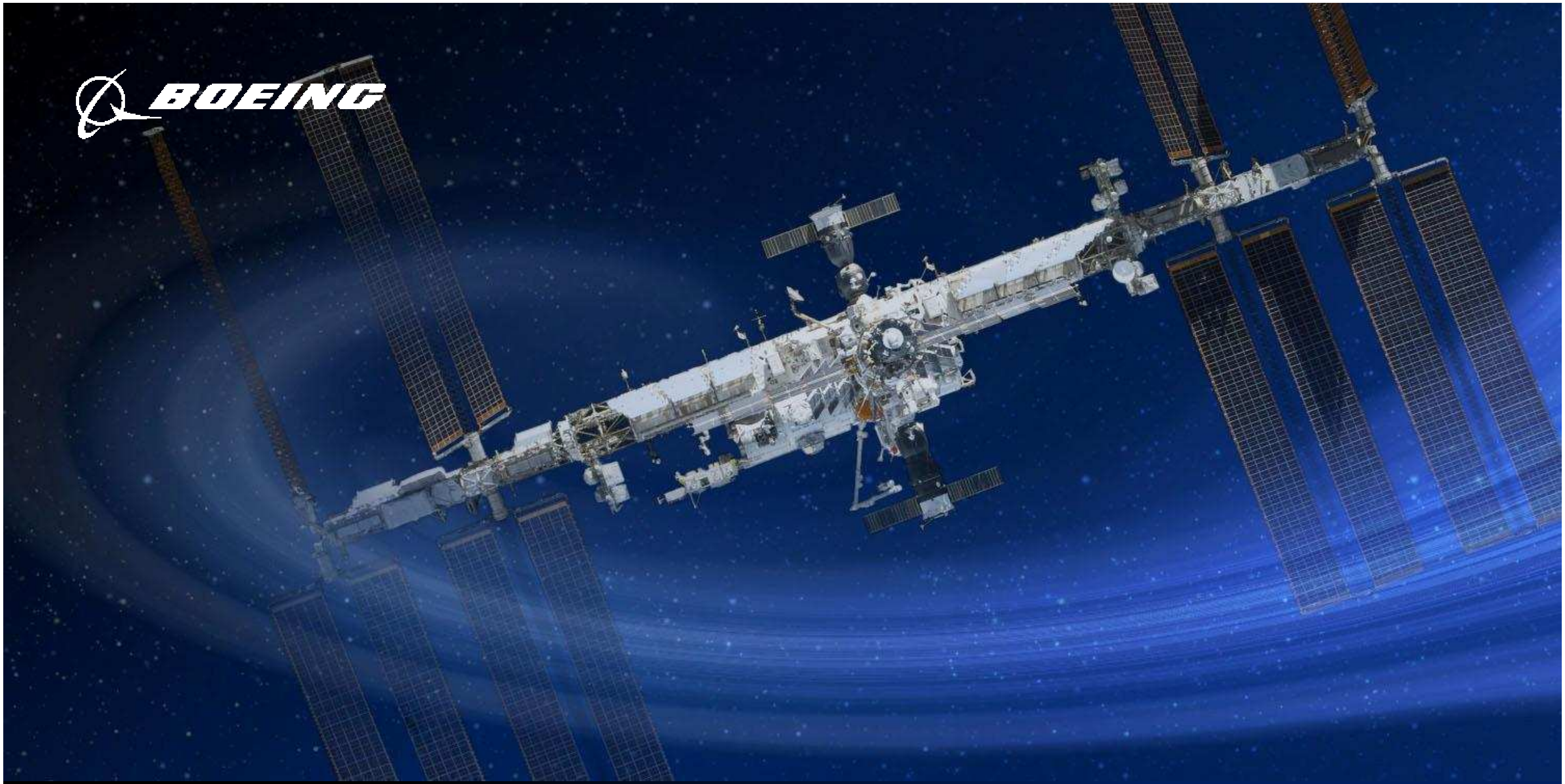
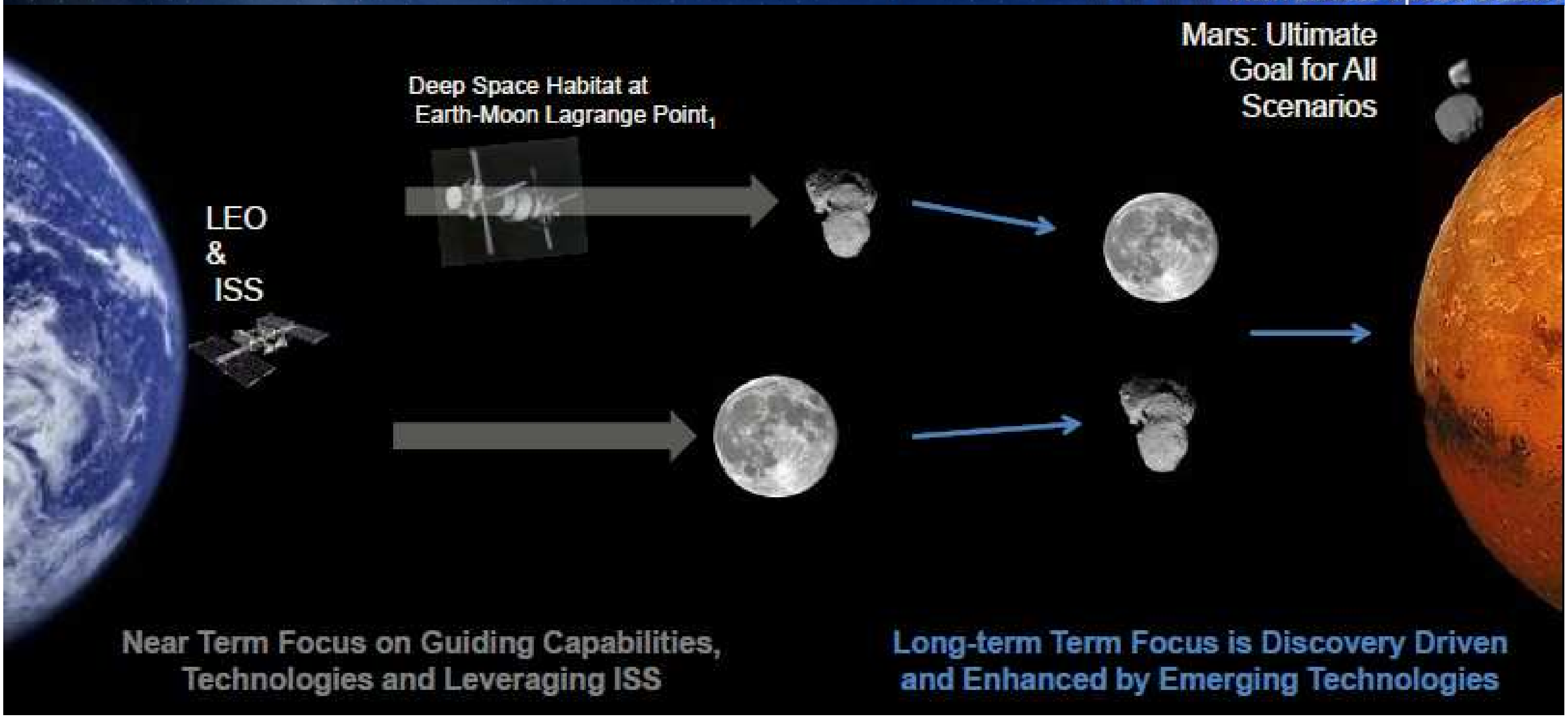


Global Exploration Workshop – Asteroid Mission Concept with Solar Electric Propulsion

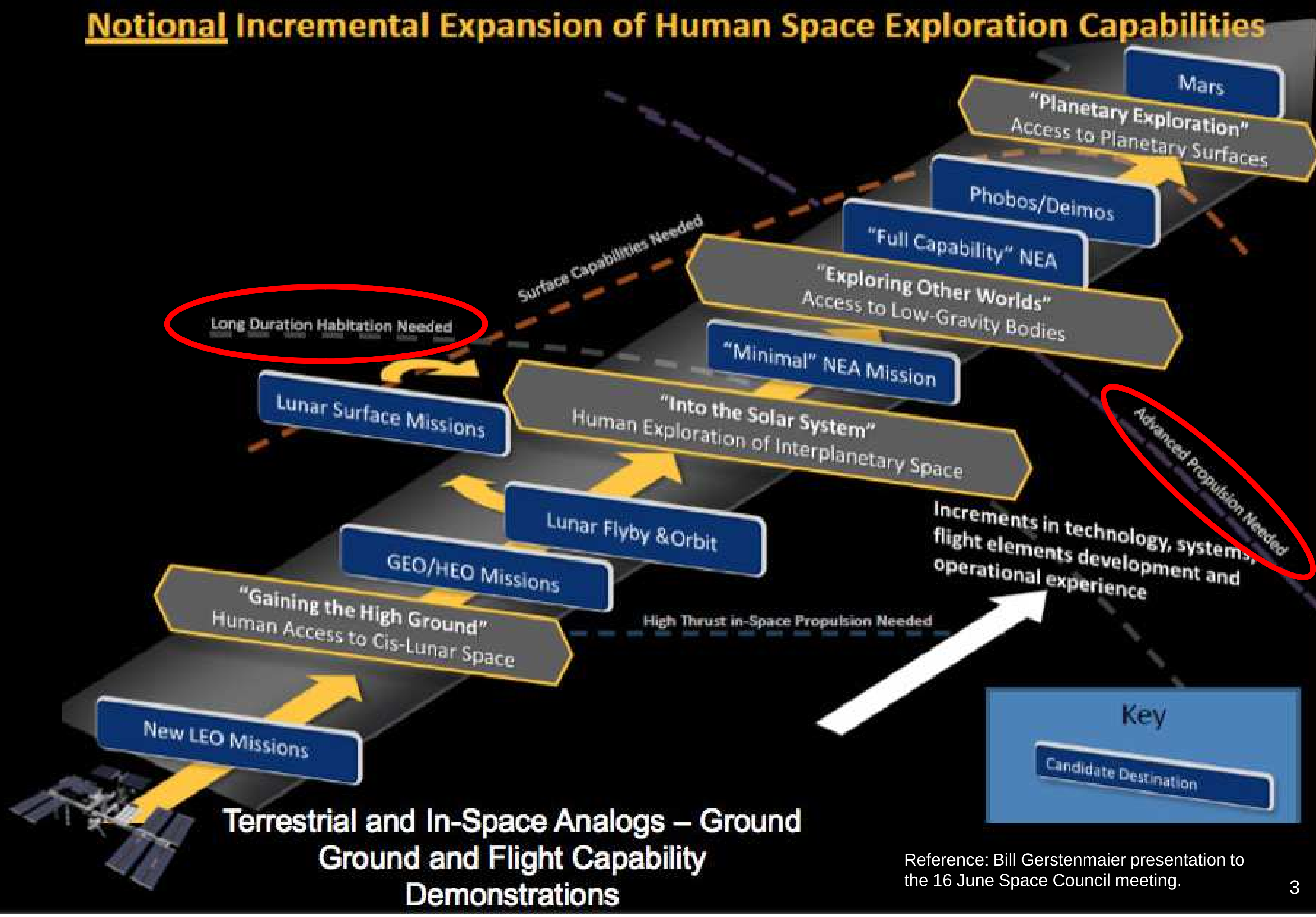
Mike Elsperman
Director, Advance Space Exploration

November 14, 2011

Global Exploration Roadmap

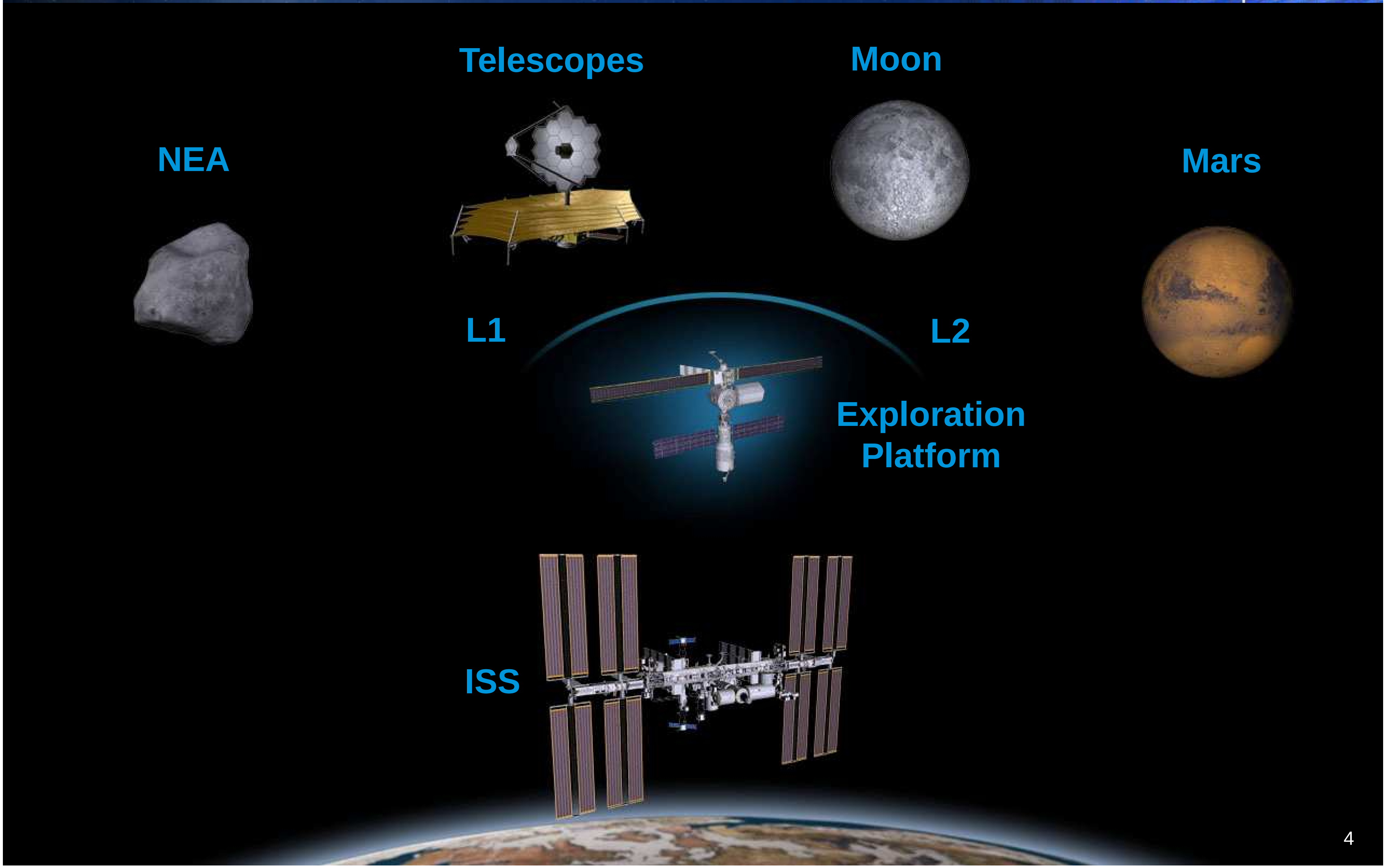


Capability Driven Exploration



Reference: Bill Gerstenmaier presentation to the 16 June Space Council meeting.

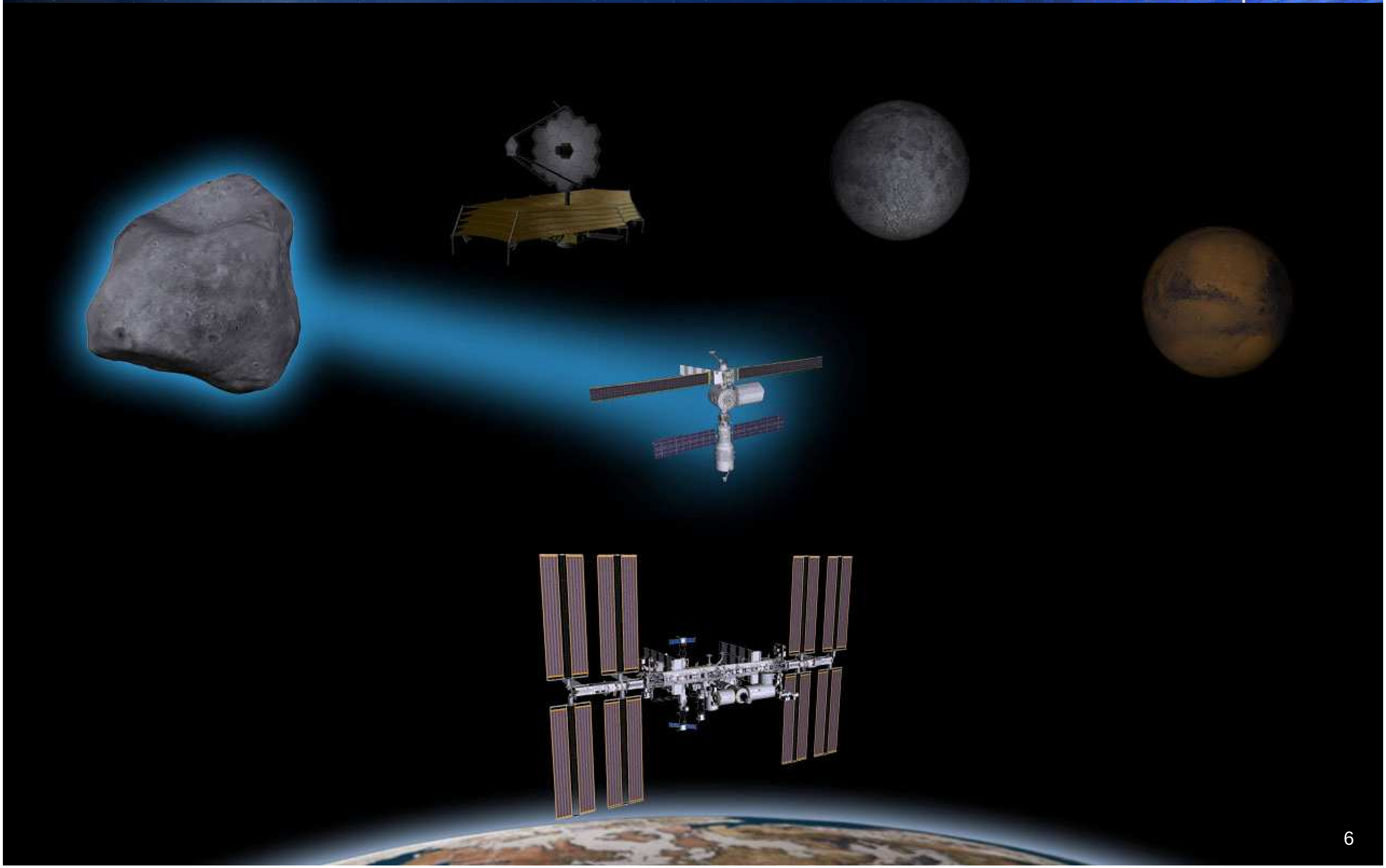
Flexible Path for Exploration



Asteroid Mission – Key Technologies

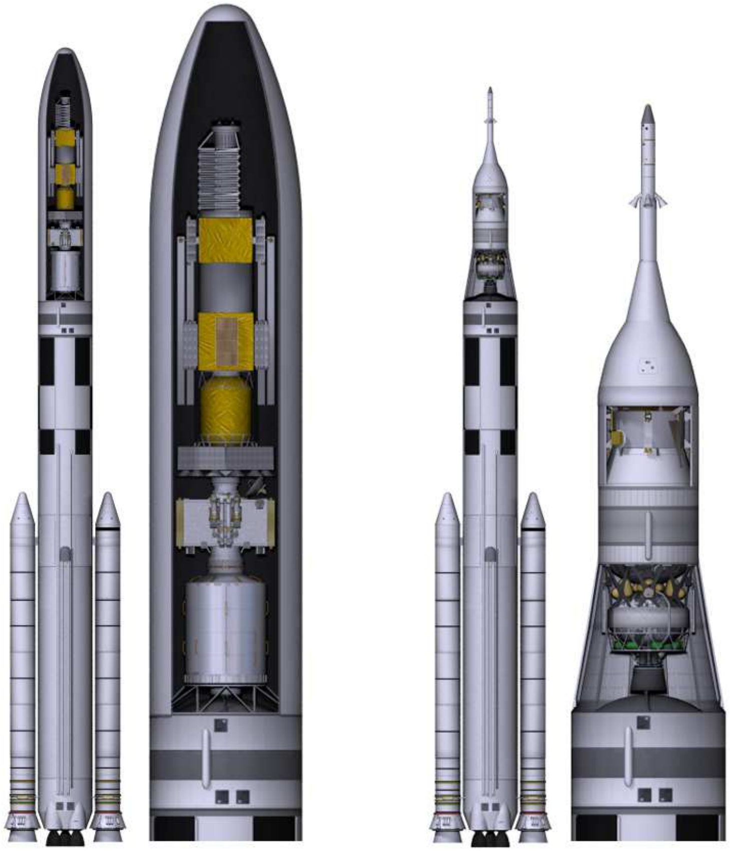
- Long Duration Habitat
- Radiation Storm Shelter
- High I_{SP} Propulsion
- Telerobotics

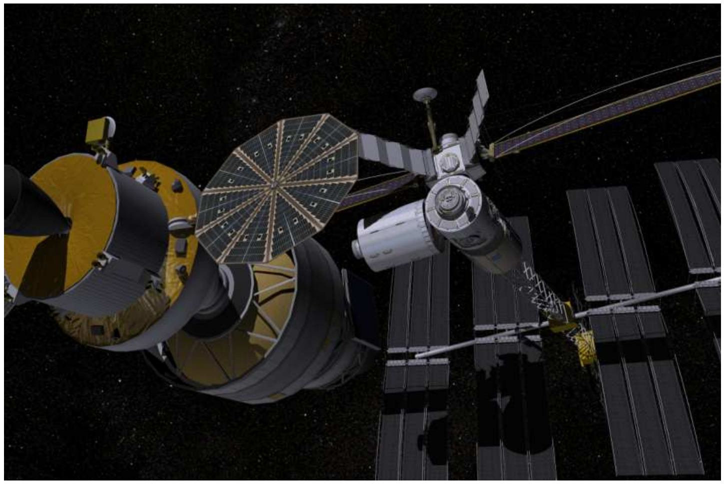
Flexible Path for Exploration



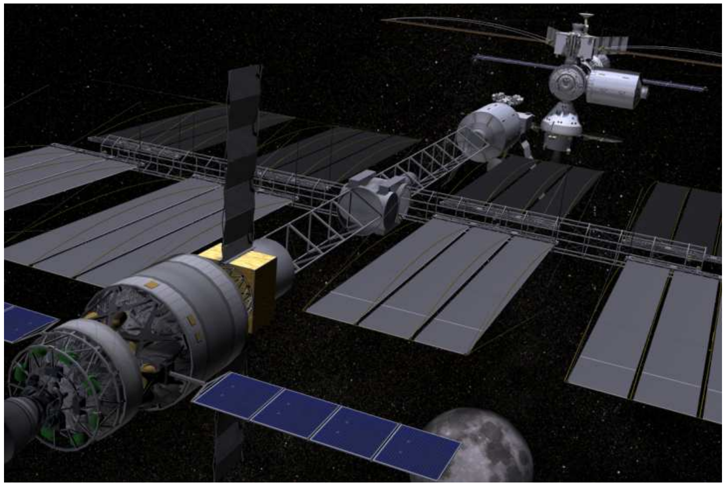
Asteroid Mission – Electric Option

- **The mission system is launched to the ISS-EP followed by the crew with a cryogenic kick stage**
- **We propose use of a SEP tug for deep space propulsion aided by the kick stage**





Before Crew Activation



After Crew Activation

Long Duration Habitat Evolution

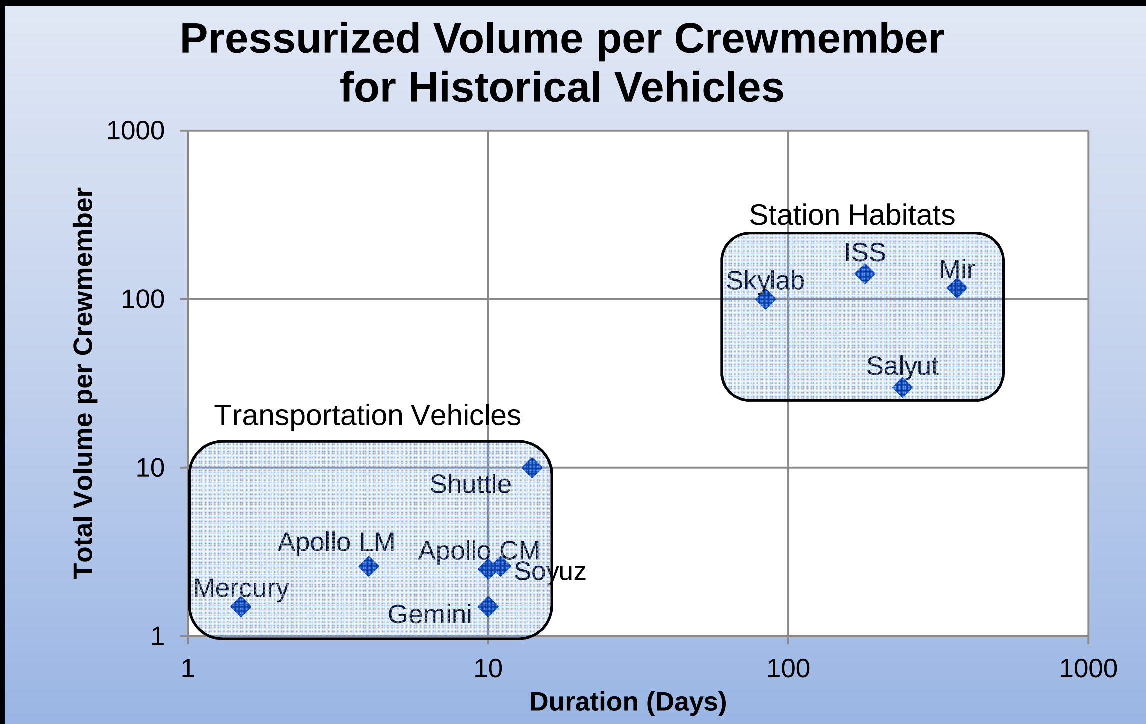
- **Construction**

Block 1	Block 1a	Block 2	Block 3
			
Block 1 **ISS-EP** **(MPLM Derived)**	**Block 1a** **NEA TransHab** **(MPLM Derived)**	**Block 2** **Mars TransHab** **(Composite Shell or Inflatable)**	**Block 3** **Mars SurfaceHab** **(Composite Core, Inflatable Shell)**

- **Subsystems**

Block 1	Block 1a	Block 2	Block 3
ECLSS • 3 crew, 3 months • Replenishment • Partially Closed	**ECLSS** • 3 crew, 12 months • No Replenishment • Partially Closed	**ECLSS** • 3 crew, 9 months • No Replenishment • Partially Closed	**ECLSS** • 3 crew, 12 months • No Replenishment • Partially Closed • Surface Hygiene Facilities
INTERFACES • CBM/NDS	**INTERFACES** • NDS on both ends	**INTERFACES** • NDS on both ends	**INTERFACES** • NDS on one end
EVA • Airlock	**EVA** • Airlock	**EVA** • Airlock	**EVA** • Airlock/Suit Lock

Habitat Volume



Vehicle	# of crew	Mission Duration	Total Vol (m3)	Vol/Crew (m3)
Skylab	3	84	300	100
Salyut	3	240	90	30
Mir	3	365	350	117
ISS	6	180	850	142

- **NASA BVAD (NASA/CR-2004-208941) recommends 5 – 18.5 m3 per crewmember for long duration transit and surface habitats**
- **Surface habitat volumes are similar to transport habitat volumes but attention must be given to specific geometry**

Volume Study

- **Boeing and Hamilton Sundstrand performed an extensive habitat volume study to validate assumptions on habitat sizing**
- **Concept missions (DRMs) were used to drive out hab requirements**
  - **ISS Exploration Platform (ISS-EP) at EML1:** Man-tended; crew of 3 with surge up to 6 crew for 14 days; periodic system replenishment
  - **NEA, Mars Transit, Mars Surface:** 3 crew; varying duration; no replenishment
- **Study validated the importance of ECLSS mass and volume estimates**
  - ISS experience and the addition of regenerative ECLS has significantly altered consumables requirements from previous baselines.
- **Study showed that large new habitats are not needed for early phases of exploration**

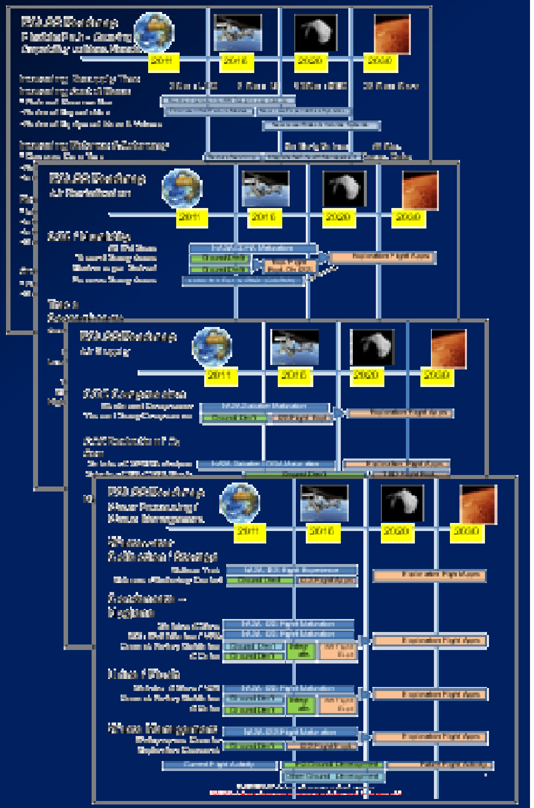
	NEA 365 Days	Mars Transit 269 Days	Mars Surface 575 Days	Mars Return 200 Days
	m^3	m^3	m^3	m^3
Habitable Volume	75	75	75	75
Systems	25.6	25.3	26.2	25.2
Consumables	5.5	4.0	10.9	3.0
Cargo / Payloads	2.0	2.0	2.0	2.0
Margin	5.0	5.0	5.0	5.0
TOTAL	**113.1**	**111.3**	**119.2**	**110.2**

Hamilton Sundstrand
A United Technologies Company

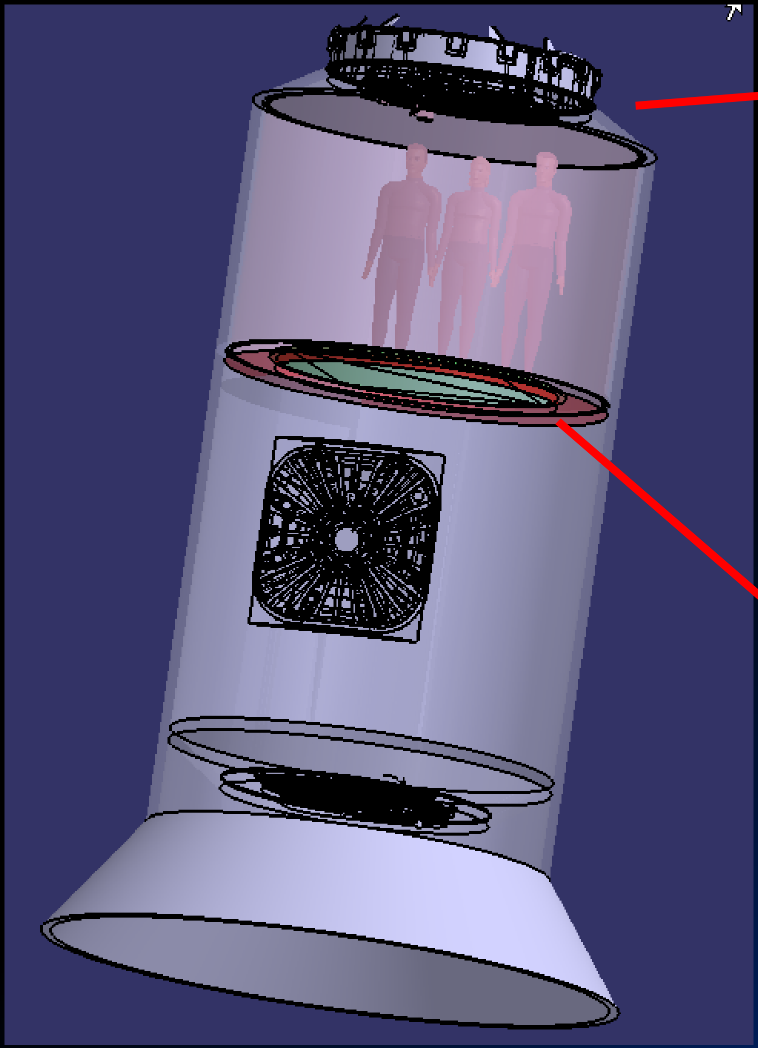
BOEING

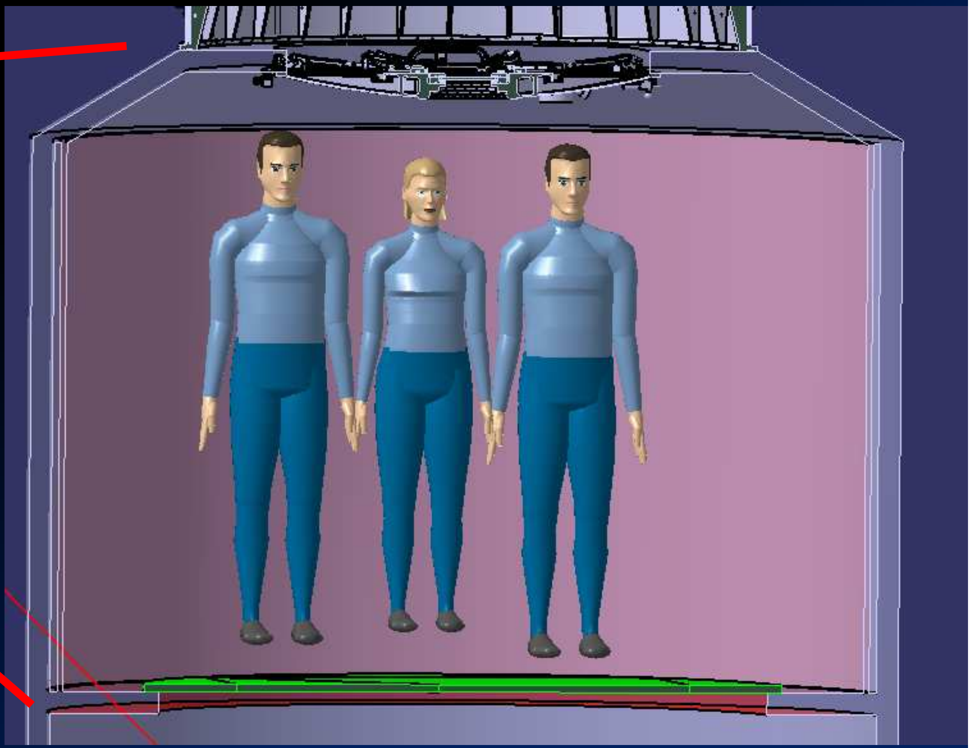
ECLSS Roadmap

- **Enhanced ISS technologies can meet exploration needs with reduced risk**
  - ISS experience shows that increasing reliability and robustness of ECLSS systems is more important than further increasing life support loop closure.
- **Competing technologies need to be tested on-orbit before being recommended as the final solution**
  - Ground testing alone doesn't validate technology selection
  - Short-term on-orbit testing does not prove out reliability
- **Utilize ISS as an exploration ECLSS maturation platform**
  - Take full advantage of current ISS vehicle technology
  - Develop competing technologies early to allow in-space maturation before exploration mission technology decisions
- **Have defined an ECLSS Roadmap that identifies key technologies for ISS development**
  - Defines a flexible path focused on growing capabilities to meet future needs
  - Goals
    - Reducing consumables and mass/volume.
    - Decreasing crew time. Increasing reliability.
    - Reducing power and waste heat.
  - Aligned with the NASA mission framework & objectives



Radiation Storm Shelter

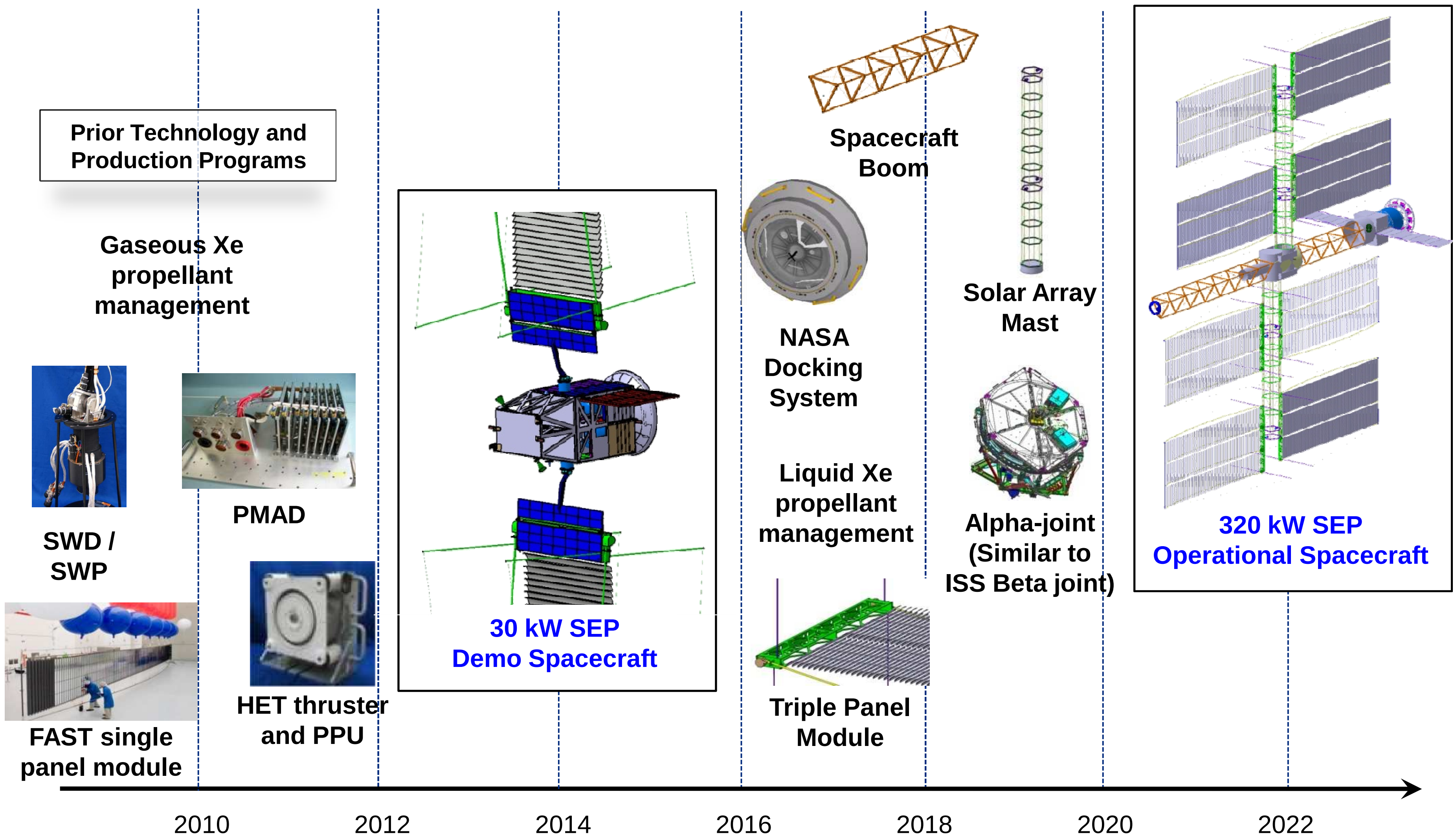




- **Storm shelter in hard inner core of the inflatable habitat**
- **Stored water & polyethylene is used to line the walls of the shelter**

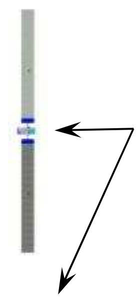
SEP Technology Readiness

Defense, Space & Security
Space Exploration
International Space Station



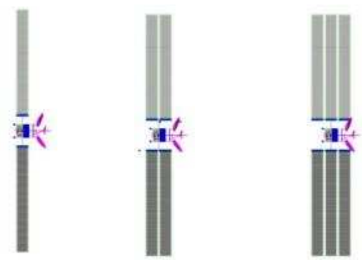
Modularity Enables Vehicle Evolution for Exploration

Minotaur IV Class Compact Bus

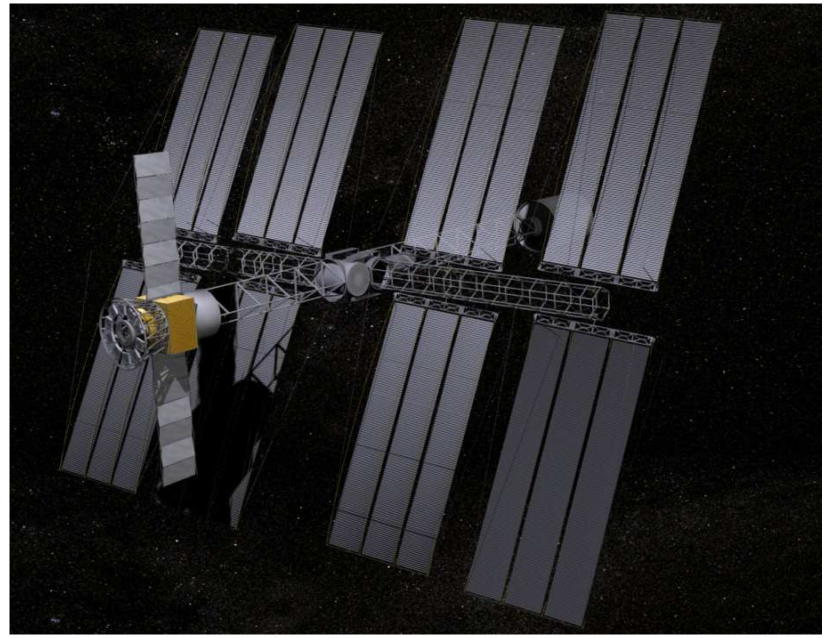


SEP Demonstrator
Qualifies 30 KW Array & PMAD

702 Class Bus

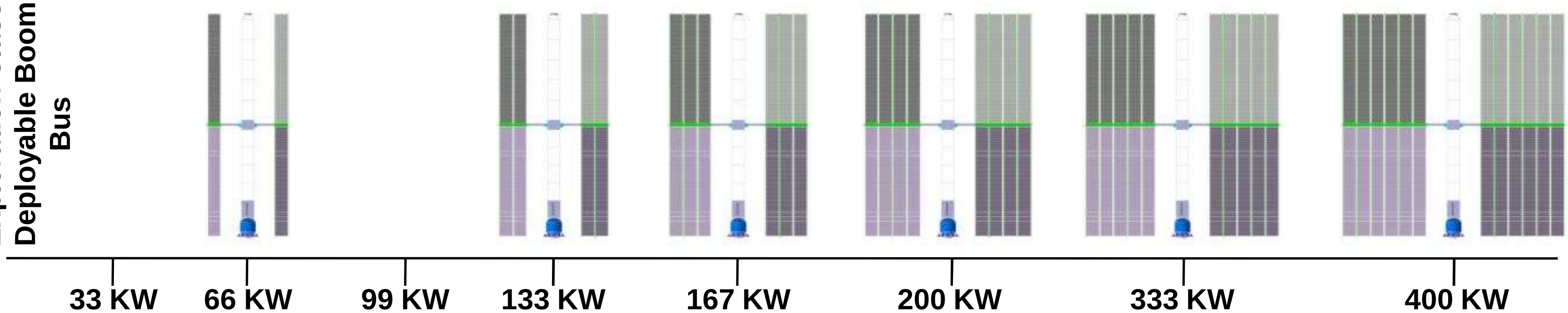


Additional modules power flight-proven 702 for deep space and other missions



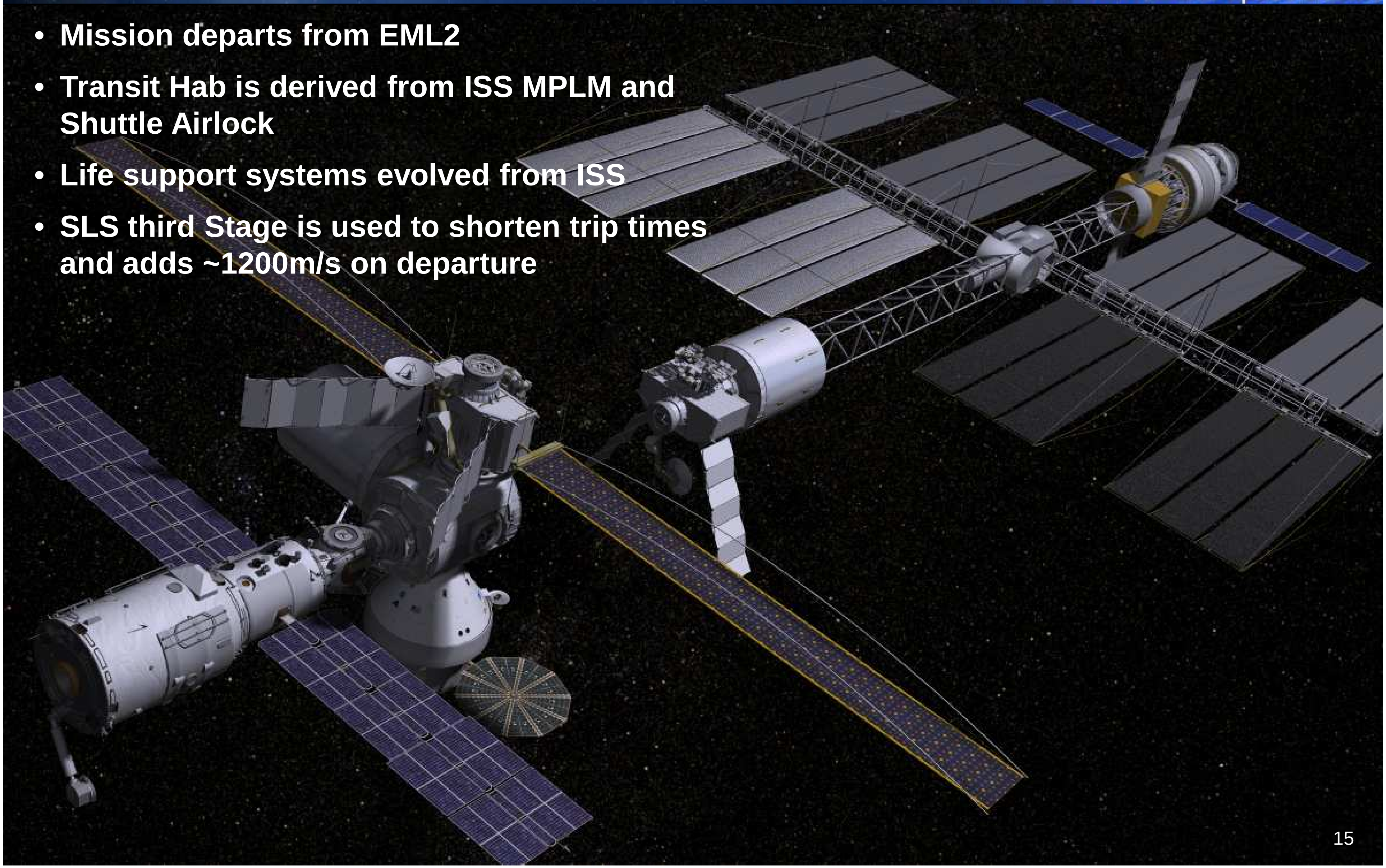
New large spacecraft bus supports heavy cargo and crewed missions to GEO, L-1, NEO's, and beyond
Modular system allows thrust/payload/trip time optimization of total acquisition cost

Exploration Class Deployable Boom Bus



NEO Mission Departure from Exploration Platform

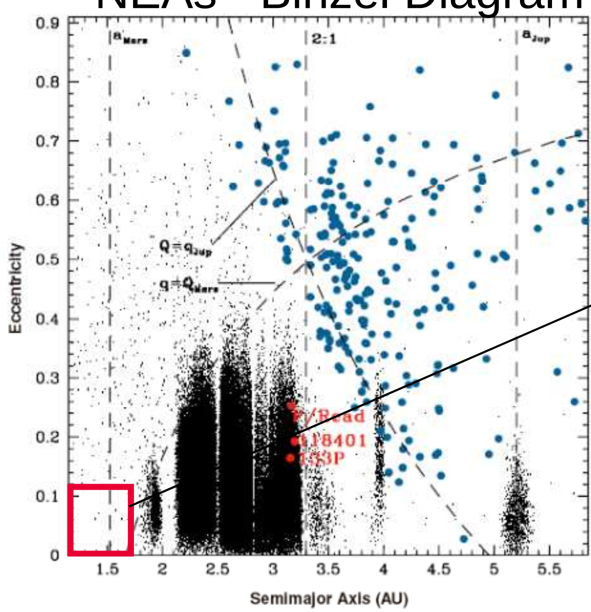
- Mission departs from EML2
- Transit Hab is derived from ISS MPLM and Shuttle Airlock
- Life support systems evolved from ISS
- SLS third Stage is used to shorten trip times and adds ~1200m/s on departure



Asteroid Mission Target Selection

- **Considerations:**
  - Eccentricity (close to 0)
  - Semi Major Axis (close to 1.0)
  - Min Delta V
  - Launch Period

NEAs - Binzel Diagram



DASTCOM Search Criteria

Inclination between 0 and 8 degrees.
Reference plane for measuring inclination is Mean Ecliptic of J2000
Eccentricity between 0 and .1.
Semi-major Axis between .9 and 1.1 AU.

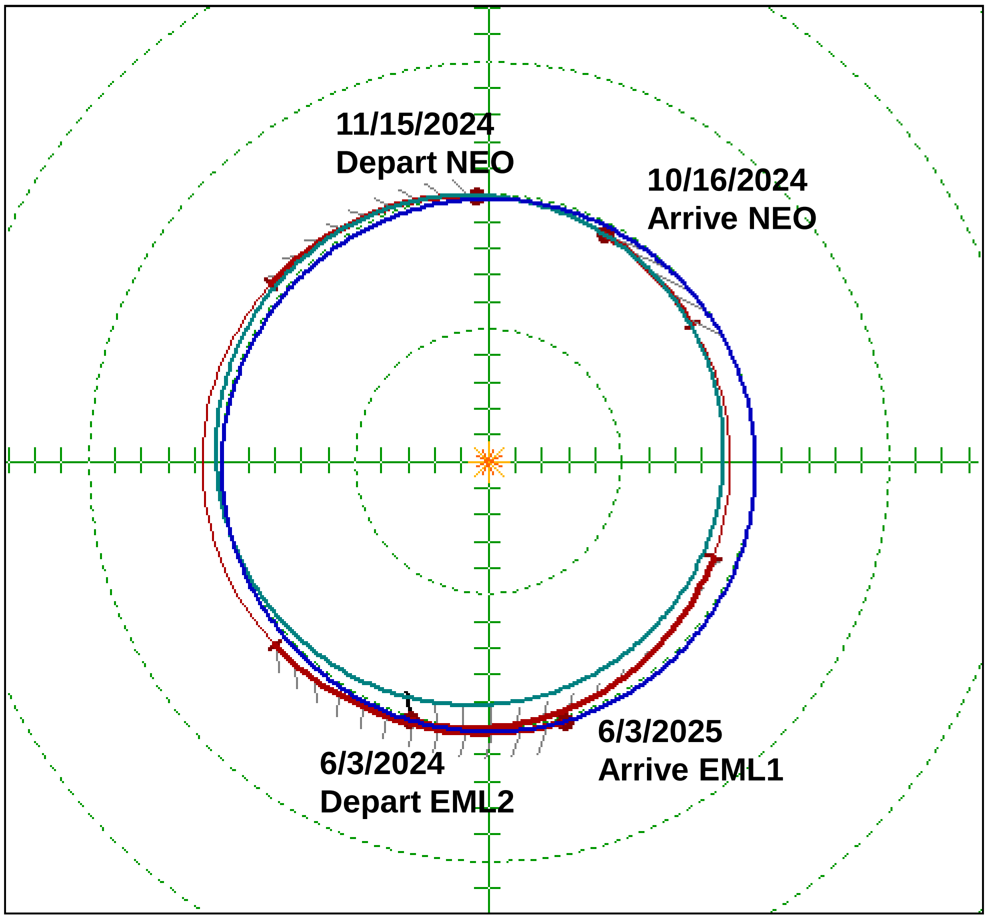
DASTCOM Query Results

400108	1991 VG
403107	1999 CG9
408406	2000 SG344
410272	2001 FR85
411321	2001 GP2
412270	2001 QJ142
448447	2003 YN107
496930	2006 BZ147
498950	2006 DQ14
503679	2006 JY26
506830	2006 QQ56
509961	2006 RH120
549881	2007 UN12
551969	2007 VU6
565423	2008 EV5
565475	2008 EA9
571315	2008 HU4
572170	2008 JE
572715	2008 KT
587429	2008 UA202
587431	2008 UC202
596801	2009 BD
610390	2009 SH2
640008	2010 JW34
657567	2010 UC
657573	2010 UJ
658160	2010 UE51
659099	2010 VT21
660036	2010 VQ98
661892	2010 XU10
663060	2011 AA37
664404	2011 BL45
664495	2011 BQ50
672726	2011 MD

All Candidate Targets are Very Small Bodies - "Zero G"

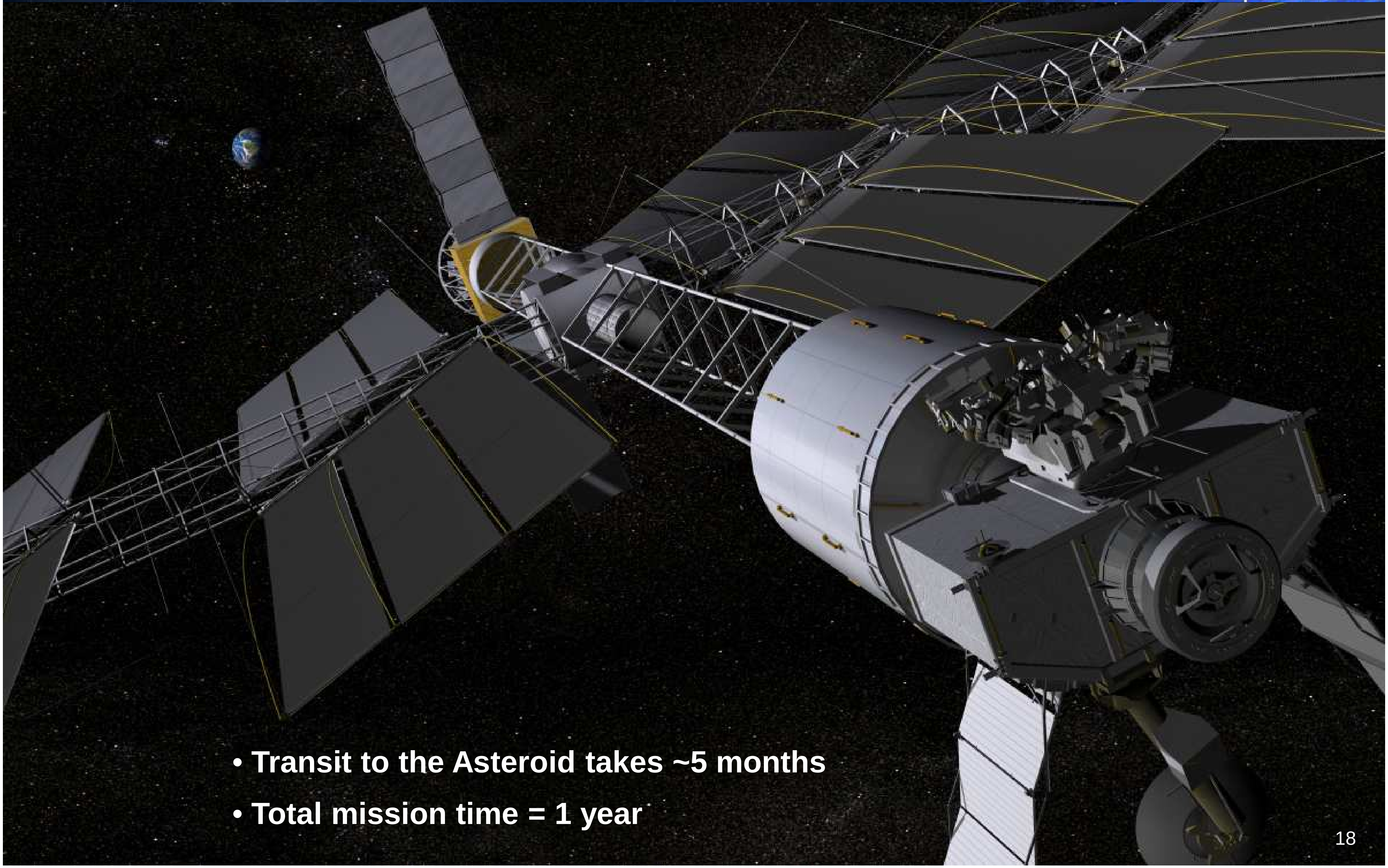
NEA 2008EV5 Mission Trajectory

2024 Crew Mission to NEA 2008EV5



- **Transit to Asteroid takes about 100 days; Kick stage used to shorten trip**
- **Approximately 30 days at NEA; Overall trip takes ~ one year**

Arriving at NEA 2008EV5



- Transit to the Asteroid takes ~5 months
- Total mission time = 1 year

Tele-presence Introduction

Communication latency — round-trip light travel time,
a challenge to current robotic exploration.

Why we want to send <u>people</u> to new sites, rather than only <u>robots</u>.

Consider

Voyager	**~32 hour 2-way comm latency to Earth now**
Mars	**~8-40 minute 2-way comm latency to Earth**
Moon	**~2.6 seconds 2-way comm latency to Earth**

Latency smaller than our "*cognitive timescale*" leads to "telepresence"

When 2-way latency exceeds our *cognitive timescale*, the brain works differently. "Move and wait" to avoid instability – inefficient.

- Content courtesy of Dr Dan Lester, UT, AIAA Space 2011

Tele-presence: Latency Reduction

What is our "cognitive timescale"?

- **Human reaction time for visual stimulus is ~200 ms, ~150 ms for audio**
- **High performance online gaming depends on latencies of <100-200 ms**
- **Telerobotic surgery (cutting, suturing) requires <500 ms**
- **Telerobotic mining operations (driving bulldozers) assume ~500 ms**
- **Drone piloting with latencies of ~1000 ms (but flying is easy!)**

<u>All of the same order! ~500 ms</u>

(a lot smaller than from Earth to Moon)

- Content courtesy of Dr Dan Lester, UT, AIAA Space 2011

Tele-presence & the “Cognitive Horizon”

Let’s say ~500 ms two-way latency is roughly what you need to ensure a “cognitive” connection with a telerobot. <u>Tele-presence</u>.

That defines a *<u>cognitive distance scale</u>*, using the speed of light,

$$500 \text{ ms} \times c / 2 = 75{,}000 \text{ km}$$

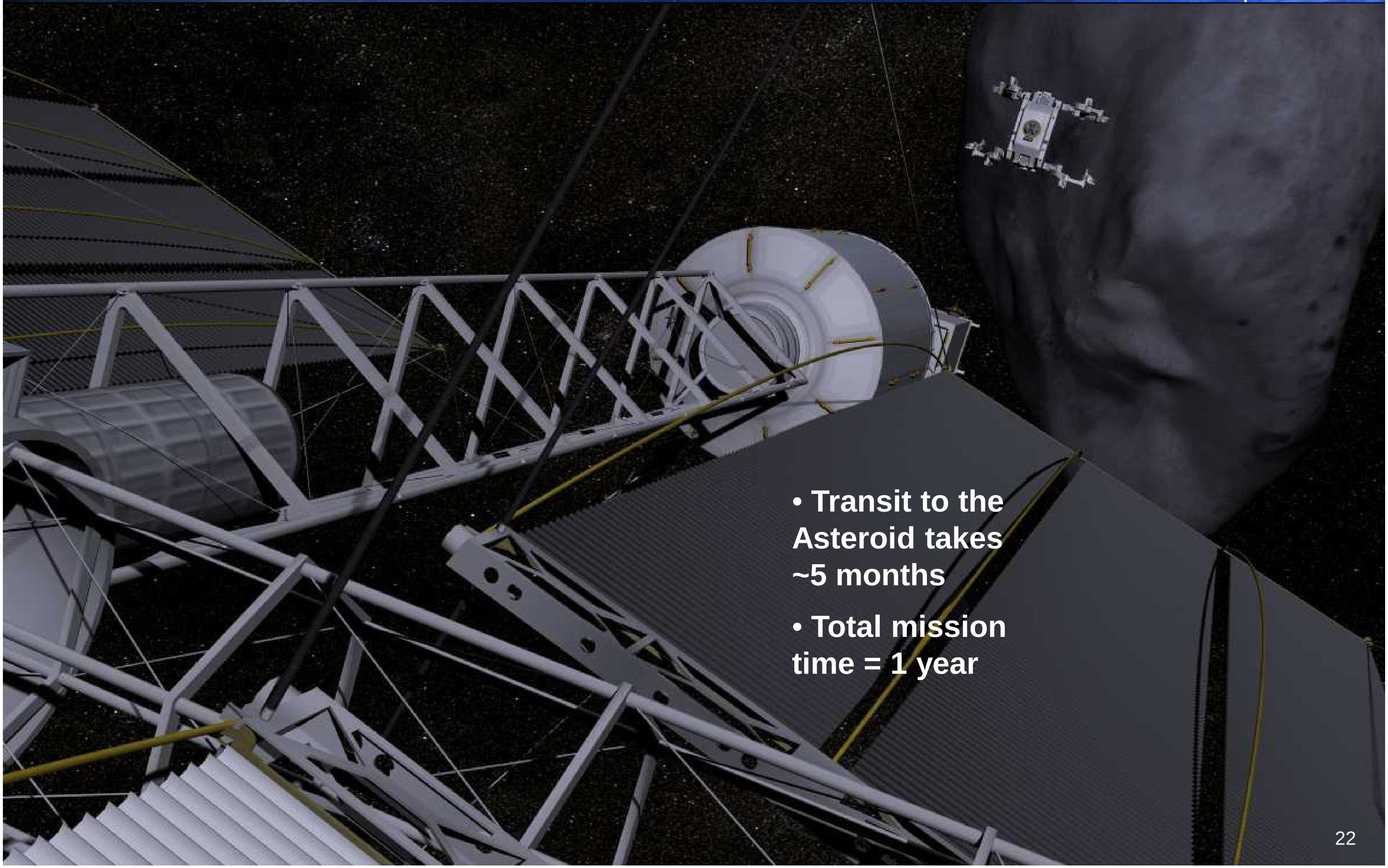
If d<75,000 km, quality cognitive connection with telerobots there.

Specific destinations?

- **Earth-LEO** 350 km (1 ms) (TDRSS makes it a LOT longer)
- **Earth-GEO** 36,000 km (240 ms)
- **Earth-Moon** 385,000 km (2600 ms)
- **Earth-Mars** 8-40 minutes

- Content courtesy of Dr Dan Lester, UT, AIAA Space 2011

Telepresence Introduction



- **Transit to the Asteroid takes ~5 months**
- **Total mission time = 1 year**

Telepresence Introduction

Asteroid Mission – Summary

- **Asteroid "First" Mission benefits**
  - **Increased Scientific understanding of NEAs and "Deep Space" environment**
    - **Physical composition**
    - **Environments/Hazards**
    - **In Situ Resource characterization**
  - **Validate and utilize critical exploration capabilities**
    - **Long Duration Habitats**
    - **ECLSS**
    - **Radiation Storm Shelter**
    - **High I_{SP} Propulsion (High Power SEP)**
    - **Telerobotics**
  - **Expand Human presence far beyond LEO**
    - **Operations**
    - **Logistics**

Exceptional Training Ground for Crewed Mars Missions