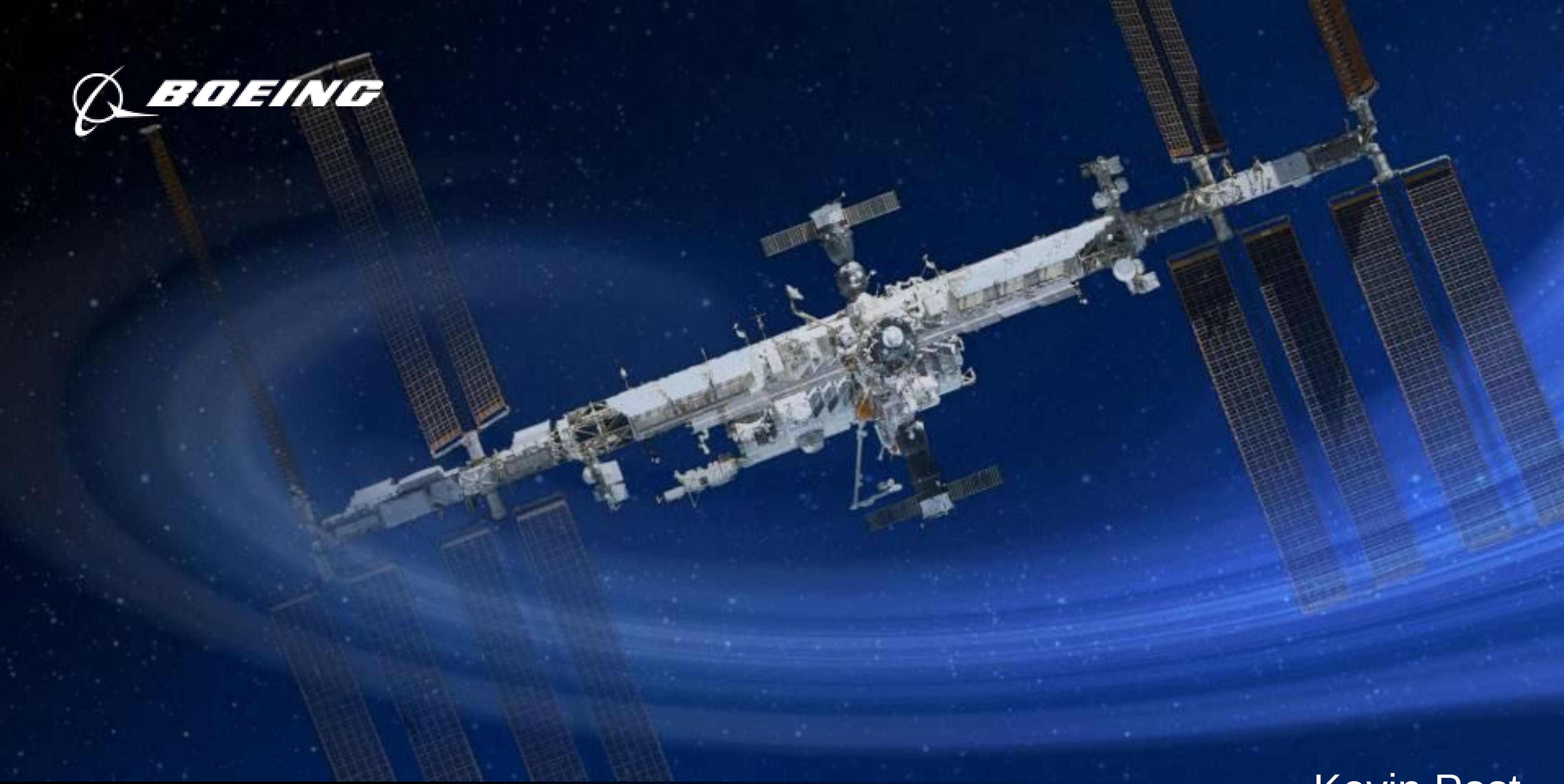

ISS-Exploration Platform

Reusable Lunar Lander Based at EML1

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September 7, 2011

Agenda

- ISS Exploration Platform (ISS-EP)
- Lander Intro & Launch Configuration
- Surface Mission Performance
- Lander Configuration & Mission Description
- LOX / Methane Propulsion System
- Evolution to Mars Crew Lander

ISS Exploration Platform

The ISS Exploration Platform is a small piece of ISS placed in the Earth – Moon Libration system and used to support Exploration objectives

Reference Previous FISO Presentations:

Raftery – 5/25/11

- **NEA mission concept**
- **Mars Mission concept**

Hatfield – 8/10/11

- **Construction of the ISS-EP**

ISS Exploration Platform
Purpose & Functions

HSF Exploration Gateway at EML1/2

Primary destination for initial flights beyond LEO
- Provides a habitat destination for MPCV & Soyuz for short duration stays
- Enables early characterization of environment outside radiation belts

“Local” control of Lunar robot assets
- Allows use of robots that are controlled through tele-presence
- Development of remotely controlled ISRU capabilities critical for Mars exploration

Gateway for a mission to a Near Earth Asteroid
- Enables assembly, test, & checkout of NEA spacecraft prior to departure
- Enables lowest mass mission spacecraft which will shorten trip times to / from NEA

Base for re-usable Lunar lander
- Allows re-use of expensive lunar lander assets
- Enables much more flexible mission operations for lunar access and “anytime return”

Gateway for a human mission to Mars
- Enables assembly, test, & checkout of Mars spacecraft prior to departure
- Enables lowest mass mission spacecraft which will shorten trip times to / from NEA
- Safe orbit for nuclear tug assets

Service Station for SEL Telescopes
- Repair and refueling for high value telescope assets
- Potential assembly site for new generation telescopes

ISS Exploration Platform
Functional Requirements

	Near Term DSH Destination	Base for Lunar Telerobotics Assets	Gateway for a NEA Mission	Base for Reusable Lunar Lander	Gateway for a Mars Mission	Service Station for SEL2 Telescopes
Life Support Systems	+	++	+	+	++	+
Docking Interfaces	2	2	3	4	6	3
Robotics - SSRMS			+	+	++	++
Robotics - SPDM / RSS			+	+	++	++
Robotics - Telepresence		++		+	+	++
ACS – RCS Propulsion	+	+	+	+	+	+
ACS – CMGs		+	+	+	+	++
Translation Propulsion	+	+	++	++	++	++
Propulsion Refueling	+	+	++	++	++	++
Contingency EVA			+	+	++	++
Ku / Ka Band Comm		++	+	++	++	++
Electrical Power / Thermal	+	++	+	++	++	++

ISS Exploration Platform
Key Driving Requirements

- **Man tended; Periodic presence of crew**
- **ECLSS sized for 3 crew; Surge to 6 crew for 14 days**
- **Docking support for:**
  - **Simultaneous: MPCV, Soyuz, Lander, SEP Tug, Cargo module, & Spare**
  - **IDSS compatible docking ports**
- **Propulsion / ACS:**
  - **Station keeping RCS; Refuelable bi-prop**
  - **Control Moment Gyros**
  - **Translation up to 300m/s; Refuelable SEP**
- **Robotics:**
  - **Berthing & assembly via SSRMS-like arm**
  - **Repair ops via SPDM / RRM-like end effectors**
  - **Tele-presence workstation**
- **EVA:**
  - **Capability for contingency EVA; 2 EMUs**
- **Communication:**
  - **HDTV video transmission**
  - **High reliability command and control link**
- **EPS & Thermal:**
  - **Solar arrays: 30KW; FAST arrays**
  - **Heat rejection: 20KW; PVTCS-type radiators**

ISS Exploration Platform
Functional Allocation

Docking Interfaces

Structural Interfaces

OR

Crew Habitation & Life Support

Airlock
(Contingency EVA)

AND / OR

AND / OR

AND

Electrical Power

Comm

Heat Rejection

Attitude Control

SSRMS

Shuttle OBS

+

SSRMS On SLP

ISS Exploration Platform
Four Basic Elements

Docking Hub

- Structural Hub
- Docking Interfaces
- SSRMS Base
- CCAA

Utility Module

- 30 KW Power
- 20 KW Heat Rejection
- SSRMS launch carrier
- Ku / Ka Band Comm
- CMGs
- RCS
- Translation Propulsion (Hall Thrusters)
- Airlock for 2 EMUs

Hab Module

- Evolved ECLSS
- Central Computer
- Robotics Control

International Module

- Evolved ECLSS
- RCS
- Translation Prop
- Soyuz Docking

Exploration Platform Derived from Existing Assets


Node STA


MPLM (2 Avail)


Orbiter External Airlock (2 Avail)

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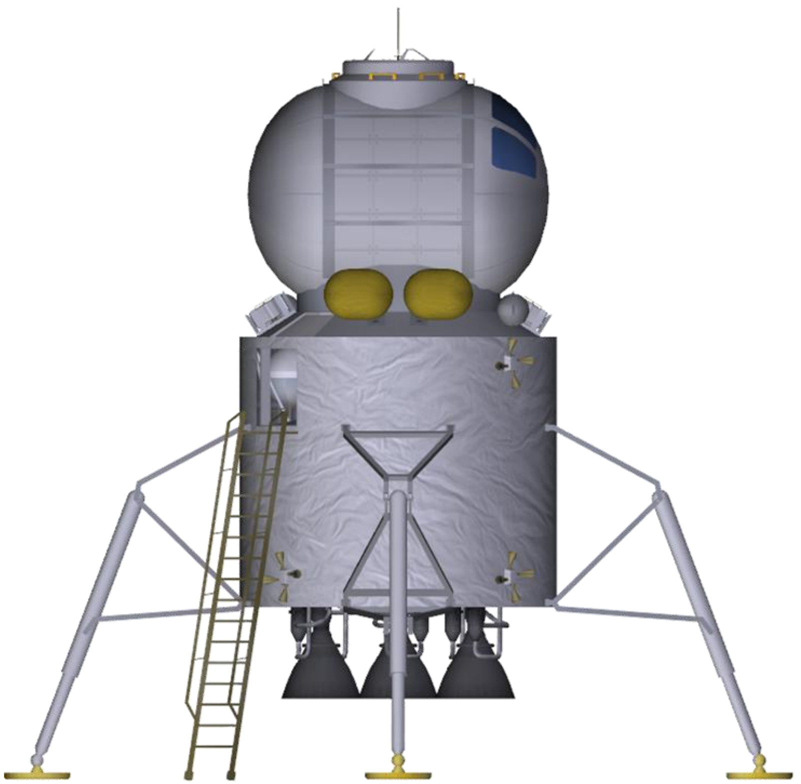
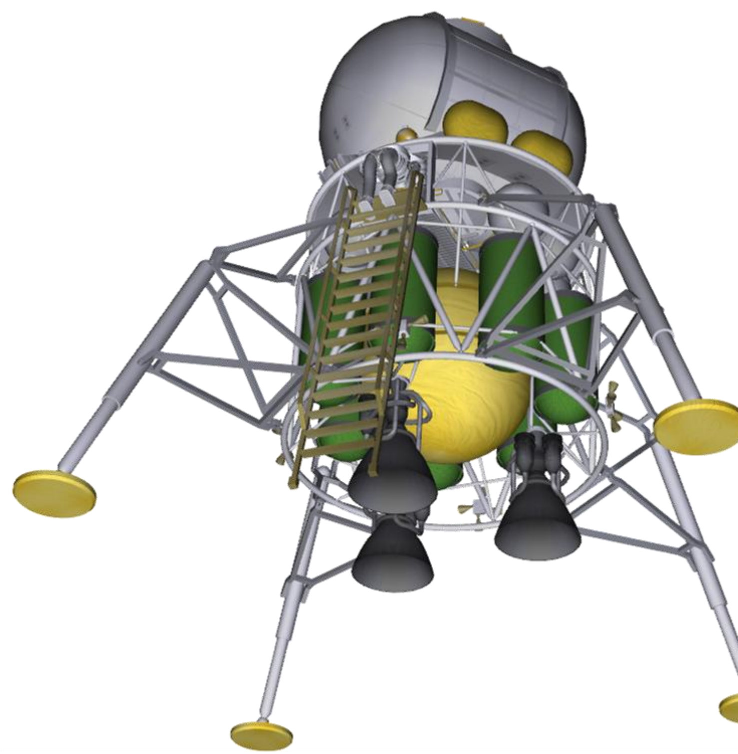
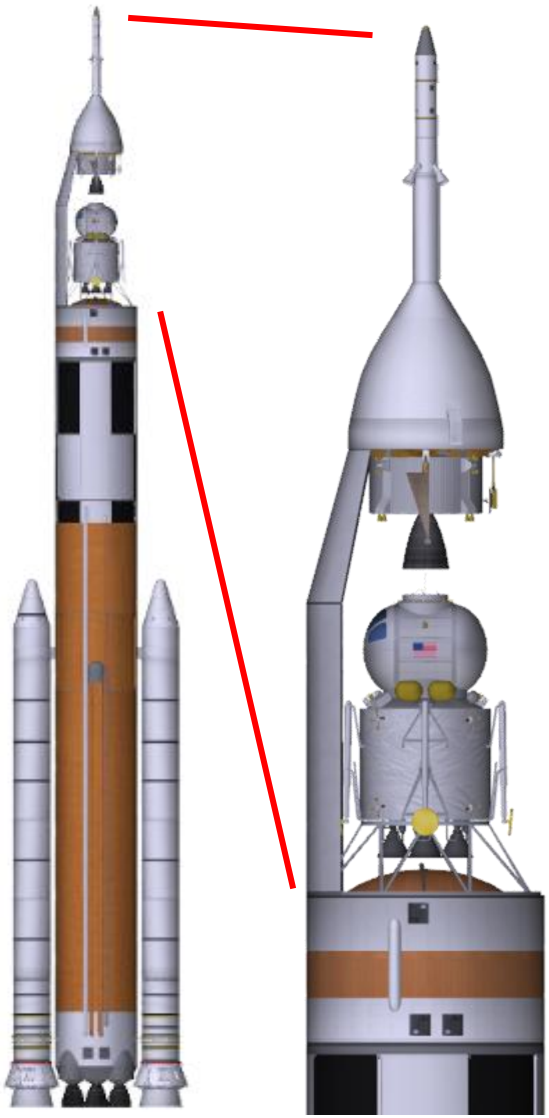
LOX / Methane Lunar Lander

- The lunar lander is designed to be reusable and is a pathfinder for the propulsion needed for Mars; The same propulsion system is intended to be used as the ascent stage for the Mars lander
- It is much smaller than Altair; Dry mass of 7t, wet mass of 15t (Altair was ~45t wet)
- The propulsion system is LOX/Methane and is designed to be re-fuelable

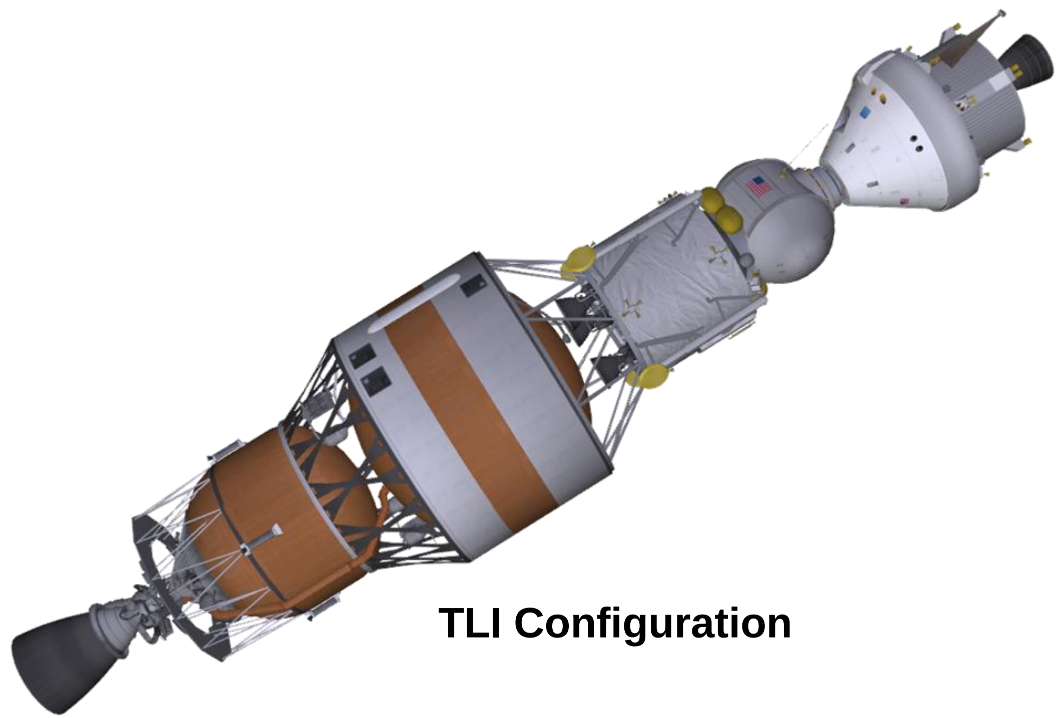




Lunar Lander Delivery to the ISS-EP at EML1



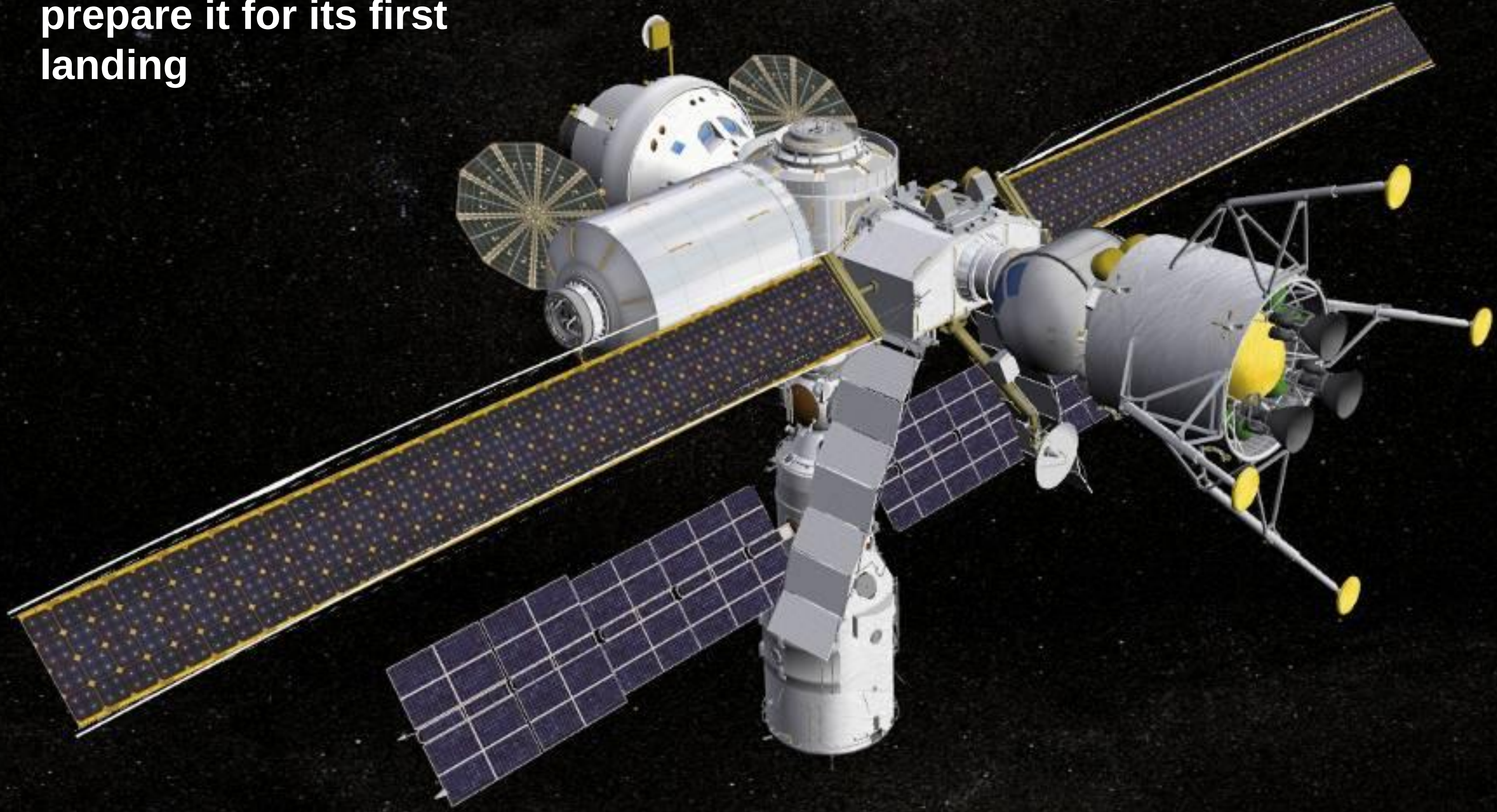
- The lander would be launched to EML1 with a commissioning crew using SLS
- Combined lander / MPCV mass is ~42t



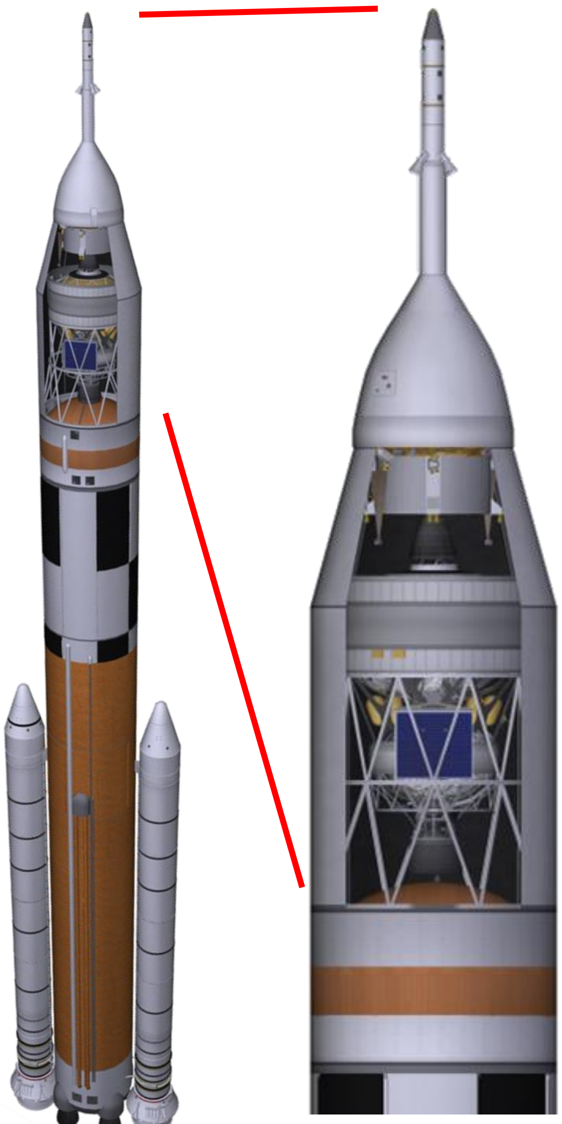
TLI Configuration

Re-Usable Lunar Lander Stationed at EML1

- **Testing is done in the vicinity of the ISS-EP to prepare it for its first landing**

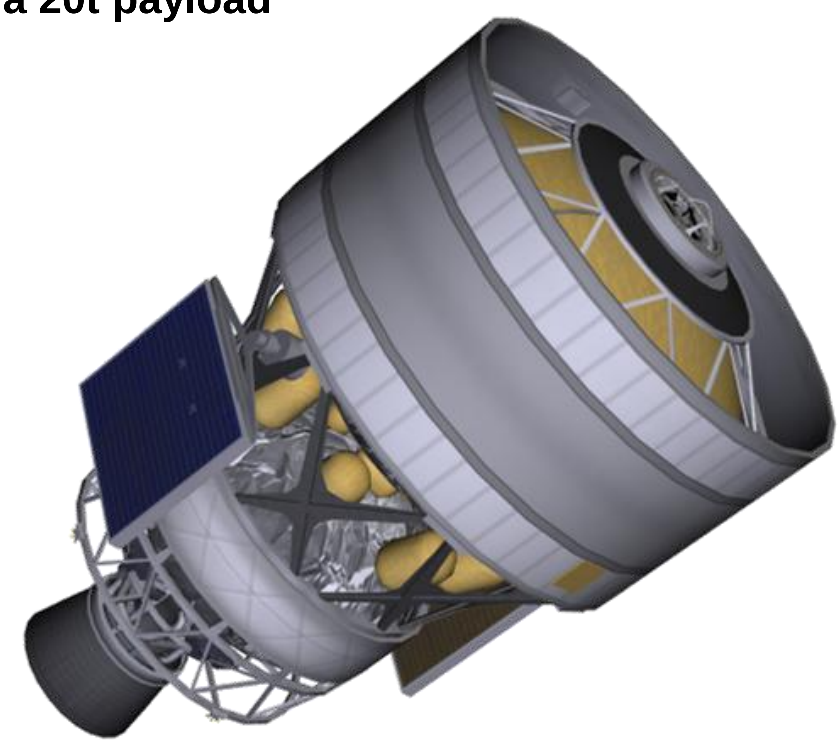


SLS Third Stage Introduction



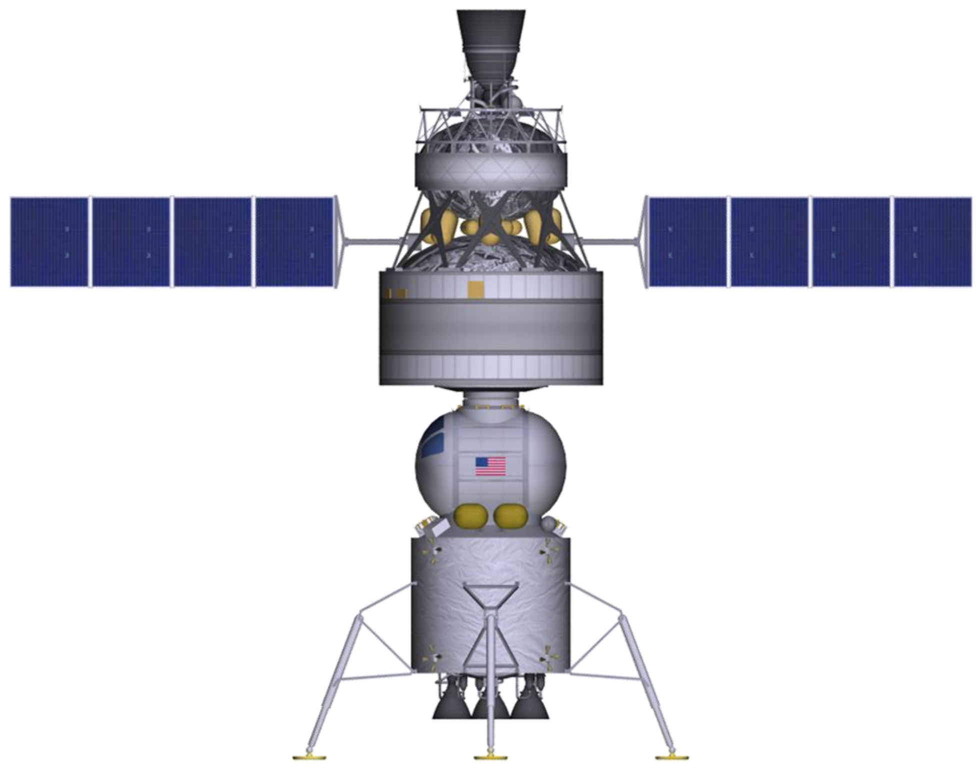
- A third stage for SLS has several important functions in the exploration architecture
    - Increased SLS performance for C3
    - Kick stage for SEP mission departures from EML1/2
    - Descent stage for a reusable lunar lander

- Fully fuelled, it can provide a Delta V capability of ~4.3 km/s with a 20t payload



Lunar Landing Configuration

- SLS third stage provides propulsion for lunar orbit injection and most of the lunar descent burns
- Lander provides terminal landing and ascent propulsion
- Expensive crew cabin and avionics are re-used



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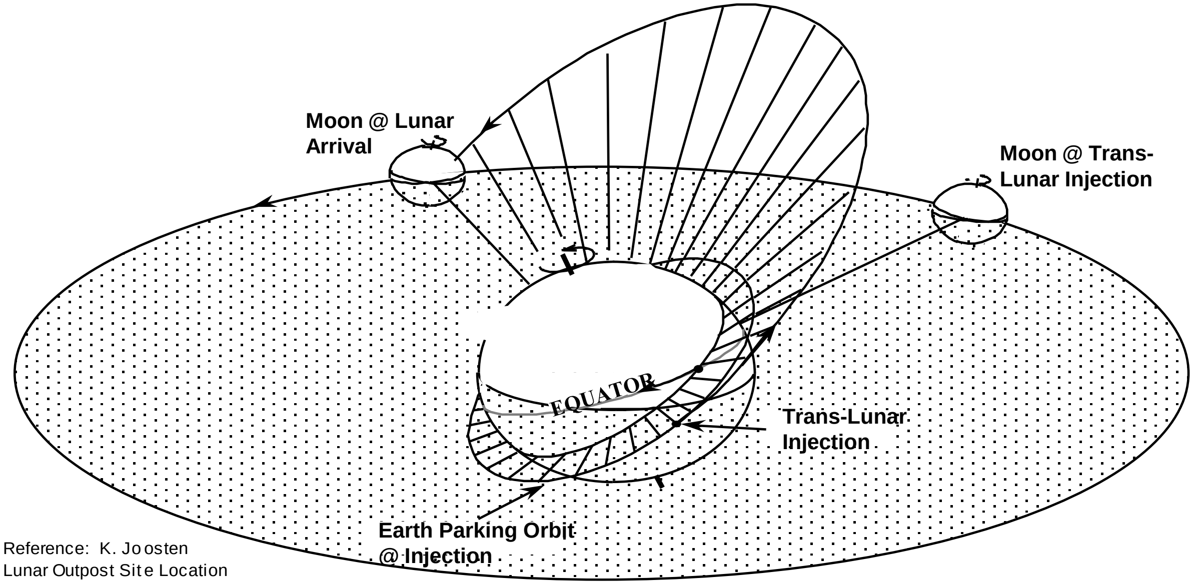
Lunar Surface Access

TLI from LEO to LLO



Reference: K. Joosten
Lunar Outpost Site Location
Implications to Mission Planning

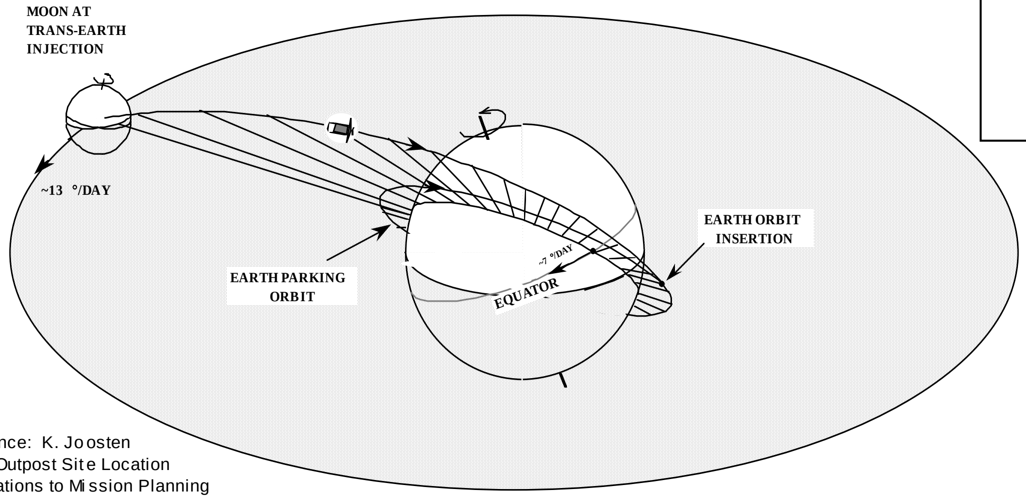
Lunar Site Access and Anytime Return

- During the Constellation program, access to different sites on the lunar surface became a significant issue for the Altair lander
  - This requirement was a driver on Altair because plane change maneuvers were often needed in order to provide the additional mission planning flexibility
- The ISS-EP is in a Lissajous orbit about EML1. Plane changes for lunar surface landing site access are accomplished via the ISS-EP
  - Allowing the lander to depart the platform and enter lunar orbit in the appropriate inclination for the designated landing site

•To keep the re-usable lander small, it does not include the capability for large plane changes
•The ISS-EP executes an orbital maneuver by firing RCS into the Z-vector of the orbit. This maneuver inclines the orbit of the ISS-EP in reference to the Earth-Moon libration point X-Y plane and the moon's equator

Anytime Return

TEI from LLO to Earth



Reference: K. Joosten
Lunar Outpost Site Location
Implications to Mission Planning

Lunar Site Access and Anytime Return

- Crew contingency departure requirements were also a driver for Altair
  - With staging in LLO, the ascent must be phased with the on-orbit vehicle
  - The vehicle in LLO needs to phase its departure with the lunar orbit departure point and the Earth target.
  - When EML1 is used as a staging point, it provides a relatively stable platform from which to depart the surface and leave LLO for EML1
- The return to Earth requires targeting the landing site on Earth, but very little phasing from the EML1 departure.

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Lunar Mission Description Staging Events: to Touchdown

1. The 14.95mt reusable O_2/CH_4 lander is emplaced at the L1 node by SLS launch.
2. 16.8mt Crew Capsule boosted by the SLS Second Stg and the Third stg (w added cargo).
3. Second stage provides half of the dV to reach L1 (2,013 of required 4,015m/s).
4. Third stage provides the remaining dV (2,002 m/s) to L1. (its first use)
5. From the L1 Hab the Crew oversee the attachment of the Third stage to the Lander
6. The partially full Third stg boosts lander into LLO (2nd use),
7. Third Stg then provides most of the dV for descent (1,695 of 1,995 m/s required).(3rd use)
8. Five km above the surface, lander engines are started, empty Third stage is jettisoned, and the remaining dV (500 m/s) is done by the lander.

Observations:

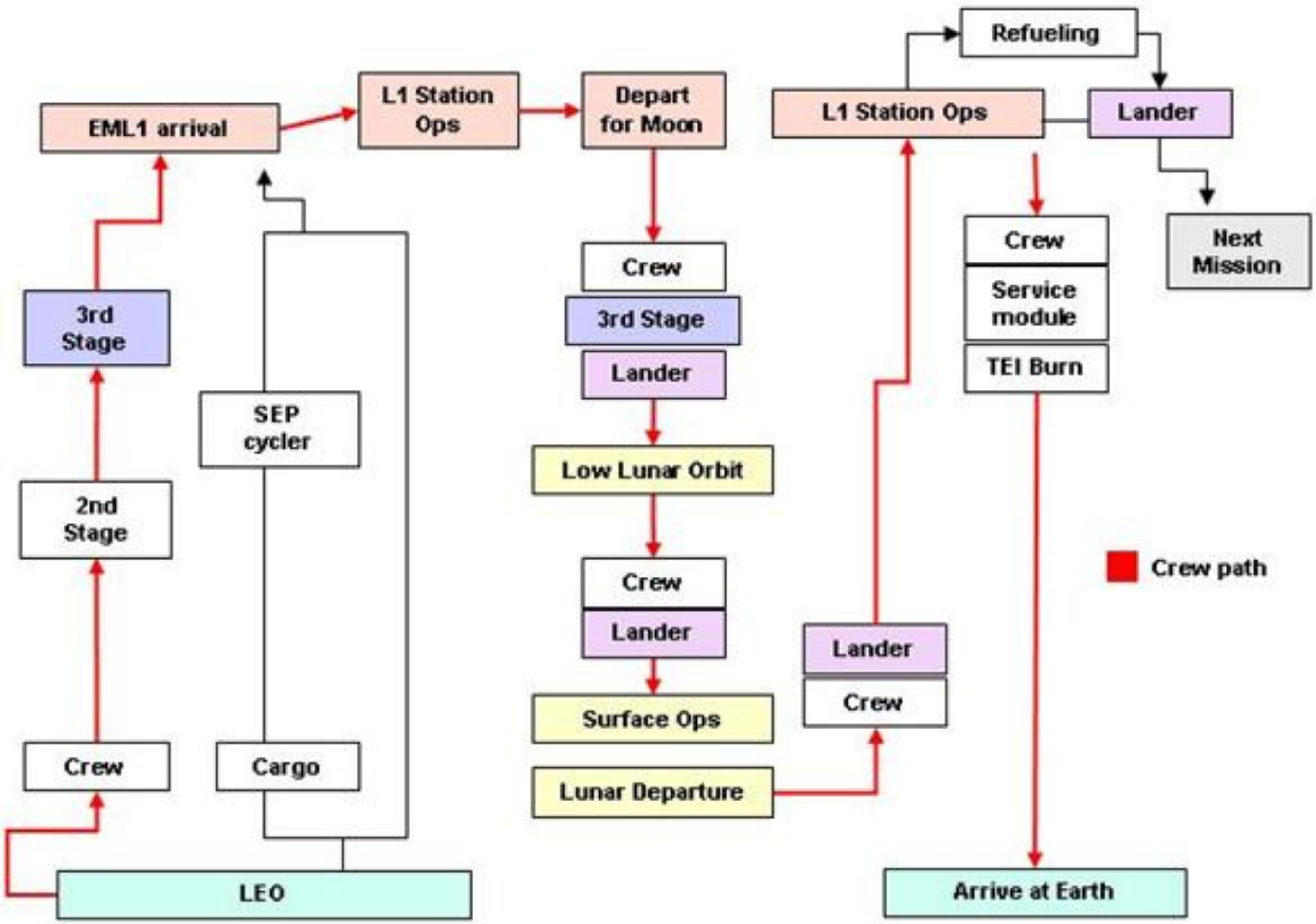
-Approach eliminates a large propulsion volume, providing a much smaller, lighter lander

-Staging eliminates the need for a deep throttling descent engine

-Reusable lander may be viewed as an ascent stg that does a modest portion of the descent burn

-The 1960's *Surveyor* robotic lunar lander used this approach; most of its descent dV was done by a separate stage, to allow a much smaller lander.

Lunar Mission Events Diagram



Post Landing Events and Observations

9. Initially the Crew Lives out of the Ascent Crew Cabin

10. Later Crew transitions to the 8.6 mt Surface Hab delivered by the Cargo Lander

11. Surface power systems deployed by Crew

12. After the surface mission, the crew ascends back to L1

13. After rendezvous, the lander is refueled and prepared for the next sortie.

14. Crew returns to Earth via MPCV Capsule/SM

Observations:

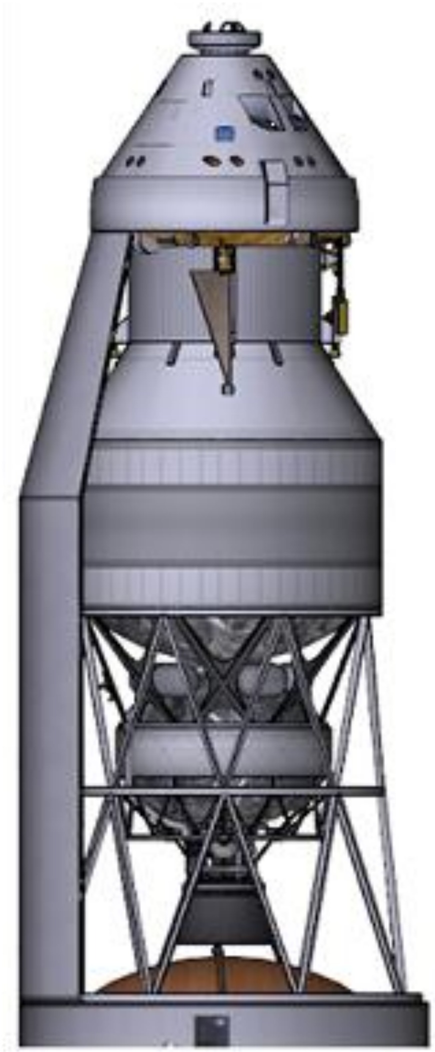
- A complete Lunar sortie can be flown with elements provided by one SLS launch.

- The Lunar surface Hab is a prototype for the inflatable Mars surface Hab.

- The Lunar Lander is a pathfinder for the Mars Lander

- “Reusability” operations (transfer of fuel, consumables, telecommunications, Internal Vehicle Health Monitoring) are demonstrated and refined in Near Earth Space

Lunar Third Stage Upper Stage with Capsule/SM



Lunar System: 3rd Stage

Tank volumes:
LH2 tank 5.5 m dia
-volume 3247.2 ft3 (91.95 m3)
-(includes 4% ullage vol)

LO2 tank is 4.4 m dia
-volume 1108.4 ft3 (31.38 m3)
-(4% ullage vol)

Tank lengths:
LH2 total tank length: 16.9 ft (5.15 m)
- top dome height: 6.3 ft
- cyl (barrel) height: 4.3 ft
- bottom dome height: 6.3 ft

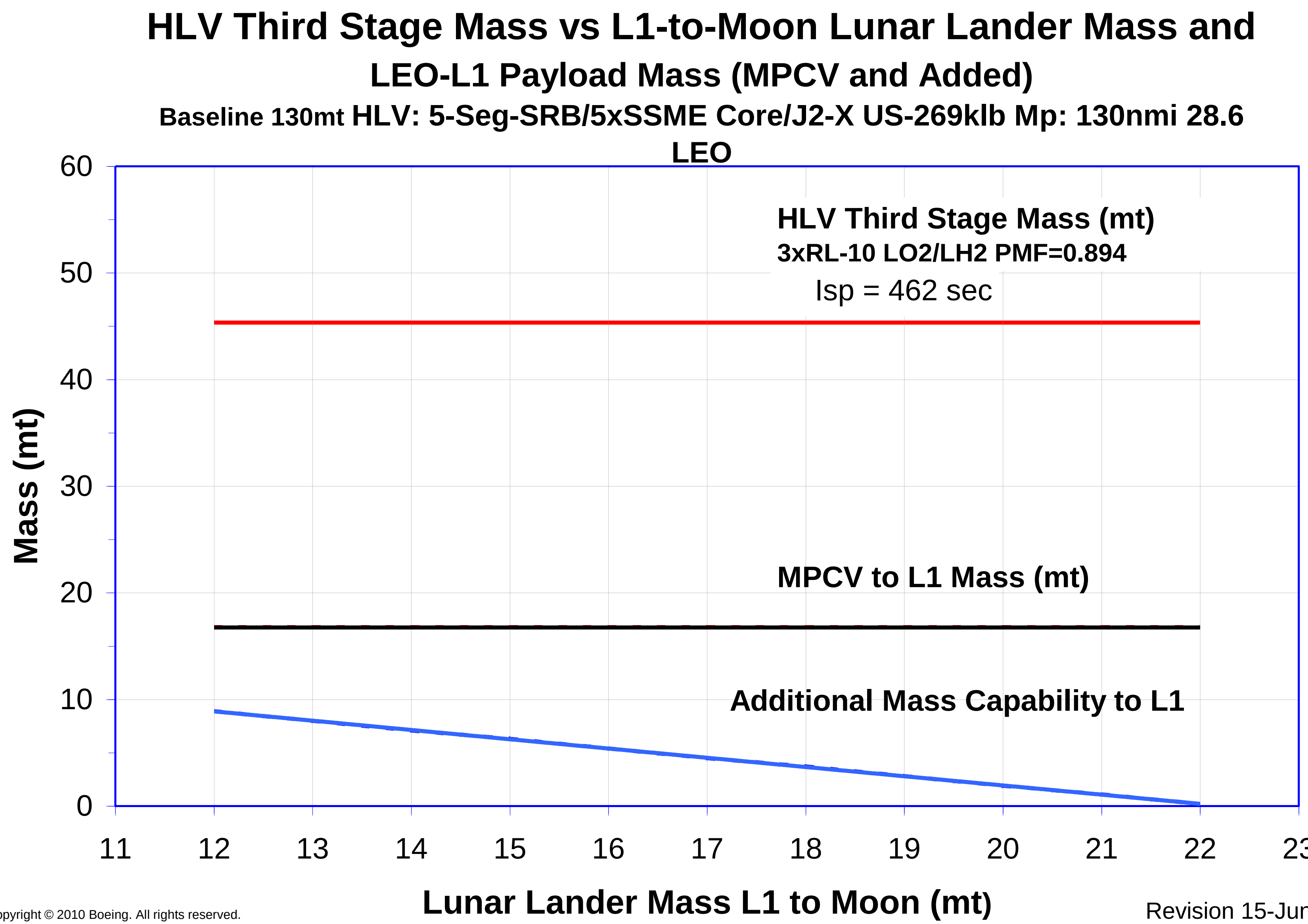
LO2 total tank length: 10.1 ft (3.08 m)
- top dome height: 5.0 ft
- cyl (barrel) height: 0.1 ft
- bottom dome height: 5.0 ft

Stage Mass:
Total mass: 45,691 kg (45.6 mt)
Dry mass: 4,683 kg
PMF (total prop/total stg); 0.897
Inert mass: 6,001 kg
Total prop: 40,781 kg
Usable prop: 39,691
Reserve prop: 1,091 kg
RCS prop: 227 kg

Performance:
Vac Isp: 462.0 (long nozzle RL-10)
Mix ratio: 5.5
Two Engine Version:
Stack T/Wt at 3rd stg ignition: 0.31;
T/W at end: 1.02
Single Engine Version:
Stack T/Wt at 3rd stg ignition: 0.16;
T/W at end: 0.51

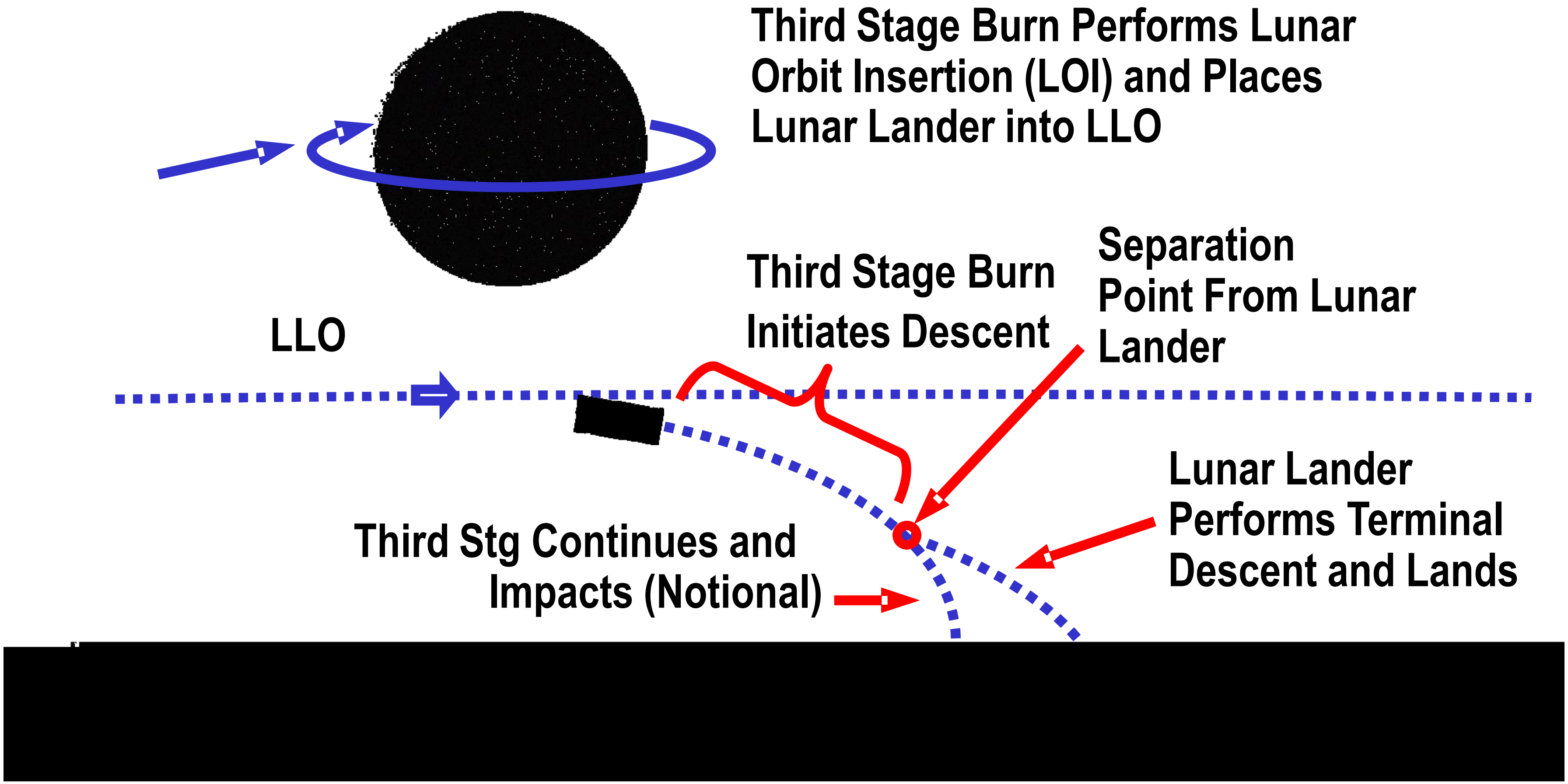
462 Isp O2/H2 Upper Stage (3rd Stage) boosts 16.8 mt MPCV, 6.7 mt added payload, and 0.4 mt Adaptor to L1, Drops MPCV and payload, acquires 14.95 mt Lander and boosts to Moon for Landing. 3rd stg jettisoned 500 m/s prior to touchdown. Total dV done by 3rd stage is 4,357 m/s (14,294 ft/s)

Capability for 3rd Stage

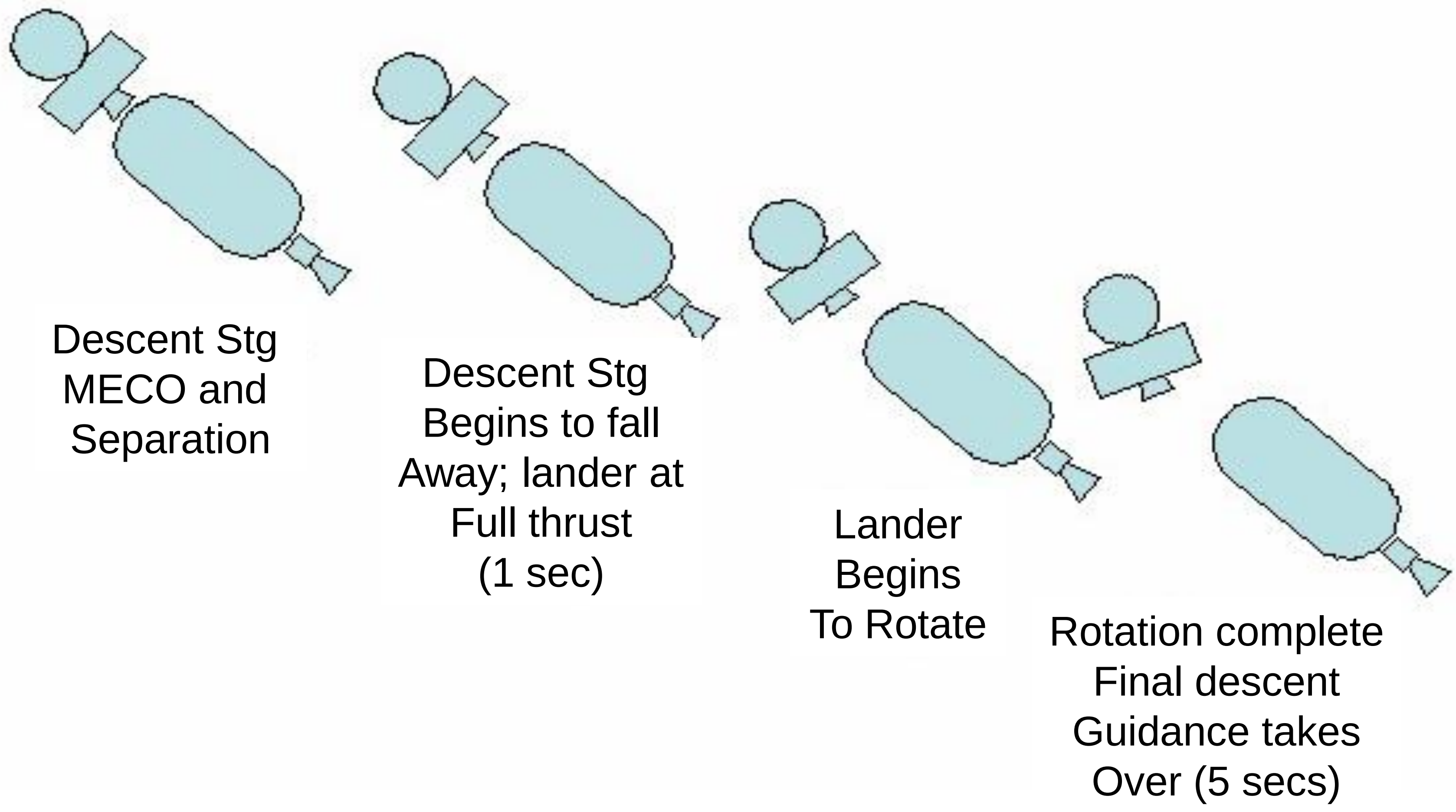


Revision 15-June-2011

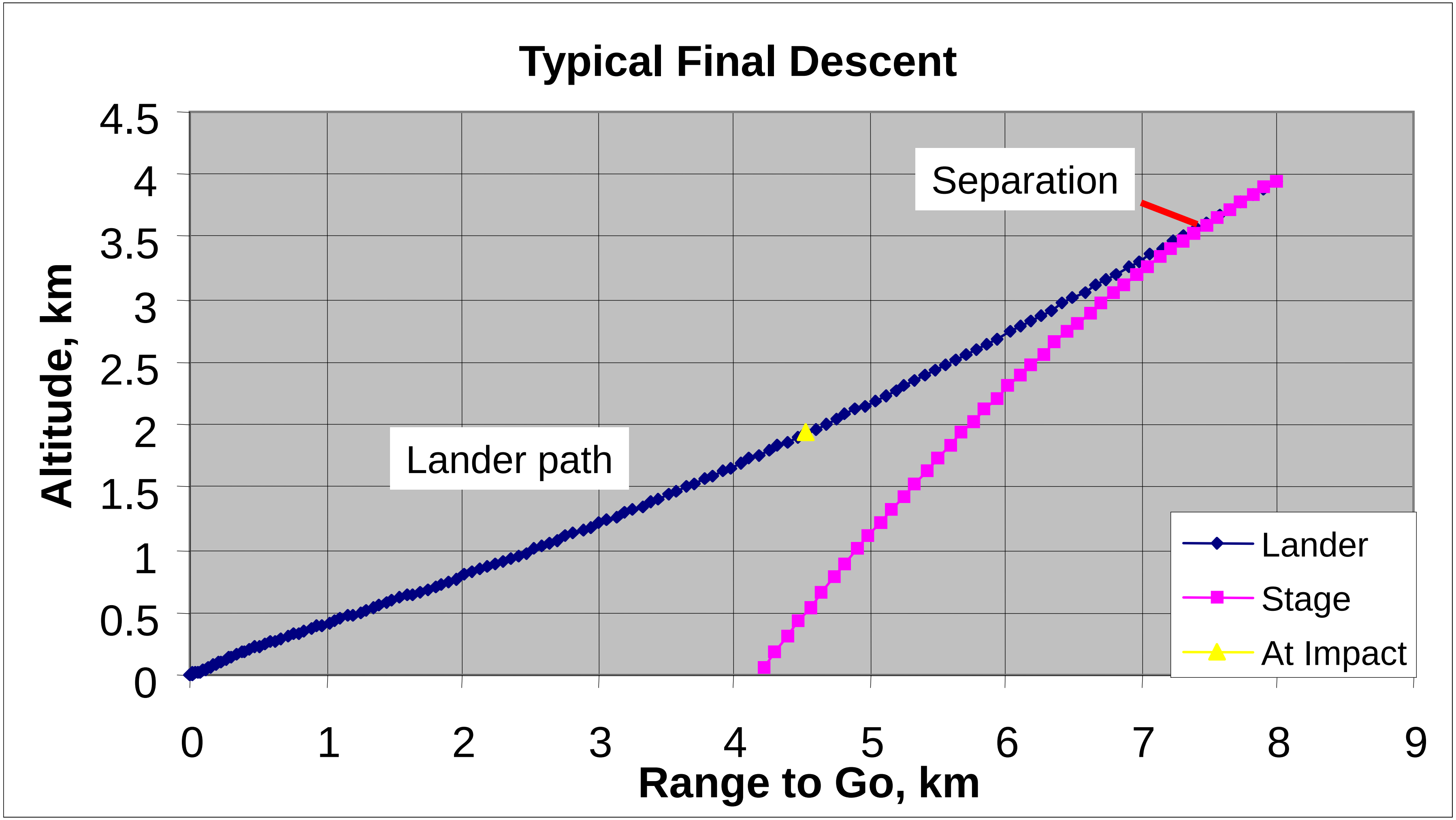
Lunar Descent Profile



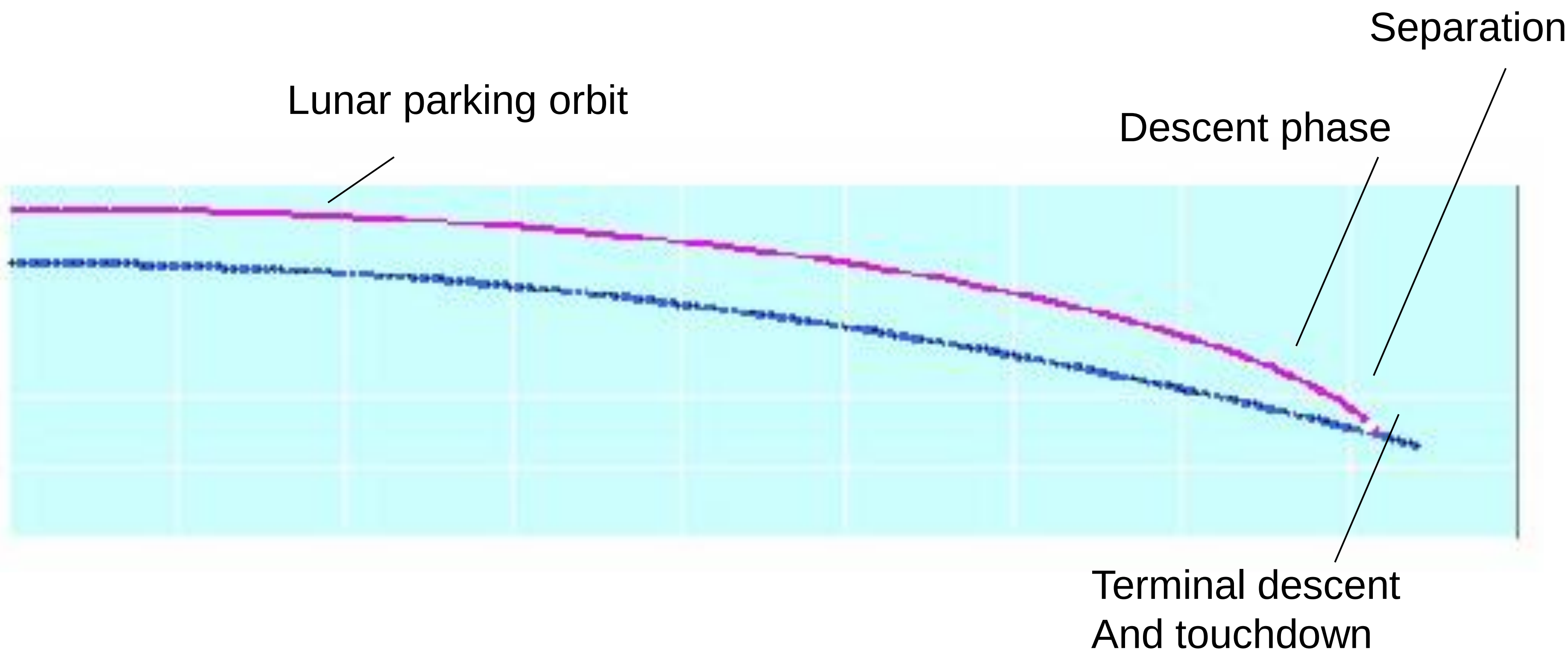
Descent Staging Graphic



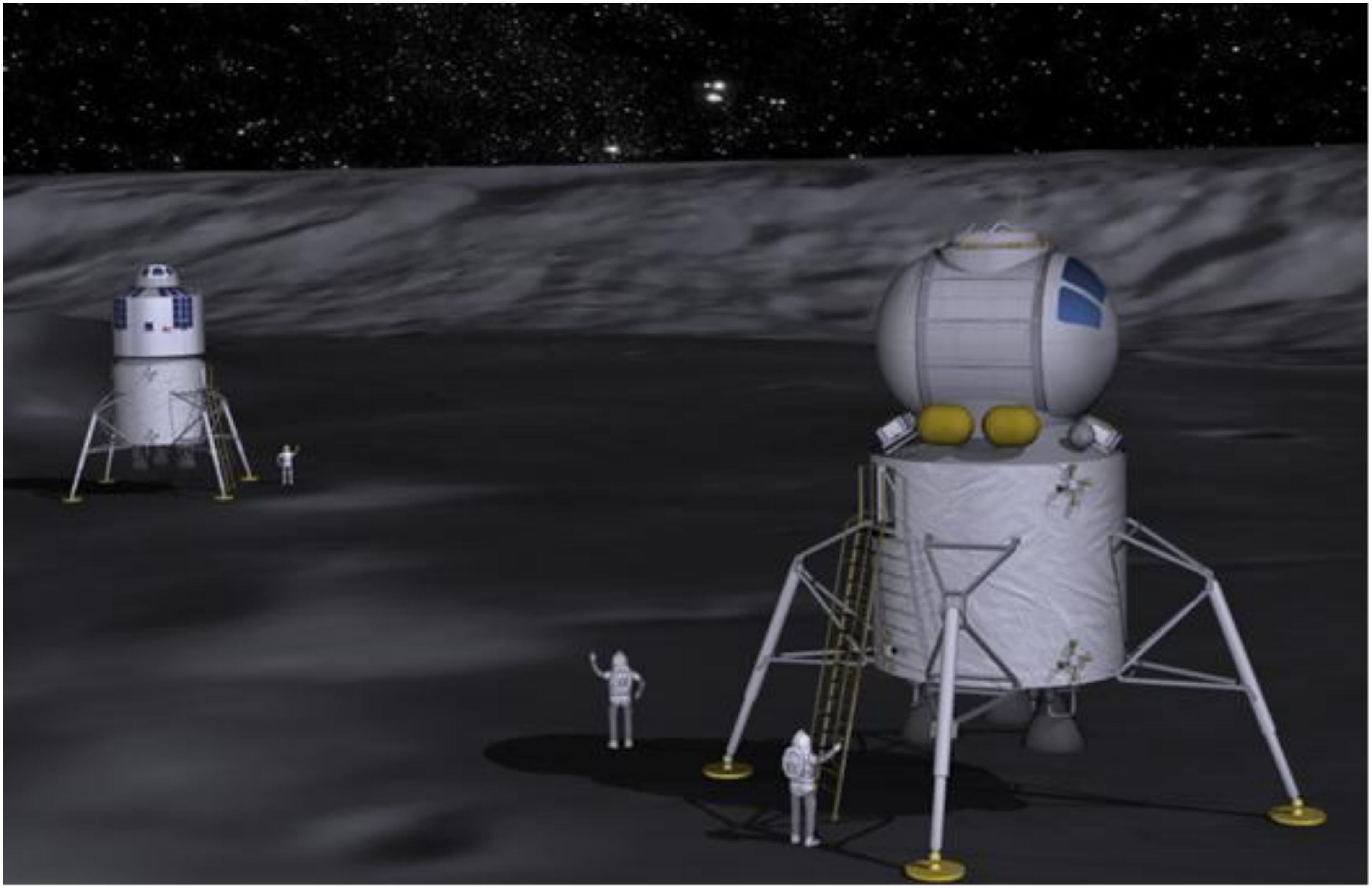
Separation and Final Descent



Descent and Landing Profile
Third Stage and Lander

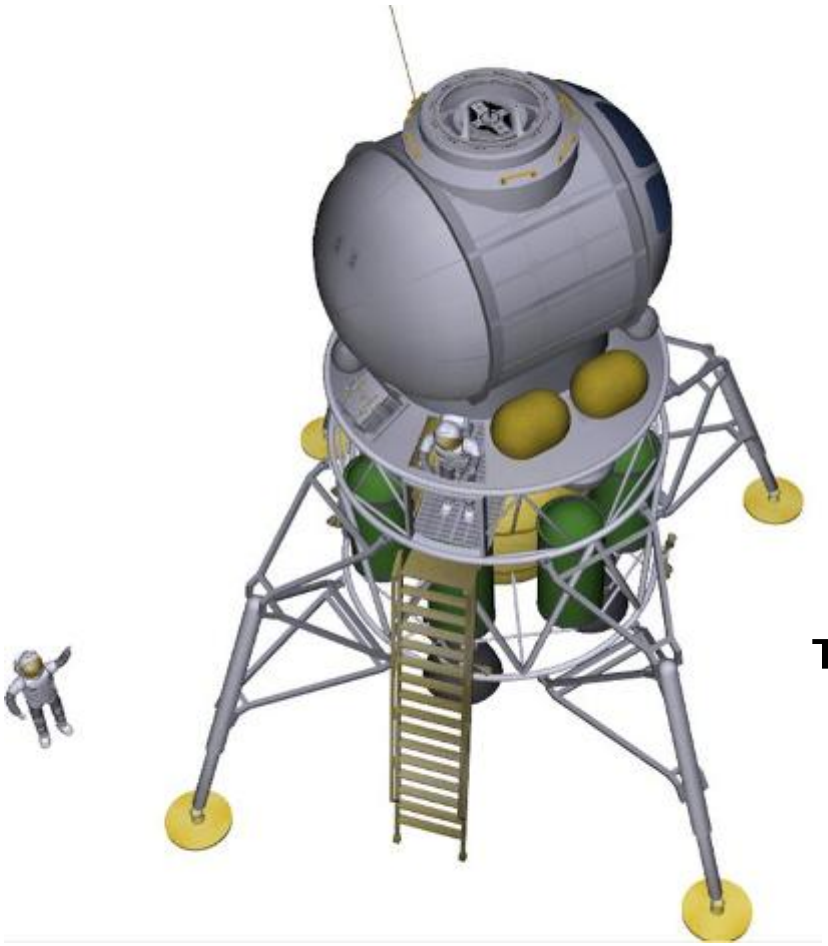


Lunars On Surface



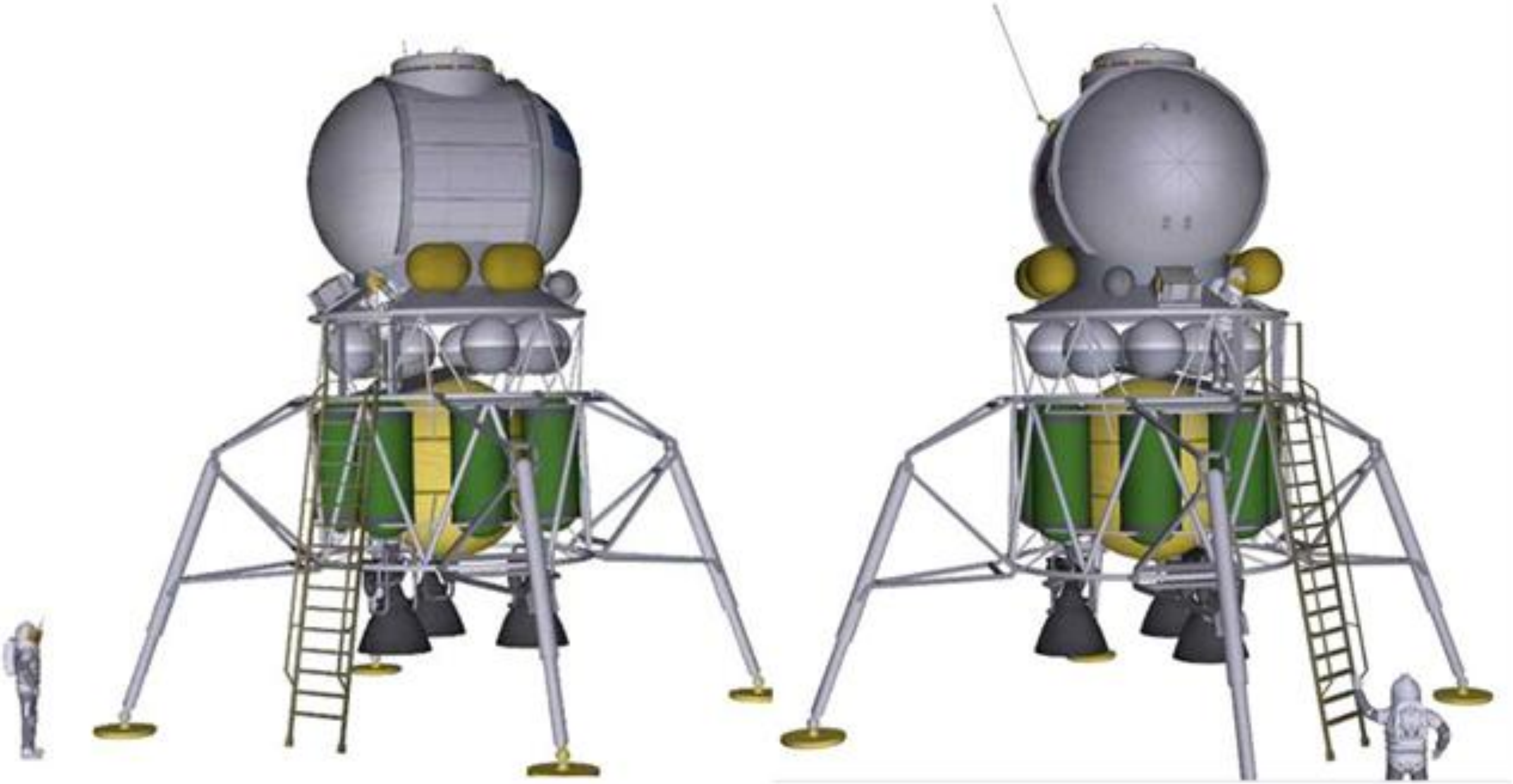
Crew Lander Lander Mass – Terminal Desc/Asc

O2/CH4 propulsion, 372 sec Isp, Terminal Descent/ Ascent Stage



	mass	delta-V
Total Systems Mass	**14.98 mt**	
Surface Payloads	**0.50 mt**	
Total Lander Mass	**14.48 mt**	
Crew Cabin and Systems	**3.15 mt**	
Dry Mass	**2.72 mt**	
Propellant total	**8.61 mt**	
Propellant Masses	**8.61 mt**	**3,133 m/s**
Propel Reserves	**0.17 mt**	
L1 to LLO Prop Main	**n / a**	
L1 to LLO RCS	**0.02 mt**	**5 m/s**
Terminal Desc Propel Main	**1.92 mt**	**500 m/s**
Terminal Desc RCS	**0.04 mt**	**10 m/s**
Ascent Propel Main	**5.20 mt**	**1950 m/s**
Ascent RCS	**0.04 mt**	**10 m/s**
LLO to L1 Prop Main	**1.18 mt**	**640 m/s**
L1 RCS Prop	**0.04 mt**	**18 m/s**

Lunar Crew Lander with Ascent Crew Cabin



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LO2 / Methane CH4 Engines for Descent and Ascent

- ISRU derived Methane may be used for Mars ascent descent
- Developmental programs underway at Aerojet and ATK/COR
- LO2 residuals left in desc stg tanks available Crew on surface
- Pump-fed Methane engine provides significant Isp (372-375 s) over press-fed storable engine (320-328)
- Shared propel tank O2/CH4 main / RCS system in test

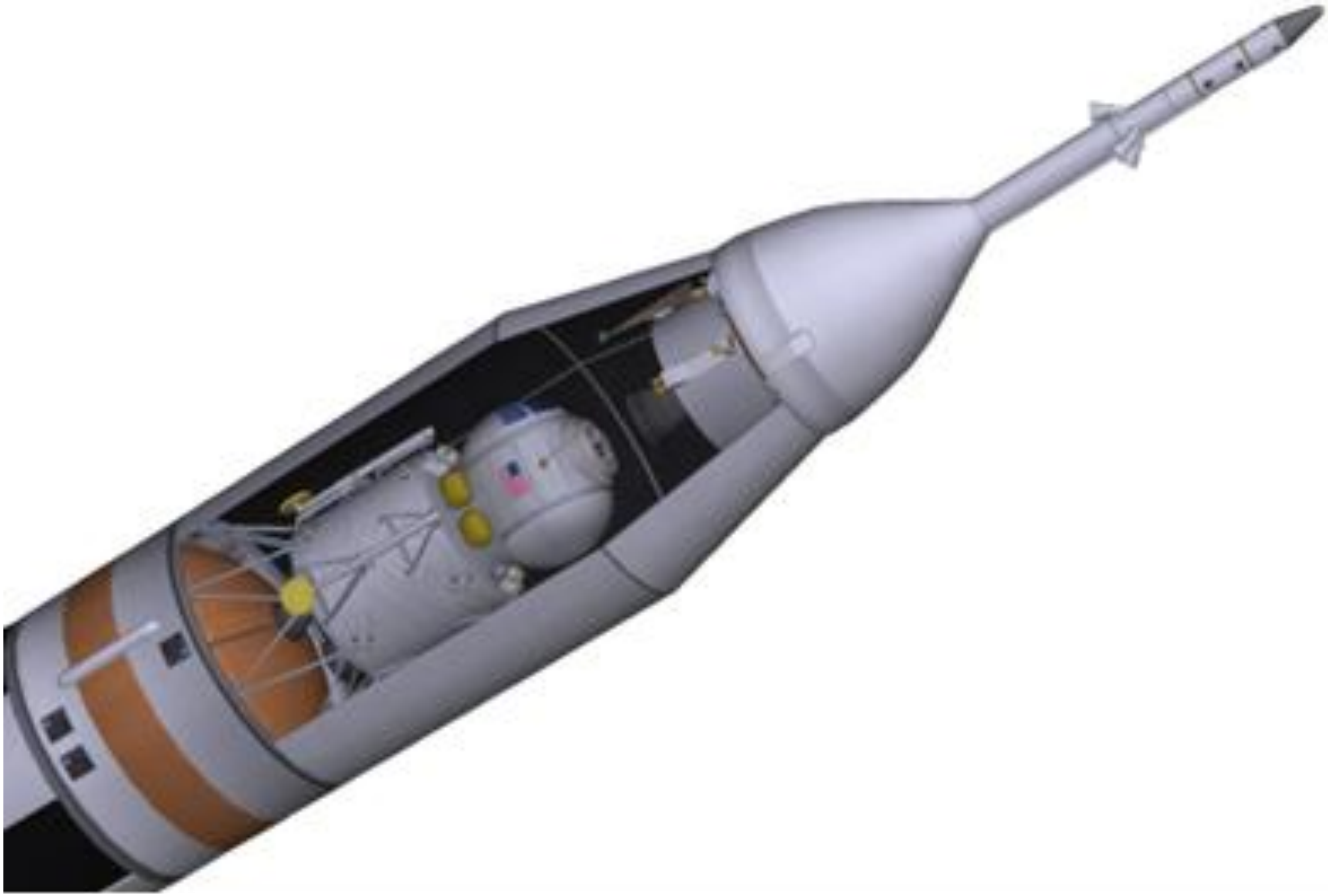
Aerojet, T = 5.5 k-lbf, Isp = 350 sec

ATK/XCOR, T =7.5 k-lbf

O2 / Methane Isp vs Chamber Pressure :
16klbf Thrust, 65 in diam Nozzle

Chamber Pressure Pc (psia)	Nozzle Exit Diameter (in)	Nozzle Area Ratio (-)	Prop Mixture Ratio (-)	Engine Total length (in)	Isp Vac With Losses (sec)	Thrust Level Max (lbf)
600	65	181	3.2	128	368	16 klbf
750	65	223	3.2	130	371	16 klbf
1000	65	296	3.2	133	375	16 klbf

Lunar Launch Manifest Example – Lander & Capsule



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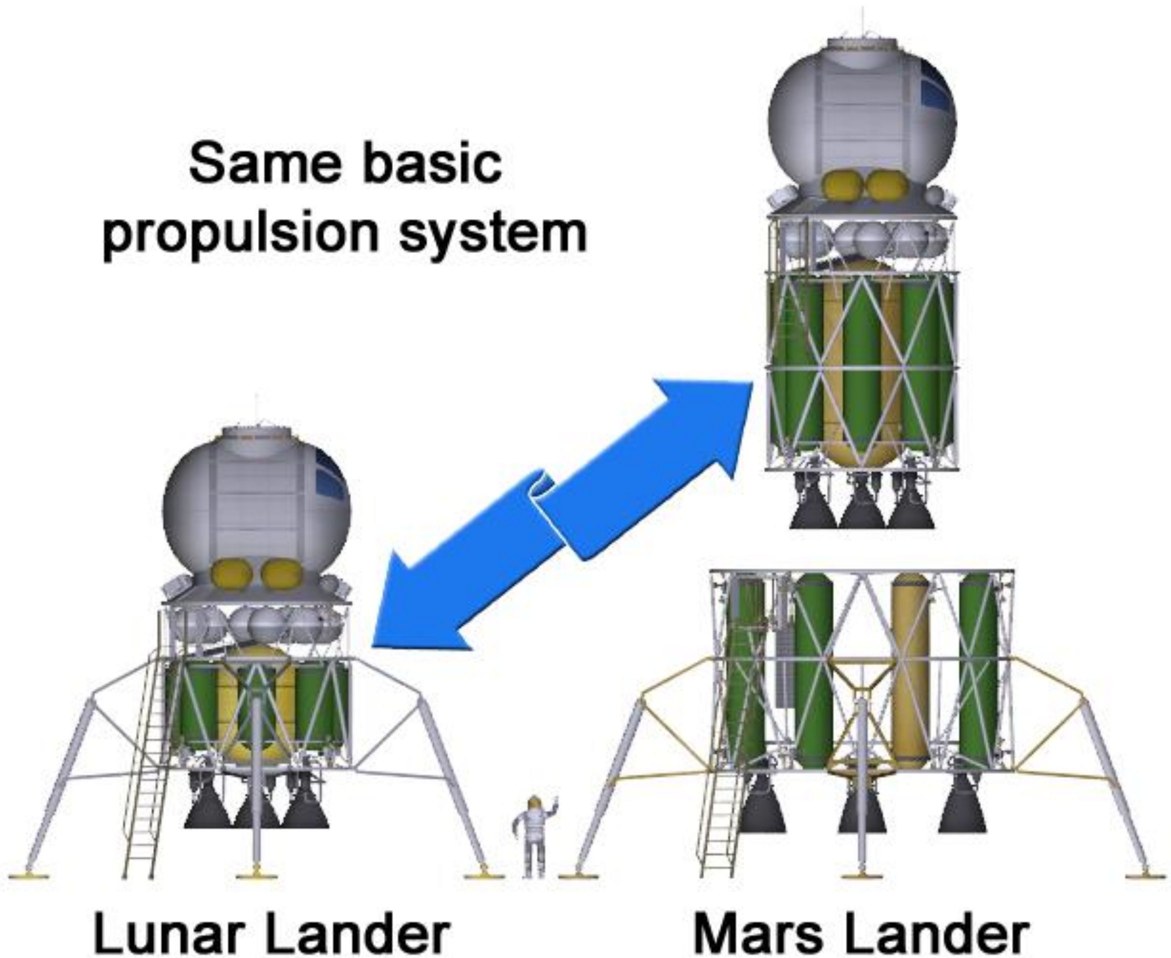
Evoution: Mars From Lunar Systems



Linkage: Lunar to Mars
Demonstration of Major Elements

1. Mars ascent O_2 / CH_4 propulsion is validated at the Moon (3 days distant)
2. Engines, tankage, feed systems, thermal, avionic, power and other systems necessary to ascent and descent are all demonstrated.
3. Operational issues are identified and corrected in the near Earth space environment; by the time the Mars lander derivative is in place, high confidence in its capabilities has been achieved.
4. (The only major new development required for a Mars mission would be the Mars descent aeroshell).
5. This progression begins in the early 2020s and continues into the 2040s. The EML1 base serves as the assembly point, checkout/ refurbishment/ refueling node, technology maturation center and mission return node