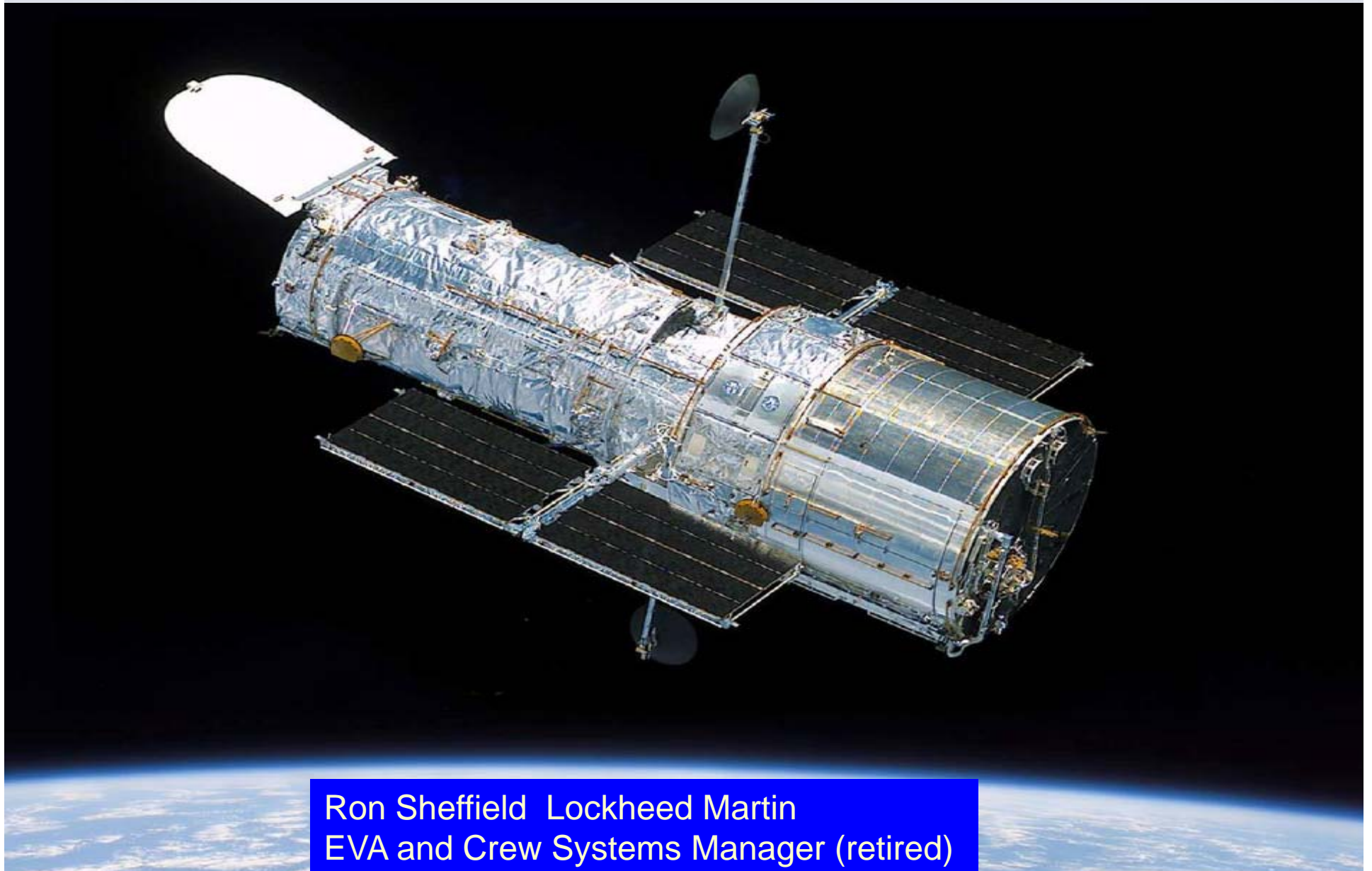
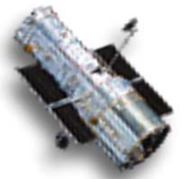
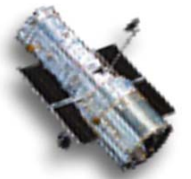


Hubble Space Telescope



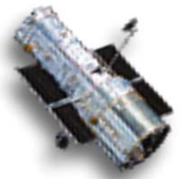
Ron Sheffield Lockheed Martin
EVA and Crew Systems Manager (retired)



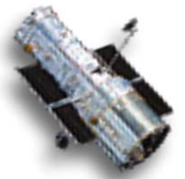
Hubble Space Telescope

- I am going to give you an overview of the Hubble Space Telescope
 - Its history,
 - its dimensions and characteristics,
 - its servicing missions with emphasis on SM4
 - its science results,
 - and some historical HST space shots.

Hubble Space Telescope



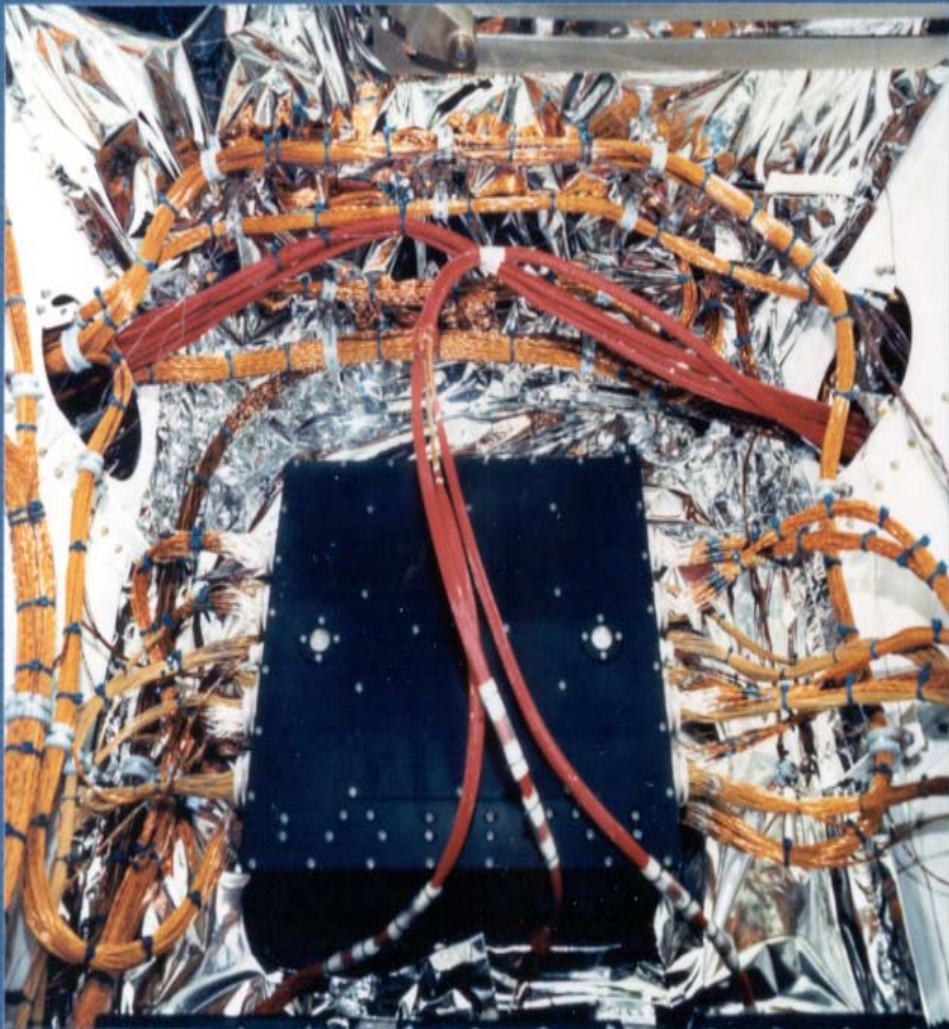
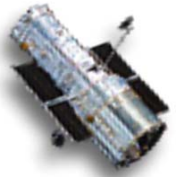
- The contract to build HST was awarded in Oct 1977. It was a two part contract-one for spacecraft and one for the mirror.
- In 1977, all components were to be designed to be replaced on-orbit.
- Reduction in funds in 1980 and 1983 reduced Orbit Replacement Units (ORUs) to 14 different types. Total number was 24 ORUs boxes in 1985.
- In 1985, I was assigned to make as many HST components as possible serviceable on-orbit.
- When we launched in 1990, 94 types of electronic boxes and mechanisms, and all connectors were made to be serviceable on orbit.
- All 94 ORUs were EVA enhanced with nomenclature, serial number, orientation, connector map, connector identification, and powered-on connector decals.
- The HST was designed to have an on orbit life span of 15 years.
- The HST has been on orbit for 21 years as of April 25, 2011.



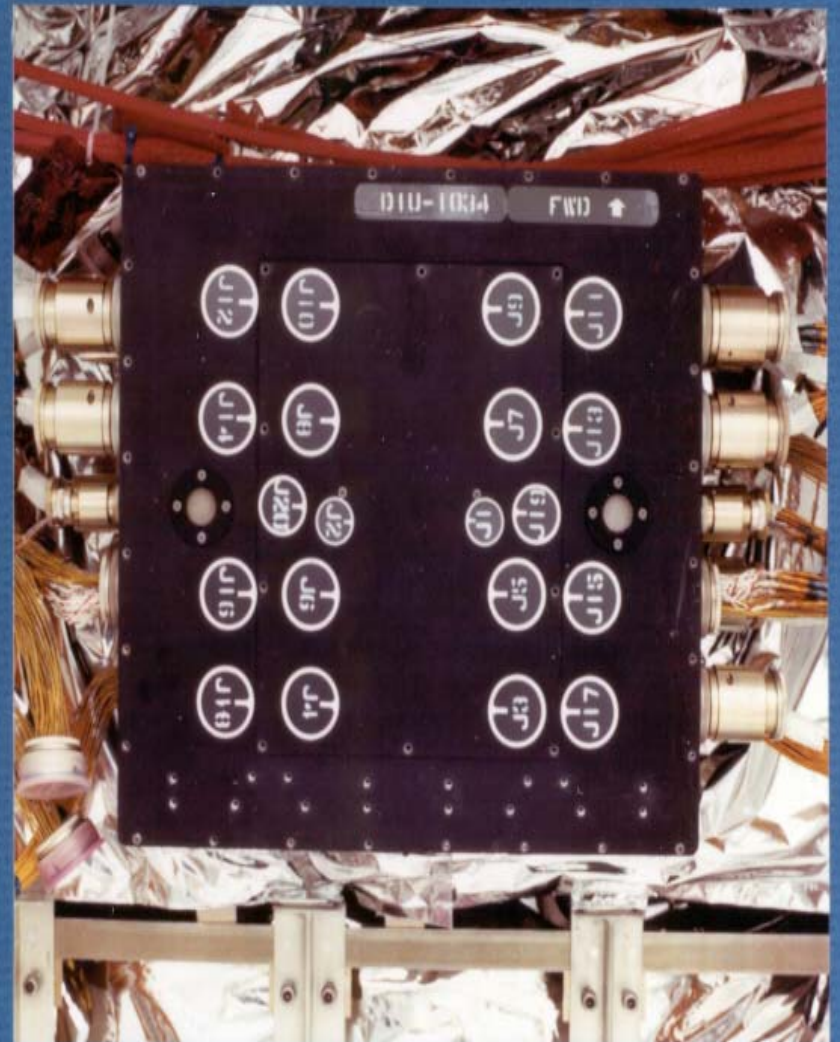
HST Dimensions and Characteristics

- The HST is 43.5 feet long and 14 feet in diameter.
 - The size of a regular yellow school bus
- The HST mirror is 2.4 meters in diameter (94 inches).
- HST weighs almost 26,500 pounds.
 - Exactly 126.83 times my weight
- HST is 325 nautical miles above the earth.
 - San Francisco to Los Angeles
- HST has taken pictures out to 13+ billion light years.
 - Distance light travels in one light year=5,878,000,000,000 miles
- HST pointing accuracy is .0000019 degrees plus
 - Able to hit a dime with a laser at 400+ miles
- HST is designed for servicing
 - Has 4 Aft shroud large doors, 10 Equipment Section Doors, 7 Optical Telescope Assembly Bay door, 224 of handrails and 31 foot restraints
 - 94 types of ORUs have been designed for replacement on orbit

Data Management Unit Decals

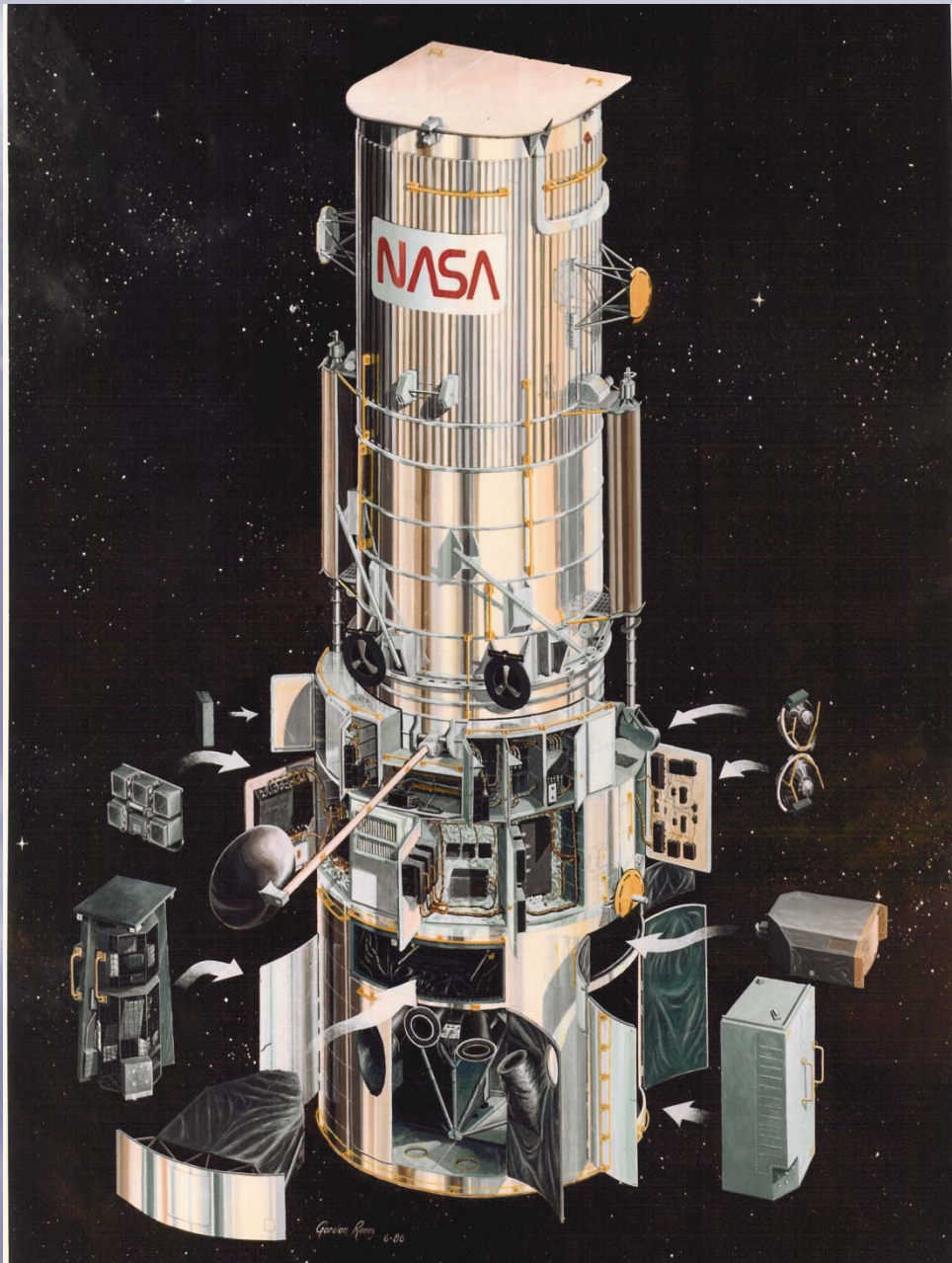
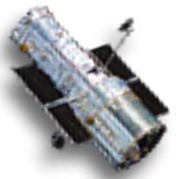


BEFORE

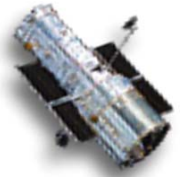


AFTER

Exploded View of HST

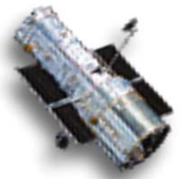


HST Dimensions and Characteristics



- HST orbits the earth approximately every 94-97 minutes at a speed of 17,500 MPH. (Mach 25)
- In 21 years the HST has made 117,400+ trips around earth.
- HST was designed for external temperature ranges from -150F to +200F. The temperature for the mirror and focal plane structure is 70 degrees to prevent warping and distortion.
- Power is provided by two rigid Solar Arrays and 2 Batteries.
- HST operates 24 hours 365 days a year.
- There are over 60,000 pictures of the HST satellite and space support hardware.
 - 25,000 pictures taken before launch and 35,000 to date from the servicing missions.

Hubble Space Telescope Servicing Missions

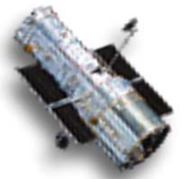


The HST missions are:

- **Deployment Mission** **25-29 April 1990**
- **Servicing Mission 1** **17-21 December 1993**
- **Servicing Mission 2** **11-21 December 1997**
- **Servicing Mission 3A** **19-27 December 1999**
- **Servicing Mission 3B** **1-12 March 2002**
- **Servicing Mission 4** **11-24 May 2009**

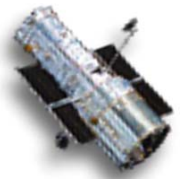
I have trained 40 astronauts to do these missions. There were 4 women and 11 are in the Astronaut Hall of Fame.

Hardware Replaced on Servicing Missions



- Deployment Mission (STS-31) **Deployment of HST**
- 1st Servicing Mission (STS 61) **Restored HST Vision**
 - 3 Rate Sensor Units, Solar Arrays, Wide Field Camera, & Corrective Optics Space Telescope Axial Replacement
- 2nd Servicing Mission (STS 82) **Expanded HST's Universe**
 - Near Infrared Camera and Multi-Object Spectrometer, Space Telescope Imaging Spectrograph, 1 RSU, 1 Reaction Wheel, & 1 Solid State Tape Recorder.
- 3-A Servicing Mission (STS-103) **To the Rescue**
 - 3 RSUs, Fine Guidance Sensor, Main Computer, Thermal Protection Kit, Transmitter, Electronics Control Unit, Voltage Improvement Kits

Hardware Replaced on Servicing Missions



- 3-B Servicing Mission (STS-109) **Better Than Ever**
 - 2 Solar Arrays, 1 Wide Field Camera 2, Advanced Camera for Surveys, Cooling Radiator for STIS, Power Control Unit, New Outer Bay Layer Thermal Cover
- 4th Servicing Mission (STS-125) **The Last One**
 - Purpose is to extend life and increase science
 - 3 RSUs, 2 Ni H2 Batteries, STIS (Repair), 1 Fine Guidance Sensor, 1 Wide Field Camera 3, 1 Cosmic Origins Spectrograph, Advanced Camera for Surveys (Repair), Scientific Instrument Control and Data Handling, Soft Capture Mechanism, New Outer Bay Layer Thermal Cover

HUBBLE MISSIONS

De-Orbit Mission

SM4



Gyros
Wide Field Camera 3
Cosmic Origins Spectrograph
Batteries
Fine Guidance Sensor
STIS Repair
ACS Repair
New Outer Blanket Layer
Soft Capture Mechanism

SM3B



Advanced Camera
Solar Arrays
Power Control Unit
NICMOS Cooling System

SM3A



Gyros
Advanced Computer
Fine Guidance Sensor

SM2



Imaging Spectrograph
Near Infrared Camera
Fine Guidance Sensor

SM1



Wide Field Planetary Camera 2
COSTAR
Gyros
Solar Arrays

Launch!



1990

1993

1997

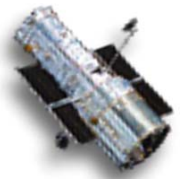
1999

2002

2008

NET 2020

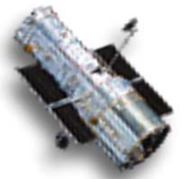
The STS-125 SM4 Patch



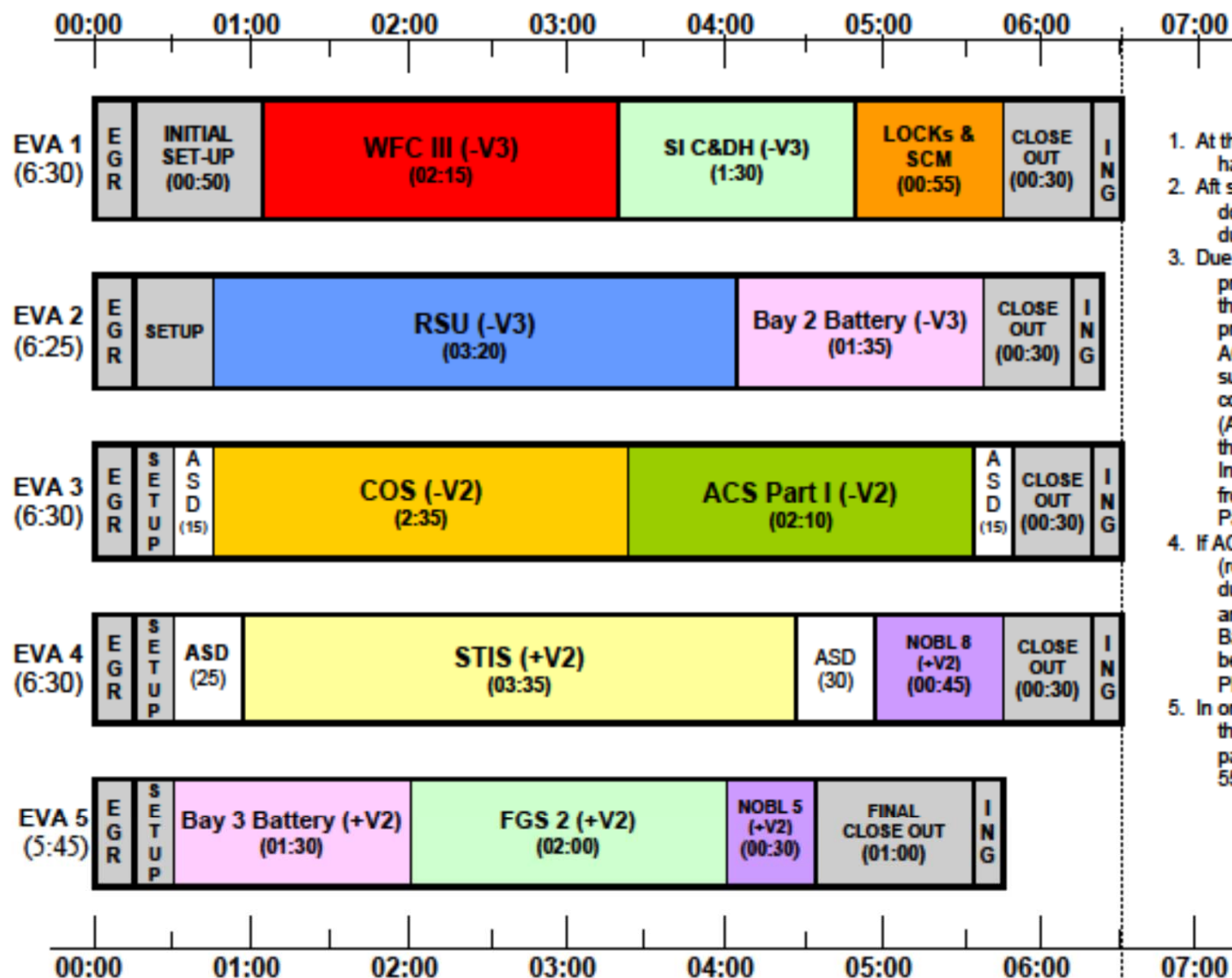
Keeping with tradition, SM4 Crewmembers, with previous HST experience, were assigned to the mission STS-125 was flown on the Atlantis shuttle



SM4 Crew Members



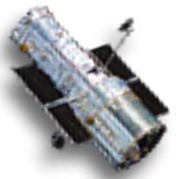
HST SM4 EVA Timelines (w/ ACS Part I only)



Notes:

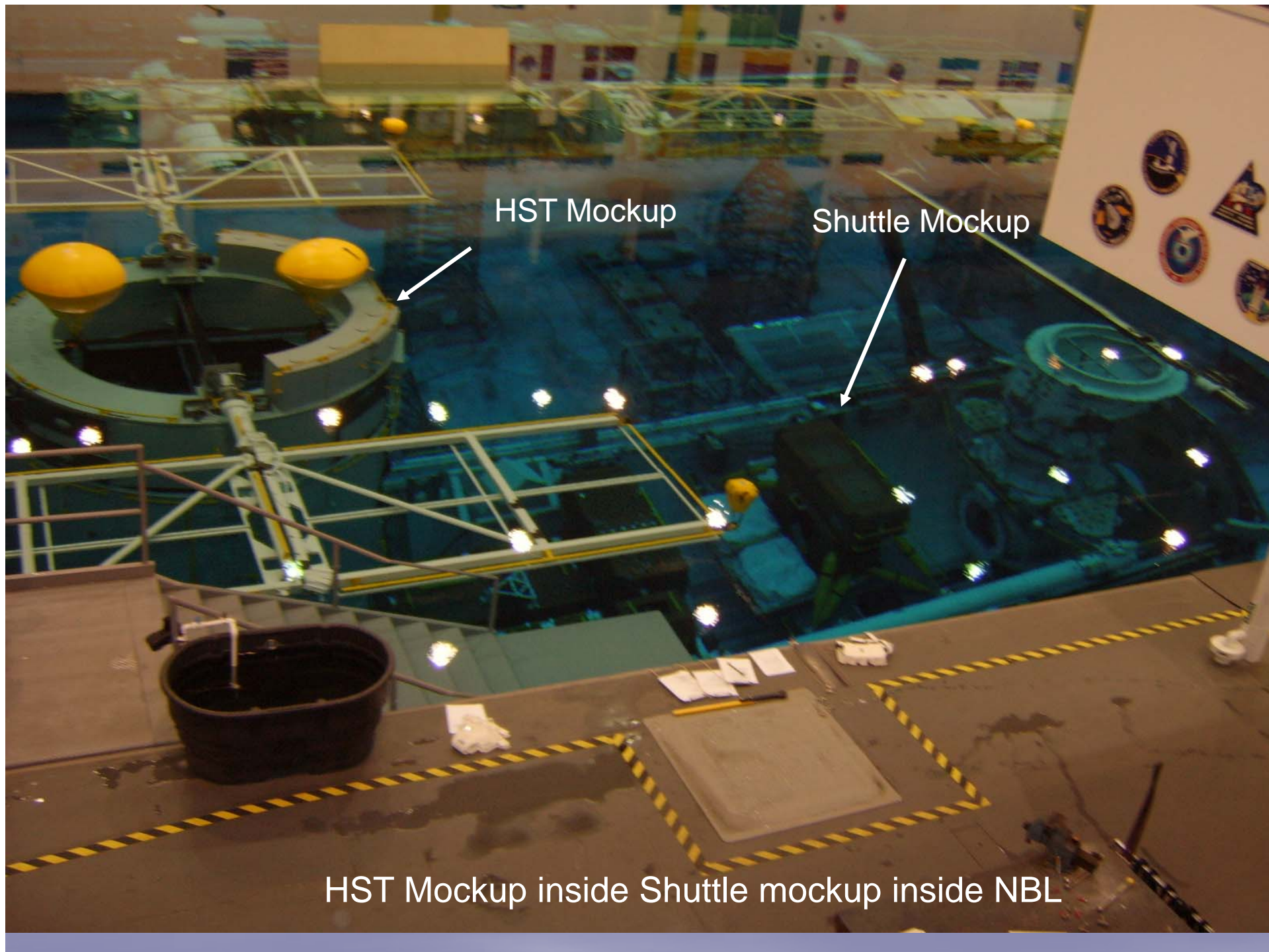
1. At the end of ACS Part I, two cards have been removed.
2. Aft shroud door open/close for -V2 doors is shorter than the other doors due to LOCKs being installed.
3. Due to time limitations and mission priorities, ACS Part II is not shown in the timeline since FGS 2 is higher priority than one of the SI repairs. ACS Part I task is scheduled in support of preparing the telescope for completion of the ACS repair task (ACS Part II) on EVA 5 in the event that the STIS repair is not successful. In that case, FGS would be deleted from EVA 5 and replaced with ACS Part II.
4. If ACS Part II is added into EVA 5 (replaces FGS), the total task duration for that block would be 2:15, and it would be performed after the Bay 3 Battery. The entire EVA would be executed with -V3 fwd w/ an EVA PET of 6:00.
5. In order to complete ACS during EVA 3, the EVA would have to be extended past 6:30. Possibly by as much as 55-60 min (w/ LOCKs installed).

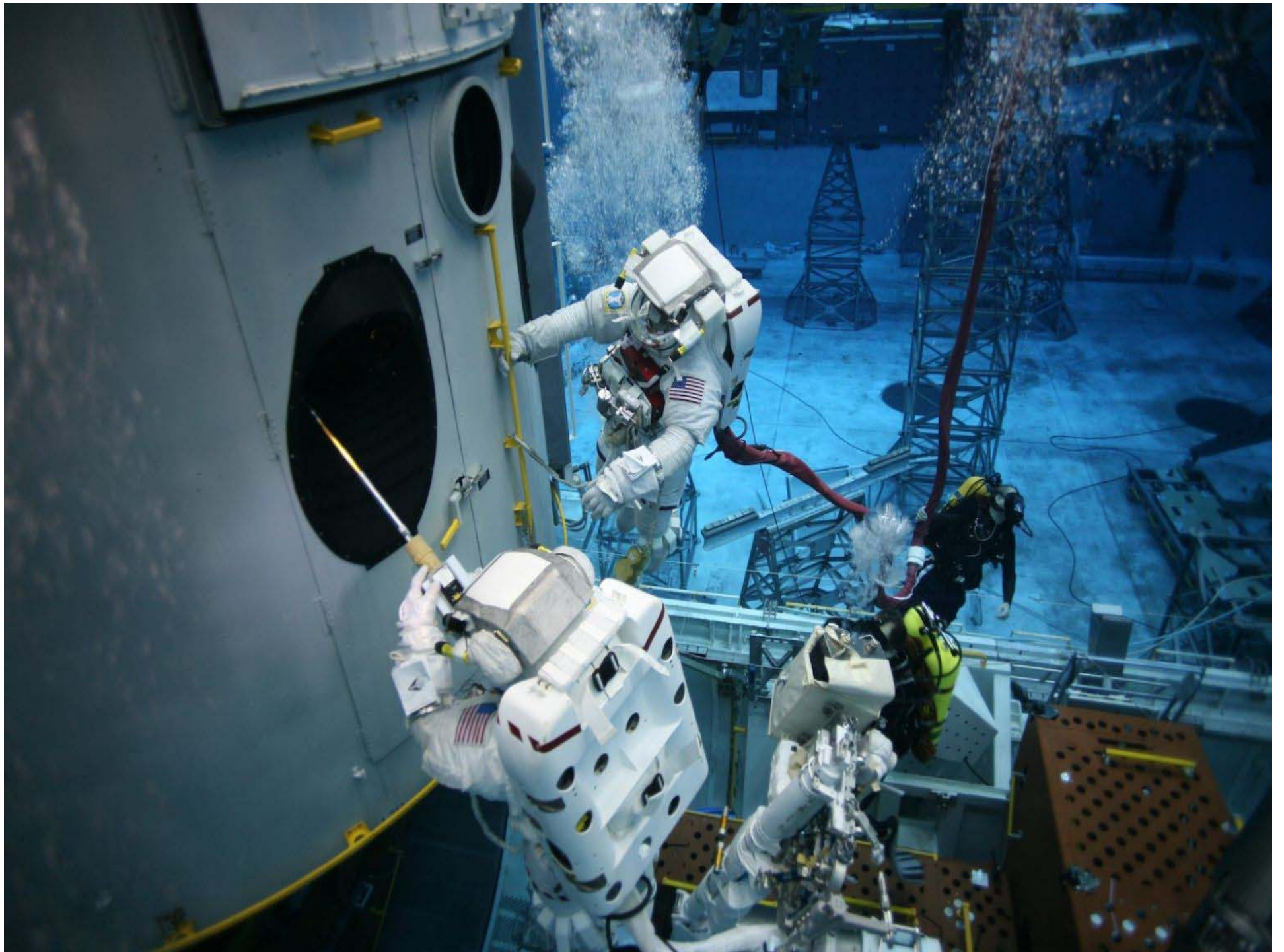
Neutral Buoyancy Training

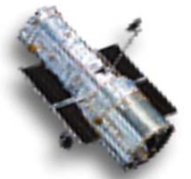
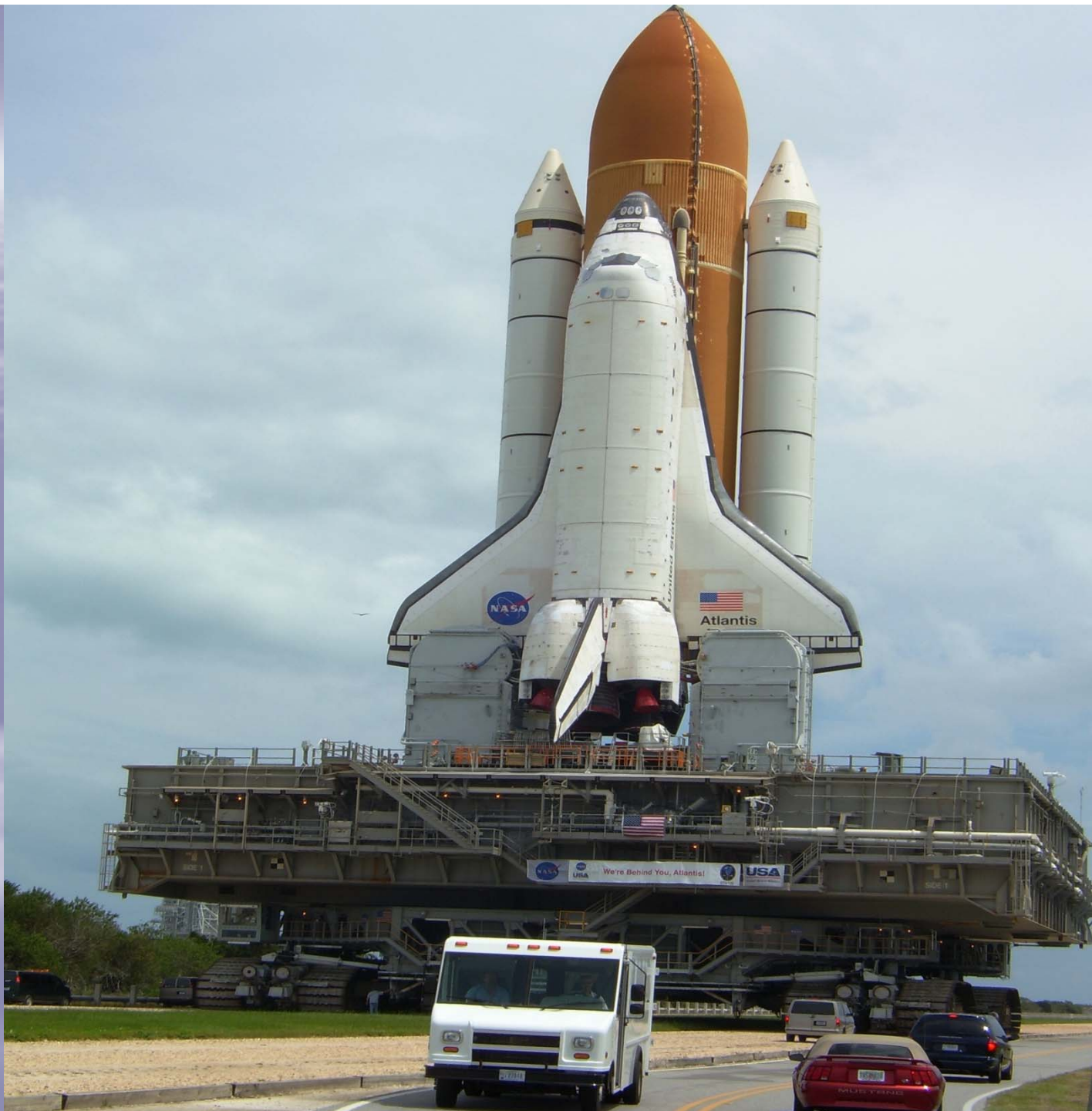


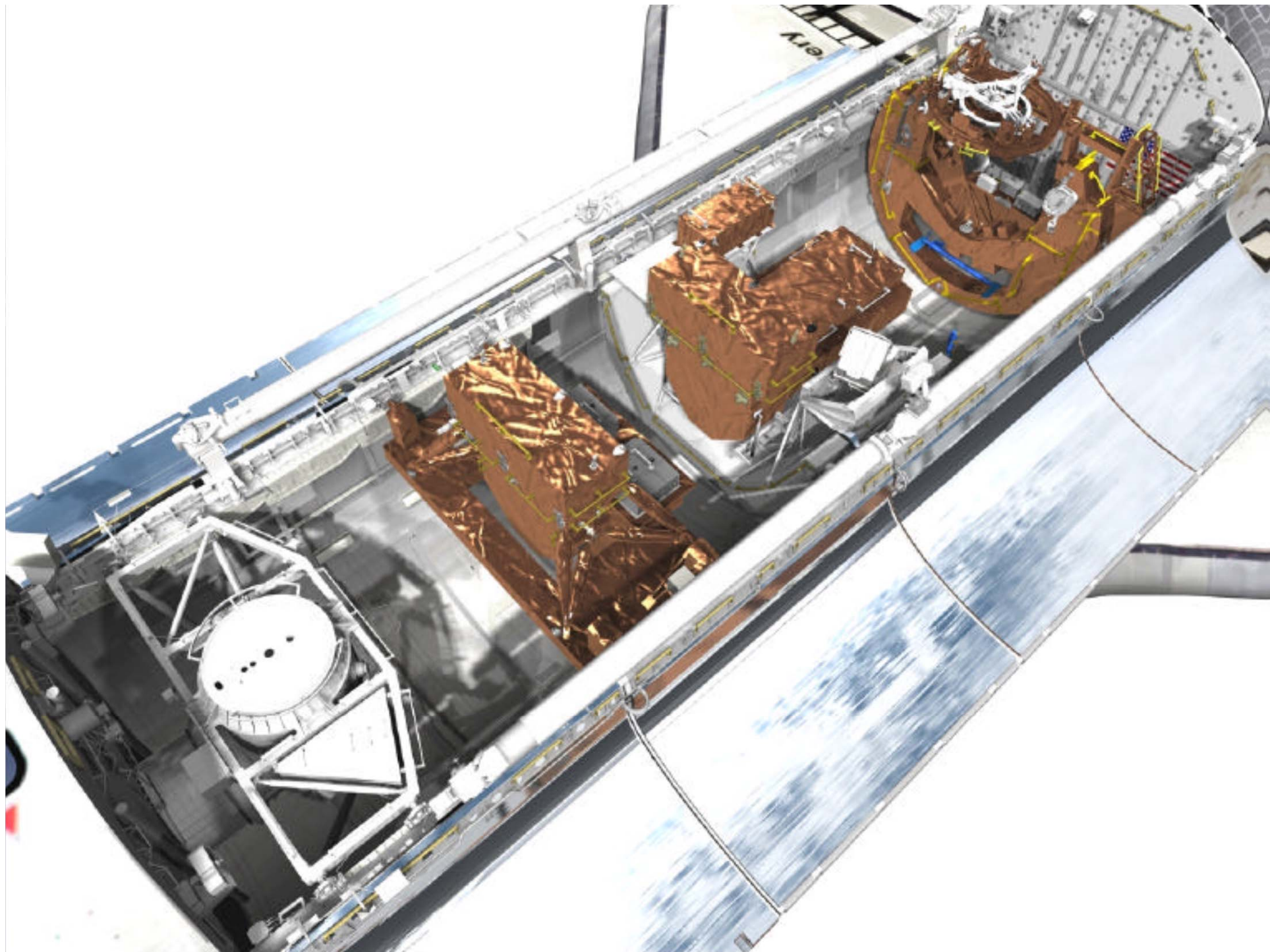
NBL Facility at Houston

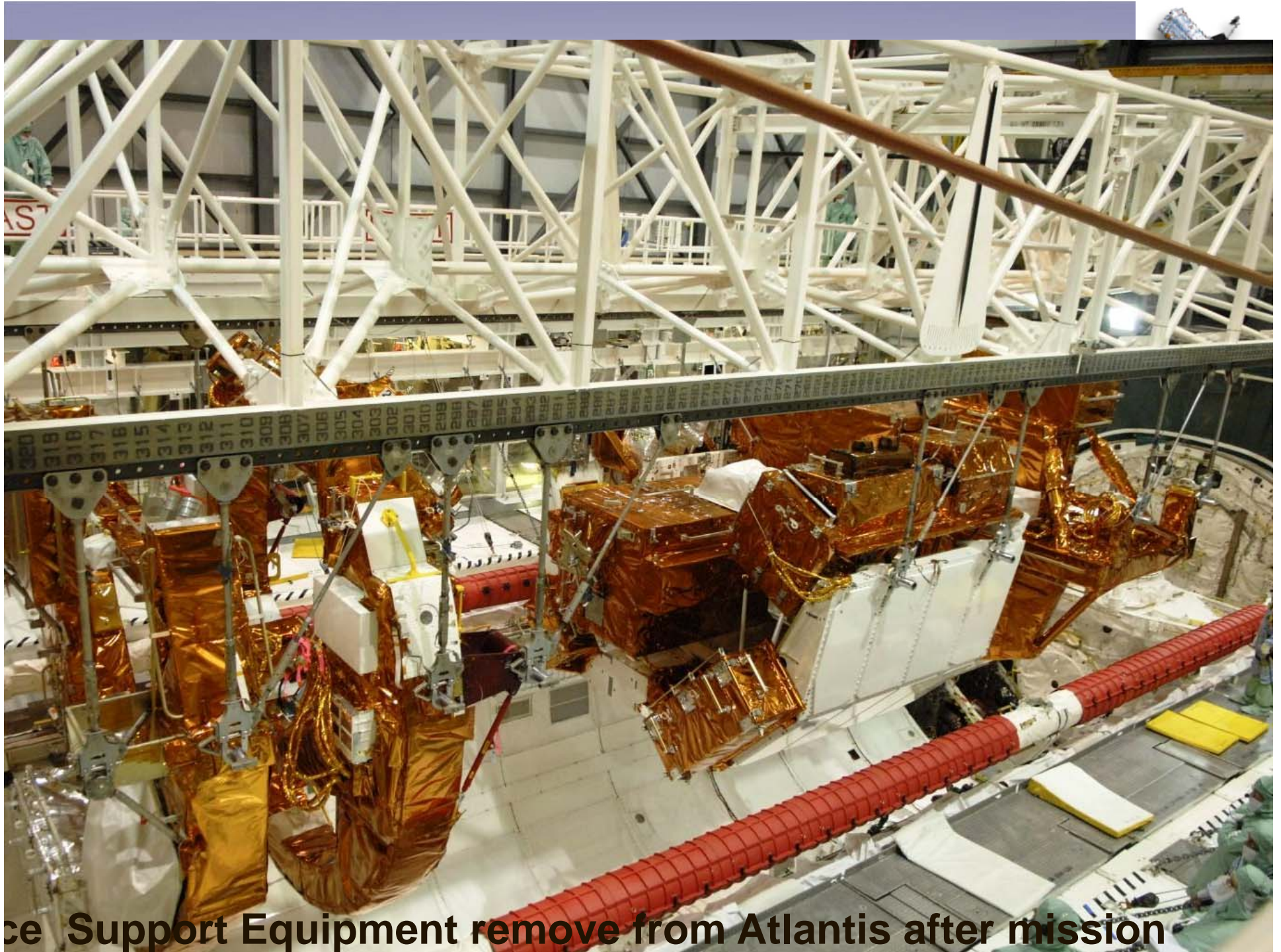






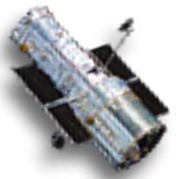






Space Support Equipment remove from Atlantis after mission

Inside Shuttle Cockpit

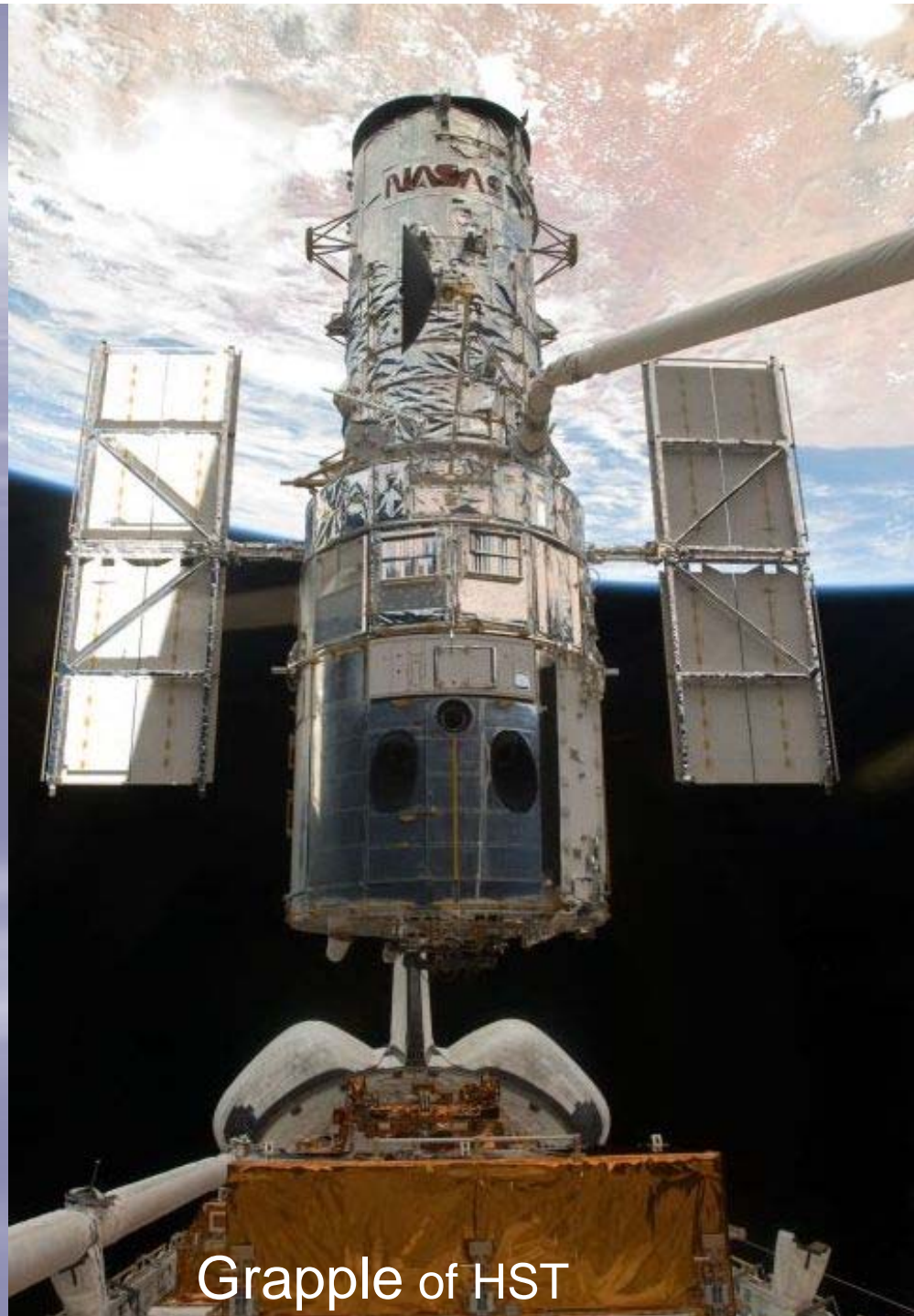




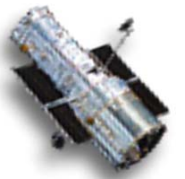




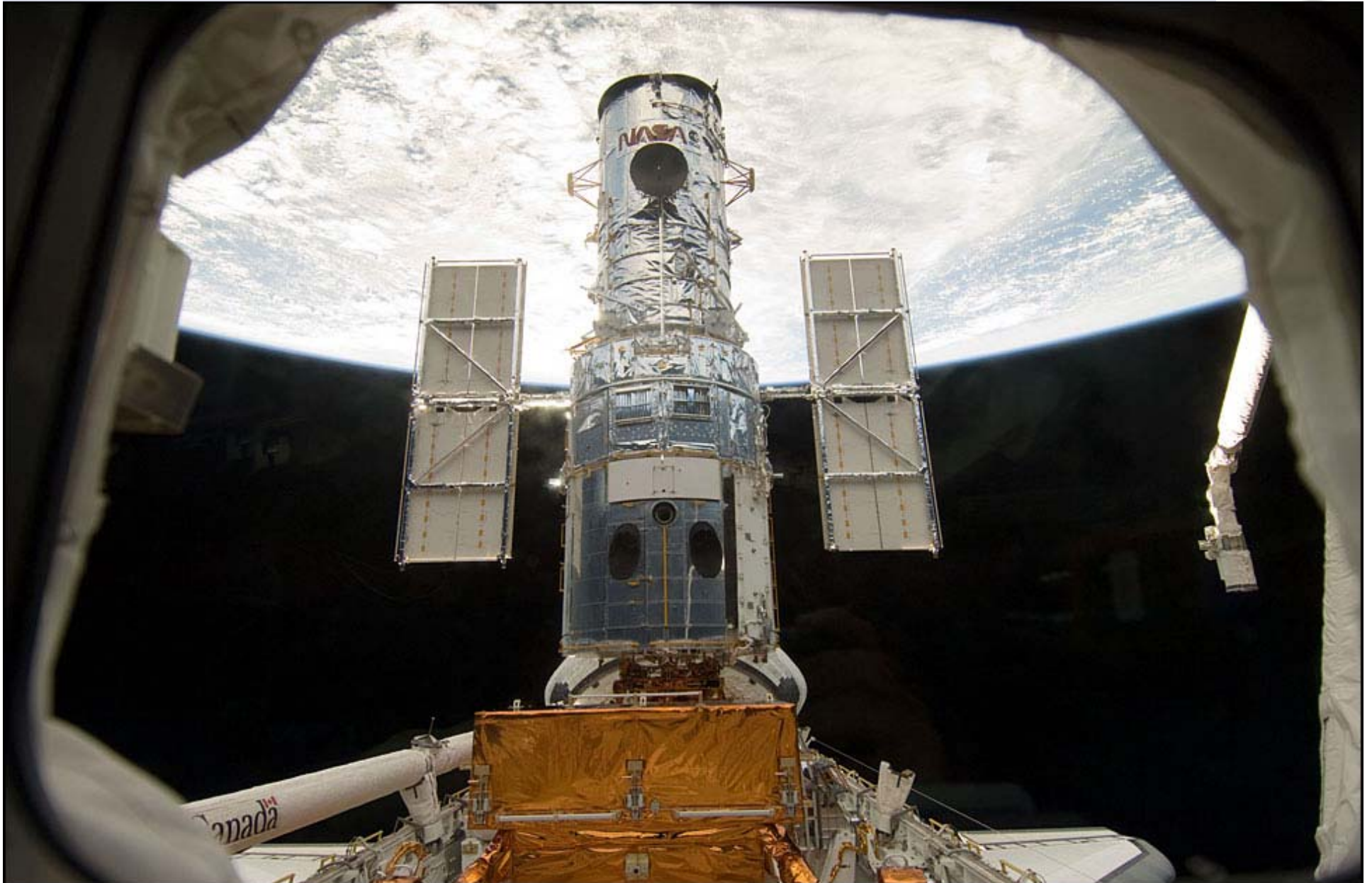
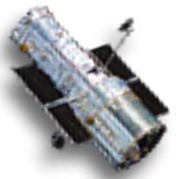
Shuttle and HST silhouetted against the sun



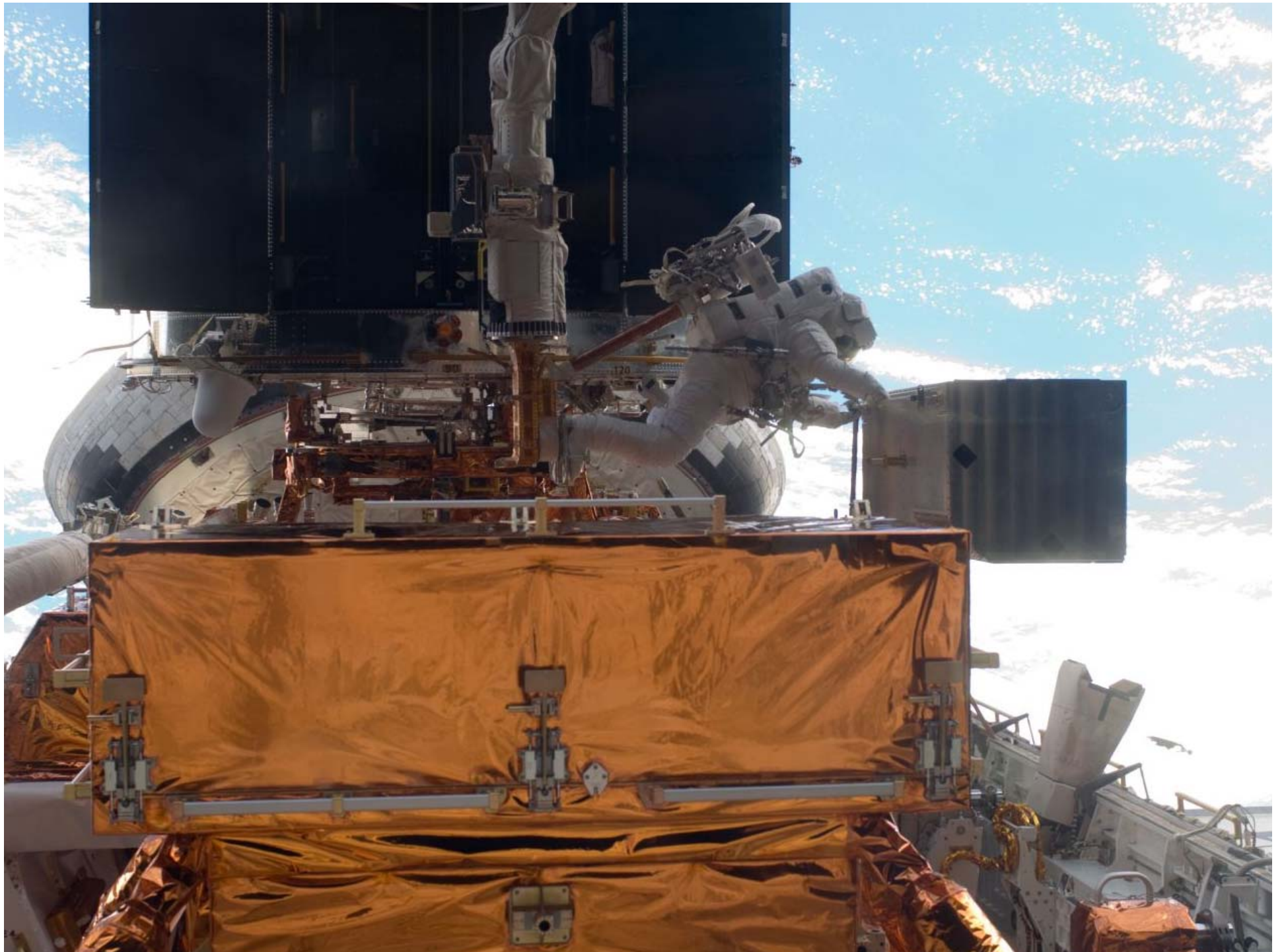
Grapple of HST



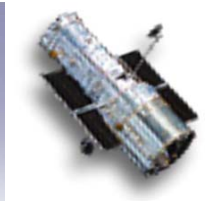
Captured and Secured











PCU on-orbit
out





Ground STIS Trainer



On-orbit Helmet camera



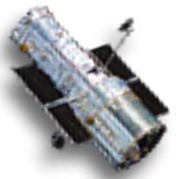
Bad board

STIS MEB Cover removed





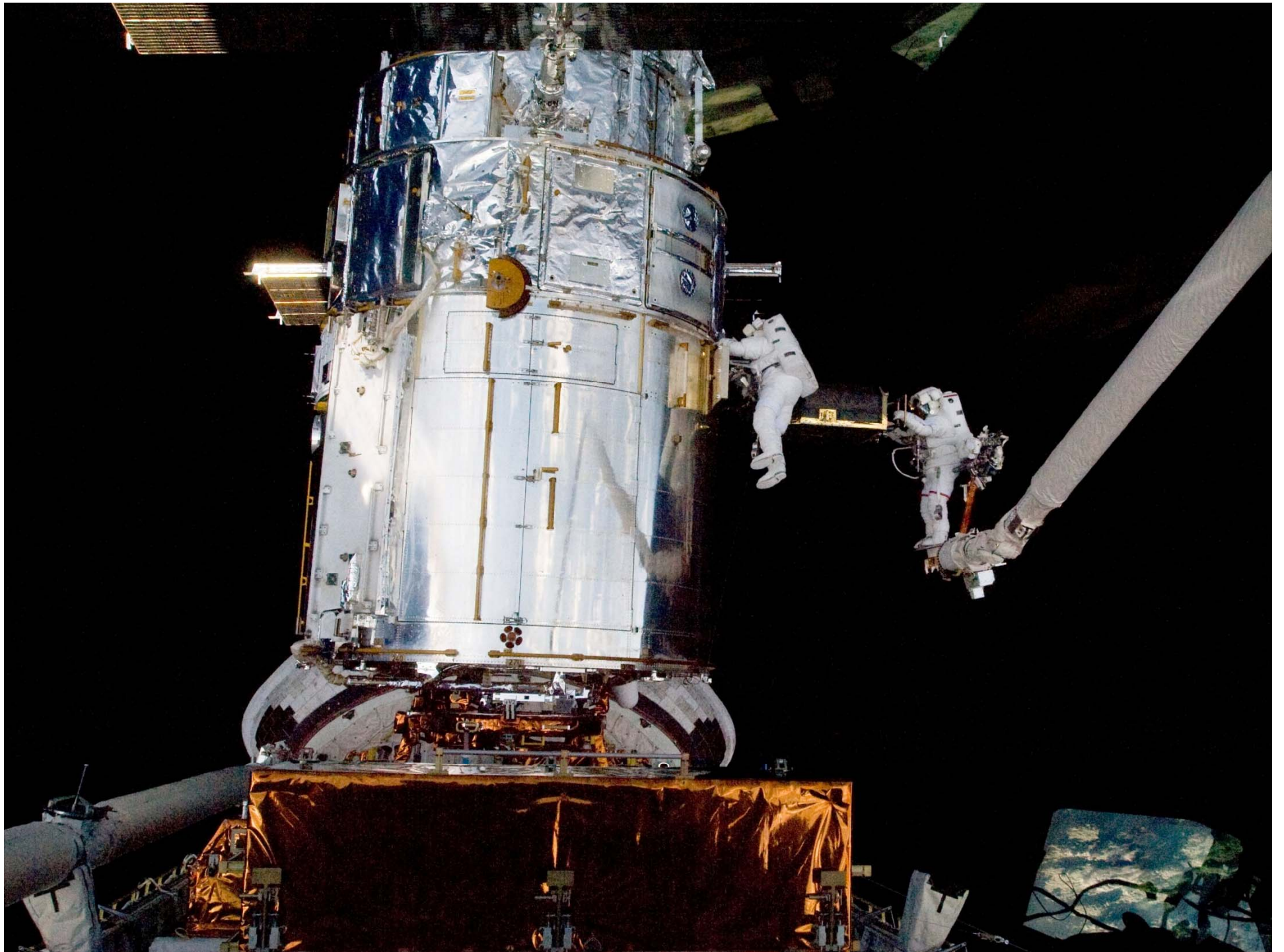
Sunrise On-orbit







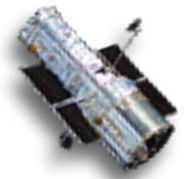


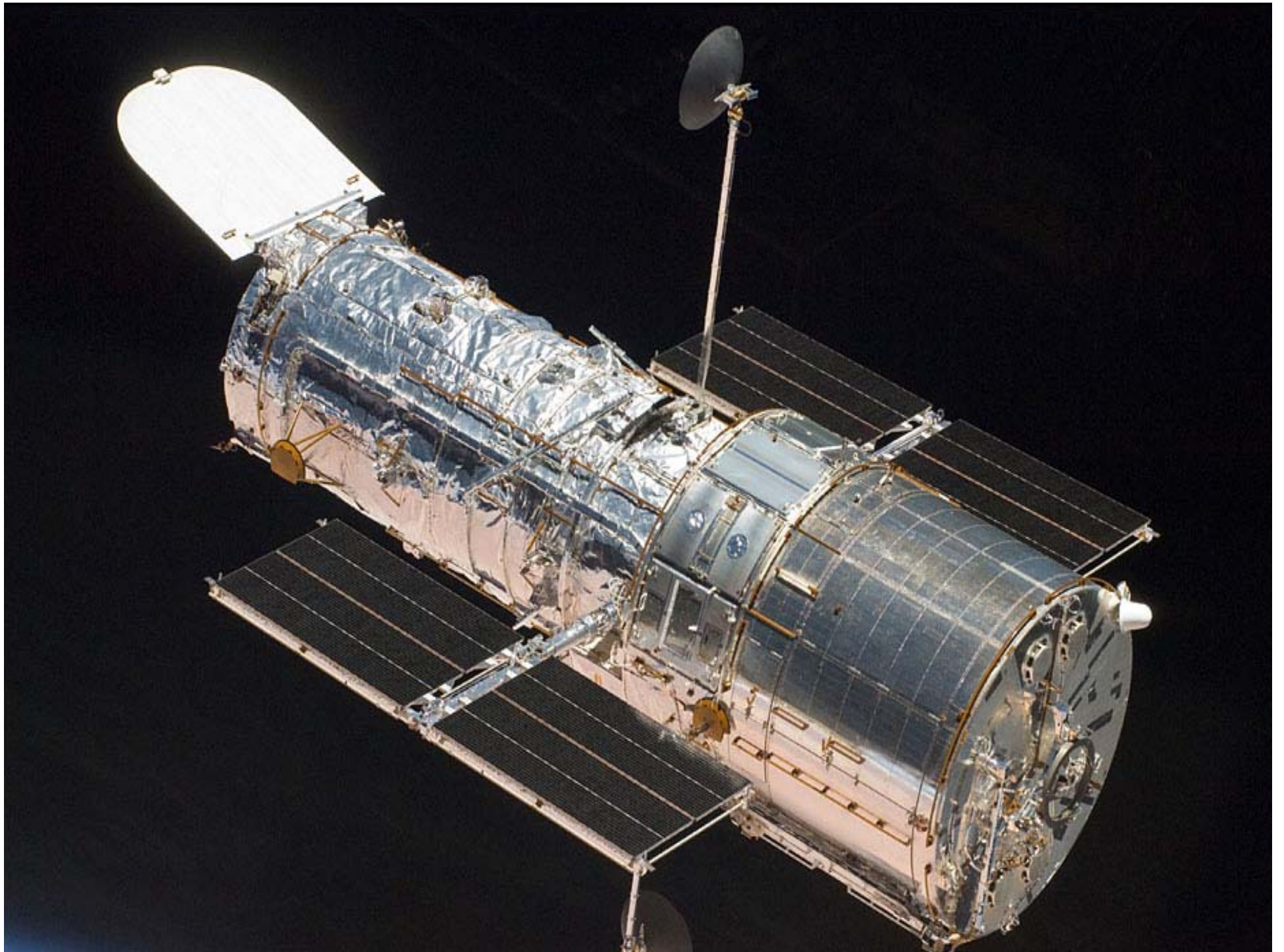




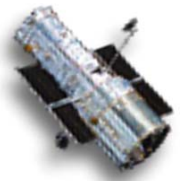


Release of HST

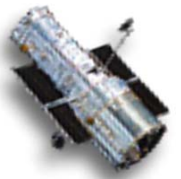




Shuttle Returning to KSC

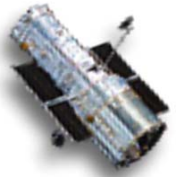


HST Scientific Discoveries



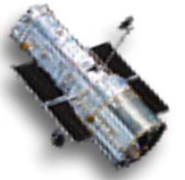
- HST compared to earth-based telescopes:
 - Sees celestial objects that are 50 times fainter.
 - Provides images that were 10 times sharper
 - Sees objects that are 7 times further away.
- HST has established the age of the universe at about 13.75 billion light years.
- HST has proven there are black holes.
- HST has discovered that something exists called “dark energy” that pushes galaxies apart and “dark matter” that pulls galaxies together.
- HST has discovered over 100 extra-solar planets.
- In HST’s 21 years on orbit has taken
 - 880,000 observations
 - 570,000 images of 29,000 celestial objects
 - 117,400 trips+ around the earth

HST Science Data

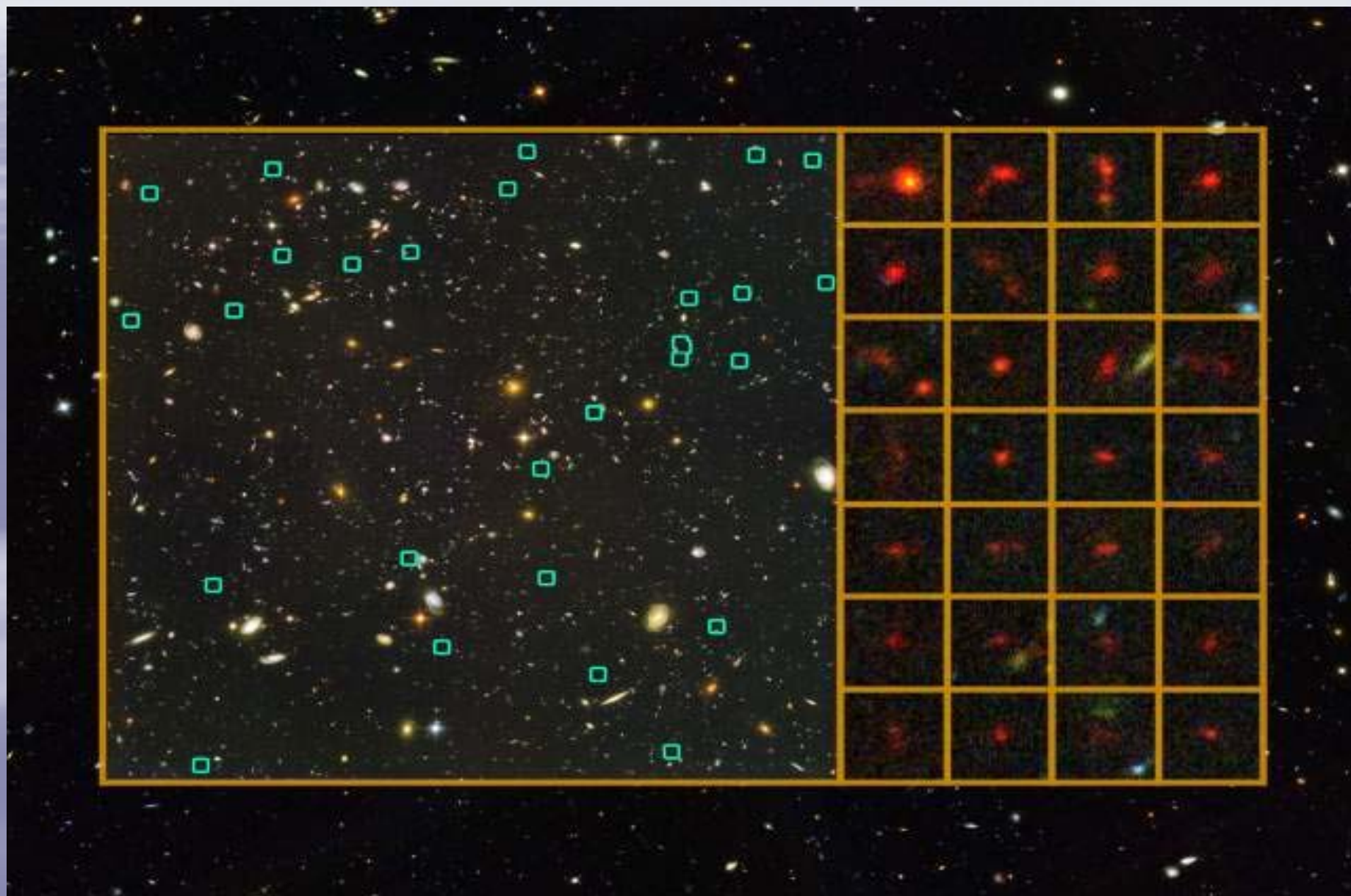
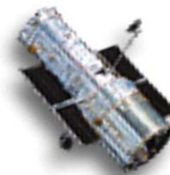


- HST has produced nearly 38 terabytes of data enough to fill two collections in the US Library of Congress.
- Every month HST generates more than 80 gigabits of data.
- 7700 scientists worldwide are registered users of the Hubble data archive.
- Every day astronomers world wide withdraw over 50,000 gigabytes from the HST archive
 - This is three times the ingress rate of new data
- Astronomers using HST data have published more than 7,500 scientific papers

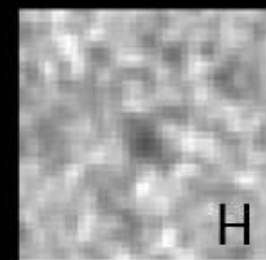
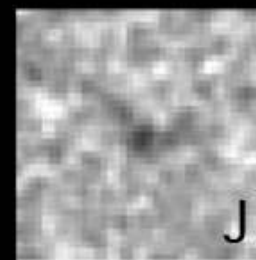
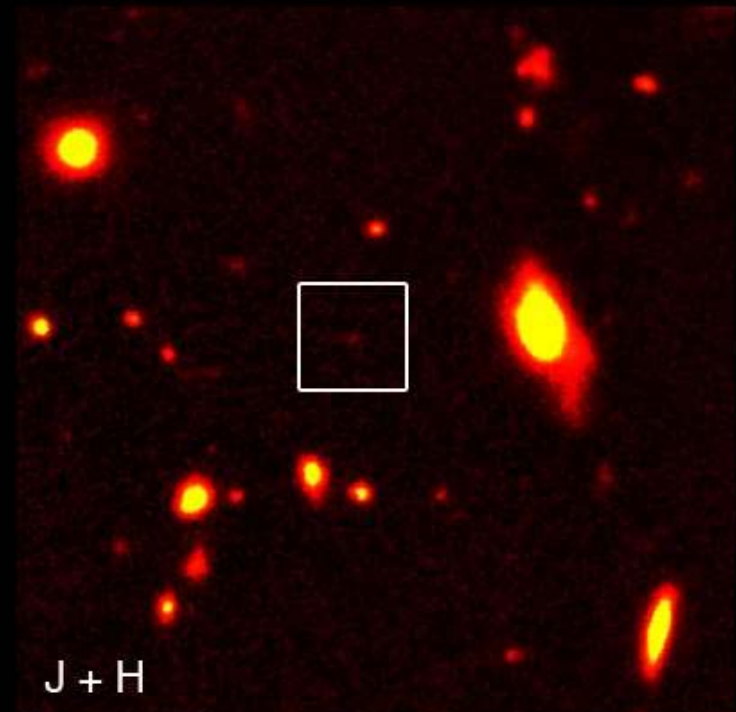
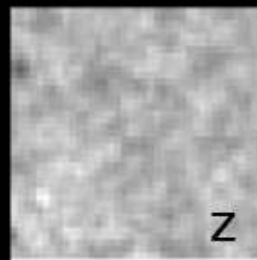
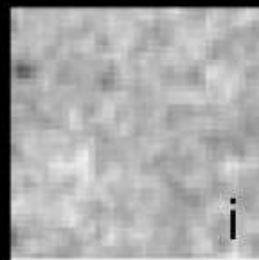
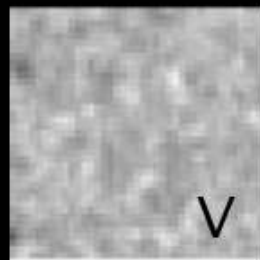
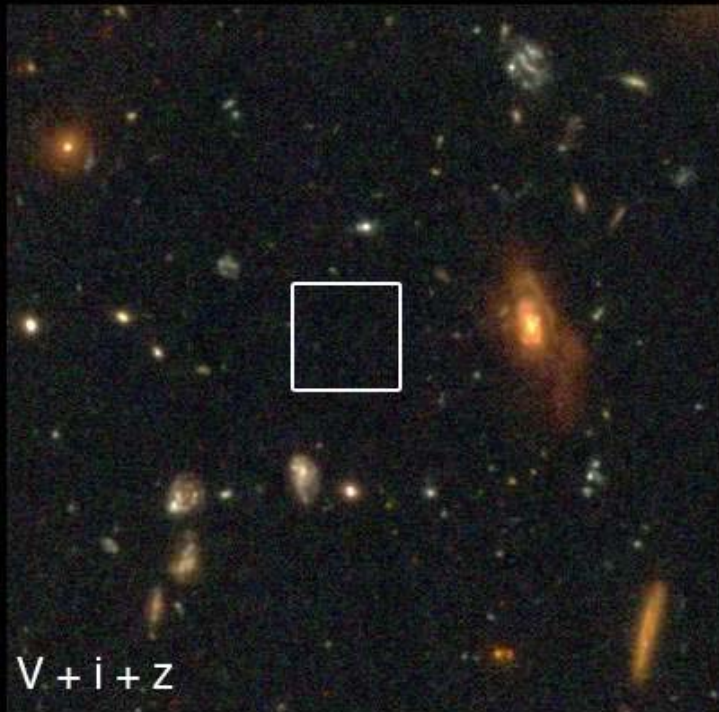
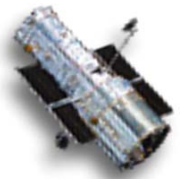
Deepest Image Ever Taken – Hubble Ultra Deep Field



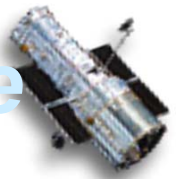
Over 500 Extremely Distant Proto-Galaxies Discovered In Hubble Ultra-Deep Field



Proto-Galaxy That Emitted Its Light 13 Billion Years Ago

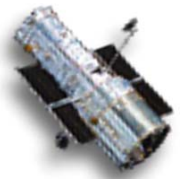


Hubble telescope's top five greatest space photographs



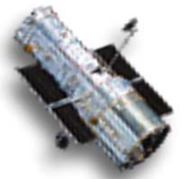
The Sombrero Galaxy - 28 million light years from Earth - was voted best picture taken by the Hubble telescope. The dimensions of the galaxy, officially called M104, are as spectacular as its appearance. It has 800 billion suns and is 50,000 light years across.

Hubble telescope's top five greatest space photographs



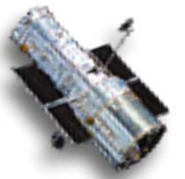
The Ant Nebula, a cloud of dust and gas whose technical name is Mz3, resembles an ant when observed using ground-based telescopes. The nebula lies within our galaxy between 3,000 and 6,000 light years from Earth.

Hubble telescope's top five greatest space photographs



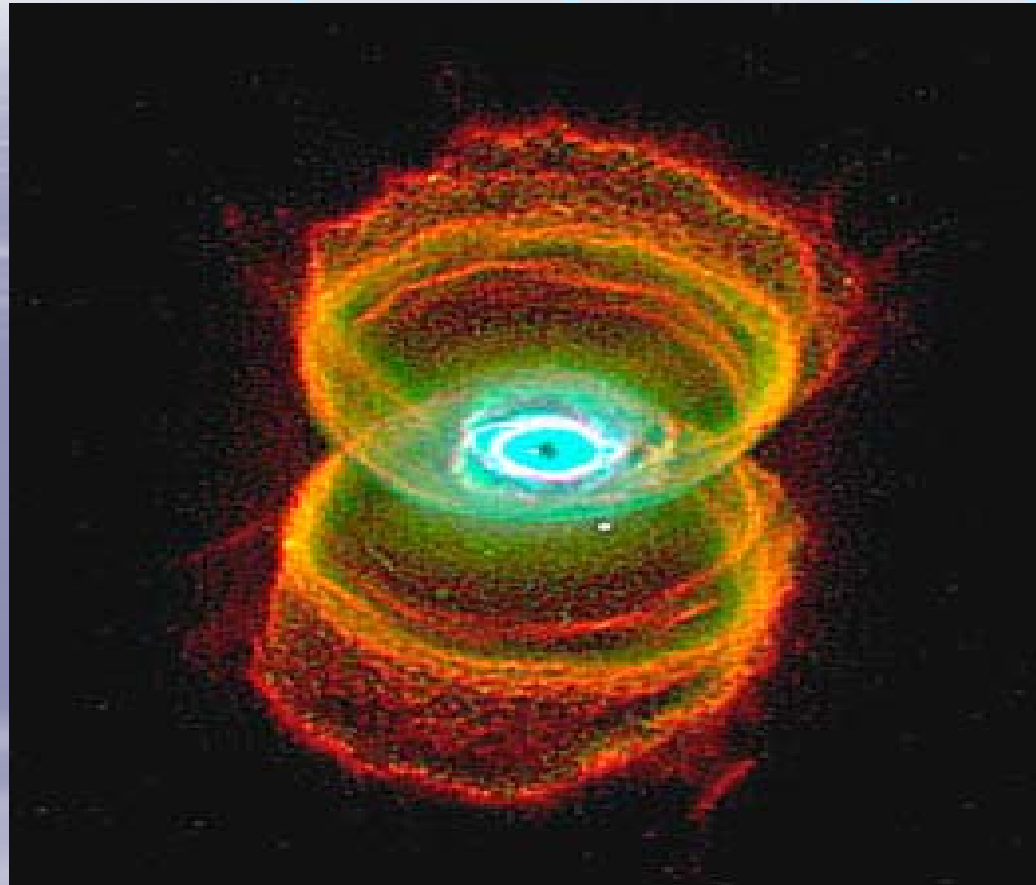
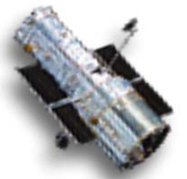
- *In third place is Nebula NGC 2392, called Eskimo because it looks like a face surrounded by a furry hood. The hood is, in fact, a ring of comet-shaped objects flying away from a dying star. Eskimo is 5,000 light years from Earth.*

Hubble telescope's top five greatest space photographs



At four is the Cat's Eye Nebula, which looks like the eye of disembodied sorcerer Sauron from Lord of the Rings.

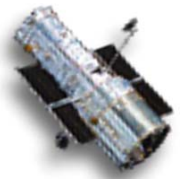
Hubble telescope's top five greatest space photographs



- *The Hourglass Nebula, 8,000 light years away, has a pinched-in-the-middle look because the winds that shape it are weaker at the centre. It is also called the Eye of God.*

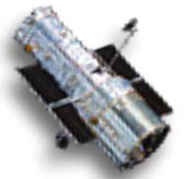
Celestial Butterfly

First Hubble Pictures After Servicing Mission



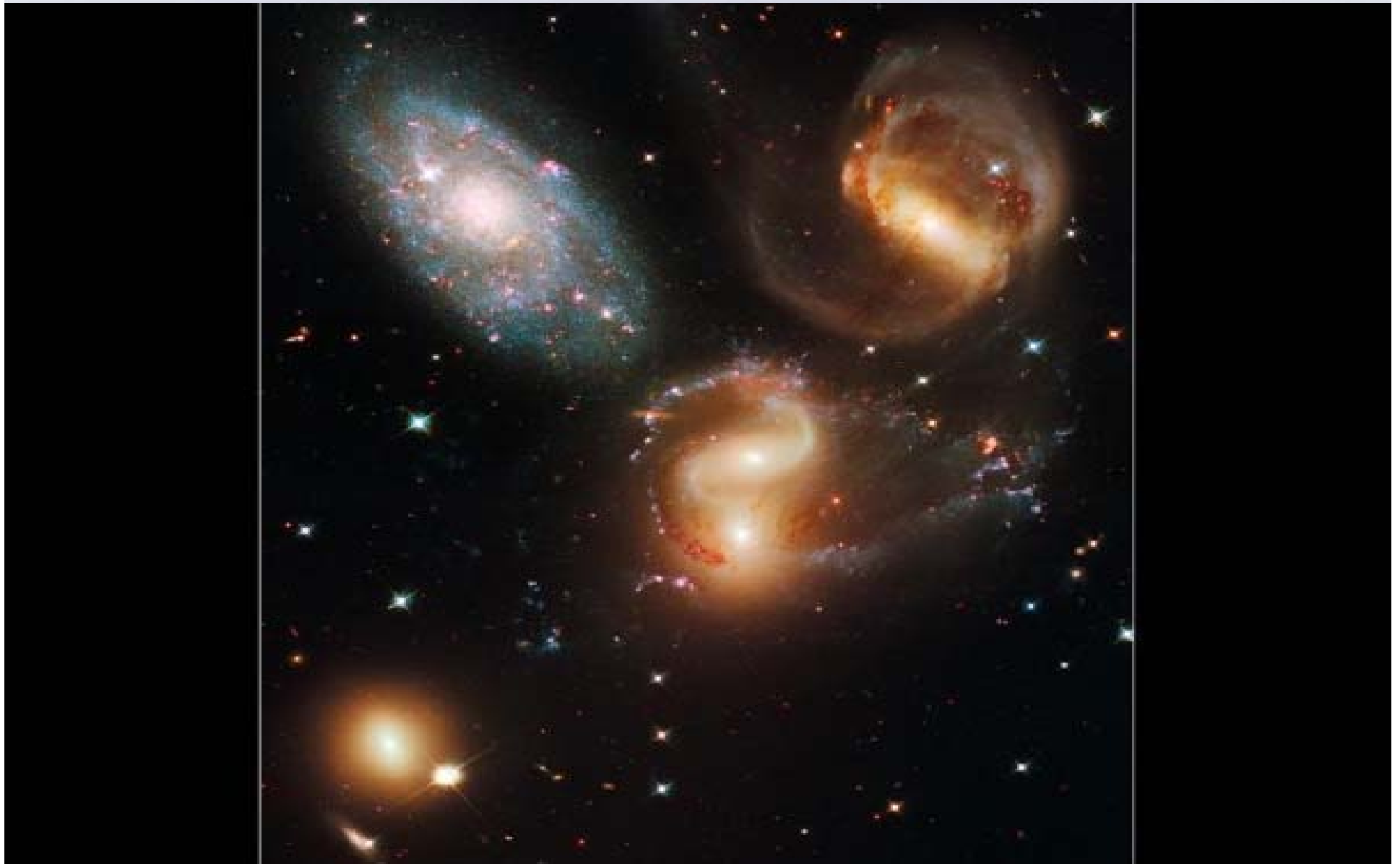
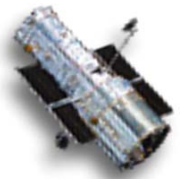
100,000 Stars in Omega Centauri

First Hubble Pictures After Servicing Mission



Stephan's Quintet

First Hubble Pictures After Servicing Mission





Interacting Galaxies Arp 273







