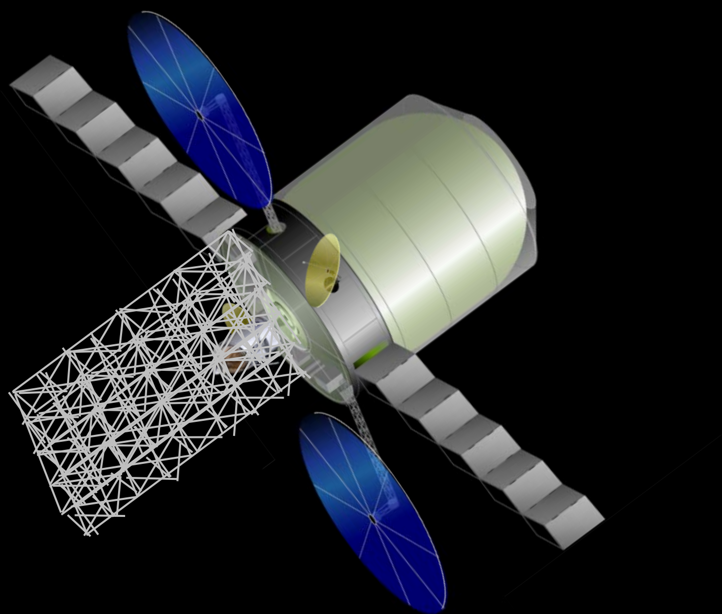
Future In-Space Operations Colloquium

SKYLAB II

Making a Deep Space Habitat from a Space Launch System Propellant Tank

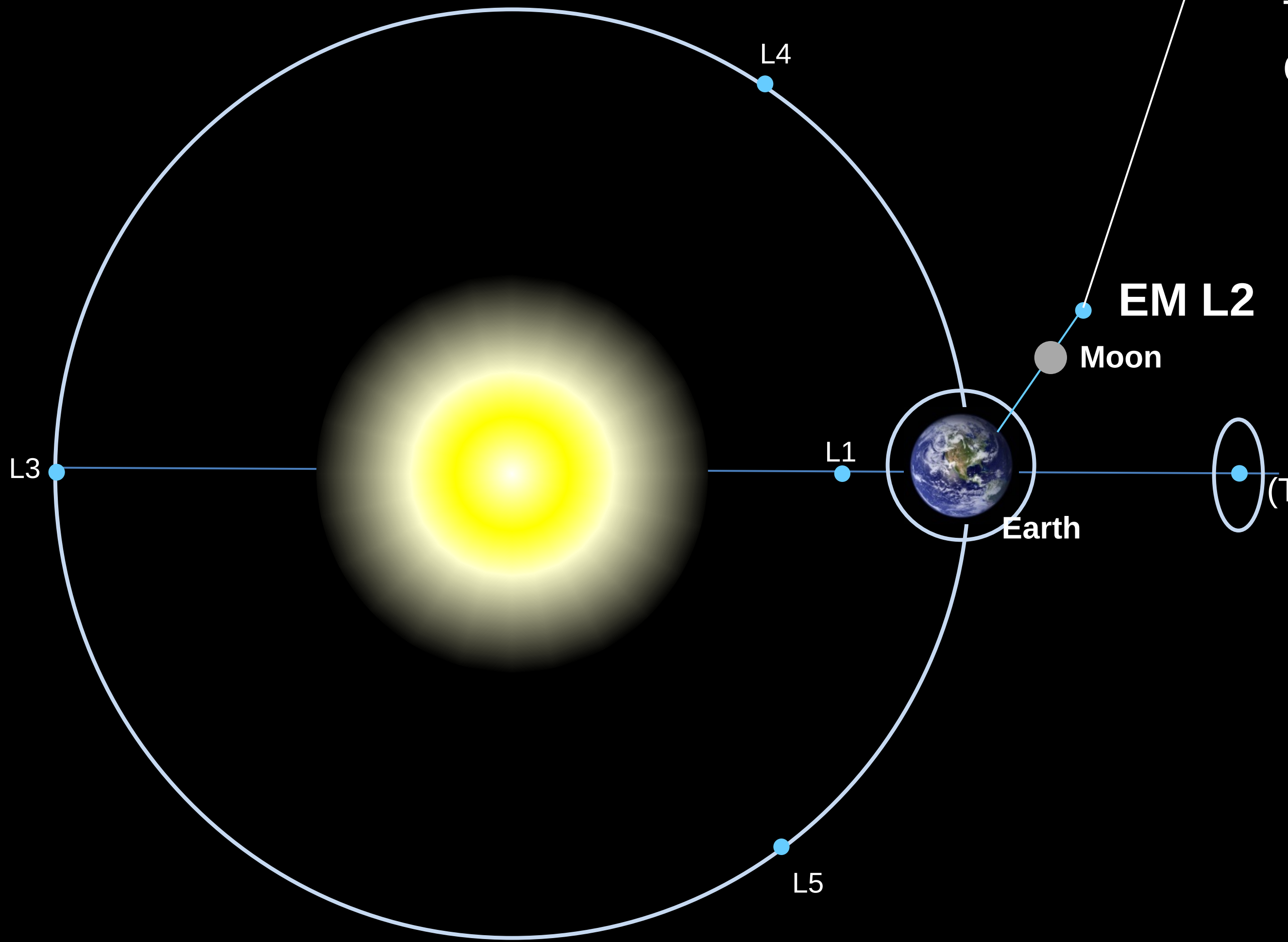
March 27, 2013



Brand Griffin

"Skylab II, Making a Deep Space Habitat from a Space Launch System Propellant Tank," B. Griffin, D. Smitherman, K. Kennedy, L. Toups, T. Gill, and S. Howe, AIAA Space 2012 Conference, Pasadena, CA, September 11-13, 2012, AIAA 2012-5207

Habitat for Humans Beyond LEO



Deep Space Habitat
Crew of 4
Three 60 day missions
Grow to 180 day missions

Different than ISS
No rapid return
Costly, infrequent reupply
More Hab than ISS Lab

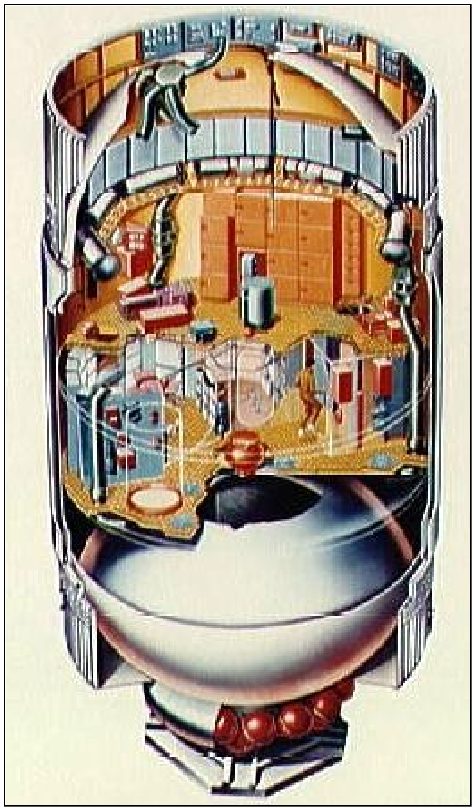
GRAY RESEARCH, INC.
a MacAulay-Brown Company

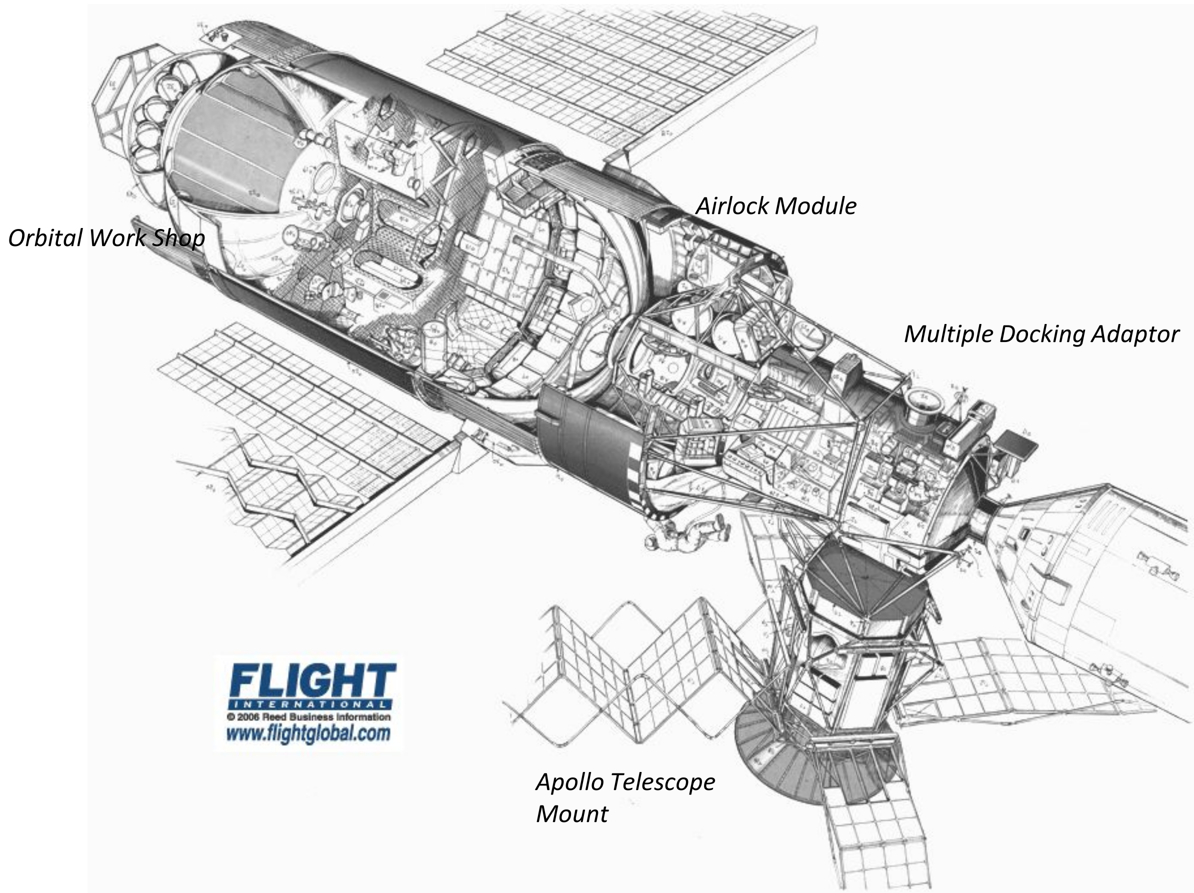
Skylab moved astronauts out of the couch

B Griffin

- **Post Apollo (used Apollo assets)**
- **First US Space Station**
- **1973 Saturn V launch (fully provisioned)**
- **Occupied by 3 crews, 3 astronauts each**
- **Crew duration: 28, 59 and 84 days**

- **Launch mass 77,088 kg (169,950 lb)**
- **"Dry" Workshop (3rd stage propellant tank)**
- **Included telescope, airlock and docking adaptor**
- **LEO ~ 440 km altitude, 50° inclination**
- **Last crew 1974, re-entered 1979**





Heavy Lift, Large Diameter, Single Launch

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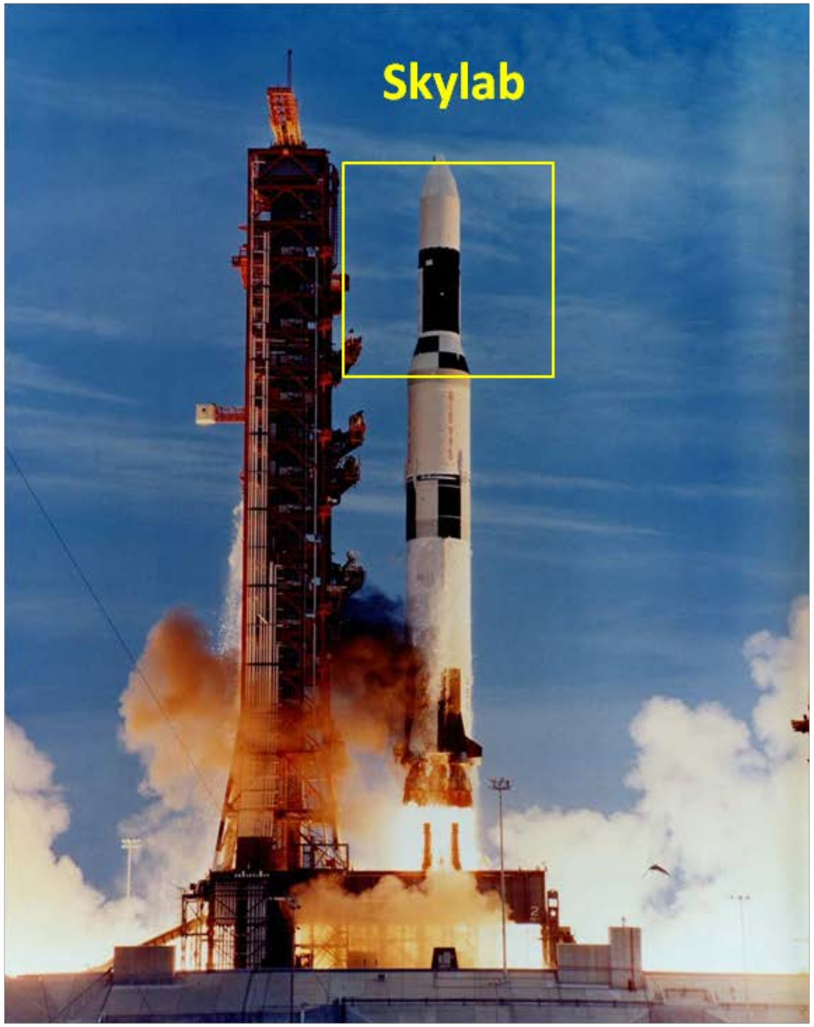
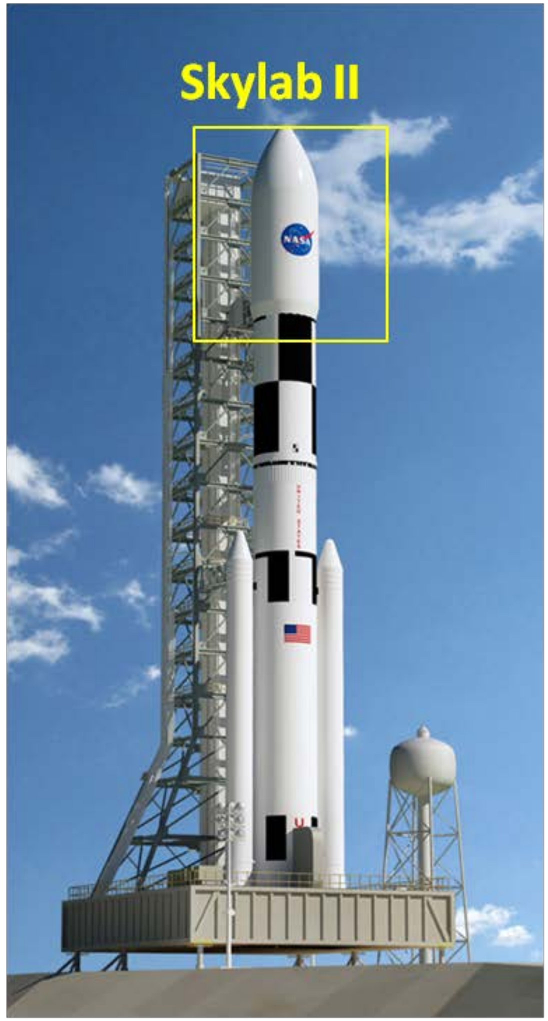


Saturn V



Space Launch System

SLS Upper Stage H2 Tank

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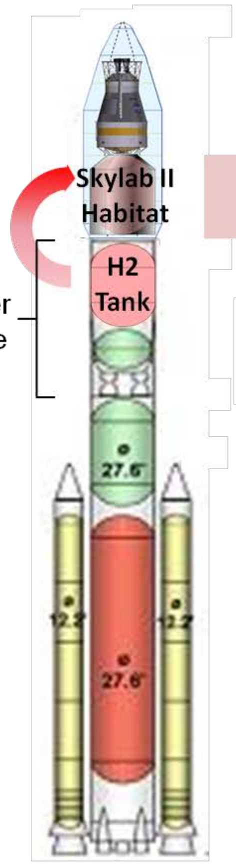
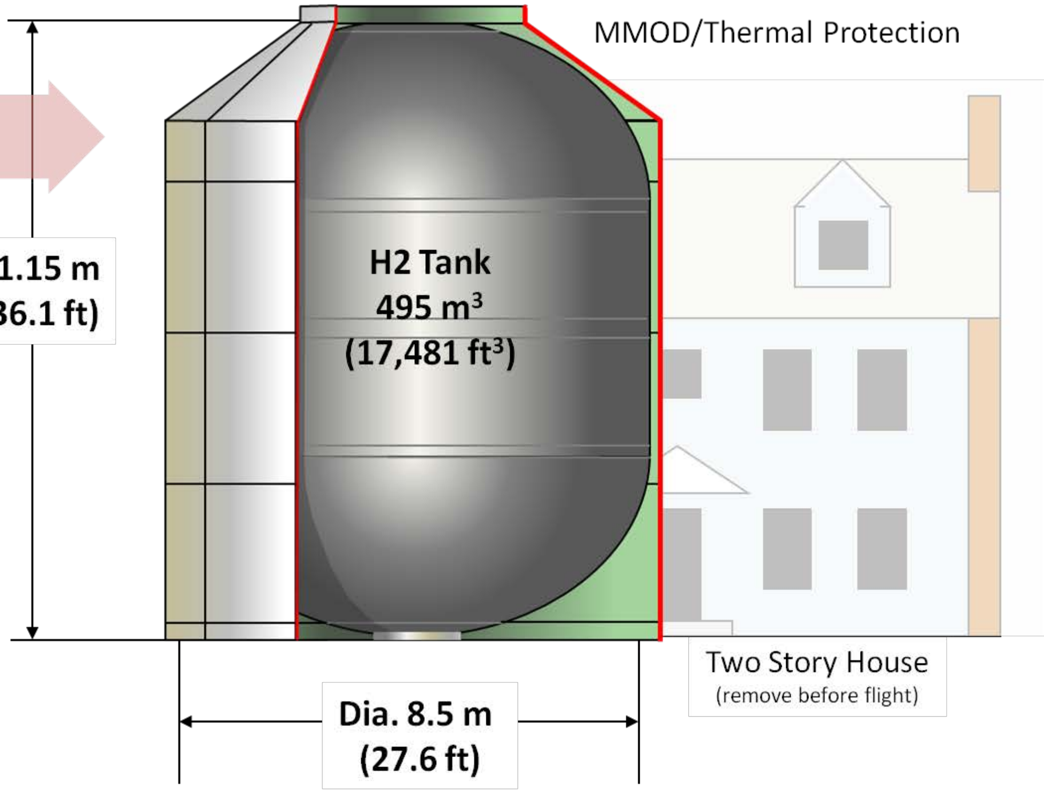
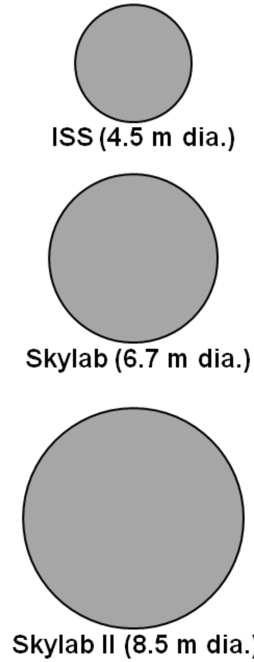
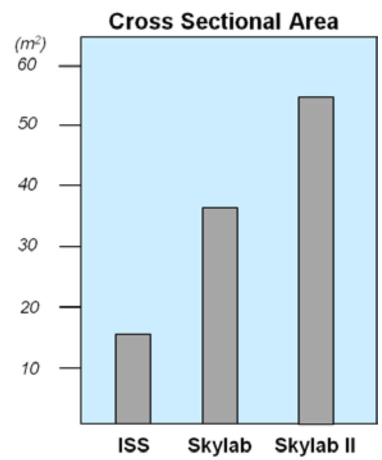




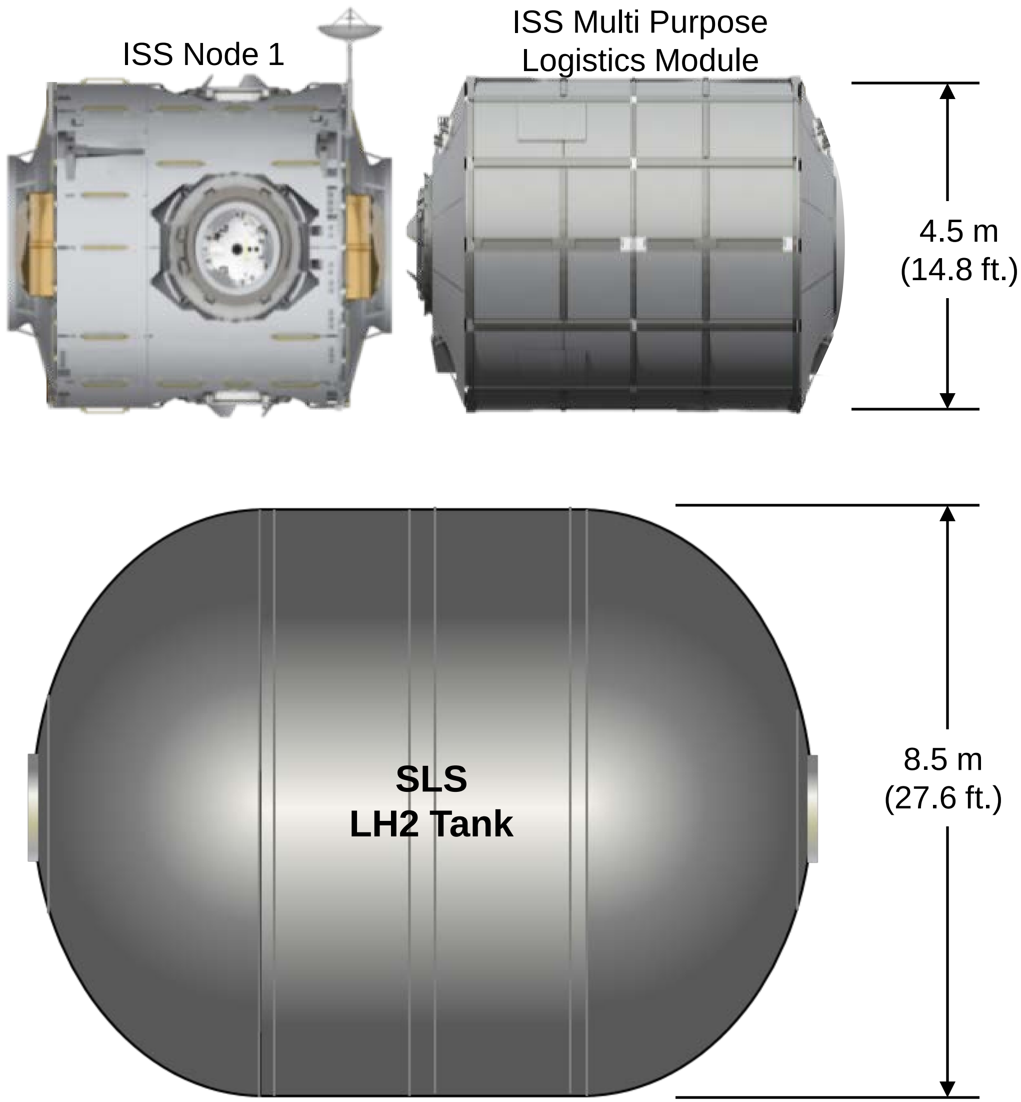




ISS-Derived Deep Space Habitat

B Griffin

ISS Derived Deep Space Habitat



DDT&E Complete, Existing Manufacturing

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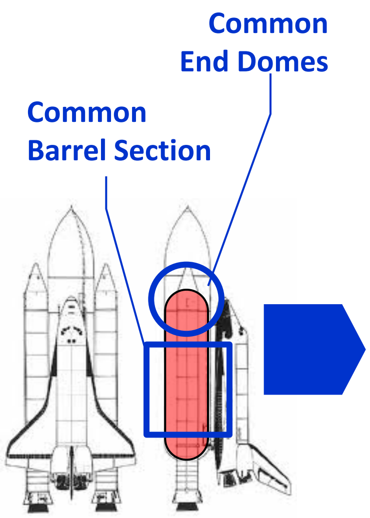
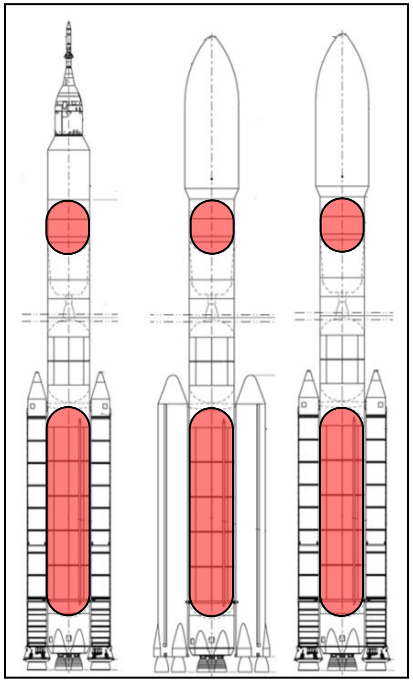
SLS based on External Tank



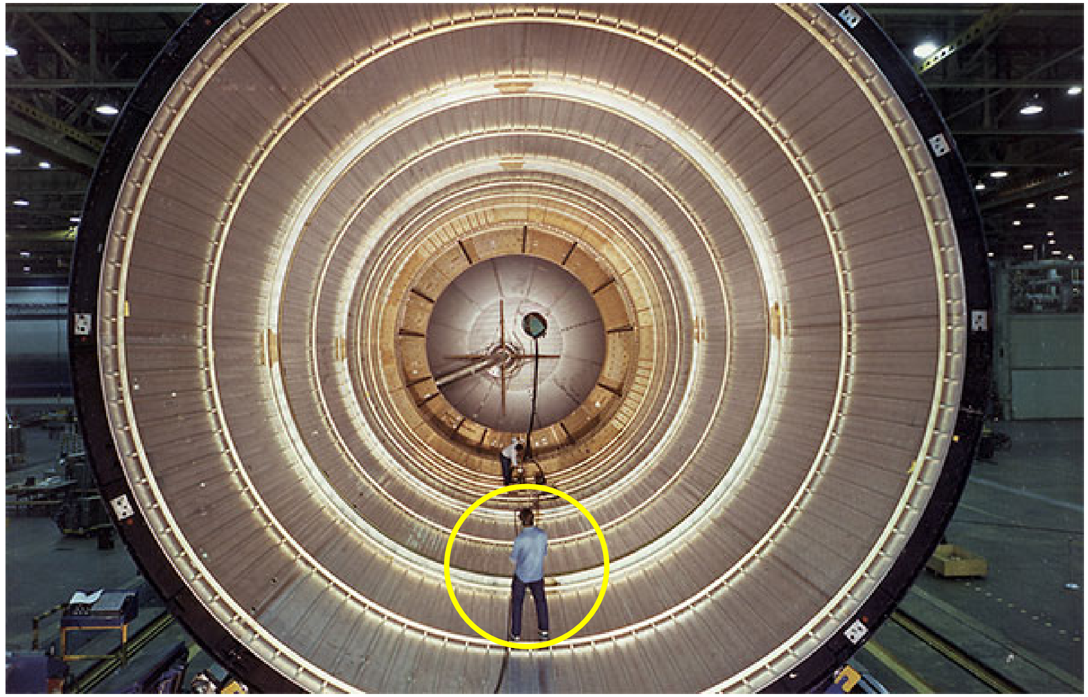
External Tank



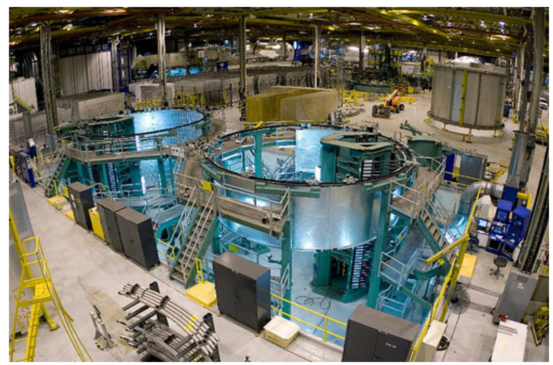
SLS Family

Flight Experience-135 Launches

Person shows scale of the H2 Tank



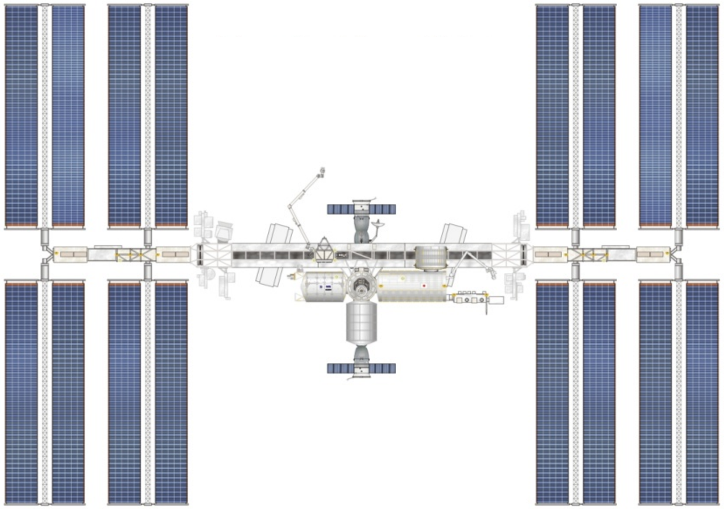
DSH would use the same SLS Facility and Personnel

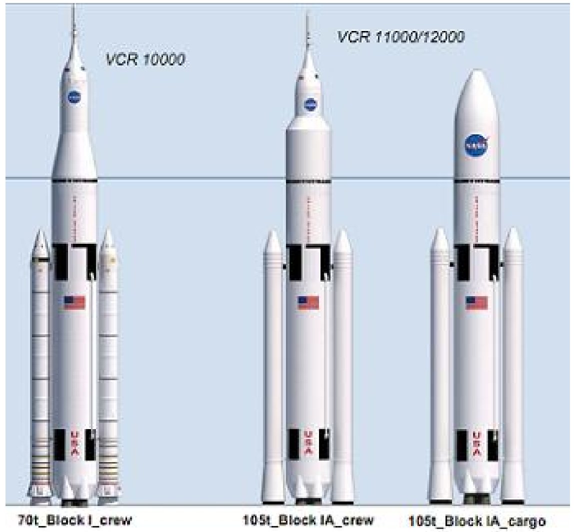


Common Sense Commonality

B Griffin

ISS	MPCV	SLS	Other
First Element Launch 24 years ago			





Russian,
European,
Canadian,
Japanese,
AR&D
Etc.

Technology over 30 yrs old by Cis-lunar launch

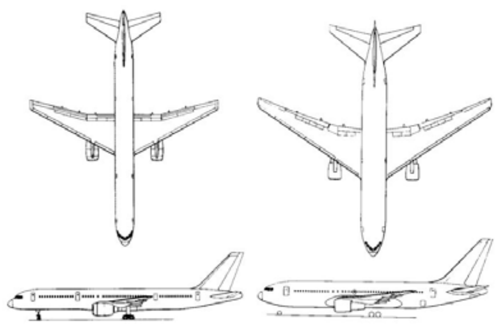
Assessment-by-subsystem

- Structures
- Mechanisms
- ECLSS
- Communication
- Guidance Nav. and Control
- Software
- Data management
- Crew Systems
- EVA

What is the relevance of hardware and software to cis-lunar mission?
What does is take to make ground assets flight ready?
Are the drawings and specs available?
What re-verification/certification is required?
Access to original suppliers, integrators, and fabrication techniques?
What is the lead time and process for procurement?
What are the cost/benefits?
How are the lessons learned incorporated into the cis-lunar Habitat

Example-Mgt. Decree

Narrow Body	Wide Body

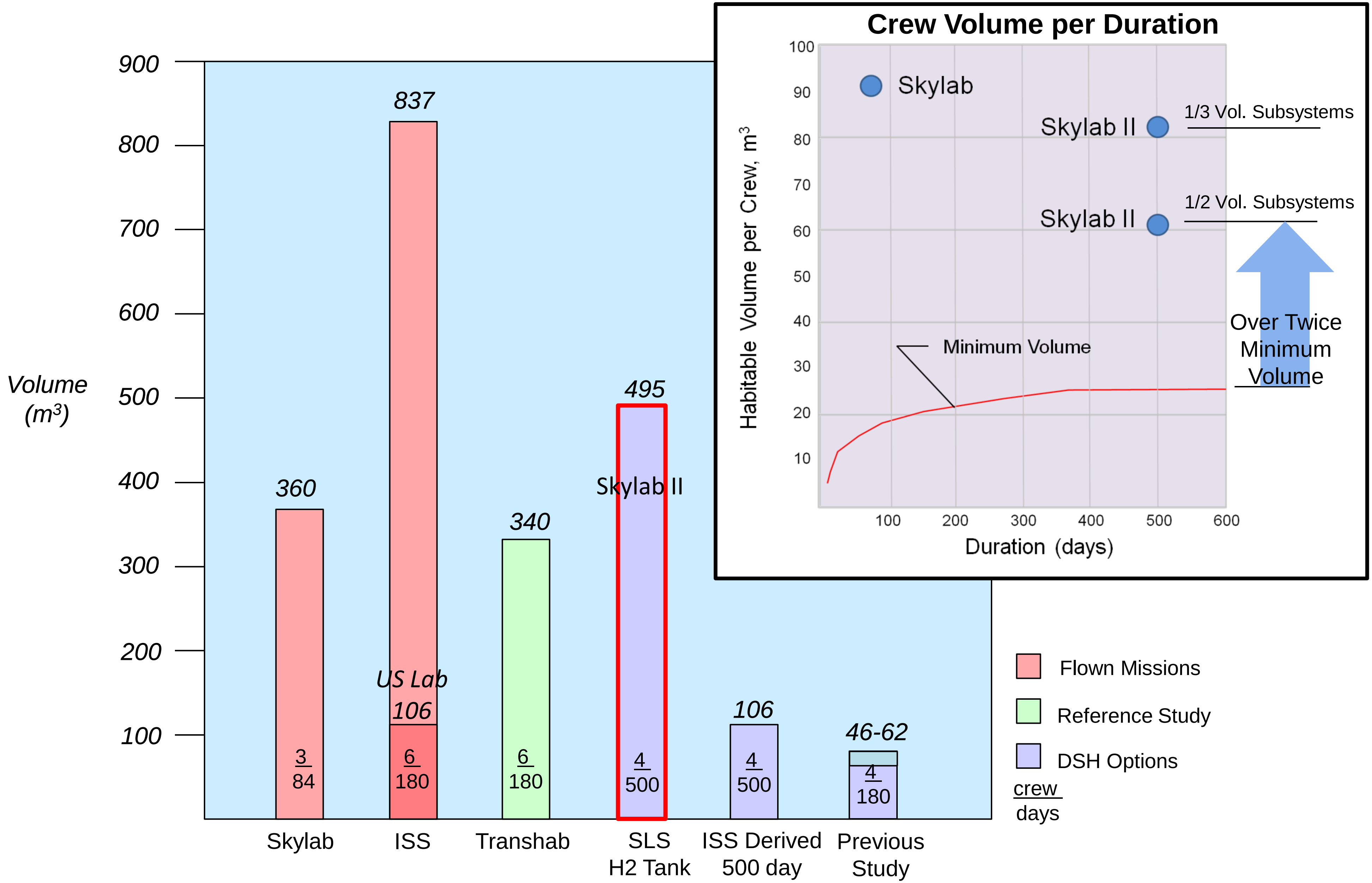


757	767

Same Cockpits
(Same type-rating for pilots)

Volume Comparison

B Griffin



More than Habitable Volume

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Skylab
(Good Accessibility)

ISS USLab (Destiny)
(Cluttered, Difficult Access)

Volume to flight test AMU

Additional DSH volume allows:

- Subsystems designed for servicing
- Improved access to utilities
- Improved access to stowage
- Offload Logistics Module to free up port
- Margin for trash

Mass, Outfitting and Cabin Pressure

B Griffin

LH2 Tank Weighs less than 2 SUVs

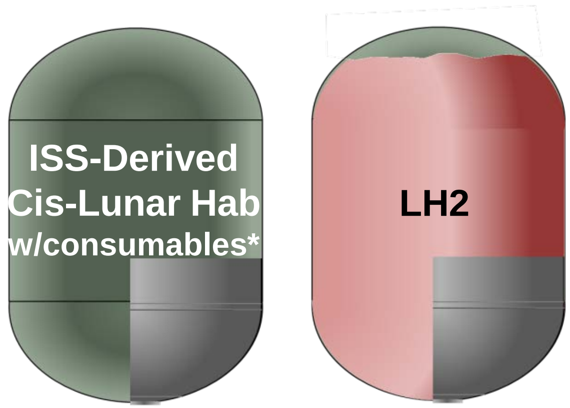
Sport Utility Vehicle

2631 kg (5800 lb)

4200 kg
(9,240 lb)

5262 kg
(11,600 lb)

Outfitting Weighs less than LH2 Propellant

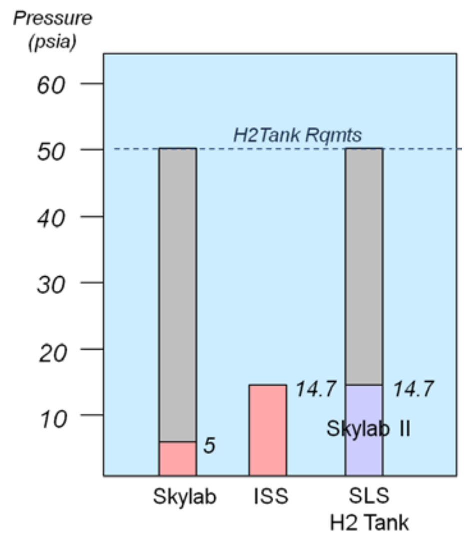


Outfitting
11,400 kg
(25,200 lb)

LH2
33,100 kg
(72,960 lb)

• Three 60 day missions using the Deep Space Habitat Based on ISS Systems, Advanced Exploration Systems, NASA, MSFC, February 14, 2013

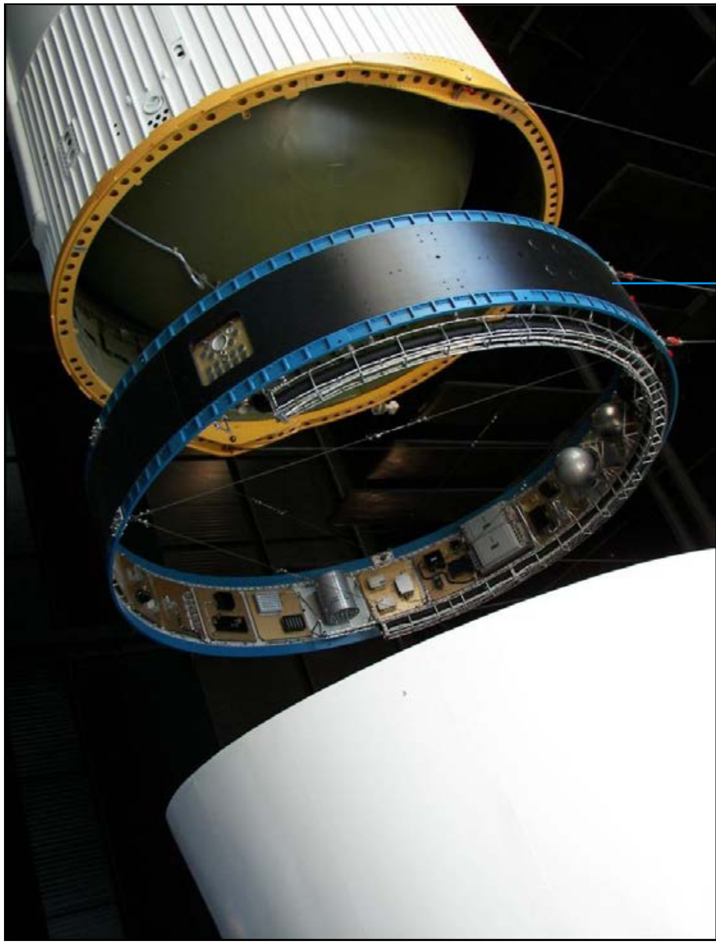
Accommodates All Cabin Pressures

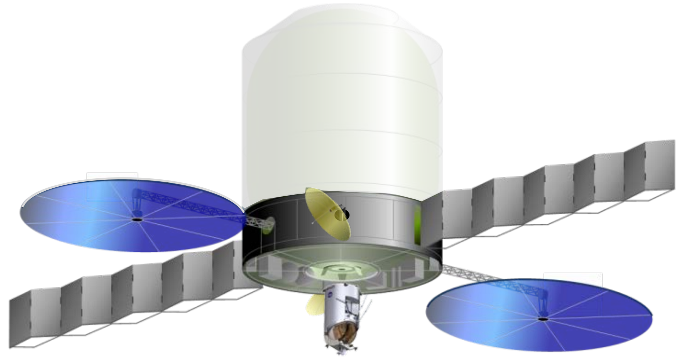


External Equipment and Airlock

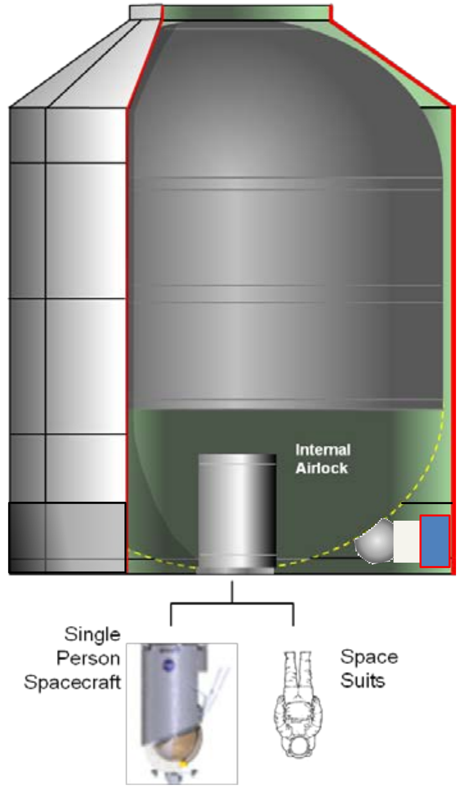
B Griffin

Saturn V





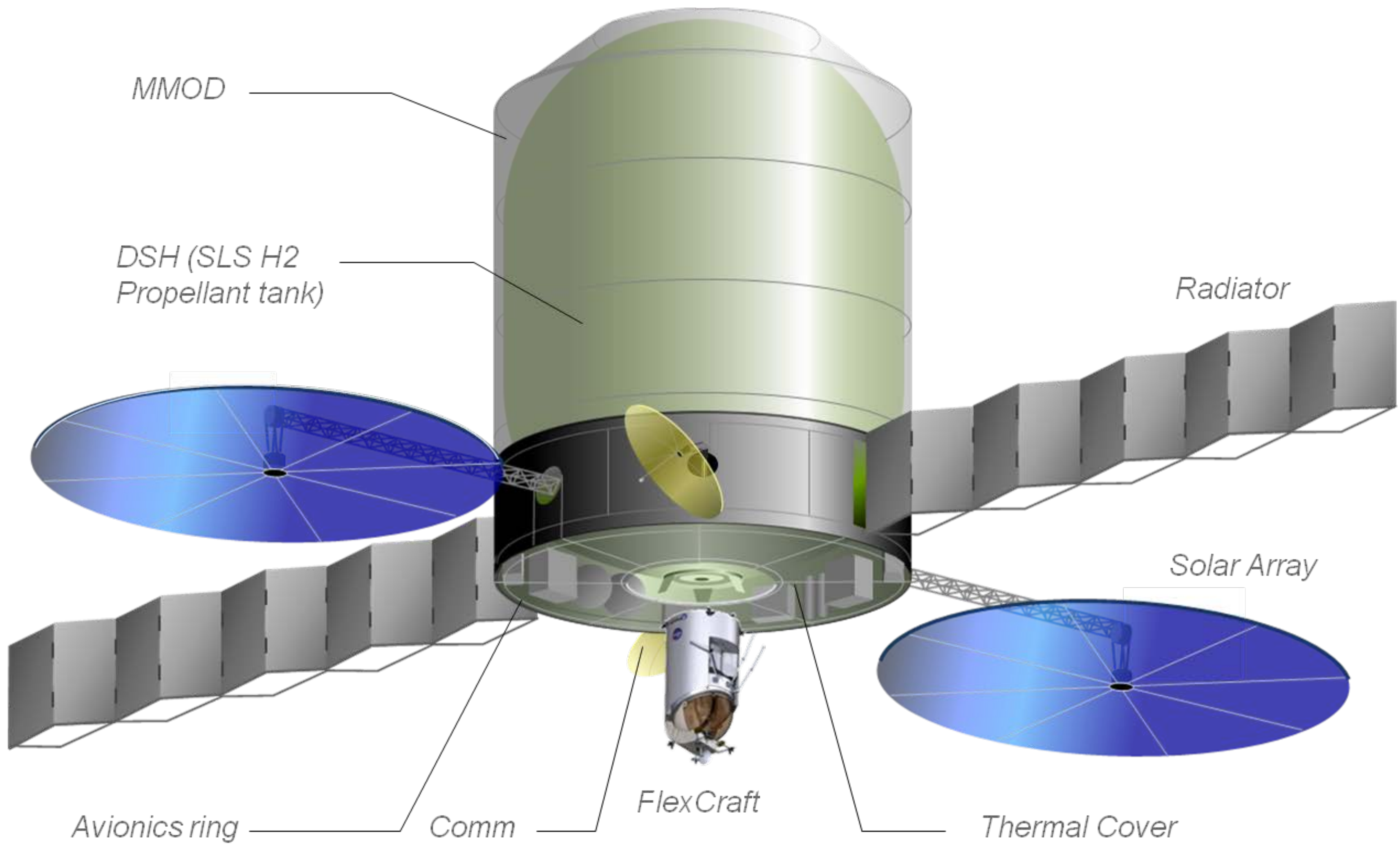
Instrument Ring
External Hardware
Deployable Systems



Skylab II

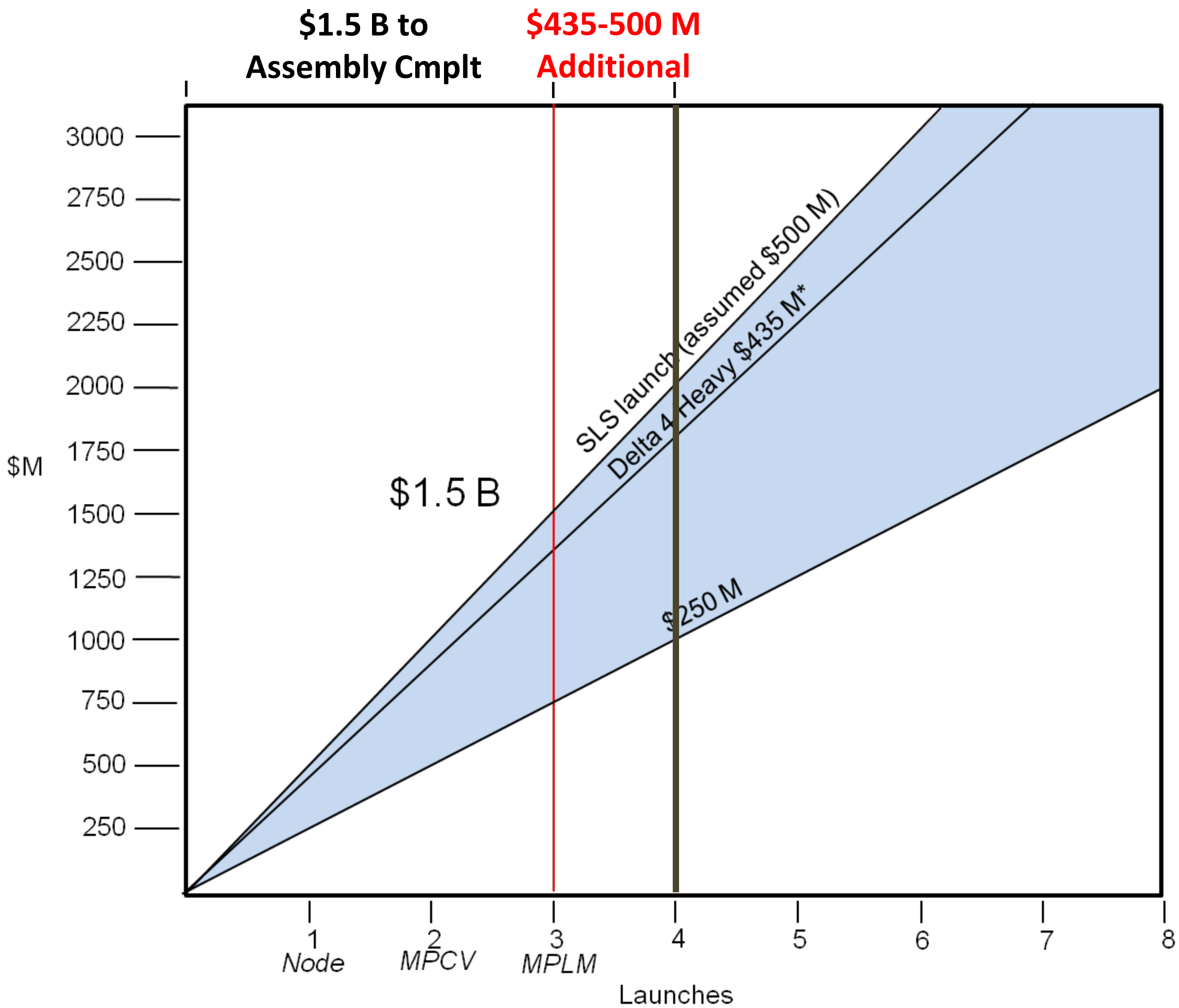
EVA Options

Habitat Configuration



Incentive for Fewest Launches

B Griffin

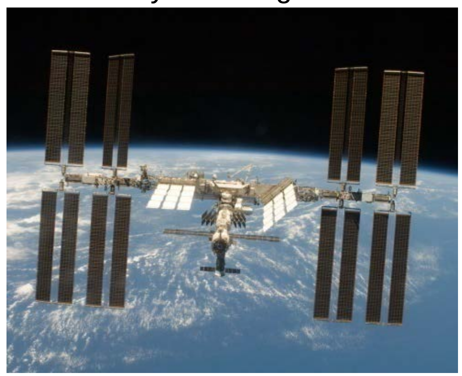


Skylab

Single Launch Space Station

ISS

10 yrs 115 flights



* Delta 4 Heavy launches cost $435 million each (calculated from an Air Force contract of $1.74 billion for 4 launches)

Launch Cost Savings

B Griffin

5 Fewer Launches or Approximately $2.175 Billion Savings

	Previous Cis-lunar Study			TOTAL	Skylab II			TOTAL
Year	SLS	Com/Log	ELV/Log		SLS	Com/Log	ELV/Log	
2019	Node 1				Skylab II			
2020	MPCV	X			MPCV			
2021	MPCV	X	X		MPCV			
2022	MPCV	X	X		MPCV			
Number	4	3	2	**9**	4			**4**
COST $M	2000[1]	1305[2]	870[2]	**4175**	2000			**2000**
2023	MPLM	X			MPCV	X		
2024	MPCV	X			MPCV	X		

1 Assume $500M per launch ($65M more than Delta IV Heavy)
2 Delta IV Heavy launches cost $435 million each (calculated from an Air Force contract of $1.74 billion for 4 launches)

Number of Elements

B Griffin

10 Fewer Elements over first 4 years

(Does not include MPLM)

	Previous Cis-lunar Study					TOTAL	Skylab II					TOTAL
Year	Node 1	MPCV	Bus	Log Mod	MPLM		Skylab II	MPCV	Bus	Log Mod	MPLM	
2019	X		X				X		X			
2020		X	XX	X				X	X			
2021		X	XXX	XX				X	X			
2022		X	XXX	XX				X	X			
#	1	3	9	5		18	1	3	4			8
2023	X		XXX	X	X	6		X	XX	X		4

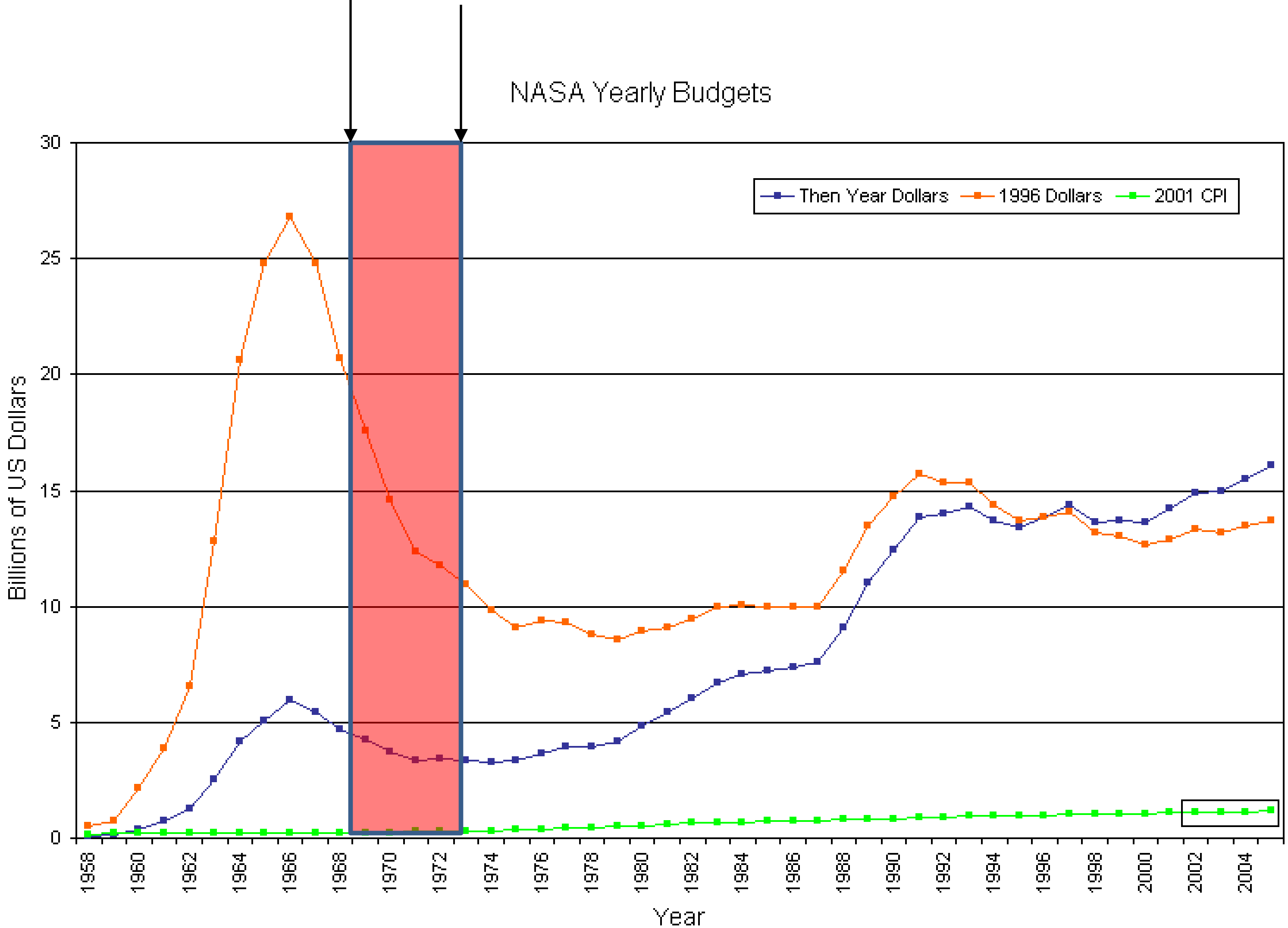
Possible SLS-Derived Log Mod

Skylab Built During Budget Decline

B Griffin

NASA Administrator announces Dry Workshop (Skylab)

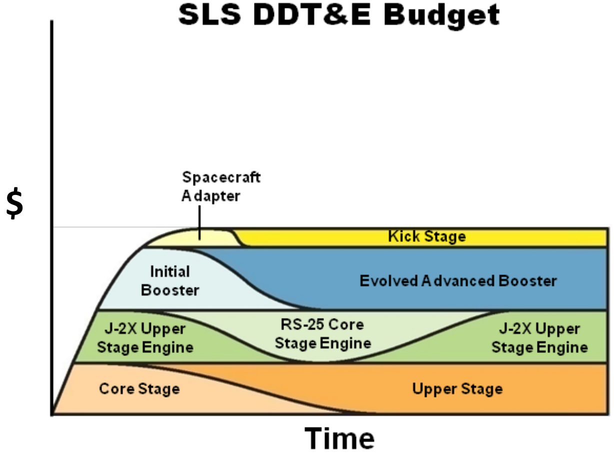
Skylab Launched



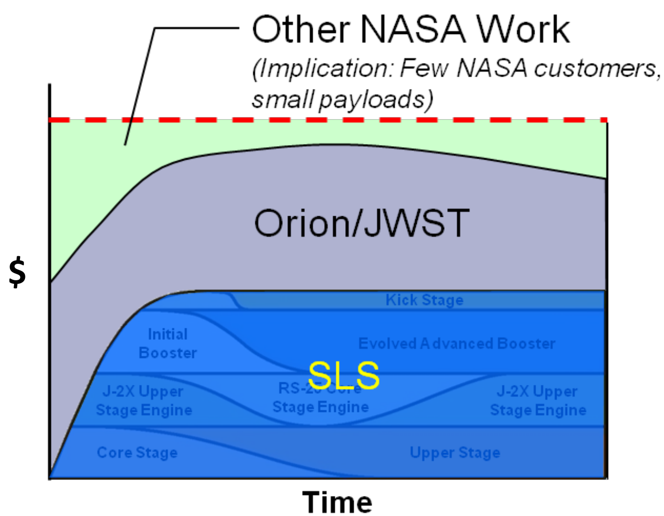
Why Low Cost

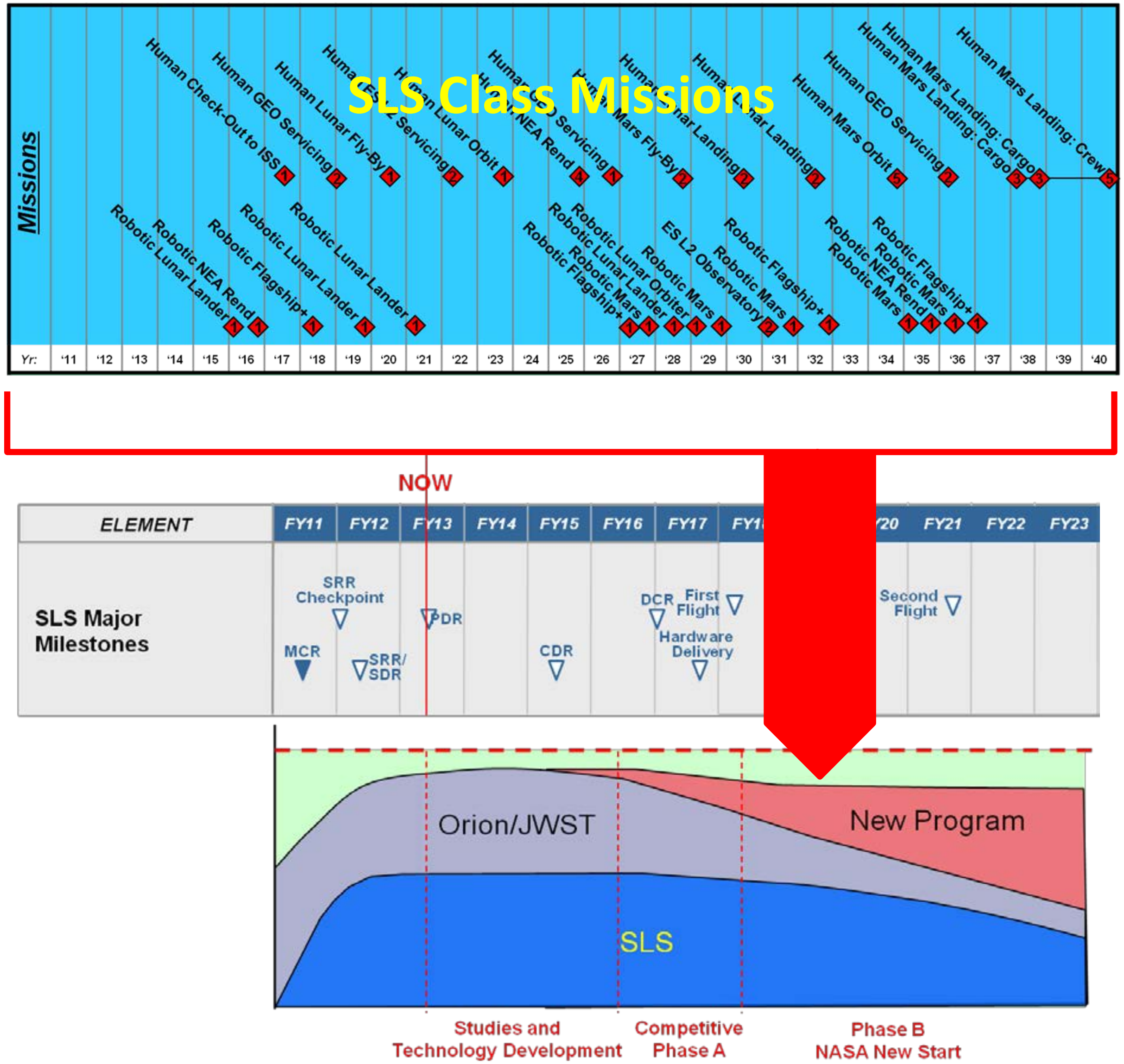
B Griffin

SLS DDT&E Budget



Assumed NASA Budget





Funding Profile

(Representational)

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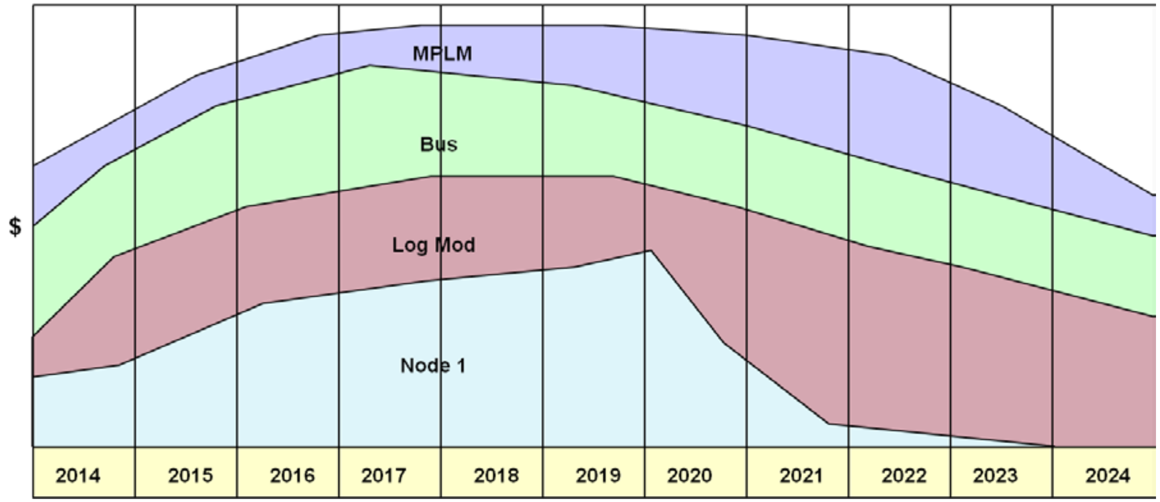
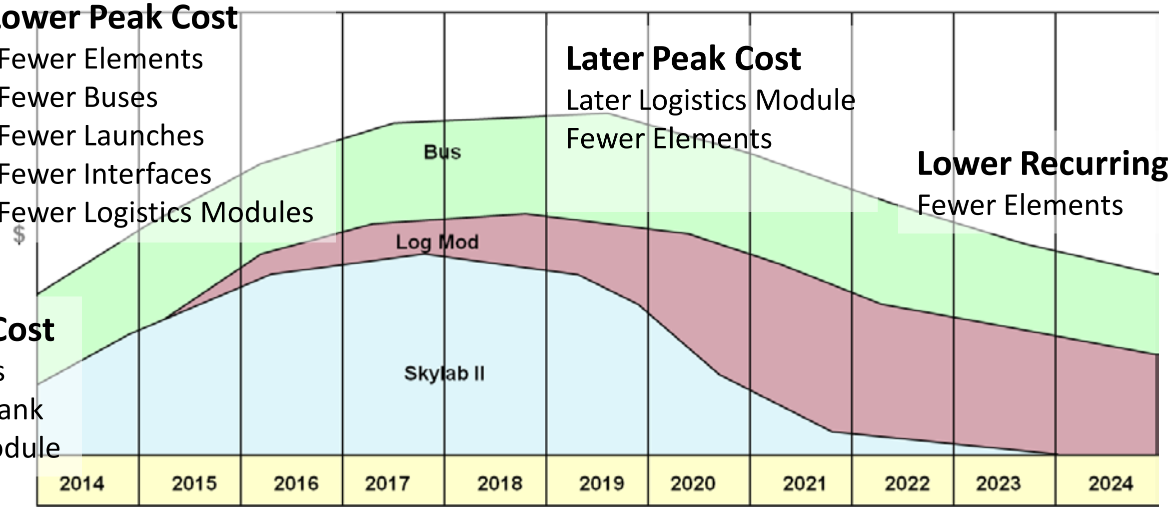
Previous Cis-lunar Study



Skylab II



Lower Peak Cost
- Fewer Elements
- Fewer Buses
- Fewer Launches
- Fewer Interfaces
- Fewer Logistics Modules

Later Peak Cost

Later Logistics Module

Fewer Elements

Lower Recurring Cost

Fewer Elements

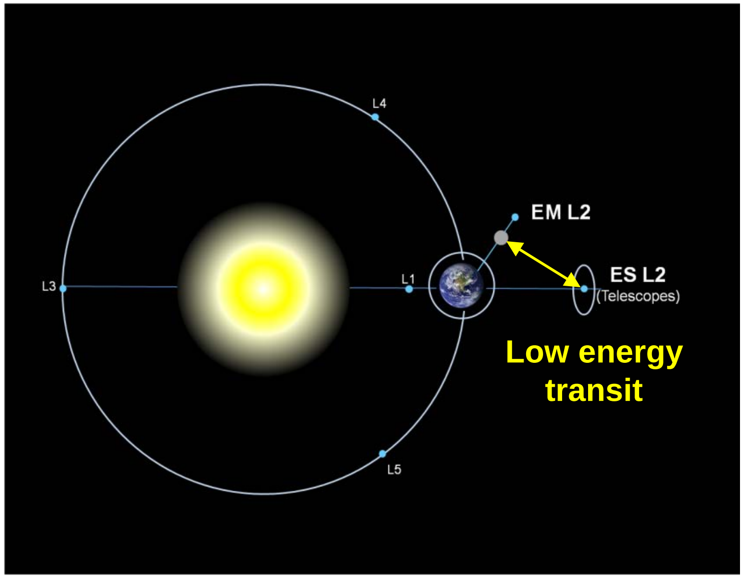
Lower Initial Cost
- Fewer Elements
- No DDT&E for tank
- No Logistics Module

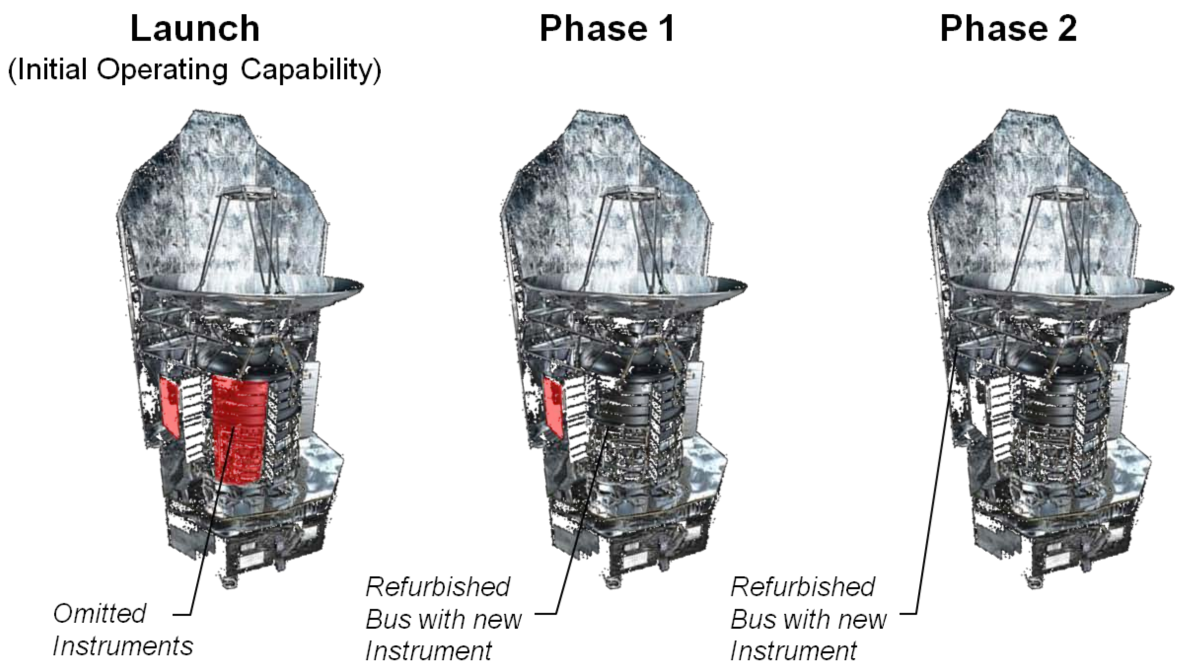
Fly Now, Upgrade Later

Approach to Space Observatories

B Griffin

Human Servicing at EML2



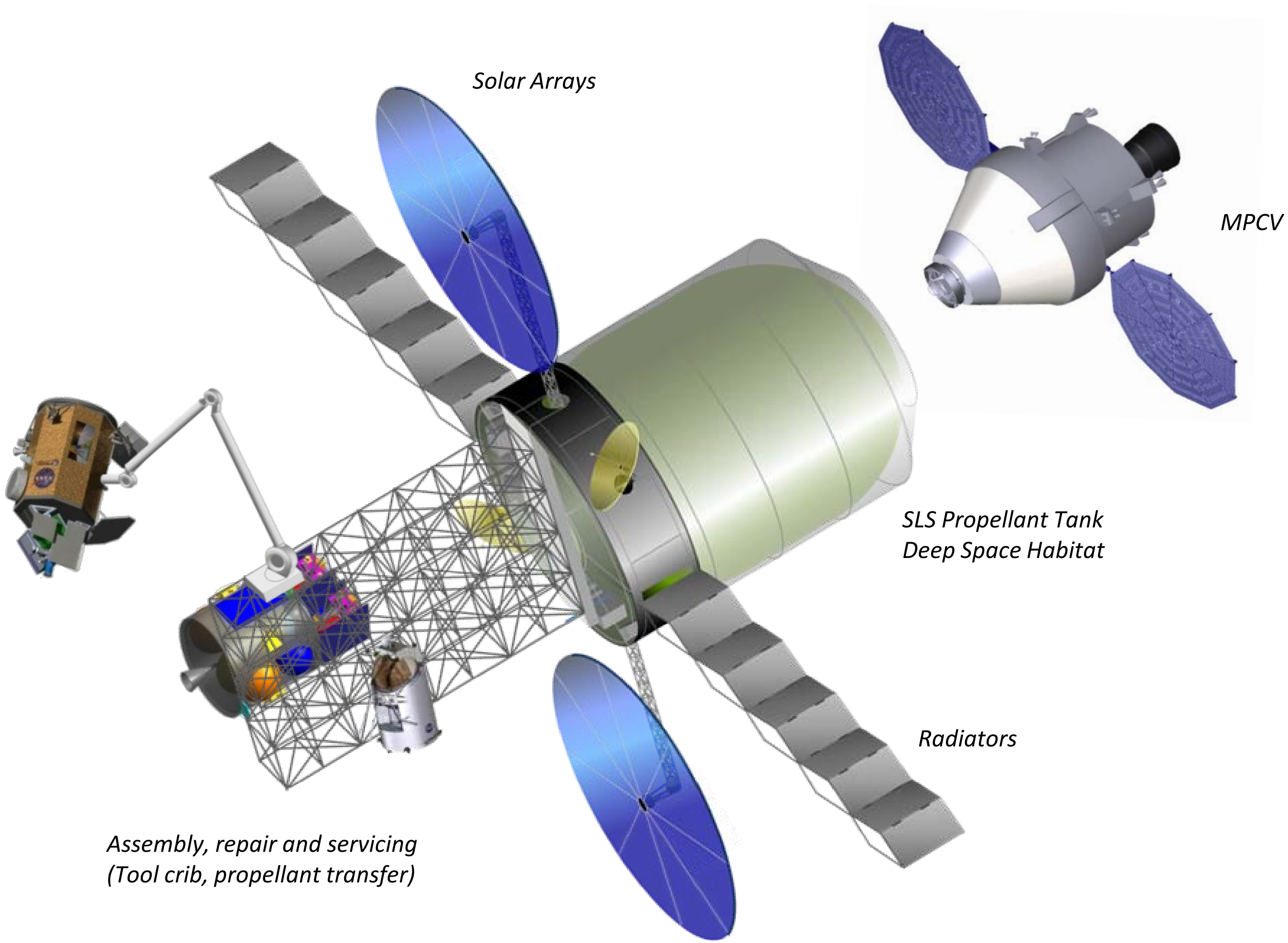


- **Similar to Hubble**
- **Reduces initial cost**
- **Minimizes development schedule**
- **Allows low TRL instruments later**

- **ES L2 popular observatory site**
- **Very low delta v between EM L2 and ES L2 (~ 20 m/s)**
- **No upper stage to transit between L2s (RCS)**
- **Establish servicing capability at E-M L2**

Lunar Science & Satellite Servicing

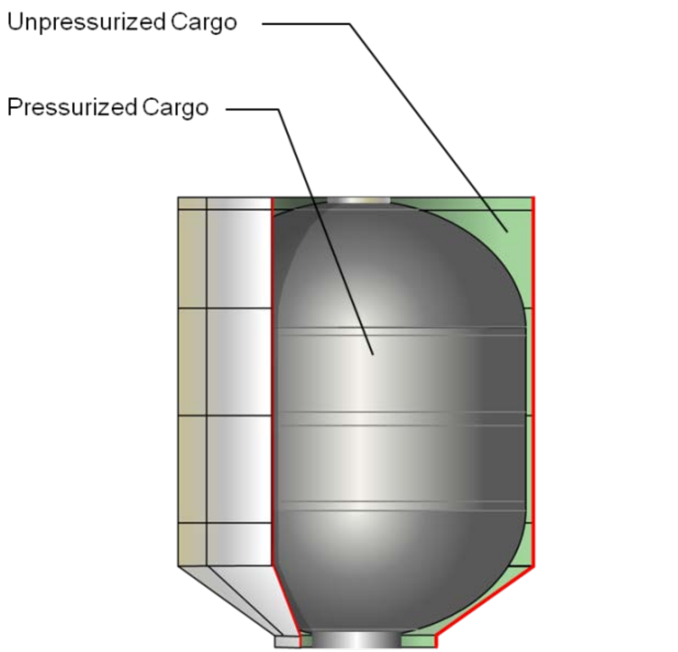
B Griffin



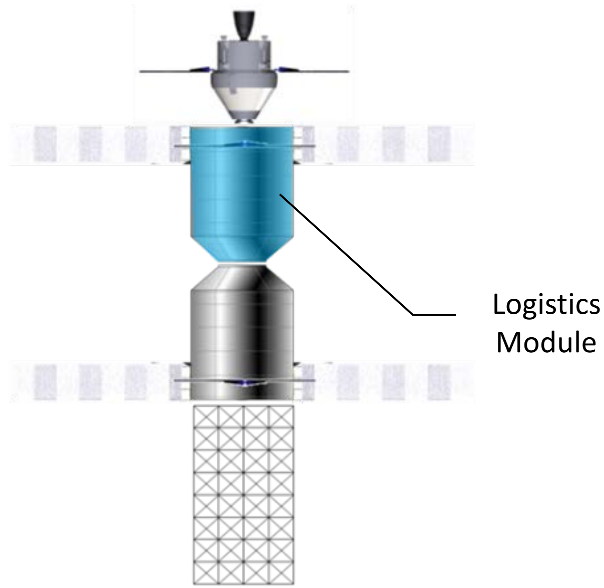
Jumbo Logistics Vehicle

B Griffin

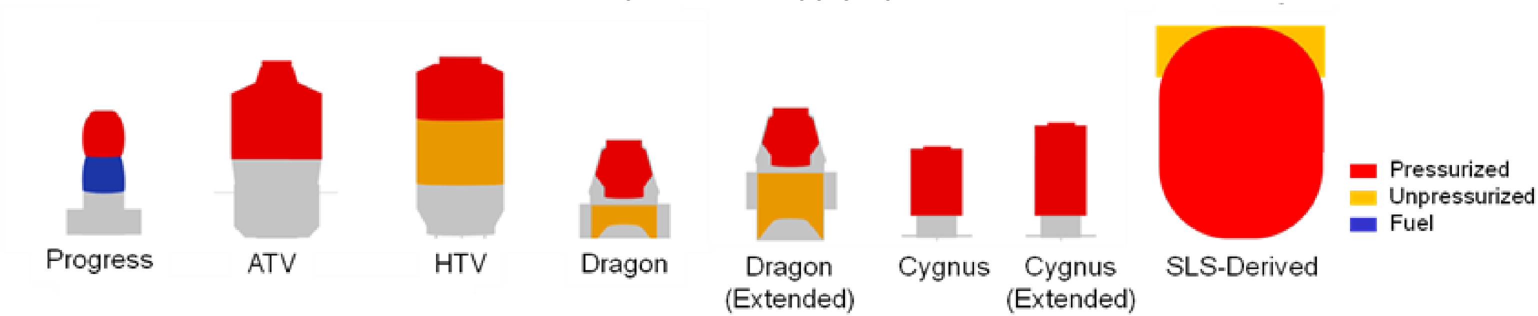
SLS-Derived Logistics Module



Skylab II DSH



Comparison-Resupply Options



Summary

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- **Single Launch for 3 missions (no resupply for 4 years)**
- **Large light weight pressure vessel**
- **No design changes for SLS launch loads**
- **Accommodates all cabin pressure options**
- **Volume (exceeds habitable requirement, allows for stowage and maintenance)**
- **Multiple vehicles over time (Mars transit Hab, LEO, Asteroid, etc.)**
- **Early and Sustained Occupancy (no additional elements for 180 day stay)**
- **Low Cost (and risk)**
    - 5 Fewer Launches
    - 10 Fewer Elements
    - Fewer Interfaces
    - Avoid DDT&E for Tank
    - Manufacturing facility and labor in place (no unique procurement or tooling)
    - Commonality with SLS launch system
- **Jumbo Logistics Vehicle Option (DHS and ISS)**

Supporting Material

Deep Space Habitat Enabling Attributes

B Griffin

Attribute	Rationale
Very low cost	• NASA budget is not expanding • Commitments: SLS, ISS, JWST, MPCV, Commercial Space, Soyuz launches, new upper stage, robotic missions, etc. • Bow wave delays any new SLS-class Program start • Lead time for competitive procurement
Super light weight	• No current upper stage for transfer to EM L2 • Cannot afford ISS model of many launches • Fewer launches mean early occupancy
Easily maintained	• 5 days one way from Earth to EM L2 • Reliance on in-situ maintenance (diagnostics, tools, procedure, training, ORU philosophy, sparing, etc.) • Ready visual, physical access to ORU and connectors • Retain life critical functions while being maintained (redundancy, functional isolation, etc.)
Common Sense Commonality	• “Relevant” as it applies to the mission, maturity, lessons learned • Vertical: Sources of common hardware and software • Horizontal: Across Cis-lunar elements

Avoid Transporting Tools To and From ES L2

Service at EM L2

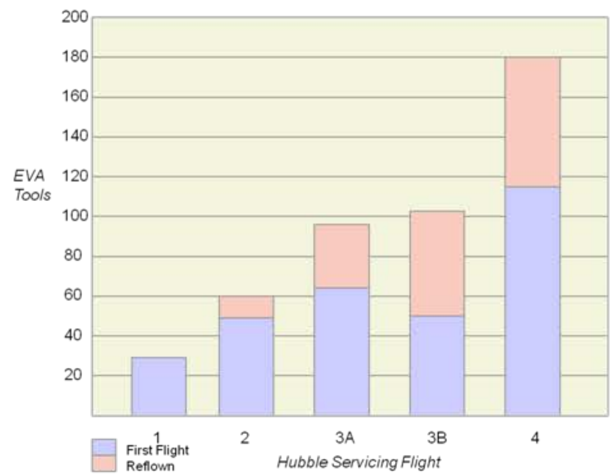
B Griffin

Tools- HST Servicing*

- **Servicing Mission 1**
  – 28 Tools Processed for flight
- **Servicing Mission 2**
  – 60 Tools Processed for flight
  - 48 First Flight, 12 Reflown
- **Servicing Mission 3A**
  – 95 Tools Processed for flight
  - 63 First Flight, 32 Reflown
- **Servicing Mission 3B**
  – 102 Tools Processed for flight
  - 49 First Flight, 53 Reflown
- **Servicing Mission 4**
  – 180 Tools Processed for flight
  - 114 First Flight, 66 Reflown

2600 lbs and 90 ft^3 (1182 kg and 2.6m^3) were manifested for suits, tools, carriers and consumables on STS-103 (Mission 3A) for Hubble Space Telescope servicing.

Advanced EVA Roadmaps and Requirements, Richard K. Fullerton, NASA/JSC, ICES2001-01-2200



**HST Crew Aids and Tools: Working in Space Today and Tomorrow,* Jill McGuire , HST Crew Aids and Tools Manager
National Aeronautics and Space Administration, Goddard Space Flight Center

NASA Ames Workshop[1]: Astronomy Results Applied to SLS

B Griffin

Concepts/Mission	Scientist	Enabled Science/ SLS Benefits	EH/EA[2]
Single Aperture Far Infrared (**SAFIR**)	D. Lester	• Large monolithic mirror enables higher sensitivity and spatial resolution • Resolve galaxies at time when star formation was at a maximum • No deployment mechanisms = reduced complexity, risk, testing, lower cost • Size enables a design for servicing and instrument upgrade	EH
Advanced Technology Large-Aperture Space Telescope (**ATLAST**)	M. Postman	• Unprecedented sensitivity and angular resolution • Investigate formation of Universe, galaxies and planetary systems • With occulter, characterize atmospheres of exoplanets • Reduced deployment mechanisms = reduced complexity, risk, testing, lower cost	EA
Stellar Imager (**SI**)	K. Carpenter	• UV/Optical Interferometer (200 times resolution of Hubble) • High angular & spectral energy resolution with dynamic imaging = breakthrough science • Improved understanding of solar and stellar magnetic activity • Lager mirror elements = dramatically improved sensitivity and reduced observation times	EH
Generation-X	R. Brissenden	• X-ray telescope for black holes, stars and galaxies • New insights into the physics of matter in extreme environments • Ares V (SLS) provides simplified option to Delta-IV 6 telescope solution • SLS diameter provides configuration margin because the telescope is volume limited	EA
Submillimeter Probe of the Evolution of Cosmic Structure (**SPECS**)	S. Rinehart	• Spatial resolution in the far infrared = Hubble optical wavelengths • Much simpler deployment than Delta IV packaging = risk reduction and reduced cost • Carry more propellant for longer mission life • Larger telescopes = more and deeper (fainter) observations	EH
Dark Ages Lunar Interferometer (**DALI**)	J. Lazio	• Cosmological observations of early “Dark Ages” universe • High angular & spectral energy resolution with dynamic imaging = breakthrough science • Improved understanding of solar and stellar magnetic activity • Lager mirror elements = dramatically improved sensitivity and reduced observation times	EA
Starshades	T. Hyde	• Lifefinder mission using medium resolution spectroscopy of exoplanet atmospheres • Requires 8 to 16 m telescope in conjunction with a starshade • Low resolution spectroscopy sufficient to detect oceans and continents • Resolution (mirror size) is critical	EH

1 NASA/CP-2008-214588 Workshop Report on Astronomy Enabled By Ares V, August 2008, S. Langhoff, D. Lester, H. Thronson and R. Correll
2 EH = enhance, EA = enable (assessment made by scientists ate the workshop)

Multiple Docking Dome Option

B Griffin