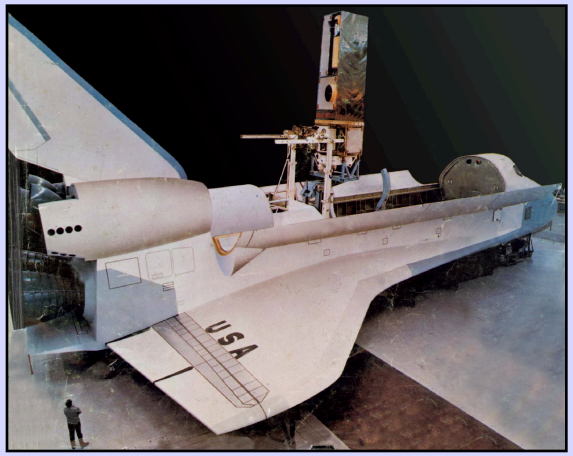
Hubble Space Telescope Servicing Mission 4

"The Technology Leap in Satellite Servicing"

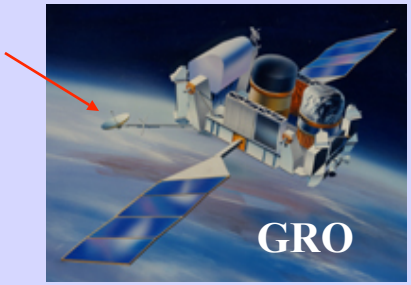
Lessons from *HST*: Maximizing the value of large investments

"The Technology Leap in Satellite Servicing"

From 1976 to 1984



From 1985 to 2002



From 2008 -

?

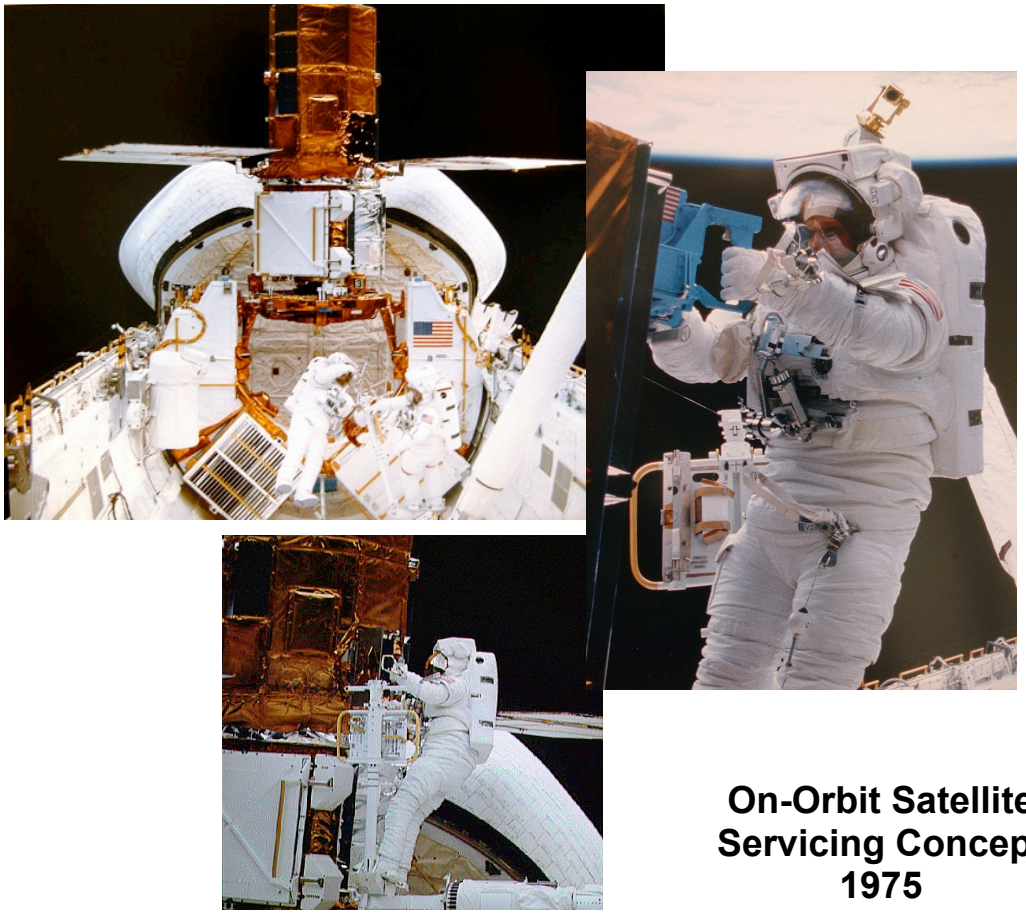
"It is dumb to launch complicated, expensive telescopes into space that cannot be serviced."

Michael Griffin
NASA Administrator
February 11, 2008

Can we continue the history of satellite servicing?

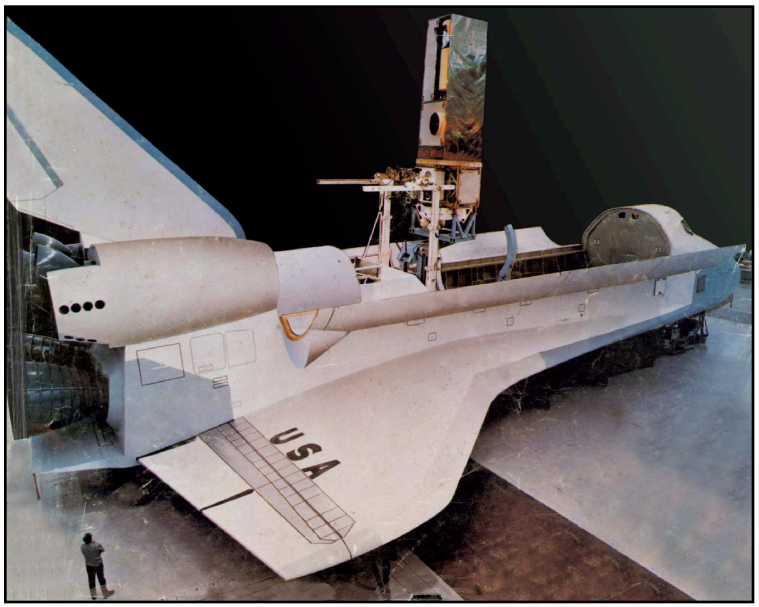
Solar Max Repair (1984)

The first capture with the arm was during the very first on-orbit servicing mission in history—the Solar Max Repair Mission. The value of on-orbit repair, Center partner- ships, and standardized modularity suddenly became quite high.



On-Orbit Satellite Servicing Concept 1975

GSFC partnered with JSC in 1972 at the start of Space Shuttle development, following the Apollo era. From this partnership came a lot of good things…



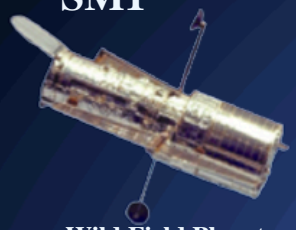
To date: 9 servicing missions after Solar Max

"Architecture is the single most significant aspect of servicing costs."

HUBBLE MISSIONS

Launch!

SM1

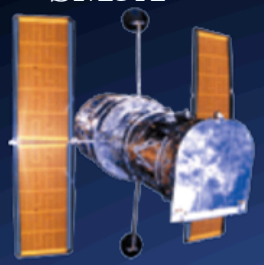


Wild Field Planetary Camera 2
COSTAR
Gyros
Solar Arrays

SM2

Imaging Spectrograph
Near Infrared Camera
Fine Guidance Sensor

SM3A



Gyros
Advanced Computer
Fine Guidance Sensor

SM3B

Advanced Camera
Solar Arrays
Power Control Unit
NICMOS Cooling System

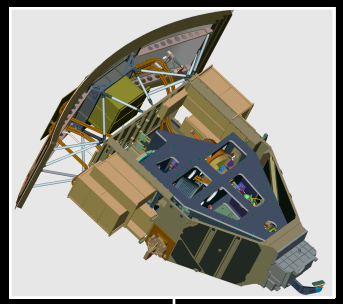
SM4

Cosmic Origins Spectrograph
Wide Field Camera 3
Fine Guidance Sensor
Aft Shroud Cooling System
Batteries
Gyros
Repair of STIS and ACS
Addition of Soft Capture Mechanism

De-Orbit Mission

1990 1993 1997 1999 2002 2008 2013

Servicing Mission 1, 1993



WFPC2

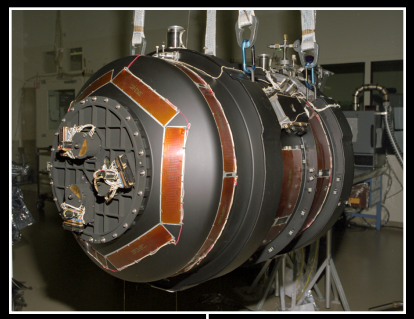
New instruments, New Discoveries

- ✓ Age of the Universe
- ✓ Birth and Death of Stars
- ✓ Formation of Planets and Stars

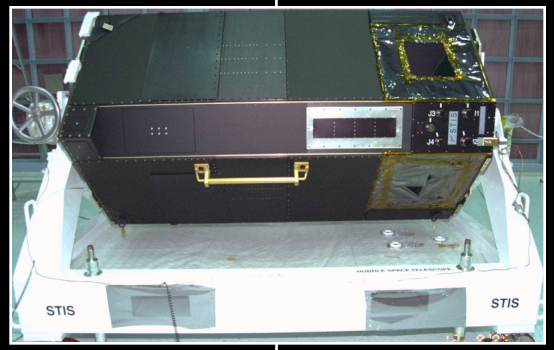
Servicing Missions

SM1

Servicing Mission 2, 1997 and Servicing Mission 3a, 1999



NICMOS (1–2 μm)



STIS (=40X Original Spectrographs)

New instruments, New Discoveries

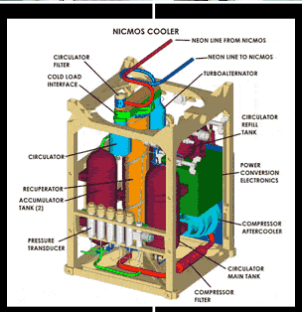
- ✓ Proof of Black Holes
- ✓ Supernova 1As
- ✓ Accelerating Universe
- ✓ Hint of Dark Matter, Dark Energy
- ✓ Hubble Deep Field

Servicing Missions SM1 SM2– SM3A

Servicing Mission 3B, 2002

ACS
(=10X WFPC2)

NICMOS/NCS

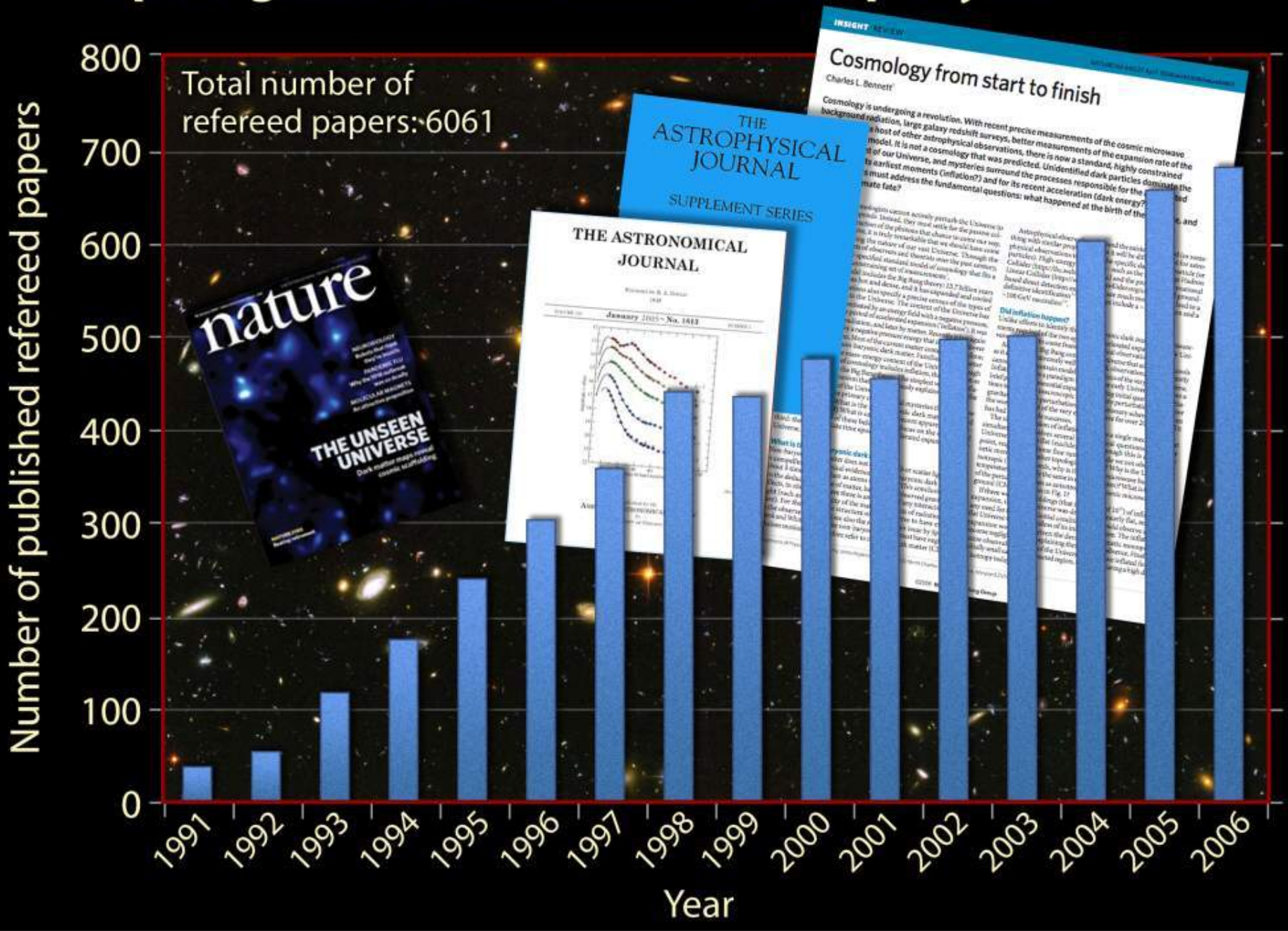


Servicing Missions: SM1 SM2 SM3A SM3B

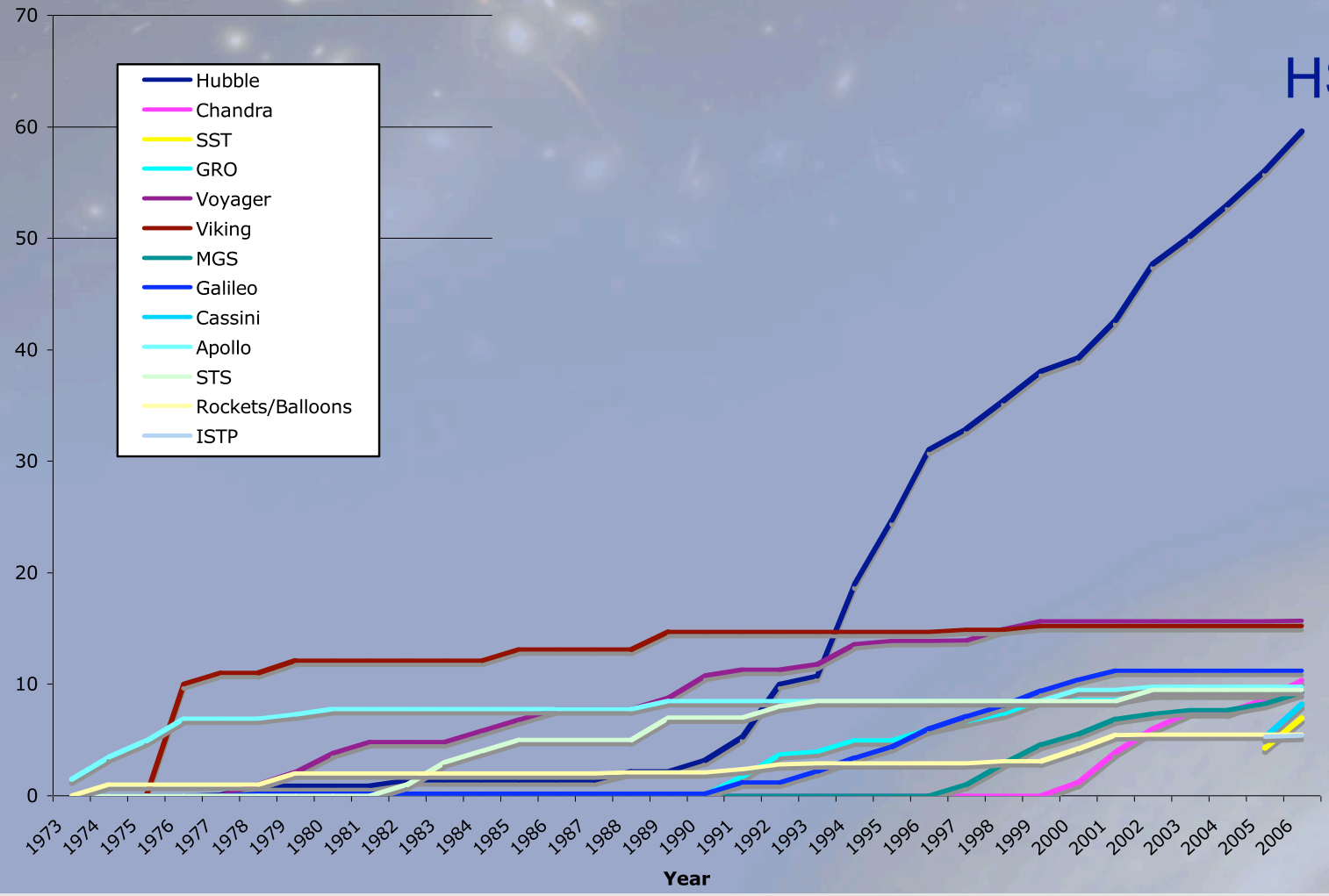
New instruments, New Discoveries

- ✓ Hubble Ultra Deep Field
- ✓ Evolution of Galaxies
- ✓ Confirmation of Dark Energy Principle
- ✓ First Direct Mapping of Dark Matter
  Survey of 160,000 stars, 26,000 light years away – 16 of which have Jupiter-size Planets
- ✓ First Detection of an Organic Molecule in the Atmosphere of a Jupiter-like planet in the Milky Way Galaxy
- ✓ Detected over 500 extremely old proto galaxies formed just after the Big Bang. One object emitted light after 700 million years

Papers generated from HST data per year

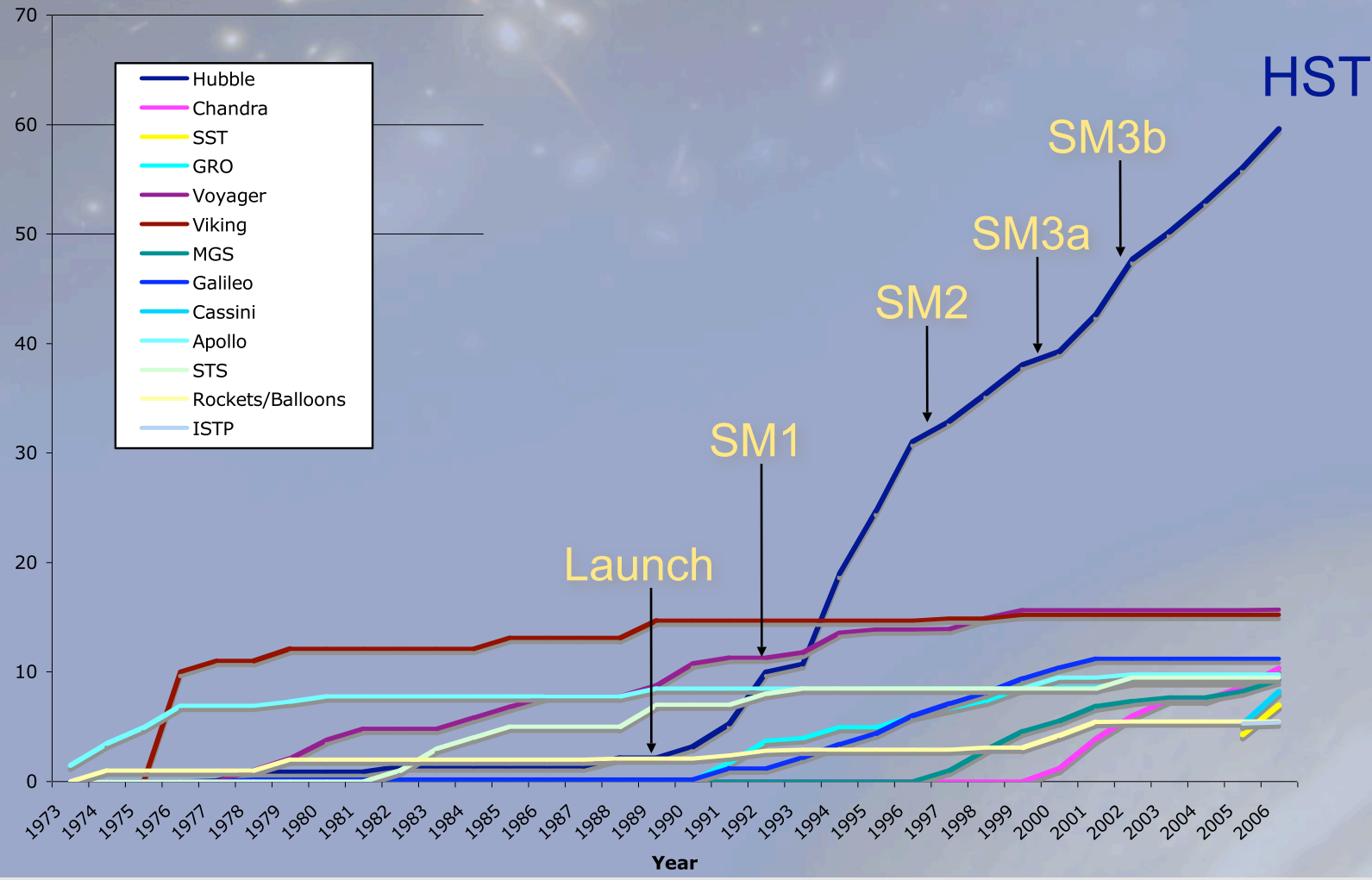


The evolving impact of Hubble, NASA's metric: Science News cumulative



NASA's space science impact is outstanding, and the *cumulative impact* of *HST* to *Science News* top stories has had no peer in the last decade

The evolving impact of Hubble, NASA's metric: Science News cumulative



NASA's space science impact is outstanding, and the *cumulative impact* of *HST* to *Science News* top stories has had no peer in the last decade

Servicing Mission 4, 2008

WFC3
(=25X NICMOS)

COS
(=20X STIS)

New instruments, New Discoveries

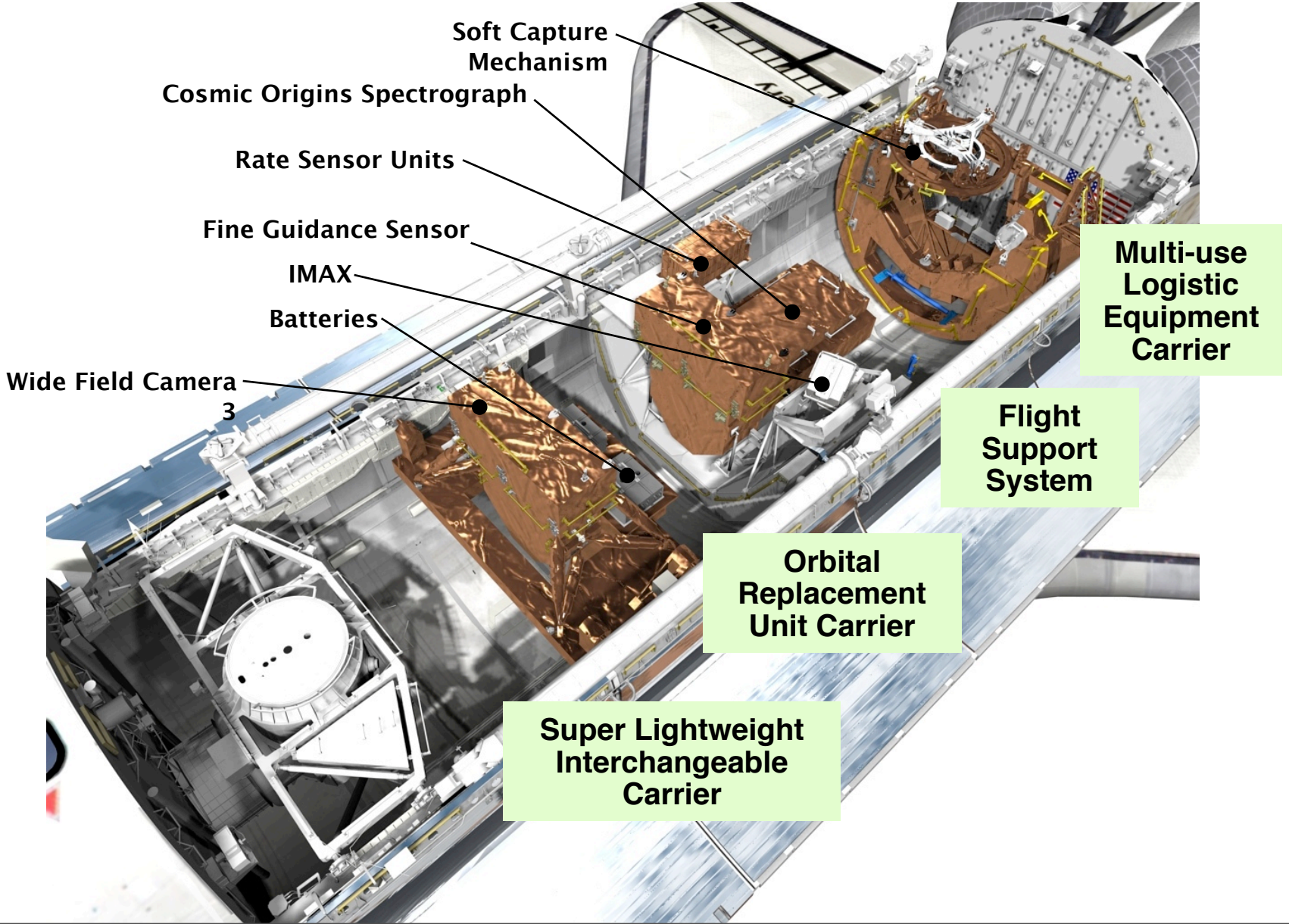
✓ TBD

Servicing Missions SM1 SM2 SM3A SM3B **SM4**

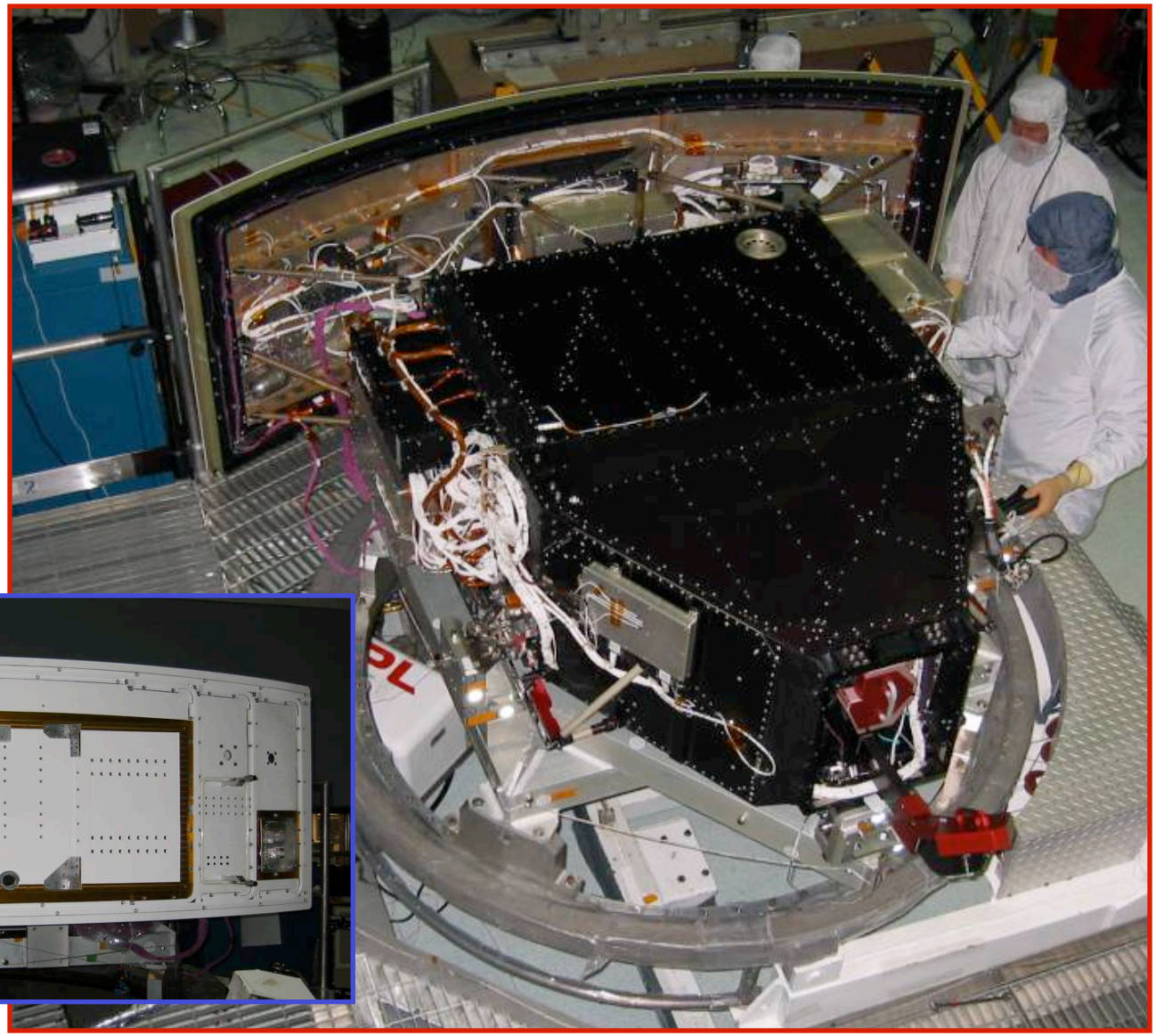
"Each and every mission flies with the latest detector technology"

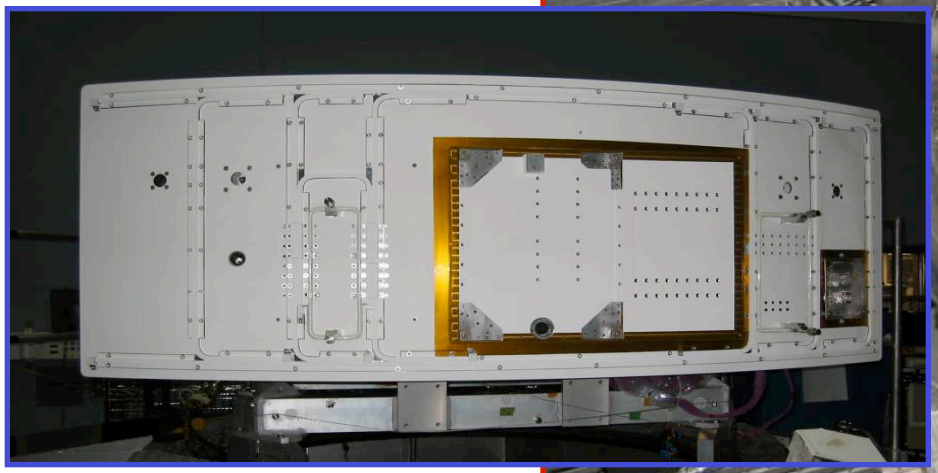
HST Servicing Mission 4

(SM4) Configuration



Wide Field Camera 3 (WFC3)



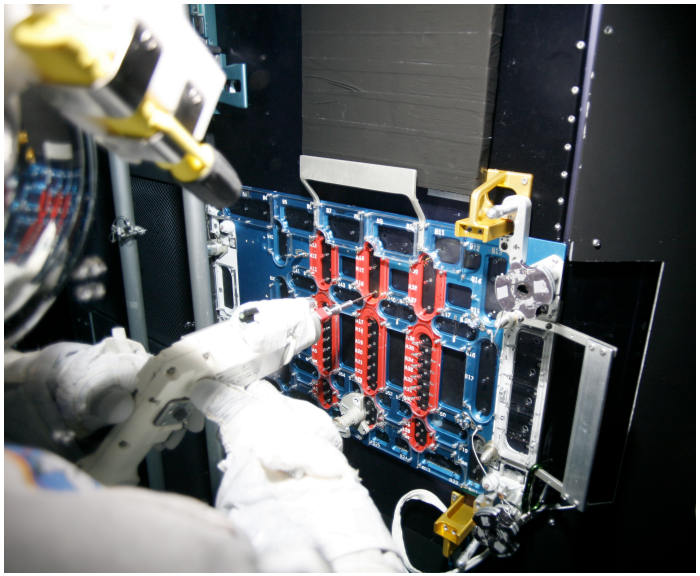


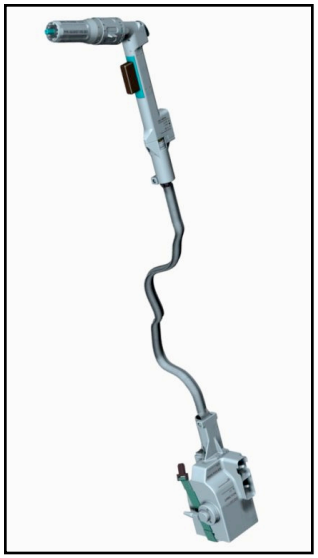
SM4 Super Lightweight Integrated Carrier (SLIC)

“First all-composite carrier for STS makes 4 scientific instrument renewals on SM4 possible.”

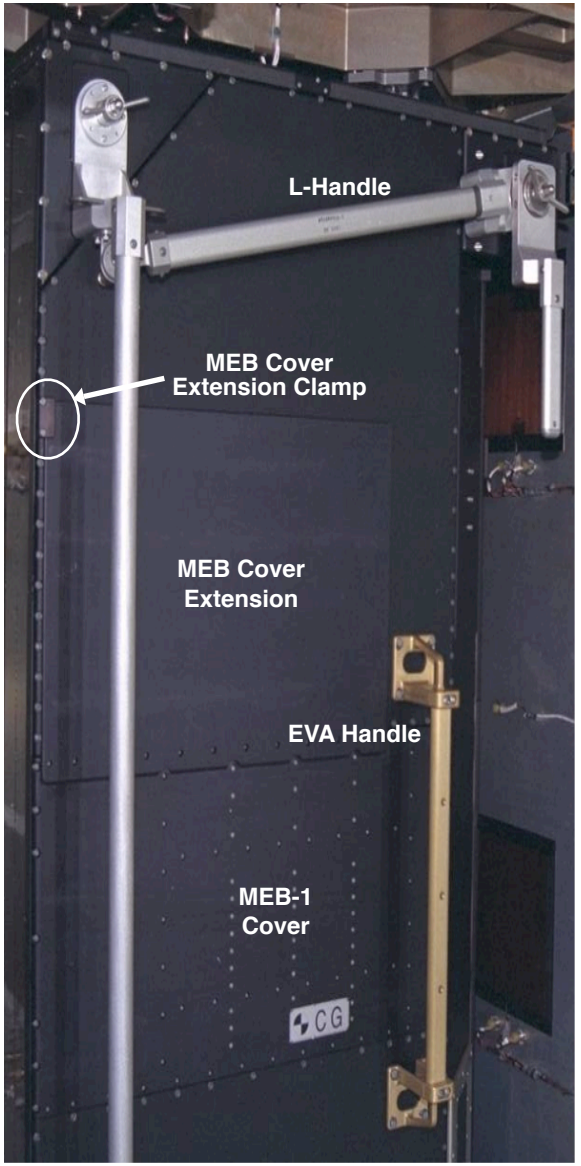
Space Telescope Imaging Spectrograph (STIS) Repair

Flight STIS Instrument





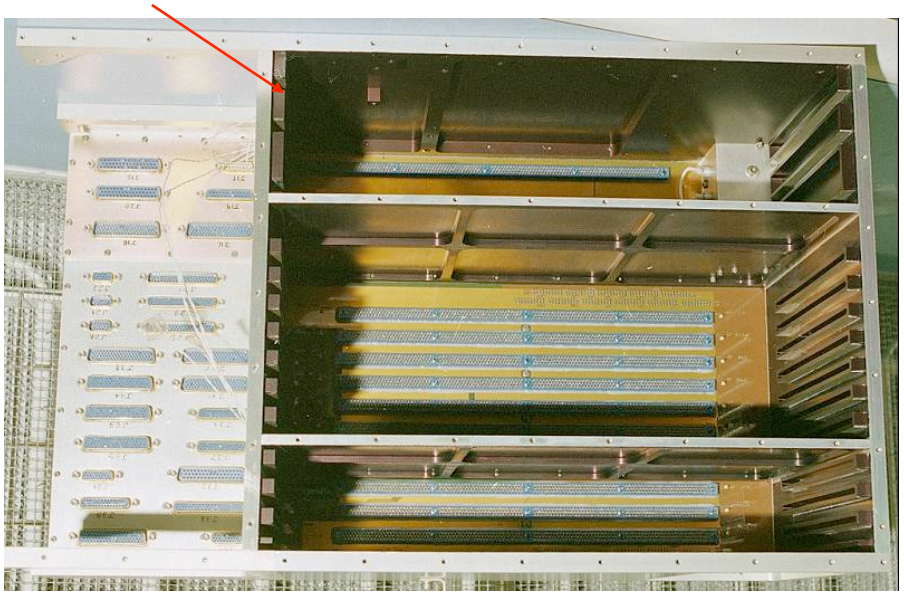
STIS Fastener Capture Plate and Mini Power Tool

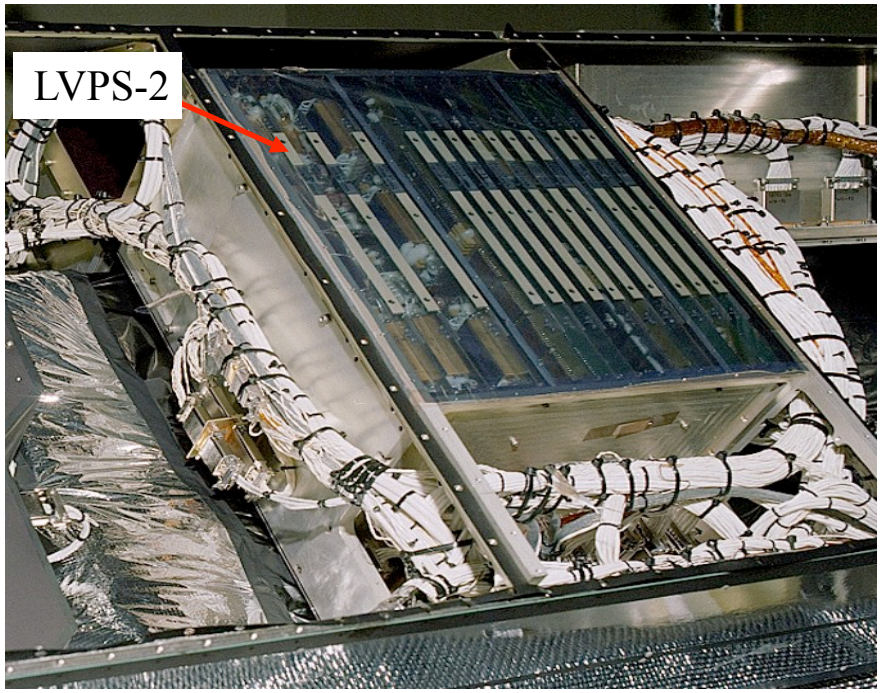


STIS Closeup

"EVA fatigue elimination is achieved through power tools."

Replacing the STIS LVPS-2 Power Supply Card

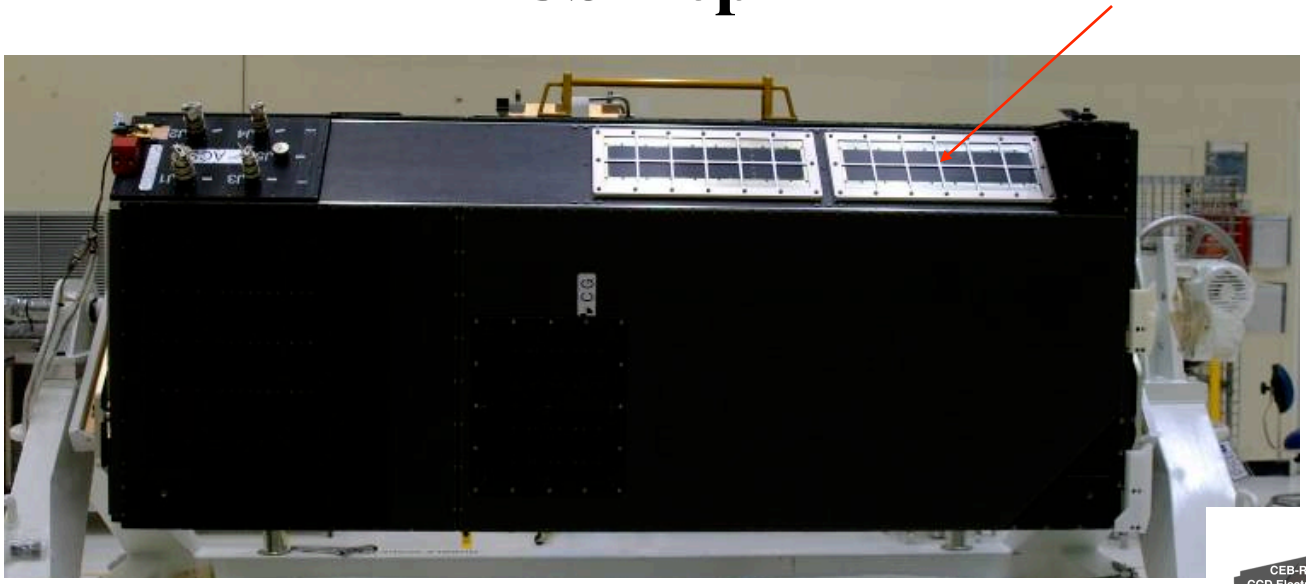




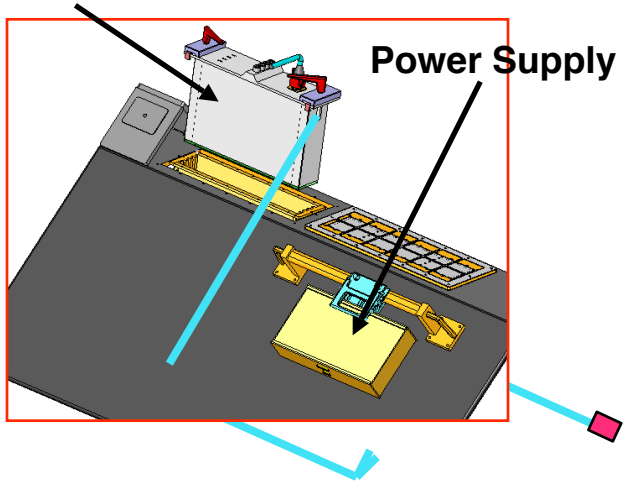
MEB1 with Cover Removed

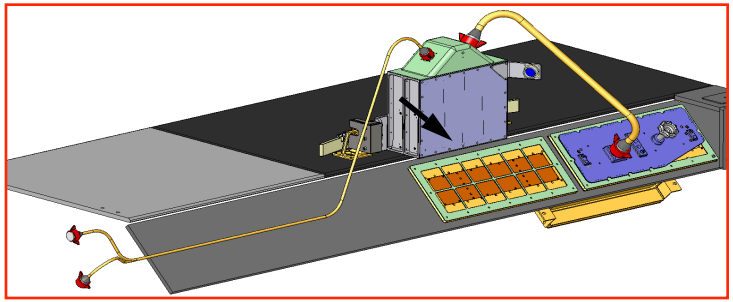
After removing the STIS cover, the EVA crew will remove LVPS-2, replace it with the new power supply card, and install a new, EVA-friendly cover

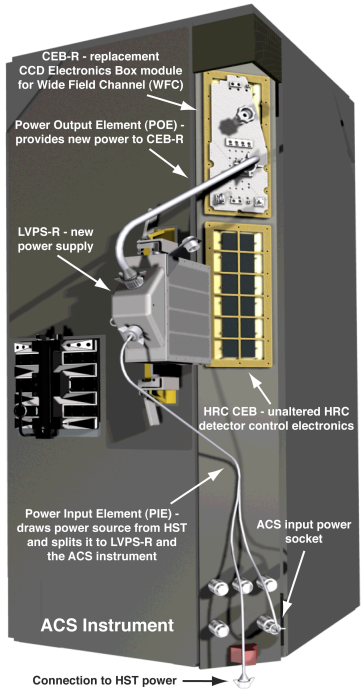
ACS Repair



CEB Replacement Module

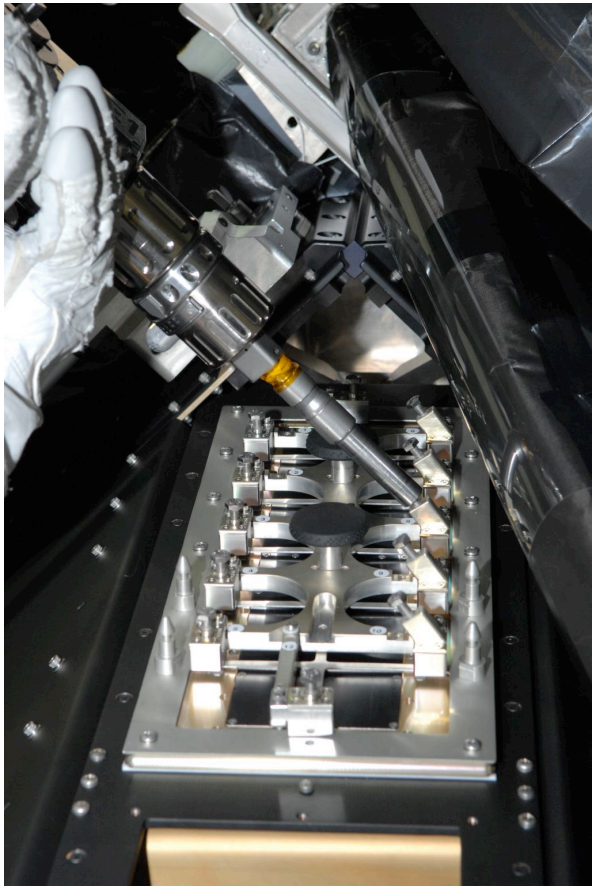




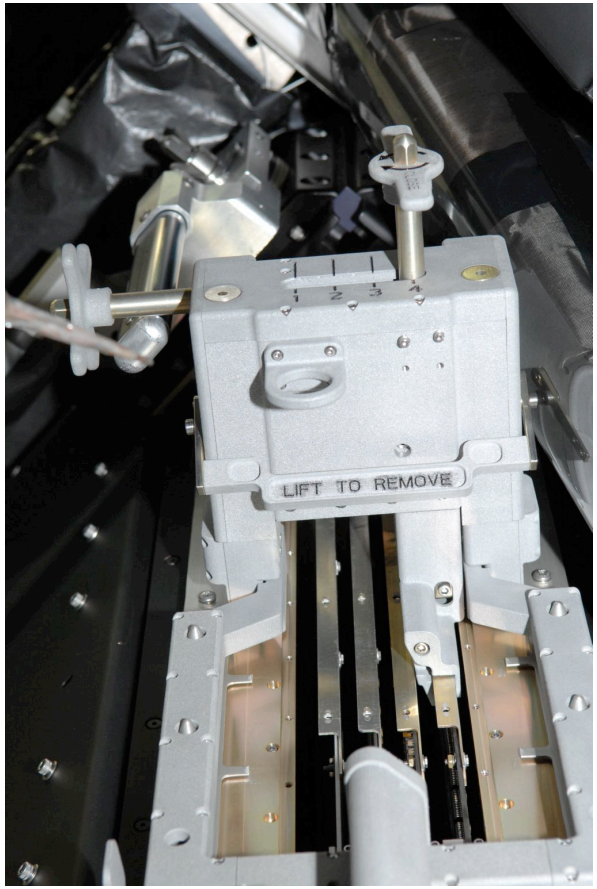


"ACS Repair made possible by experienced astronauts and smart tools."

ACS Repair Development

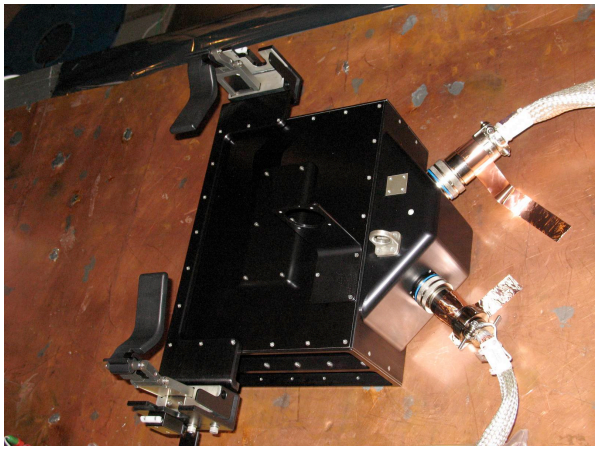


Grid Cutter 1G Development



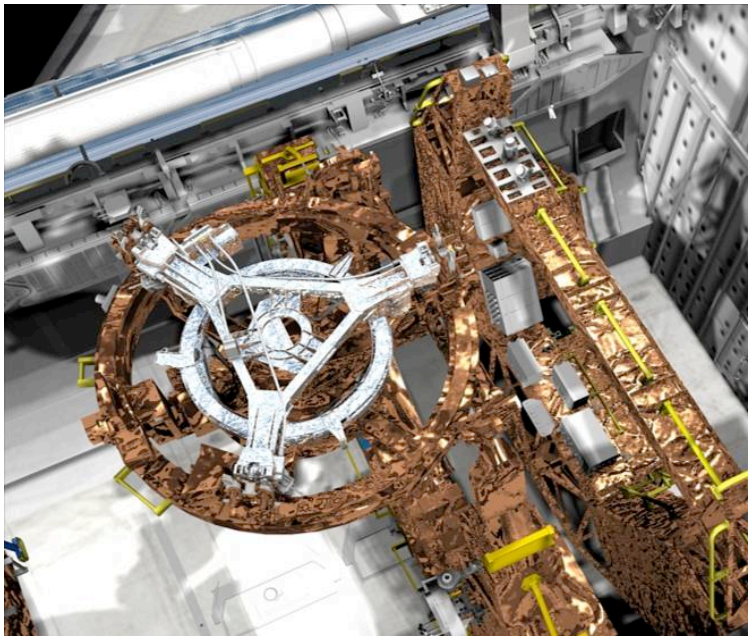
Card Extraction Tool Development

ACS-R LVPS Flight EMI Test

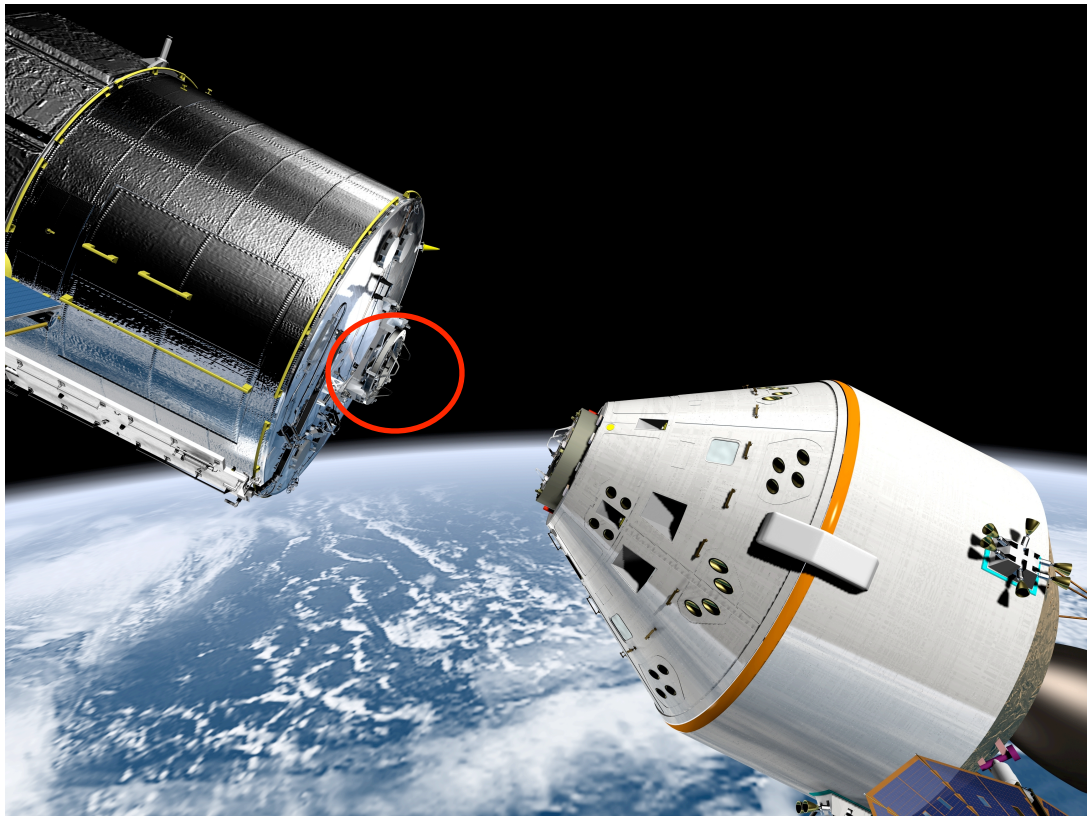


"The secret behind EVA servicing capabilities are the tools."

Flight Support System



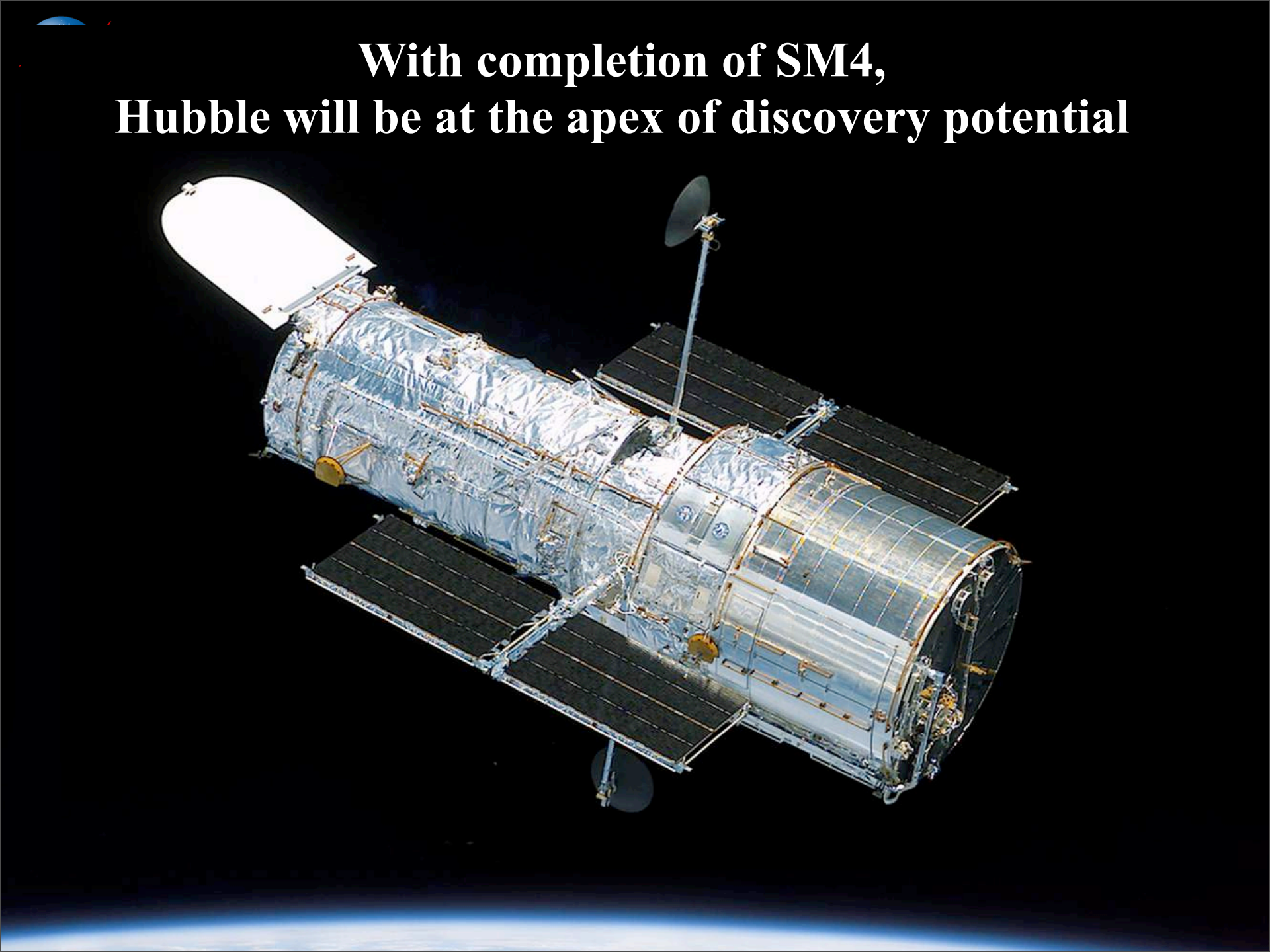
SCM (shown in white for contrast) mounted to FSS: BAPS pivoted up, ready for HST berthing



"Plan for the future."

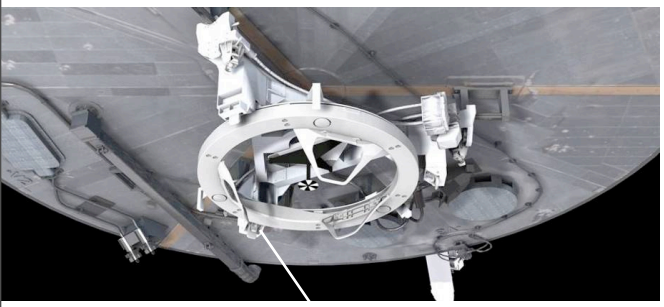
"Think ahead with hardware on each new NASA mission."

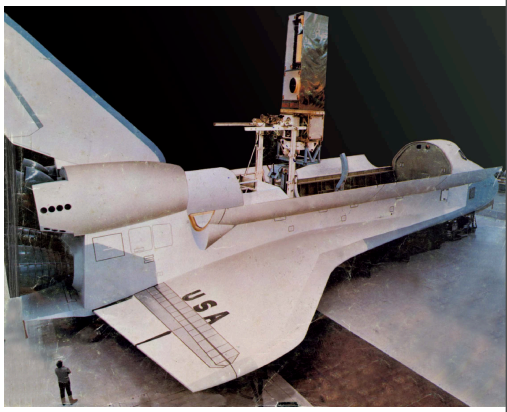
With completion of SM4, Hubble will be at the apex of discovery potential



Where Do We Go From Here?

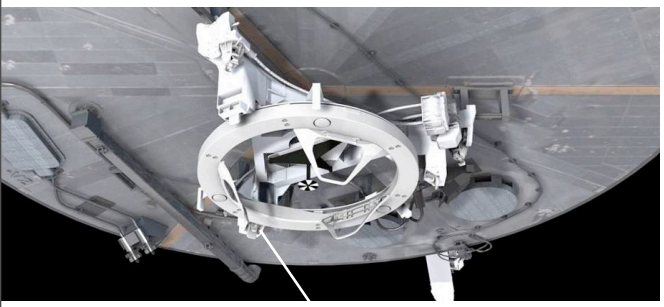
Concept for CEV support to HST Deorbit via telerobotic operation of a free-flying robot

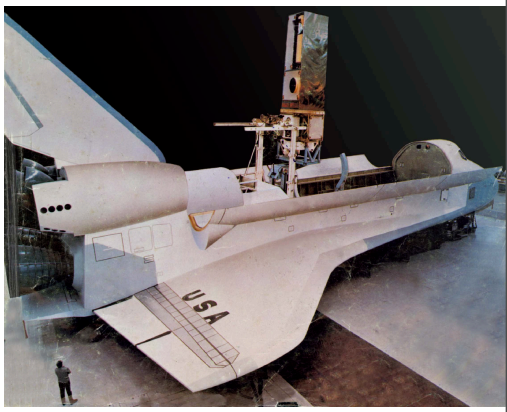




“History has demonstrated that now is the time to get started.”

Concept for CEV support to HST Deorbit via telerobotic operation of a free-flying robot

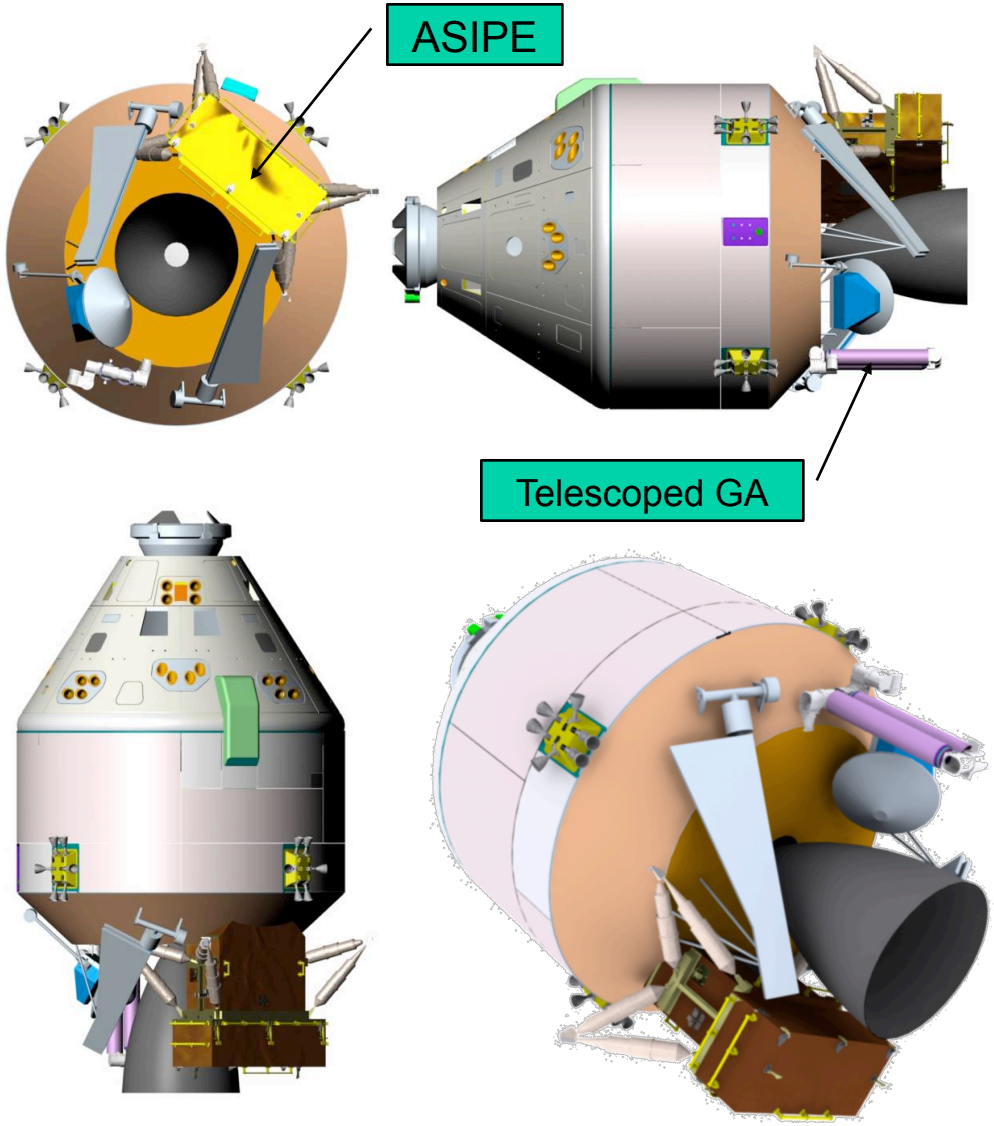




“History has demonstrated that now is the time to get started.”

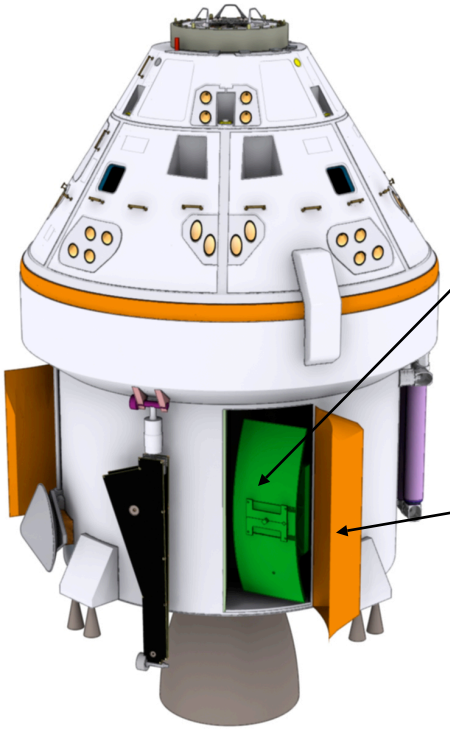
Concept for Crewed Orion Servicing Vehicle

- We can barely squeeze a full ASIPE onto the CEV SM aft fairing between bulkheads
  - Modify load isolators
  - Modify lid assembly (smaller for FGS only)
- Telescoping GA & other hardware can be mounted opposite the ASIPE and around perimeter



"Will we be ready for the future?"

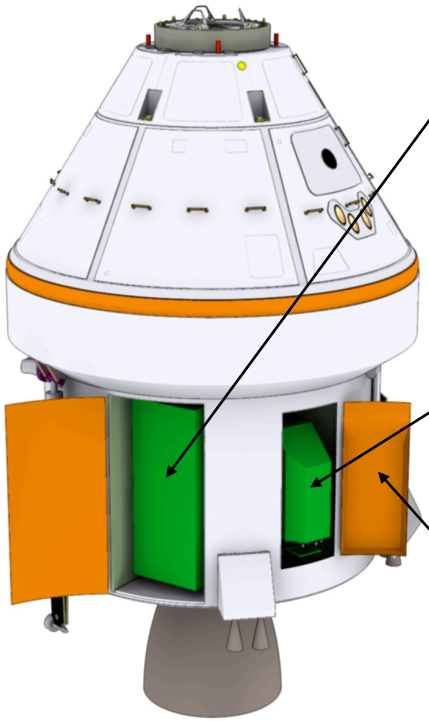
CEV Stowage Configurations



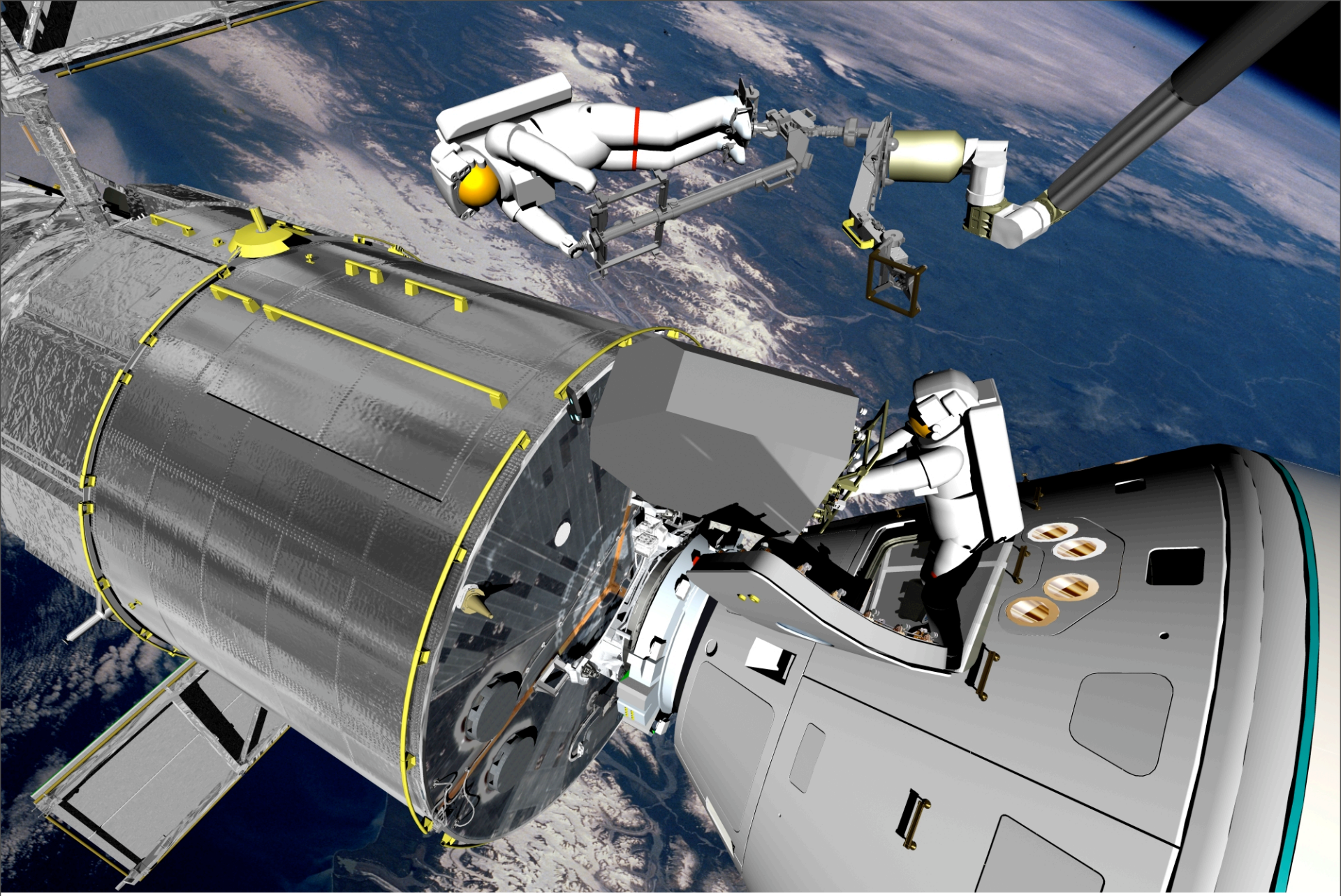
WF4 Stowage

- Potential stowage for WF4 instrument in SM bay
- WF4 breaks OML by ~18”
- Clamshell Door with bump-out to enclose instrument

Axial SI & FGS Stowage

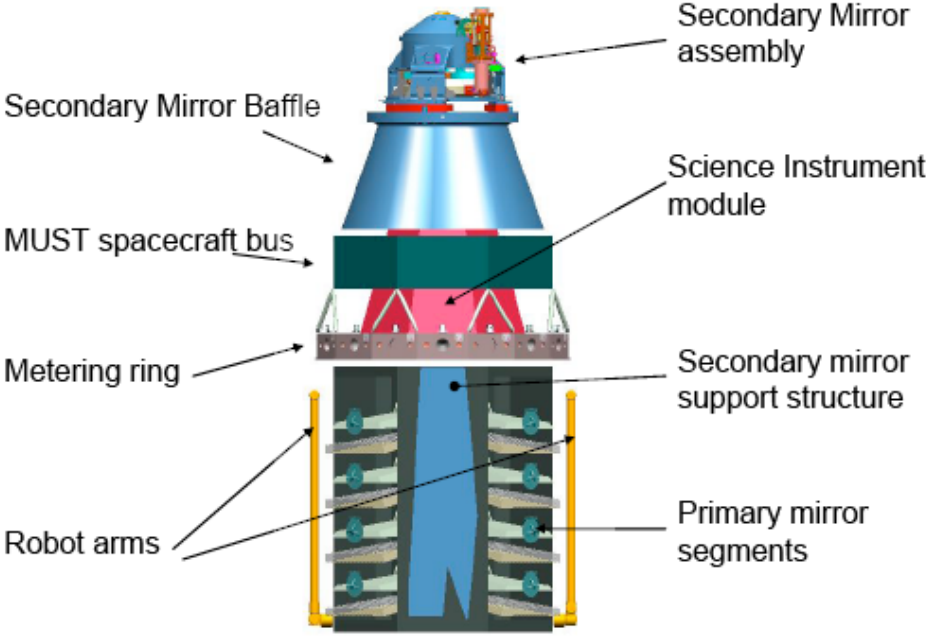


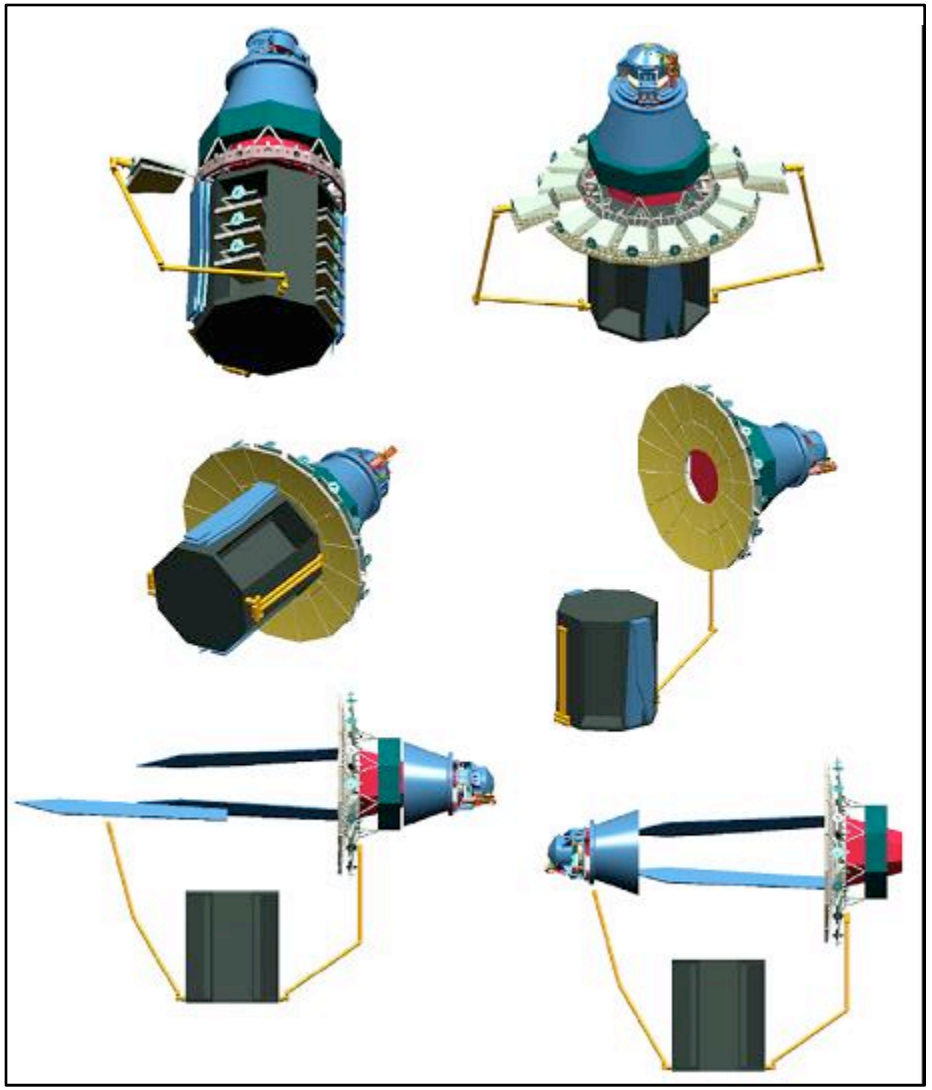
- Axial SI and FGS could be launched in same bay of SM but require individual doors
- Potential stowage for Axial SI in SM bay
- Axial SI in “standup” position does not break OML but has tight removal clearance
- FGS stowed in same bay opposite of Axial SI
- FGS breaks OML by ~4”
- Clamshell Door with bump-out to enclose FGS



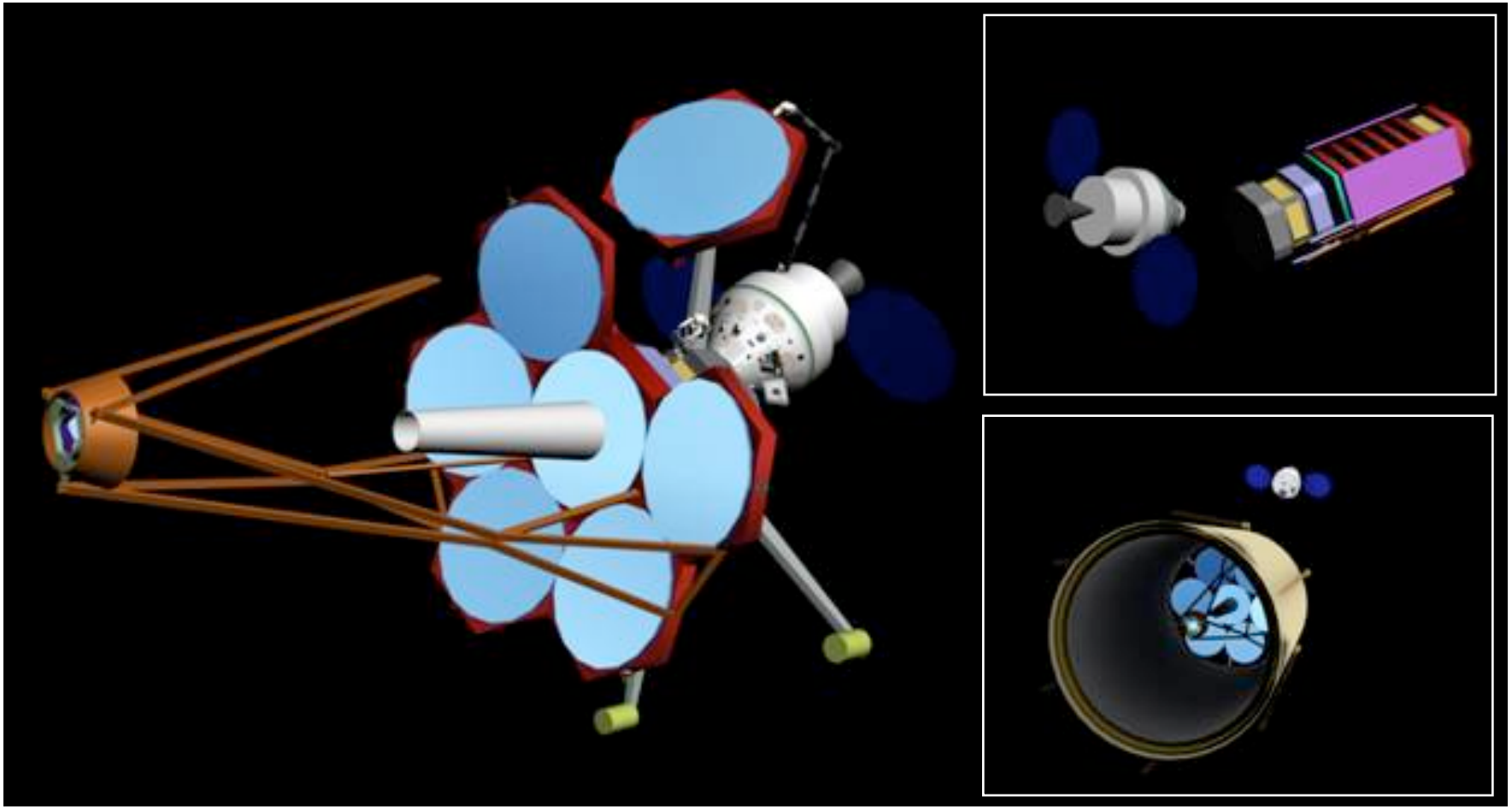
“The future needs near-term pathfinders to keep the vision clear.”

“All of NASA must work together to take part in the vision.”
-- Humans, transportation, and science --

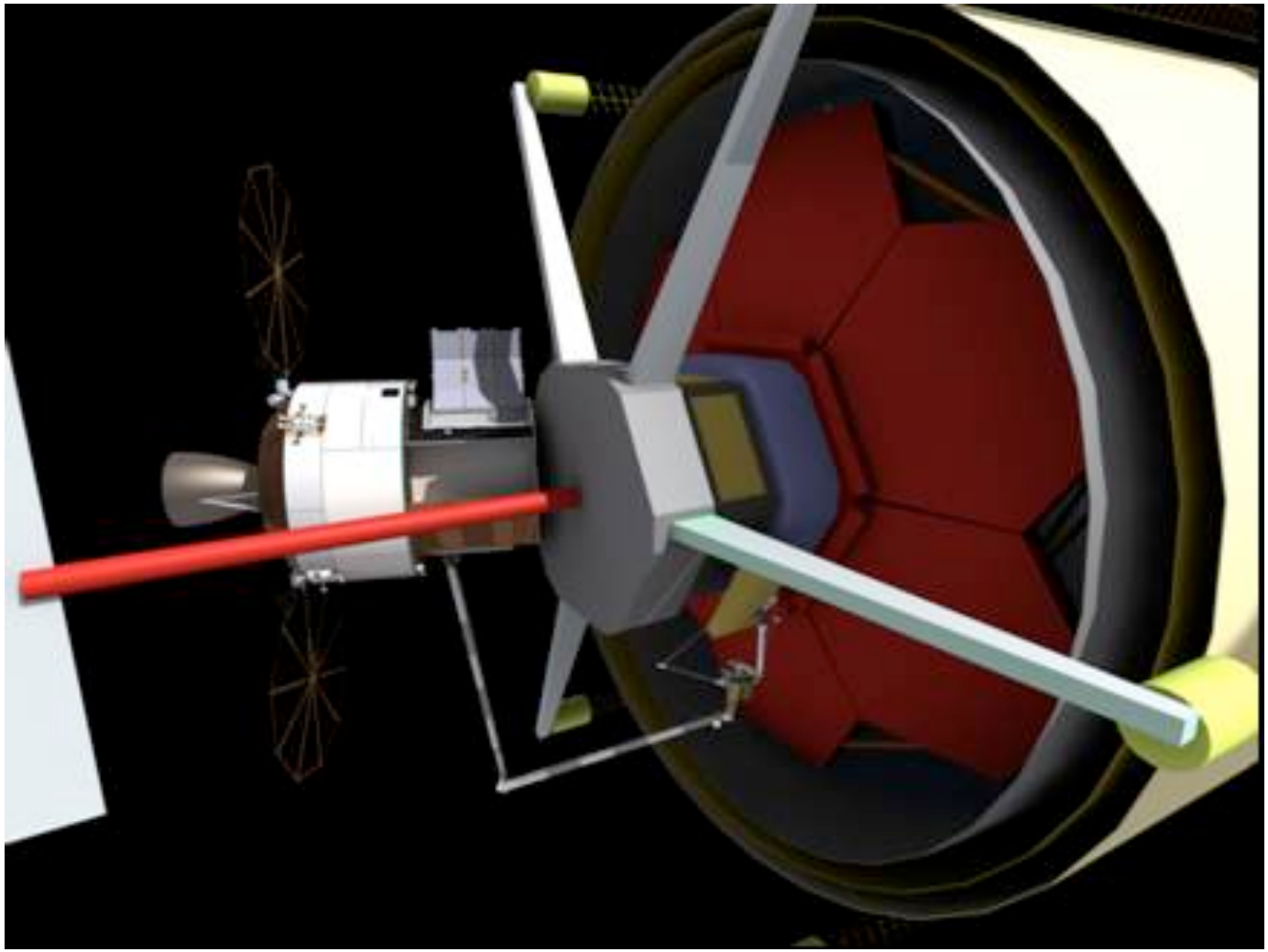

Secondary Mirror assembly
Secondary Mirror Baffle
Science Instrument module
MUST spacecraft bus
Metering ring
Secondary mirror support structure
Robot arms
Primary mirror segments



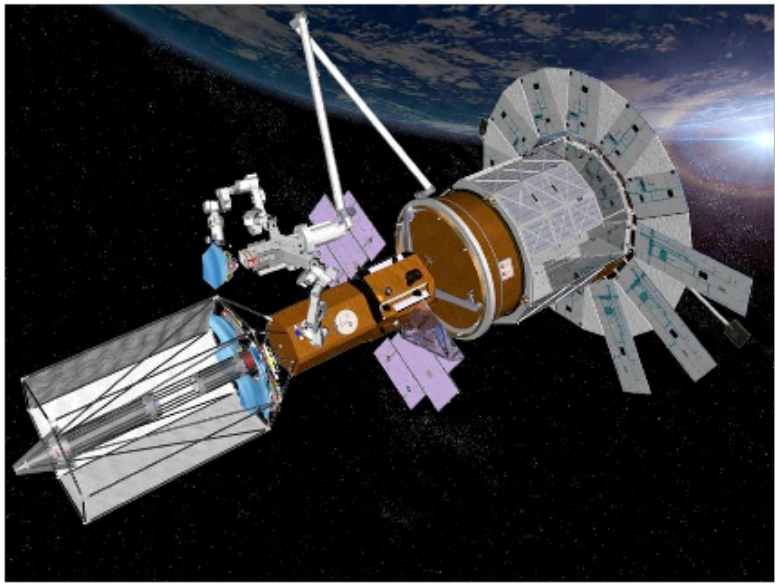
Human assembly of large space telescope in LEO

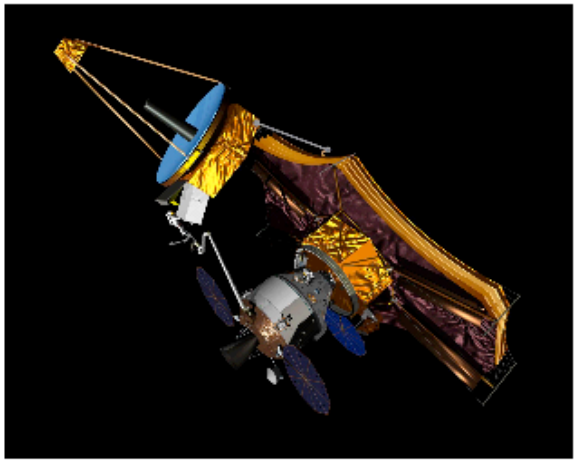


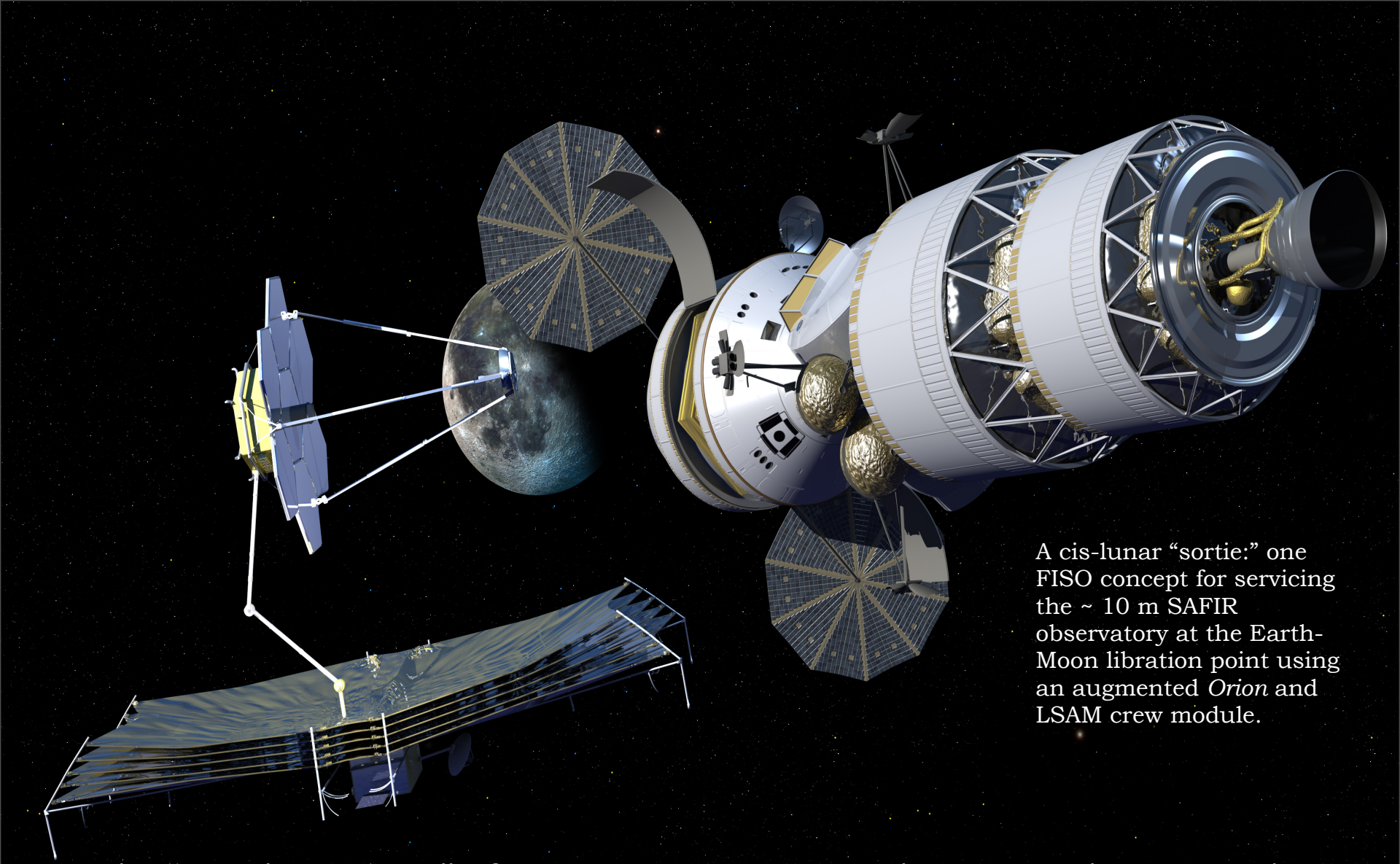
CEV-Robotic servicer replacing instrument of large space telescope at L2



Robotic and manned servicing of 10+ meter telescope at L-2







A cis-lunar “sortie:” one FISO concept for servicing the ~ 10 m SAFIR observatory at the Earth-Moon libration point using an augmented *Orion* and LSAM crew module.

The “grand questions” of astronomy may require large, complex optics that cannot be operated on the Earth’s surface.

As was the case with Hubble, will astronauts be the key enabling capability to realize these goals? And with robotic partners?

A cost comparison was conducted to examine program cost for expendable new telescope development versus a serviceable telescope approach (with equivalent scientific goals)

New Development Space Telescope vs. Servicing ($B)

NEW DEV. SCENARIO	LAUNCH YEAR	L+5 YEARS	L+10 YEARS	L+15 YEARS	L+20 YEARS	L+25 YEARS	L+30 YEARS	$ TOTALS
DEV. COST	$ 4,000		$ 5,376		$ 7,224		Decomm.	$ 16,600
L/V	$500		$672		$903			$ 2,075
GRAND TOTAL	**$ 4,500**		**$ 6,048**		**$ 8,128**			**$ 18,675**
SERVICING SCENARIO								
DEV. COST	$ 4,000						Decomm.	$ 4,000
L/V	$500	$464	$538	$623	$722	$838		$ 3,684
SERVICING BUDGET	$ -	$464	$538	$623	$722	$838		$ 3,184
GRAND TOTAL	**$ 4,500**	**$927**	**$ 1,075**	**$ 1,246**	**$ 1,445**	**$ 1,675**	**$ -**	**$ 10,869**

Servicing scenario is less than 60% the cost of new development scenarios. Technologies are updated twice as often.

"It is dumb to launch complicated, expensive telescopes into space that cannot be serviced."

Michael Griffin, NASA Administrator
Addressing the Congressionally chartered Astronomy and Astrophysics Advisory Committee (AAAC), February 11, 2008

"We have to start studying how the Orion can continue the benefits of human exploration and we have to do it in parallel with Orion development and a science pathfinder mission. **But we have to start <u>now</u>!!"**

Frank Cepollina, National Inventors Hall of Fame Inductee
March 6, 2008

We are running out of time to achieve profound science goals through the effective use of humans and robots in free space.

"We did it with Shuttle, why not with Orion?"

Benefits to the Science Community

- Budget realities will only allow for one or two large space telescopes over the next 30 years, if that.
- A servicing concept for those platforms allows the science community to maximize science return by:

1. Periodic change out of instruments to focus on new scientific questions and changing scientific emphases
2. Eliminates waiting 15 to 20 years for flight of new telescopes so as to perform new science
3. Eliminates flying old instrument detector technology in new telescopes because of telescope development cycles

Continuous rejuvenation of knowledge from old instrumentation to new results in a pace of innovation and discovery four to five times faster than can be achieved with expendable