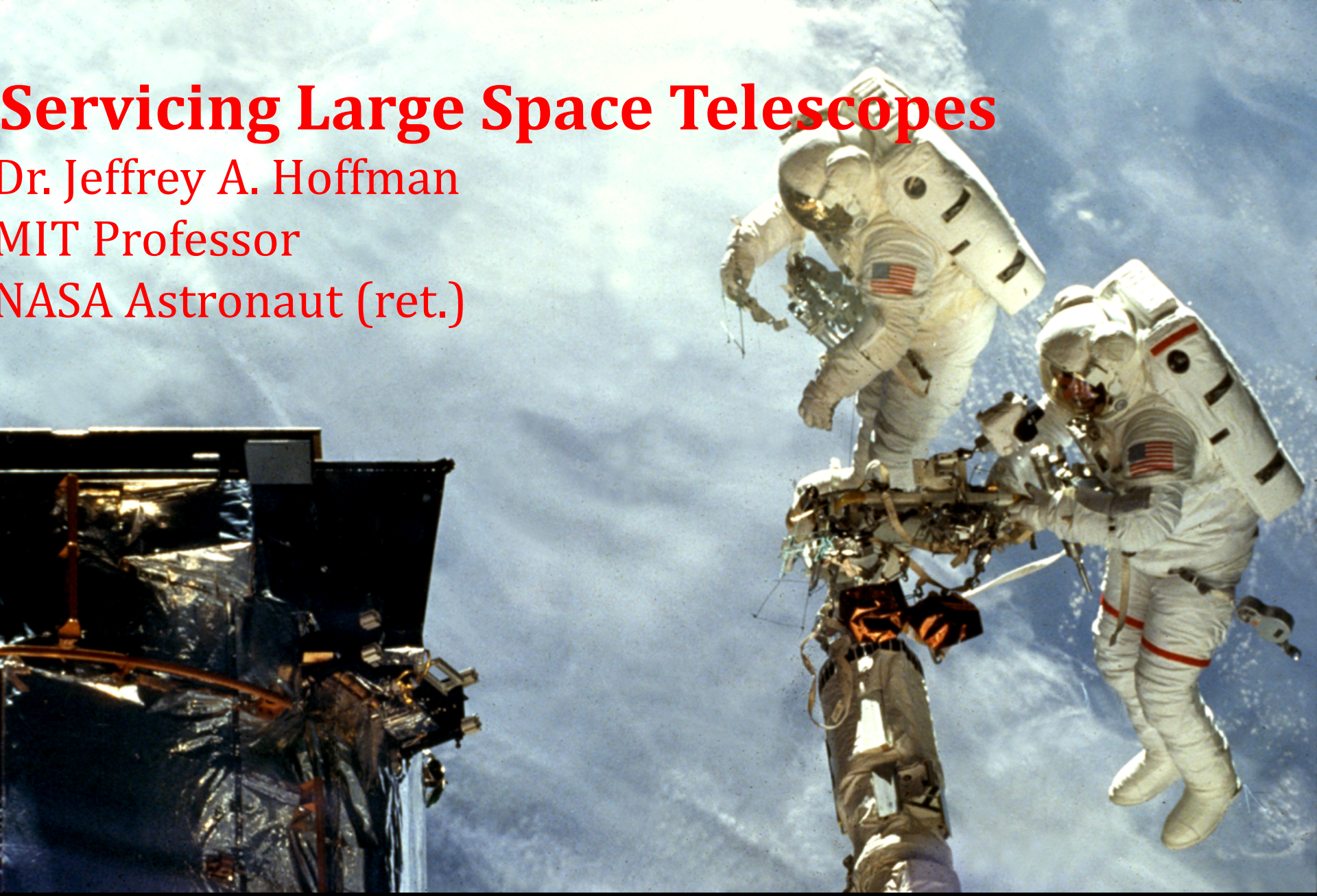
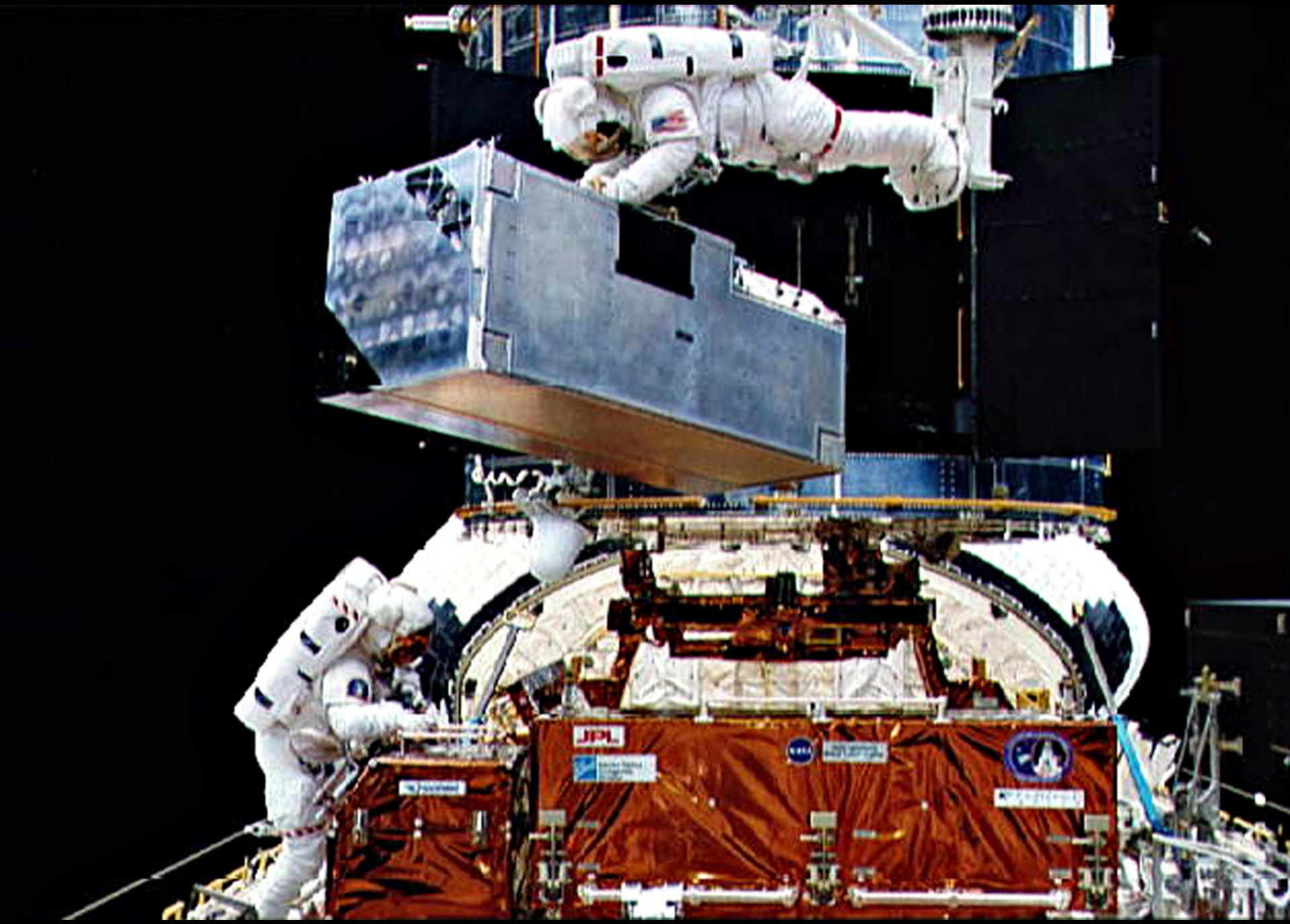
Servicing Large Space Telescopes

Dr. Jeffrey A. Hoffman
MIT Professor
NASA Astronaut (ret.)

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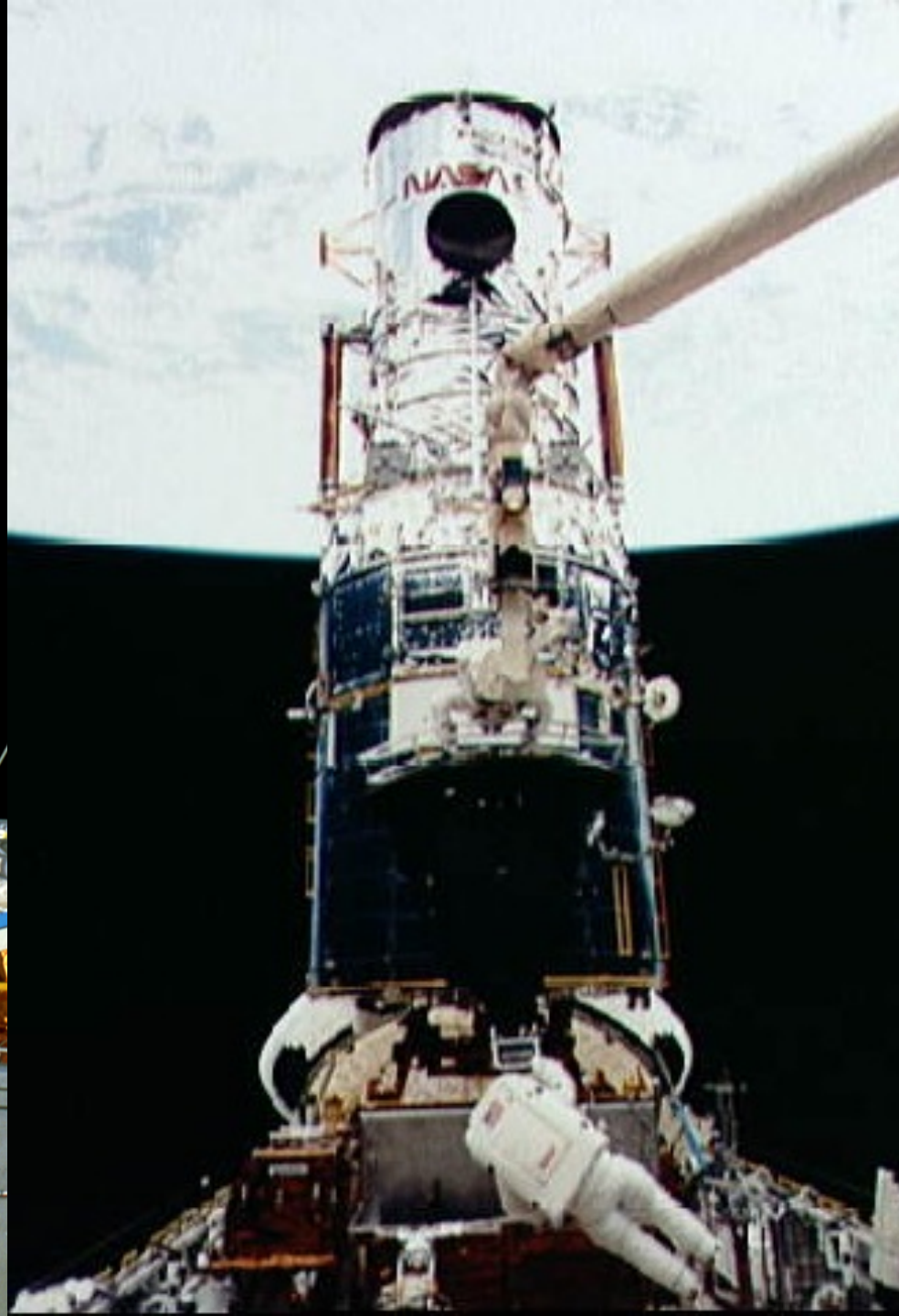
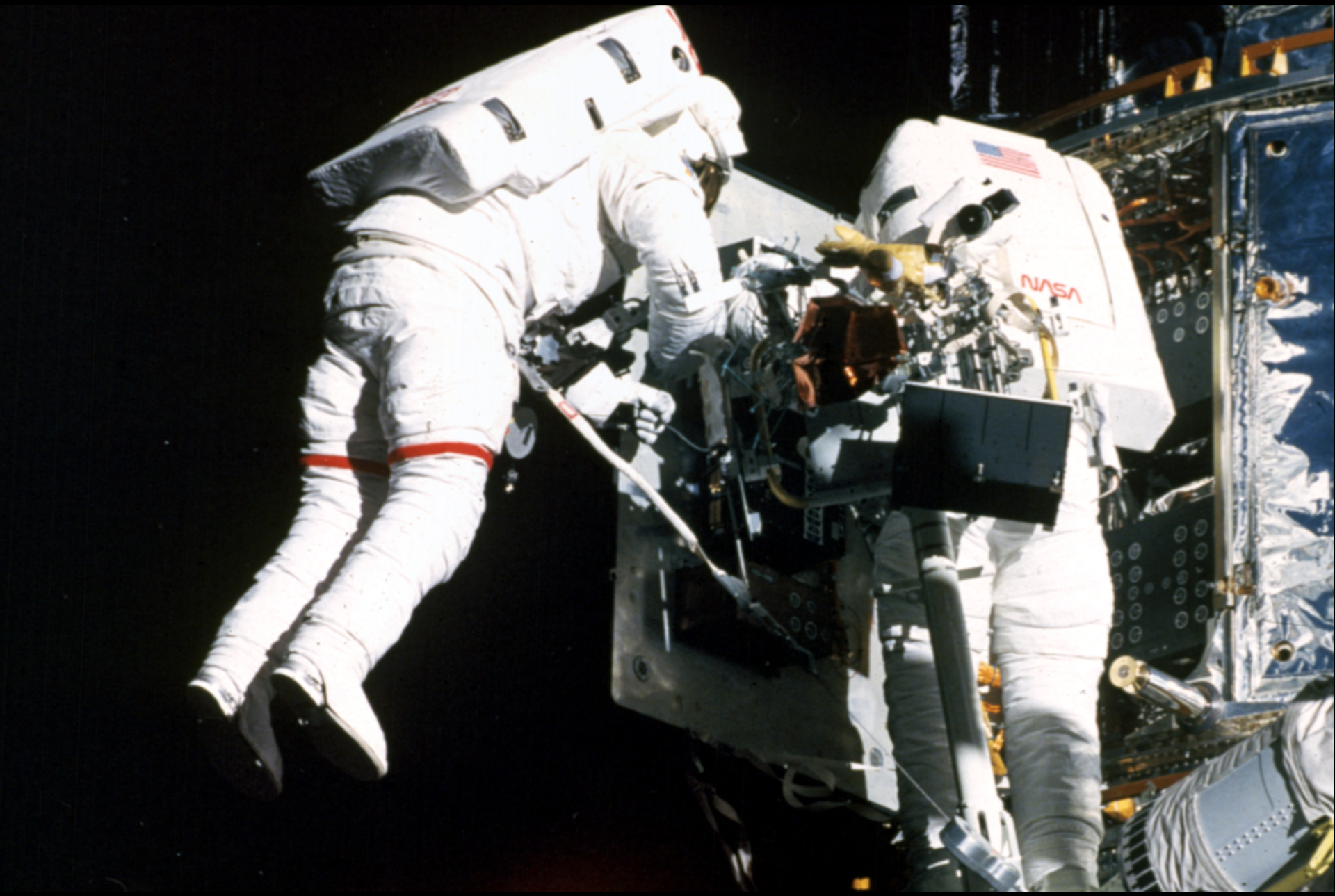

NASA


NASA

HUBBLE MISSIONS

Launch!

1990

Wild Field Planetary Camera 2
COSTAR
Gyros
Solar Arrays

SM1

1993

Imaging Spectrograph
Near Infrared Camera
Fine Guidance Sensor

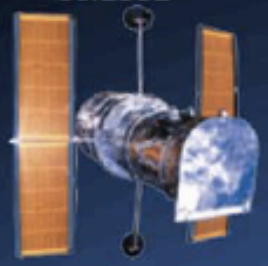
SM2

1997

Gyros
Advanced Computer
Fine Guidance Sensor

SM3A

1999



Advanced Camera
Solar Arrays
Power Control Unit
NICMOS Cooling System

SM3B

2002

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

SM4

2008

De-Orbit Mission

2013

New instruments, New Discoveries

Servicing Mission 1, 1993

WFPC2

Discoveries

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

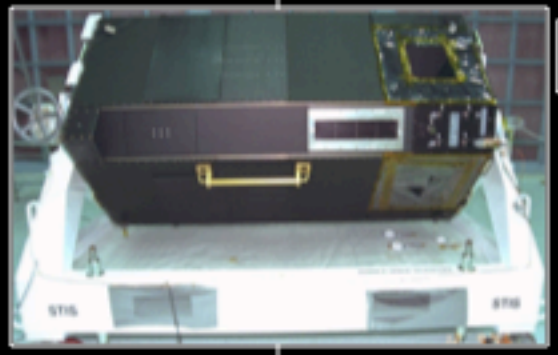
Servicing Missions

SM1

New instruments, New Discoveries

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

NICMOS (1–2 μm)



STIS (=40X Original Spectrographs)

Discoveries

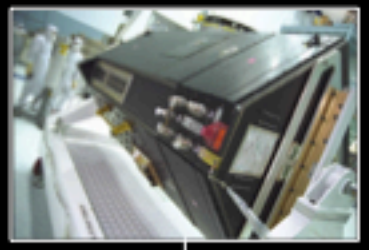
- ✓ Proof of Black Holes
- ✓ Supernova 1As
- ✓ Accelerating Universe
- ✓ Hint of Dark Matter, Dark Energy
- ✓ Hubble Deep Field

Servicing Missions SM1 SM2–SM3A

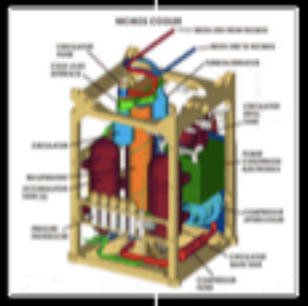
New instruments, New Discoveries

Servicing Mission 3B, 2002

ACS
(=10X WFPC2)



NICMOS/NCS



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

Servicing Missions SM1 SM2 SM3A SM3B

New instruments, New Discoveries

Servicing Mission 4, 2009

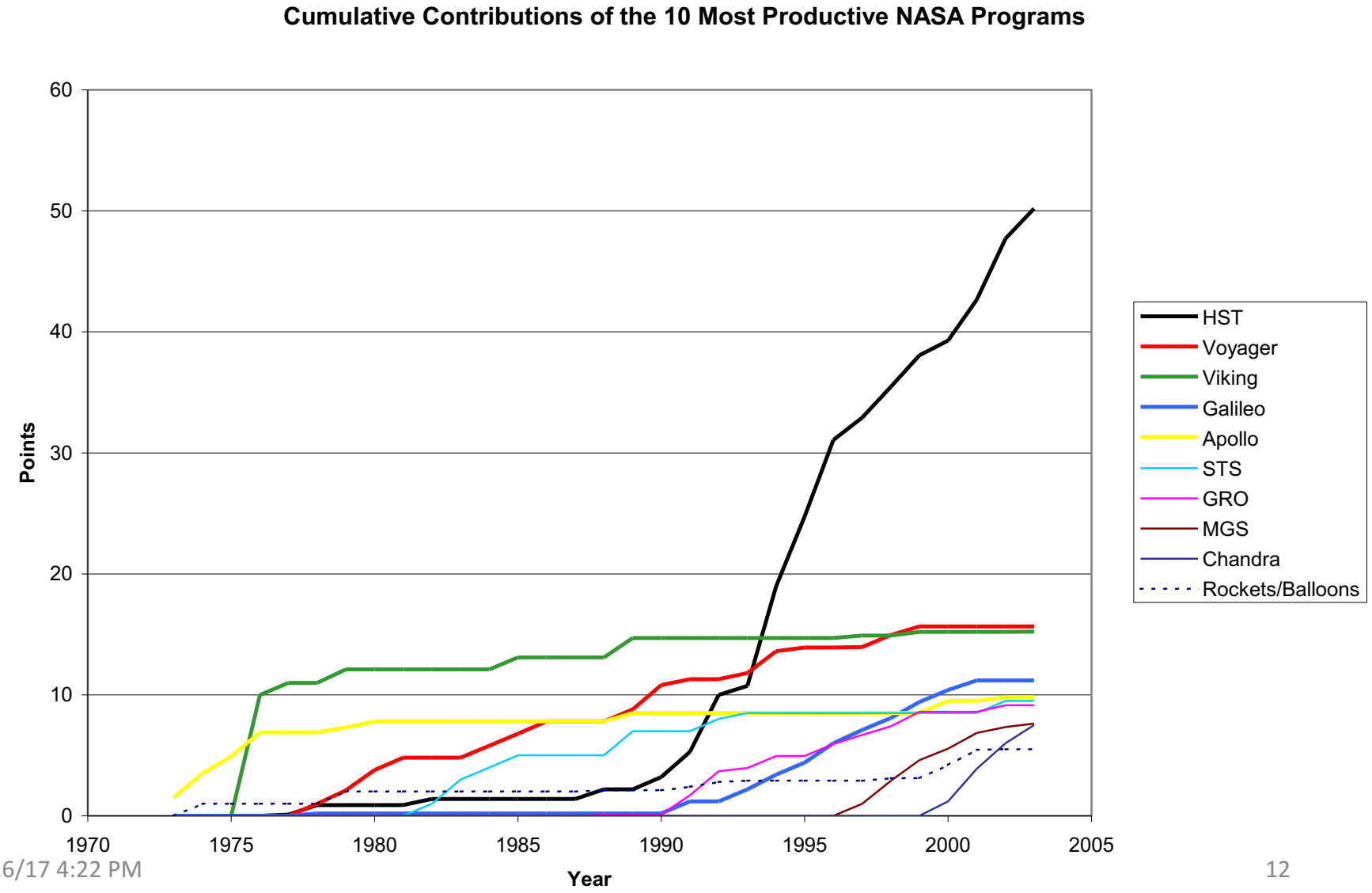
WFC3
(=25X NICMOS)

COS
(=20X STIS)

Discoveries Continuing

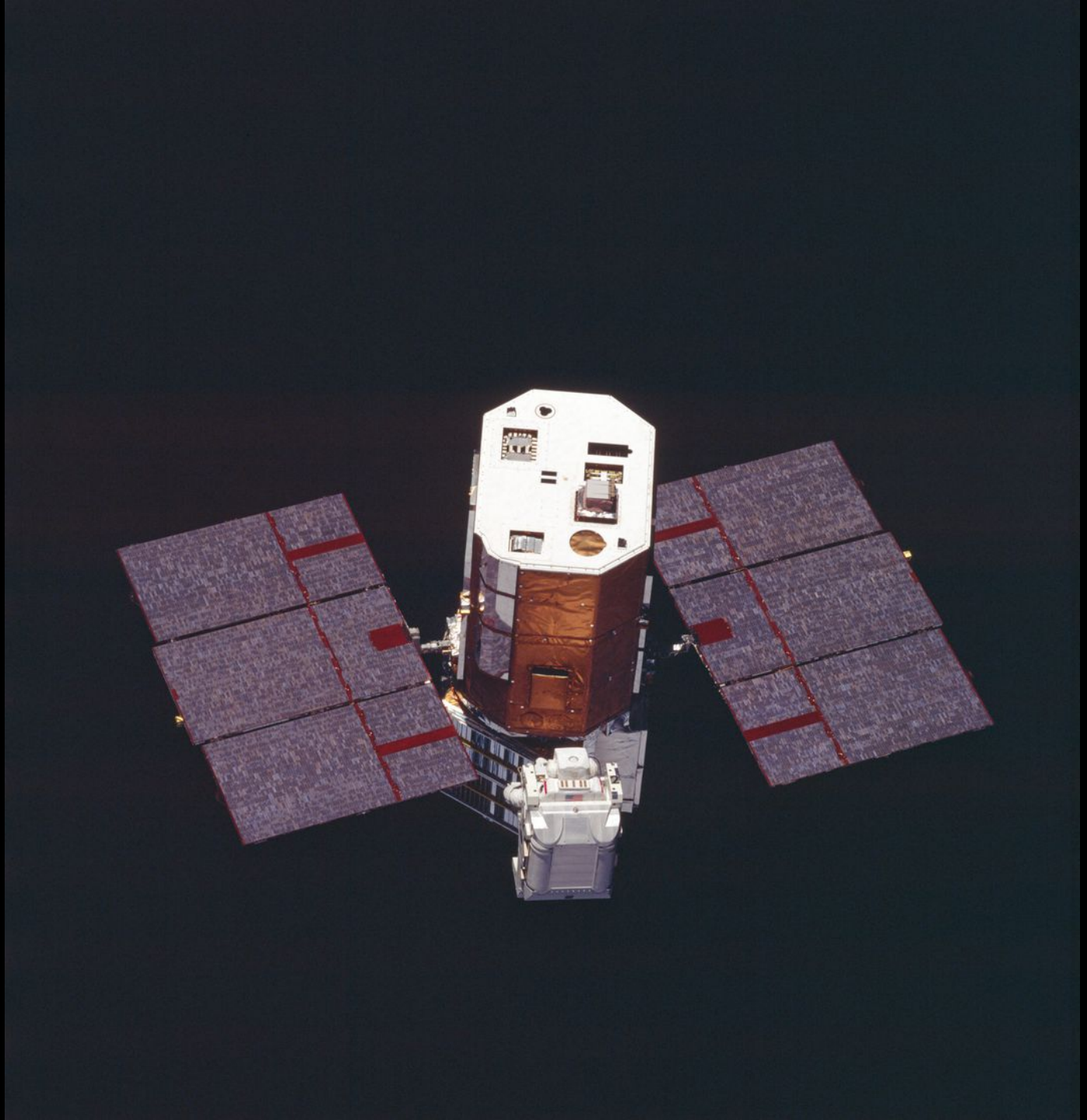
Servicing Missions SM1 SM2 SM3A SM3B SM4

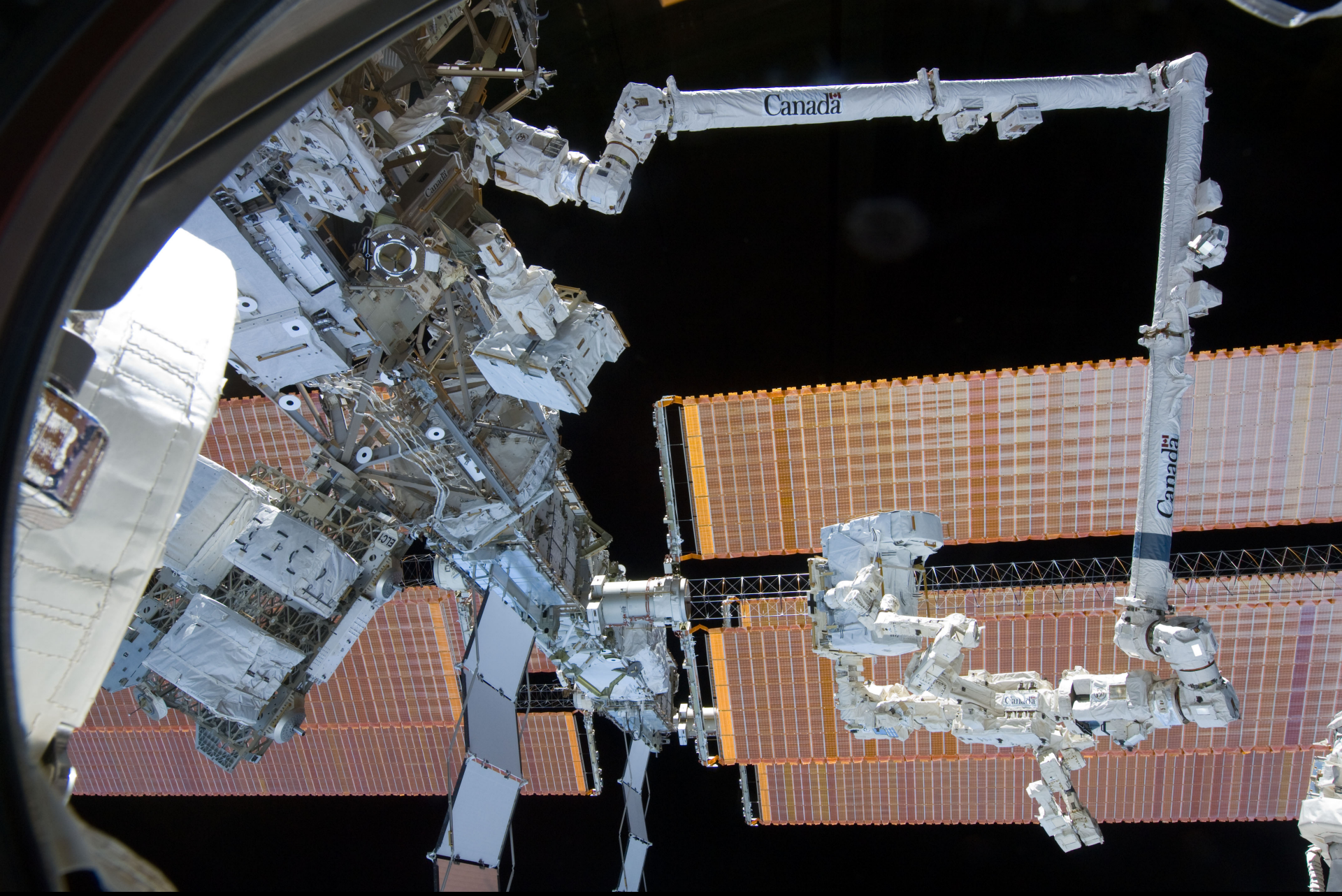
HST's Dominance of *Science News* "Annual Discoveries" List Reflects the Effectiveness of Regular Servicing by Astronauts and Collaborative Work with Science Community

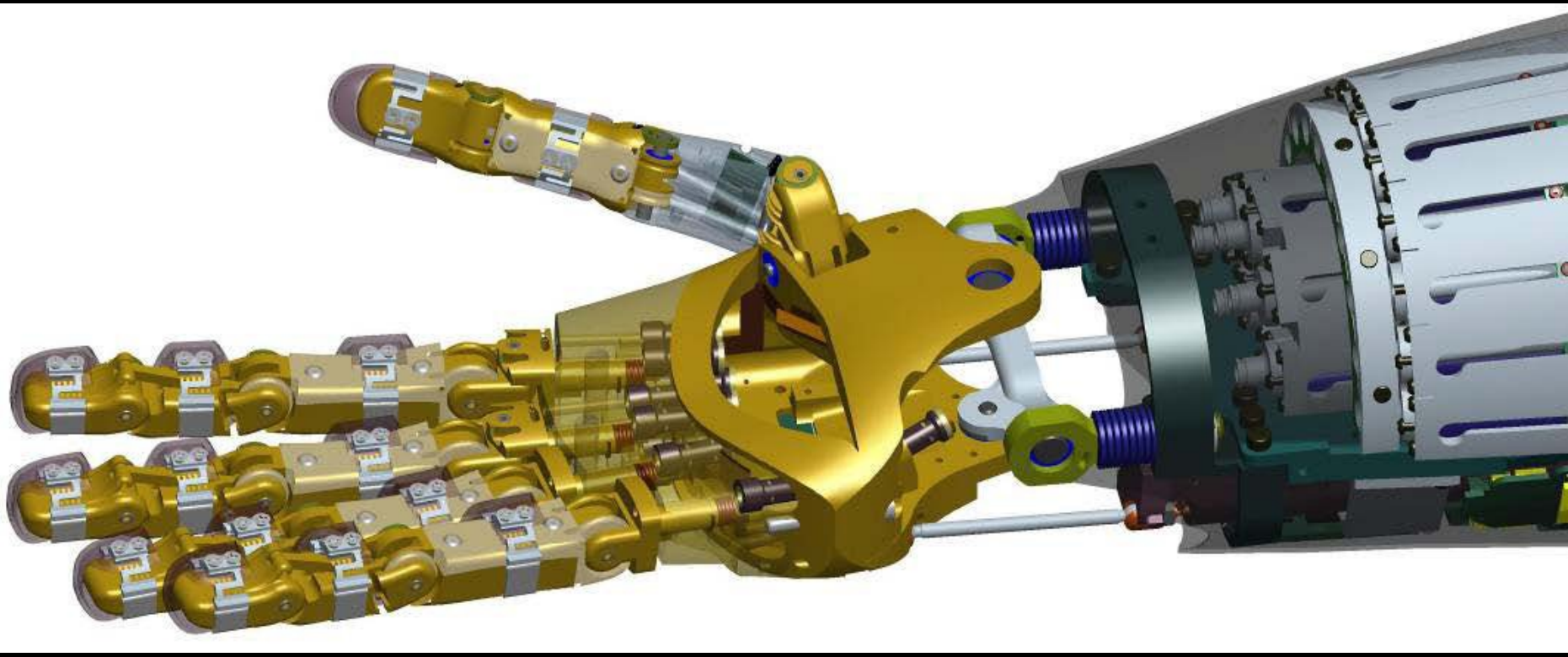


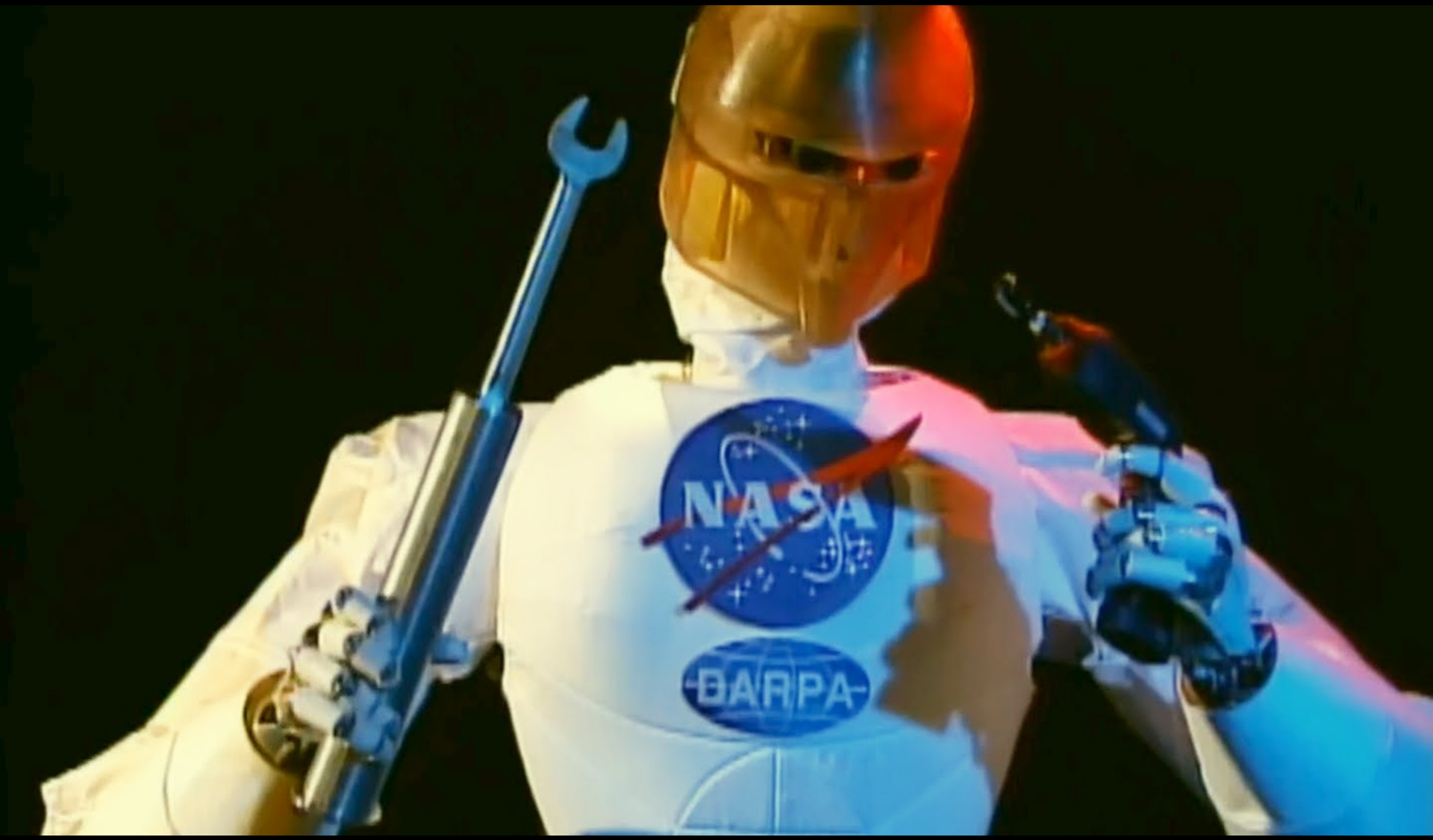
Hubble

- Servicing by the Shuttle re-invented the telescope at each visit.
- The complexity of what the crew accomplished increased with each mission.
- HST continues to make remarkable scientific discoveries powered by new instruments taking advantage of current technology.

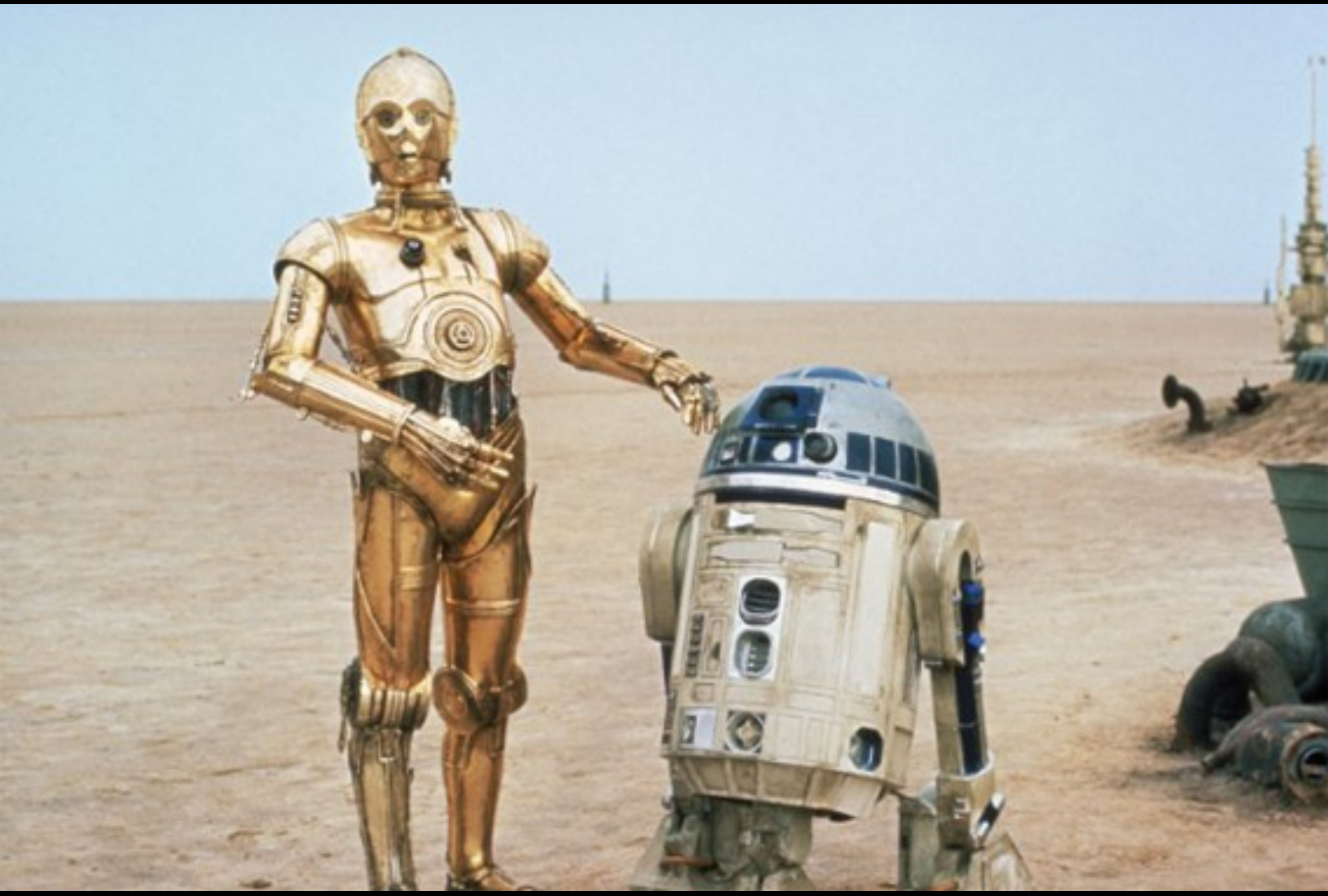


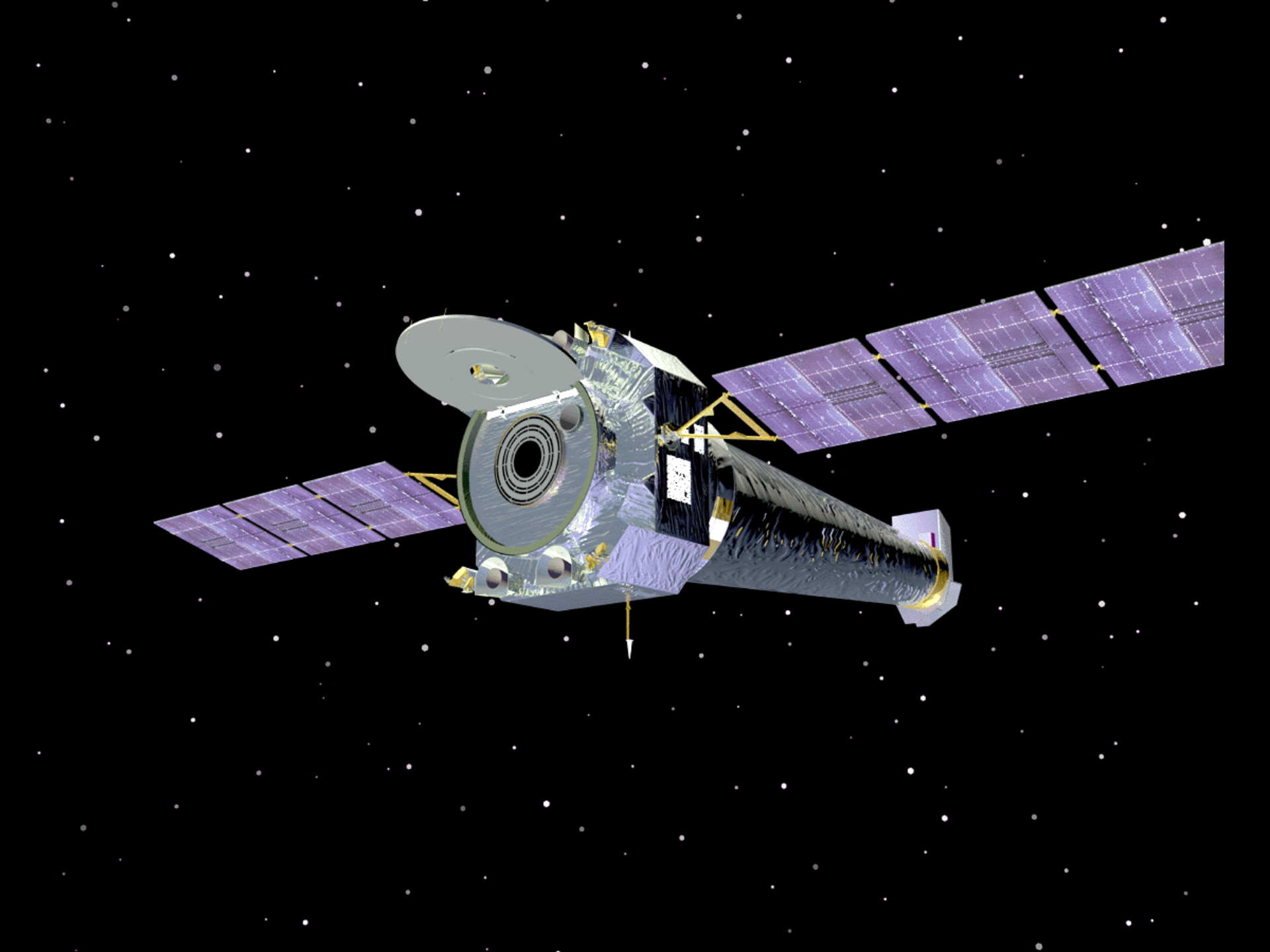

Canada
Canada

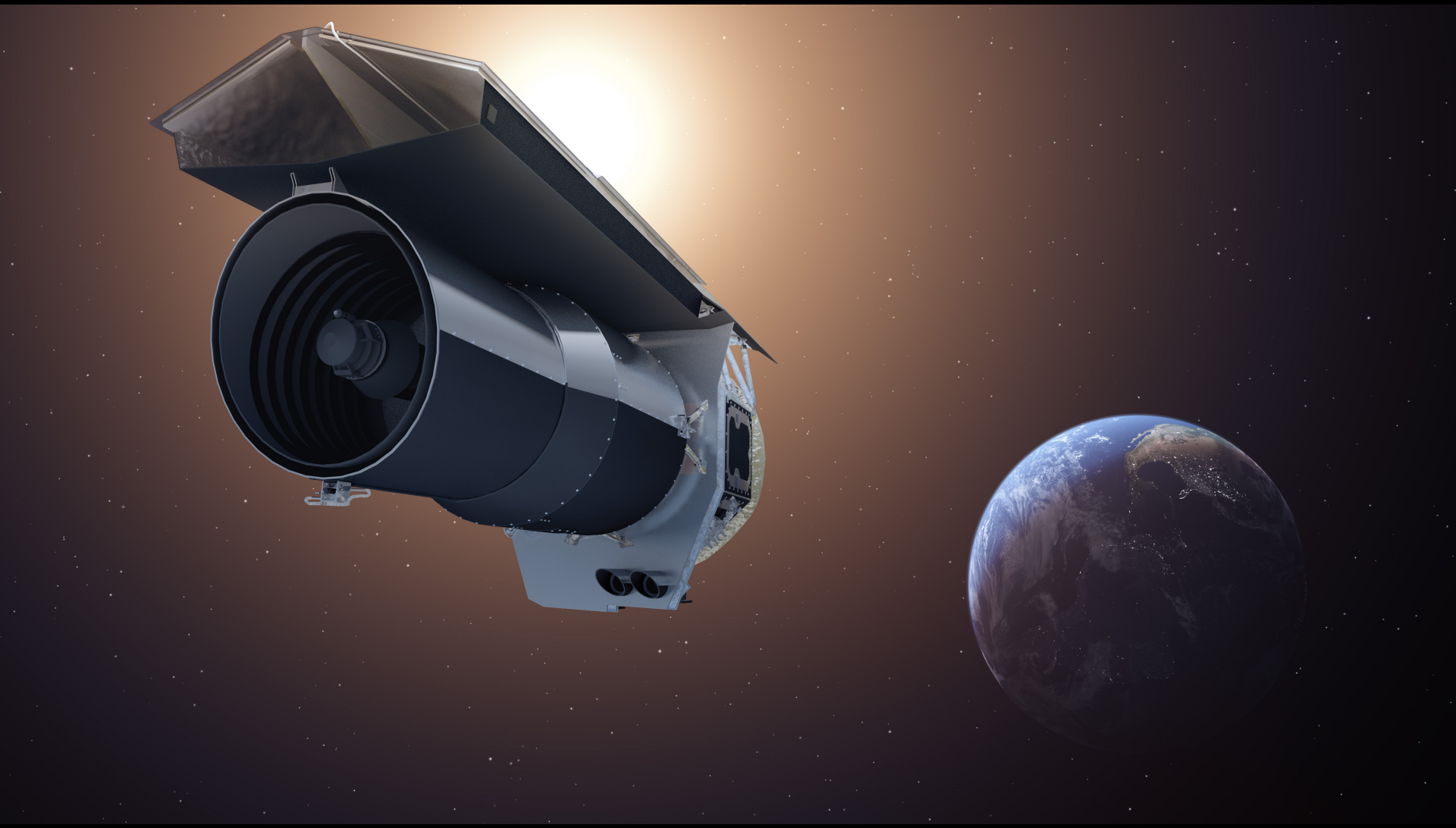



NASA
DARPA

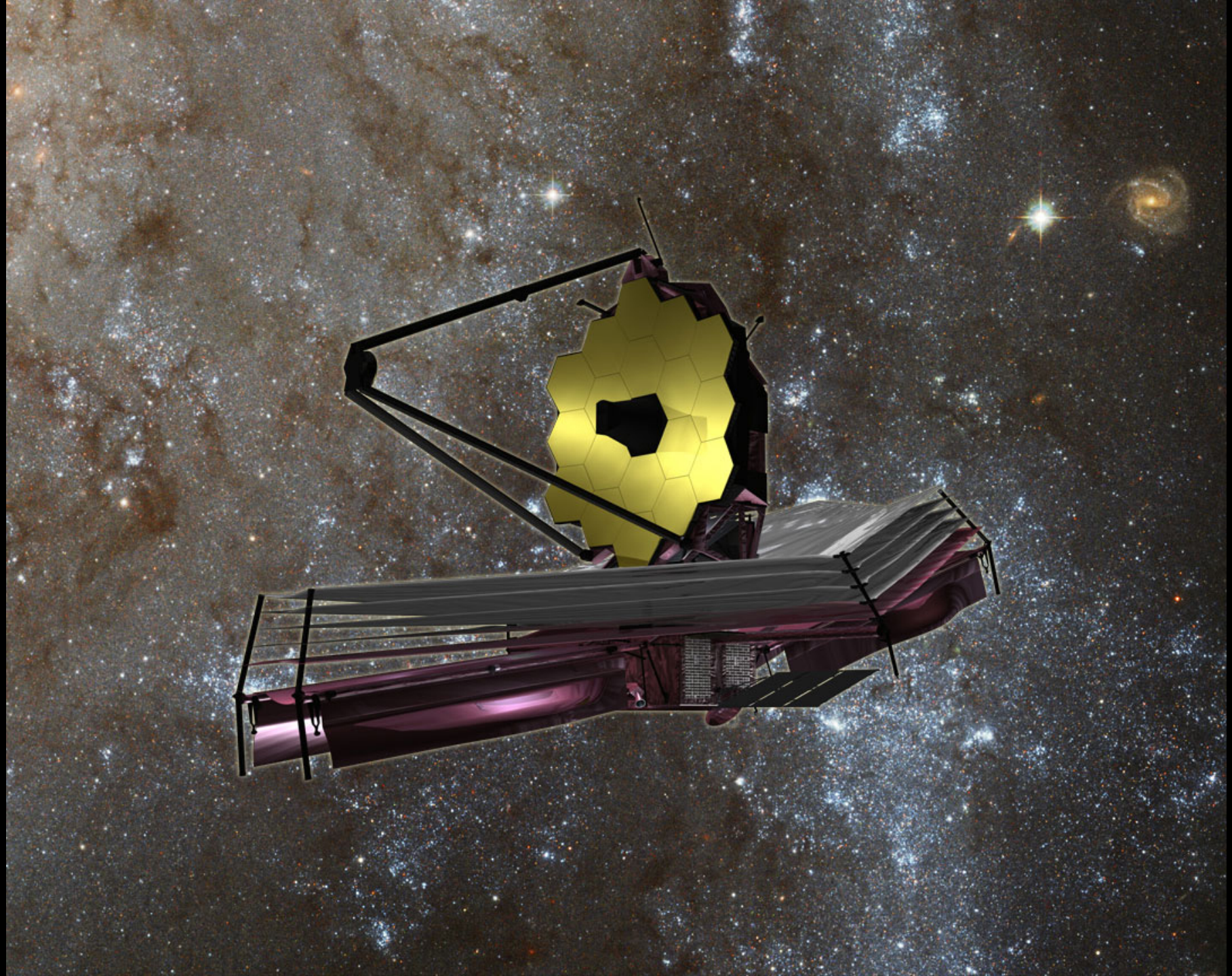

STBD
EXIT

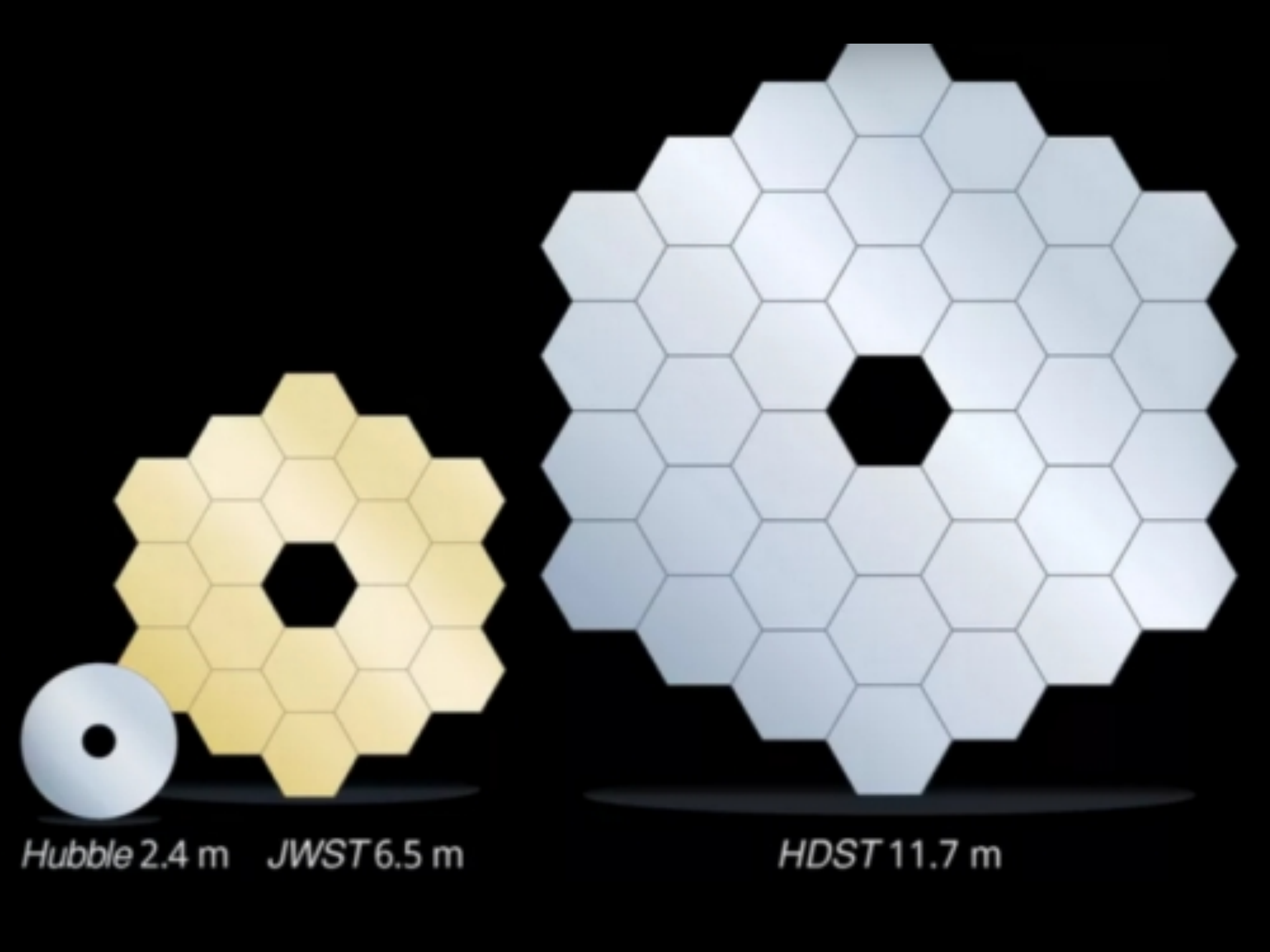


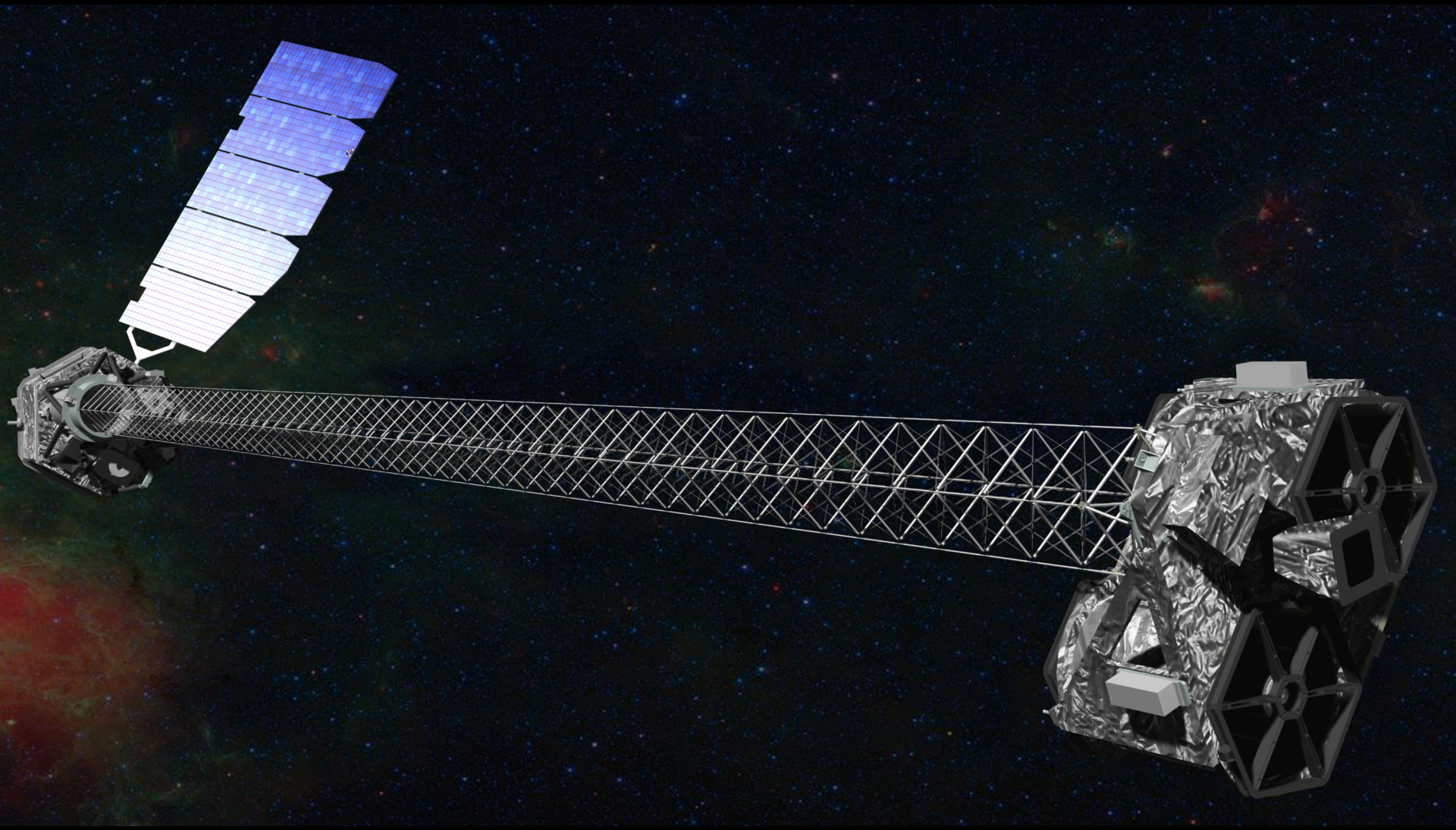





AMS
AMS




Hubble 2.4 m
JWST 6.5 m
HDST 11.7 m



Bottom Line

- The more complex a system is, the more likely it is for something to go wrong
- Design for servicing from the start
- Allow for new technology
- Make servicing tasks robot-compatible
- Make servicing safe, but be flexible on human rating
- Control and document configuration