Hubble - 26 years of utilization and on-orbit servicing

Space Science School
17-26 October 2016
@GISTDA Si Racha

Claude Nicollier
ESA & EPFL

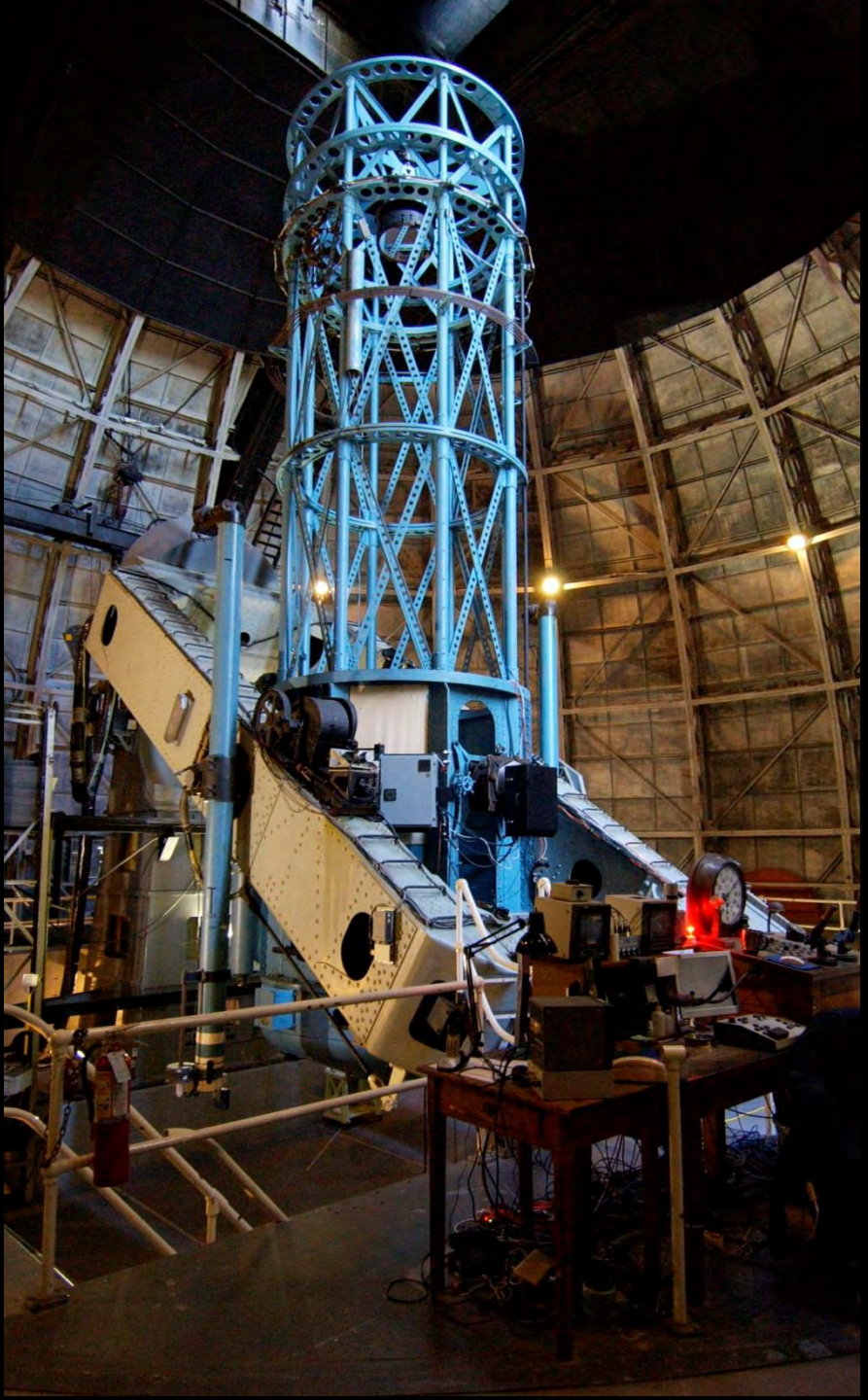
Hubble

the Astronomer

Edwin Powell Hubble, 1889-1953

University of Chicago (math, astronomy), Oxford University (law)

US Army (WW1), Yerkes Observatory, Mt Wilson Observatory, Palomar Observatory



2.5 m Hooker Telescope
Mt Wilson Observatory

Discoveries made using this instrument:

The Universe is much bigger than the Milky Way Galaxy!

Hubble Law (1922-1925)

Expansion of the Universe

Classification of Galaxies

Hubble's Law

The dominant motion in the universe is a smooth expansion expressed by the **Hubble's Law**:

> Recessional Velocity of galaxies = Hubble Constant times their distance

$$V = H_o D$$

where

V is the observed velocity of the galaxy away from us, in km/sec
H_0 is Hubble's "constant", in km/sec/Mpc
D is the distance to the galaxy in Mpc

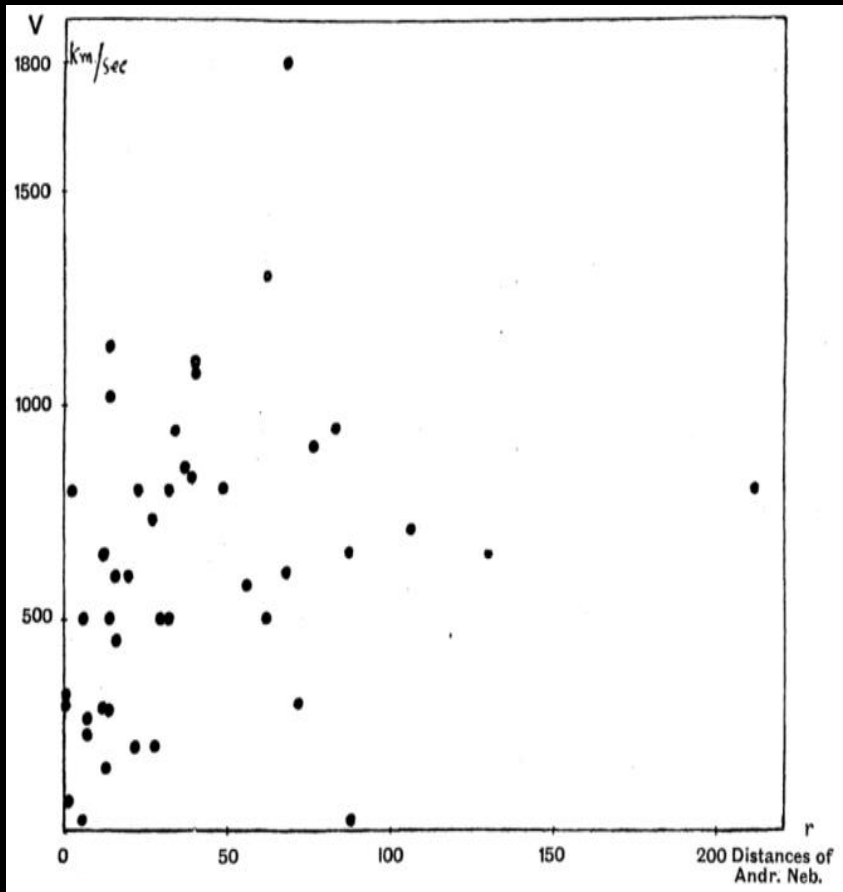


FIG. 5.—Relation between the relative distances (the unit is the distance of the Andromeda nebula) and the measured radial velocities of spiral nebulæ.

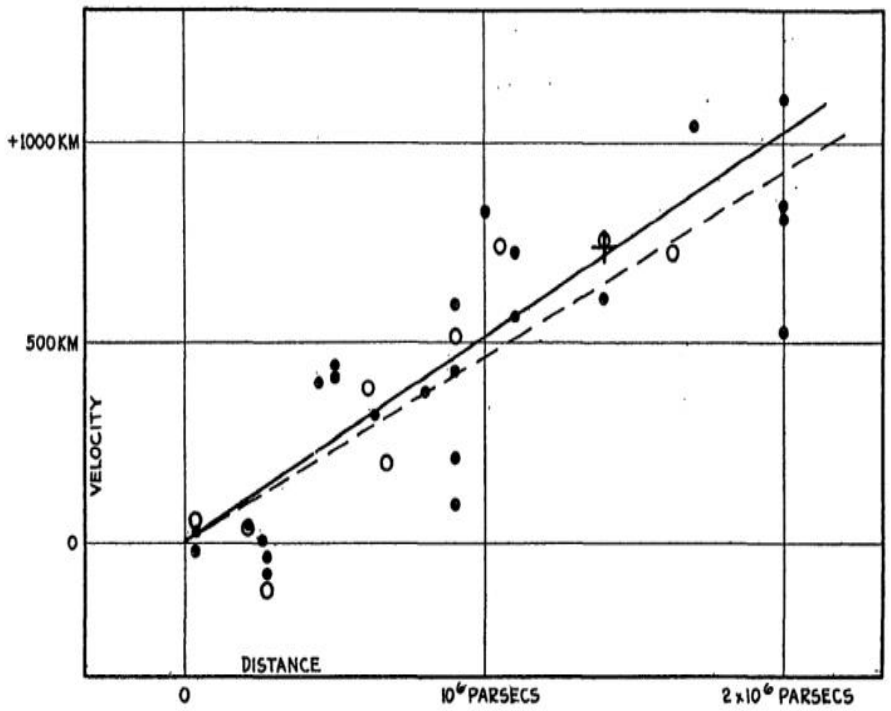


FIGURE 1

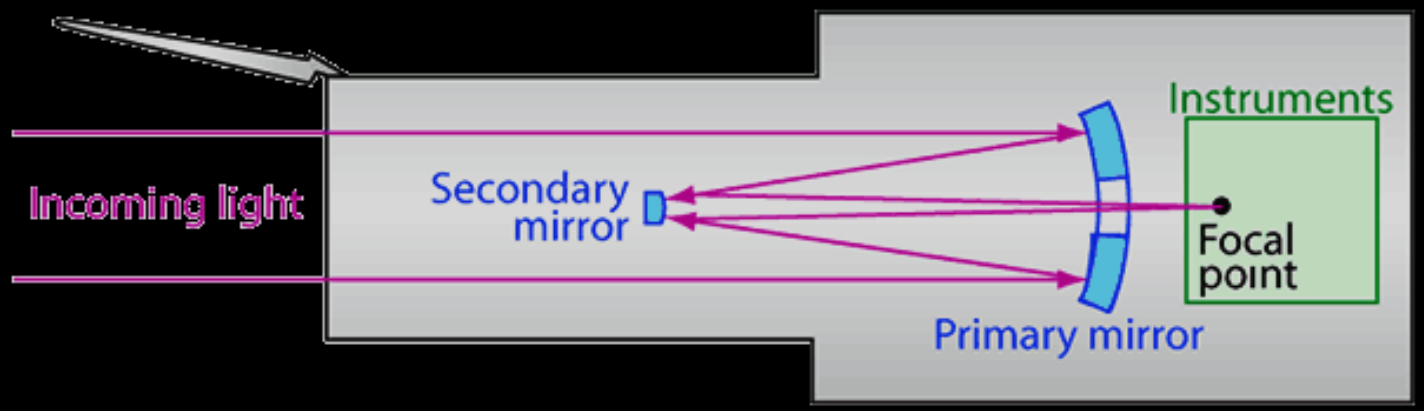
Velocity-Distance Relation among Extra-Galactic Nebulae.

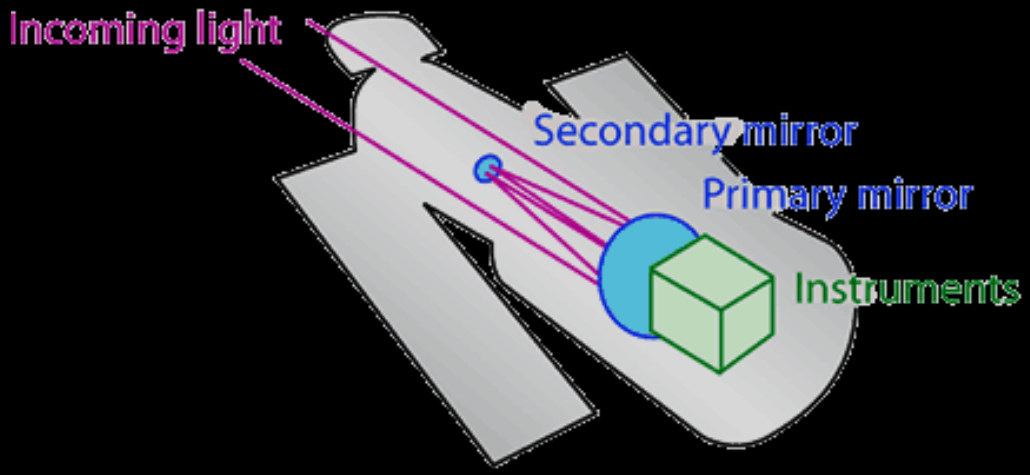
Lundmark 1924

Hubble 1929

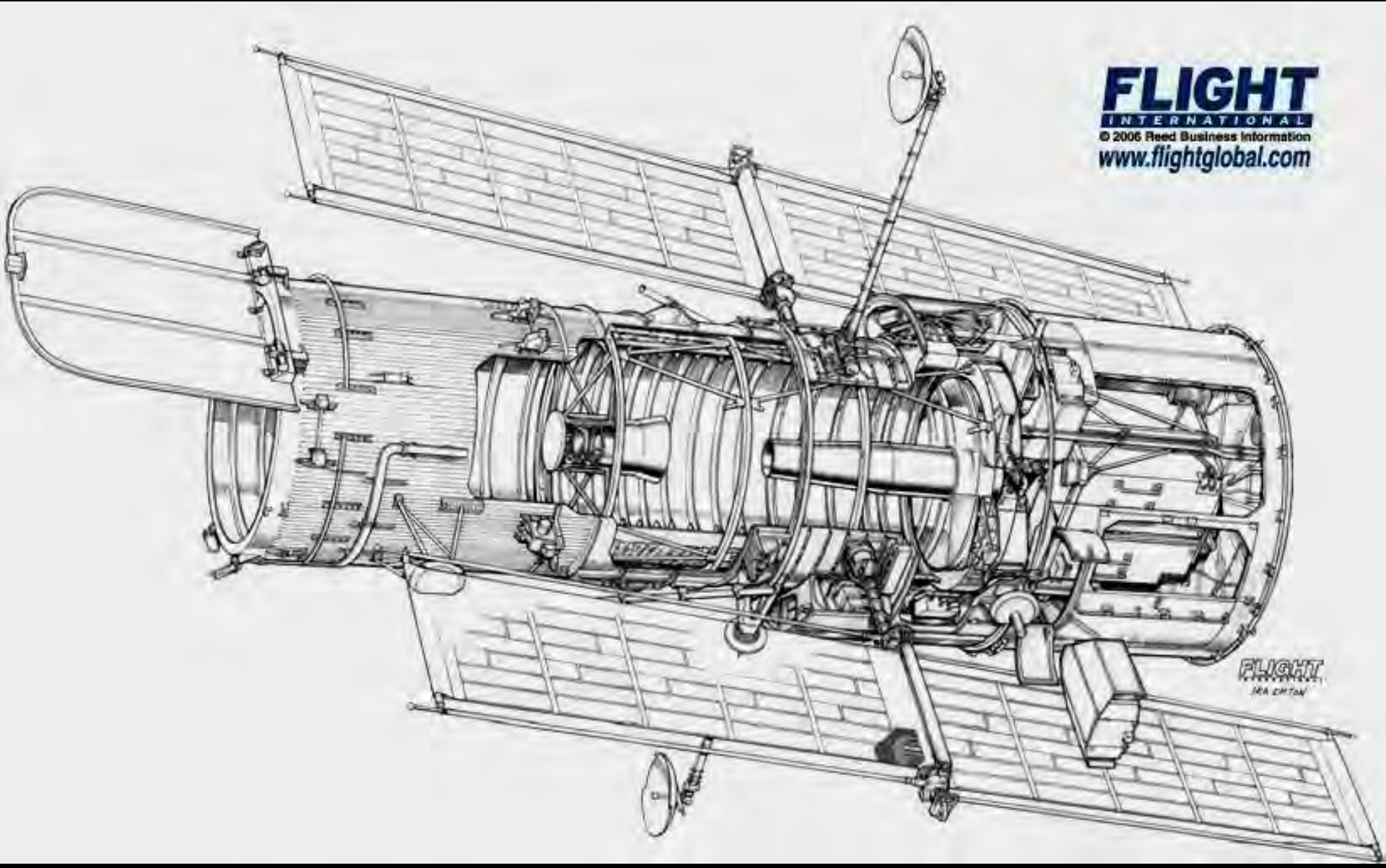
Hubble  the Telescope

NASA/ESA project, to provide an optical high resolution observatory in LEO

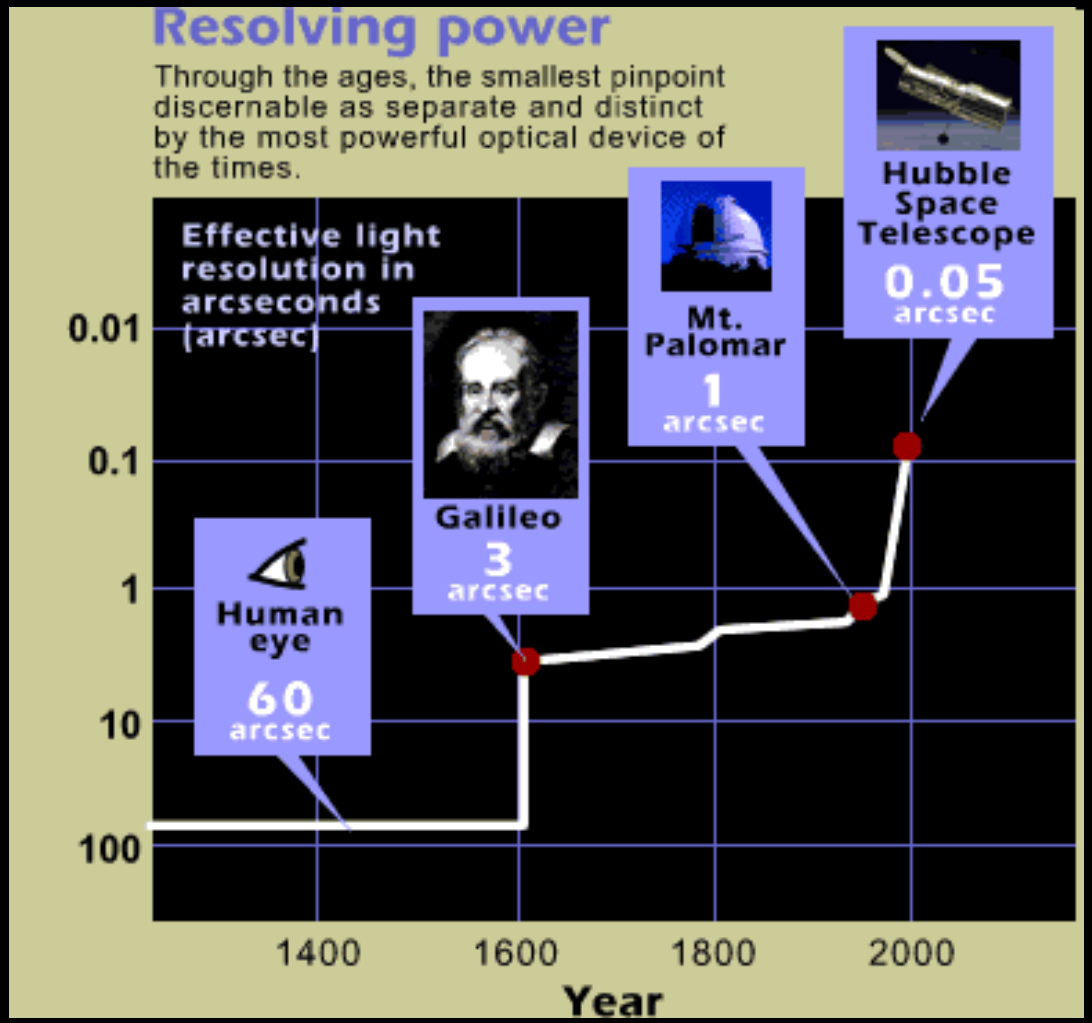




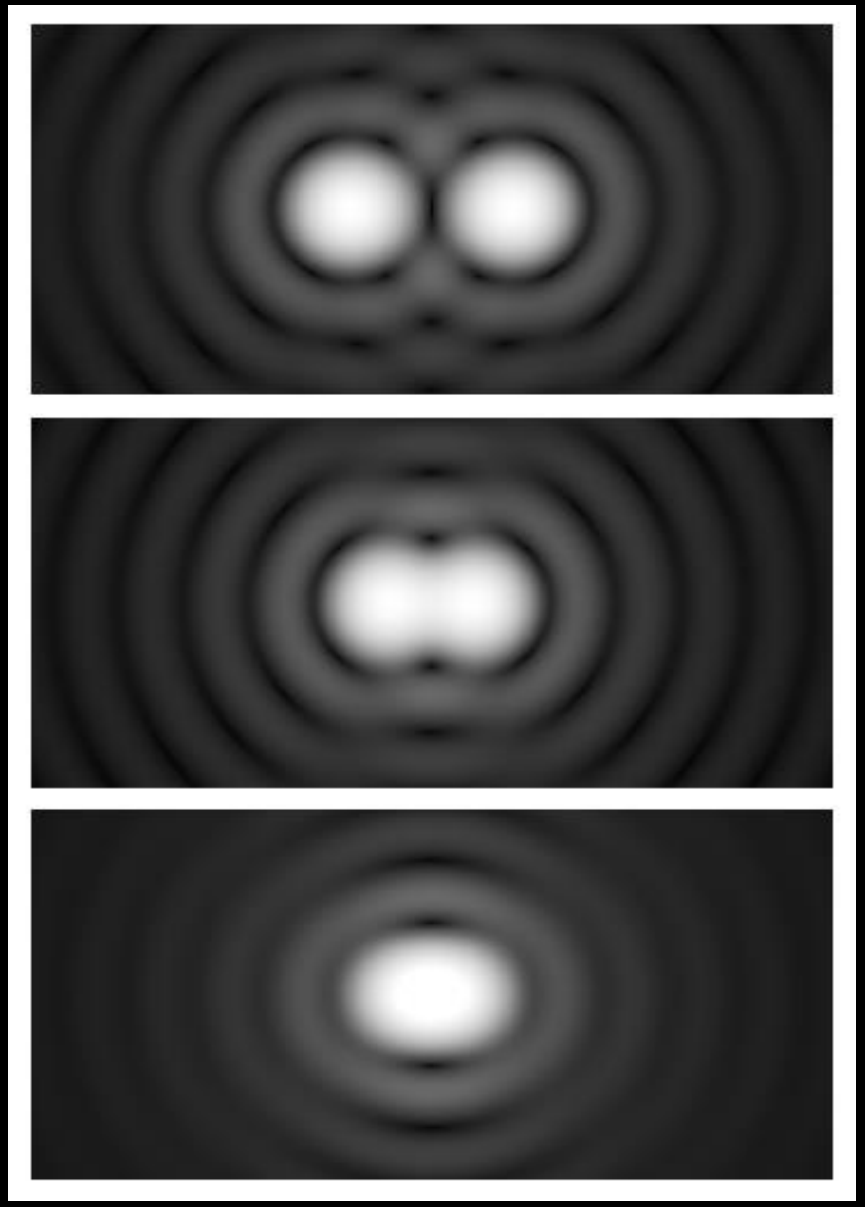
Hubble optical system



The Telescope



Expected resolution of the Telescope, compared to other optical systems



resolved

just resolved

not resolved

Airy diffraction patterns generated by light from two points passing through a circular aperture

The angular resolution R of a telescope can be approximated by

$$R = \lambda/D$$

λ is the wavelength of the observed radiation
and D is the diameter of the telescope's objective or mirror.

Resulting R is in radians. Sources larger than the angular resolution are called extended sources or diffuse sources, and smaller sources are called point sources (stars are obviously point sources).

For example, in the case of yellow light with a wavelength of 580 nm, for a resolution of 0.1 arc second, we need D = 1.2 m.

For Hubble, we have D = 2.4 m, so that the resolution is

0.05 arc second 

A very carefully polished primary mirror, but there was a problem, not discovered until on-orbit…


The Shuttle was
a necessity for
Hubble
Installation
on orbit,
and
Servicing
Missions
NASA
SIDE 1
SIDE 1

Shuttle Cockpit

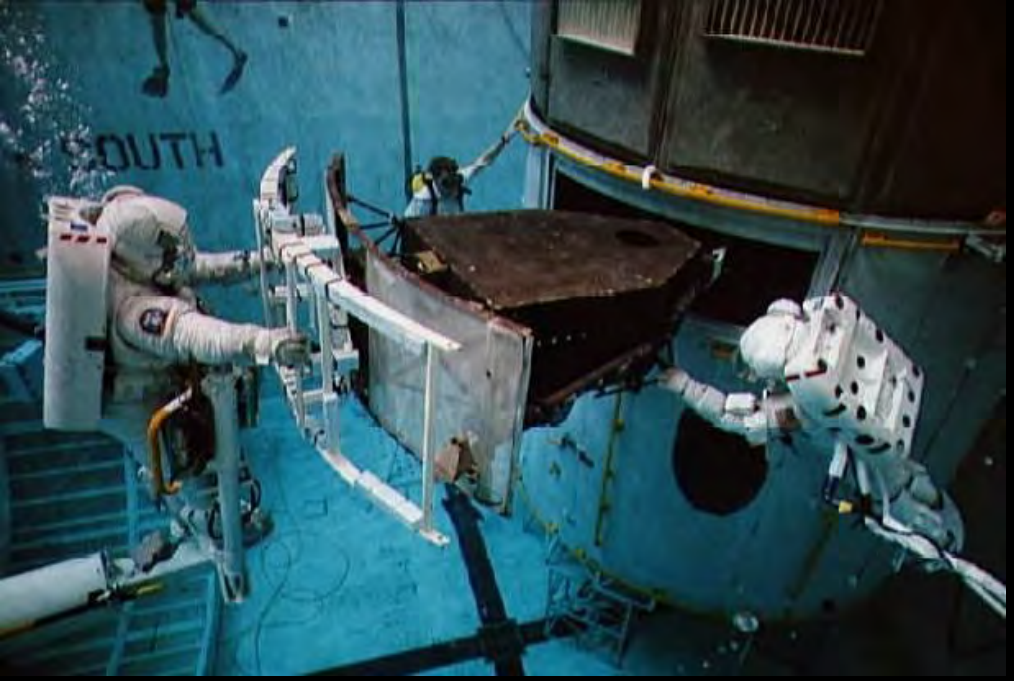
STS-31
on Discovery
April 24, 1990
HST payload
12,000 kg

Orbit:
h 600 km
i 28.5°

Servicing Missions (SM) from 1993 to 2009

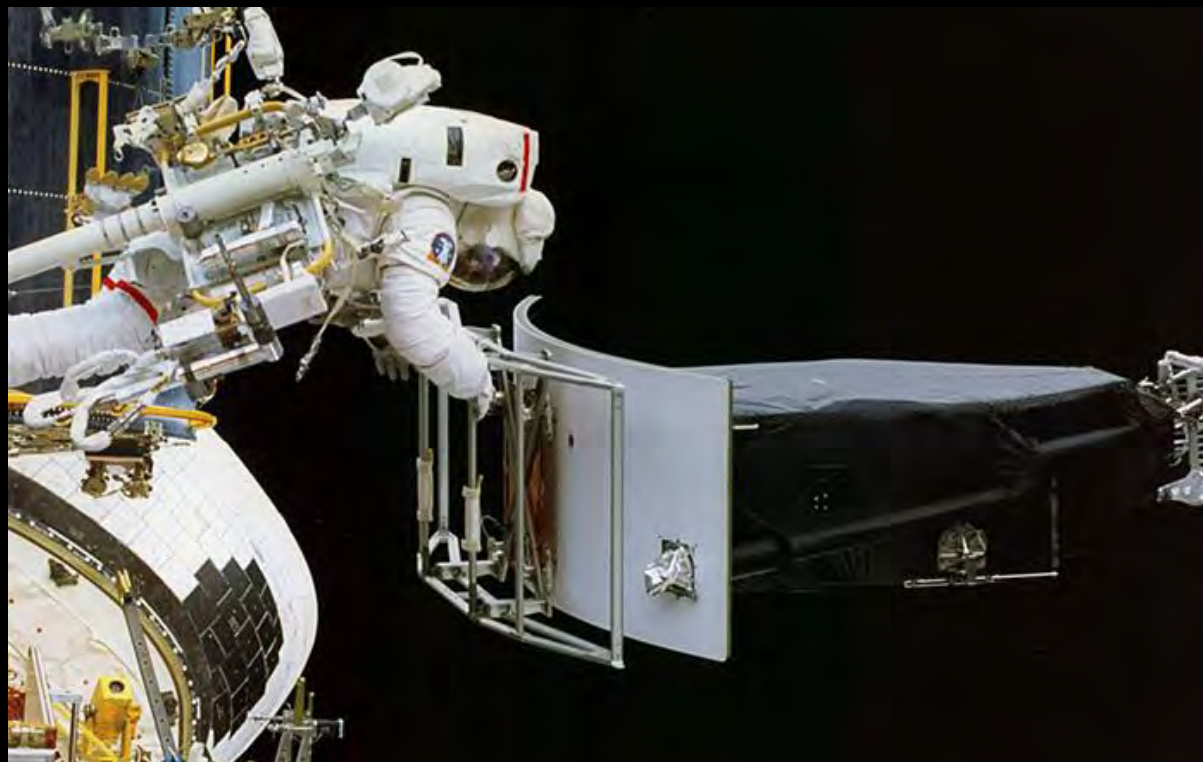
Crew of HST SM 1 (STS-61), 1993

Evaluation of servicing strategies for SM 1

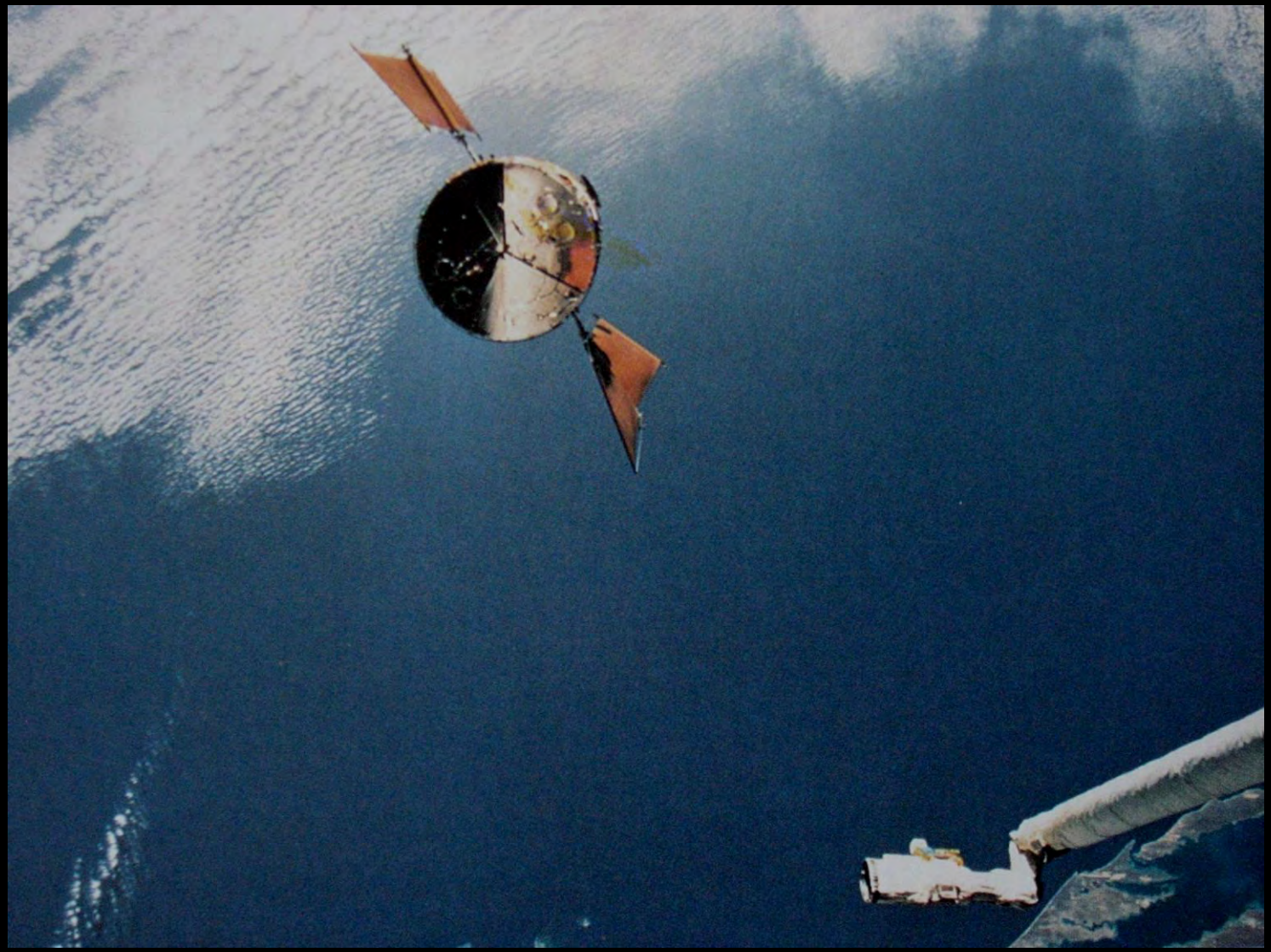


SM 1 training in the water…
MSFC Huntsville, Al.

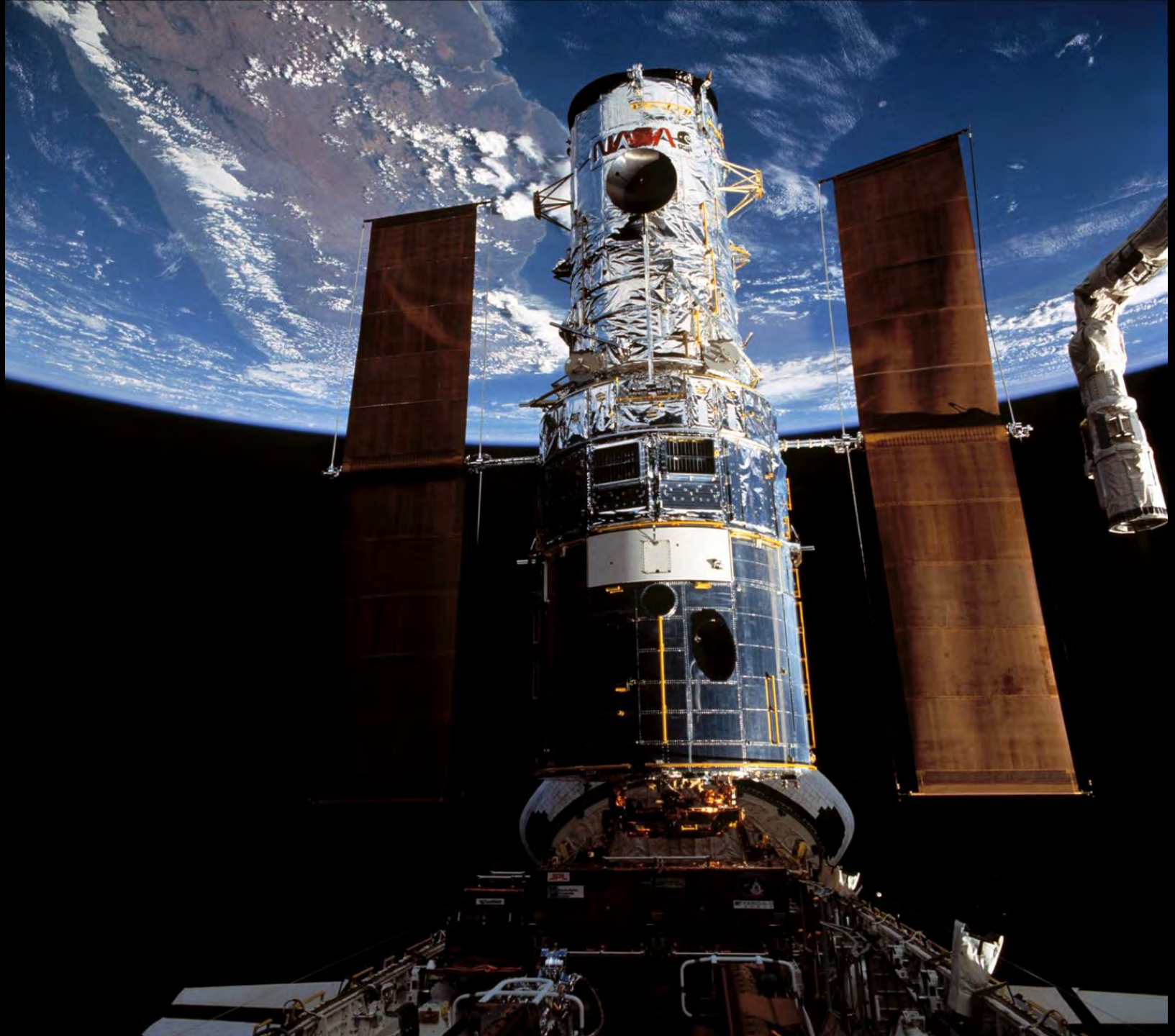
…and reality

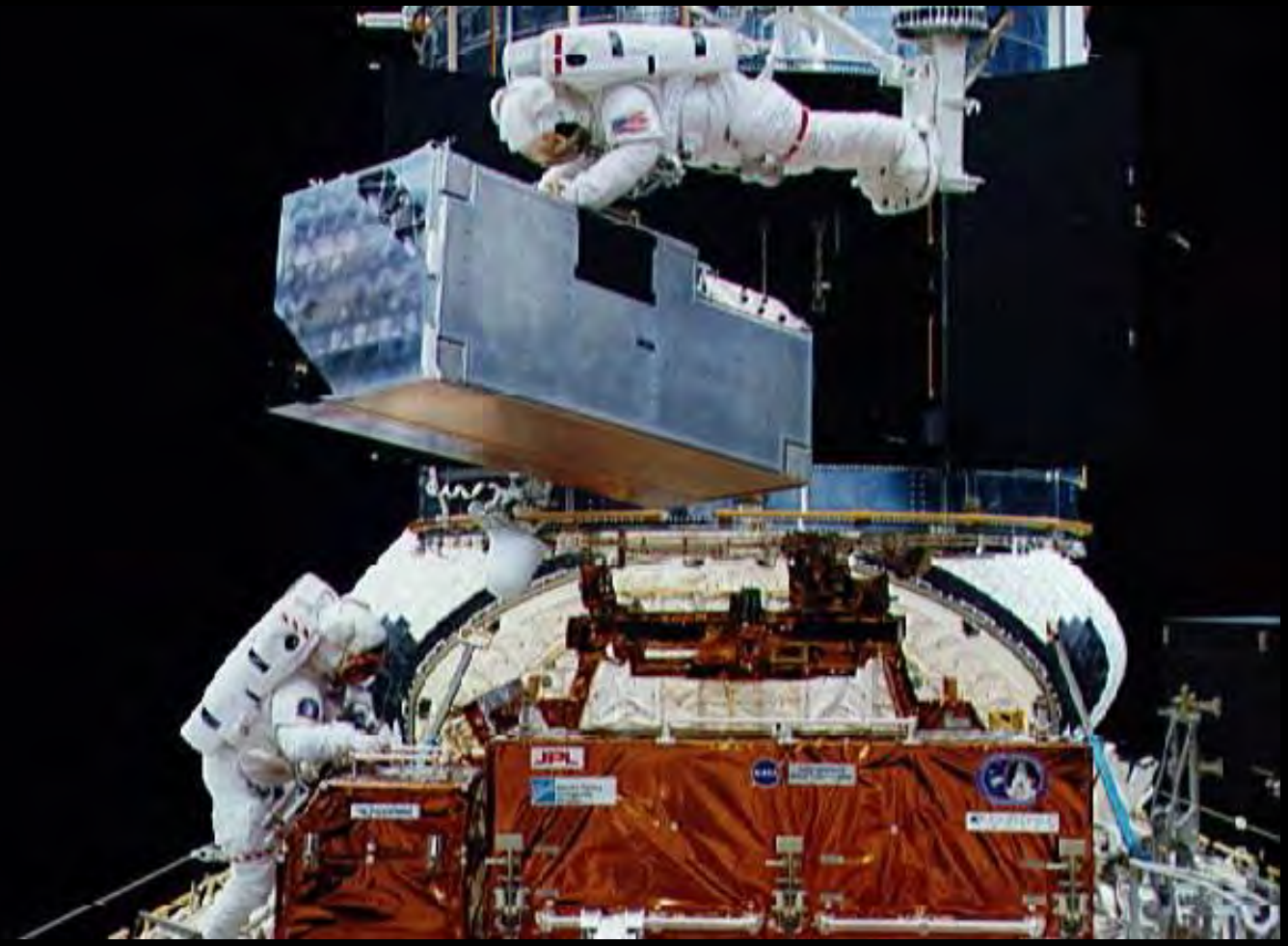



Lift-off - December 2, 1993 - 4:26AM

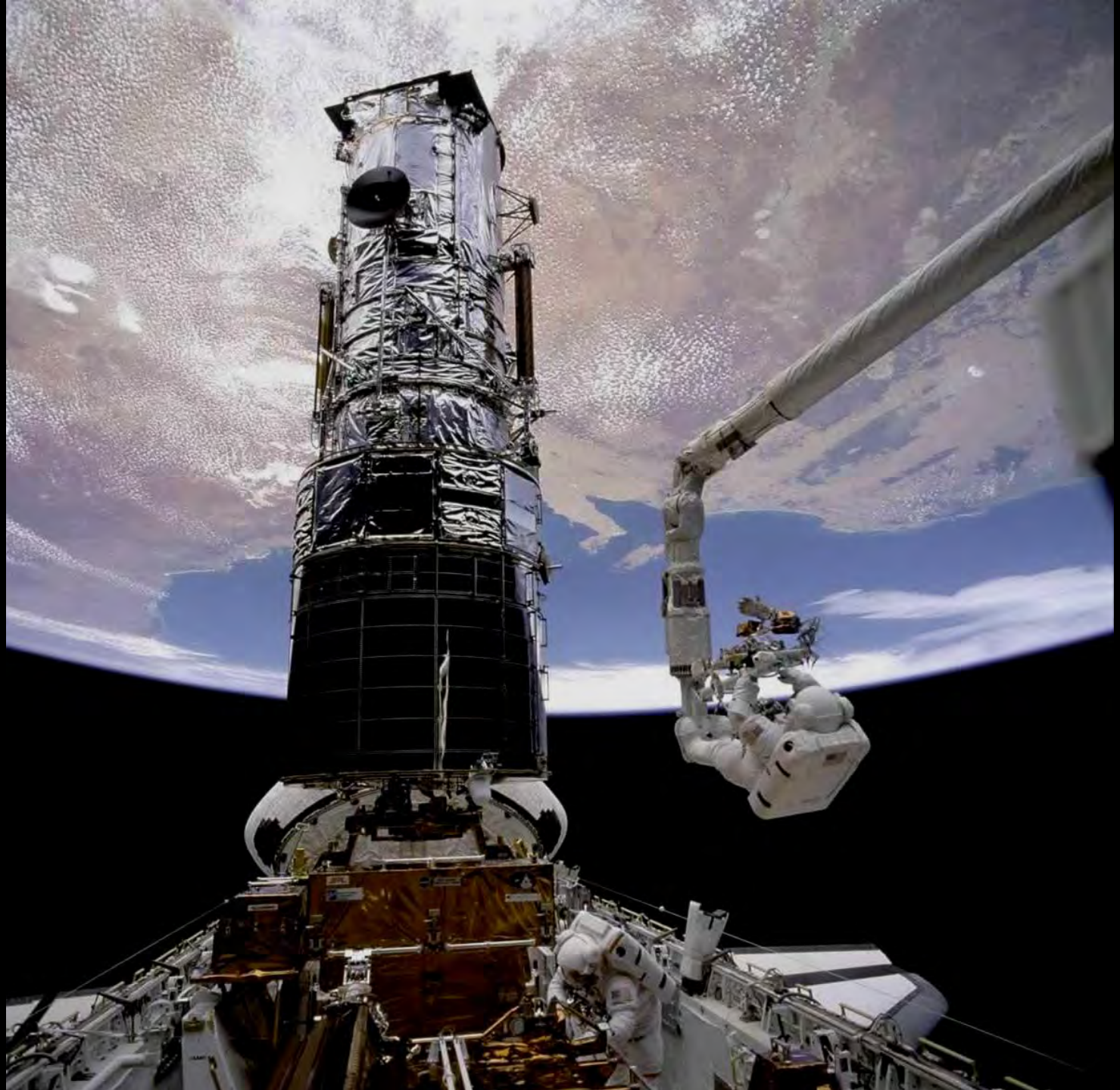


We found it!


NASA



COSTAR installation



A happy crew!

The view!


Atacama desert

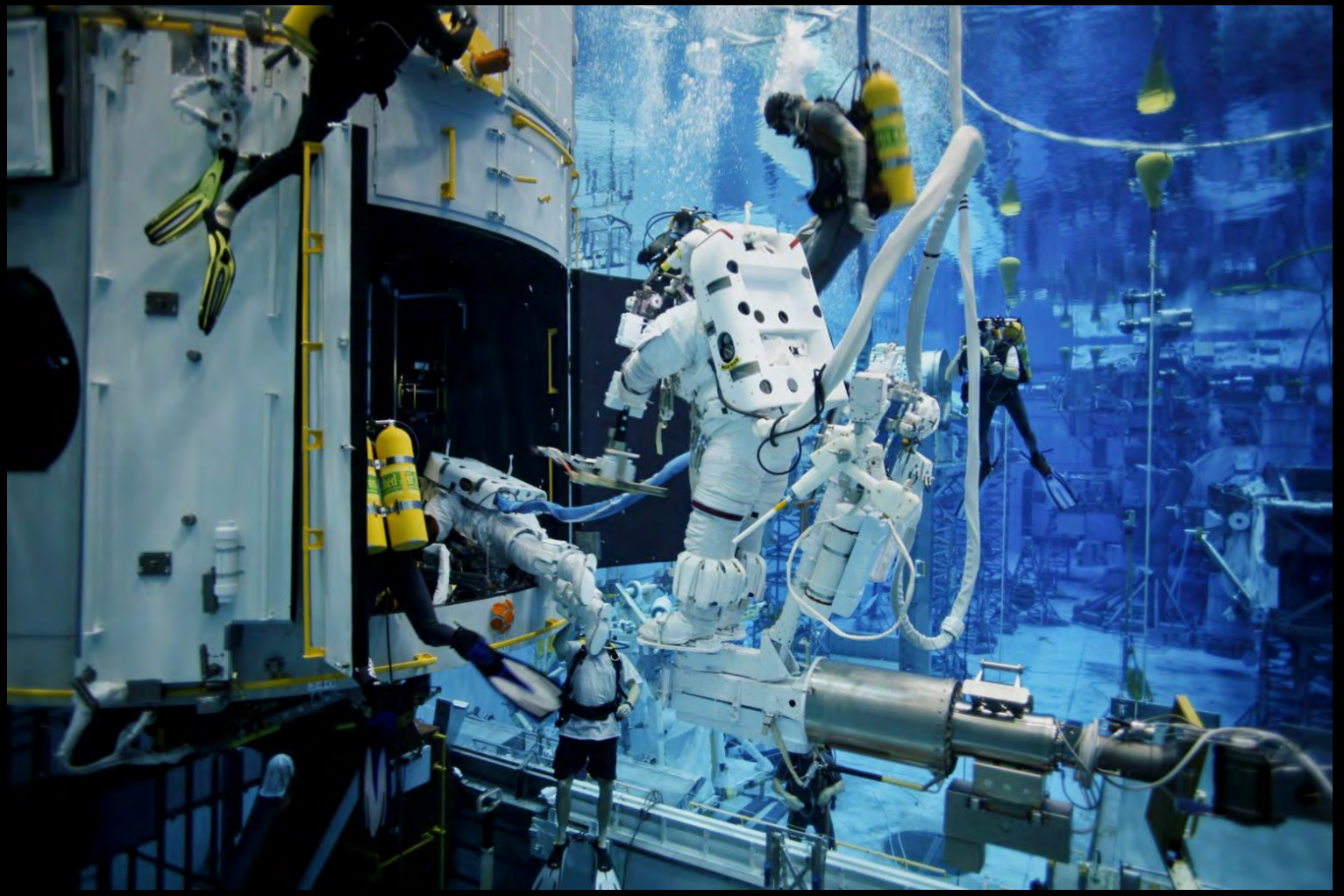
Reentry… HOT!


United States

Milt Heflin

Lead
Flight Director

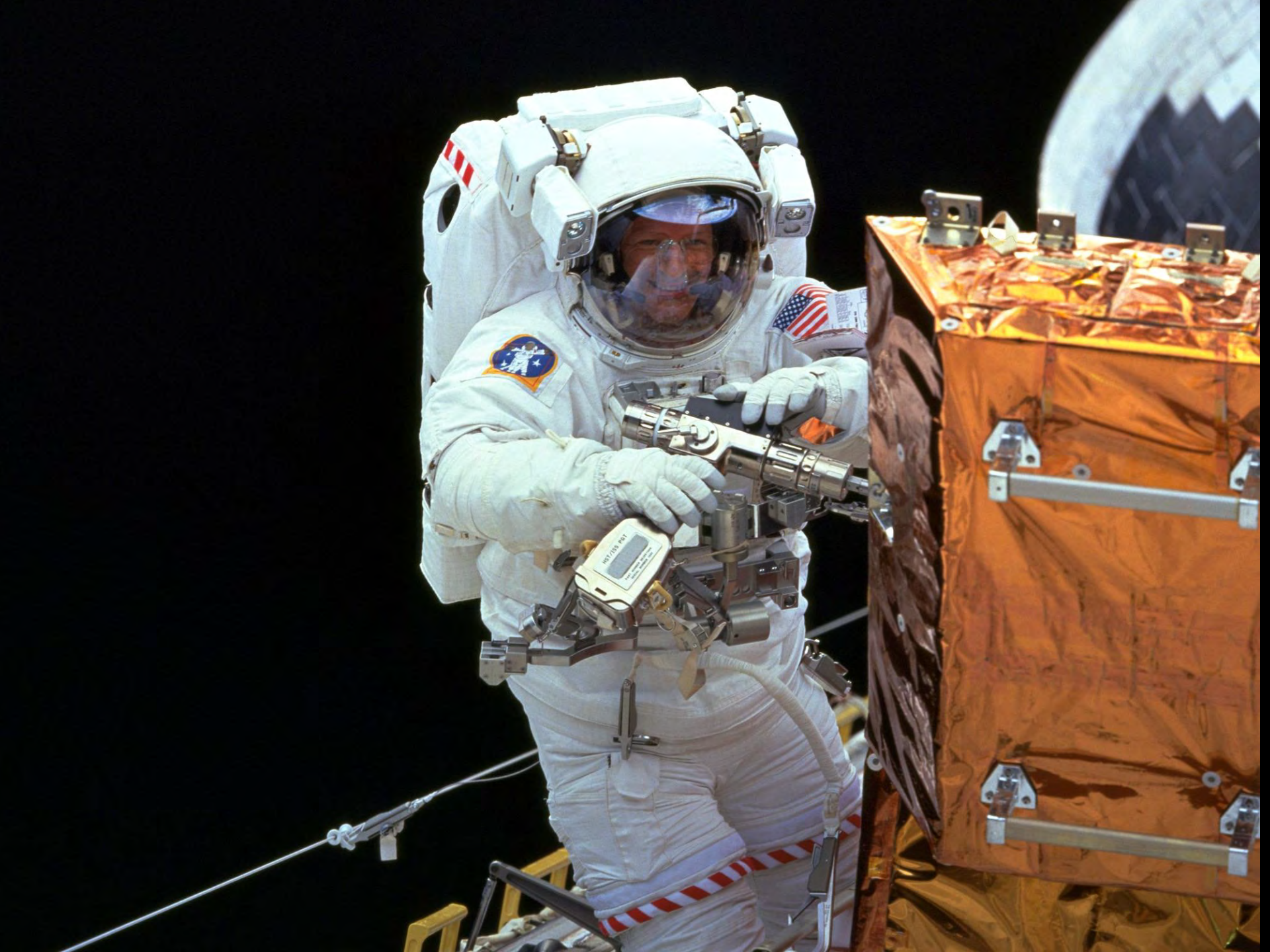
Hubble First
Servicing
Mission



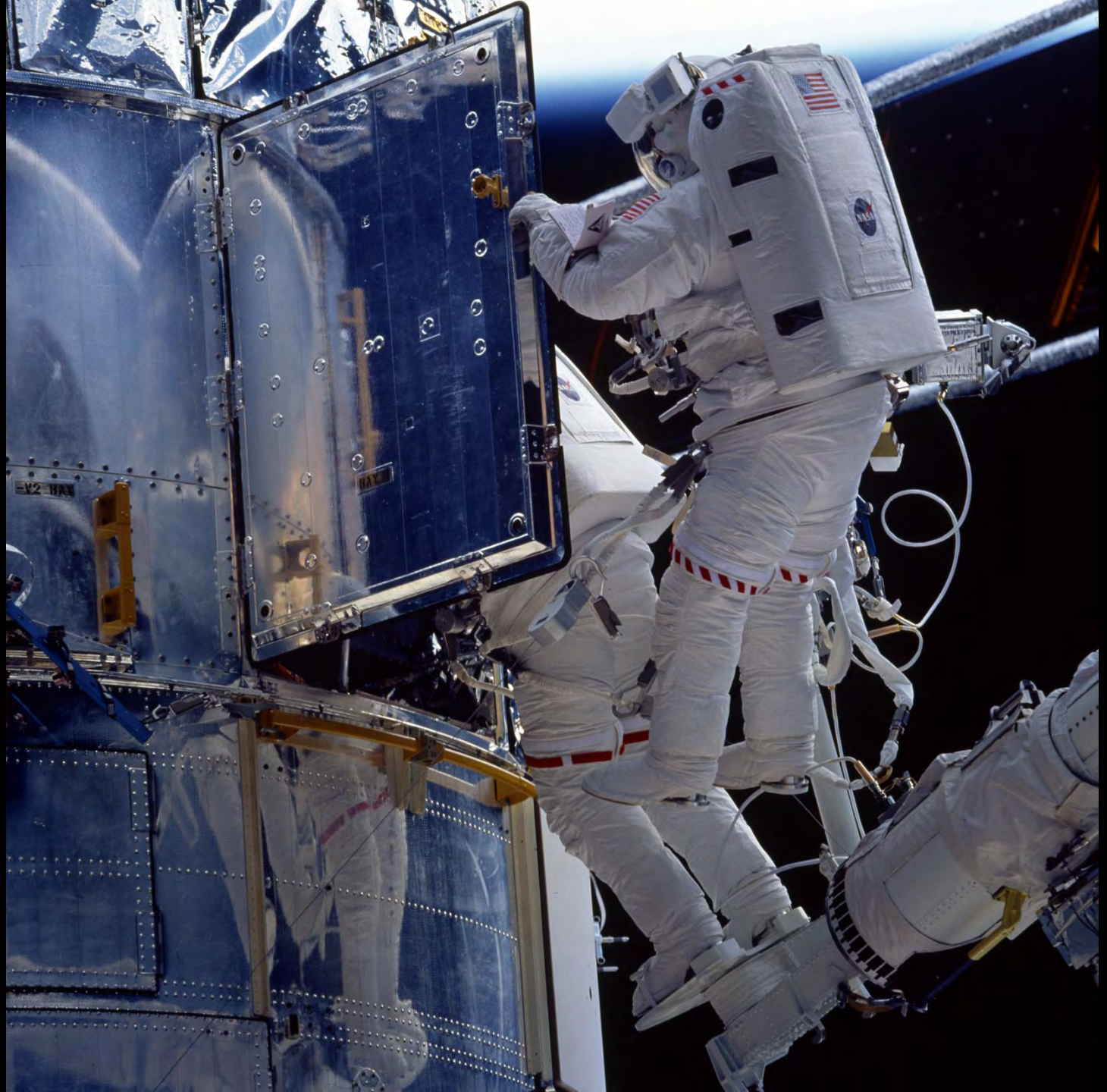
SM 3A Training


NASA
GODDARD SPACE FLIGHT CENTER


LEFT GLOVES
RIGHT GLOVES
EYE GLASSES
CUFF CHECKLIST
WRISTLETS
LEFT GLOVE
PL4




HST/ISS PGT



…it was Christmas Day, 1999!

Hubble SM 4 crew


M16
Eagle
Nebula


NGC 602
in the SMC

Cat's Eye Nebula • NGC 6543

Hubble Heritage


M 104

Interacting Galaxies Arp 273

Hubble Heritage

HDF
(Hubble
Deep Field)

position
in
Ursa Major

HDF
Hubble Deep Field

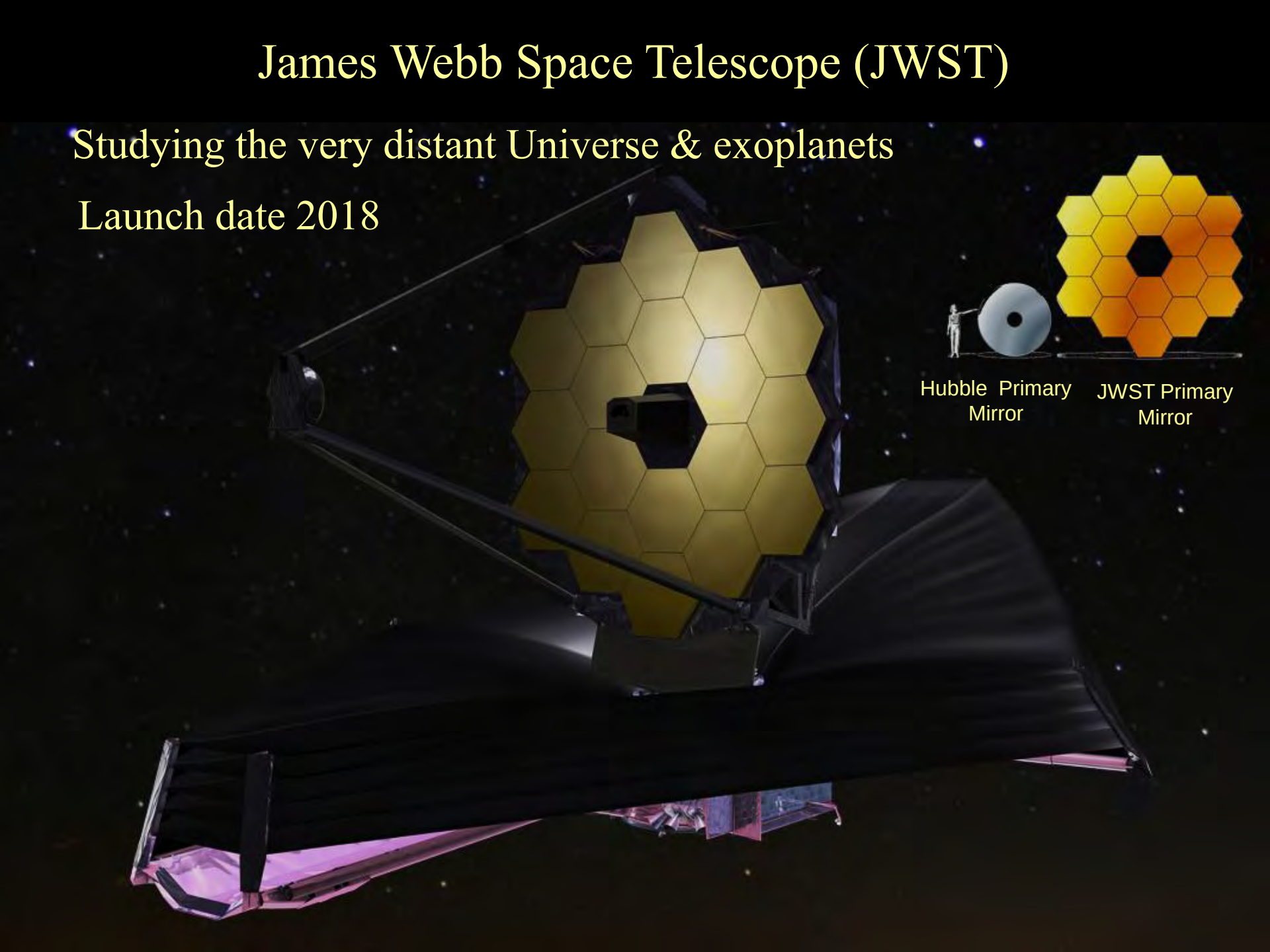
Why so much success in HST servicing?

- Clear goals and priorities
- Strict operational discipline, in space and on the ground
- Teamwork
- Thorough training in realistic environments - extensive practice for handling malfunctions

James Webb Space Telescope (JWST)

Studying the very distant Universe & exoplanets

Launch date 2018



Until (and hopefully beyond) JWST, we hope that we will enjoy many more discoveries and stunning pictures from the Hubble Space Telescope!


Thank you for your attention!