The Evolution of Ground Systems on Hubble and Future NASA Missions

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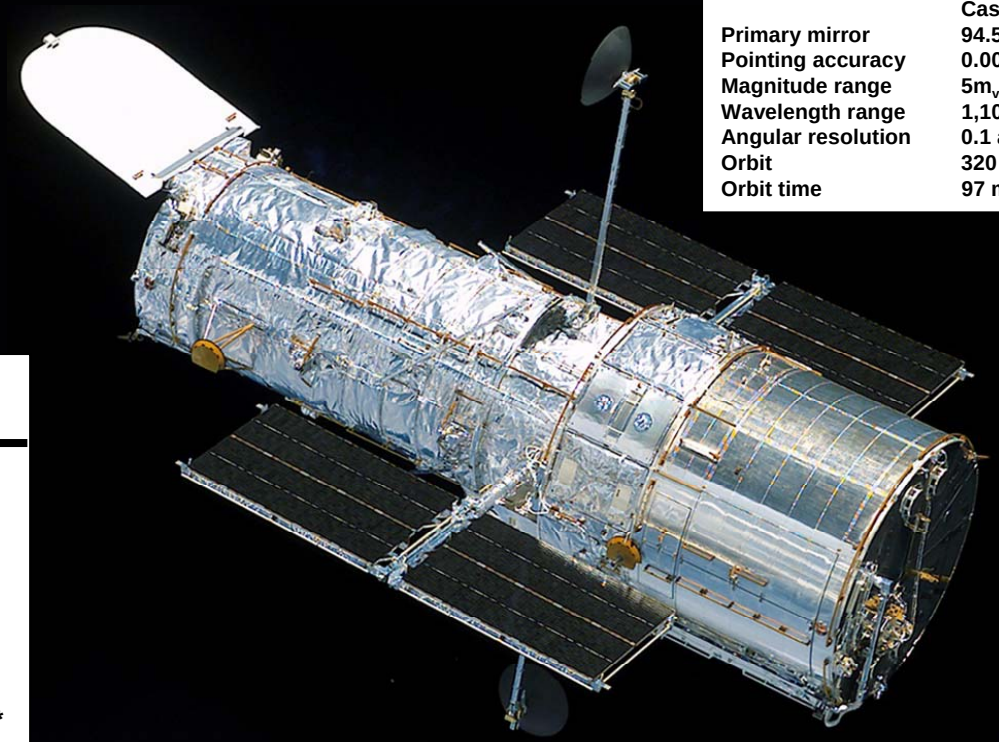
"Couldn't we get a Hubble?"

Hubble Space Telescope (HST)

Weight	24,500 lb
Length	43.5 ft
Diameter	14 ft (Aft Shroud)
Optical System	Ritchey-Chretien design Cassegrain telescope
Primary mirror	94.5 in. dia.
Pointing accuracy	0.007 arcsec for 24 hours
Magnitude range	$5m_v$ to 30 m_v (visual magnitude)
Wavelength range	1,100 to 24,000 Å
Angular resolution	0.1 arcsec at 6328 Å
Orbit	320 nmi, inclined at 28.5 degrees
Orbit time	97 minutes per orbit



HST Science Program

HST Scientific Instruments

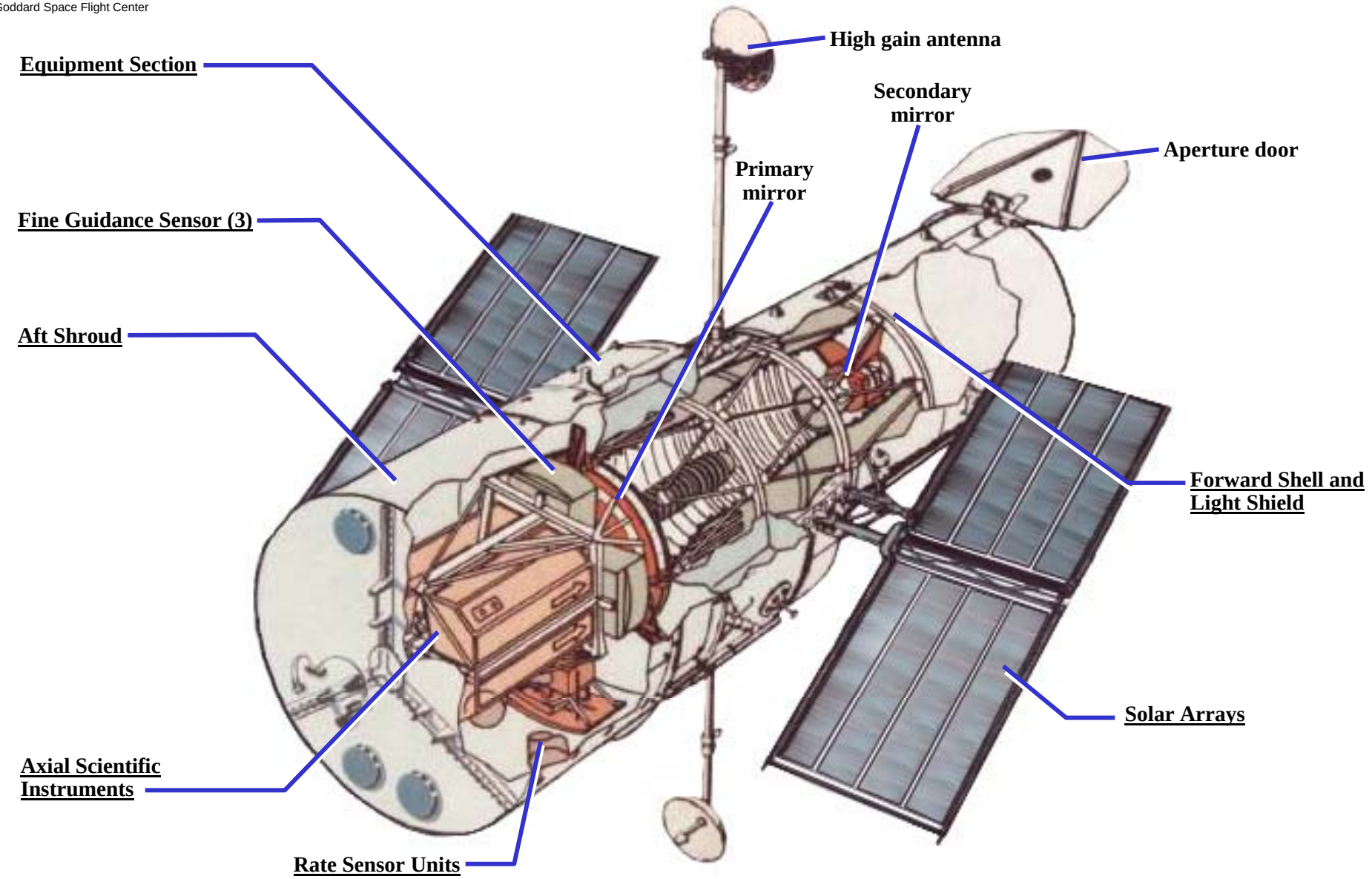
WF/PC 2	ACS
NICMOS	FGS
STIS	

HST Observing Program

- 200 GO&AR Programs/year
- 10,000 Exposures/month
- 563 U.S. Astronomers from 33 states *
- 261 non-U.S. astronomers from 28 countries *
- 1,600 registered archival users
- 9 terabytes total archive

* Cycle 11 results

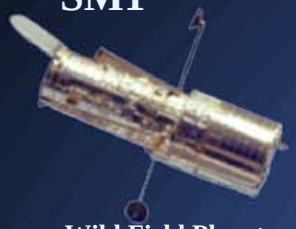
HST Spacecraft



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

De-Orbit Mission

1990 1993 1997 1999 2002 2006 2010

Hubble Space Telescope Observatory

Commands
Science Data
Engineering Data

Research Proposals

Data Products

Science Program Admin
Science Planning
Mission Scheduling
Data Processing
Science Analysis
Archive
Real Time Control

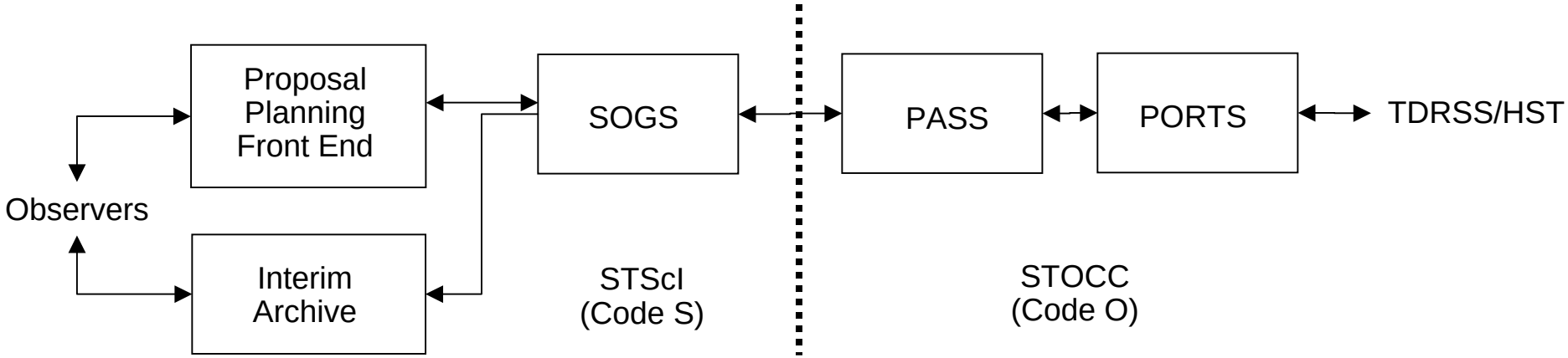
Command Loads

Data Sets

Engineering Analysis
Orbit Determination
Science Data Capture
Servicing Operations

11/19/01

HST Ground System - Late 1970s/1980s/1990



Requirements Emphasis:
- Initial HST in-orbit check-out
- Science Operations
- Pre-launch science instrument I&T

Computer Hardware:
- Dec VAX 11/785 and VAX 8650
- PDP11 front ends (TACs)
- VT-100 “dumb” terminals evolved to “smart” terminals

Flight Ops Staff:
- Check-out: 20-30/shift
- Normal ops: ~9/team

STScI Staff:
- Original estimate: ~100 total
- Launch (4/1990): ~400 total

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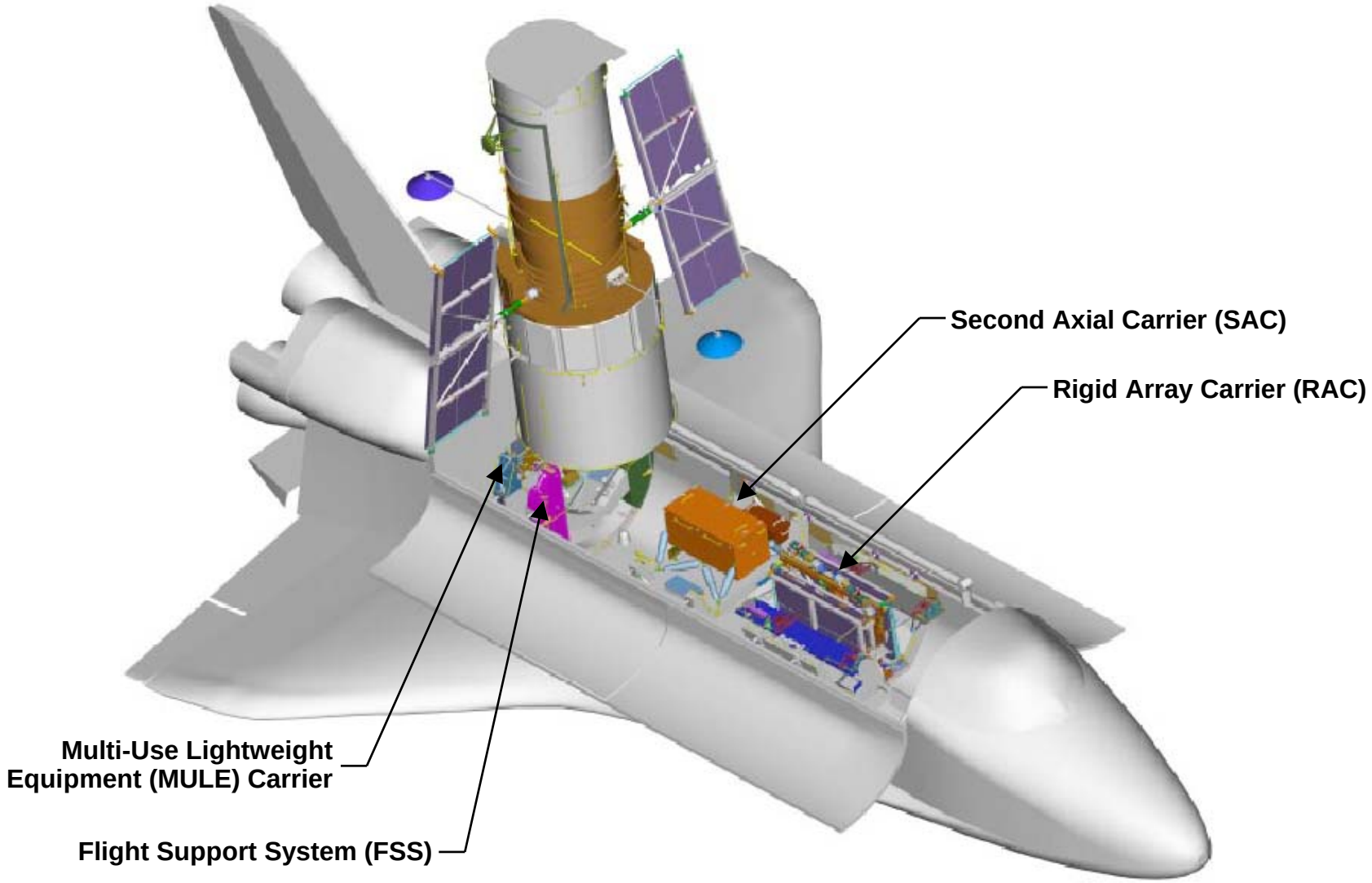
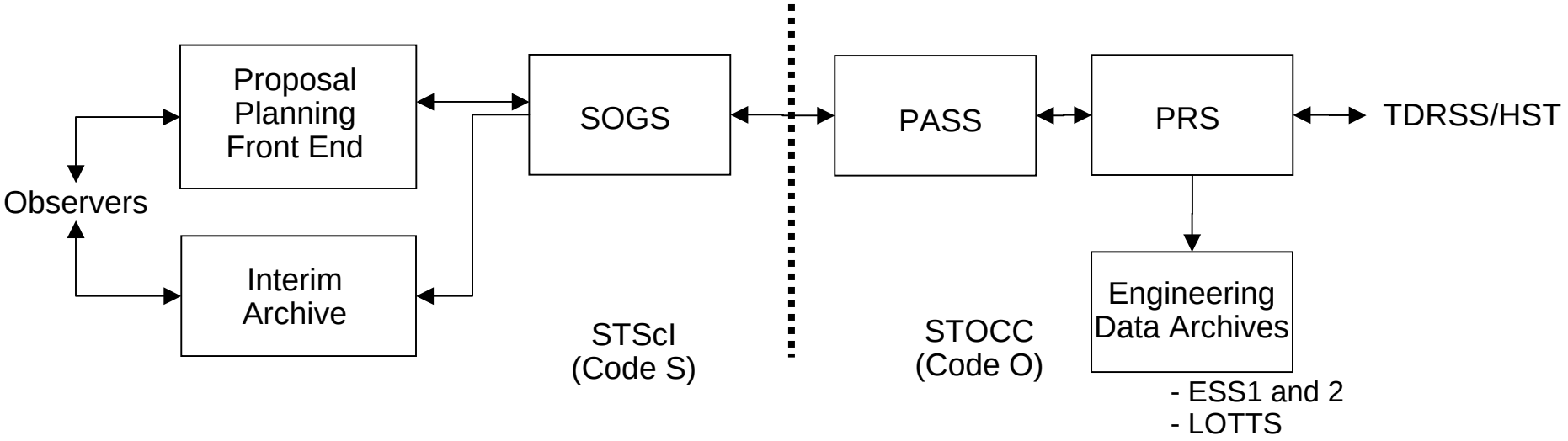
HST SM3B Shuttle Profile



HST Ground System - 1990 to 1993



Requirements Emphasis:
- On-orbit servicing

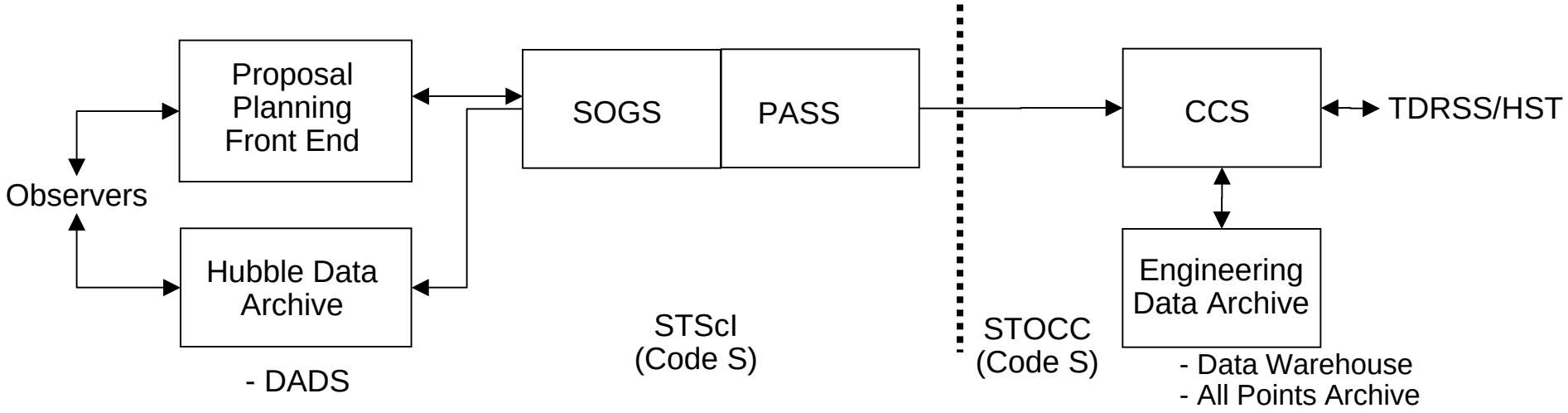
Computer Hardware:
- Distributed decomm architecture
- VAX 4400 servers
- Micro VAX (4000, Model 90) work stations
- ~100 work stations

Flight Ops Staff:
- Servicing: ~150/shift (~300 total)
- Normal ops: ~6/team

STScI Staff:
- ~400 total

Servicing Mission Operations at the STOCC

HST Ground System - 1994 to 2000



Requirements Emphasis:
- Re-engineering

Computer Hardware:
- Server/client - Unix platform
- Multi-server SGI Origin 2200
- Work stations - Dell PCs, Model 400

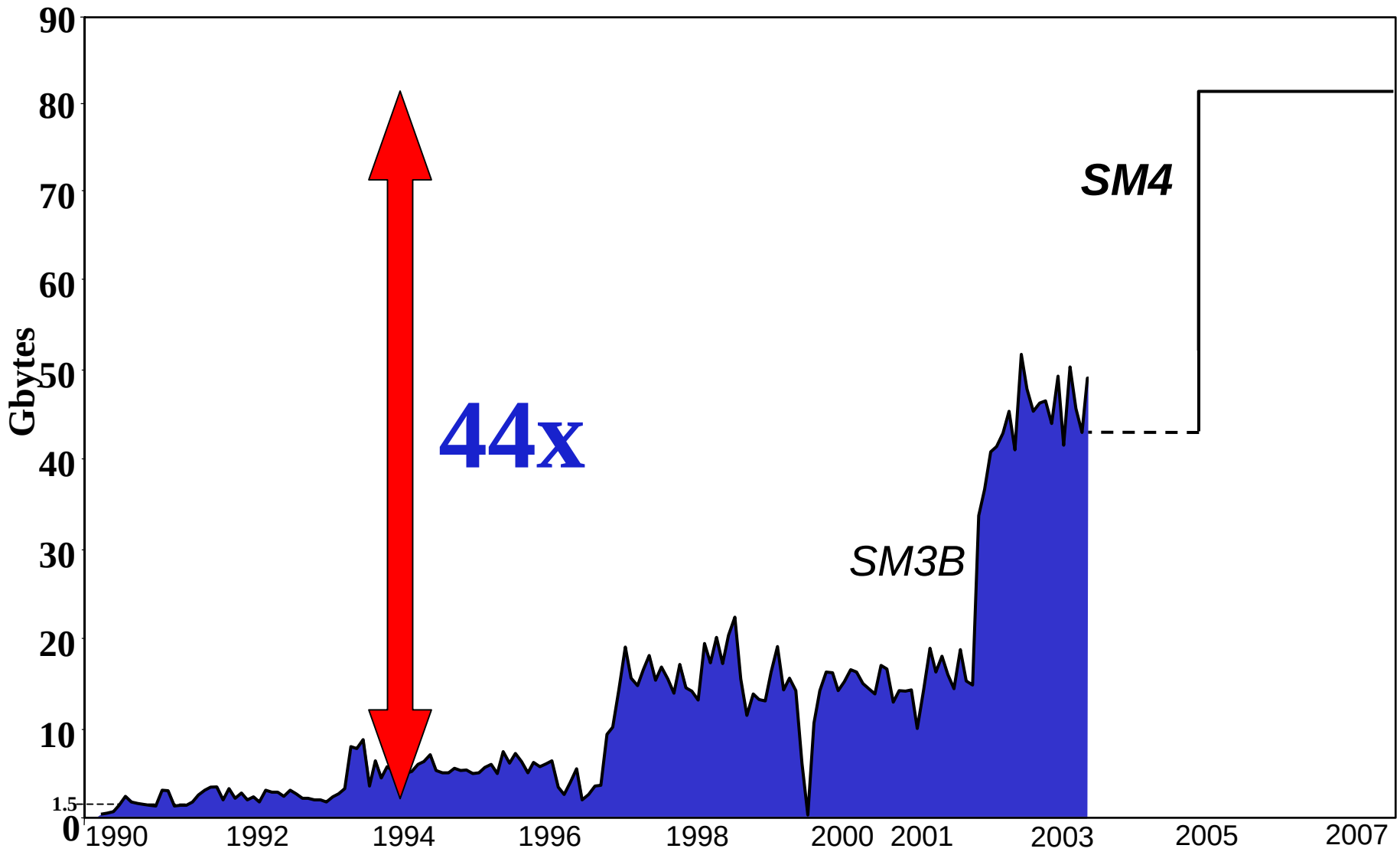
Software:
- COTS + GOTS + Legacy + Custom

Architecture:
- Secure core system and backbone protected by multiple firewalls

Flight Ops Staff:
- Servicing: ~150/shift (~300 total)
- Normal Ops: 3/team

STScI Staff:
- ~400 total

Monthly Archived Science Data



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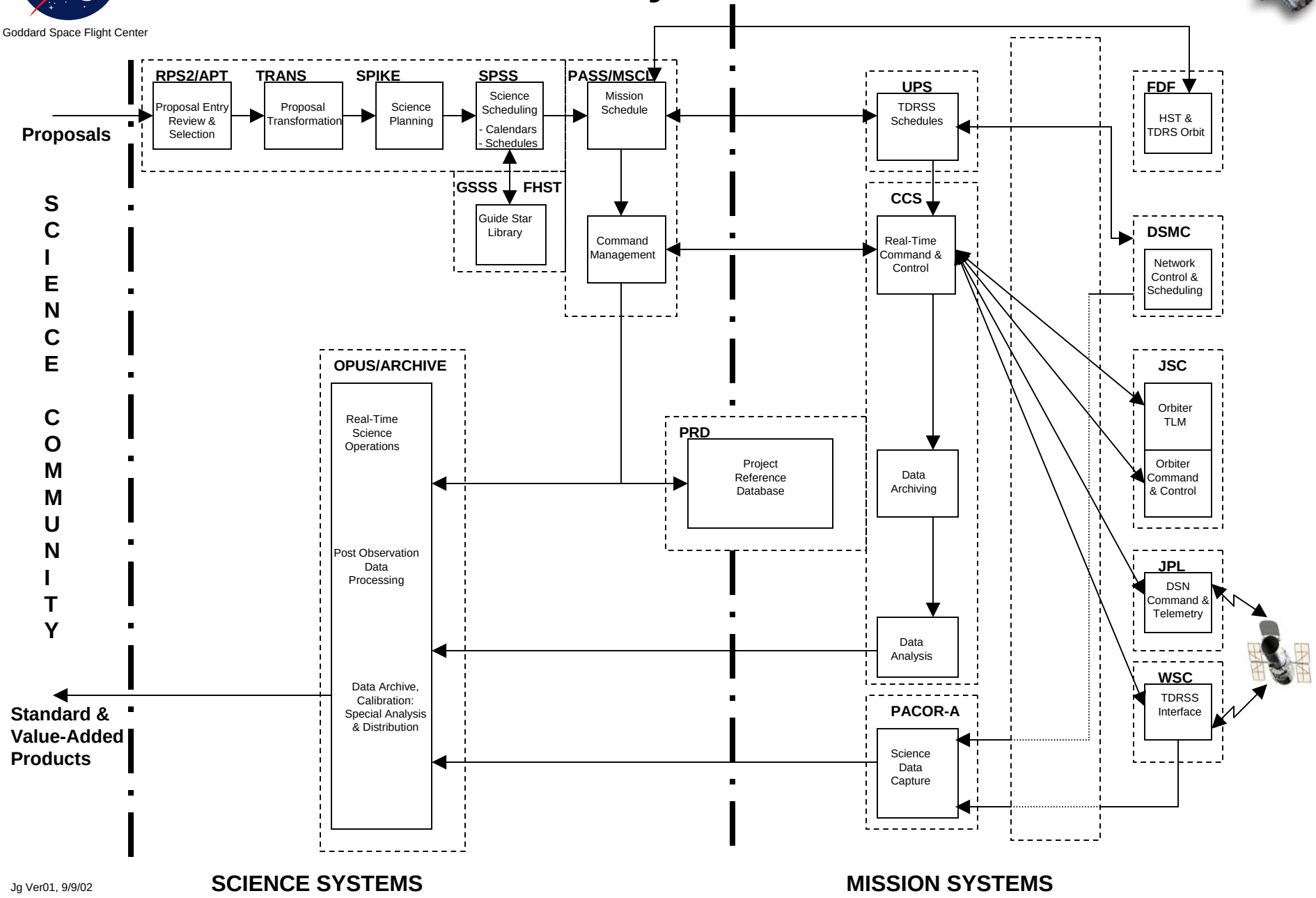
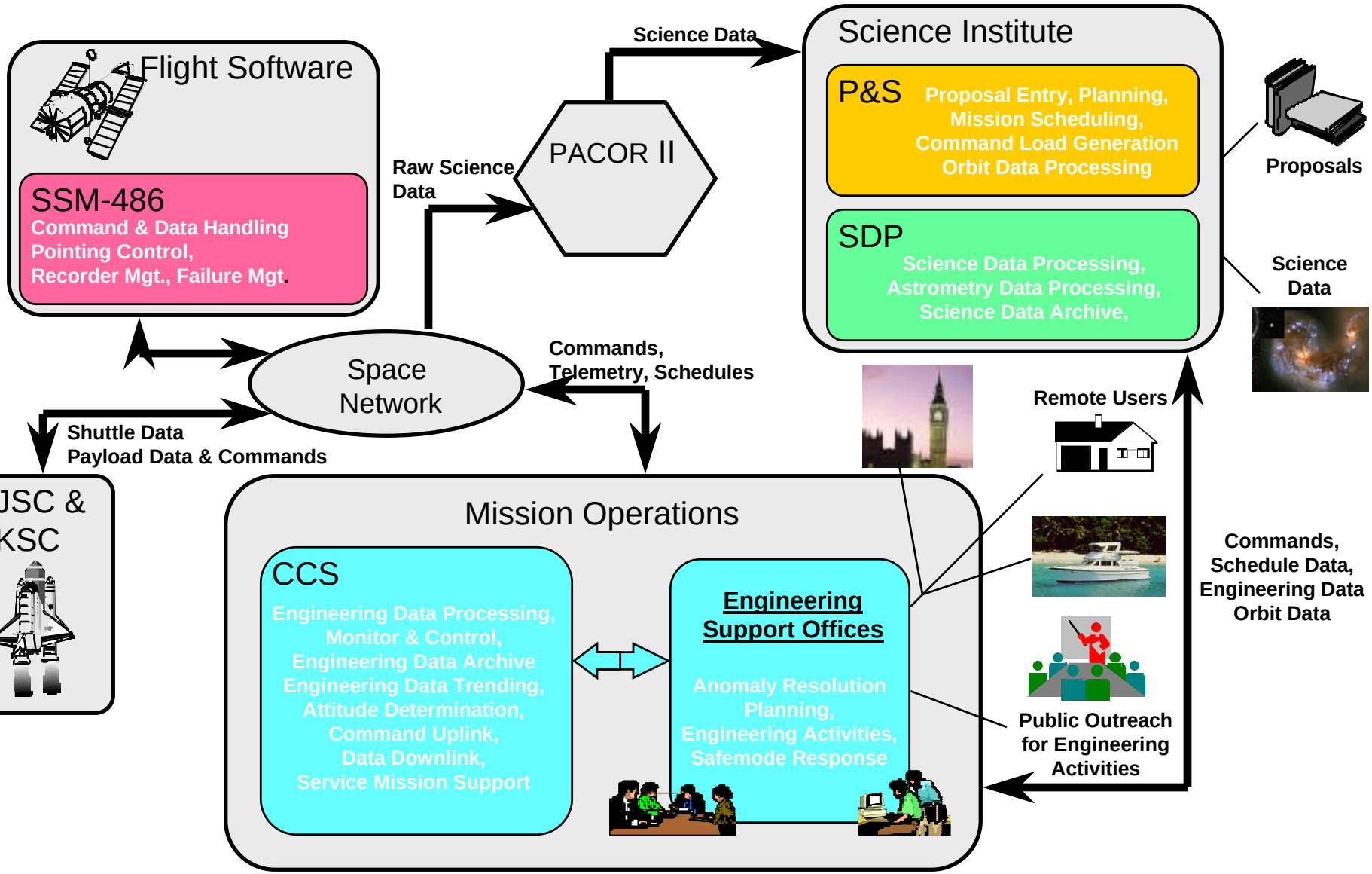
Hubble Space Telescope Program

HST Ground System Elements



Vision 2000 System Architecture



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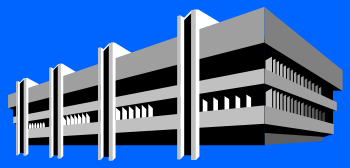
Hubble Space Telescope Program

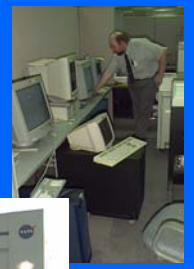
Vision 2000 Development

BALL, G'BURG - ACS/COS



NBB - 486

B29 - VOCC/VEST



DASDF - DF224

ESTIF - SIs

CCS

TRAILERS

B23 - PRF

DANBURY - FTS

STScI

STOCC

OPERATIONS

5 multi-server strings
21 single-processor systems

Summary

- **Hubble ground systems have evolved as IT environment changed over the past 25 years**
  - IT made many rapid advances, e.g., PCs, Internet, fiber optic communications, high density data storage, and COTS S/W products
  - HST ground systems went from mainframe based VMS systems to UNIIX based distributed architecture
  - New challenges surfaced, e.g., IT security
- **Hubble operational requirements expanded from supporting a conventional pre-planned LEO robotic type mission to real time servicing mission using astronauts and Space Shuttle**
- **High cost of operating and maintaining original Hubble ground systems necessitated massive re-engineering in the mid to late 1990s (Vision 2000)**

Future NASA Missions

- Potential robotic servicing of Hubble
- Large scale observatories in space
- Lunar Testbeds
- Mars Research
- Outer Moons Research
- Human Exploration and Colonization

HST Robotic Servicing Concept

Hubble Recovery Vehicle
Approaching HST

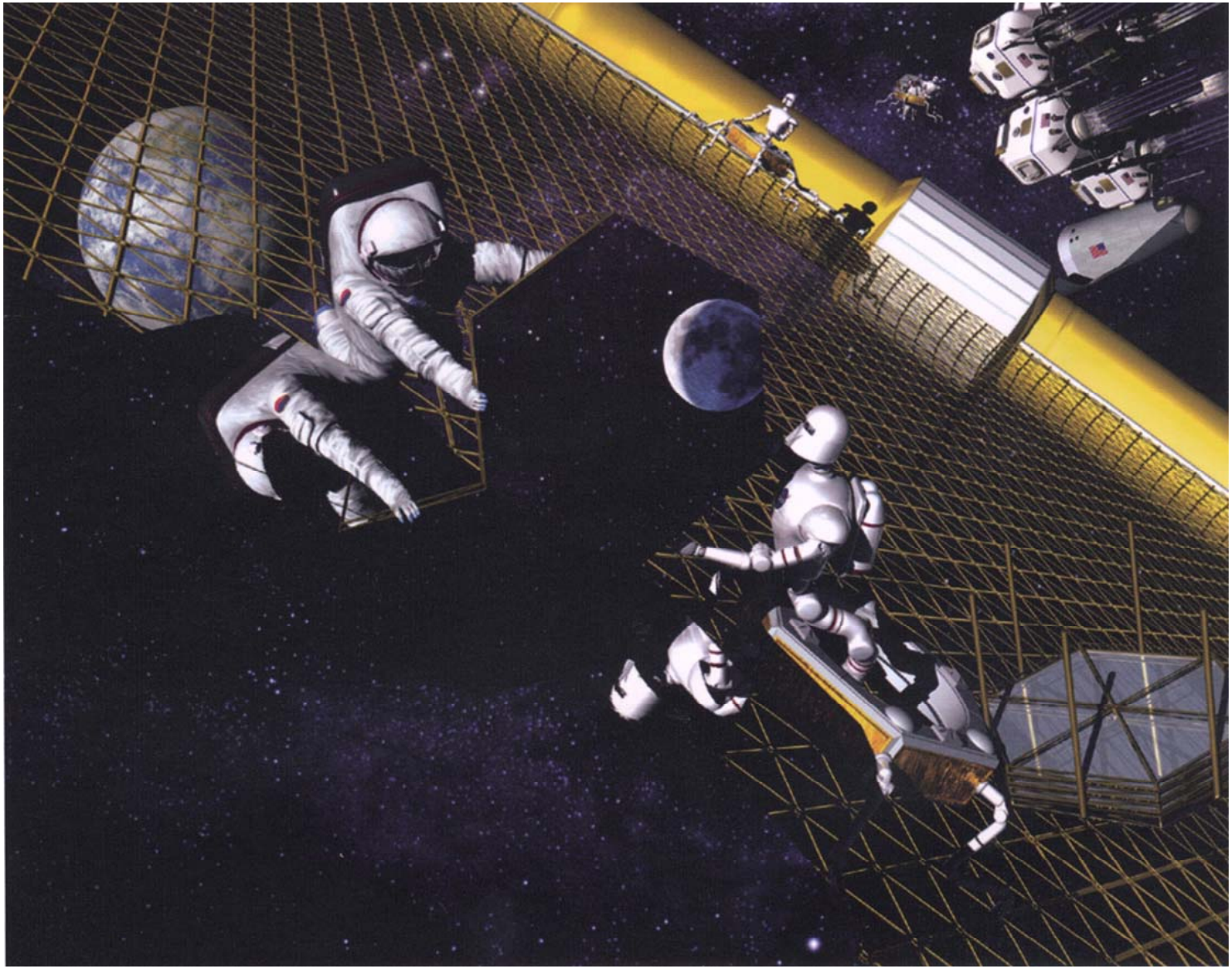
HRV Robotic Arm
Capturing HST

Shroud
Separation

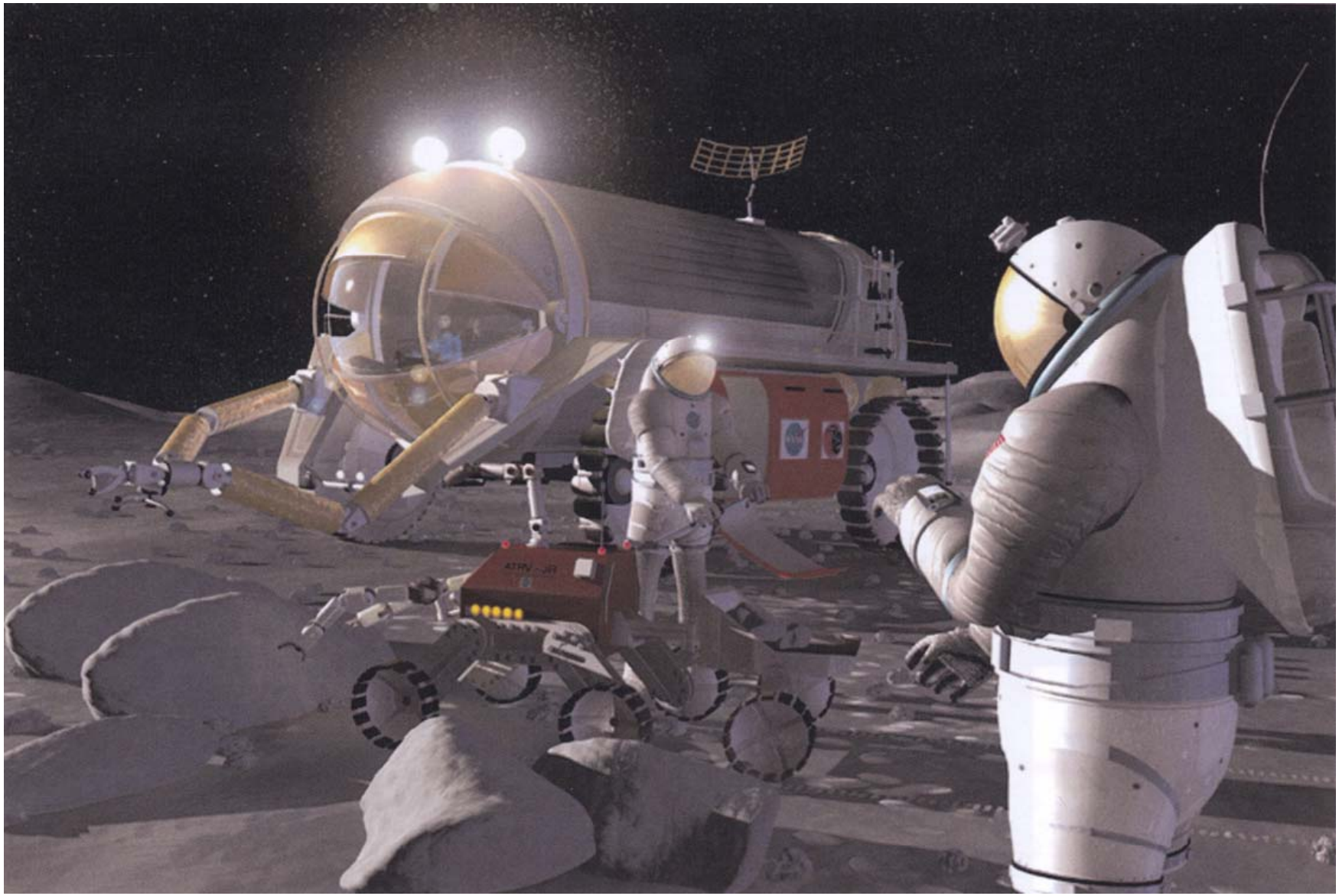
Launch!

HRV Servicing HST

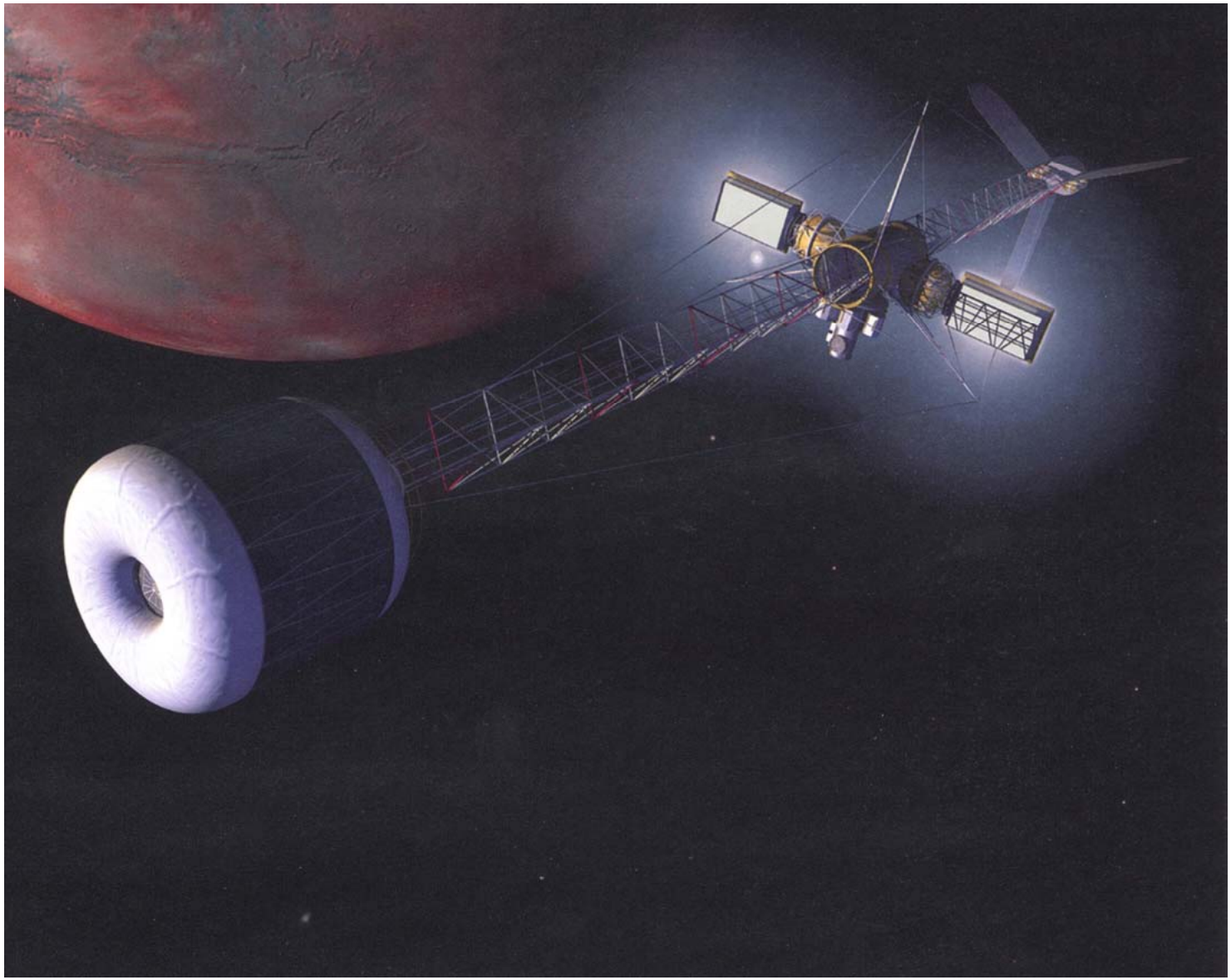
A Drawing of Humans and Advanced Robotic Assistants Building a Space Telescope



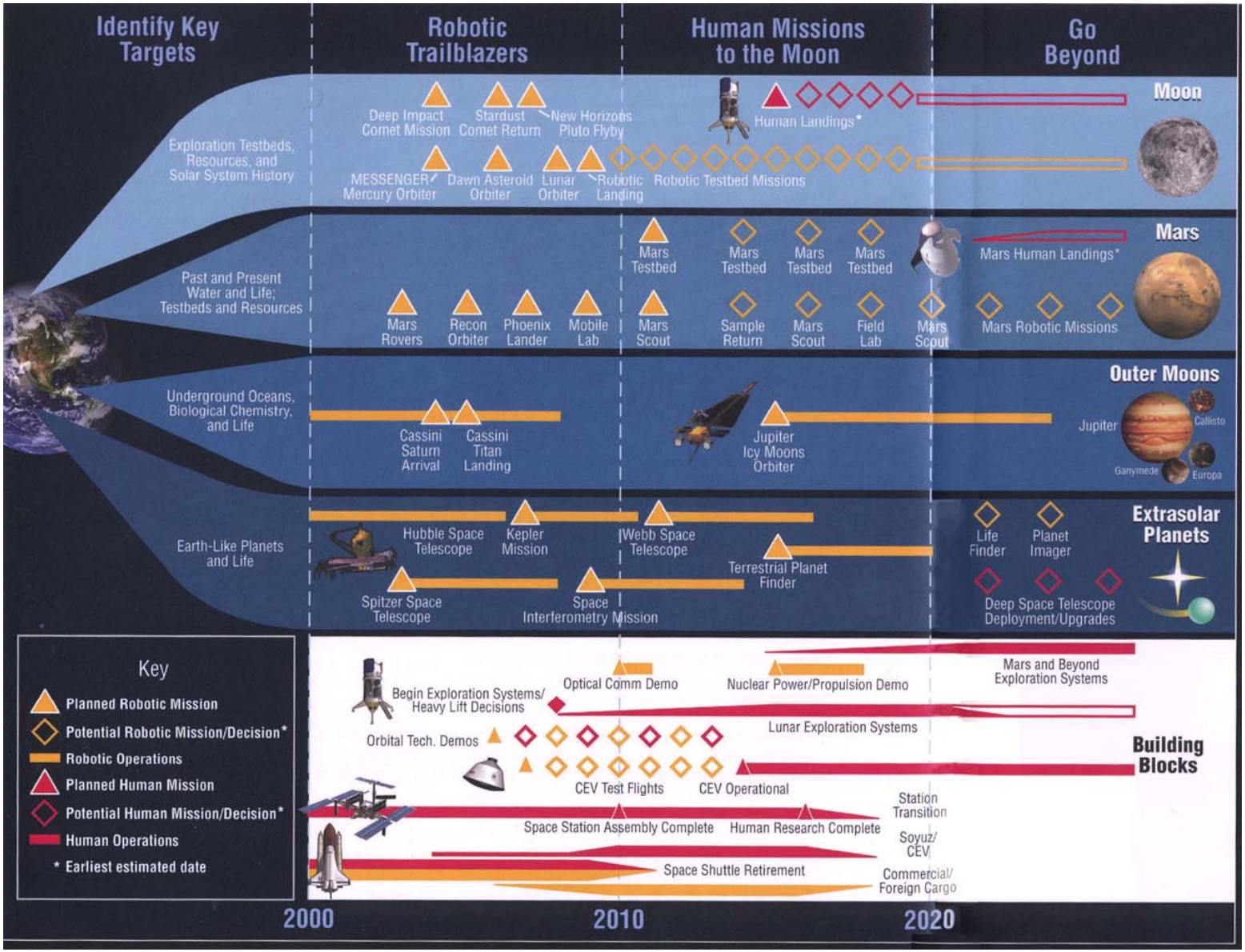
An Artist's Concept of Lunar Exploration



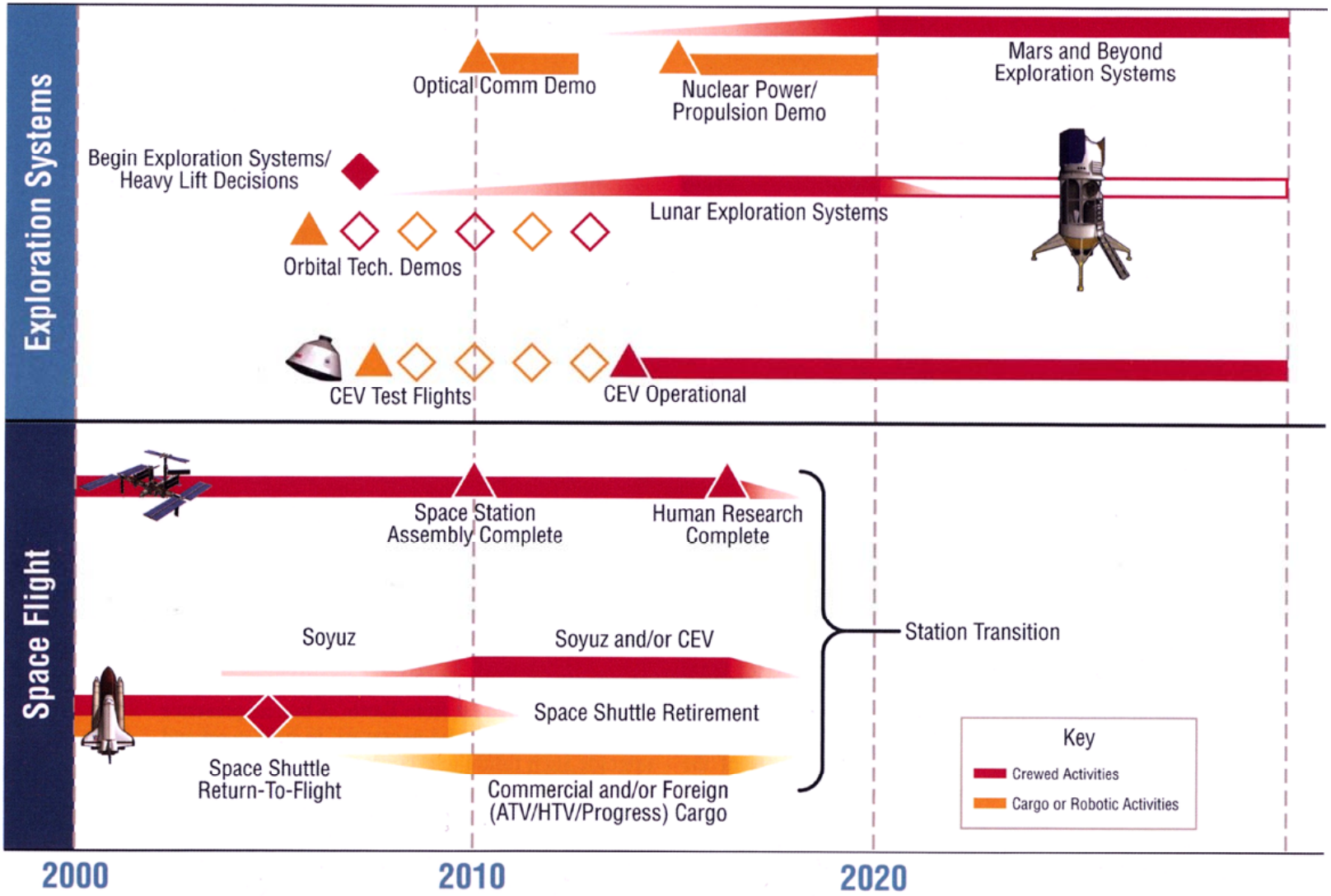
Spacecraft, Equipped with a Centrifuge and Nuclear-Electric Propulsion, Traveling to Mars



Solar System and Beyond - Exploration Roadmap



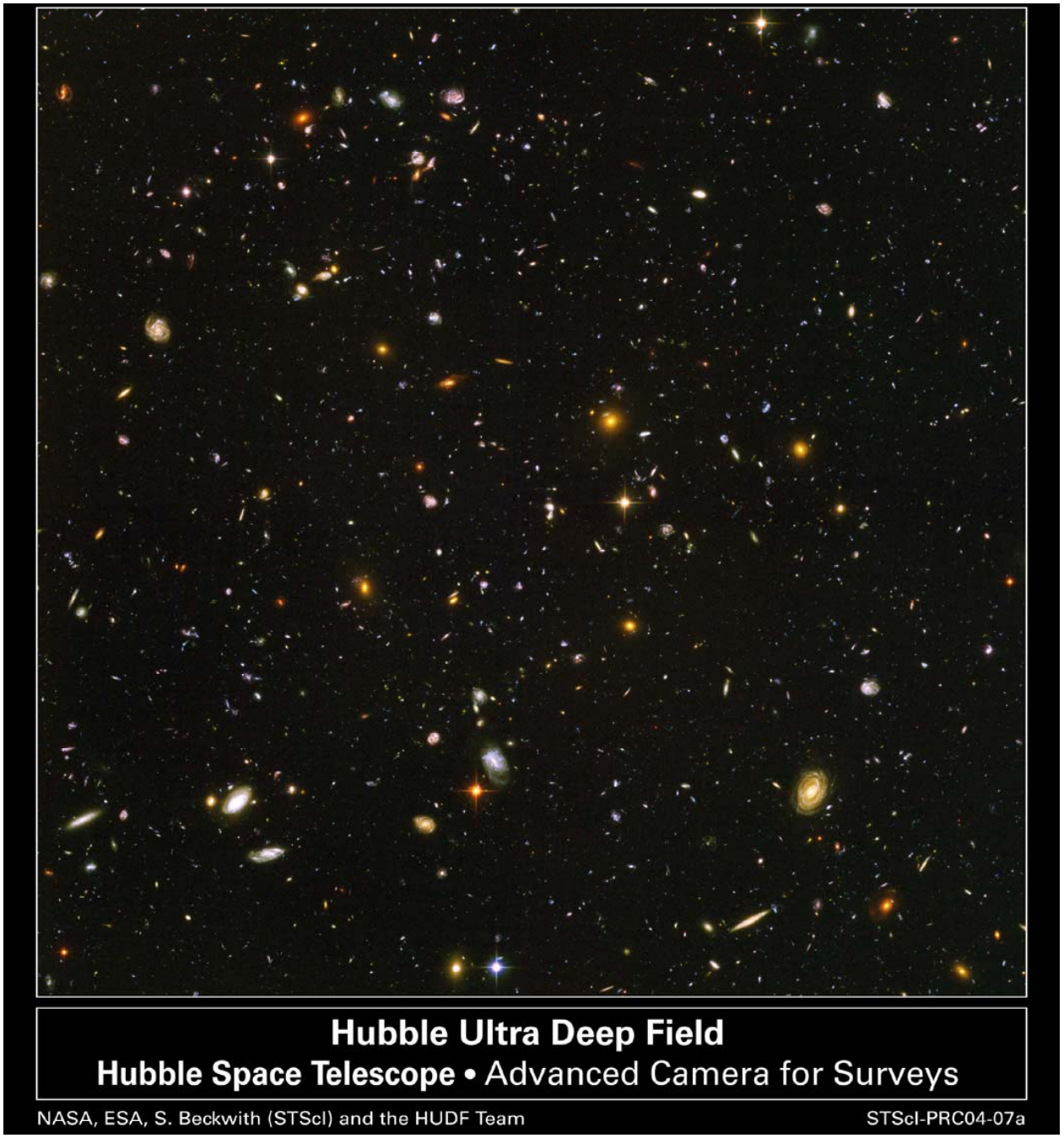
Exploration Building Blocks will Provide the Capabilities Necessary for Exploration of the Solar System and Beyond



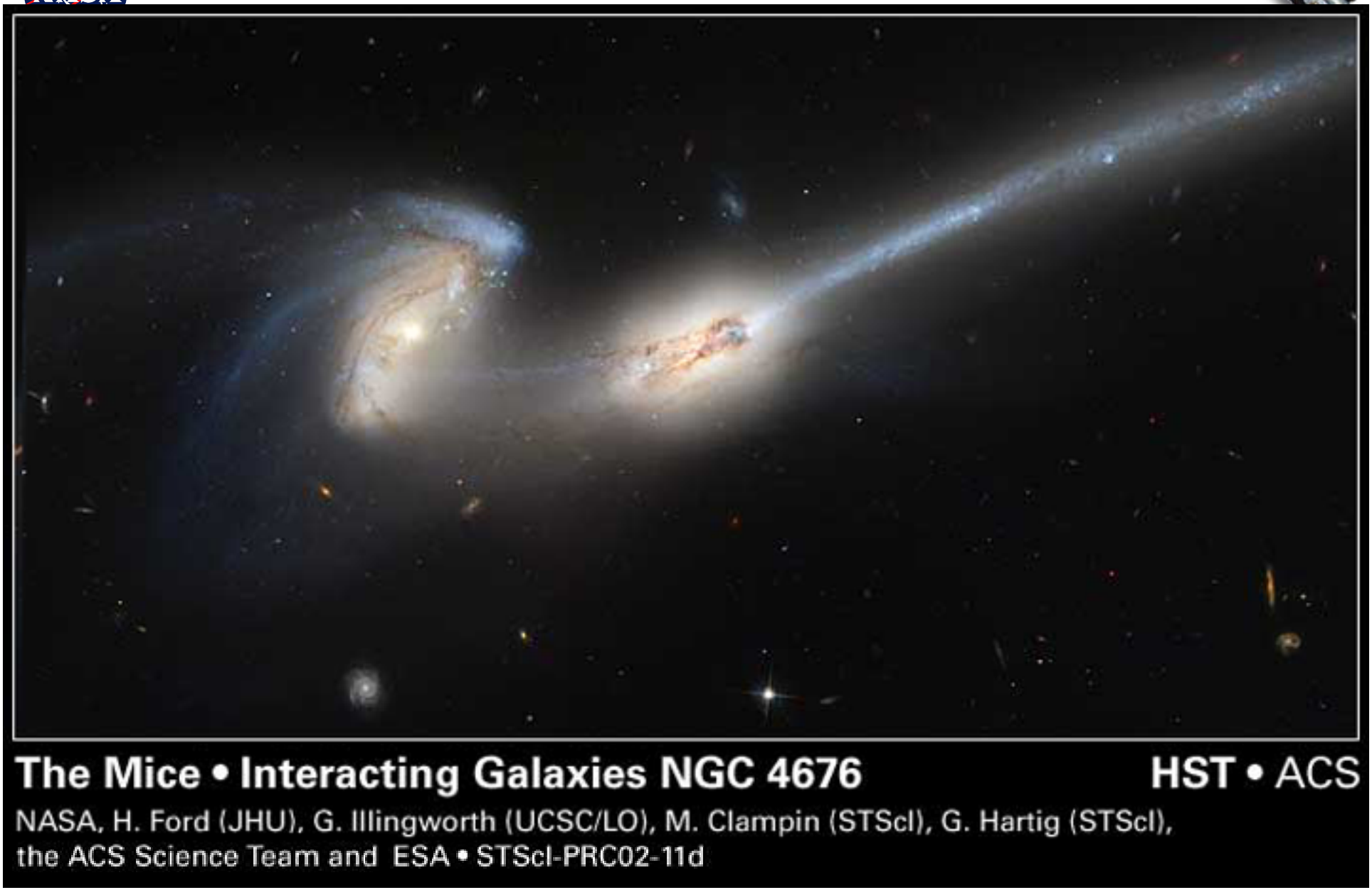
Implications on Future Ground Systems for Long Duration Programs/Missions

- **High bandwidth laser based communications over long distances**
- **High capability "ground systems" on Lunar and Mars stations**
  - Scientific data collection and operations
  - Housekeeping support for human facility operations
  - Human medical support
- **Operation and support of extensive robotic capabilities**
- **Higher reliability and longer service life**
- **In-the-field repairability and re-configurability**
- **Programmatic ability to evolve as requirements and technologies change**

Hubble Space Telescope Program

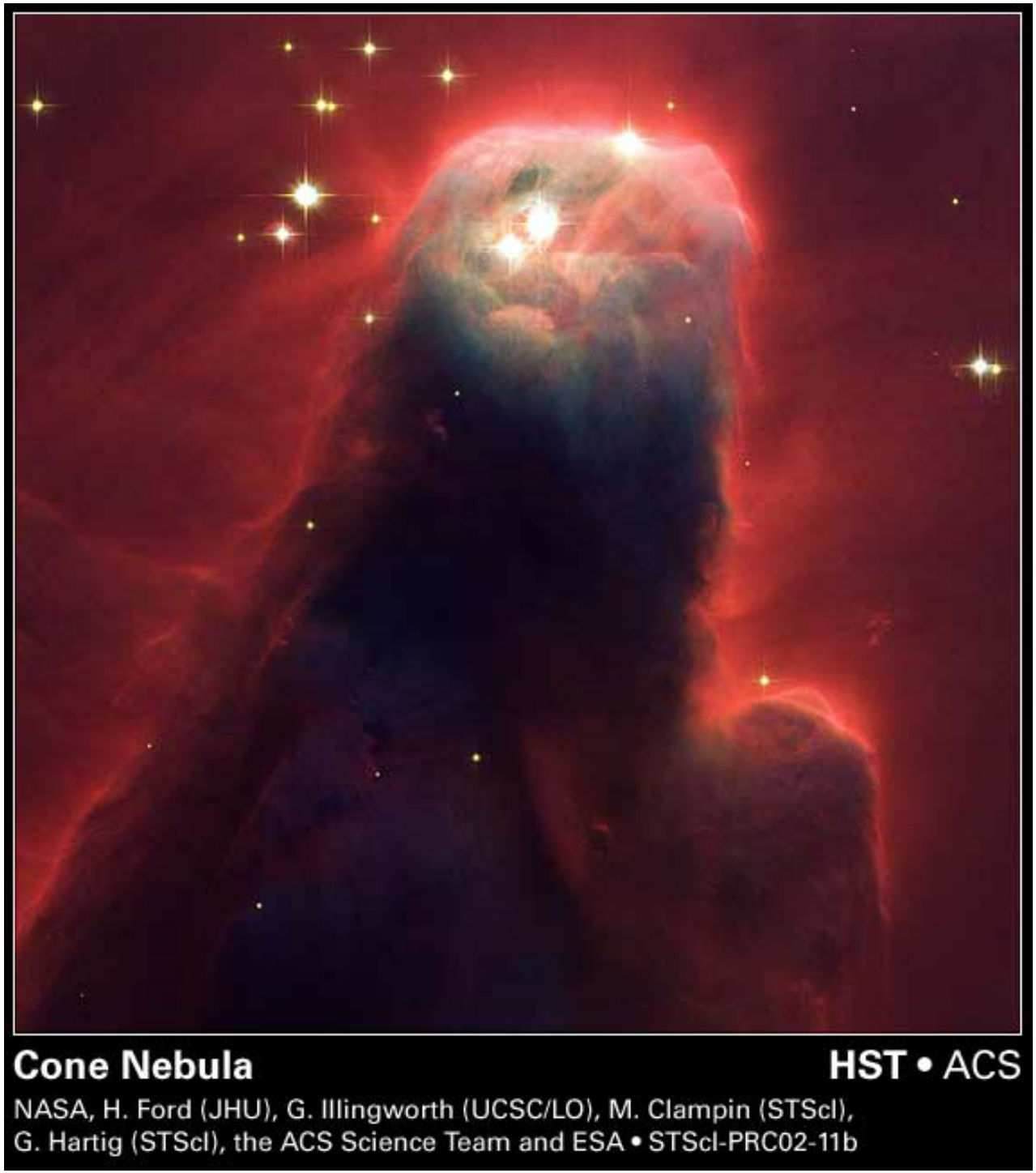


Hubble Space Telescope Program



The Mice • Interacting Galaxies NGC 4676 **HST • ACS**

NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M. Clampin (STScI), G. Hartig (STScI), the ACS Science Team and ESA • STScI-PRC02-11d


Cone Nebula
HST • ACS
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