Space Telescope Science Institute

Overview and Status
AURA Member Representatives

Matt Mountain

April 27, 2006

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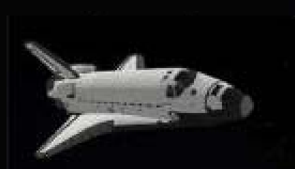
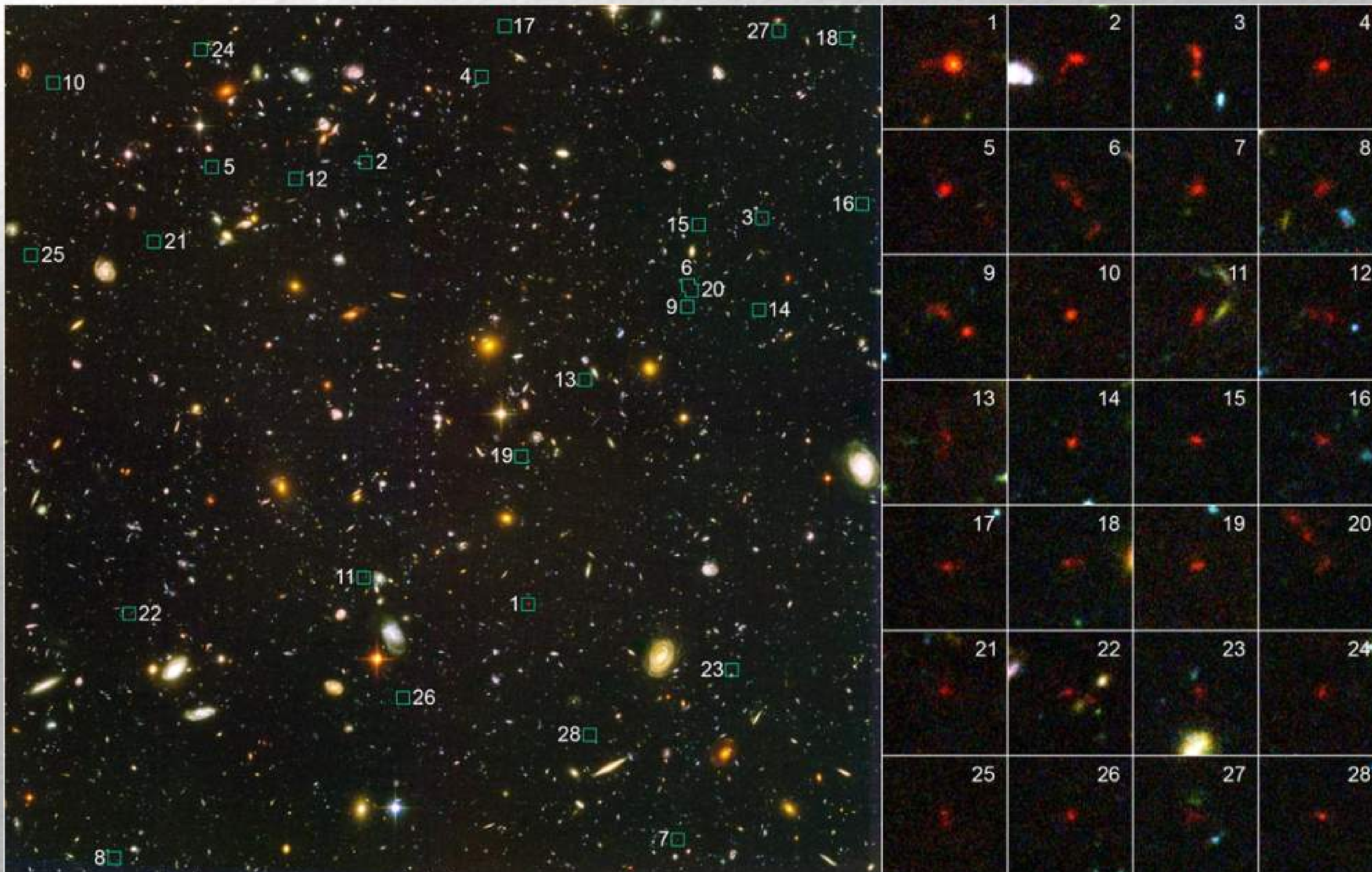


- Science Highlights
- HST & SM4
- The Budget
- JWST
- Concluding thoughts

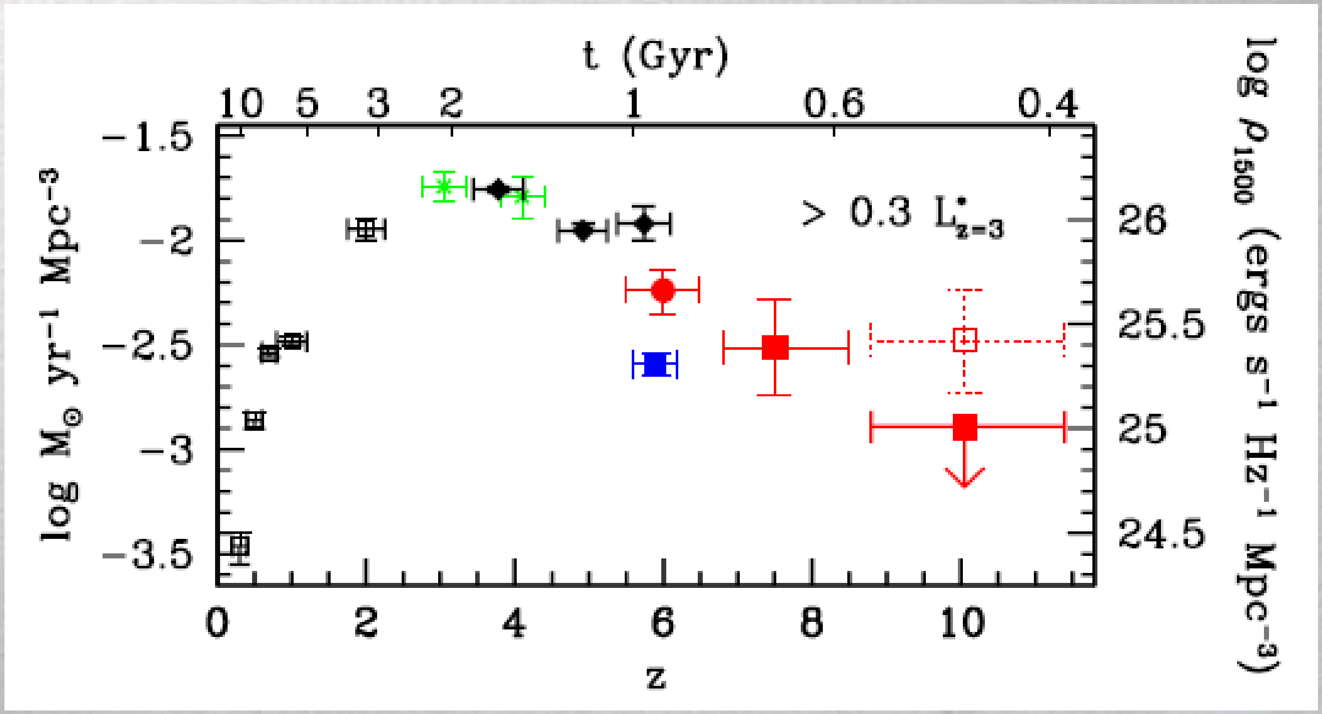
Probing the First Billion Years

Illingworth et al.: 506 galaxies with z>6 assembled from ACS data (HUDF, GOODS)
[increases previous sample of very high-z galaxies by >>10x!]



Probing the First Billion Years: The Inferences

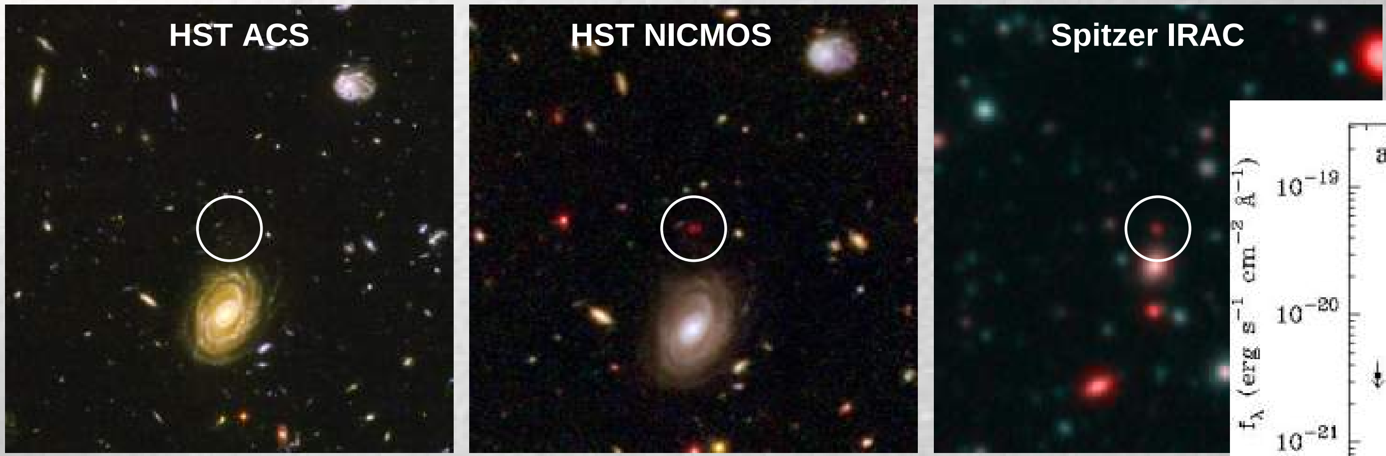
- Star formation rate at z~6 is only 30% of that at z~3 (previous studies did not confidently show a downturn)

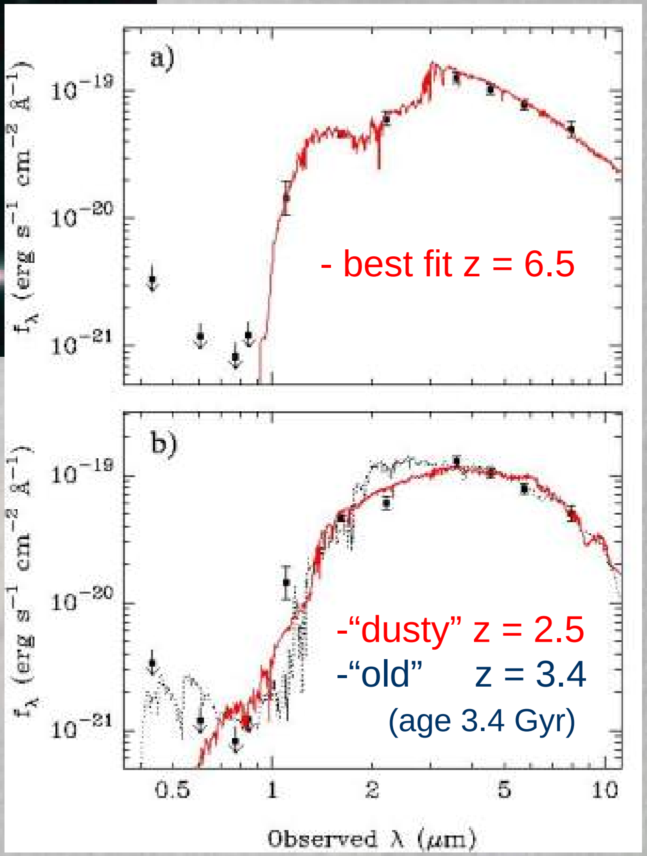


- Strong evolution of dust content and luminosity function found from z=3 to z=6 (a rather brief time interval of ~1 Gyr)

- The UV output of galaxies at z~6 is sufficient to be the mysterious energy source that reionizes the Universe

Mobasher et al.: J band dropout search for very high z galaxies in the HST UDF

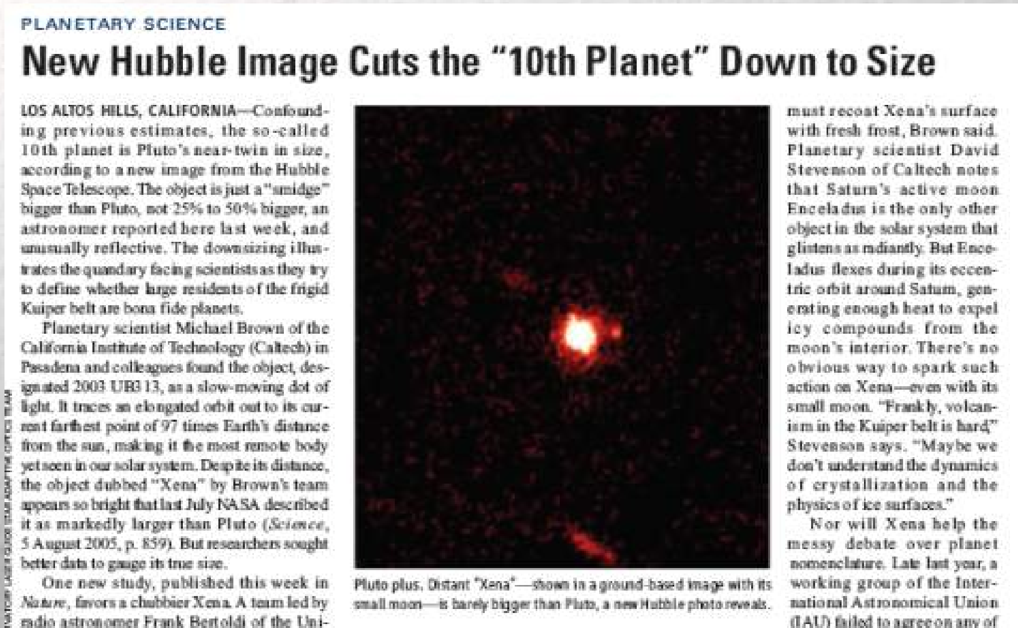




Spectral energy distribution (but no spectrum yet) best fits z~6.5: if correct, one of the most distant known objects

These objects are very challenging for ground-based telescopes (without gravitational lenses) -> JWST territory

In the Kuiper-Belt…..



PLANETARY SCIENCE

New Hubble Image Cuts the "10th Planet" Down to Size

LOS ALTOS HILLS, CALIFORNIA—Confounding previous estimates, the so-called 10th planet is Pluto's near-twin in size, according to a new image from the Hubble Space Telescope. The object is just a "smidge" bigger than Pluto, not 25% to 50% bigger, an astronomer reported here last week, and unusually reflective. The downsizing illustrates the quandary facing scientists as they try to define whether large residents of the frigid Kuiper belt are bona fide planets.

Planetary scientist Michael Brown of the California Institute of Technology (Caltech) in Pasadena and colleagues found the object, designated 2003 UB313, as a slow-moving dot of light. It traces an elongated orbit out to its current farthest point of 97 times Earth's distance from the sun, making it the most remote body yet seen in our solar system. Despite its distance, the object dubbed "Xena" by Brown's team appears so bright that last July NASA described it as markedly larger than Pluto (*Science*, 5 August 2005, p. 859). But researchers sought better data to gauge its true size.

One new study, published this week in *Nature*, favors a chubbier Xena. A team led by radio astronomer Frank Bertoldi of the Uni-

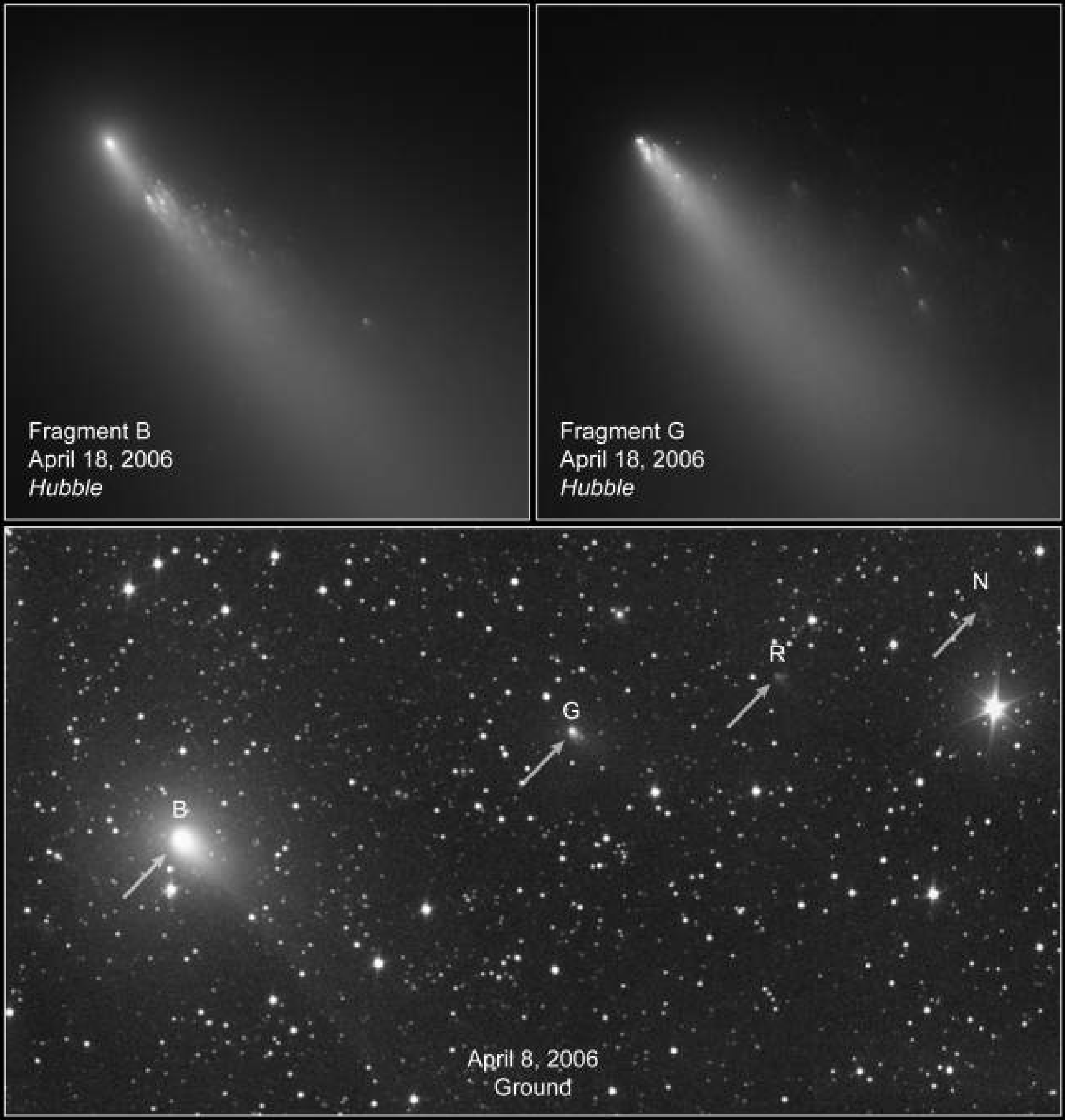
Pluto plus. Distant "Xena"—shown in a ground-based image with its small moon—is barely bigger than Pluto, a new Hubble photo reveals.

must recoat Xena's surface with fresh frost, Brown said. Planetary scientist David Stevenson of Caltech notes that Saturn's active moon Enceladus is the only other object in the solar system that glistens as radiantly. But Enceladus flexes during its eccentric orbit around Saturn, generating enough heat to expel icy compounds from the moon's interior. There's no obvious way to spark such action on Xena—even with its small moon. "Frankly, volcanism in the Kuiper belt is hard," Stevenson says. "Maybe we don't understand the dynamics of crystallization and the physics of ice surfaces."

Nor will Xena help the messy debate over planet nomenclature. Late last year, a working group of the International Astronomical Union (IAU) failed to agree on any of

"Confounding previous estimates, the so-called 1 0 t h planet is Pluto's near-twin in size, according to a new image from the Hubble Space Telescope. The object is just a "smidge" bigger than Pluto"
(Brown et al, 2006)

Weaver & Stern, 2006



Comet 73P/Schwassman-Wachmann 3
Hubble Space Telescope • ACS/WFC

Just released this morning

H. Weaver et al

BBC ON THIS DAY | 24 | 1990: Hubble telescope takes off for space - Microsoft Internet Explorer

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1990: Hubble telescope takes off for space

The American space agency Nasa has successfully launched the space shuttle Discovery from Cape Canaveral in Florida on its historic mission to carry the Hubble space telescope into orbit 380 miles (611.5 km) above the Earth.

The telescope will operate from high above the atmosphere, thus avoiding the interference which limits ground-based telescopes.

It will be able to see up to the edge of the known universe, taking images of objects and events which happened up to 14 billion years ago.

The telescope, the size of a railway carriage, has taken 20 years to build, at a cost of $1.55 billion.

It has been dogged by technical hitches, huge budget over-runs and other delays.

Seven years late

Its launch is seven years overdue, held up by problems in the space shuttle program, including the explosion of the Challenger shuttle in 1986.

The problems continued even once it was safely in space, as the British-made solar panel arrays which provide power for the six separate instruments on board malfunctioned.

The Hubble Space Telescope has taken 20 years to build

Timeline: Space

24 Apr 1990	Hubble telescope takes off for space
10 Aug 1990	Magellan starts mapping Venus
18 May 1991	Sharman becomes first Briton in space
09 Dec 1993	Astronauts put Hubble back in action
09 Feb 1995	Space pioneers take first small steps
29 Jun	US shuttle docks with

In Context

When the first pictures from Hubble came through, in May 1990, scientists were horrified. The images were blurred - no better than would have been produced by a telescope on Earth.

Stories From 24 Apr

- 1993: IRA bomb devastates City of London
- 1967: Russian cosmonaut dies in space crash
- 1982: First Briton dies in Falklands campaign
- 1975: Baader-Meinhof blow up embassy
- 1954: British crackdown on Kenya rebels
- 1990: Hubble telescope takes off for space

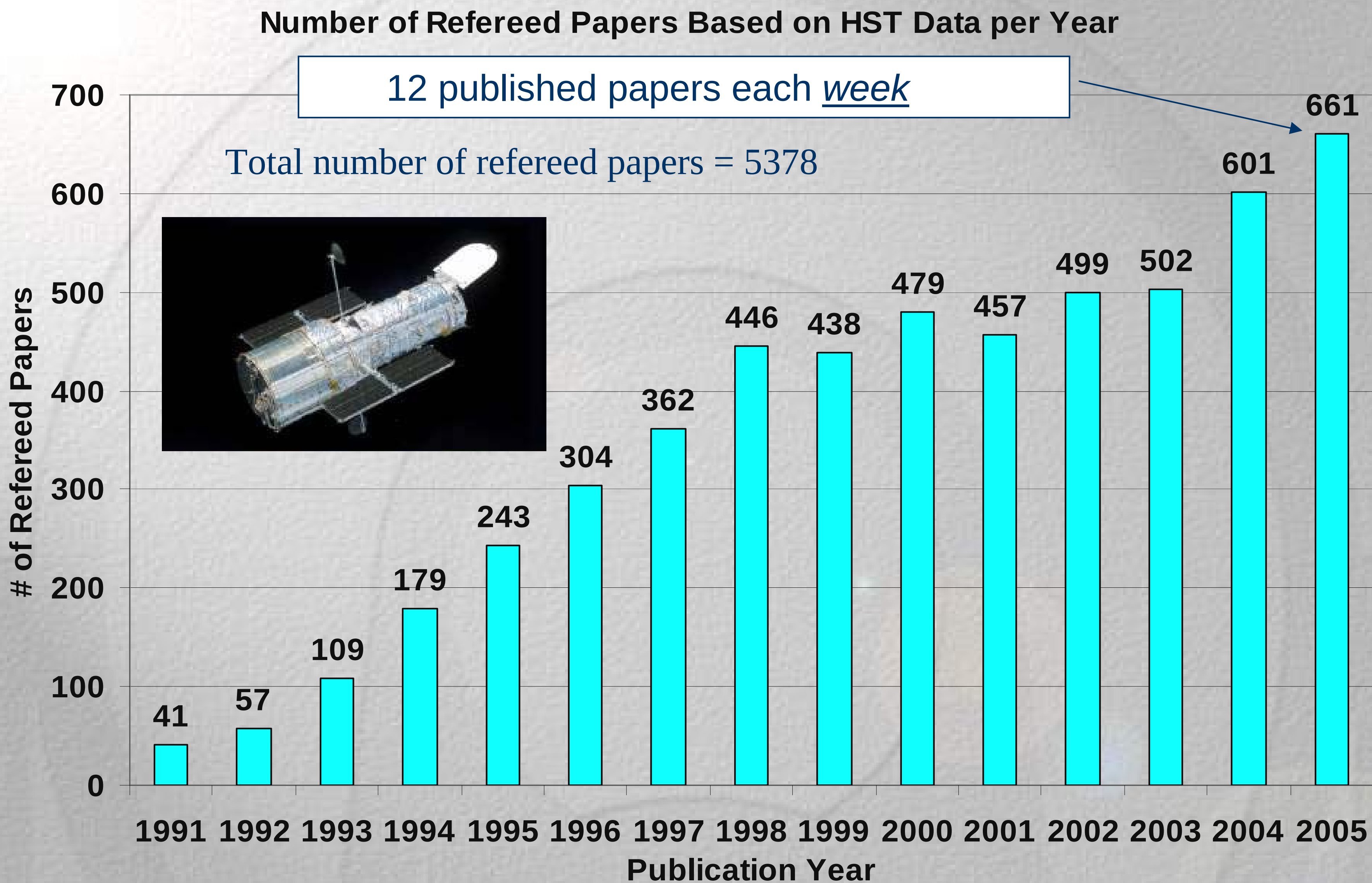
BBC News >>

- In Depth: The Hubble Space Telescope

Web Links

- Hubblesite
- Space Telescope Science Institute

The BBC is not responsible for the content of external internet sites


Number of Refereed Papers Based on HST Data per Year
12 published papers each *week*
Total number of refereed papers = 5378
# of Refereed Papers
0
100
200
300
400
500
600
700
41
57
109
179
243
304
362
446
438
479
457
499
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2002
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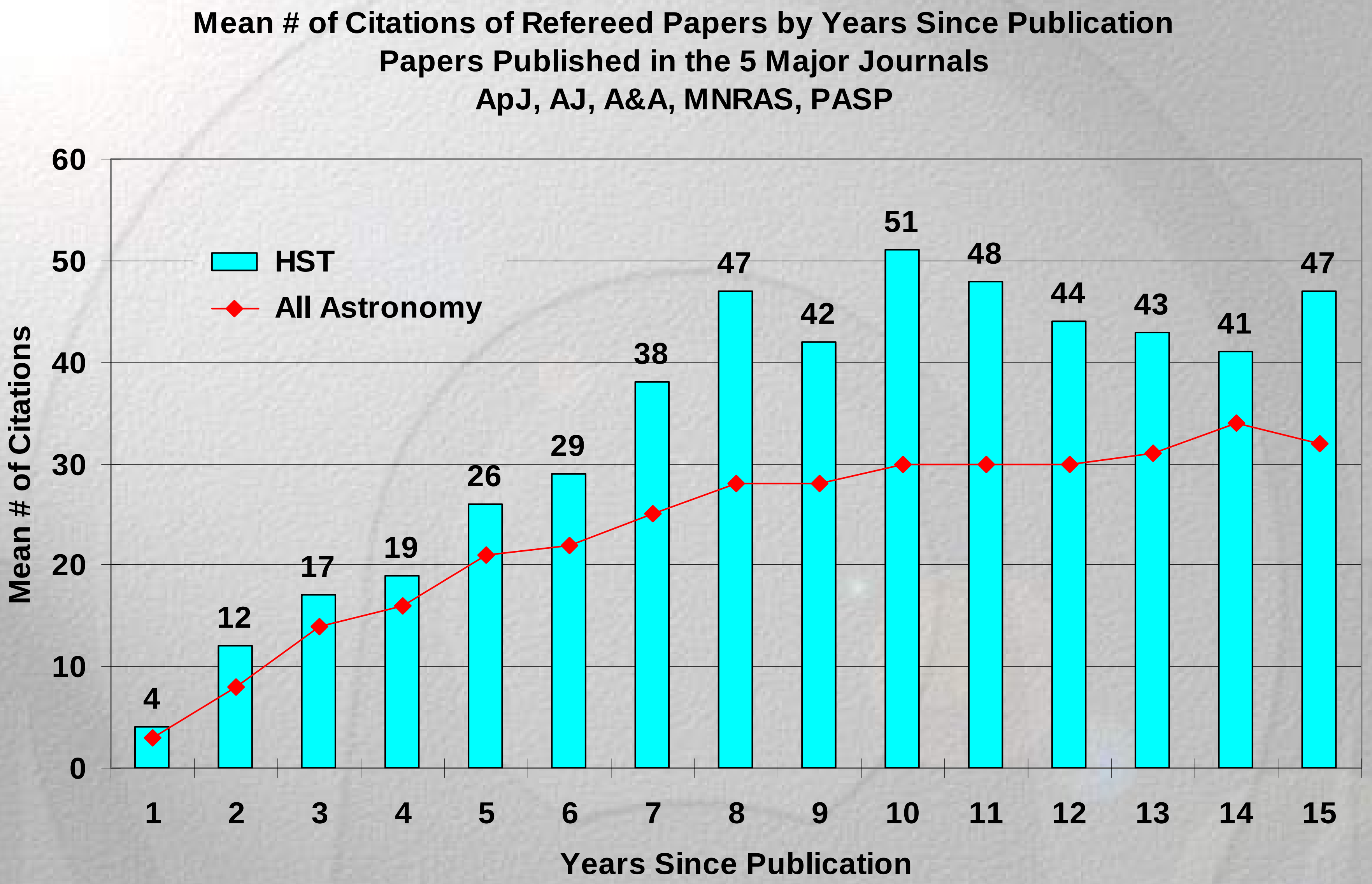
2004
2005
Publication Year



Mean # of Citations of Refereed Papers by Years Since Publication
Papers Published in the 5 Major Journals
ApJ, AJ, A&A, MNRAS, PASP
HST
All Astronomy
Mean # of Citations
Years Since Publication
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20
30
40
50
60
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2
3
4
5
6
7
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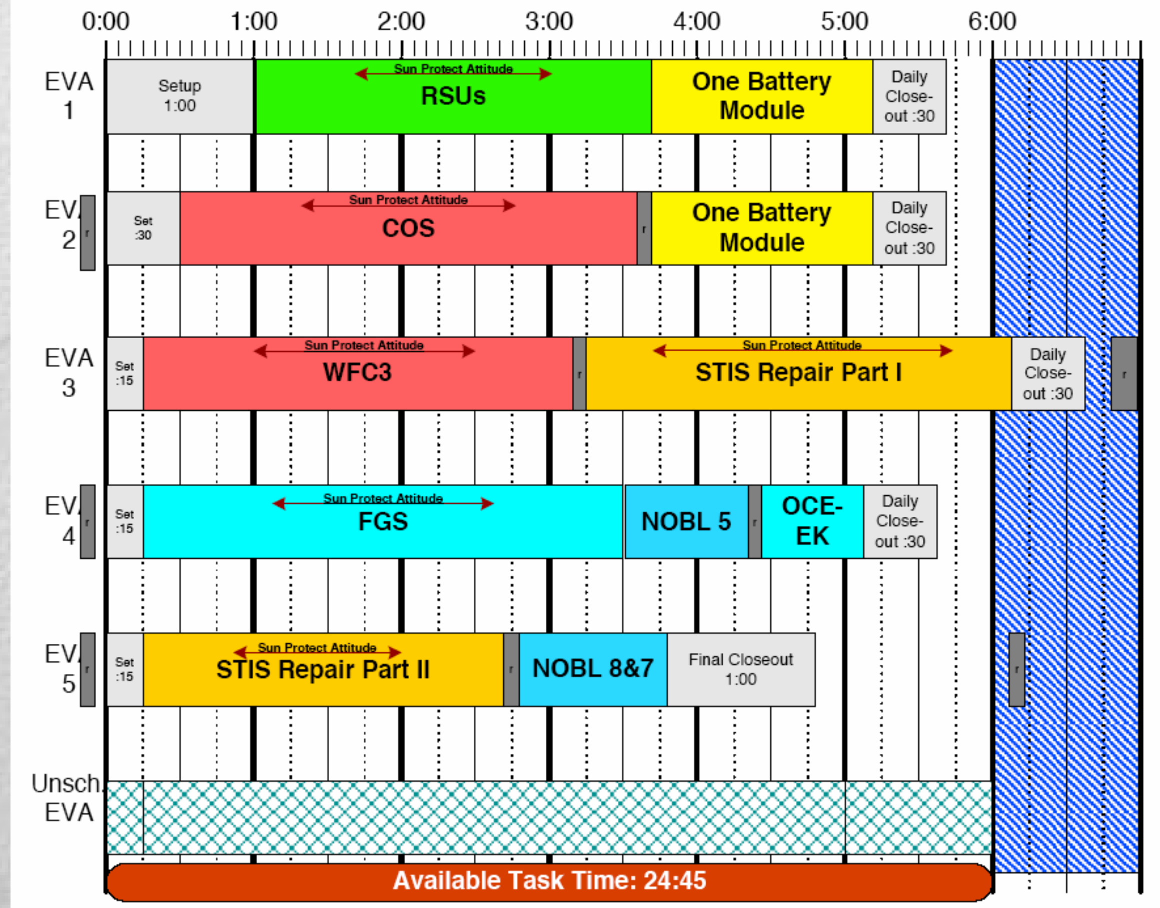
SM4 Status

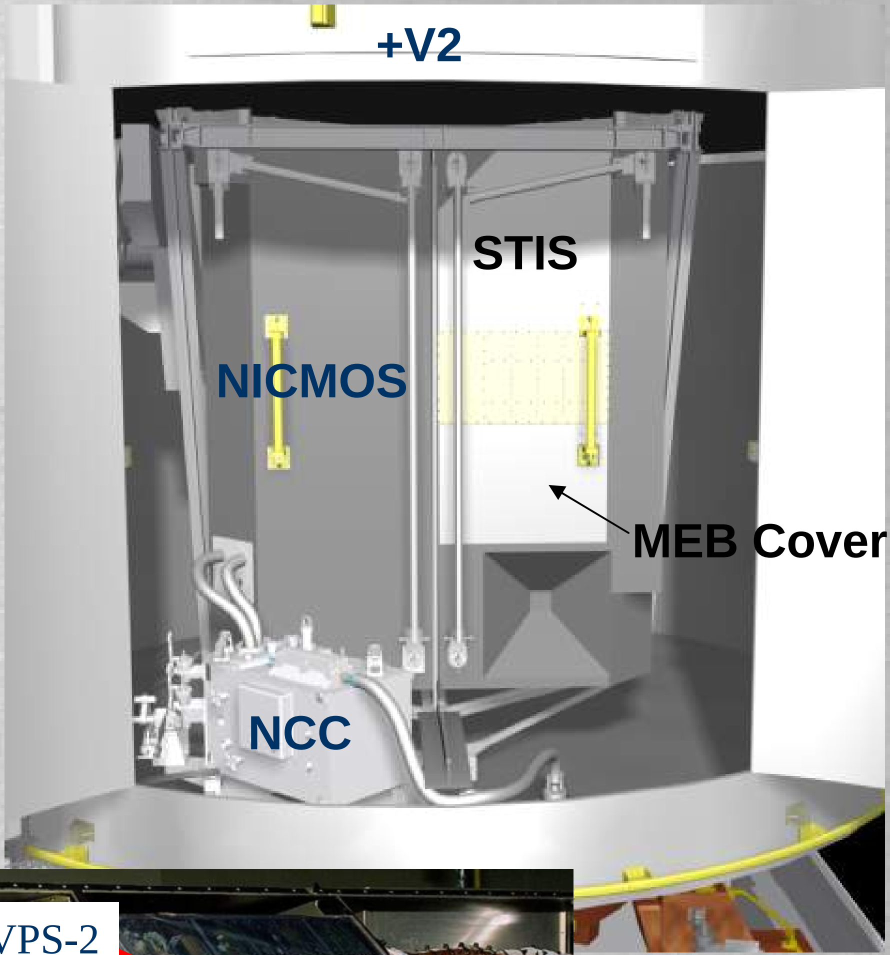


Preliminary EVA schedule

HST Servicing (SM4) is now totally dependent on the launch readiness of the Shuttle : preparing for late ’07 however..

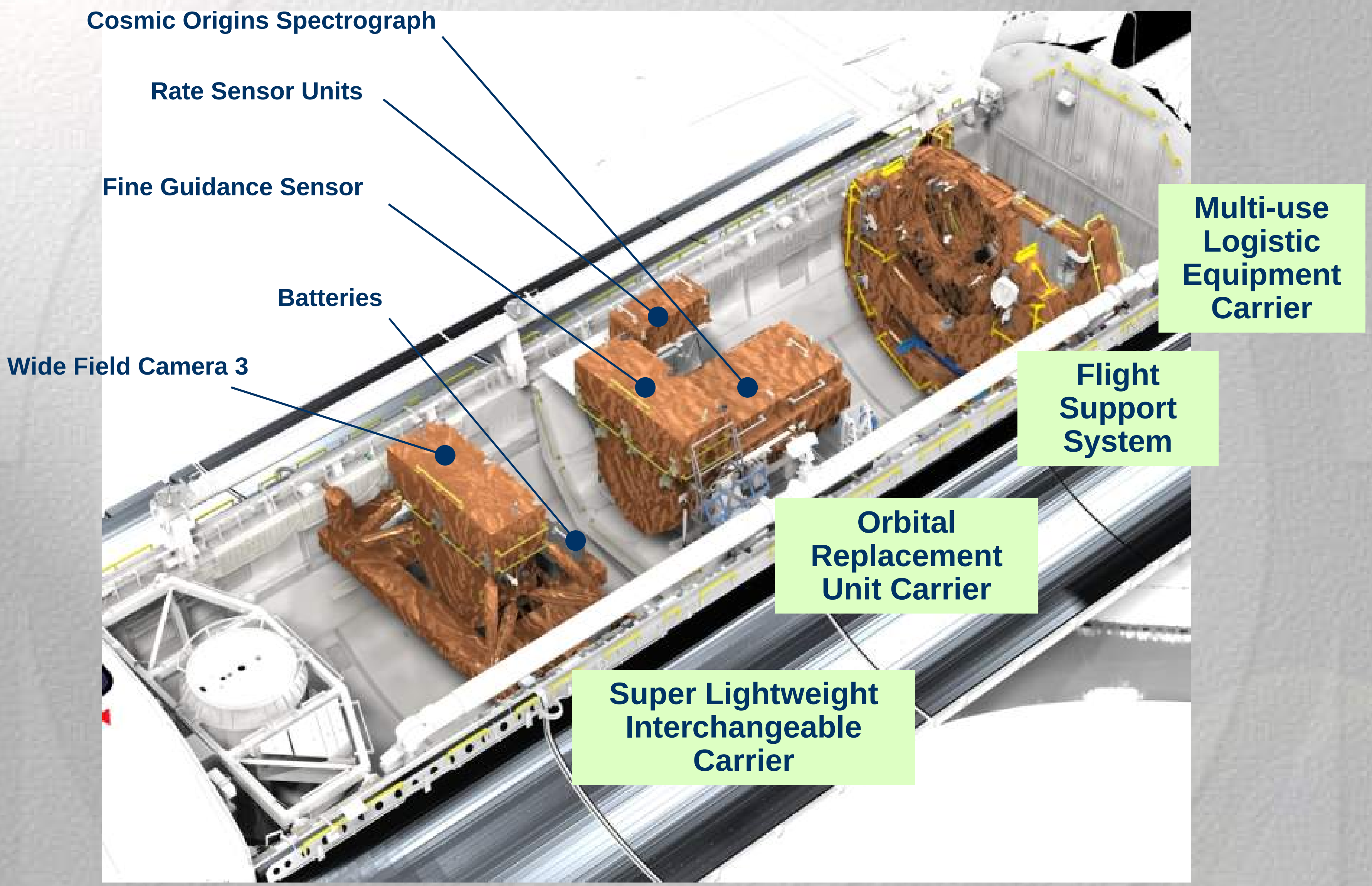
STIS Repair

- The objective is to replace and restore functionality to the Space Telescope Imaging Spectrograph (STIS) during SM4 by the replacement of the low voltage power supply board that contains the failed Side 2 Mechanism converter
- Several approaches identified for STIS repair
- Present Program assessment is that STIS repair is very feasible and affordable, and MEB1 cover removal should be performed manually



~130 screws to remove

HST Servicing Mission 4 (SM4) Configuration (Preliminary)



SCIENCE & SPACE

Scientists blast NASA budget cuts

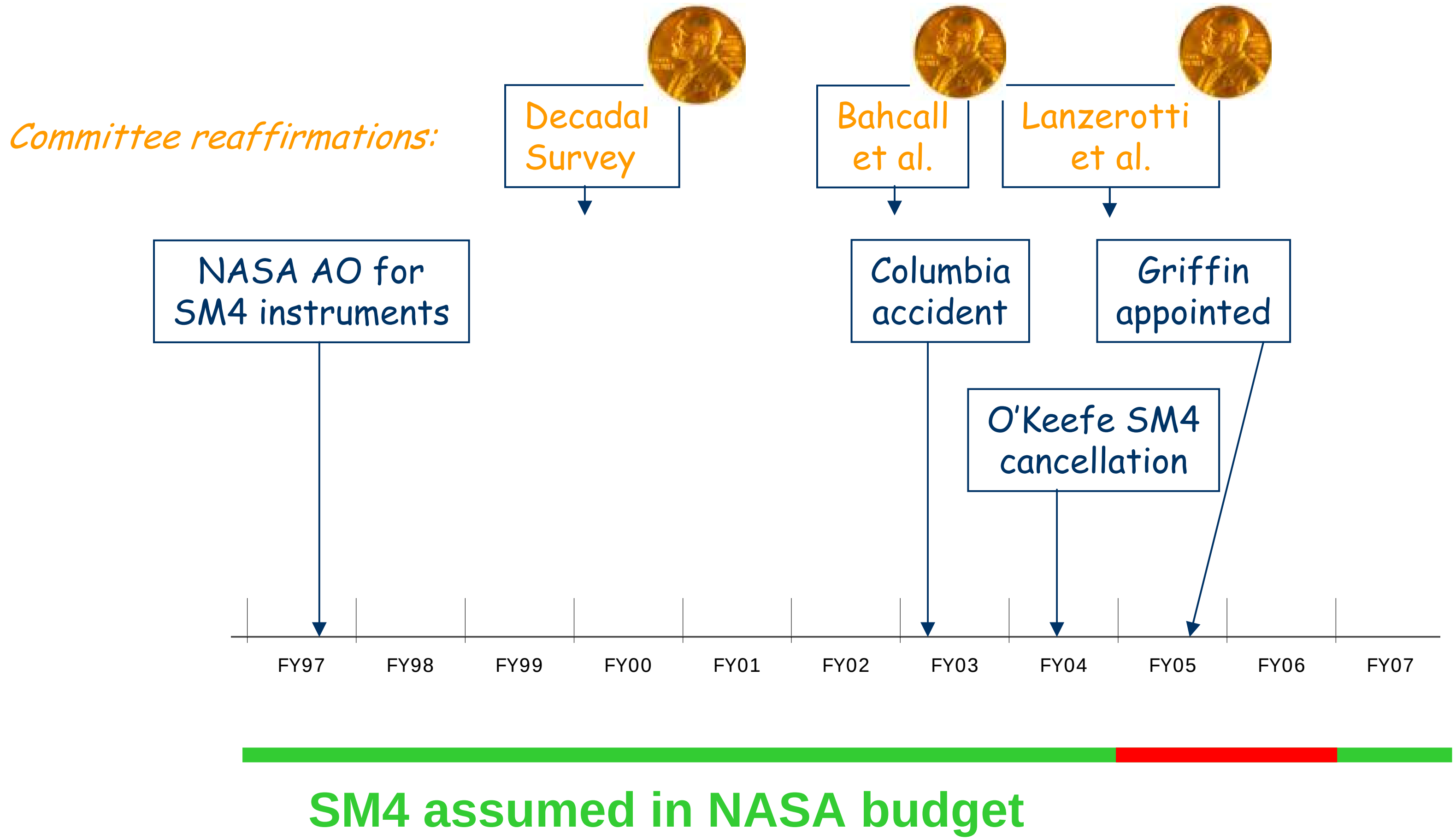
'Sense of gloom and discouragement is widespread'

Friday, March 3, 2006; Posted: 10:17 a.m. EST (15:17 GMT)

WASHINGTON (Reuters) -- The Bush administration's focus on big, expensive space missions is starving budgets for some of NASA's most productive small-scale science programs, astronomers told the U.S. Congress on Thursday.

"The 2007 budget is tilted to an unhealthy extent to large missions," said Joseph Taylor, who helped craft a U.S. 10-year survey for astrophysics.

SM4 funding: A Brief History of Time



Any statement that SM4 funding is now "new" and "displaces" other NASA programs neglects a decade of history

National Aeronautics and Space Administration
President's FY 2007 Budget Request

By Mission Directorate By Theme		FY 2006	**FY 2007**	FY 2008	FY 2009	FY 2010	FY 2011
Science, Aeronautics, and Exploration		**9,721.3**	**10,524.4**	**10,594.4**	**11,136.4**	**11,747.0**	**15,526.4**
Science	+0.1%	**5,253.7**	**5,330.0**	**5,383.1**	**5,437.1**	**5,491.5**	**5,546.4**
Solar System Exploration		1,582.3	1,610.2	1,598.6	1,840.4	1,899.6	1,846.7
The Universe		1,507.9	1,509.2	1,500.9	1,307.9	1,276.1	1,309.7
Earth-Sun System		2,163.5	2,210.6	2,283.7	2,288.9	2,315.8	2,390.0
Exploration Systems		**3,050.1**	**3,978.3**	**3,981.6**	**4,499.8**	**5,055.9**	**8,775.1**
Constellation Systems	+76%	1,733.5	3,057.6	3,067.6	3,612.9	4,083.8	7,698.4
Exploration Systems Res & Tech		692.5	646.1	632.2	605.1	679.2	764.6
Human Systems Res & Tech		624.1	274.6	281.8	281.8	292.8	312.1

Over the next 5 years, the newly proposed NASA budget moves $3,000,000,000 planned previously for space science into Constellation instead.

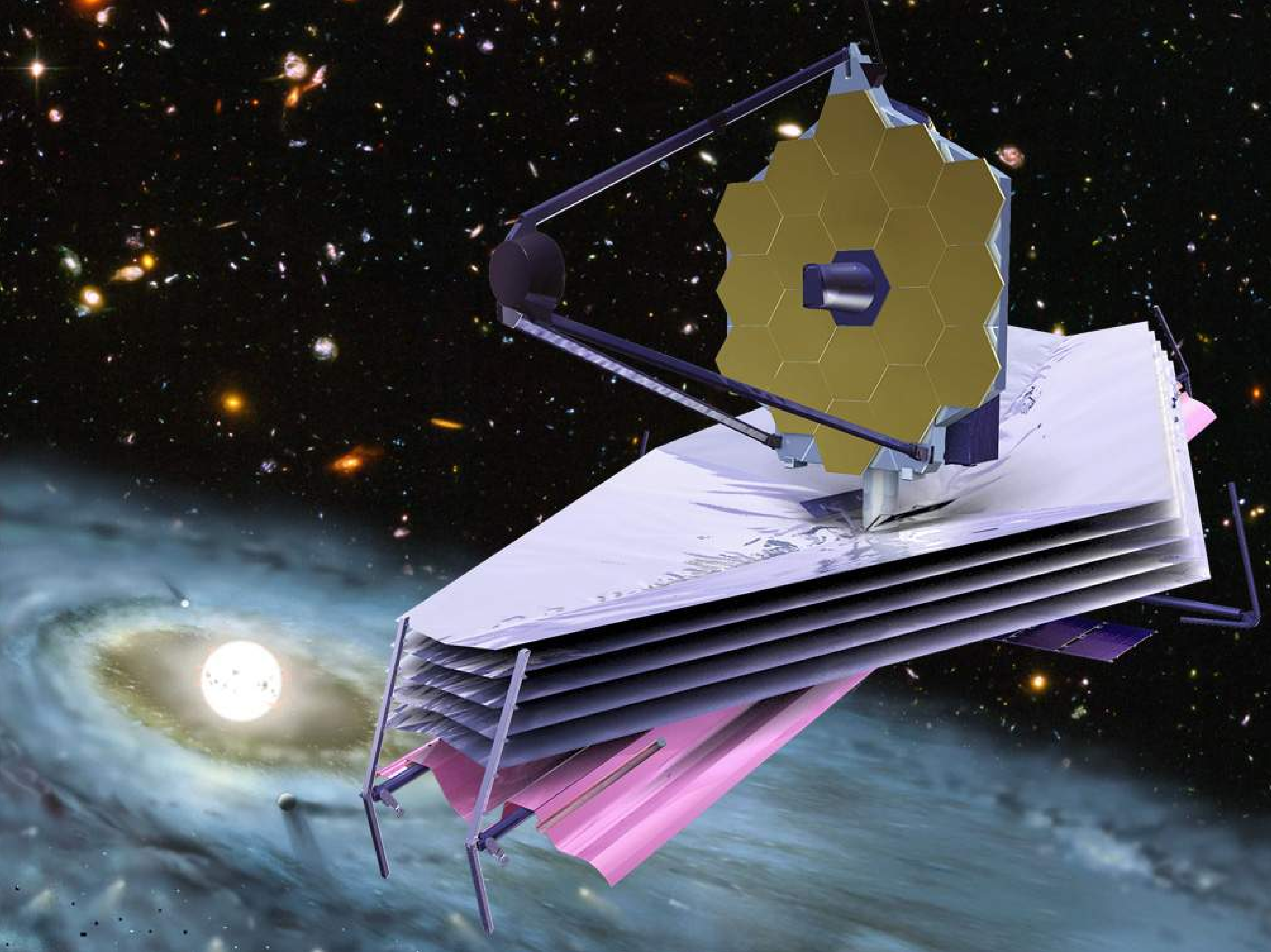
and the budget for Astrophysics almost will be 25% lower in purchasing power in 2009-2010 than now

National Space Club

Luncheon

THE HONORABLE MICHAEL D. GRIFFIN
TO SPEAK AT NATIONAL SPACE CLUB LUNCHEON
Thursday, February 9, 2006
The L'Enfant Plaza Hotel
Ballroom A, B & C, First Floor

"I do think that it is important to note that we are delaying missions, not simply abandoning them. We will still do the Space Interferometry Mission, the Terrestrial Planet Finder, and the Global Precipitation Monitoring mission. We will not do them right now. In making a decision concerning what to delay and what to keep on schedule to the extent possible, I determined that delays in starting SIM, TPF, and GPM would be less harmful to the space program overall than would further delays to the CEV program. I simply believe that further delays to CEV are strategically more damaging to this nation than are delays to other missions. I stand by this view."



Summer 2005 JWST Replan Initiated

- **Engineering Change Proposal (NGST) ~ $300M**
- **Increases in ISIM/SI costs ~ $100M**
- **Inadequate mass reserves for stage in program**

Self-induced

Externally-induced

- **Increases in full-cost accounting/HQ reduction in funds ~ $100M**
- **Estimated 1-year stretch-out cost due to delay in launcher decision and cash flow constraints ~ $400M**
- **HQ-directed increase in contingency ~ $250M**

Mike Griffin, 3 Nov. 2005: House Science Committee

"NASA attributed the cost growth to higher-than-expected costs for integration and testing, cost increases for the instruments, and program delays because of uncertainty in the selection of a launch vehicle. "

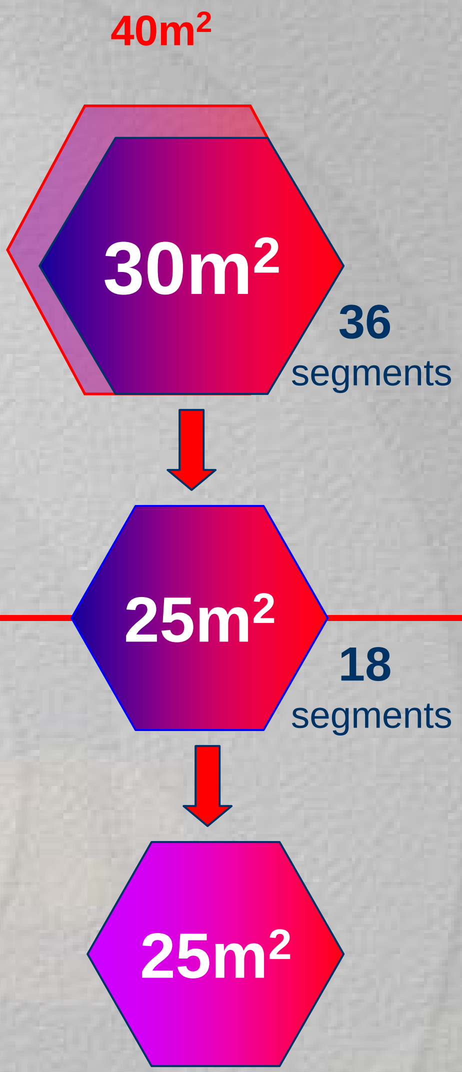
JWST Descopes to date

- Mirror has gone from 8m to 6m
- 2.5 Instruments now being built by Europe and Canada
- Instruments simplified and detector procurements “rationalized”

Pre-2005

Post-2005

- Shortwave sensitivity has been sacrificed to enable greatly simplifies Integration & Test
  - Cup-up
- Visible/Shortwave IR length requirements removed
- One Tunable filter removed



NASA’s Independent Review Team has been though the entire program (including STScI) and believe; the project has been responsive to the SAT, the technical challenges are being handled, the multi-national team is working well, but worried about early year contingencies

Has JWST "descoped enough"?

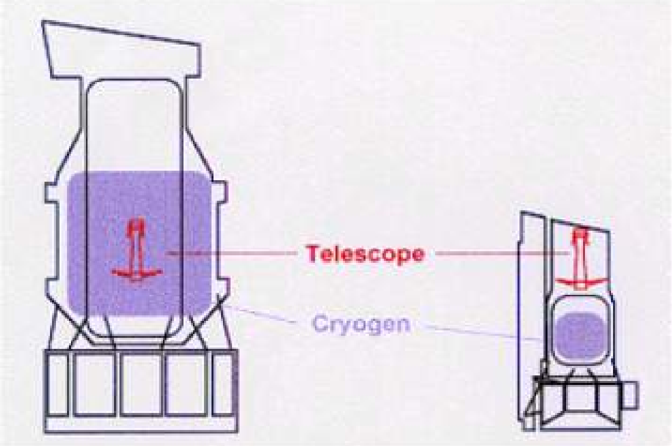
JWST

- L2 orbit
- Passive cooling
  - ➢ yes
  - ➢ yes
  - ➢ yes
  - ➢ Life 10 yrs
  - ➢ And still is

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Spitzer Space Telescope

- Innovative choice of earth-trailing orbit and cryogenic design enabled several advances:
  - Allowed the telescope to be launched at ambient temperature
  - Passive radiative cooling brings telescope temperature to about 40 K
  - Only focal plane instruments need to be cooled cryogenically
  - These factors combined allows 5 year cryogenic life with 360 liters of liquid helium compared to 2140 liters for ISO for just less than 2.5 years.
  - Was key to affordability of the mission



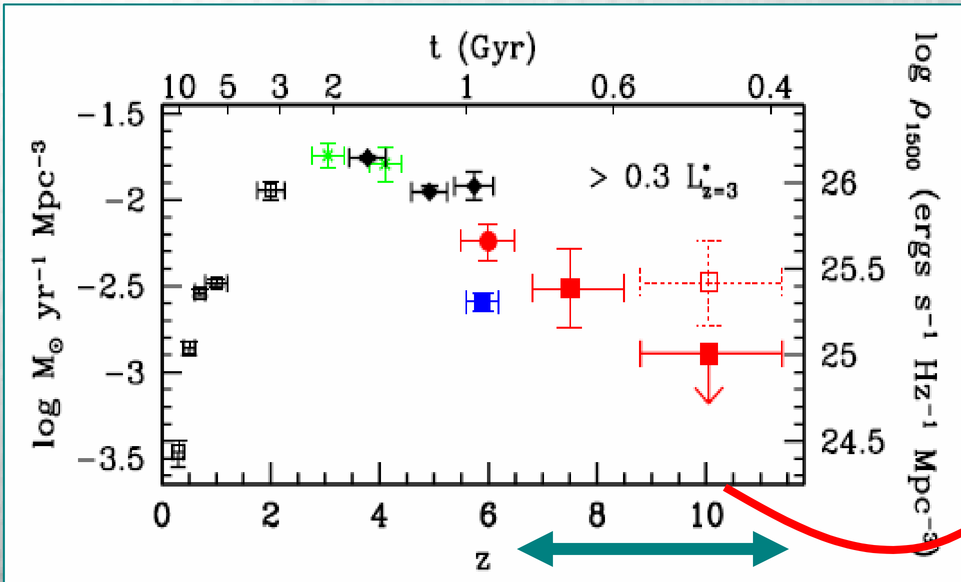
1990		2003
5700 kg	Launch Mass	870 kg
5 yrs	Lifetime	5 yrs
~$2.2B	Dev. Cost	$670M
Titan IV	Launch Vehicle	Delta

C. Elachi, CAA Nov'05

The key to JWST's success is taking *__all__* the lessons learned from previous challenging Space Science Missions, *__and__* from groundbased telescopes (segments, active optics)

Result from lessons learned: Normalize HST = 1 ($/m^2) Spitzer = 1.5 **JWST = 0.2**

We already know we are technology *and* photon limited..



Bouwens et al.: 506 galaxies with z>6 assembled from ACS data (HUDF, GOODS)

Unraveling high z universe beyond z > 6 is challenging even HST

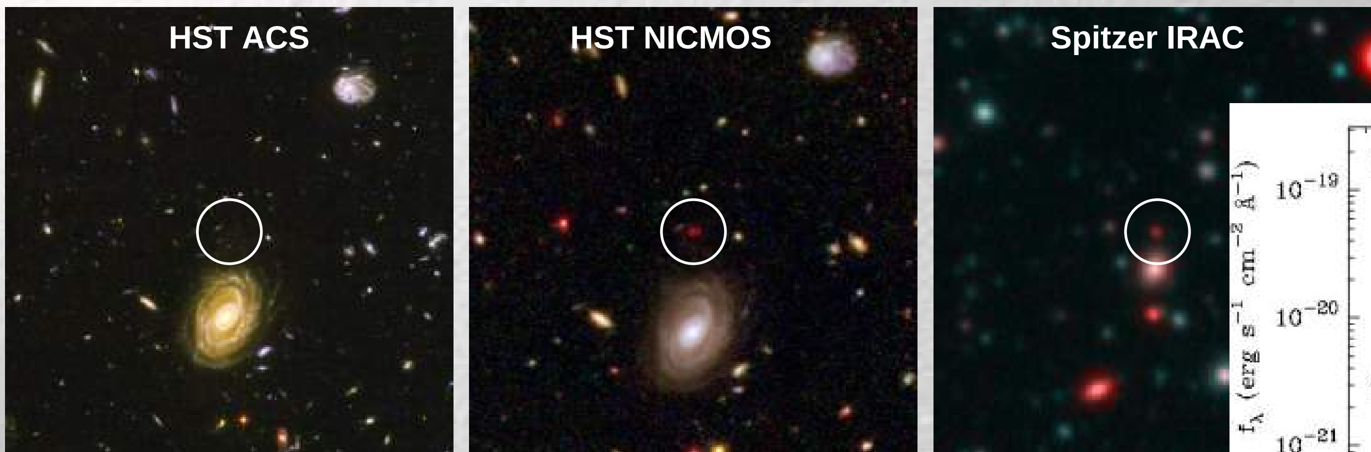
z	AB 1350	Fv (nJy)	λ (μm)
10	30.284	2.80	1.34
12	30.551	2.19	1.58
15	30.869	1.63	1.95
20	31.267	1.13	2.55

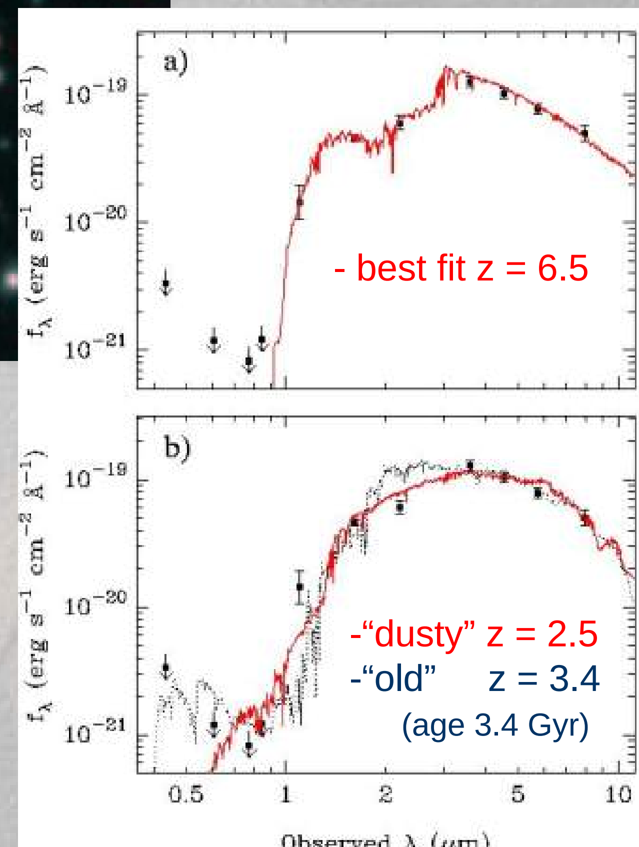
(1) Integrate for longer, ($\tau >> 10^6$ secs.)

(2) $$S/N \;\alpha\; \frac{\text{Telescope Diameter (D)} \,.\, \eta^{0.5}}{\text{Angular extent of object } (\theta)}$$

S/N α D ($\eta \sim 1,\ \theta \sim$ const.)

Mobasher et al.: J band dropout search for very high z galaxies in the HST UDF



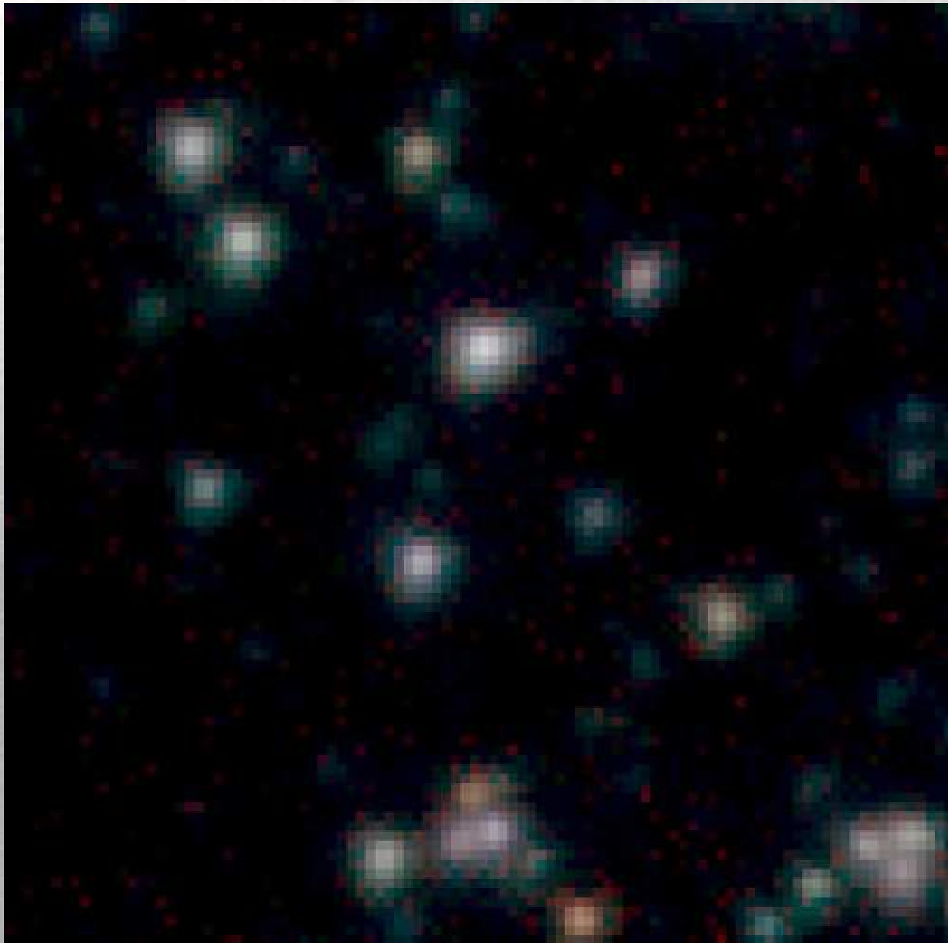


Spectral energy distribution (but no spectrum yet) best fits z~6.5: if correct, one of the most distant known objects

These objects are very challenging for 2.4m Space Telescopes *and* for 8m-10m ground-based telescopes (without gravitational lenses) -> JWST territory

JWST-Spitzer image comparison

1’x1’ region in the UDF – 3.5 to 5.8 μm



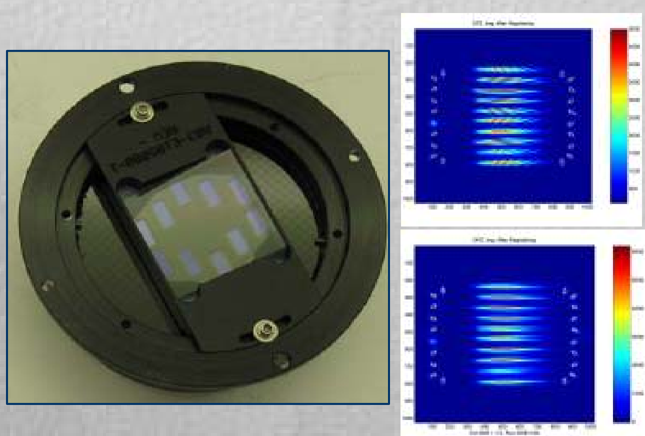
Spitzer, 25 hour per band

(GOODS collaboration)

JWST, 1000s per band (simulated)

Recent Progress – *"this is not a Powerpoint Project"*

Completed new 10,500 sq. ft. Class 10K high bay for Observatory integration and test

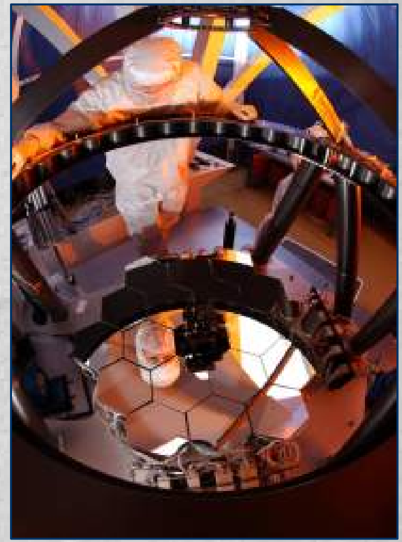


Conducted successful experiment at Keck Observatory to prove wavefront sensing coarse phasing approach

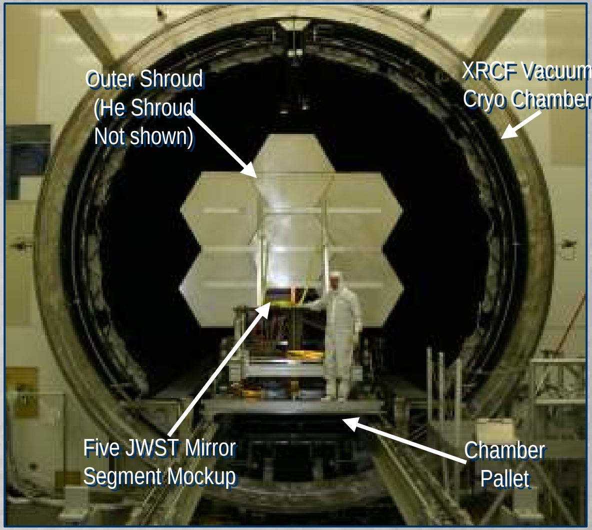
Completed manufacturing of all flight beryllium mirror blanks with 17 of 18 flight mirrors in precision machining

Recent Progress (continued)

Engineering Model mirror completed precision machining and undergoing grinding

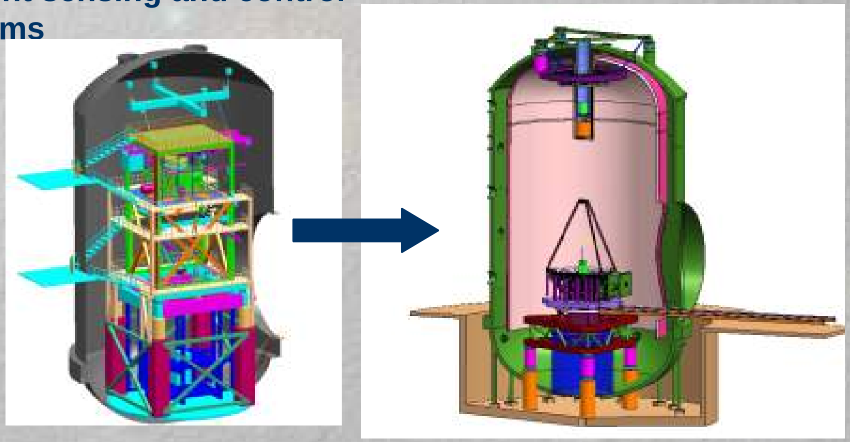


Completed 1/6th scale Test Bed Telescope integration and initial alignment to prove wavefront sensing and control algorithms



MSFC X-Ray Calibration Facility being readied to test mirrors at cryogenic temperatures

EM mirror support structure and actuators are complete



Saved 3 months and $100M by changing from “Cup Down” to simpler “Cup Up” testing

How can JWST manage further “unkown-unknows” and avoid further cost growth??

The lessons from Chandra:

- Significant up-front investment(~$1B) has been spent on technology development
- Descope discovery space: from 0.7um – 20um -> 1.7um - 20um
- Rigorous oversight of science – technology trades
  (SWG, SAT, SRT, PIT, STScI – all community based)

There are other science “knobs” we can adjust:

1. JWST is an active telescope: is some segments don’t quite reach specification, or the structure is not as stable in I&T as designed: we can use more mission time of wavefront sensing
2. We can schedule around high Zodical light regions for key deep observations (originally HST efficiencies we designed to be 35%, now achieve 50%+)
3. Instruments are still carry margins for transmission, through-put issues - getting to 1-2 nJy may just have to take longer

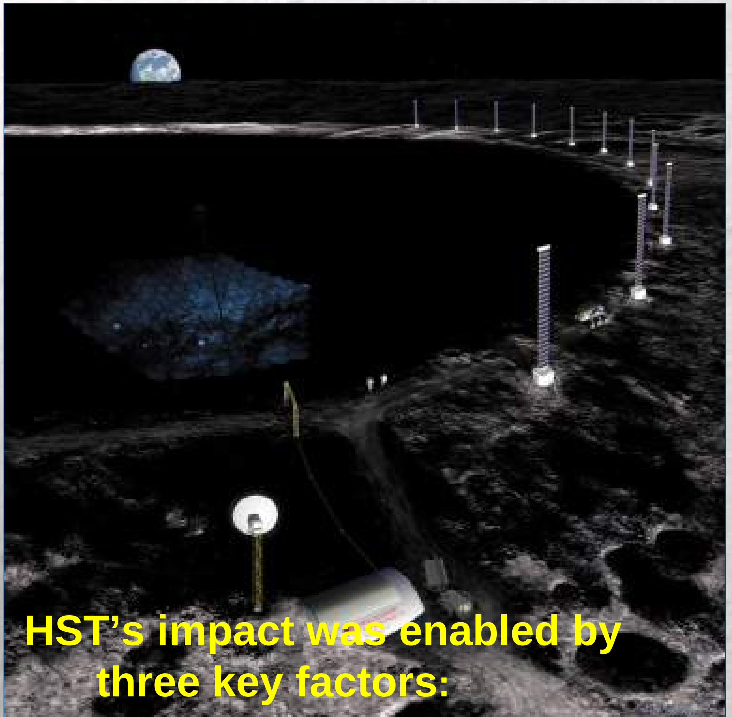
The Power of "Flagship" Projects

• Can solve problems impossible to achieve with smaller programs: if the fluxes are tiny, and the detectors nearly 100% efficient, physically larger instruments and spacecraft are the only alternative to retreating from an otherwise soluble issue.

• Are empirically known to be incredibly productive. HST has produced >5,000 refereed papers, and the annual count *increases* each year. By multiple metrics, HST has had an cumulative impact greater than any other telescope in history.

• Are vital to the financial stability of *small science.* The 3 Great Observatories return ~$70M/yr in small grants to ~10³ U.S. astronomers, far more than the entire NSF individual investigator grants program in astronomy.

Responding to the Challenge of Exploration – *Can there be a partnership with Science?*



HST's impact was enabled by three key factors:

1. **A sustaining scientific vision**
2. **A subsidized launch and transportation system**
3. **The ability to re-new the telescope and instruments through a servicing infrastructure**

ASTROPHYSICS ENABLED BY THE RETURN TO THE MOON

November 28 - 30

STScI/JHU/GSFC

Output: Position Paper/Booklet for the next Decade Survey