Engineering & Science

Servicing and Lagrange Point Operations for Astronomy

Briefing to the
International On-Orbit
Satellite Servicing Workshop

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"Future Servicing Opportunities for Space Astronomy Facilities"

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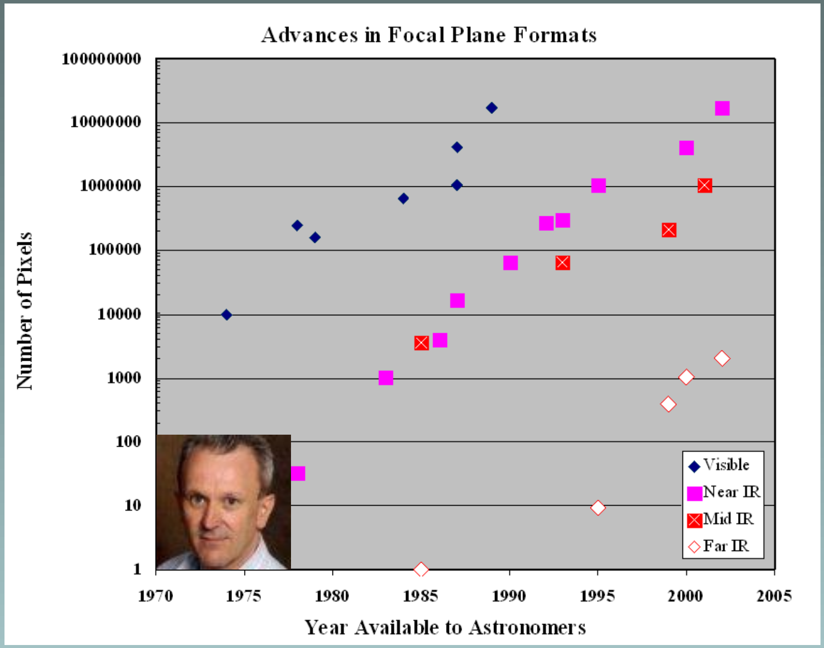
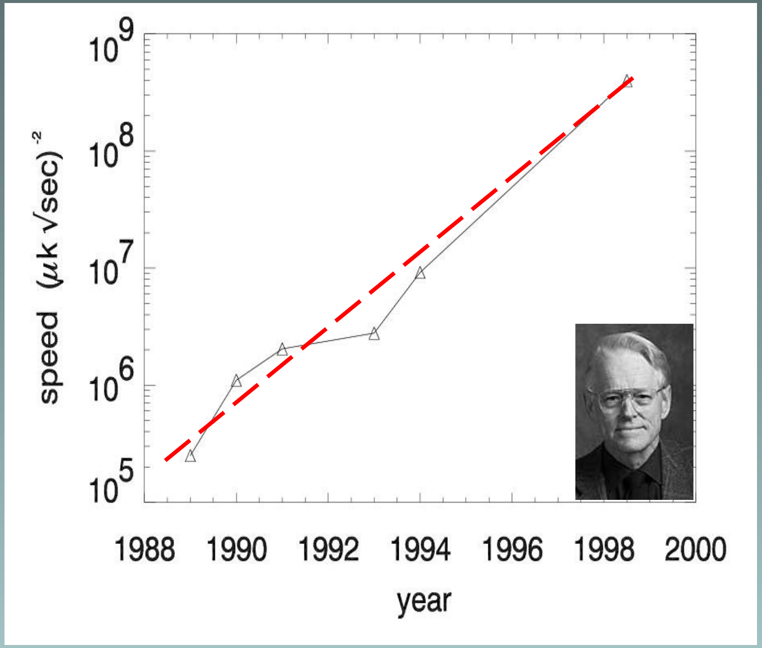
Servicing & maintenance are enabling for astronomy



Hendy's Law (focal planes)



Richard's Law (infrared)

Enabling our available telescopes to harness cutting edge detector technology give orders of magnitude improvement in capability. We do this routinely in ground-based telescopes, and we've seen done it for HST!

Why throw away a perfectly good telescope to do great things??

HST marked technology leap showing potential of free-space

- demonstrated precise pointing and tracking (0.003”)
- demonstrated wide-field diffraction-limited performance
- demonstrated precision thermal control in a difficult environment
- demonstrated high observational efficiency
- demonstrated survivability in a space environment

and, in particular

- demonstrated accessibility for servicing and maintenance

Achieved space performance with ground-based reconfigurability.
Multiplication of performance with new instruments.

All this with what is now 25 year old technology …

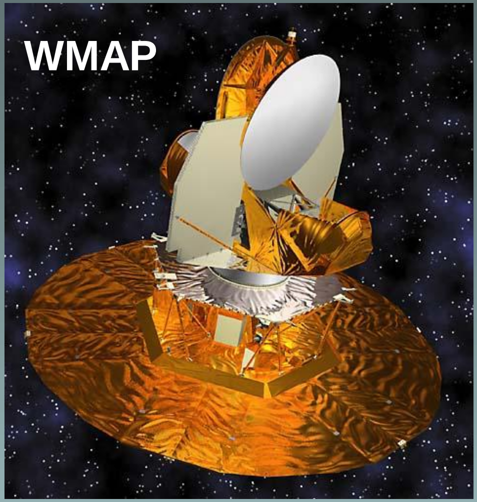
Advantages of free-space for telescopes

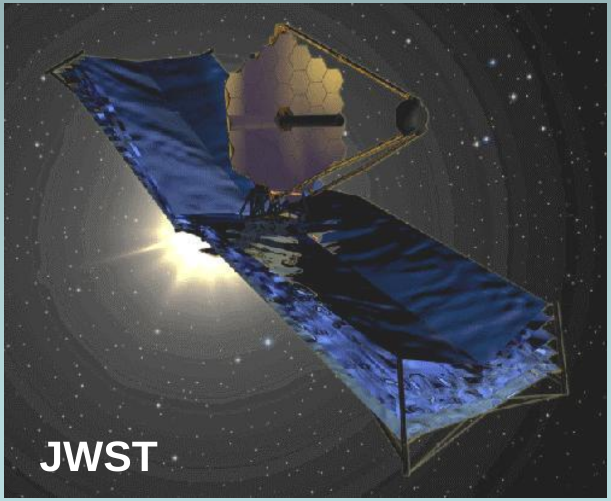
- Vacuum operation, panchromatic
- Zero-g environment; mass advantage
- Contamination free
- Low torque environment
- Low latency for Earth orbits

and, in particular, for Earth-Sun L1 and L2

- Extraordinary thermal stability
- Very low temps possible w/shields
- Extraordinarily low torques
- Continuous communications link
- Continuous solar power

Not a big surprise - in the deployment roadmap for future space telescopes, Earth-Sun Lagrange points are prime ops sites!





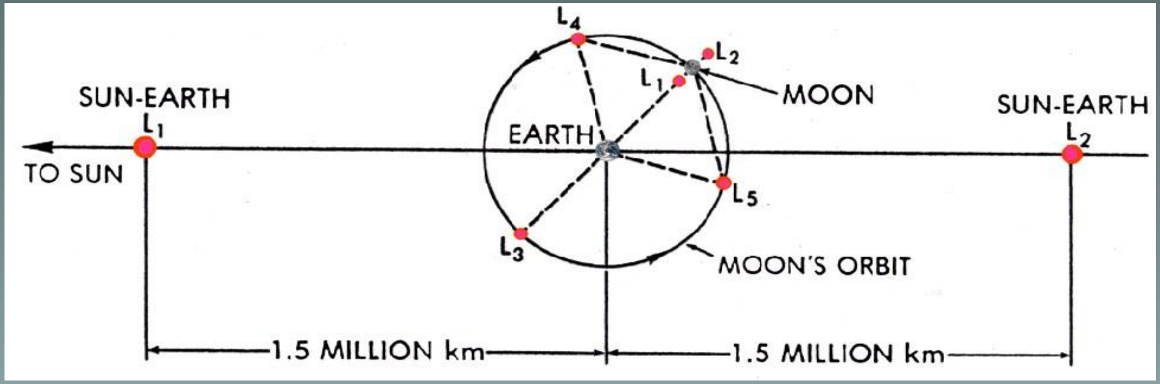
Servicing venues - a range of possibilities

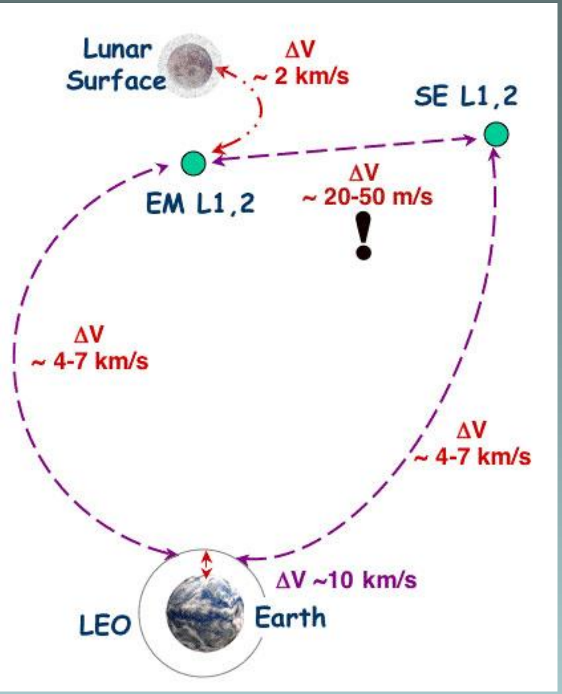
[redacted]

	LOCATION				
HUMAN PLATFORM	LEO Considerable influence from gravity and thermal shadowing by Earth	EM L1 Most benign of the options with respect to gravity and thermal disturbance effects.	Cis-lunar Might be used during transit of the observatory to ES L2	LLO Persistent thermal and gravity effects.	ES L2 Eventual operational location of most systems.
CEV with EVA	This is the Hubble model. [A]	Most likely location [B]	Possible since this is the path to be taken to the Moon.	Very likely, depending on lunar surface activity.	Excluded due to Astronaut safety concerns.
CEV with no EVA	Requires tugs, agile arms or other construction hardware. Robotic or telerobotic systems could be employed, under the control of humans.				
Dedicated and permanently manned service center	A surrogate for International Space Station. A possible replacement for the CEV options, but only if contamination issues can be addressed. [A]	Most likely location	Unlikely since no permanent human asset is expected in this location	Proposed by many architecture studies. Would also be a depot for fuel and other consumables..	
Dedicated service center with occasional human presence	Like CEV, but would be larger and not equipped to leave LEO. Also, will be smaller than ISS for cost reasons. [A]	Most likely location	Possible but is energetically inefficient because substantial propulsion is needed to maintain position.	Considerable energy penalty to get to L2	
No gateway or CEV support for testing	Testing resources must be embedded in the observatory or testing resources brought to the observatory by CEV or autonomous precision navigation. Probably precludes human roles.				

EM L1 advantageous

The interplanetary superhighway & space astronomy





- **Earth-Sun L1 & L2 are prime telescope ops sites (but kind of far away for humans …)**
- **Earth-Moon L1 & L2 are "on the way" to the Moon (but not optimal for astronomy …)**

But its EASY to travel between them! ΔV ~ 20-50 meters/sec !!

"Ops site" versus "job site". You'd rather service at some place close by!

Earth-Moon L1 as a key element in future space exploration was developed in detail by the Decadal Planning Team (c.2000).

… let’s think about that!

“ops site” *versus* “job site”

- **You don’t have to service things on-site where you use them.**
- **You want to service them close to the Earth**
  minimize control latency to Earth, escape time

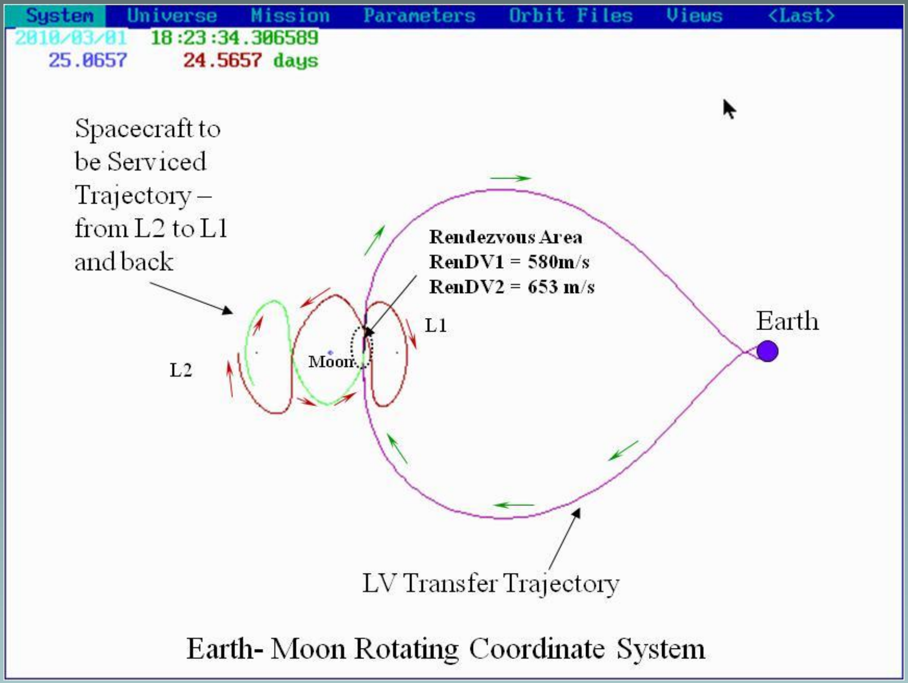
Lagrange points are essentially propulsion neutral!

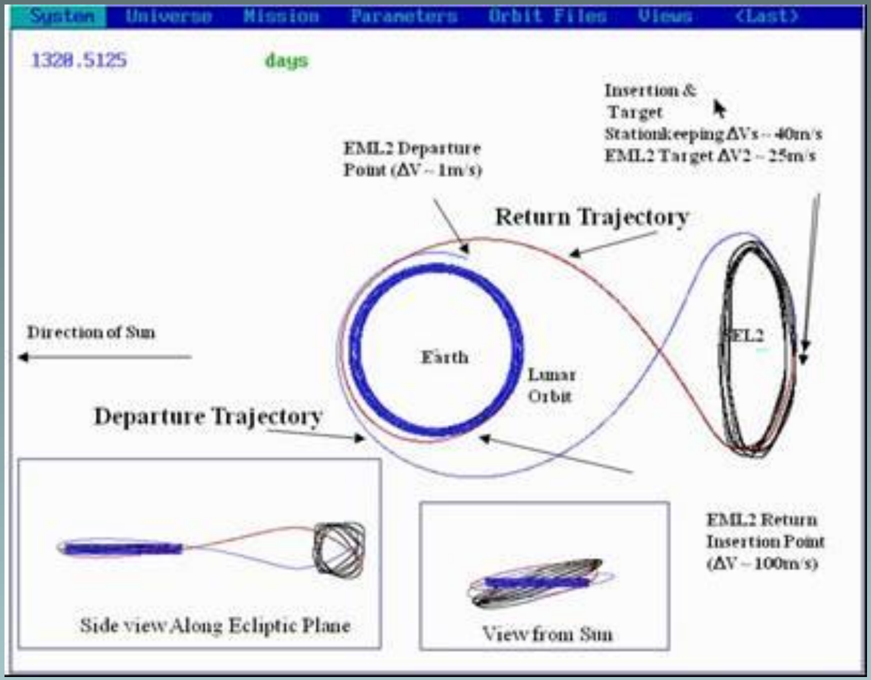
<u>Observe with the facility at the L point where observing is good.</u>

<u>Service the facility at the L point where servicing is easy.</u>

Why do servicing at Earth-Sun L2 ???

Getting there and staying there: propulsion cost





Transfer from LEO (C3 (km^2/sec^2)) ~ -1.8 to -2.2, ~5 km/s
Insert into $EML_{1/2}$ orbit: ~ 600 m/s, stationkeeping ~100 m/s/yr
Rendezvous & dock ~10 m/s (under study)

Transfers to/from ESL_2 Orbit: ~50 m/s
ESL_2 stationkeeping & etc. ~4 m/s per year

Getting there and staying there: schedule

Transfer Timing:

Xfer LEO to $EML_{1/2}$: 5 to 7 days window with ~ two week interval
Xfer $EML_{1/2}$ to SEL_2 : ~ 3-6 month transit with ~two week interval
Launch window opportunities:
any day for single transfer to $EML_{1/2,}$
2 week intervals for rendezvous to spacecraft in $EML_{1/2}$

Durations:

$EML_{1/2}$: 12 to 14 day orbital period
SEL_2 : 180 day orbital period
$EML_{1/2}$ to SEL_2 transfer: 90-120 days

Getting there and staying there: nav

<u>Orbit maintenance:</u>

Traditional

range & Doppler (USN or DSN antennae) as for LRO & etc.
… sub km position accuracy
… sub cm/s velocity accuracy

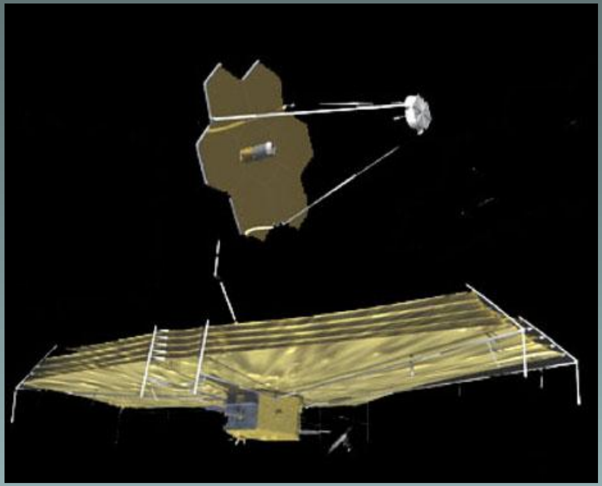
Constellation management and rendezvous:

active cross-track
distributed nav systems
radar
… sub meter position accuracy
imaging recognition systems
laser ranging
… sub cm position accuracy

SAFIR as a notional observatory for future spacecraft servicing

The Single Aperture Far Infrared (SAFIR) observatory is a general concept for a large aperture (~10m-class) cryogenic far infrared space telescope that would operate at ESL_2.

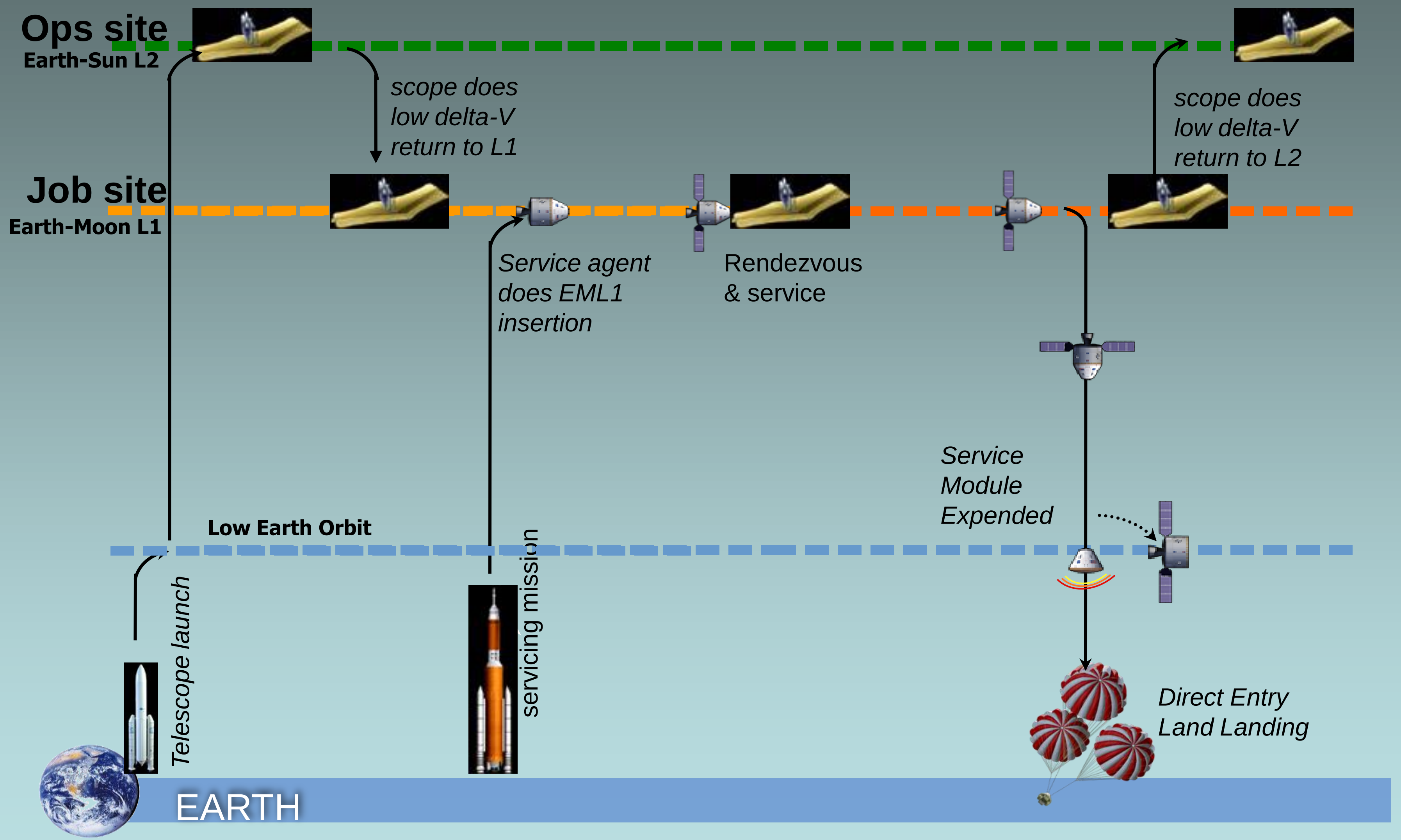
This telescope received endorsement by the 2000 Astronomy Decadal Survey as a long range priority for NASA.



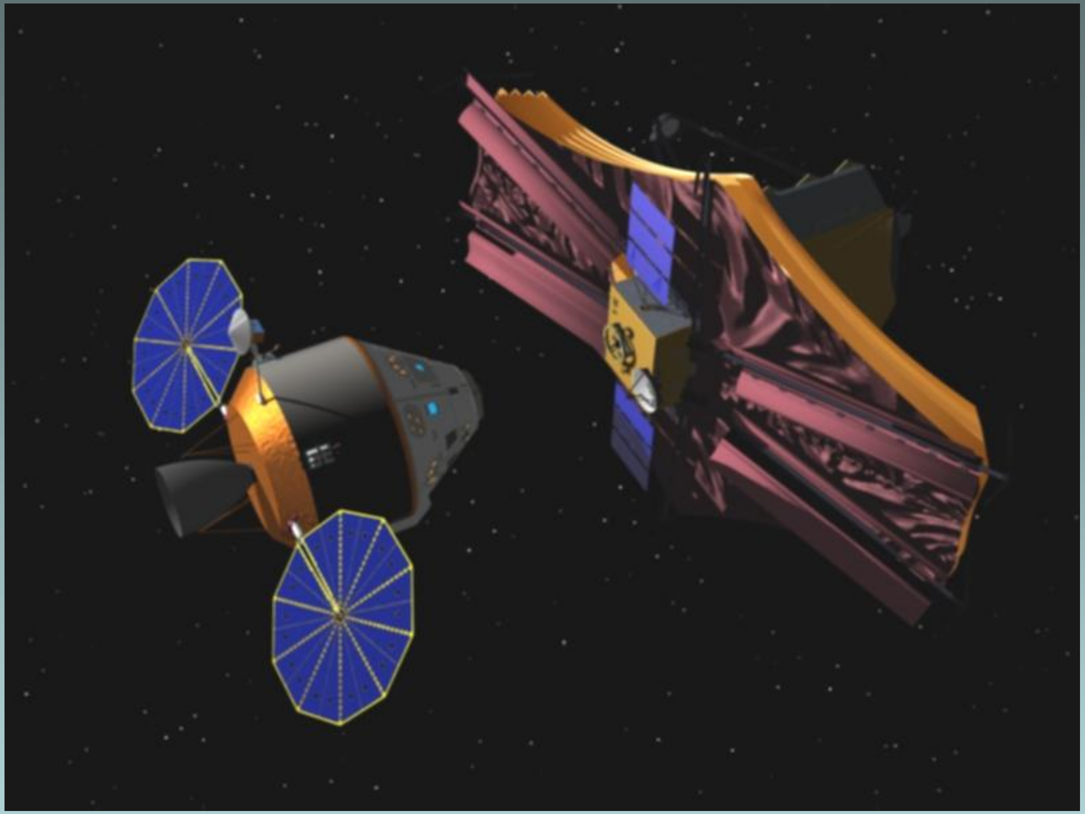
SAFIR was examined as a "Vision Mission" study in 2003-2004, and a version of the observatory adopted at that time was inspired by the JWST architecture.

This Vision Mission study specifically considered in-space servicing opportunities for SAFIR using EML1 as a job site.

Notional EM L1 servicing mission for a SAFIR - one clear path



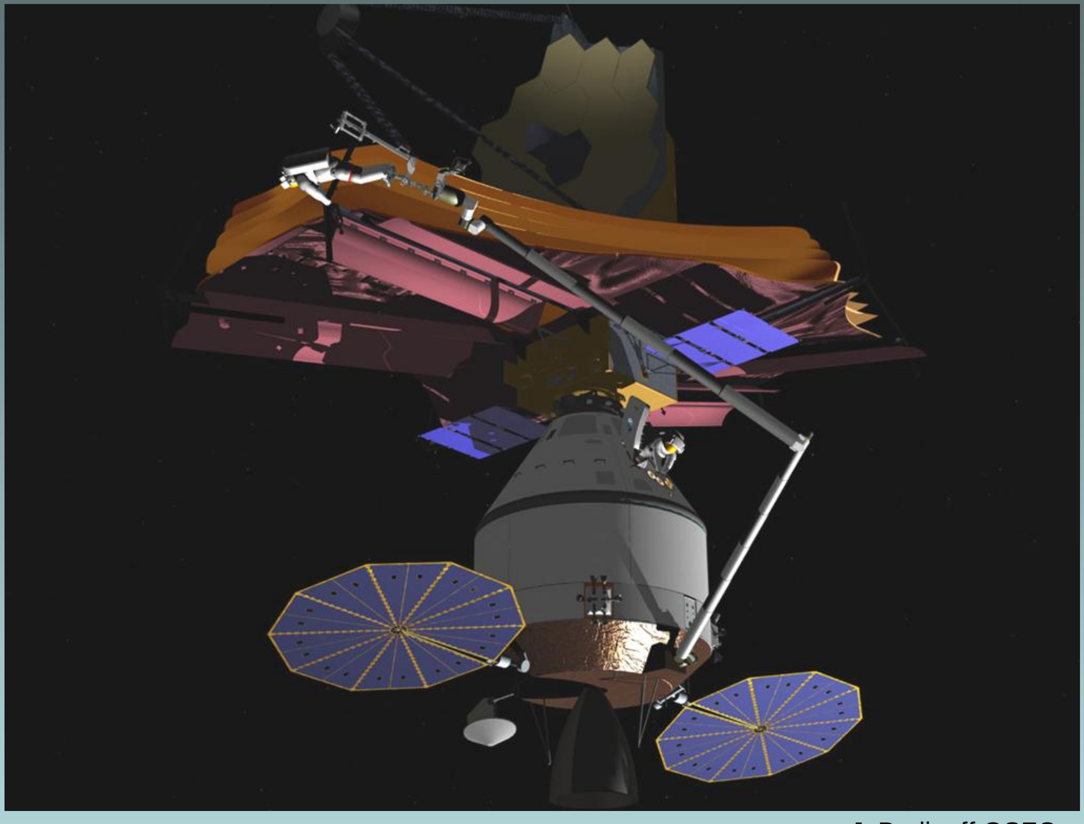
Servicing strategies for a SAFIR - I



J. Budinoff GSFC

Service vehicle approaches a SAFIR at Earth-Moon L1.
Dock on LIDS-compatible interface.

Servicing strategies for a SAFIR - II



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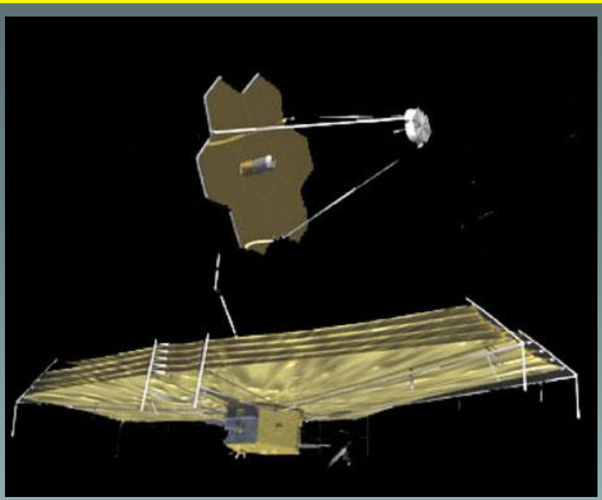
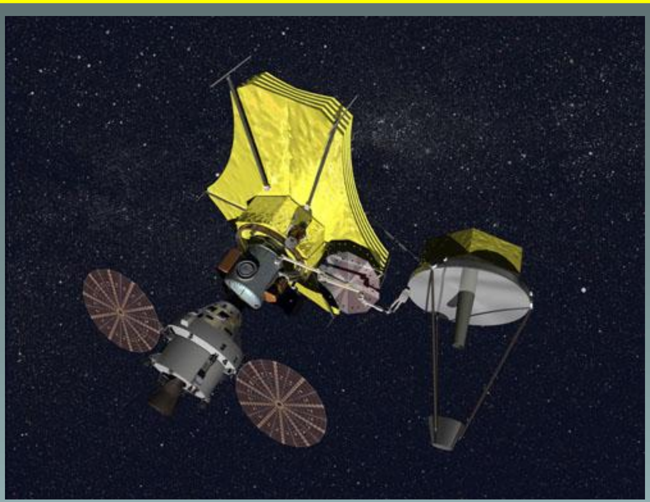
SAFIR service enabled by teleoperated deployable crane with depressurization EVA for hands-on supervision.

Servicing strategies for a SAFIR - III





Novel "boom deployed" telescope (in contrast to JWST) concept offers astronomical advantages as well as servicing advantages.

- **Adjust CM to cancel torques**
- **Larger field of regard**
- **Better thermal isolation**
- **Faster slews**

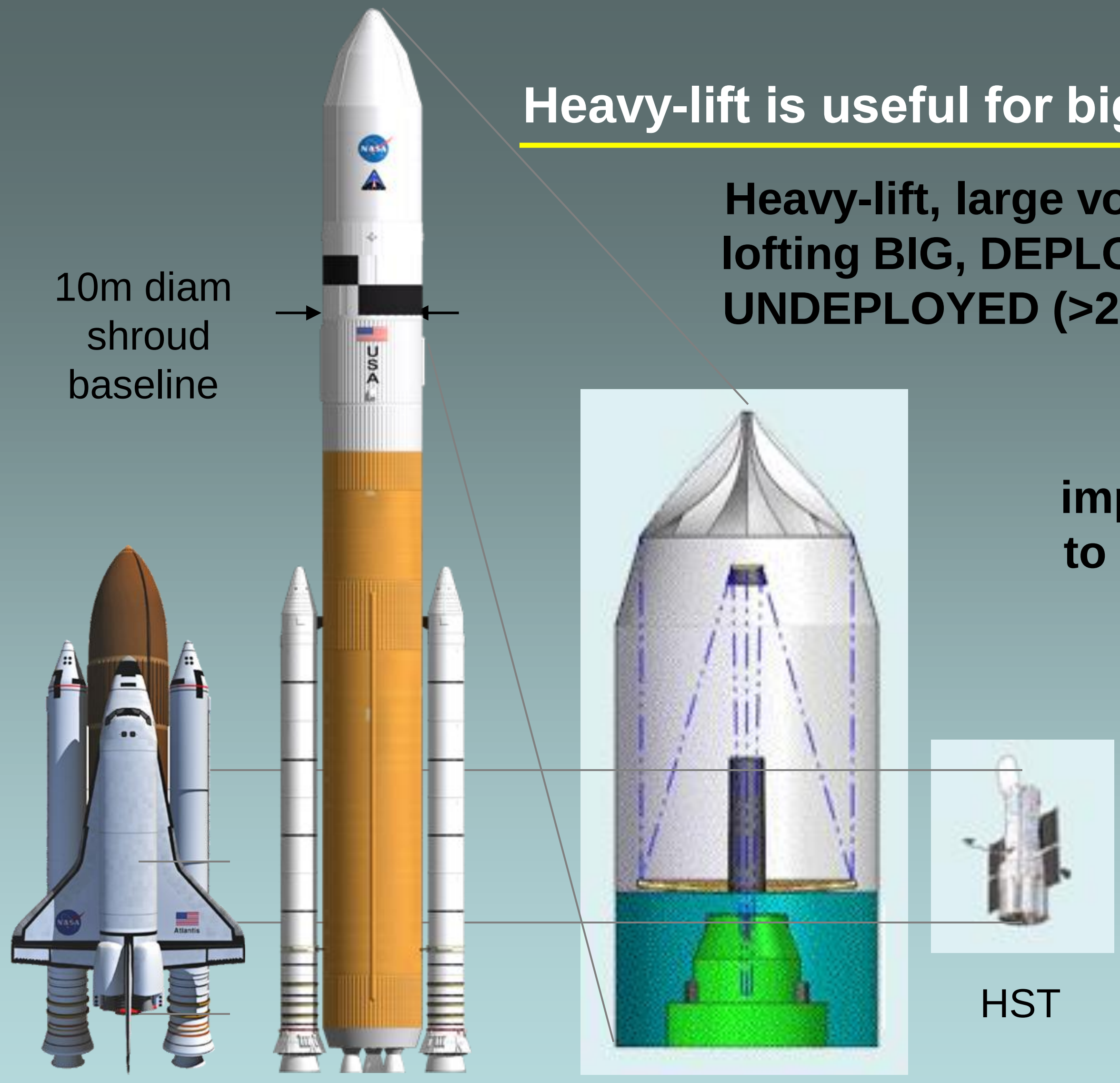
- **Present targets to Sun-side agent**
- **Maintain visual contact with target from agent vehicle**
- **Extra dexterity using boom as crane**

John Frassanito & Associates

… so picture this!

Heavy-lift is useful for big telescopes, but …

Heavy-lift, large volume options for lofting BIG, DEPLOYED (~8-10m) or UNDEPLOYED (>20m?) telescopes.



Heavy-lift offers important advantages to astronomy, but not scalable ones.

Telescope scalability means <u>construction</u>

… and that means servicing

Steps forward (policy, management, engineering)

- **Build on hard-won expertise in space servicing and construction. It's something we're really good at, at least in LEO.**
- **Assess relative importance of astronauts and telehumans for observatory servicing in view of rapidly changing technology.**
- **Develop large telescope concepts that can best accommodate remote servicing.**
- **Create TRL-raising opportunities for servicing future Lagrange point astronomy missions doing proof-of-concepts on ISS.**
- **Devise strategies for modularity, interface commonality, contamination control, accessibility, that are beneficial to large space telescopes.**
- **Establish Lagrange points as enabling "destinations" (e.g. DPT2000). Do DRM for EML_1 servicing of an ESL_2-based notional observatory.**