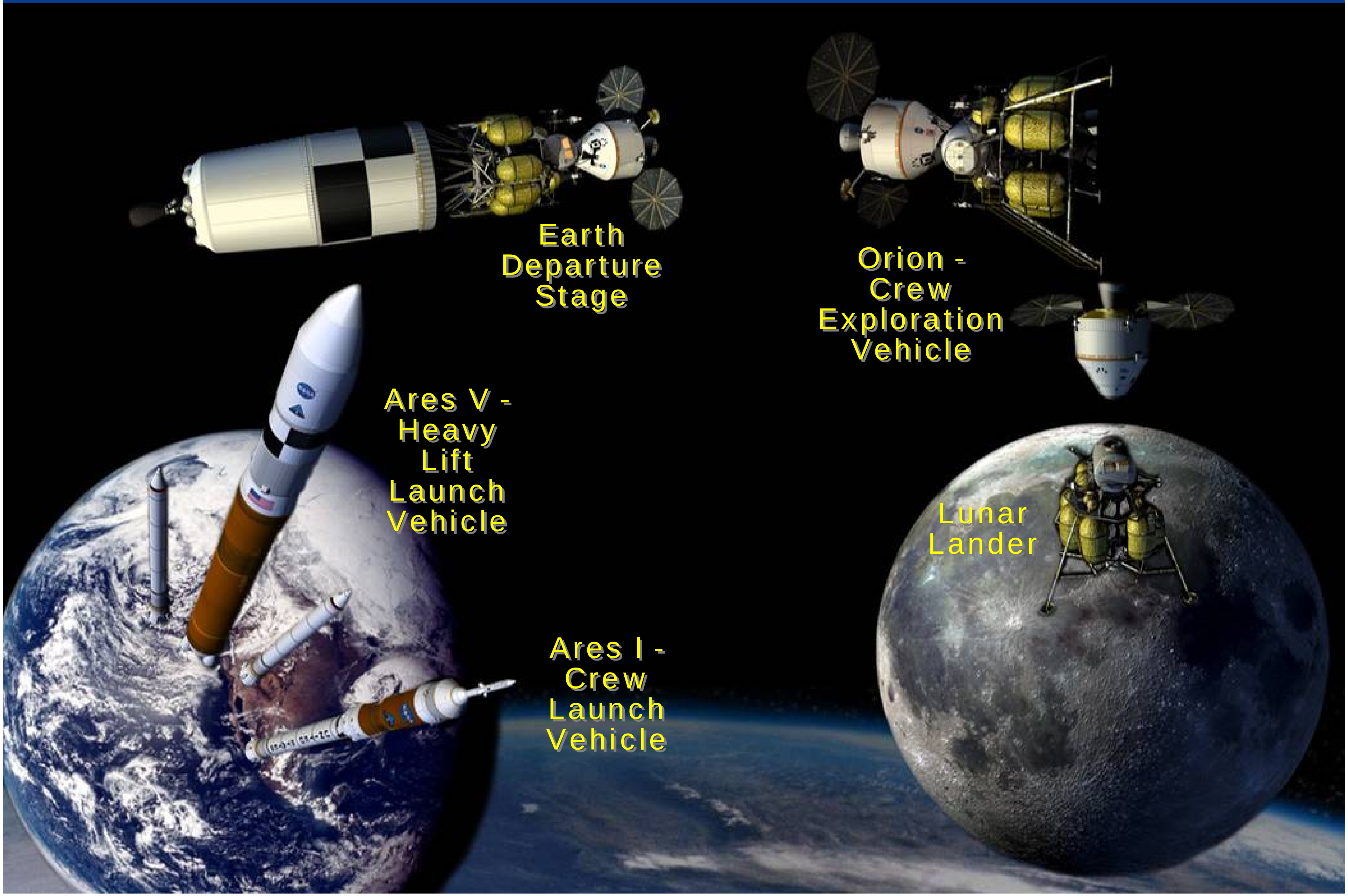
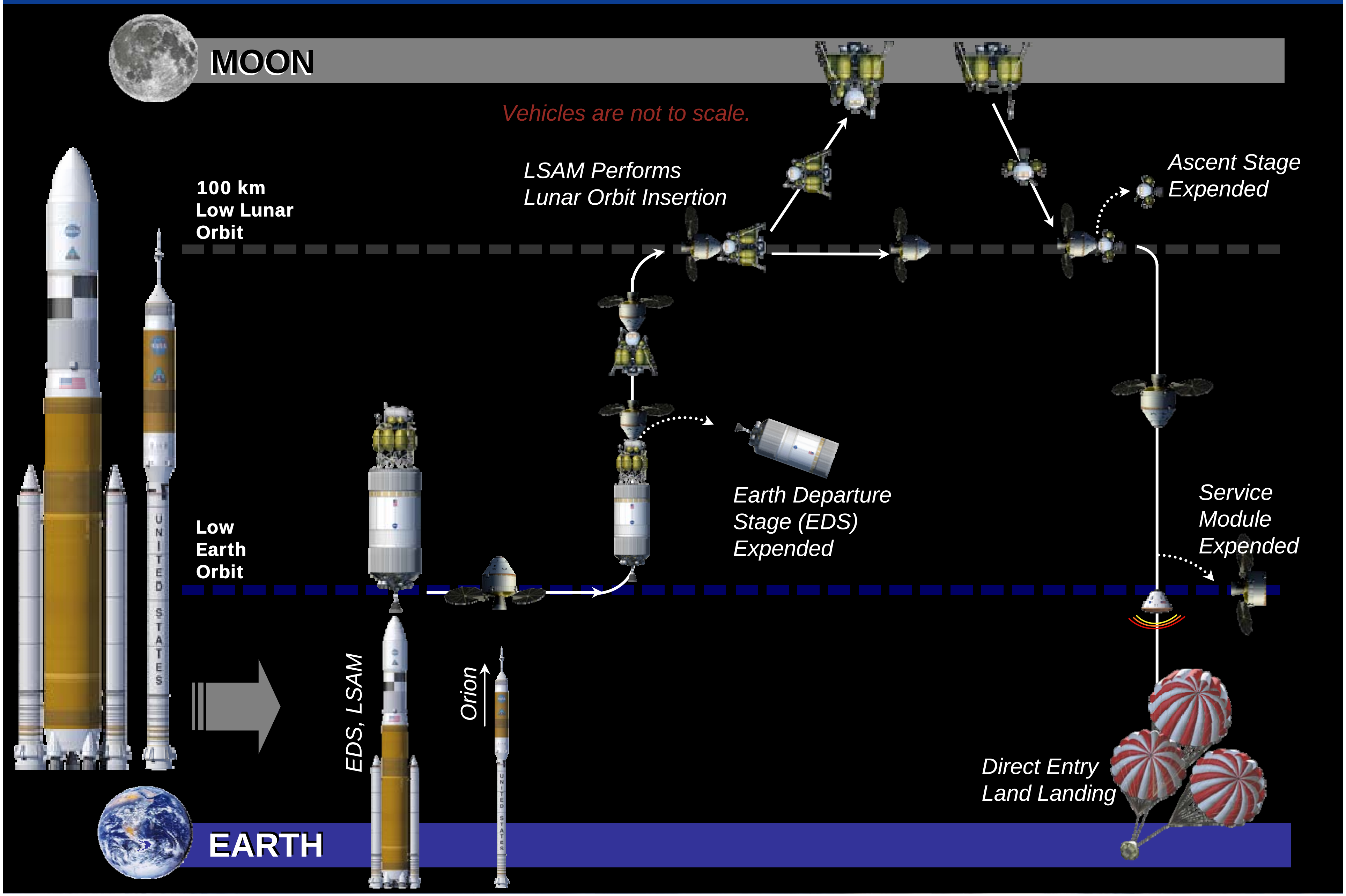

lights on, down 2 ½…
40 feet, down 2 ½…
Kickin’ up some dust…
30 feet, 2 ½ down…
faint shadow…
John Connolly
Lunar Lander Project Office

Components of Program Constellation



Typical Lunar Reference Mission



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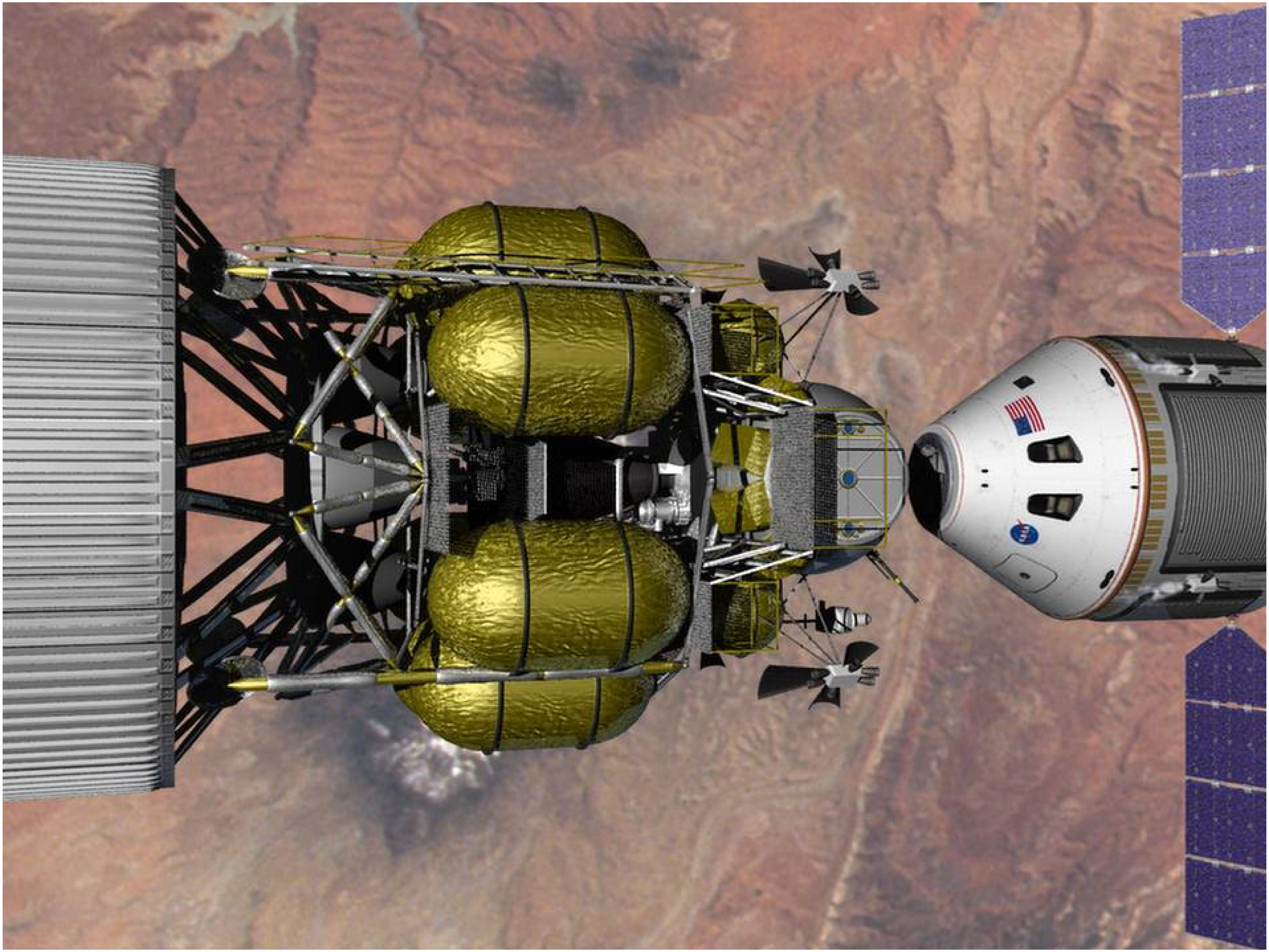

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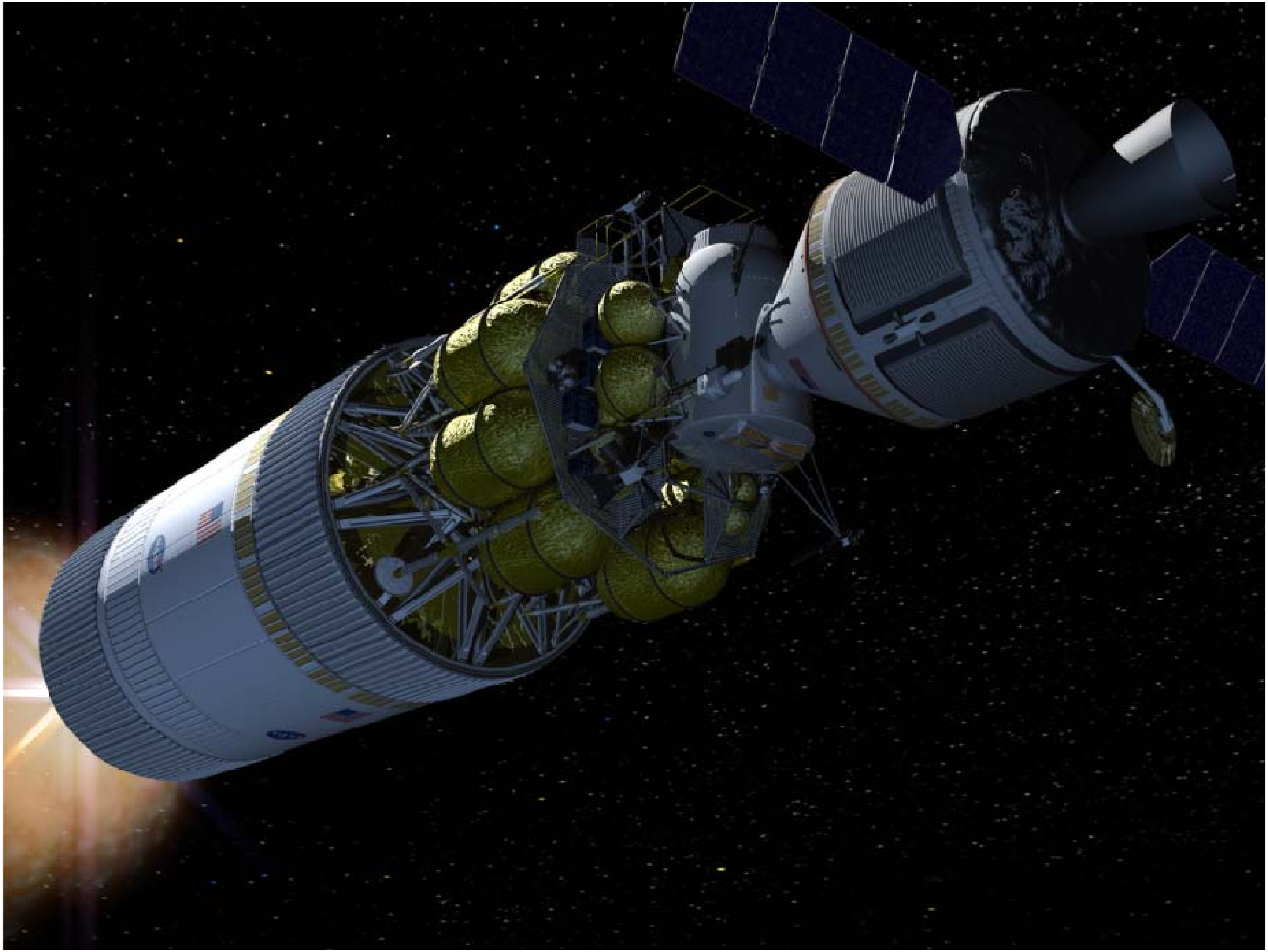

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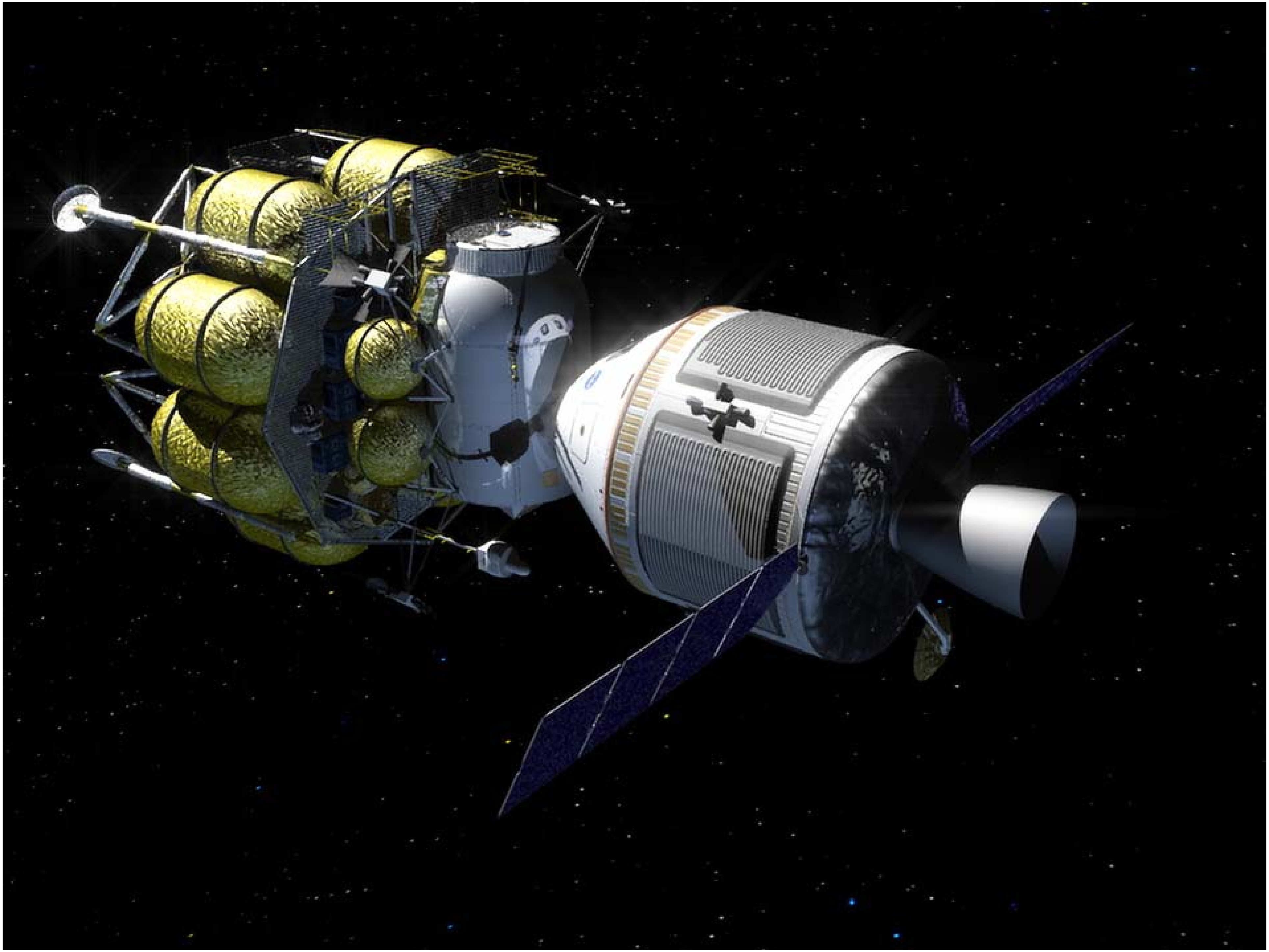

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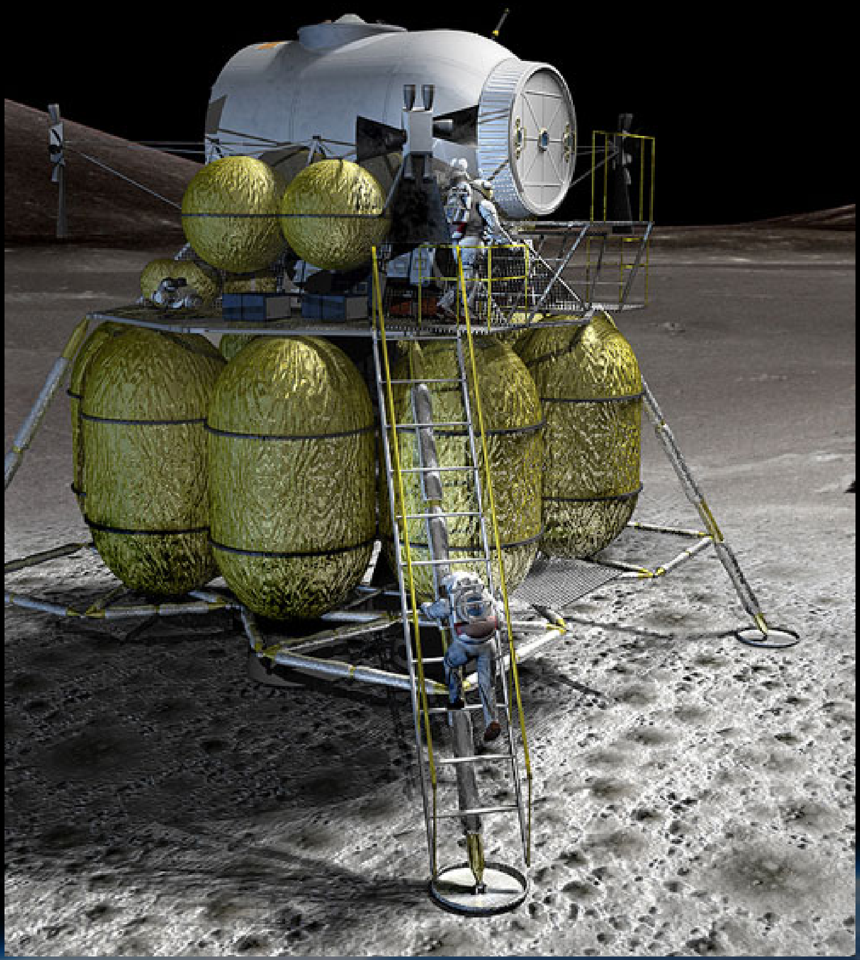
Lunar Lander



- **Transports 4 crew to and from the surface**
  - Seven days on the surface
  - Lunar outpost crew rotation
- **Global access capability**
- **Anytime return to Earth**
- **Capability to land 20 metric tons of dedicated cargo**
- **Airlock for surface activities**
- **Descent stage:**
  - Liquid oxygen / liquid hydrogen propulsion
- **Ascent stage:**
  - Storable Propellants

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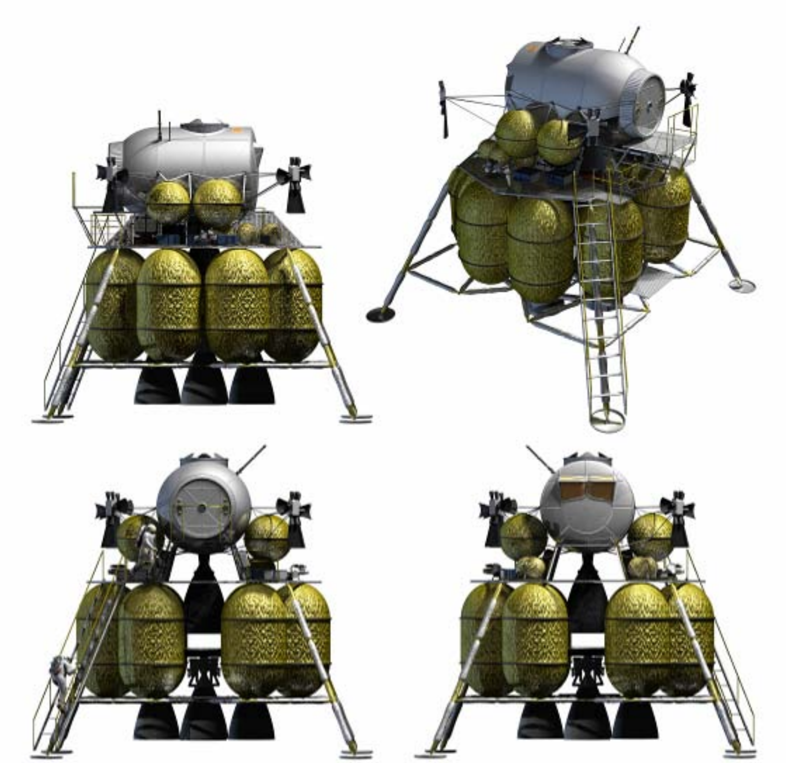
ESAS LSAM - Baseline Configuration



- 2 stage, expendable
- LOX/H2 Descent Propulsion
  - RL-10 deravitive (x4)
  - TCMs,LOI, Deorbit, Landing
- NTO/MMH Ascent Propulsion
  - CEV SM deravitive (x1)
  - Ascent, RNDZ, Disposal
- Accommodations for 4 crew for 7 days on the lunar surface
- Full Airlock functionality

Vehicle Concept Characteristics

Ascent Module Properties

	Sortie Mission	
	Mass (kg)	Mass (lbm)
1.0 Structure	1,147	2,524
2.0 Protection	113	249
3.0 Propulsion	718	1,579
4.0 Power	1,205	2,652
5.0 Control	0	0
6.0 Avionics	385	847
7.0 Environment	1,152	2,534
8.0 Other	382	841
9.0 Growth	1,020	2,245
10.0 Non-Cargo	153	337
11.0 Cargo	0	0
12.0 Non-Propellant	173	381
13.0 Propellant	6,238	13,724
Dry Mass	6,123 kg	13,471
Inert Mass	6,276 kg	13,807
Total Vehicle	12,687 kg	27,912

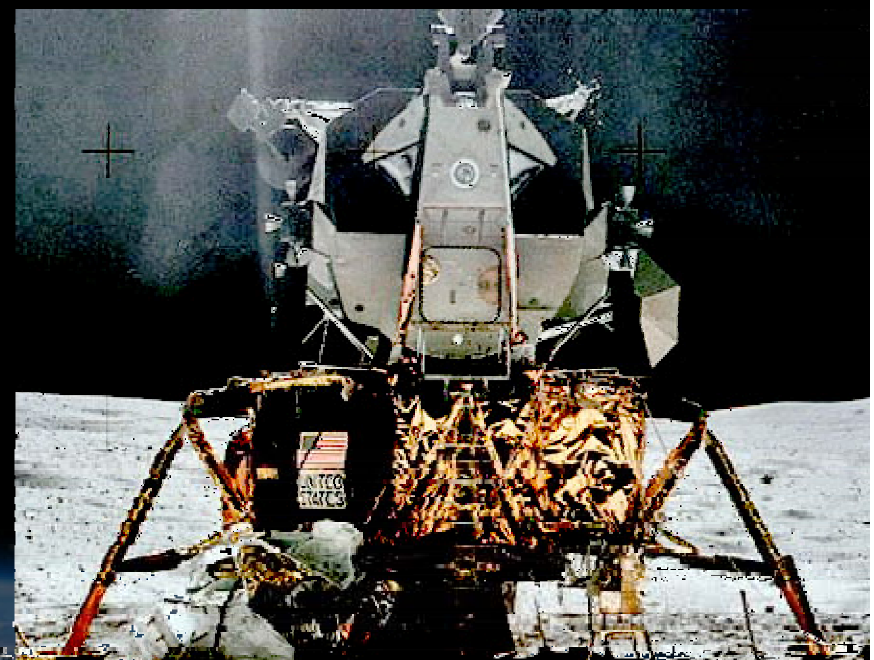
Descent Module Properties

	Sortie Mission	
	Mass (kg)	Mass (lbm)
1.0 Structure	2,214	4,870
2.0 Protection	88	194
3.0 Propulsion	2,761	6,075
4.0 Power	486	1,070
5.0 Control	92	201
6.0 Avionics	69	152
7.0 Environment	284	626
8.0 Other	715	1,573
9.0 Growth	1,342	2,952
10.0 Non-Cargo	2,498	5,495
11.0 Cargo	500	1,100
12.0 Non-Propellant	659	1,450
13.0 Propellant	30,319	66,702
Dry Mass	8051	17,712
Inert Mass	11049	24,308
Total Vehicle	42027	92,459

CONSTELLATION

Apollo Lunar Module (LM) compared to ESAS baseline Constellation Lunar Surface Access Module (LSAM)

	Apollo LM	Constellation LSAM (ESAS baseline)
Crew Size (max)	2	4
Surface Duration (max)	3 days	7 days (Sortie missions), Up to 210 days (Outpost missions)
Landing site capability	Near side, equatorial	Global
Stages	2	2
Overall height	7.04 m (23.1 ft.)	9.7 m (31.8 ft.)
Width at tanks	4.22 m (13.8 ft.)	7.5 m (24.6 ft.)
Width at footpads (diag.)	9.45 m (31 ft.)	14.8 m (48.6 ft.)
Crew module pressurized volume	6.65 m3 (235 cu. ft)	31.8 m3 (1123 cu. ft)
Ascent Stage mass	4805 kg (10571 lbs.)	10809 kg (23780 lbs.)
Ascent Stage engines	1 – UDMH-NTO	1 – LOX-CH_4 (under study)
Ascent engine thrust	15.6 Kn (3500 lbf)	44.5 Kn (10000 lbf)
Descent Stage mass	11666 kg (25665 lbs.)	35055 kg (77120 lbs.)
Descent Stage engines	1 – UDMH-NTO	4 – RL-10 derived LOX/H_2
Descent engine thrust	44.1 Kn (9900 lbf)	4x 66.7Kn (4x 15000 lbf)



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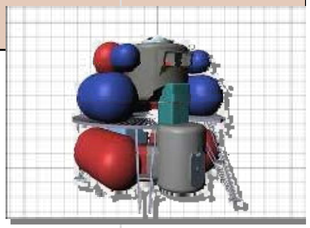
CONSTELLATION

Lunar Lander Preparatory Study

April | June | August

Lander Concept RFI — RFI — Inputs due



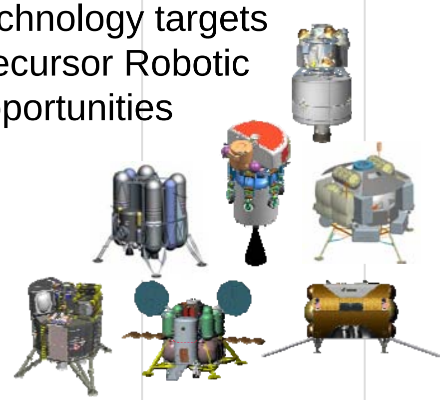
In-House Lander Concept Study

Phase 1 — Review

~30 Concepts
- Explore breadth of tradespace
- Innovation and creativity
- Address "desirements"

Phase 2 — Review

7 Concepts
- Technical Depth
- Performance
- Cost
- Identify Risks
- Technology targets
- Precursor Robotic Opportunities



Follow-on Activities: LAT, IDAC-3

- LSAM re-baselining following HQ architecture, strategy direction

Study Objectives

Multiple, innovative design concepts that answer current CxPO requirements

Broaden number of viable concepts in anticipation of Lunar Strategy Team/Lunar Architecture Team outputs and IDAC-3

Explore additional, desired capabilities (e.g., "incremental deploy" of outpost elements)

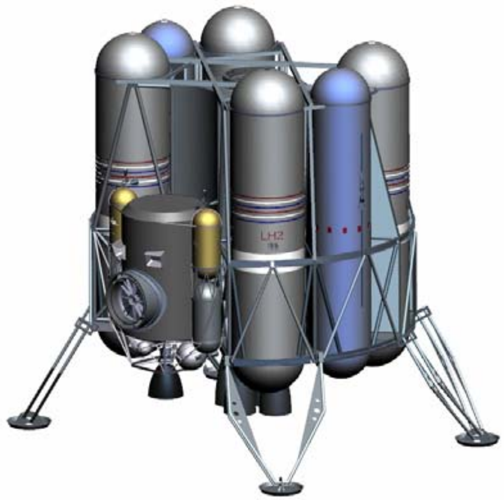
Complete in two phases:
- Phase 1 explored innovative lander design concepts
-Phase 2 concentrated on technical and programmatic details

Multiple, Center-led teams

LLPS Lander Concepts - 1

MSFC Lander

Vertical lander with side-mount, minimum ascent stage



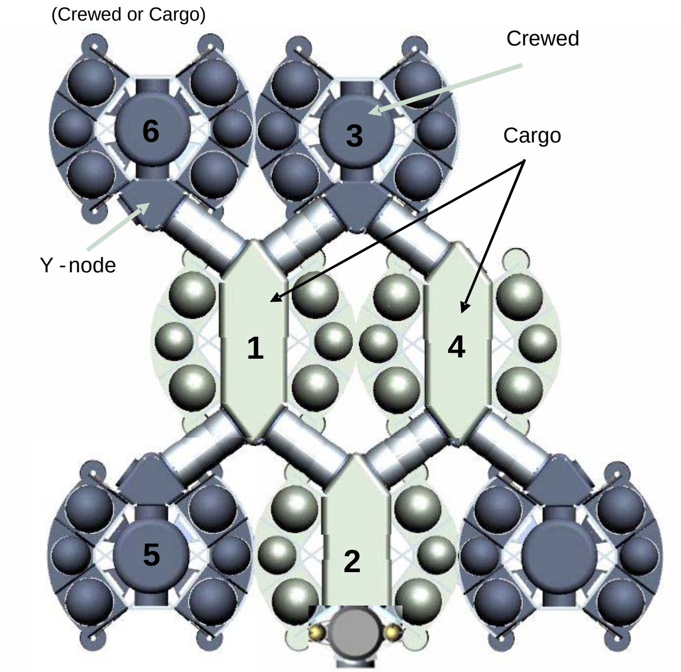
Focus

- Minimum ascent stage concept
- Landed stage mobility, including outpost deployment concepts
- Investigate outpost deployment via docking of mobile elements

Features

- Side-mount ascent stage used as airlock
- Supports 4 crew for 7-day surface stay
- Vertical cylinder surface habitat in center of descent tanks
- "MULE" mobility system

Outpost Buildup Concept

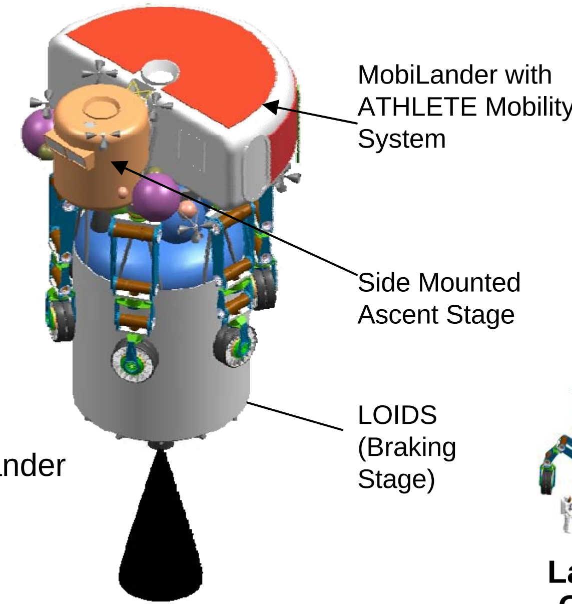


CONSTELLATION

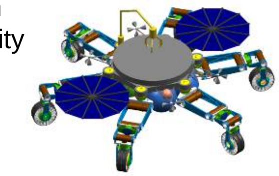
LLPS Lander Concepts - 2

JPL MobiLander

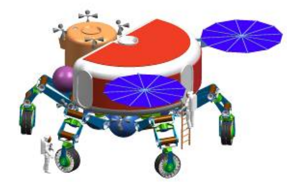
Split habitat crew lander with a minimally sized descent/ascent habitat utilizing a Lunar Orbit Insertion/ Descent Stage (LOIDS) and ATHLETE system for mobility



Crew Lander with LOIDS



Baseline Cargo MobiLander



Landed/Roving Configuration

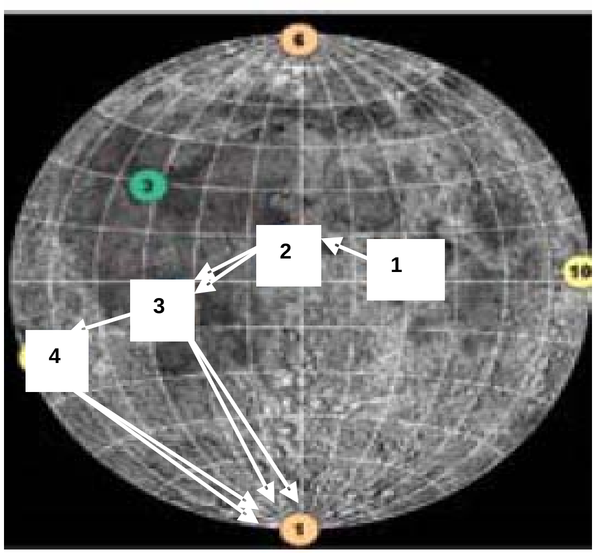
Focus

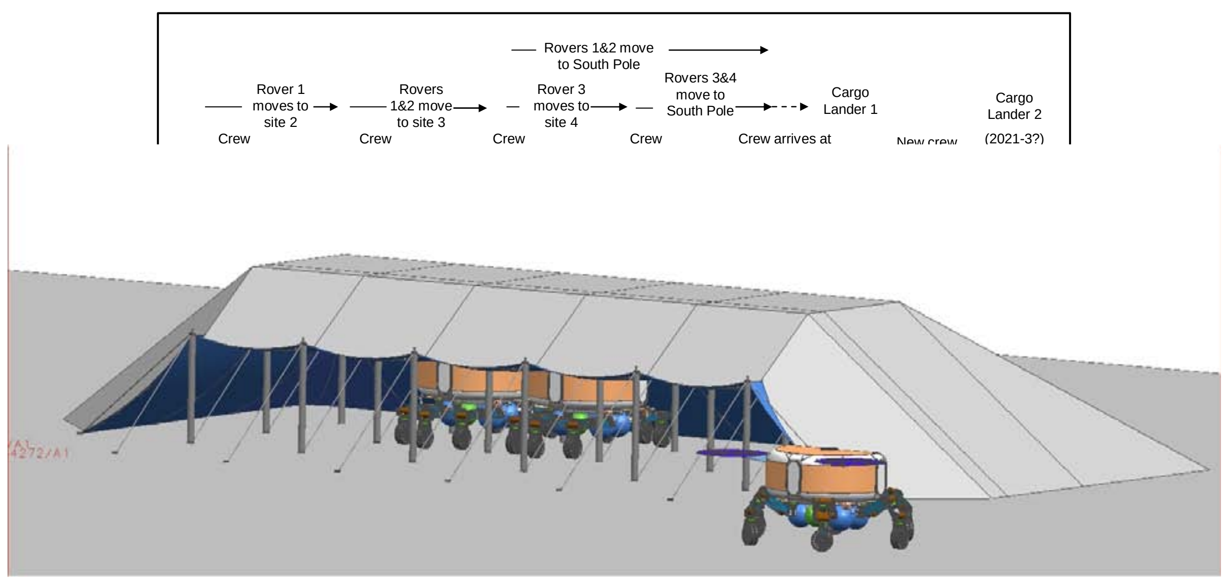
- Drop stage
- ATHLETE mobility concept
- Small ascent stage
- Outpost deployment via docking of mobile elements

Features

- ATHLETE mobility system allows for long range movement of entire lander
- Supports 4 crew for 7 days
- LOIDS performs LOI + part of descent

Outpost Buildup Concept





LLPS Lander Concepts - 3

Langley Descent Assisted Split Habitat (DASH) Lander

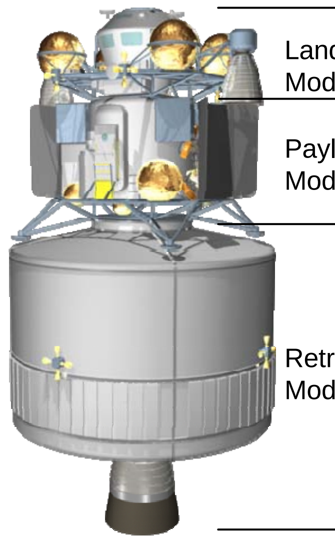
Split habitat crew lander with a minimally sized descent/ascent habitat utilizing a descent assisting Retro Module (RM), reconfigurable to accommodate a dual habitat or cargo mission

Focus

- DASH concept refinement, emphasis on drop stage issues
- Small ascent/transport hab stage
- Options for underslung cargo

Features

- Split habitat design facilitates crew egress/ingress and cargo unloading/deployment
- Supports 4 crew for 7 days
- Retro Module performs LOI + part of descent
- Inflatable airlock for EVA and alcove



Crew Lander with Retro Module

Langley Cargo Star Lander

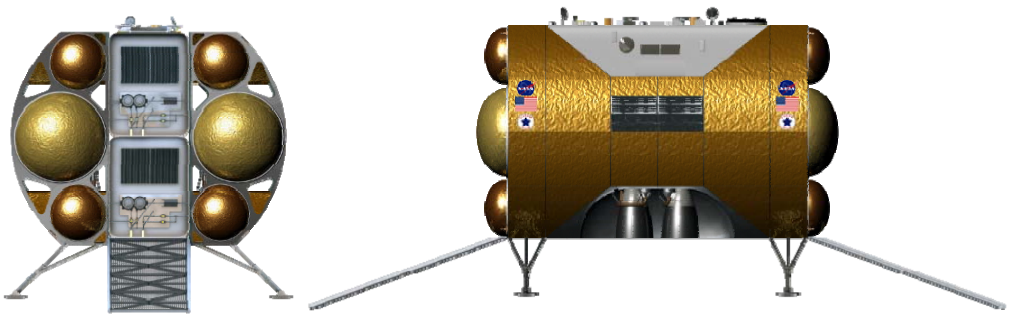
Horizontal lander, LOX/LH2 descent stage, hypergolic minimum ascent stage

Focus

- Horizontal lander concepts, including launch, landing, and cargo issues
- Cargo unloading from horizontal landers

Features

- Sortie Lander - Minimum ascent stage + surface habitat Supports 4 crew for 7 days.
- Descent stage performs LOI and descent
- Cargo Lander – Low-to-the-surface cargo, large cargo capability with easy unloading.

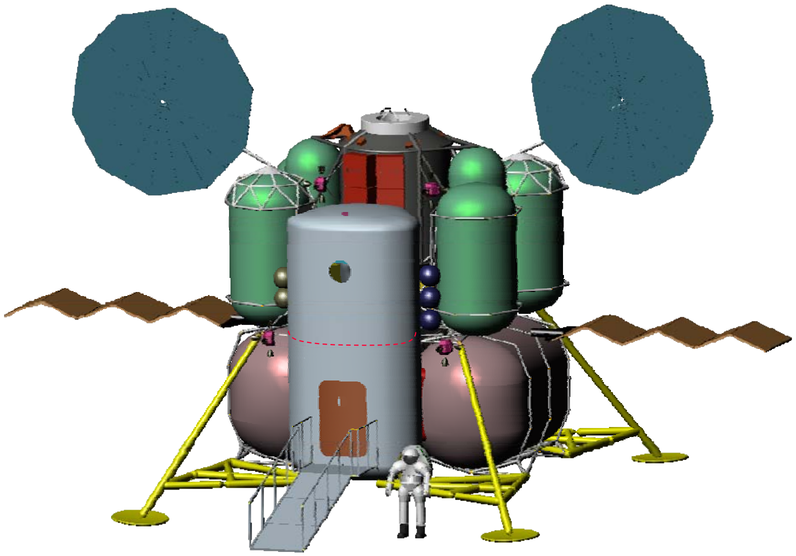


Cargo Configuration

CONSTELLATION

LLPS Lander Concepts - 4

JSC Habitank Lander



Vertical lander with two hydrogen tanks converted to habitats after landing. Two-level surface hab with crew egress near ground level.

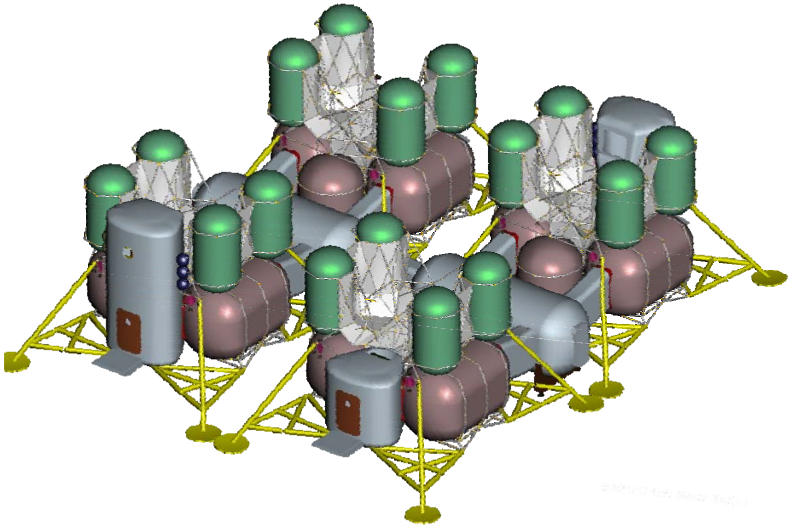
Focus

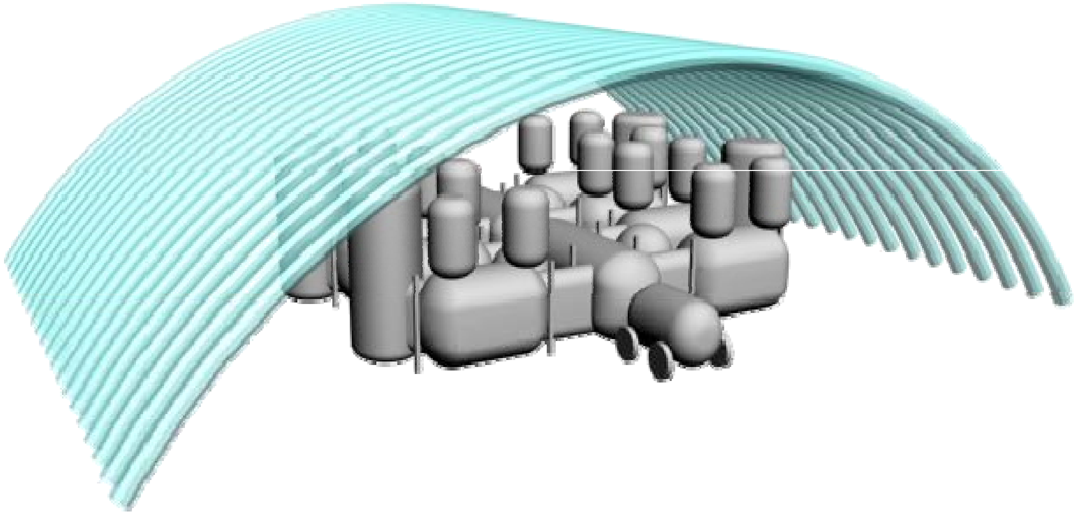
- Configure wet hab from descent prop tanks
- Small ascent stage
- Operations required to configure cryo tank as habitable volume

Features

- Single engine, lox/methane ascent stage
- Single engine, lox/LH2 descent stage
- Two Habitanks

Outpost Buildup Concept





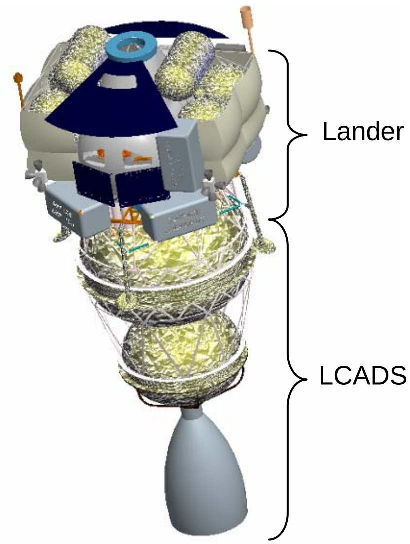
LLPS Lander Concepts - 5

GRC Split Descent with Drop Stage Lander

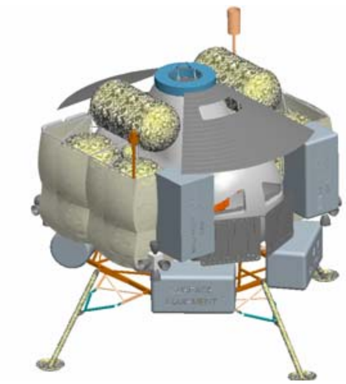
Split Descent with Drop Stage design - a simplified design focusing on only two main vehicles. No surface habitat left on surface. Sortie design adaptable to provide 210-day surface stay with cryogenic propellant storage and uncrewed cargo delivery mission

Focus
- Split descent concept; investigate launch shroud packaging
- Zero boiloff story for 180 day cryo ascent
- Cargo lander and cargo unloading techniques

Features
- Single-stage cryogenic stage, reusable
- LOx/LH2 Lunar Capture and Descent Stage (LCADS) Landing gear and some ancillary systems left on surface



Split Descent with Drop Stage



Habitat Lander/Ascent Vehicle

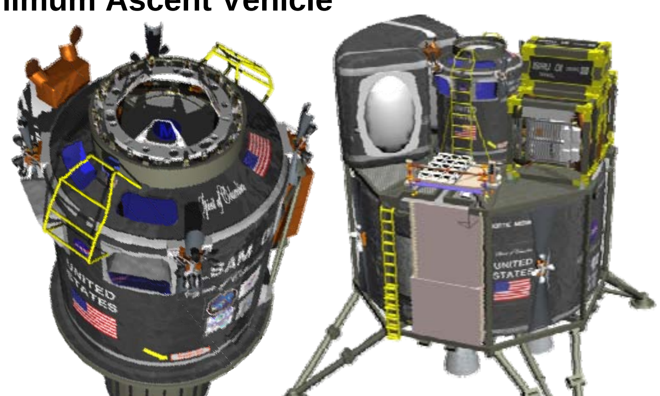
GSFC-JSC-GRC Lunar Lander Concept

Vertical configuration with airlock re-used as ascent crew cabin. Innovative concepts for getting crew and cargo from descent stage deck to the surface.

Focus
- Airlock-based ascent stage more fully
- Cargo unloading options

Features
- Minimum volume ascent vehicle (MAV) to support crew transfer to and from Lunar surface
- MAV significantly increases cargo to the surface for both sortie and outpost missions when compared to ESAS
- MAV serves as sleeping quarters and extended living space while on lunar surface
- MAV transports astronauts in Mark III suits and PLSSs
- Storables (MMH/NTO) or cyrogenic (LO_2/LH_2) propulsion subsystem

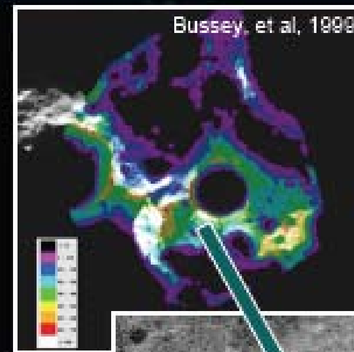
Minimum Ascent Vehicle

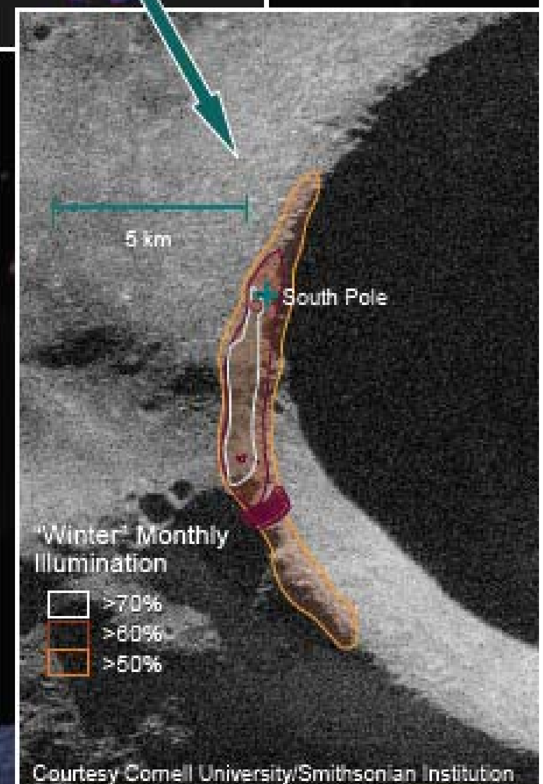


Sortie Configuration

Key Decisions: Sortie vs. Outpost

- First: What is the fundamental lunar approach?
- LAT concluded outpost first is best approach
- Top 2 Themes – “Exploration Preparation” and “Human Civilization” drive to outpost
- Enables global partnerships
- Allows development and maturation of ISRU
- Results in quickest path toward other destinations
- Many science objectives can be satisfied at an outpost





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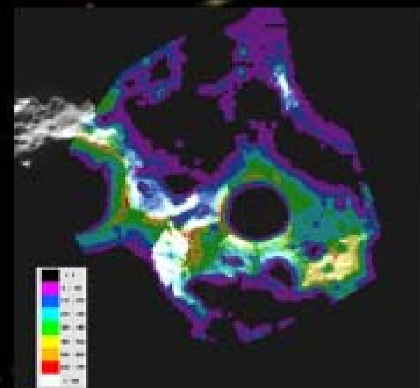
Outpost Site Location

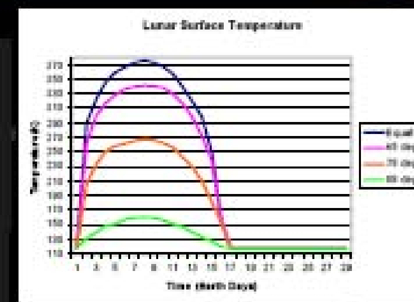
Outpost Site: Polar

- **Safe**
  - Thermally Moderate
- **Cost Effective**
  - High percentage of sunlight
  - Allows use of solar power
  - Least Delta V required
- **Resources**
  - Enhanced hydrogen (possibly water)
  - Potentially other volatiles
  - Oxygen
- **Flexibility**
  - Allows incremental buildup using solar power
  - Enhanced surface daylight ops
  - One communication asset (with backup)
  - More opportunities to launch
- **Exciting**
  - Not as well known as other areas
  - Offer unique, cold, dark craters

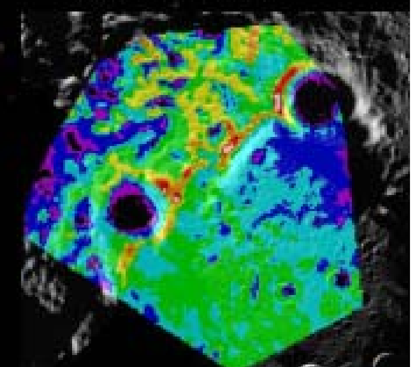
South Pole



Data obtained during southern winter (maximum darkness)



North Pole



Data obtained during northern summer (maximum sunlight)

Implementing the Vision

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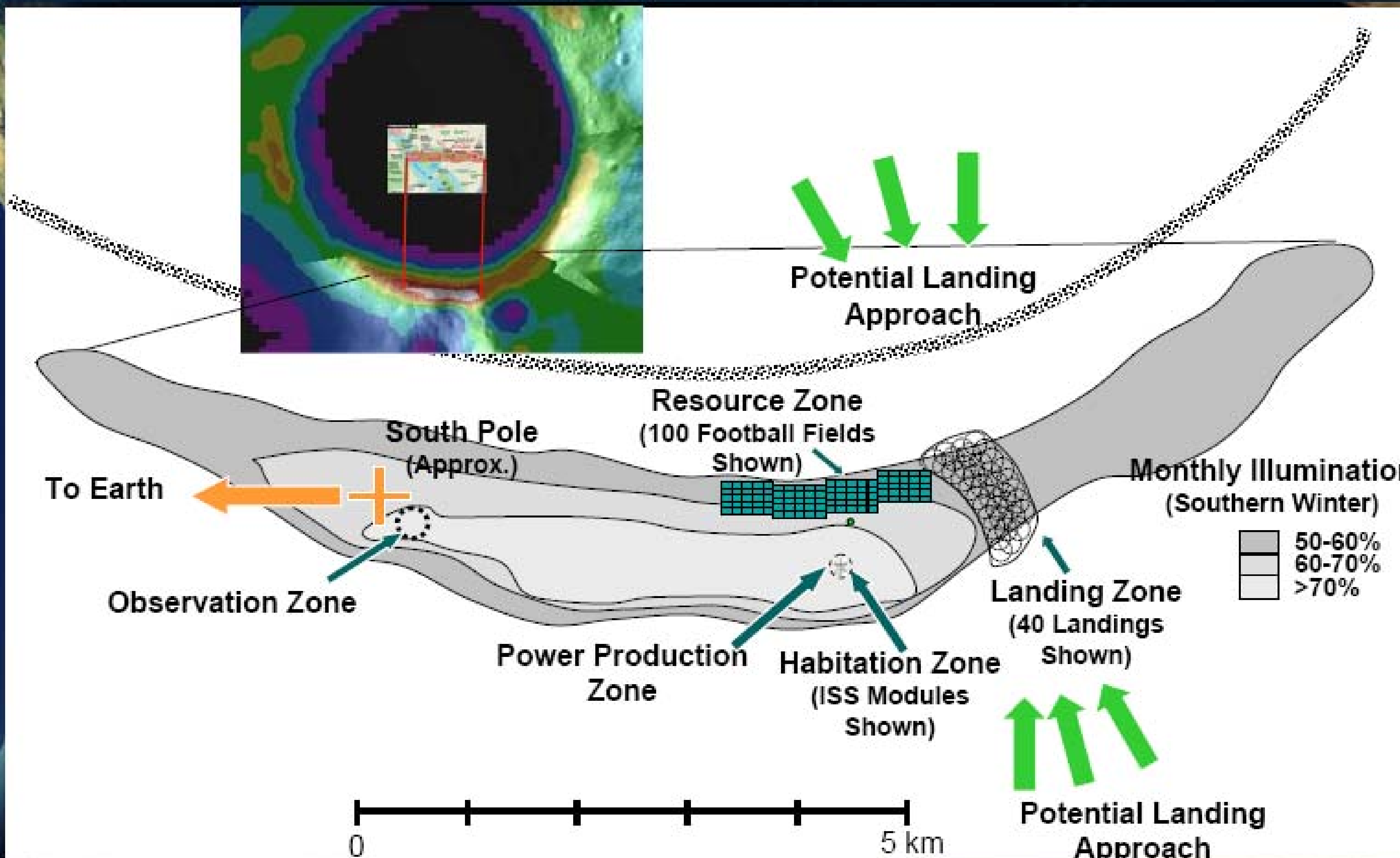
Shackleton Crater Rim with Notional Activity Zones



Implementing the Vision

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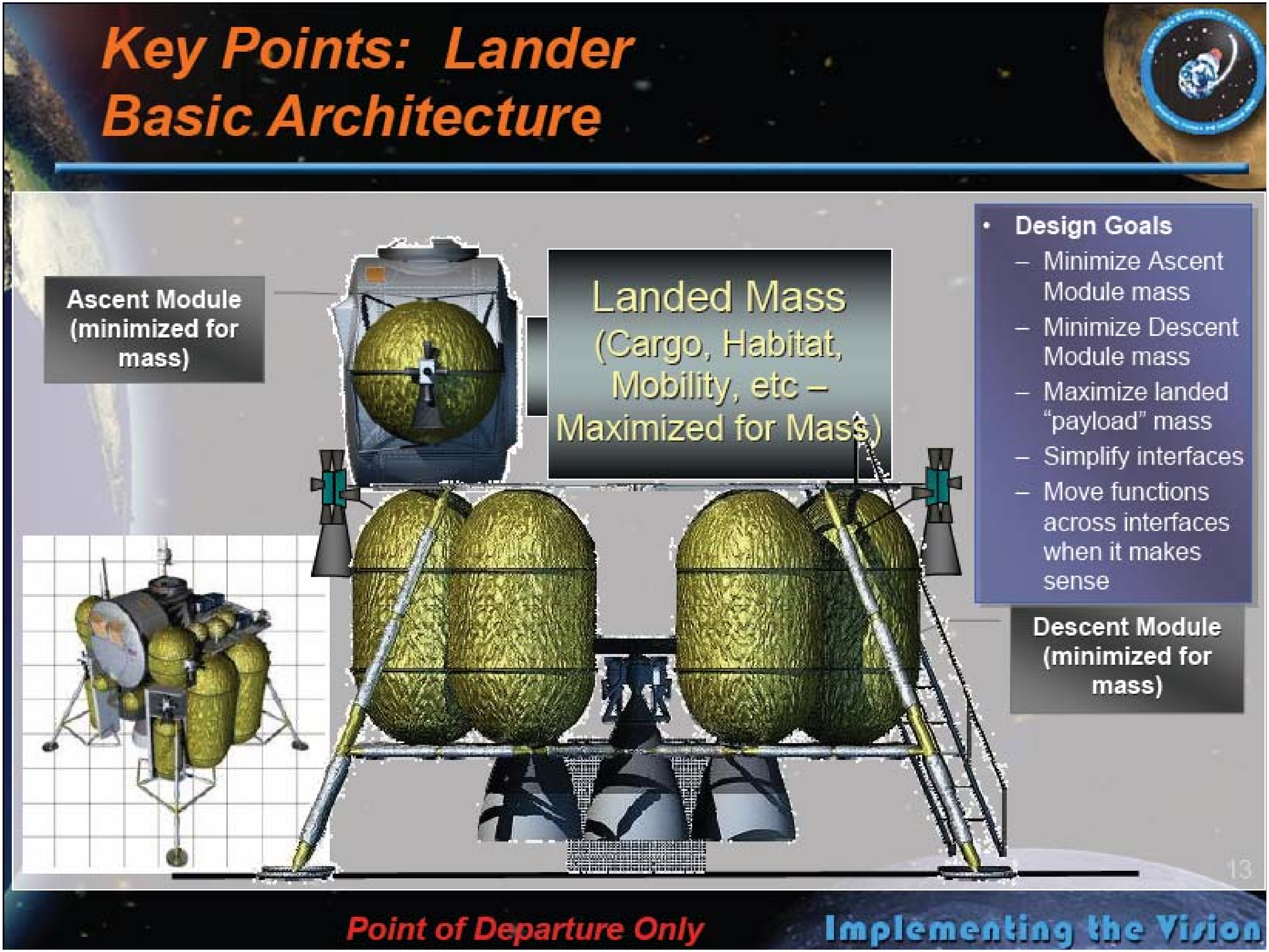
Key Points: Lander Basic Architecture
Ascent Module (minimized for mass)
Landed Mass (Cargo, Habitat, Mobility, etc – Maximized for Mass)
• Design Goals
– Minimize Ascent Module mass
– Minimize Descent Module mass
– Maximize landed “payload” mass
– Simplify interfaces
– Move functions across interfaces when it makes sense
Descent Module (minimized for mass)
13
Point of Departure Only
Implementing the Vision

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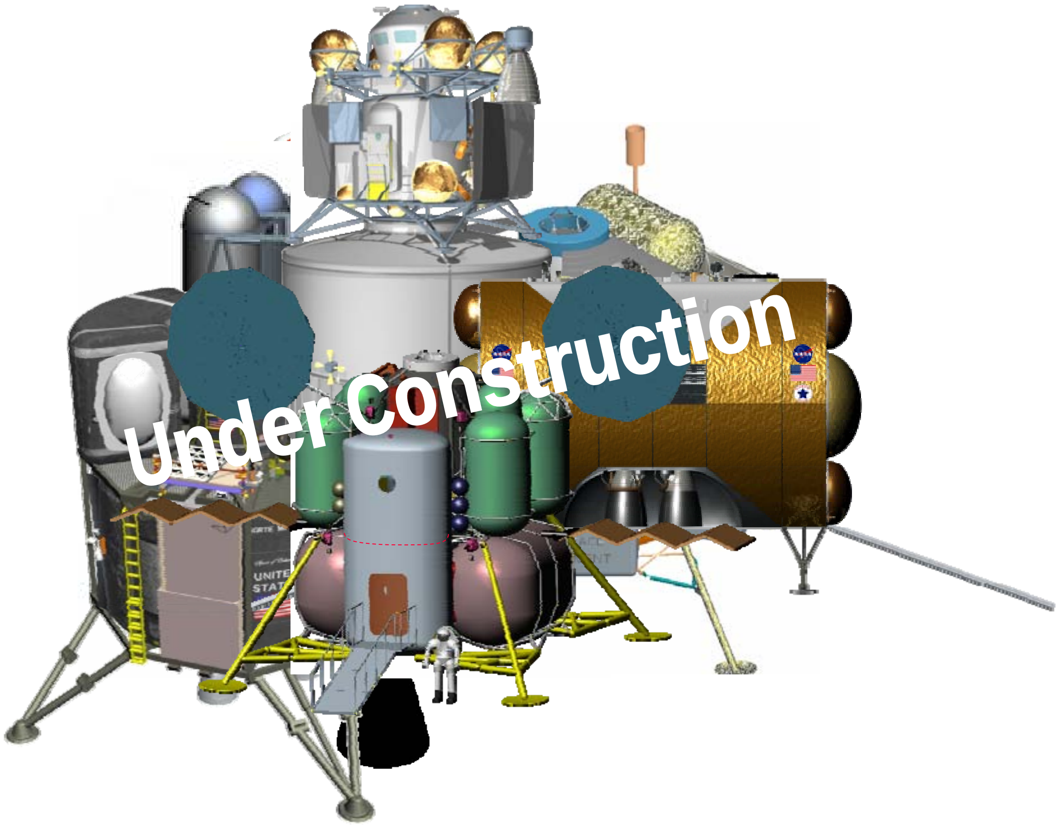
Forward Work

- Definition of the Lunar Lander continues in cooperation with the Lunar Architecture Team (LAT)
- The Lunar Lander Project Office is constantly in search of innovative concepts and configurations
- A lunar lander is a "physics machine". Unless a large technology change comes about, don't expect it look like the Millenium Falcon



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