First photos from the Hubble

The moon

Jupiter

Saturn

Taxpayers

The Hubble Space Telescope - launched 1990
servicing makes Hubble unique
A new camera WFPC-2, and corrective optics (COSTAR) made the telescope even better than the original specifications.
Science and Satellite Servicing

Lesson 1

If you screw up, you can fix things
Sensitivity Improvement over the Eye

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

Approved for public release, distribution unlimited
“Davidson” metric, NASA contributions to worldwide scientific discovery and technological achievement

Approved for public release, distribution unlimited
The first extra-solar planet was discovered 6 years after Hubble’s launch, and new instruments were required to make these observations.

HD 209458b Charbonneau et al, 2002

2001 - first spectra with STIS installed 1997

2008 - first image with ACS installed 2002
2010 Hubble images *early galaxies* with WFC-3 installed 2009

galaxies from when the Universe was less than 600 Myr old

courtesy of the HUDF09 Team
Pl: Garth Illingworth

Approved for public release, distribution unlimited
This is only possible with new camera technologies

the highest redshift z~8 galaxies

ACS filters WFC3/IR

V i z Y J H

redshift

z~8.4

z~8.7

not detected detected

(Bouwens et al and Oesch et al papers)

redshift z~7 galaxy images

comparing the old and new Hubble infrared cameras

WFC3/IR NICMOS

galaxies in the first 700 million years Garth Illingworth www.firstgalaxies.org gdi@ucolick.org
Science and Satellite Servicing

Lesson 2

New technologies enable new science and science can change faster than mission life cycles.
HST can observe changing phenomena

2003

2005

2007

Approved for public release, distribution unlimited
HST can observe changing phenomena

V838 Mon, ACS 2002-2004

SN1987a, ACS 1994-2006
Lesson 3

Longevity can enable new science

Planet HR 8799 b hidden in Hubble’s data archive since 1998 extracted by Lafreniere et al. 2009
The Hubble Achievement

It seems hard to believe that we have already grown used to seeing images from the Hubble Space Telescope in the dozen years since it was first launched. But the startling pictures released this week from a newly restored Hubble are a reminder that we had, in fact, begun to take for granted our ability to peer into deep space, an ability no generation of humans has ever possessed before. In a sense, these new images, produced with cameras and power sources that were added or rejuvenated during a space shuttle flight in March, feel something like learning to see all over again. They remind us what an astonishing chapter of astronomical understanding, for scientists and laymen alike, the Hubble Space Telescope has opened.

the real wonder appears. Beyond the uniformity of the naked-eye universe, there is this other universe, the one Hubble discovers with astonishing clarity. This is a place full of discordant objects, of cataclysmic disturbances. Galaxies devour each other. Stars form in infernos of gas and dust and light. And they do so against the backdrop of a sky that is almost unimaginably deep.

For what the Hubble cameras show us, especially in their new incarnation, is time itself. The distance of the distant objects in these images is measured as much by their relative youth, by how far back in time we must peer to see them, as by their distance measured in a spatial dimension. By now it sounds almost natural to say that among the

It has taught

us to see the properties of a universe humans have been able, for most of their history, to probe only with their thoughts.
HST servicing has sustained media impact
2009-10: news impact of HST

Hubble’s readership in 2009

5 billion

# impressions = no. of stories x circulation

HST generated “impressions” among newspapers and internet articles
Hubble Education Program now used in all 50 states

Reaches:

506,000 pre- and in-service teachers

6.3 million students per year
Science and Satellite Servicing

Lesson 4

Longevity can enable the penetration of media and education markets

Missions can become a “brand”
Over four hundred years observational astrophysics has challenged and been enabled by technology.
Groundbased astrophysics usually build sustainable facilities and capabilities.
The “next big space thing” the James Webb Space Telescope

Can we extend the life of a spacecraft out at L2?

DARPA Orbital Express

The project aims to demonstrate several satellite servicing operations and technologies including Rendezvous, Proximity Operations and Station Keeping, Capture, Docking, Fluid (Hydrazine) Transfer, and ORU (Orbit Replaceable Unit) Transfer. Source http://en.wikipedia.org/wiki/Orbital_Express

Approved for public release, distribution unlimited
Are we alone?

the most favorable nearby stars for habitable planets

To find and characterize earth-like planets in our solar neighborhood will take 8m ~ 32m class space telescopes

Approved for public release, distribution unlimited
Future NASA heavy-lift will make such telescopes possible.
Mars: the changing scale of robotic exploration
Enabled science - finding the first Black Holes?

The first black holes are the remnants of the first stars in the universe.

Ancient black holes are intrinsically very luminous, emitting $10^{41}$ erg/sec in x-rays, but they are so distant that they are 1000x fainter than can be seen by x-ray observatories today.

They were created over 13 billion years ago.

An x-ray observatory with an effective area of 50 square meters could detect them and allow us, for the first time, to trace the cosmic history of stars to their ultimate origin in time.

50 sq m x-ray space observatory

Orion CEV:
Science is probably not alone in wanting large, complex, persistent and upgradeable facilities in space.

"I would like to see a reconnaissance of the planetary systems around the nearest 100 stars.”

Carl Sagan, 1994
(paraphrase)
Do we understand the threats to our national and global sustainability?

- have we the tools to enable informed and timely decisions?

Can we causally relate the conditions during the Big Bang to the emergence of RNA and DNA?

- how unique was this occurrence; are we alone?
We need …the right balance between manned space exploration and robotic space exploration. We need to manage the balance between looking up and looking down…

Dr. John Holdren

Extend our reach – move humans beyond low Earth orbit
Explore our Earth, our Galaxy and our Universe
  – Assemble and maintain increasingly larger capabilities in space
Expand our knowledge
  – Persistent surveillance and reconnaissance for National Security
  – Monitor greenhouse gas emissions for arbitration and compliance
  – Enable remote sensing of other worlds and search for life
  – Explore the structure of the Cosmos and find the first black holes
Future telescopes may have to be “born in space.”
(courtesy M. Postman, this workshop)

Key technology areas that need to be matured in order to realize large-aperture serviceable telescopes are:

• **Active optical systems** needed for realizing large, lightweight segmented apertures (includes mirror actuators, WFS&C, truss metrology).
• **Standardized modular designs** for spacecraft bus components.
• **Modular, replaceable** instruments, pointing and data-handling systems.
• **Expendables** that can be replenished on-orbit.
• **Computer-aided vision systems** for remote manipulator systems operating with a time delay (cf. Whitcomb’s talk at this workshop).
The future of observational space astrophysics is inexorably linked to NASA’s future

If NASA explores a future which requires a sustainable deep space infrastructure - launching, constructing and upgrading observatory-class facilities again becomes feasible. This realizes the full potential of these substantial public investments.

This has the demonstrated potential to captivate the public and inspire school children across this Nation; they can take ownership and participate in the adventure of exploration and discovery.

Hubble’s public impact in 2009

Approved for public release, distribution unlimited
This has the demonstrated potential to captivate the public and inspire school children across this Nation; they can take ownership and participate in the adventure of exploration and discovery.