BOEING

Advanced Space Systems

Human Servicing Mission: Sun-Earth L2 Telescope

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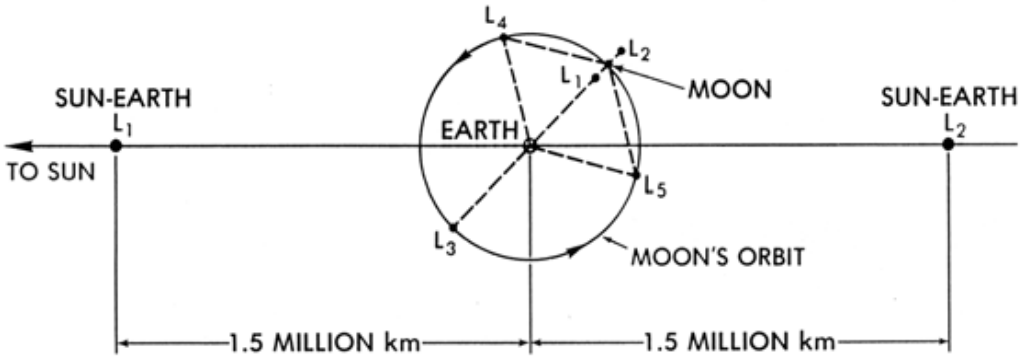
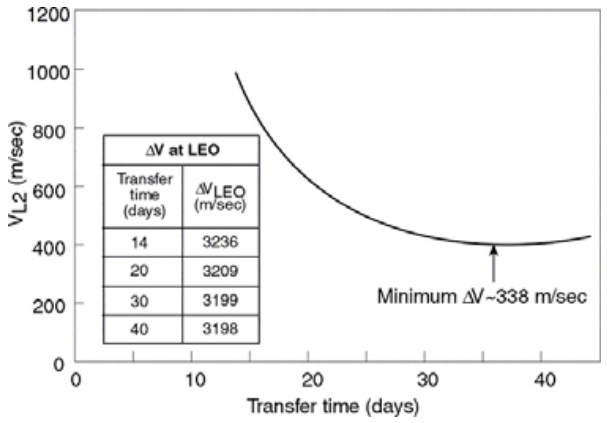
Human Servicing Mission (HSM): Sun-Earth L2 Telescope

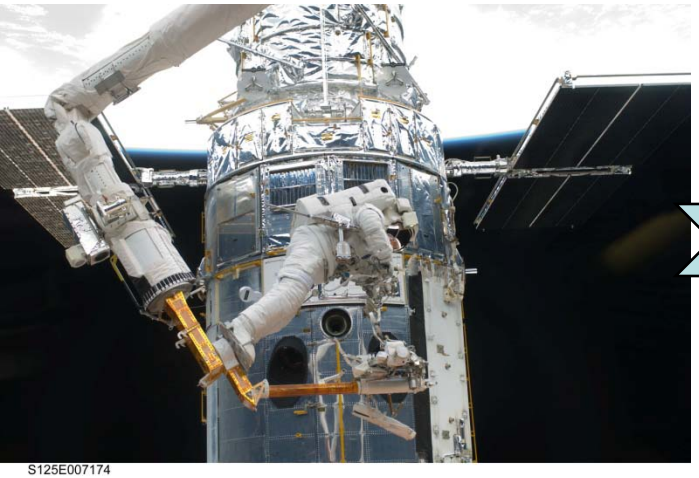
- **Mission Description**
- **Mission Requirements**
- **Mission Systems**
- **Mission Mass Statements**
- **Launch Manifests**



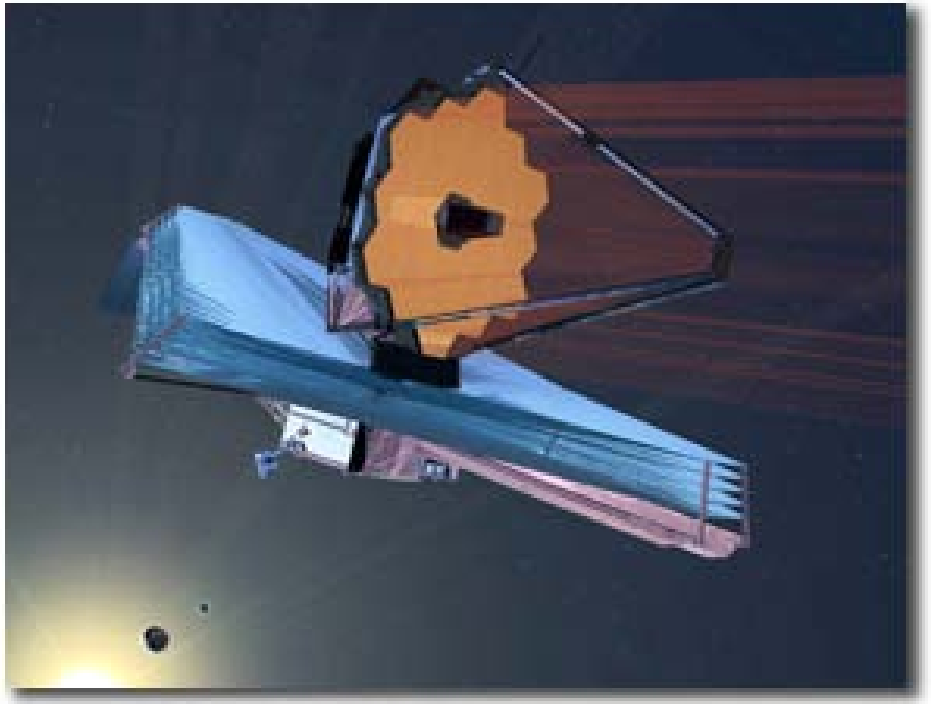


Mission Reference: "The Next Step in Exploring Deep Space," International Academy of Astronautics, 9 July 2004

Hubble Servicing Capabilities Are Applicable to JWST and other SEL2 Telescopes



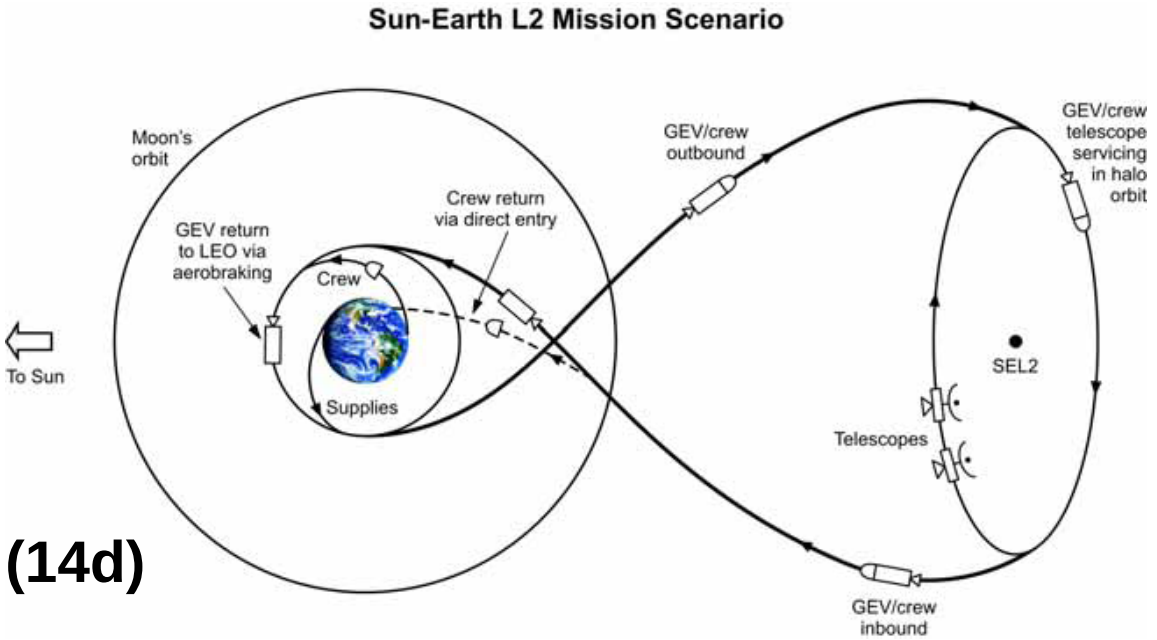
http://spaceflight.nasa.gov/gallery/images/shuttle/sts-125



http://www.jwst.nasa.gov/about.html

SEL2 HSM Description

- Launch
- LEO operations
- LEO departure
- Transit (14 - 40 d)
- SEL2 arrival
- Telescope servicing (14d)
- SEL2 departure
- Transit (14 - 40 d)
- Reentry preparation
- Direct entry, aerobrake capture, or propulsive capture



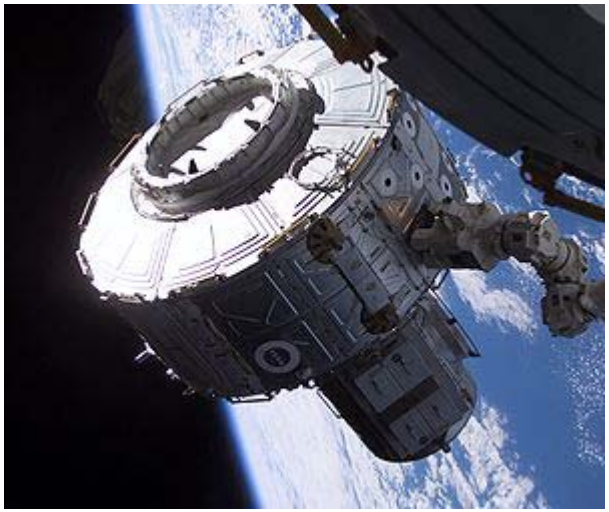
SEL2 HSM Requirements

- **Velocity changes**
  - LEO departure/capture: 3198 – 3236 m/s
  - SEL2 arrival/departure: 338 – 1000 m/s
  - Post-aerobrake circularization: 100 m/s
- **Personnel: 6 (4 EVA; 1 pilot; 1 commander)**
- **Duration: 42 – 94 d**
  - 14 – 40 d out; 14 d @ SEL2; 14 – 40 d back
- **Consumables: Oxygen, nitrogen, water, food**
- **Required capabilities: habitation, manipulators, EVA**

SEL2 Telescope HSM Systems

- Crew launch – Boeing Crew Vehicle or SpaceX Dragon
- Transit habitation module – Bigelow Sundancer
- Airlock – ISS or Shuttle Airlock
- EVA – Shuttle spacesuits
- EVA Tools – Hubble tool kit
- Manipulator – OE ARMS and ISS Dextre for robotic aid
- Telescope mechanical interface – Hubble FSS

Existing Hardware Elements Can Support HSM for SEL2 Telescope



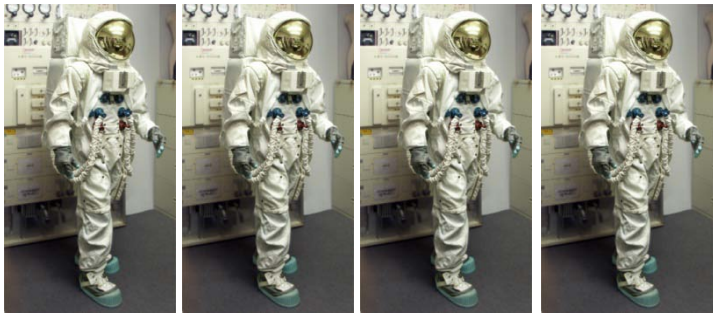
Quest Joint Airlock Module (NASA) or Shuttle Airlock

Bigelow Sundancer

Hubble Flight Support System

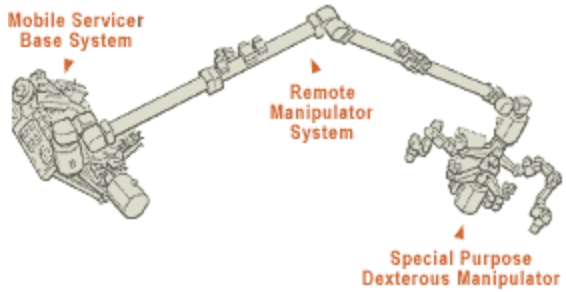
Hubble Servicing Tool Kit

ISS Dextre by MDA



Shuttle EVA Suits

Boeing Crew Vehicle



Orbital Express ARMS by MDA

Comparing Aerobrake with Direct Entry Shows Infrastructure Can Be Retained for 20 - 30 t IMLEO

Aerobrake Return to LEO	
Aerobrake	14.4
Crew vehicle	10.0
Bigelow Sundancer	10.0
Airlock	1.8 – 6.1
Crew (6)	0.8
EVA Suits (4)	0.5
Dextre	1.7
Orbital Express ARMS	0.2
Repair kit	5.0
Margin	7.0
Propellant	75.6 – 156.9
Transfer stage inert	8.3 – 15.2
	129.5 – 223.8

Direct Entry	
Crew vehicle	10.0
Bigelow Sundancer	10.0
Airlock (Shuttle – ISS)	1.8 – 6.1
Crew (6)	0.8
EVA suits (4)	0.5
Dextre	1.7
Orbital Express ARMS	0.2
Repair kit	5.0
Margin	7.0
Propellant	63.9 – 133.6
Transfer stage inert	7.1 – 14.8
	111.1 – 192.4

SEL2 HSM Manifests
Need 11 – 160 t Launch Capability

Aerobrake Return to LEO

- **Manifest without Depot**
  1. Aerobrake, Hab, Tools 43.3 – 50.1
  2. Transfer Vehicle **84.1 – 156.9**
  3. Crew Vehicle 10.8
- **Manifest 1 with Depot**
  1. A/B, hab, tools, stage **53.5 – 59.9**
  2. Crew Vehicle 10.8

     Depot Propellant 75.7 – 88.5
- **Manifest 2 with Depot**
  1. A/B, tools, stage **40.6 – 55.0**
  2. Habitat 11.1 – 12.6
  3. Crew Vehicle 10.8

     Depot propellant 75.7– 88.5

Direct Entry

- **Manifest without Depot**
  1. Hab, Tools 27.8 – 34.6
  2. Transfer Vehicle **71.1 – 148.5**
  3. Crew Vehicle 10.8
- **Manifest 1 with Depot**
  1. Hab, tools, stage **36.6 – 43.0**
  2. Crew Vehicle 10.8

     Depot Propellant 64.0 – 133.6
- **Manifest 2 with Depot**
  1. Hab, tools, stage **23.8 – 36.9**
  2. Habitat 11.1 – 12.6
  3. Crew Vehicle 10.8

     Depot propellant 64.0 – 133.6

LEO Propellant Depot Reduces SEL2 HSM HLV Requirement from 70 – 160 t to 25 – 60 t

Human Servicing of SEL2 Telescopes Requires Enhanced Capabilities

- **Servicing capabilities from Hubble and Orbital Express**
- **Direct entry upon return requires…**
  - **Heavy Lift Vehicle (75 – 150 t) for transfer stage, or**
  - **LEO propellant transfer/depot, or**
  - **Assembly of multiple transfer stages in LEO**
- **Aerobrake for asset recovery in LEO**