- Sized to support payloads up to 35 metric tons during launch

Power System:

- Solar array* with secondary batteries

*Array Stowed

Stage Characteristics:

- LH₂ Diameter: 8.4m
- LOX Diameter: 5.0m
- Length: 19m
- 7-day Stage Life

Avionics System:

- Multi-day, in-space avionics

Thermal System:

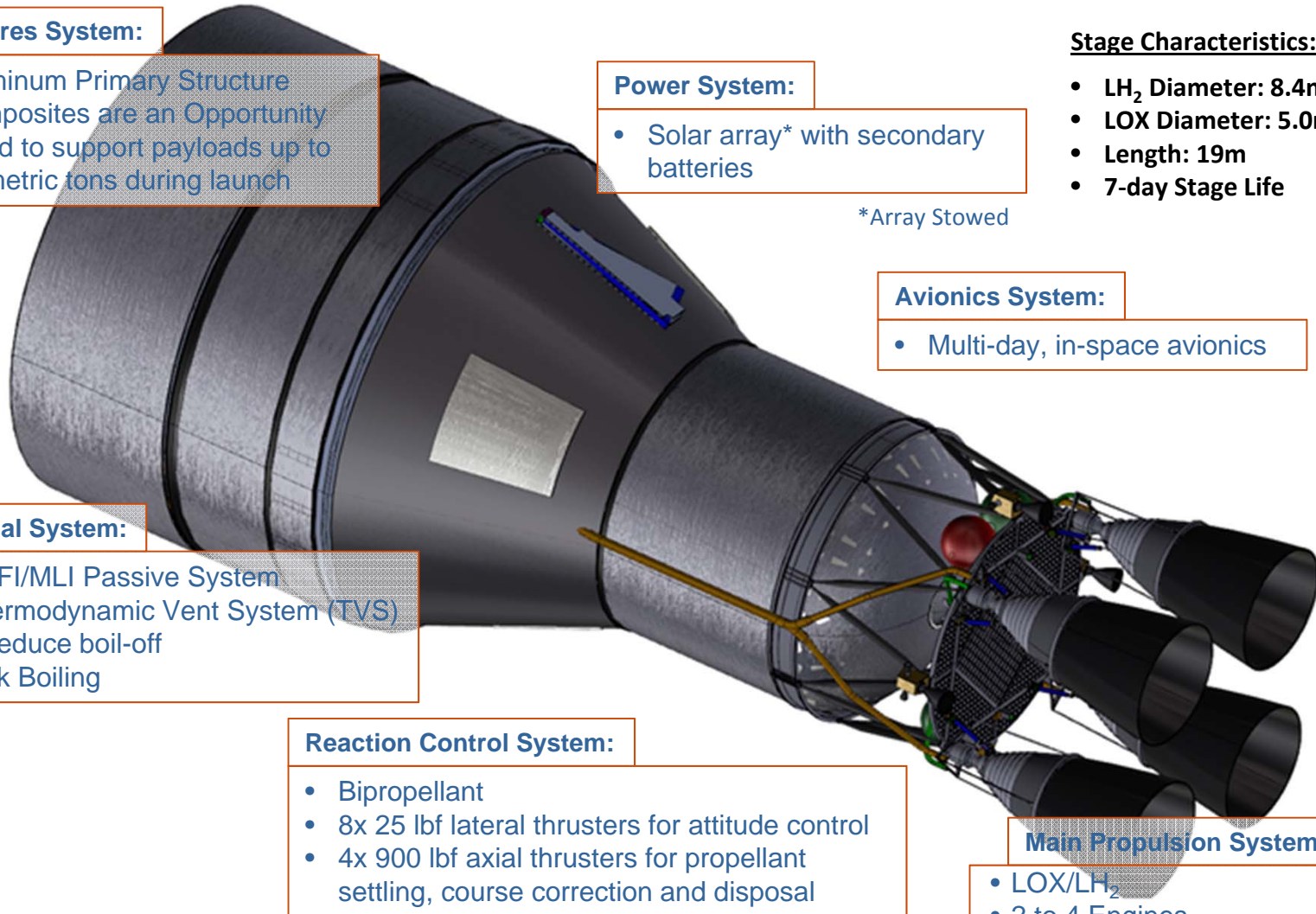
- SOFI/MLI Passive System
- Thermodynamic Vent System (TVS) to reduce boil-off
- Bulk Boiling

Reaction Control System:

- Bipropellant
- 8x 25 lbf lateral thrusters for attitude control
- 4x 900 lbf axial thrusters for propellant settling, course correction and disposal

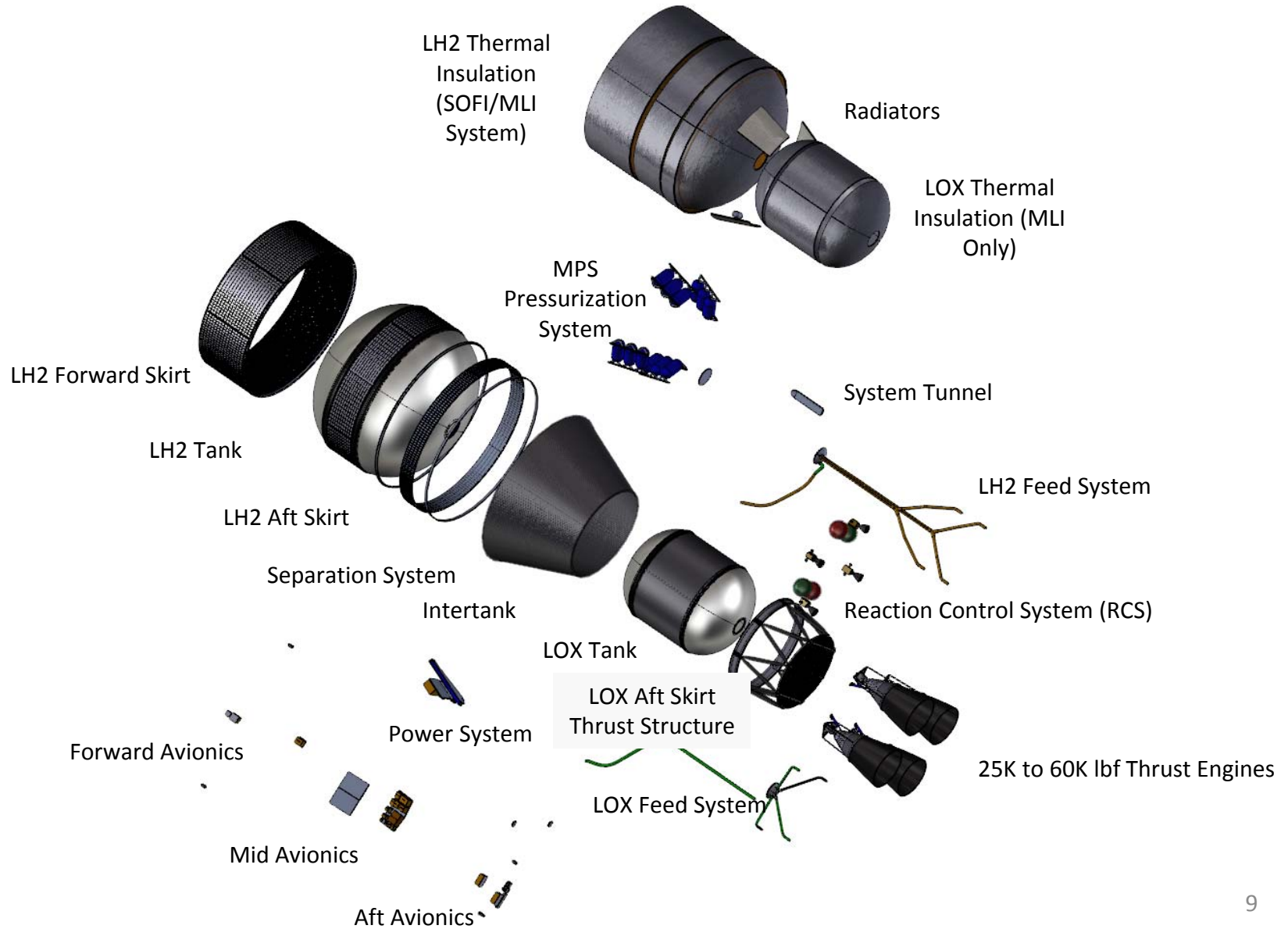
Main Propulsion System:

- LOX/LH₂
- 2 to 4 Engines
- 100K-120K lbf total Thrust Class
- 462 – 465 sec I_{sp}



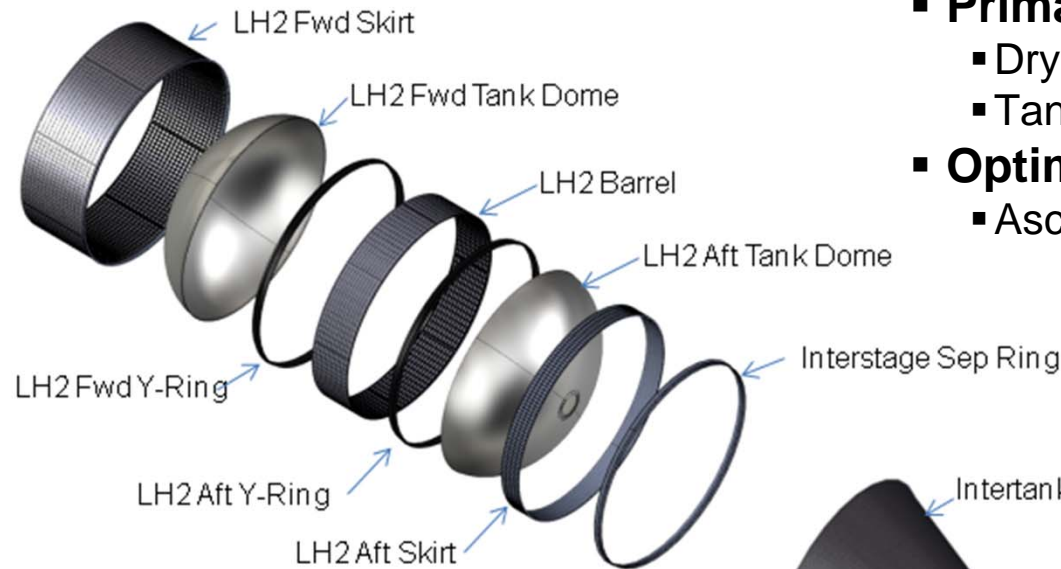


DUUS Description (Exploded View)



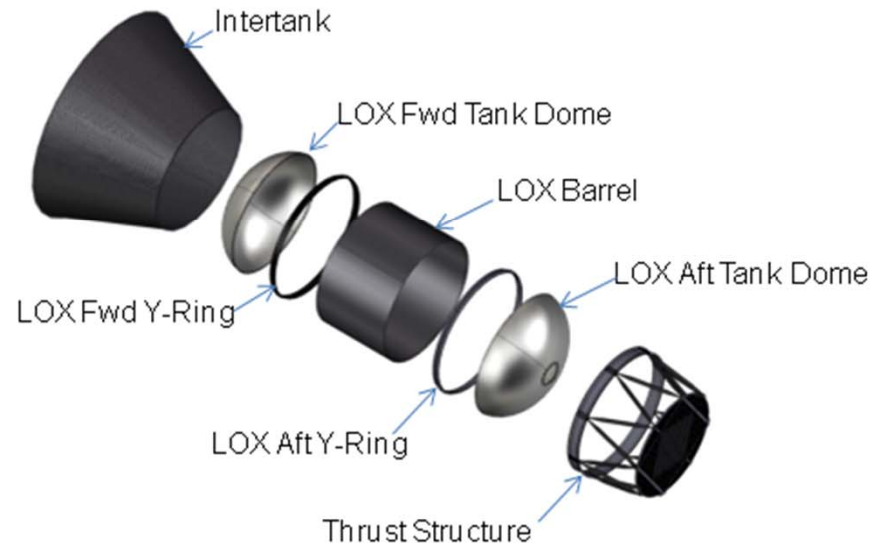


DUUS Primary Structures



- **Primary structures:**
 - Dry Structure (Composite)
 - Tanks (Aluminum)
- **Optimized for SLS Launch Loads**
 - Ascent Load Relief

- **Ortho-Grid Stiffened**
 - LOX Forward Skirt
 - LH2 Barrel
 - LH2 Aft Skirt
- **Isogrid Stiffened Intertank**
- **Monocoque Tank Domes**
- **Forged Y-Rings**
- **Composite Strut Thrust Structure**
 - Primarily driven by thermal considerations (boil-off reduction)





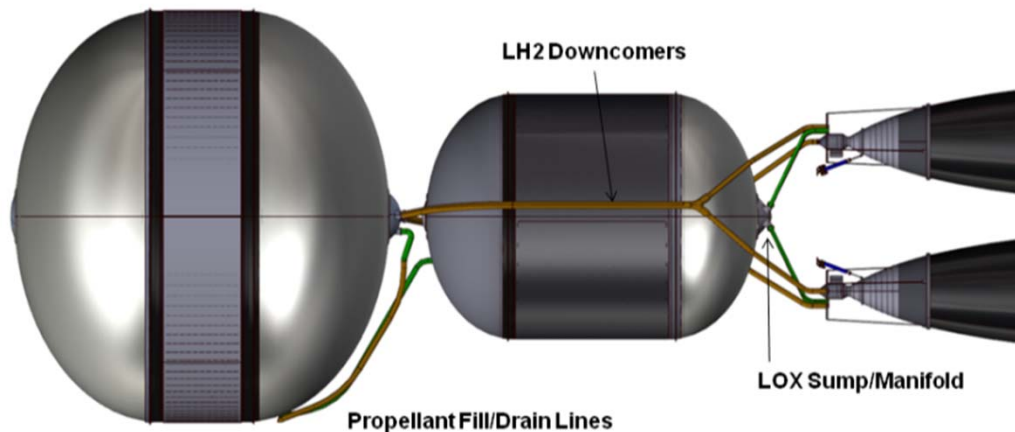
DUUS Subsystem: Cryogenic Fluid Management

- **Propellant Management and Conditioning**
 - Boil-off reduction
- **Thermal Insulation System**
 - Spray-On Foam Insulation (SOFI)
 - Ground Environments
 - Multi-Layer Insulation (MLI)
 - In-space Environments
- **Thermodynamic Vent System (TVS)**
 - Mixing device
 - Heat exchanger
 - Allows venting in micro-gravity
- **Bulk Boiling Fluid Control Option**





DUUS Subsystem: Main Propulsion System



- **MPS provides up to 99K lbf of mainstage thrust required for the LOR-Lunar Mission**
 - Four notional engines with the extendable nozzle operating at a 5.88 MR
 - Thrust per engine: 25K to 60K lbf class
 - Engine I_{sp} : 462 to 465 seconds

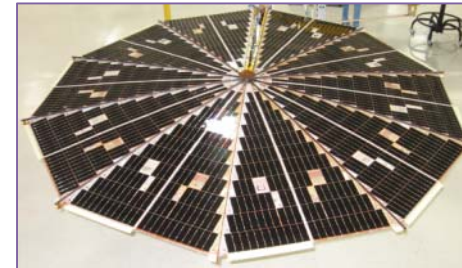
- **MPS supplies liquid propellant to the four notional engines at the flowrates, temperatures and pressures required for nominal engine operation.**
 - Two 5.0 inch rundsucts are connected to the fuel tank via a sump.
 - Each rundsuct supplies LH₂ to a manifold which connects two 3.5 inch propellant feedlines.
 - Four 2.5 inch propellant feedlines are connected to the LOX tank via a sump.
 - The feedlines carry propellant from the manifold and sump to the engine LH₂ and LOX interfaces, respectively.
- **MPS supplies regulated gaseous helium for MPS and RCS pneumatics, and pressurant gases for the propellant tanks.**
 - Ten COPVs carry ~ 240 lbm gaseous helium.
 - Helium is regulated through a helium regulator package containing two parallel legs for redundancy.
 - Each parallel leg contains an electronically actuated isolation valve in the event a regulator fails open.
- **MPS supplies the LH₂ tank with GH₂ pressurant gas during engine mainstage.**
 - Hot GH₂ is bled off the engines and used for autogenous pressurization.



DUUS Subsystem: Electrical Power System

- **Power Generation**

- Capability similar to one 6.5m diameter UltraFlex solar array with two-axis tracking
- Provides up to 7.7kW at EOL



- **Energy Storage**

- Two lithium ion batteries
- Single fault tolerant
- Each battery provides up to 6.9kW-hr to loads



- **Power Management and Distribution**

- Single fault tolerant electronics



DUUS Subsystem: Thermal Control System

- Provide thermal conditioning for avionics components
- Active TCS is required for long, in-space duration
- Maintain RCS propellant & MPS pressurant within acceptable temperature range
- Minimize heat leak into propellant tanks
- RCS & Helium Tanks Thermal Conditioning Subsystem
- Inputs to Cryogenic Fluid Management (Orbital Environments)

