Hubble SM4

John Mace Grunsfeld PhD

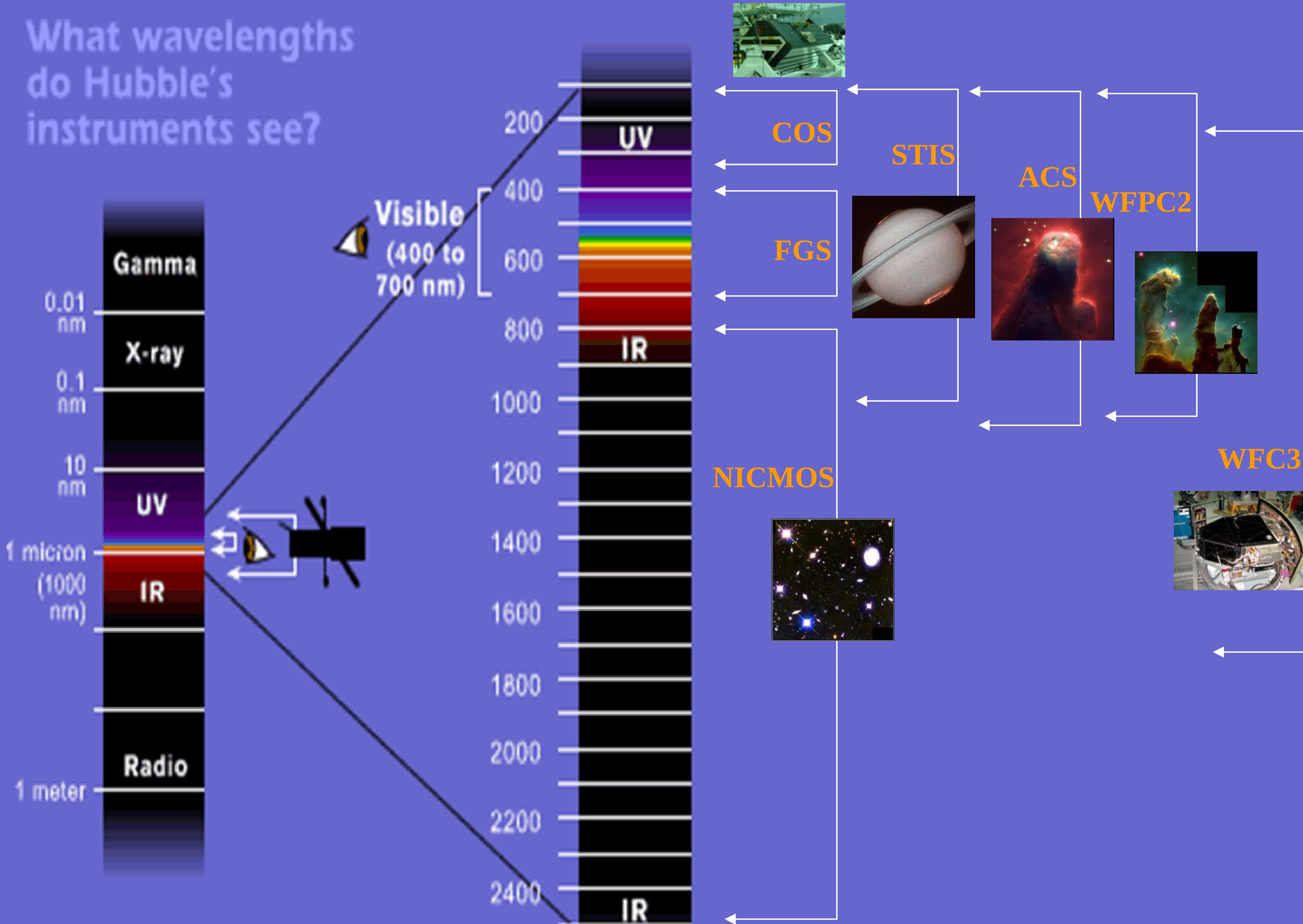
NASA Astronaut

ASTR 4800 – Space Science: Practice & Policy

Hubble Space Telescope (HST)

Weight	**25,500 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**
Wavelength range	**1,100 to 24,000 Å**
Angular resolution	**0.1 arcsec at 6328 Å**
Orbit	**305 nmi, inclined at 28.5 degrees**
Orbit time	**97 minutes per orbit**

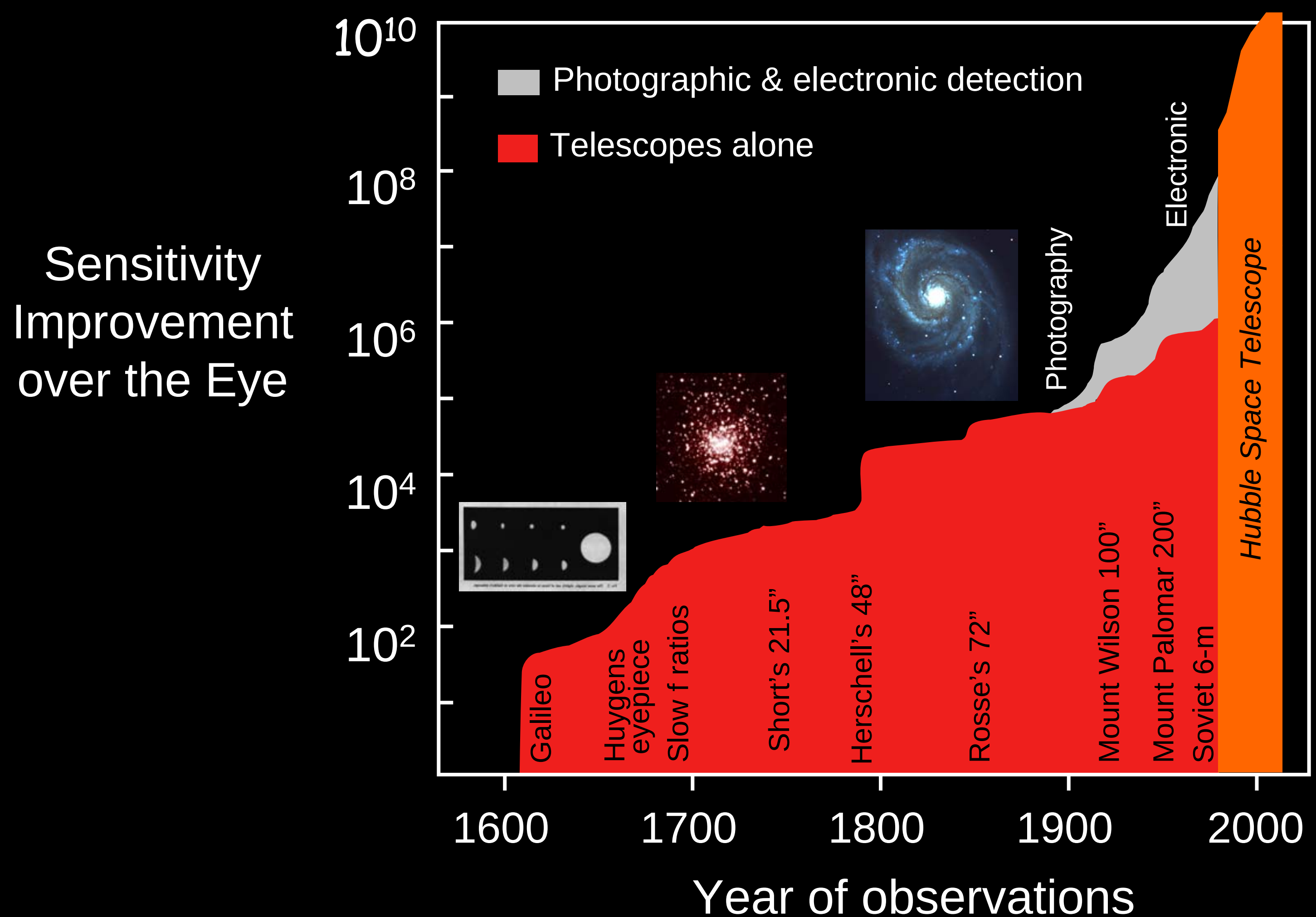
What wavelengths do Hubble's instruments see?

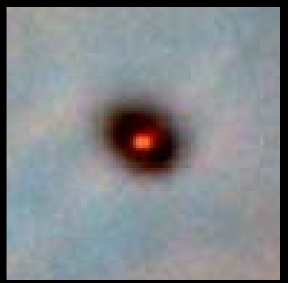


Images from hubblesite.org

Search & Discovery

After Fig. 3.10 in *Cosmic Discovery*, M. Harwit

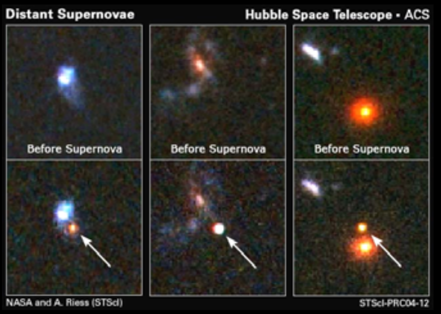


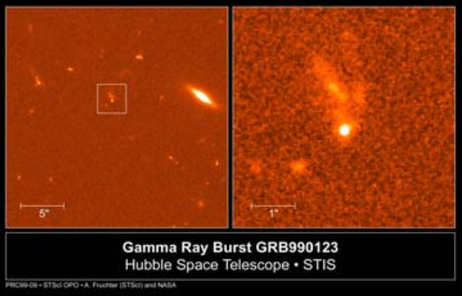


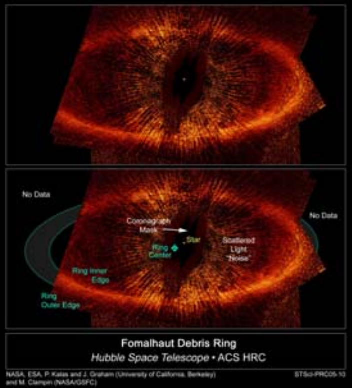
The 10 Most Heavily Cited Achievements of HST

- anticipated
- unanticipated

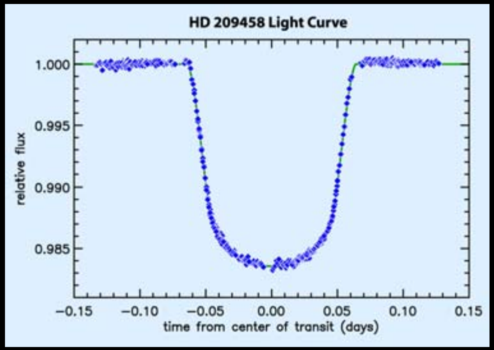
- Creation of galaxies (HDF, UDF)
- Acceleration of Universe: SN Ia
- Distance scale of the Universe: H_0
- Giant black holes in galaxies
- Emission lines in active galaxies
- Intergalactic medium (QAL)
- Interstellar medium chemistry
- Gamma Ray Burst sources
- Protoplanetary disks
- Extrasolar planets

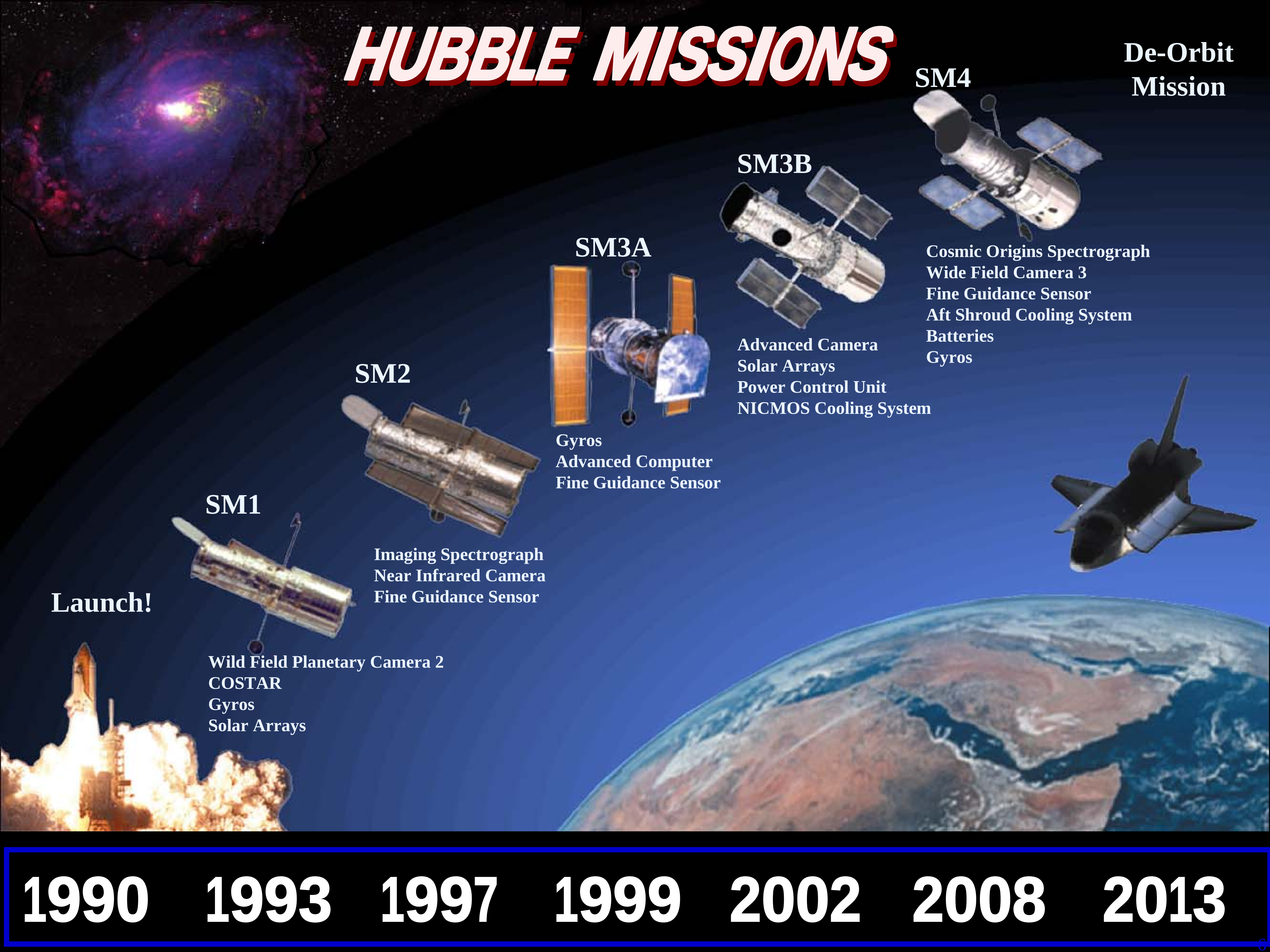






Half of Hubble's highest-impact scientific achievements are in areas of research unanticipated prior to launch. Broadly capable flagship missions promote the element of surprise.




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 2008 2013

Hubble Servicing Mission 4

- Loss of Columbia
- Columbia Accident Investigation Board Report
- Vision for Exploration and Budget
- Announcement of Cancellation of SM4 (on the basis of risk and cannot comply with CAIB recommendations)
- Public Service, defending leaderships position

- Politics and Science
  - –Priorities
  - –Decadal Surveys
  - –Budgets
  - –White House (Executive Office of President, OSTP)
  - –Congress (Mikulski, Udall)
  - –Community (AURA, STSCI, AAS)
  - –Media (editorial boards)
  - –Individuals (Bahcall, Beckwith, Turner, kids, non-astronomers
  - –GAO, NRC, Aerospace

United States Senate

COMMITTEE ON APPROPRIATIONS
WASHINGTON, DC 20510–6025
www.senate.gov/~appropriations

January 21, 2004

Honorable Sean O'Keefe
Administrator
National Aeronautics and Space Administration
300 E Street NW
Washington, DC 20024

Dear Administrator O'Keefe:

I was shocked and surprised by your recent decision to terminate the next scheduled servicing mission of the Hubble Space Telescope (HST). I fully appreciate and support your emphasis on astronaut safety. Astronaut safety is my number one priority. However, given Hubble's extraordinary contributions to science, exploration and discovery, I ask you to reconsider your decision and appoint an independent panel of outside experts to fully review and assess all of the issues surrounding another Hubble servicing mission.

This panel should report its findings to you and the relevant committees in both houses of Congress this year so we can understand fully the risks, costs and benefits of another Hubble servicing mission. In addition, I request that all planning, preparation and astronaut training activities continue without interruption until Congress has reviewed and decided this issue. Should this panel confirm the need, value and safety of another servicing mission, it is critical that time not be lost. Given Hubble's extraordinary contributions to science, exploration and discovery and its value to the nation and the world, a decision to terminate the next servicing mission must not be made without a thorough, rigorous and comprehensive analysis.

Hubble has become the most successful NASA program since Apollo. It can not be terminated prematurely with the stroke of a pen without a thorough and rigorous review while planning, preparation and training activities continue. I look forward to hearing from you.

Sincerely,

Barbara A. Mikulski

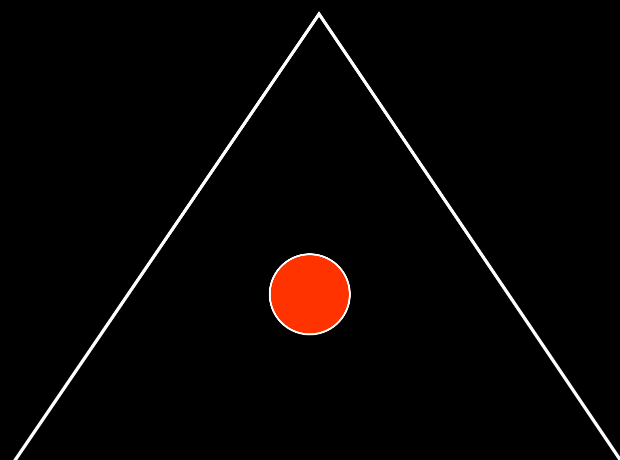
Barbara A. Mikulski
Ranking Member
Subcommittee on VA/HUD
And Independent Agencies

Moving Forward on HST/Strategy

Use same strategy as STS-61/SM1: intense effort to "save HST"
Engage broader team to kick start exploration effort through HST

Science/Exploration

"triangulate"



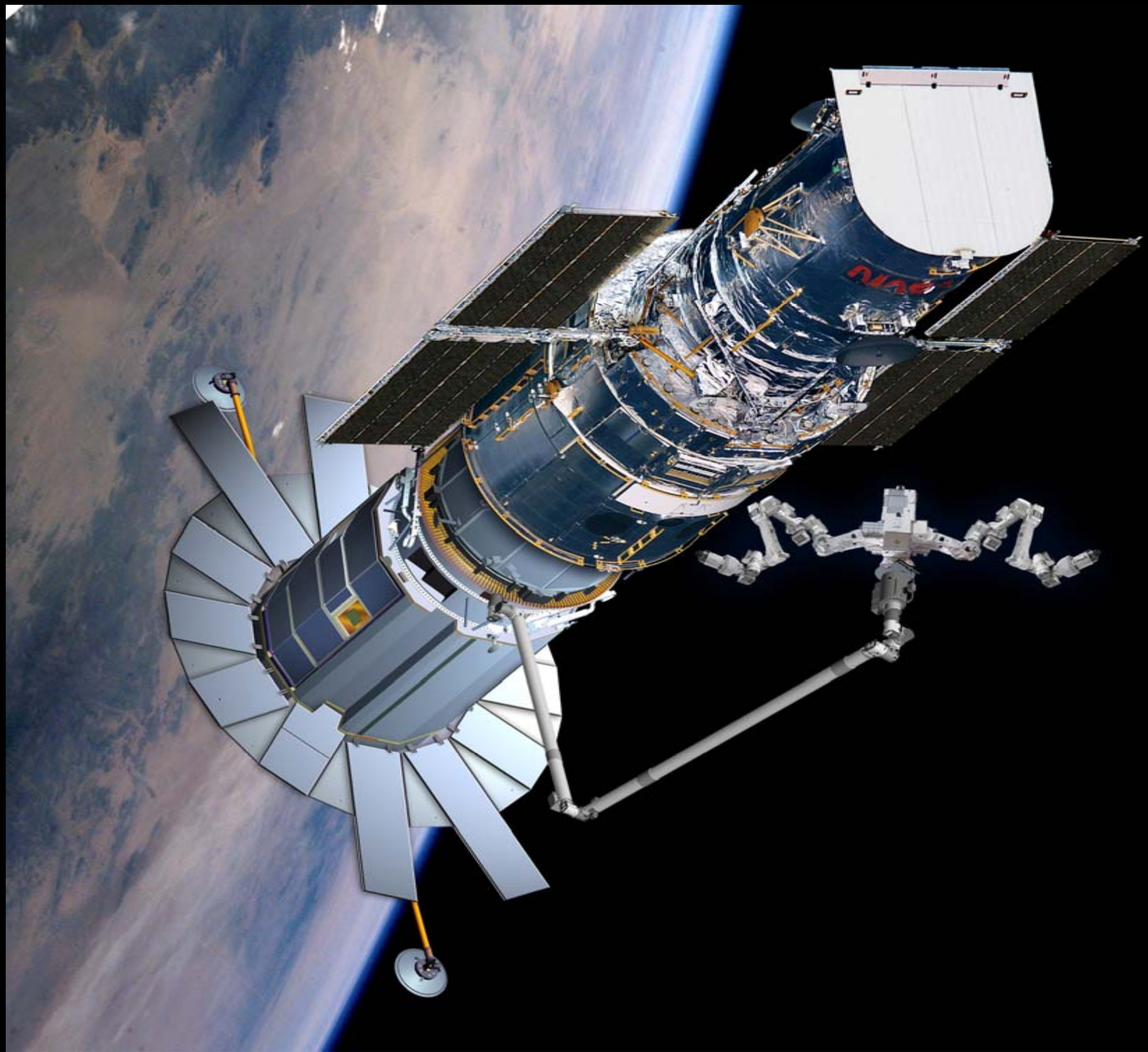
HST Final Chapter

Legislative

Public Outreach
Media

AS/John Grunsfeld

Robot to the Rescue!



The Climb Back for SM4

June 04: NRC Preliminary Recommendation – Service HST (Shuttle or Robotic, but favor Shuttle

April 04: Robotic Preliminary Assessment

March 04: Congressional Mandate and CAIB letter recommending an in-depth Assessment

Jan 04: SM4 Cancelled

Jan 03: Columbia Accident

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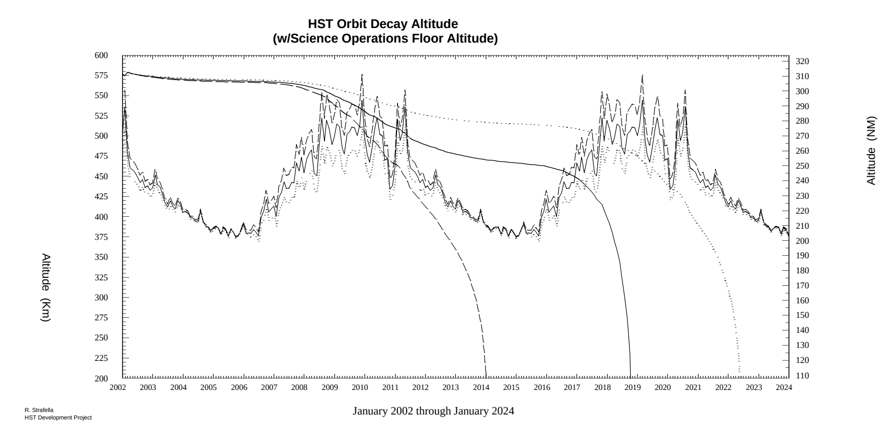

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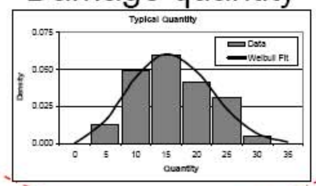
S&MA Assessment
HST Expected Ascent Debris Environment

The S&MA assessment is based on a Monte Carlo model (ADAM) that simulates missions with respect to ascent related lower surface tile damage.

INPUTS

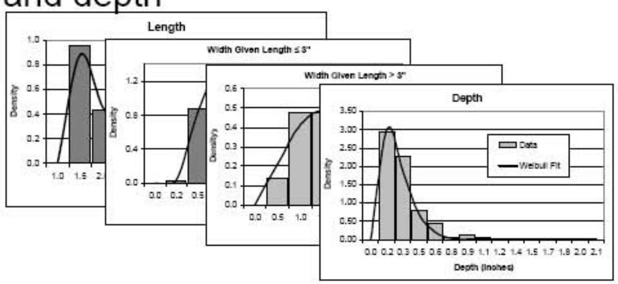
Damage quantity



Damage Location based on the proportion of hits in each zone

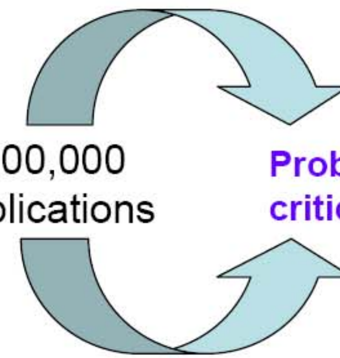
Ice/ Foam assessment based on damage width

Damage Length, width and depth



Probability of criticality

100,000 replications

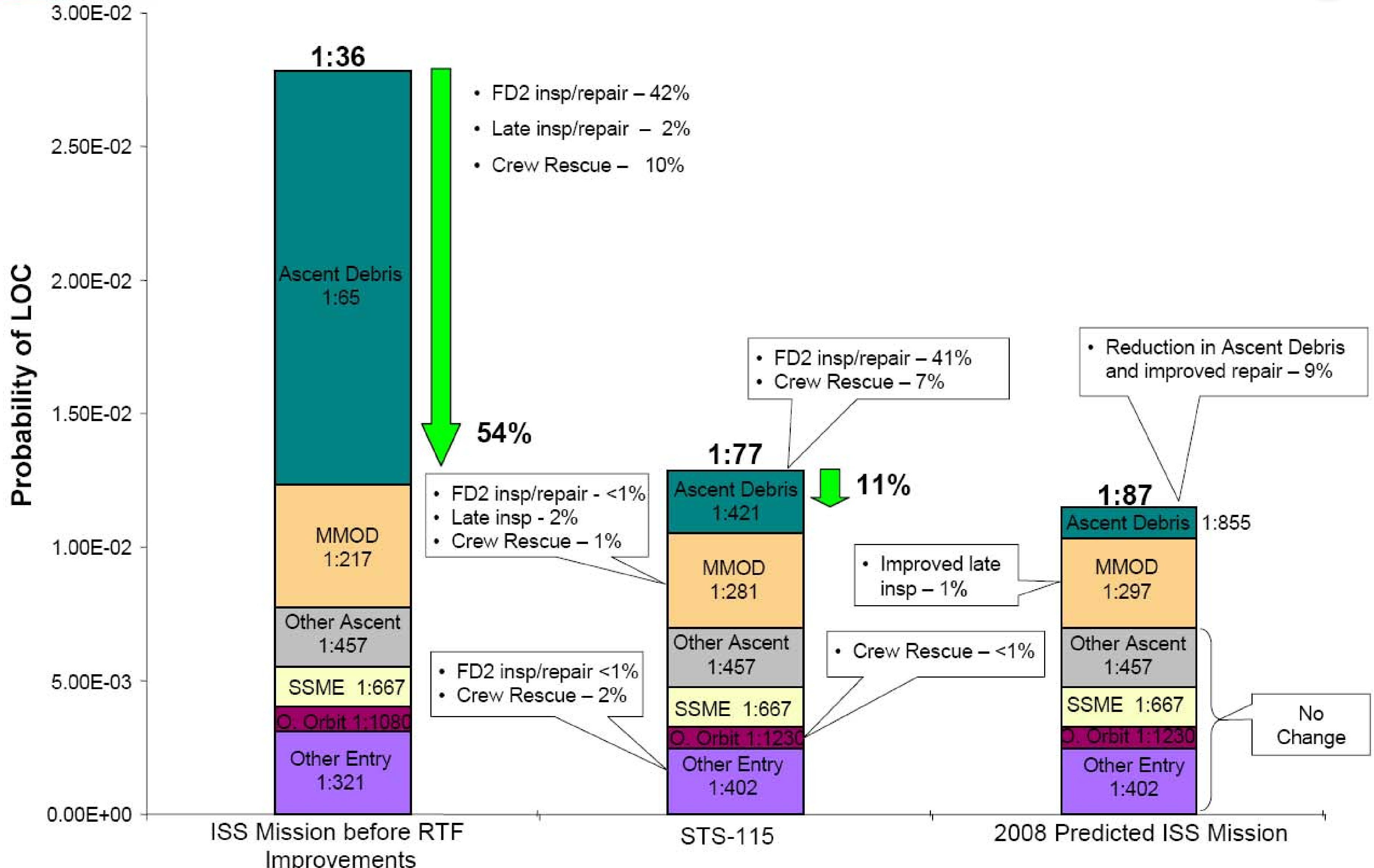


Probability of critical damage.

Inputs are based on:

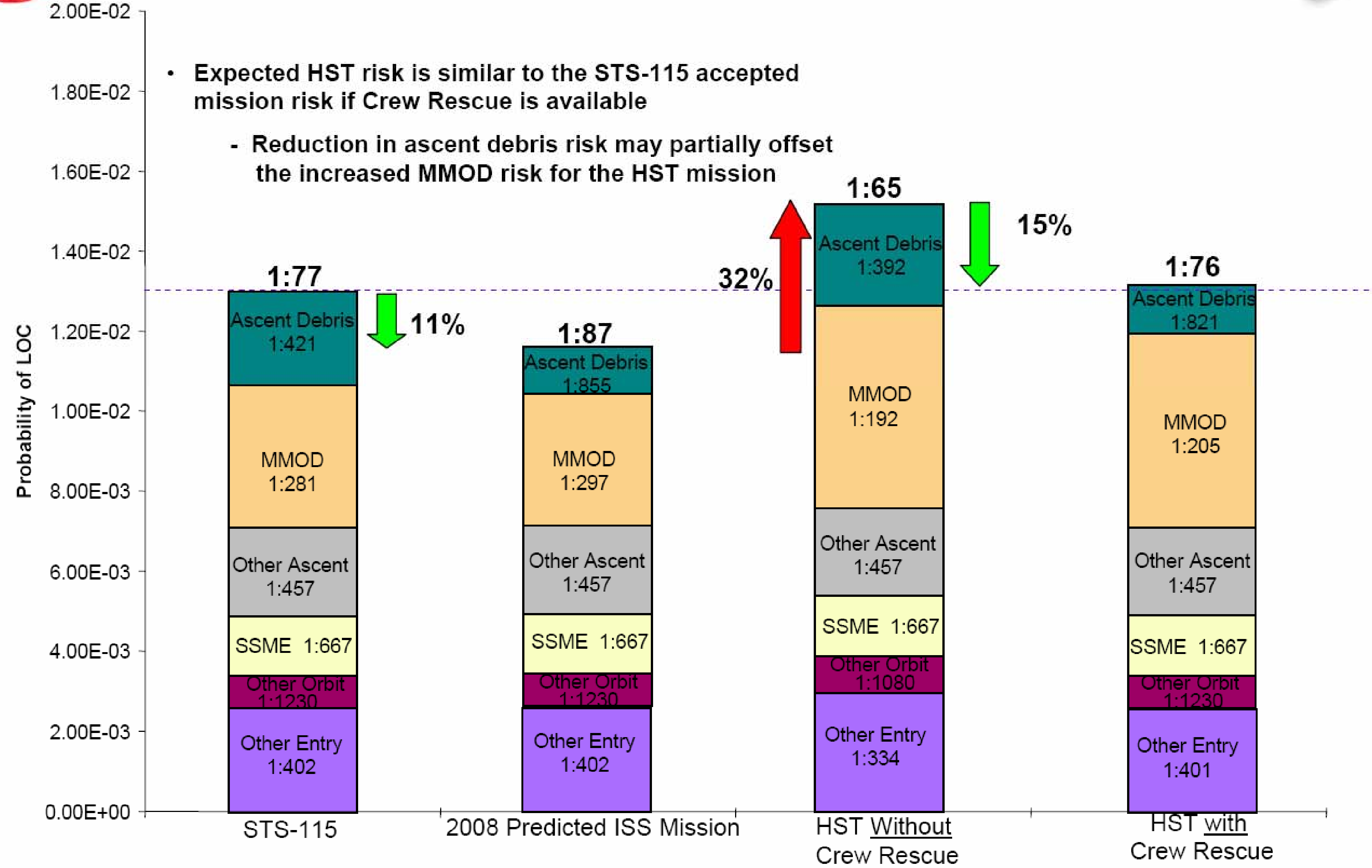
- Historical Ascent Debris Hit Maps (~83 flights)
- Orbiter Project Office Damage Tolerance Distributions
- Orbiter Project Office Inspection Criteria

ISS Mission Risk Reduction



Risk Comparisons

- **Expected HST risk is similar to the STS-115 accepted mission risk if Crew Rescue is available**
  - **Reduction in ascent debris risk may partially offset the increased MMOD risk for the HST mission**



Expected 2008 Operations Environment

Unique Risks for a Stand Alone Mission

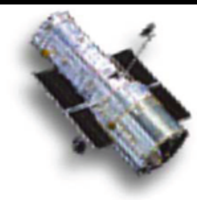
The 2004 Case Against HST (Cancellation Rationale)	**The 2006 Case FOR HST SM4** (Mitigation/Risk Acceptance Rationale)
1) Lack of Safe Haven – Typical ISS Mission will provide 60-90 Days of CSCS which allows for additional planning and near standard processing of the rescue vehicle	SM4 planning will assure sufficient consumables are onboard to support a stranded crew for at least 25 days till rescue. This will require manifesting additional LIOH and implementing a significant power down protocol
a) Limited time to modify rescue vehicle to avoid whatever situation damaged the HST vehicle	Low likelihood that the same catastrophic failure scenario will occur on consecutive flights based on expected ascent debris environment
b) "Double workload" associated with processing two vehicles for launch within 10-15 days of each other. Risk associated with a fatigued Launch Team	Compliance with Personnel work load requirements will assure fatigue risk is mitigated. KSC plans for either single or dual pad ops not judged to be a significant Human Factors impact.
2) TPS Inspection Capability Compromised if not docked to the ISS. No RPM for Tile Inspection	OBSS capability exists for accomplishing all RCC and TPS inspections. This was demonstrated during the TPS focused inspection on STS-115.

Expected 2008 Operations Environment

Unique Risks for a Stand Alone Mission

The 2004 Case Against HST (Cancellation Rationale)	The 2006 Case FOR HST SM4 (Mitigation/Risk Acceptance Rationale)
3) Repair Capability Compromised if not docked to the ISS. SSRMS required to provide adequate worksite reach and stability	DTO on SS-121 demonstrated SRMS/OBSS provides adequate reach and stability to serve as a repair worksite if required.
4) Hazards associated with temporary storage of rescue vehicle in VAB with hypergolic propellants loaded	Similar protocol was in place for STS-115 hurricane contingency planning and process was actually initiated.
5) Risks of Shuttle to Shuttle rendezvous and grapple	Rendezvous and grapple not outside previous experience base for targets both in planned and unplanned attitudes/rates, and not considered a significant risk driver for an HST rescue mission.
6) Crew transfer via EVA translation results in additional risk to crew. Some stranded crew not EVA trained. Suits not sized for all stranded crewmembers. Whole process is untried and uncertified.	Human Factors Analysis estimates the probability of loss of a crewmember at ~ 1 in 100 for the EVA translation activities. Full EVA training is not required. Certified EVA crewmembers will execute standard incapacitated crewmember translation techniques

Expected 2008 Operations Environment



Unique Risks for a Stand Alone Mission

The 2004 Case Against HST (Cancellation Rationale)	The 2006 Case FOR HST SM4 (Mitigation/Risk Acceptance Rationale)
11) Cannot fully comply with the CAIB Report and also execute an HST Servicing Mission	**SM4 is able to maintain compliance with the 4 mandatory CAIB requirements for a return to flight:** 1 Measures were taken to understand foam shedding and reduce it 2 Measures were taken to understand TPS tolerance 3 On-Orbit inspection capabilities exists to allow re-certification of Orbiter TPS for entry 4 Capability to perform limited Tile and RCC repairs exists The capability to comply with these requirements in a timeframe that would have been not only during the midst of the Return to Flight effort, but also within the then predicted HST health constraints would have been an near overwhelming challenge. However, the current and expected status of the Return to Flight initiatives and the schedule relief due to improved HST battery management allow compliance will all 4 requirements

The Climb Back for SM4

Current Manifest planning set August 7, 2008

November 06: Announcement of Approval of SM4

October 06: Manifesting Decision Review at NASA HQ

May 06: RTF going well, started Formal assessment of SM4 in RTF environ

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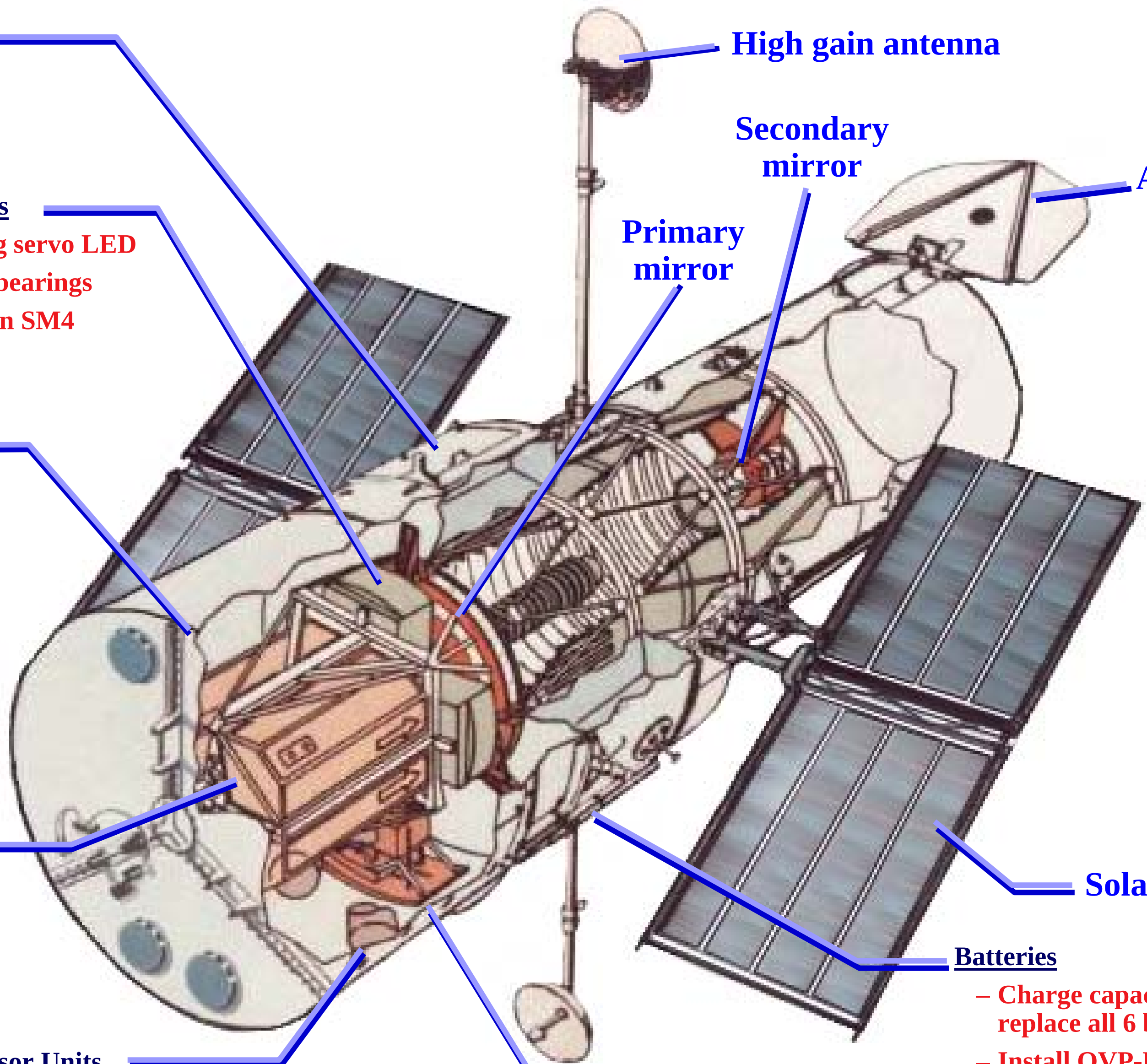
Hubble Servicing Mission 4 Crew

HST Spacecraft Health



Equipment Section
- Degraded MLI: Install NOBLs on Bays 5, 7, 8 in SM4

Fine Guidance Sensors
- FGS2R: degrading servo LED
- FGS3: degrading bearings

replace one FGS on SM4

Aft Shroud
- Higher power instruments causing warming
- Install STIS Cooling System on SM4

Axial Scientific Instruments
- STIS, failed 8/04

STIS Repair on SM4
- ACS, failed 1/07
- Install COS on SM4

Rate Sensor Units
- Gyros 2,3 and 5 failed: replace all 6 gyros on SM4

High gain antenna

Secondary mirror

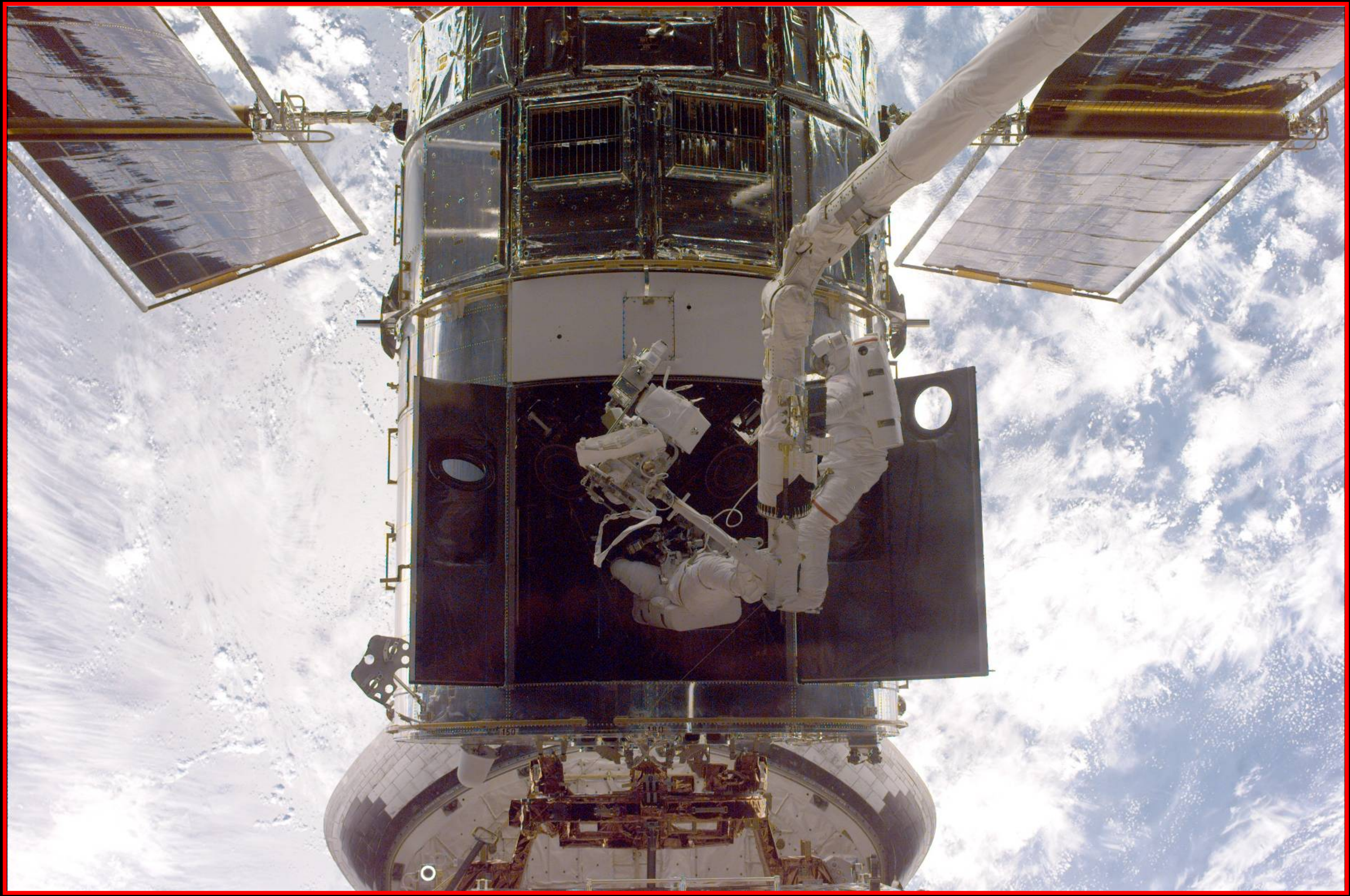
Primary mirror

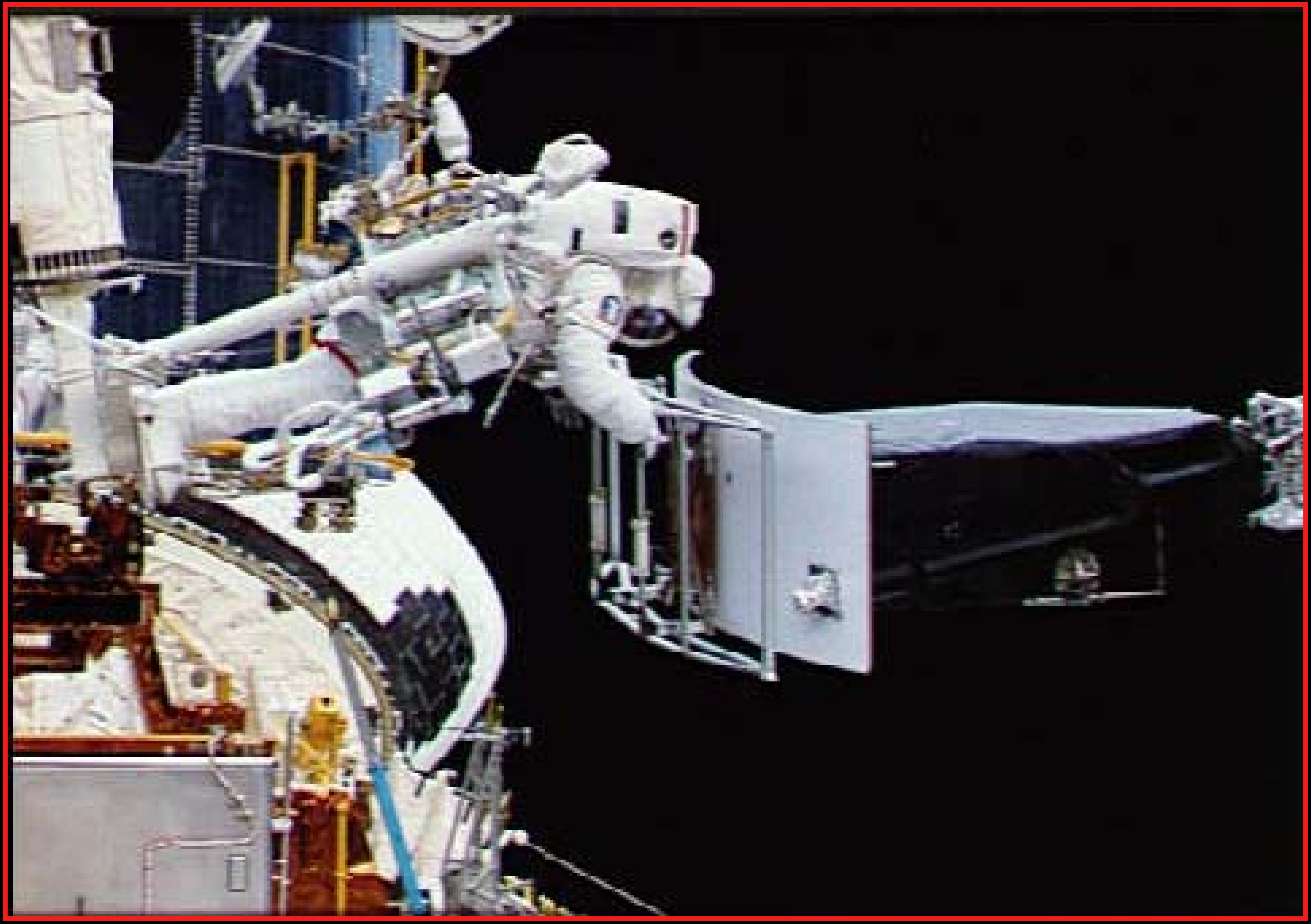
Aperture door

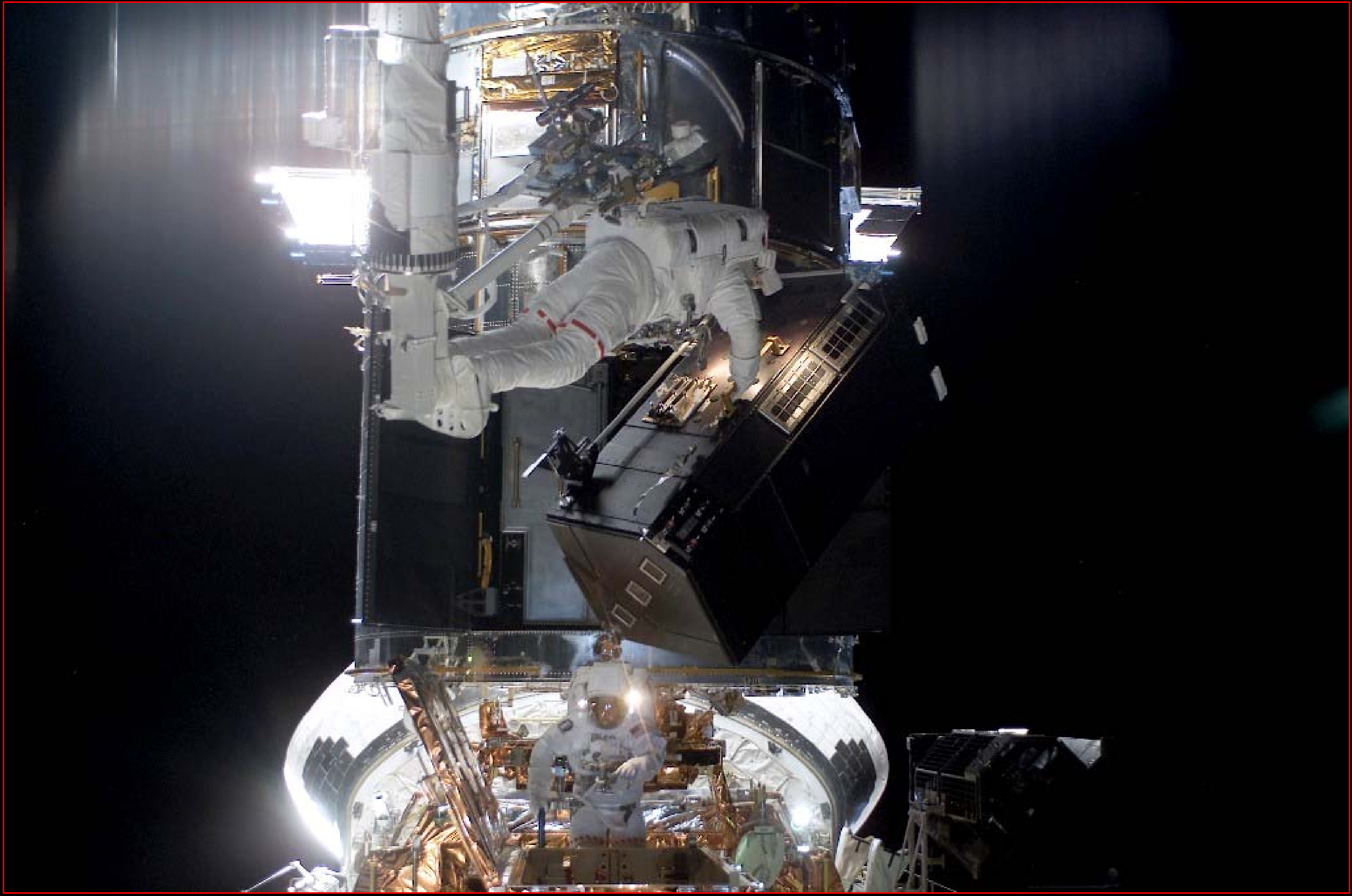
Solar Arrays

Batteries
- Charge capacity trending downward; replace all 6 batteries on SM4
- Install OVP-Kit on SM4

Radial Scientific Instrument
- Replace WFPC-II w/ WFC3 on SM4

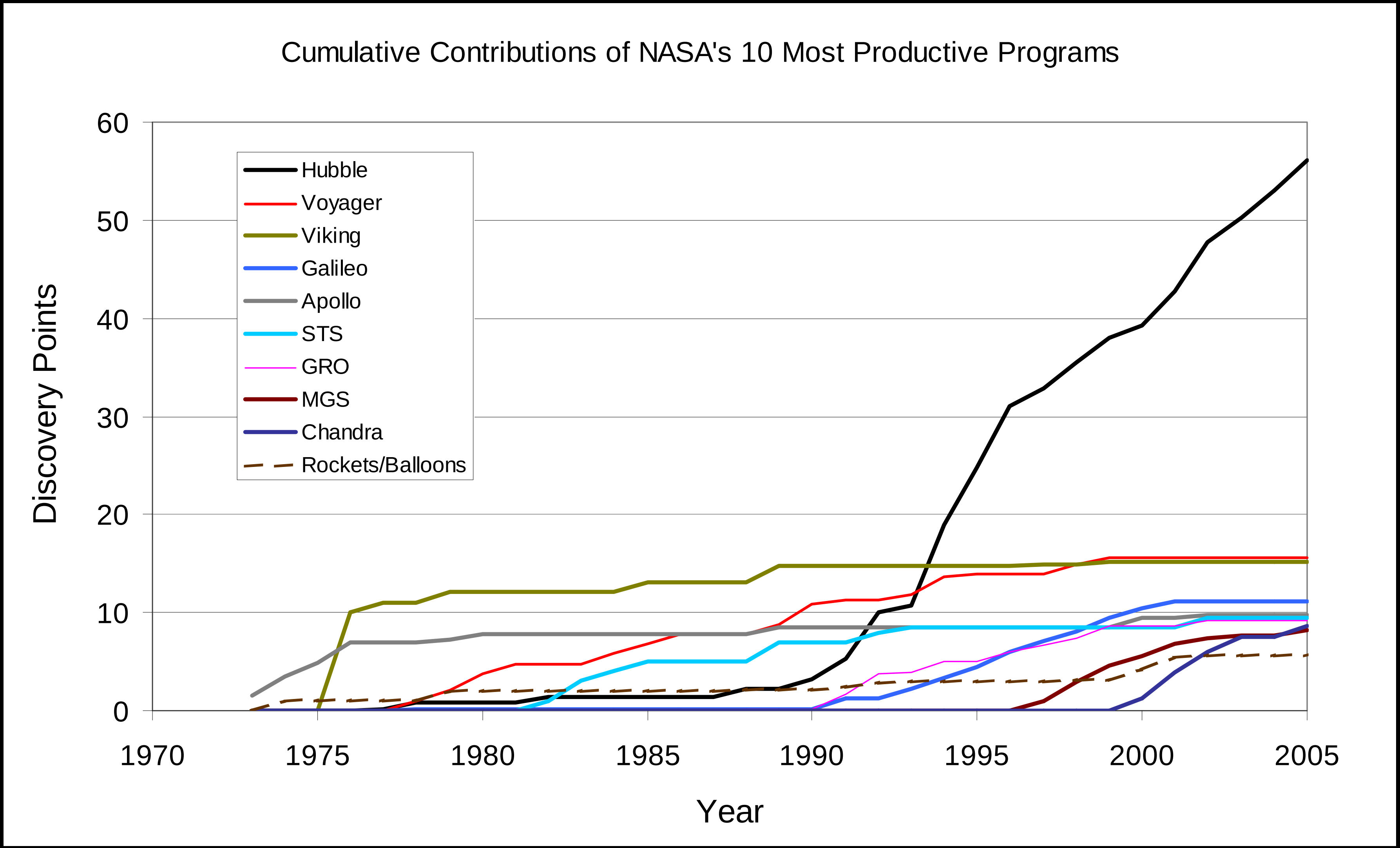






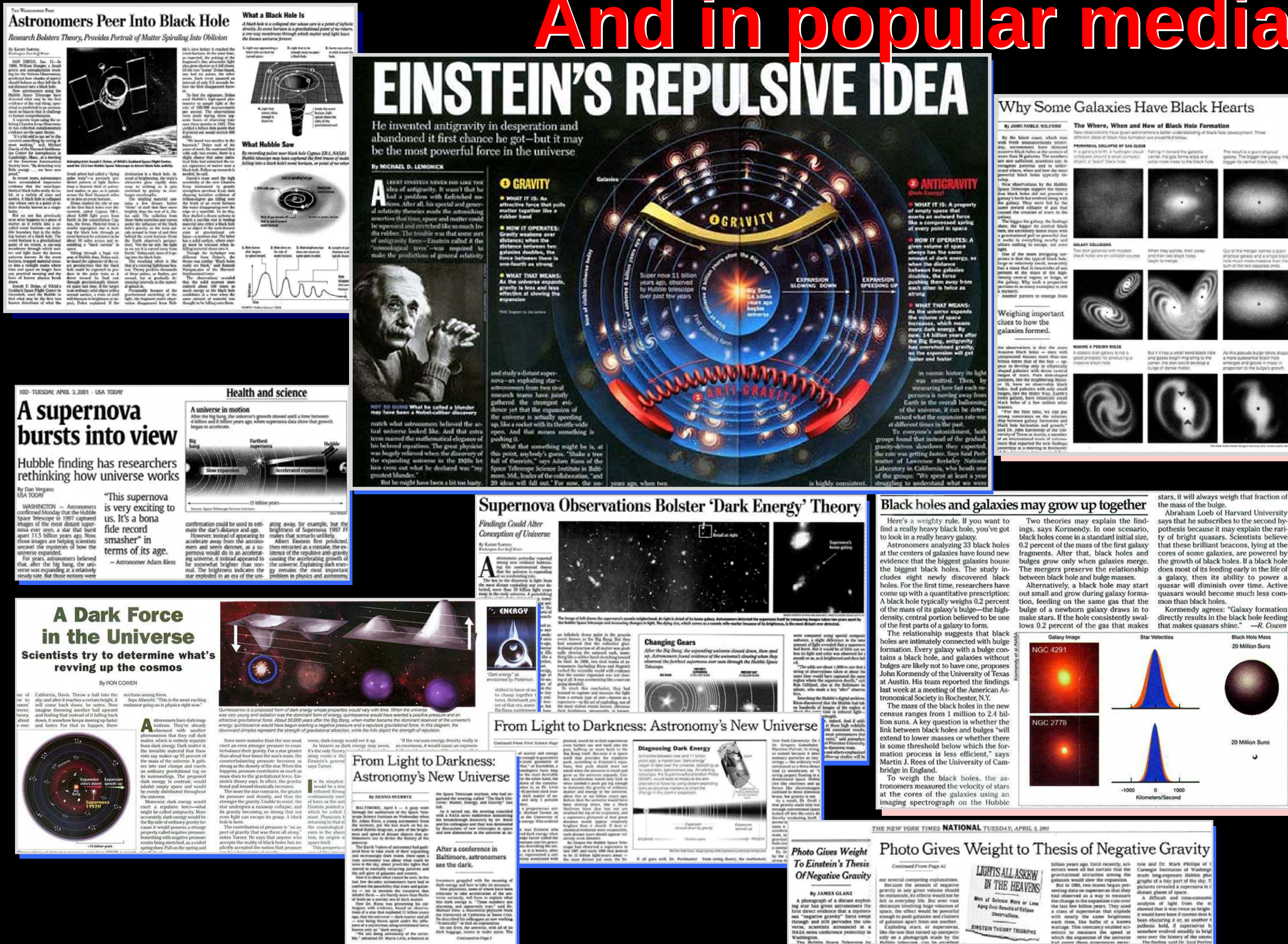
NASA Spares No Expense to get the BEST Tool Consultants

HST is an Incredible Science Machine

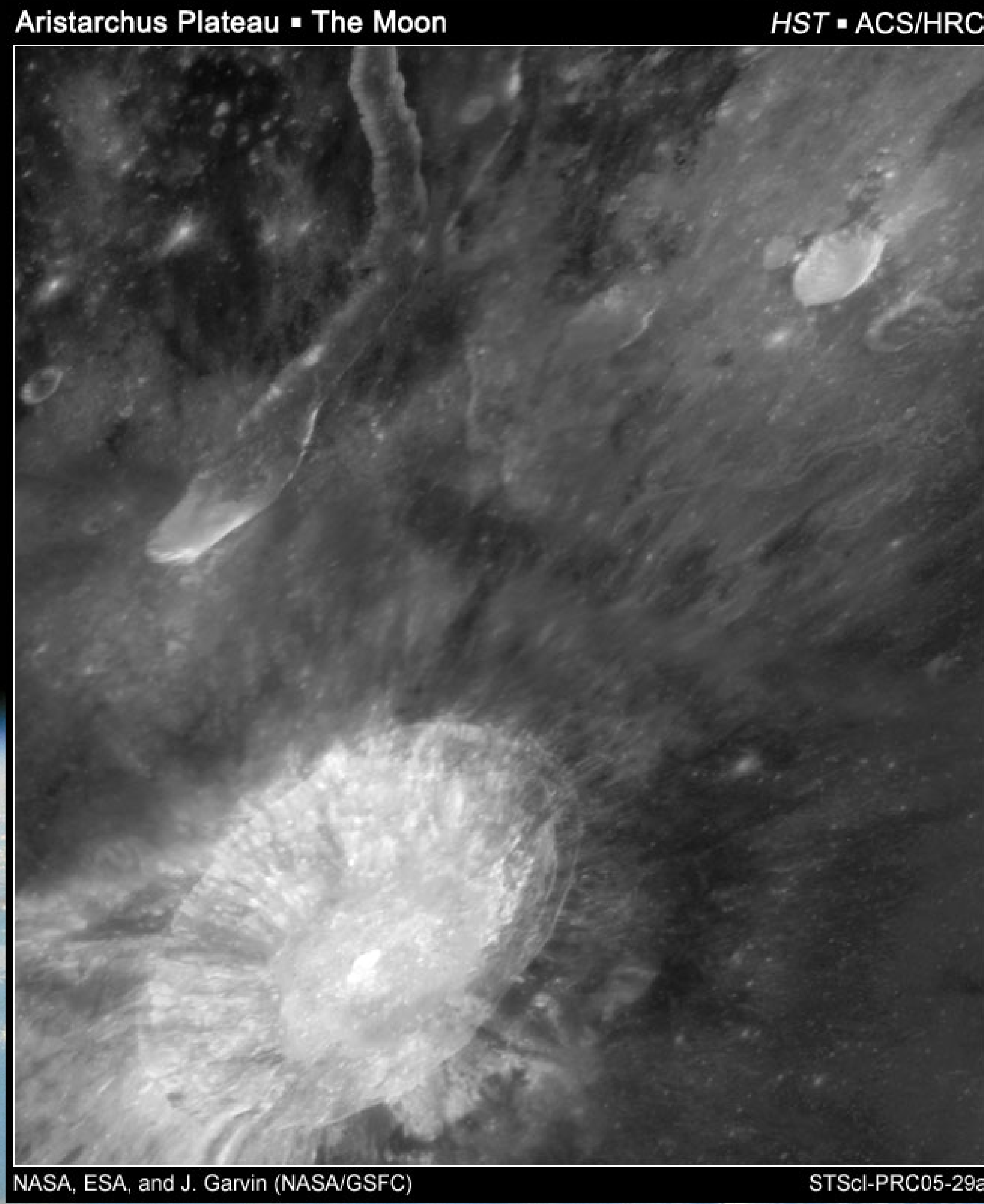


“Davidson *Science News* Metric” for 2005

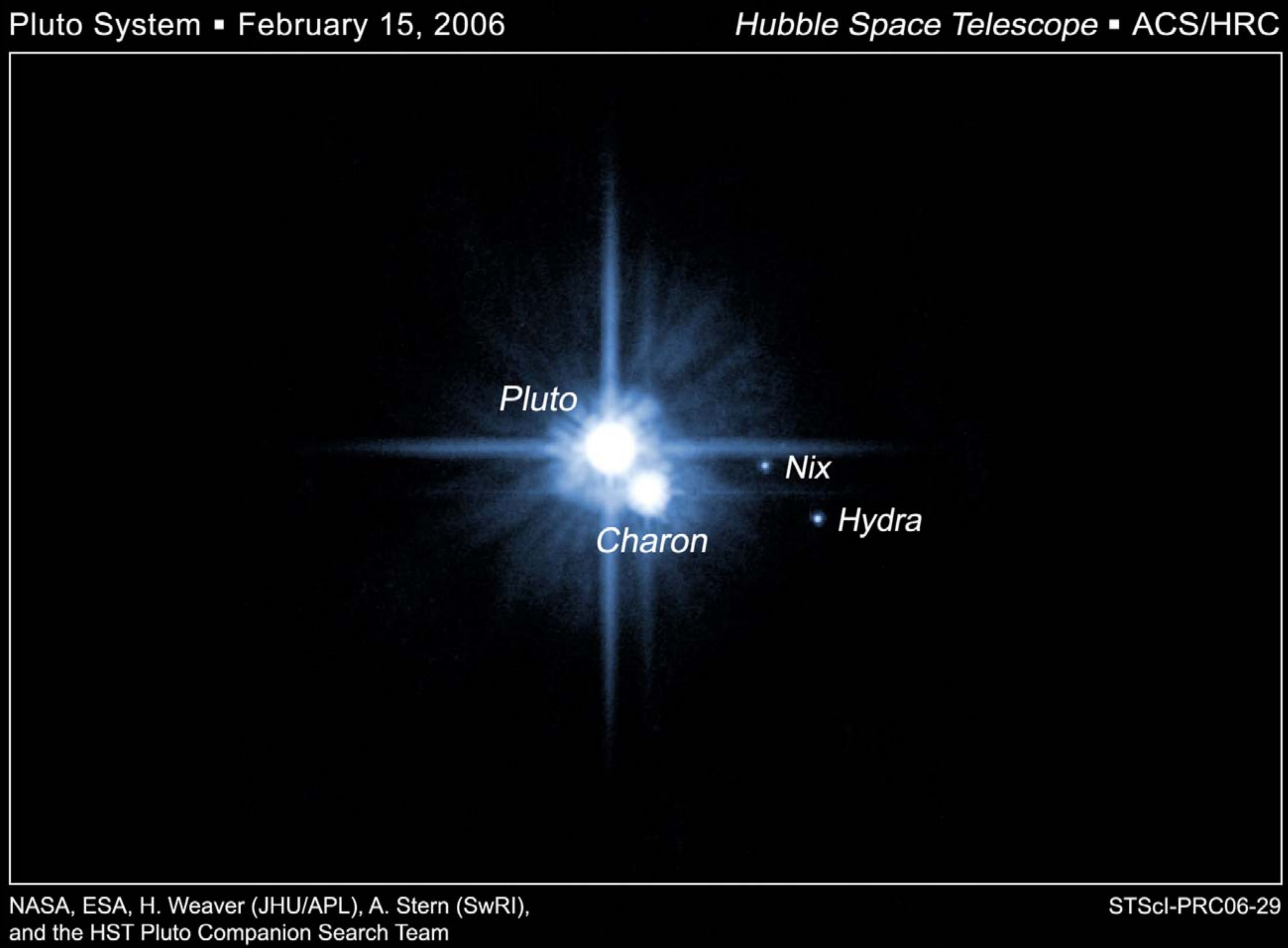
And in popular media



The Moon


Aristarchus Plateau ▪ The Moon
HST ▪ ACS/HRC
NASA, ESA, and J. Garvin (NASA/GSFC)
STScI-PRC05-29a

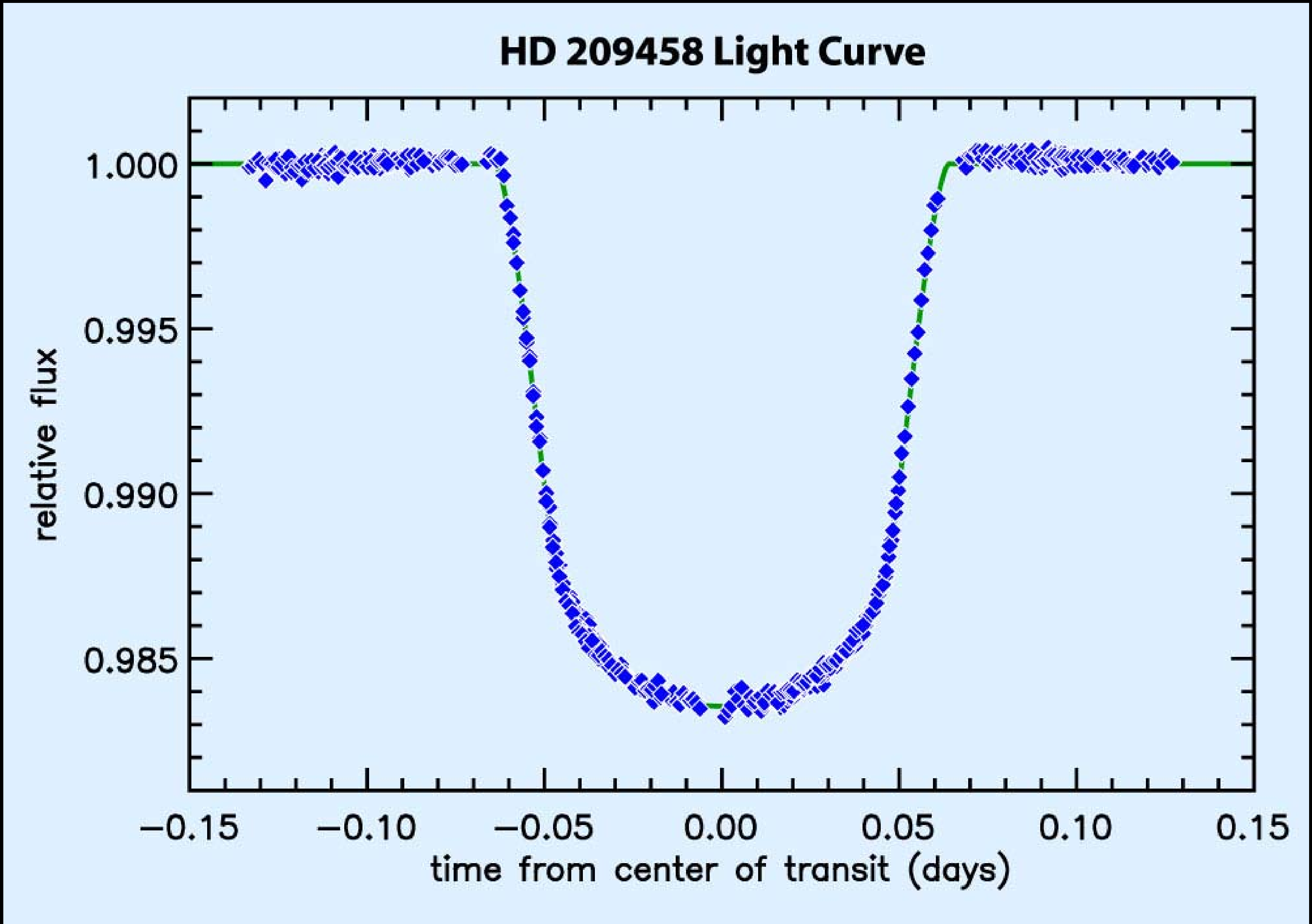
Pluto


Pluto System ▪ February 15, 2006
Hubble Space Telescope ▪ ACS/HRC
Pluto
Nix
Hydra
Charon
NASA, ESA, H. Weaver (JHU/APL), A. Stern (SwRI),
and the HST Pluto Companion Search Team
STScI-PRC06-29

Planetary Atmospheres

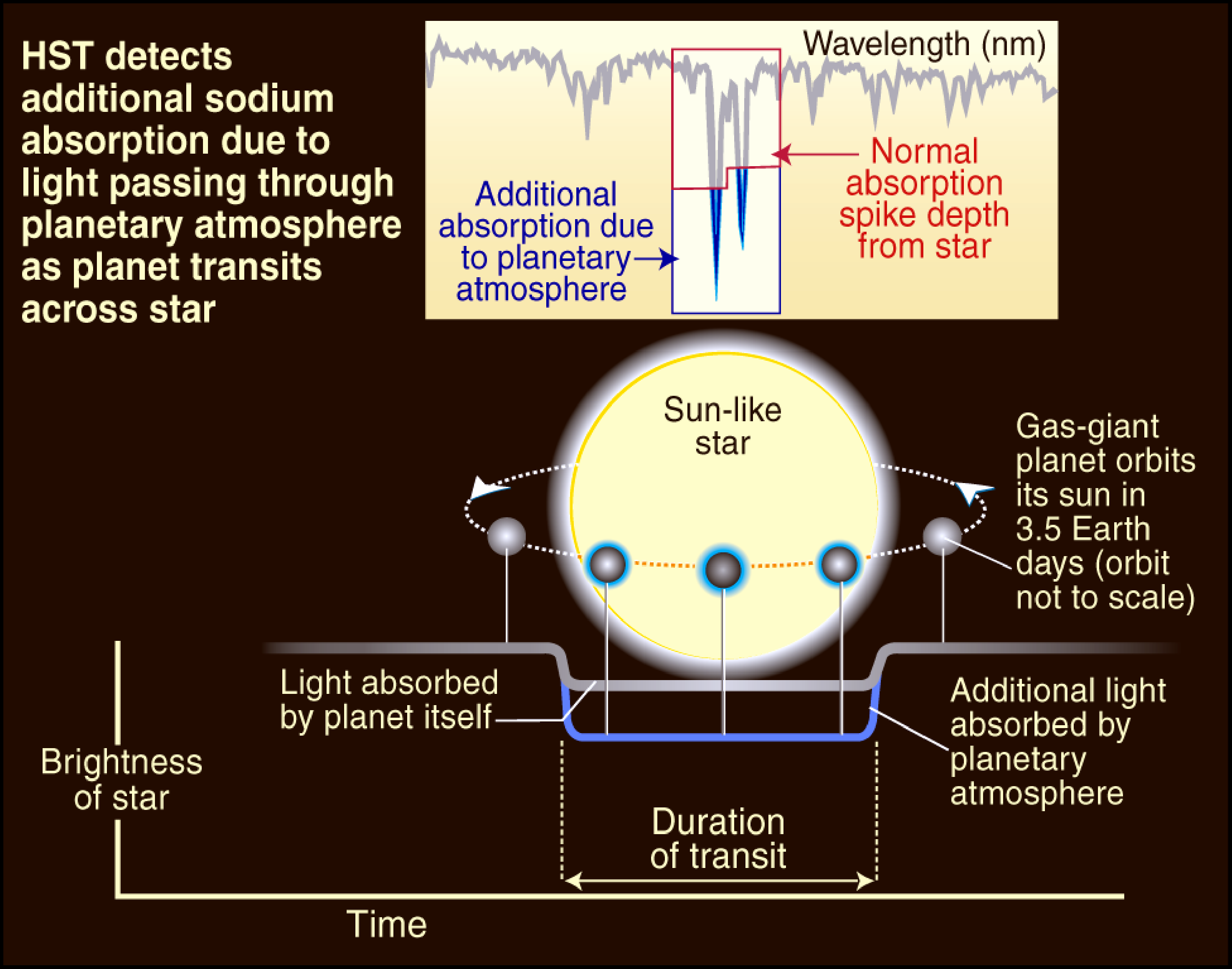
- Twenty years ago we new of 9 planets in the Universe (demoted to 8)
- Today we have discovered more than 200 outside our own solar system

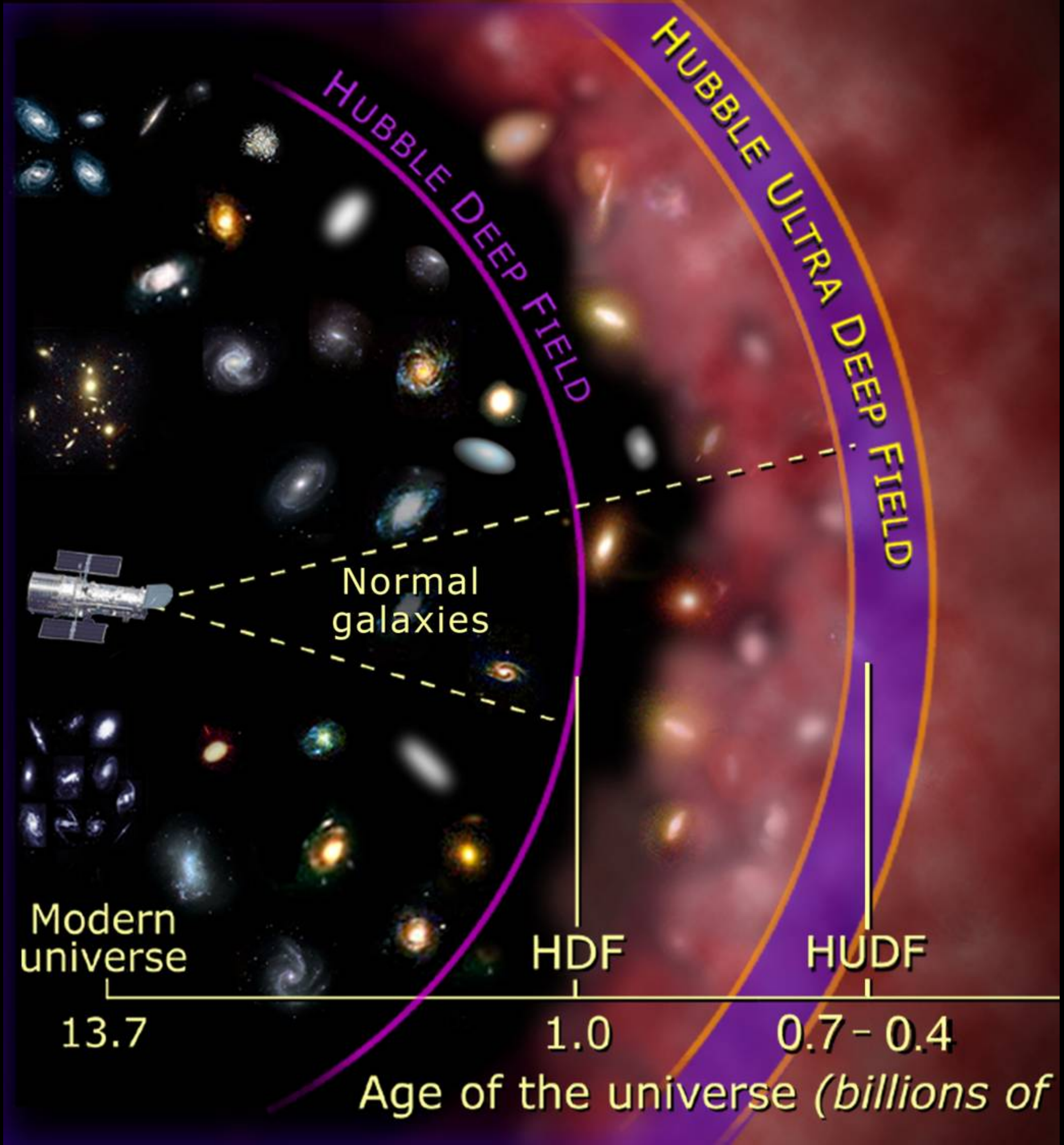
Planetary Atmosphere



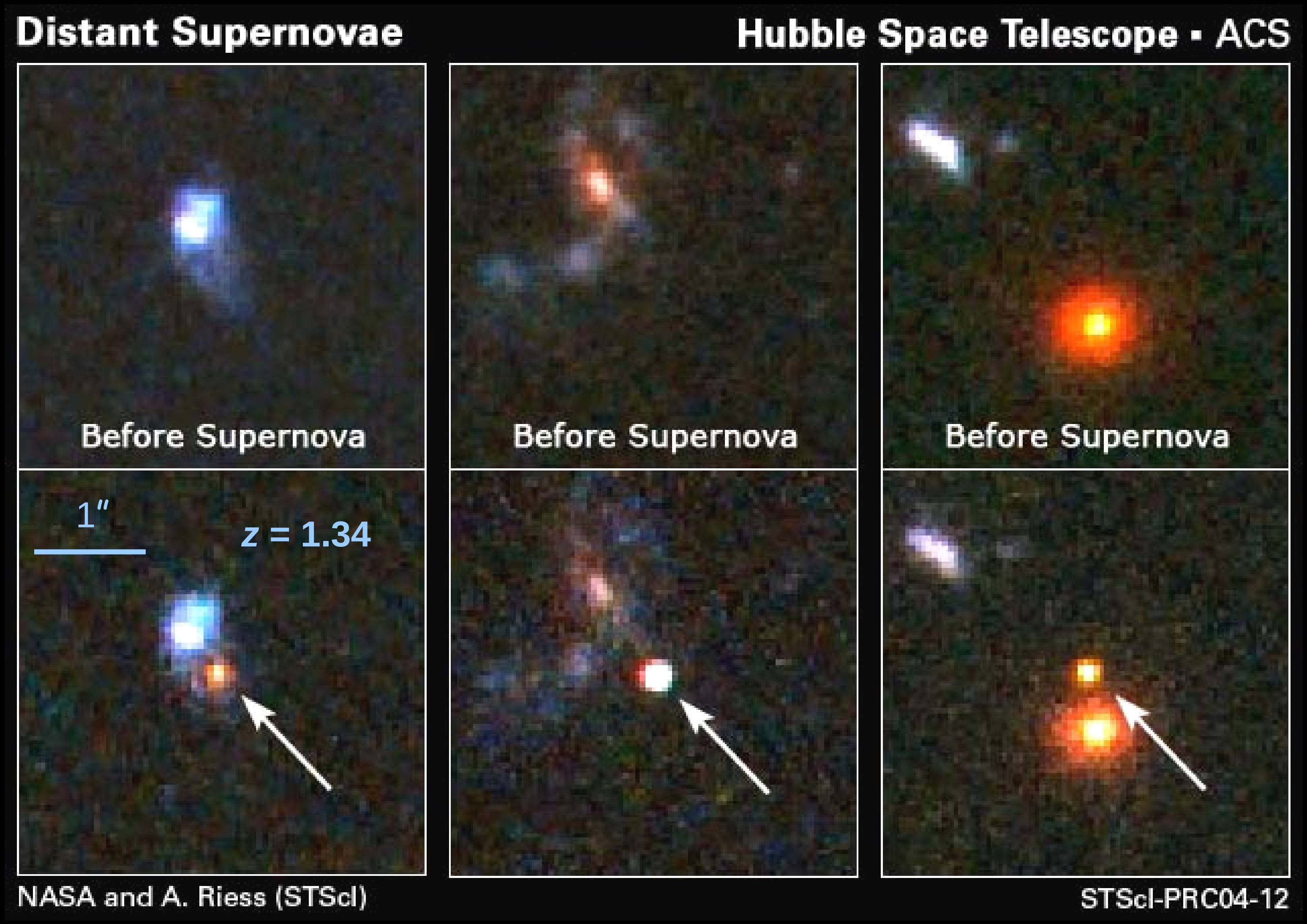
Brown *et. al.* 2001, *ApJ*, 552, 699

Planetary Atmosphere

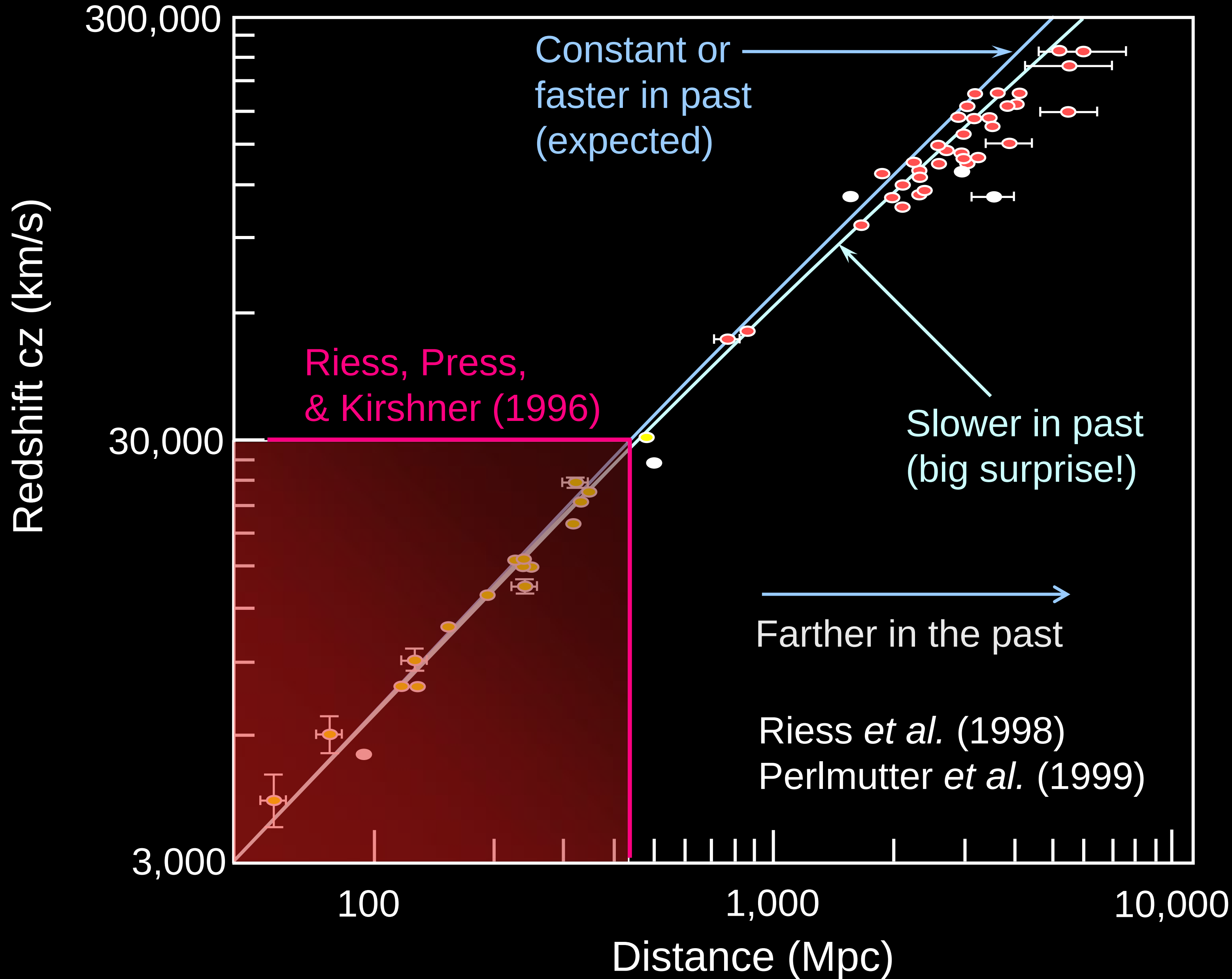



HUBBLE DEEP FIELD
HUBBLE ULTRA DEEP FIELD
Normal galaxies
Modern universe
HDF
HUDF
13.7
1.0
0.7 – 0.4
Age of the universe (billions of

HST Images of SN Ia



Expansion history of the universe

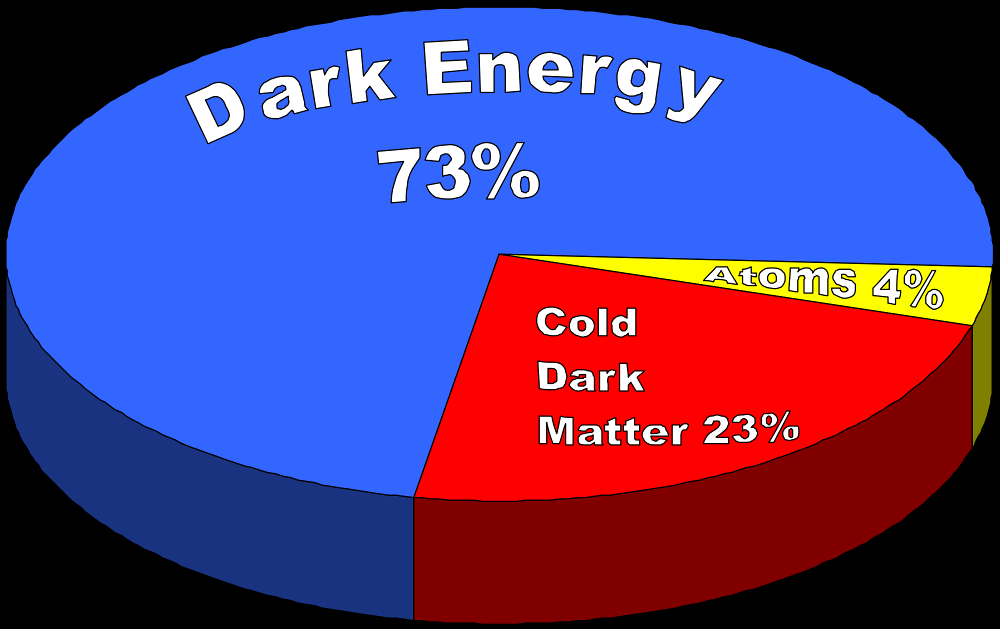


Some kind of energy (pressure) is responsible for accelerating the Universe of an unknown nature

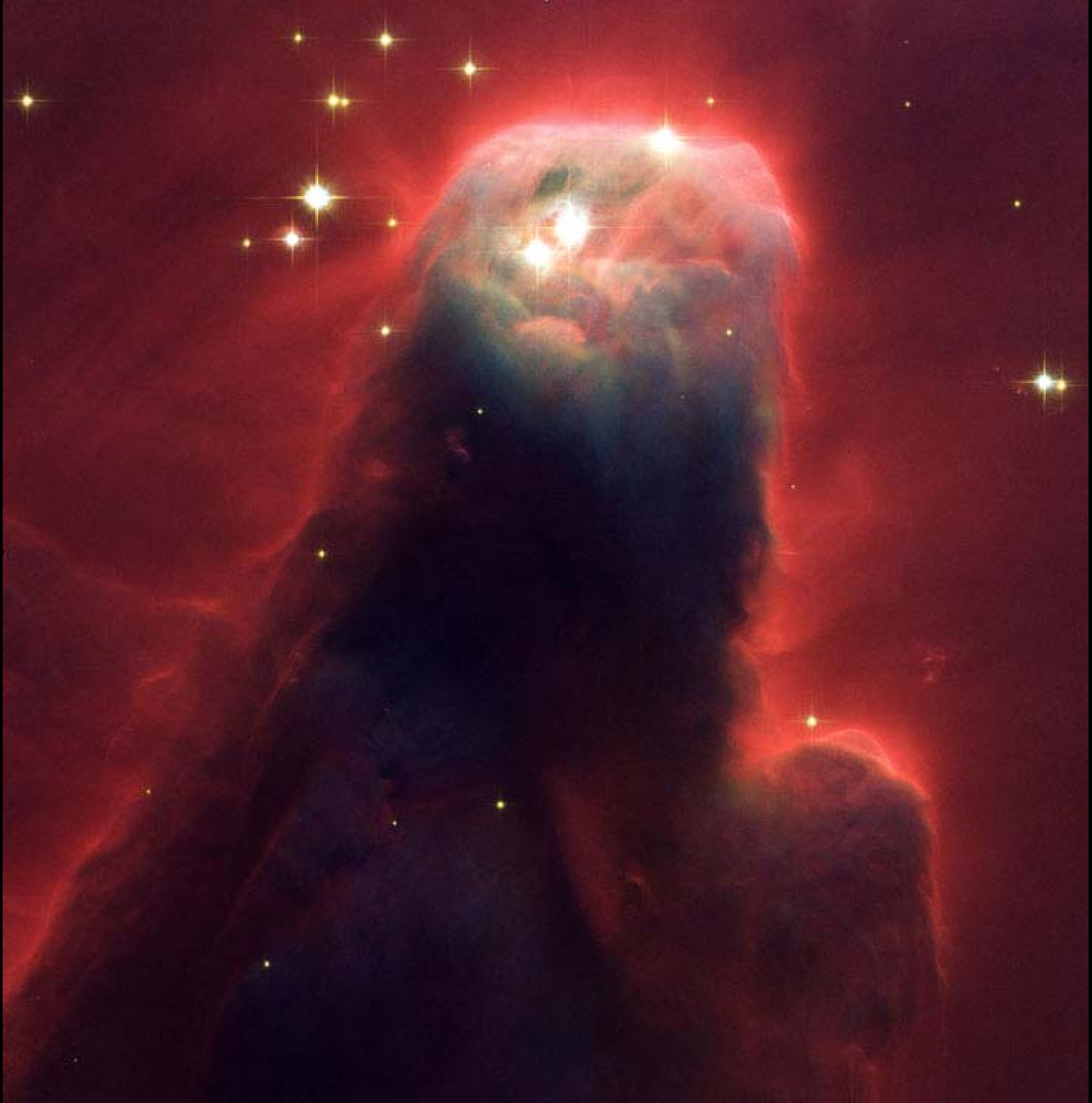
"Dark Energy"

Based on the supernova observations, and other observations, we can estimate the energy content of the various forms of energy and matter in the Universe.

How much do we know about our Universe?



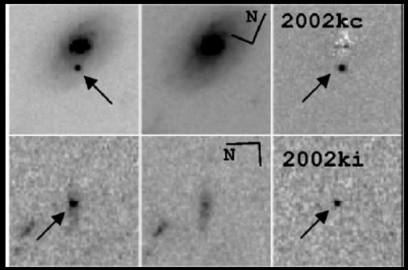
We don't know what 96% of the Universe is made of!

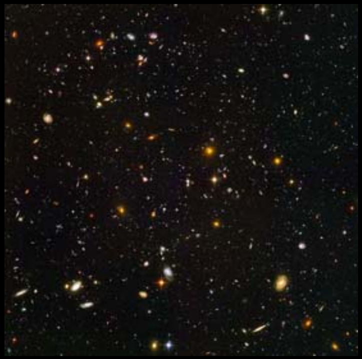


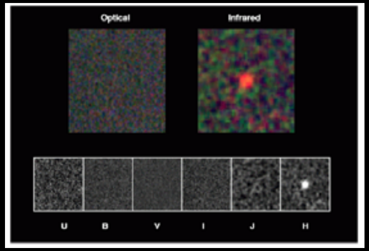
HUBBLE Will be at the Apex of Its Capabilities After SM4 in 2008

Batteries+Gyros+FGS = Sustained HST Lifetime

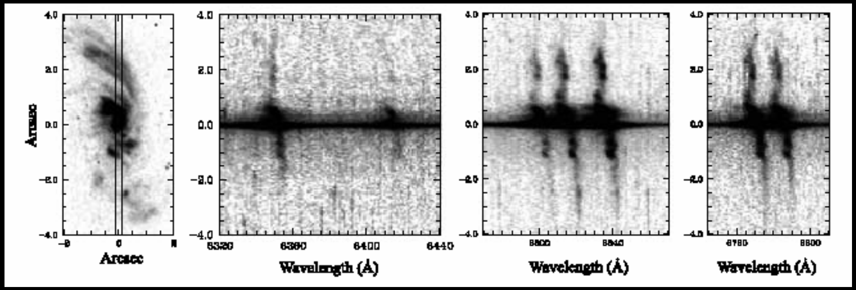
WFC3+ACS = Most powerful imaging ever

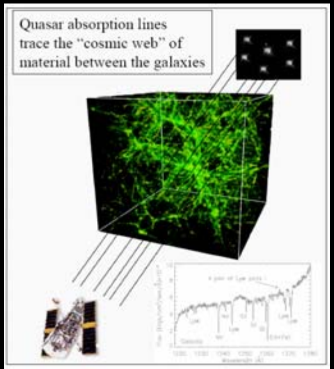


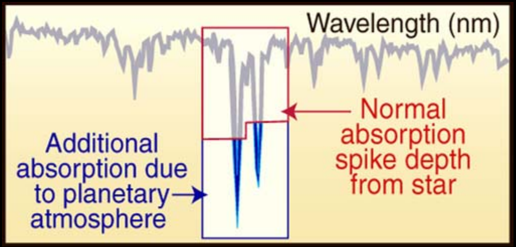




COS+STIS = Full set of tools for astrophysics







How much do Americans spend on NASA?

Exploration at what cost?

Much less than our annual
Spending on Beer or Pizza!

About the same as one family of 4
going to a feature film with
popcorn and drinks
($54 per taxpayer).

Stay tuned for SM4, with CU on board!