Cryo Propulsive Stage: HEFT Phase 2 Point of Departure

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CPS Overview

- **The CPS is an in-space high thrust propulsive stage based largely on state of the practice design for launch vehicle upper stages.**
  - However, unlike conventional propulsive stages, it also contains power generation and thermal control systems to limit the loss of liquid hydrogen and oxygen due to boil-off during extended in-space storage.
- **The CPS provides high thrust ΔV for rapid transfer of in-space elements to their destinations or staging points (i.e., E-M L1).**
- **The CPS is designed around a block upgrade strategy to provide maximum mission/architecture flexibility**
  - Block 1 CPS: Short duration flight times (hours), passive cryo fluid management
  - Block 2 CPS: Long duration flight times (days/weeks/months), active and passive cryo fluid management

Groundrules & Assumptions

- Provides ΔV for circularization of the launch vehicle 30x130 nmi delivery orbit to the LEO circular orbit for itself and any other payloads manifested with it on the launch vehicle.
- CPS includes avionics, propulsion, and attitude control for automated rendezvous and docking. When rendezvous and docking with other elements the CPS can play either the active or passive role.
- CPS structure will provide adequate load bearing strength to account for its own fully loaded mass, plus the mass of any attached payloads through all phases of the mission, including launch, loiter, docking, and active thrusting.
- While loitering in-space, the CPS provides required attitude control for itself plus any attached payloads utilizing on-board RCS (storable, bi-prop system).

Groundrules & Assumptions

- CPS has a power generation and storage system capable of providing the necessary power for itself, plus any required attached payloads (quantity TBD) for all phases of flight. The full power generation capability of the CPS can be transferred to other elements through the forward docking/payload interface.
- The CPS Block 2 includes a long duration cryogenic fluid management system that provides 0.5%/month liquid hydrogen loss (by mass), and 0%/month liquid oxygen loss.
- During high thrust maneuvers where a Solar Electric Propulsion (SEP) stage is connected, the CPS engines must maintain a thrust to weight of the assembled elements of less than 0.1g.
- The control mass of the CPS is dependant upon launch system to LEO

Cryo Propulsion Stage Characteristics: cis-Lunar Missions

Block 1

Design Characteristic	Value
Propellants	O2/H2
Approximate Stage PMF	0.825-0.875
Approximate Stage Maximum Diameter	7.5 m
Approximate Stage Maximum Length	15.0 m
# of Engines	2
Engine Thrust (100%)	125-135 kN
Engine Isp (100%)	445-455 sec
Inert Mass (Including RCS and Cyro Boiloff)	9375 - 13125 kg
Total Stage Wet Mass	67500 - 75000 kg
Active Lifetime (Launch through Disposal)	~5 days

In order to support cis-Lunar missions, a Cryogenic Propulsion Stage Block 1, at a minimum, is responsible for performing all orbital maneuvers, maintenance, and corrections for the integrated stack (including payload) after the initial orbital insertion by the SLS HLLV. In all cases, the payload mass for cis-Lunar missions is expected to range between 23.5 and 27.0 tonnes. Some combinations of CPS Block 1 characteristics and mission delta-V requirements will result in total integrated stack masses which exceed the HLLV lift capability of 100 tonnes. However, the parameters in this data package represent sufficient information to conduct a feasibility assessment of design options and trade offs that result in mission closure.

Cryo Propulsion Stage Characteristics: Long Duration Missions

Block 2

Design Characteristic	Value
Propellants	O2/H2
Approximate Stage PMF	0.75 – 0.825
Approximate Stage Maximum Diameter	7.5 m
Approximate Stage Maximum Length	15.0 m
# of Engines	2
Engine Thrust (100%)	125-135 kN
Engine Isp (100%)	445-455 sec
Inert Mass (Including RCS and Cyro Boiloff)	14550 - 17625 kg
Total Stage Wet Mass	67500 - 75000 kg
Active Lifetime (Launch through Disposal)	> 400 days

In order to support long duration missions, a Cryogenic Propulsion Stage Block 2, maintains the responsibility for performing all orbital maneuvers, maintenance, and corrections for the integrated stack (including payload) after the initial orbital insertion by the SLS HLLV. Some combinations of CPS Block 2 characteristics and mission delta-V requirements will result in total integrated stack masses which exceed the HLLV lift capability of 100 tonnes. However, the parameters in this data package represent sufficient information to conduct a feasibility assessment of design options and trade offs that result in mission closure.

Open Issues and Forward Work

- **Assessing engine trades for mission flexibility**
  - Some missions may require engines with throttling capability
- **Payload and launch vehicle integration**
  - Optimization of load paths and components
- **Continued cryogenic fluid management modeling and refinement**
  - Power and boil-off technologies are driven by CPS parameters and performance
- **Refinement of mission parameters**