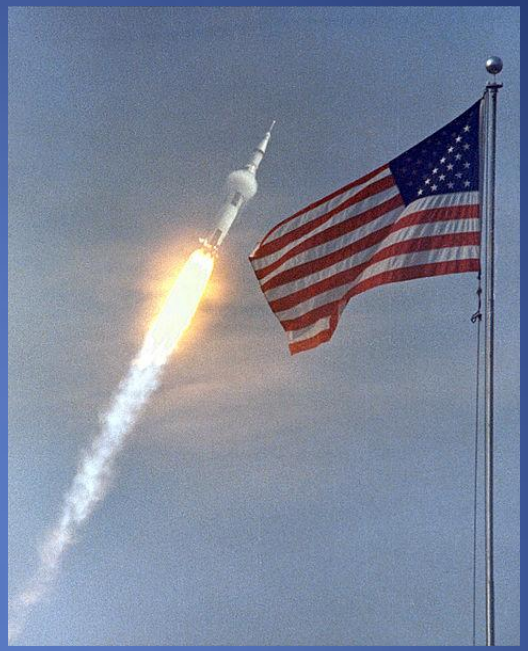
Reflections of a Chief Engineer--Honored to have served with you

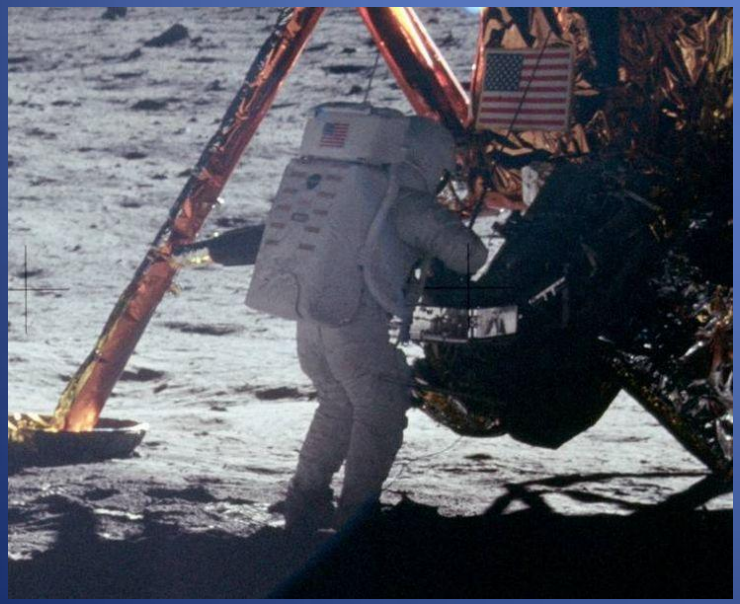
Frank Buzzard, Retired
Space Shuttle and ISS Chief Engineer
NASA/APPEL Masters Forum 20
Passing the Torch 3, April 20-22, 2011

Where it began…I can't begin to knowin'… but then I know it's growin' strong

- Building on the shoulders of giants—Mercury, Gemini, Apollo
- A Nation with bold leadership and the will to succeed. We chose to lead in space
- A NASA/Industry Team with a clear goal and vision to fly humans in space and conquer the moon and beyond. And we did it!
- We built human spaceflight core competencies with space technology design, test, and operation infrastructures-MSFC, KSC, JSC, SSC

Apollo-America Changed the World Forever!





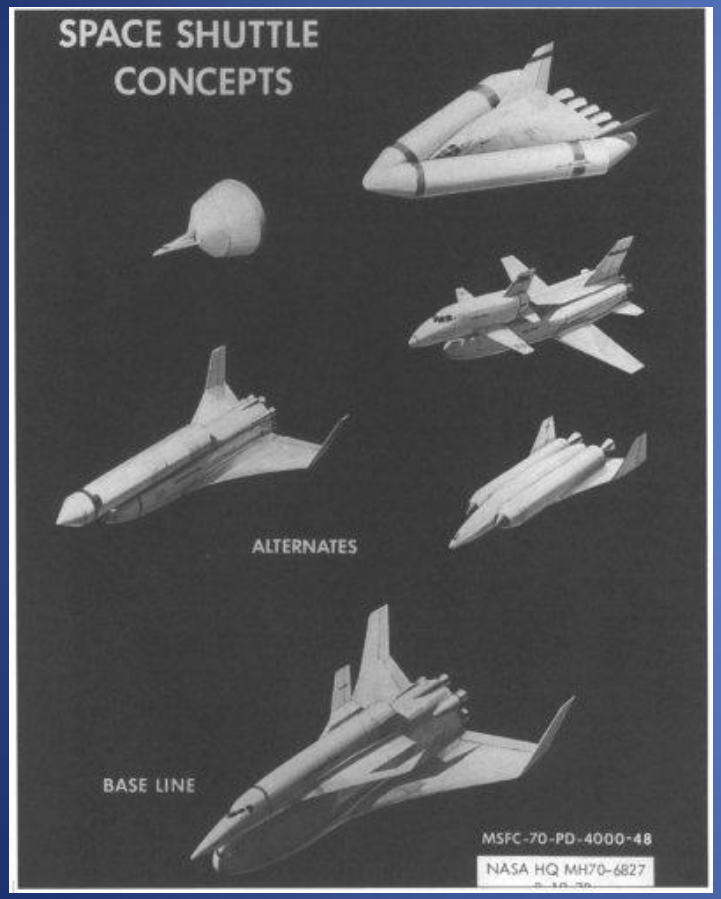
We dreamed of a reusable Space Plane to build a Space Station…A transportation node to go to Mars

President Richard M. Nixon and NASA Administrator James C. Fletcher announced the Space Shuttle program had received final approval in San Clemente, California, on 5 January 1972.

"I have decided today that the United States should proceed at once with the development of an entirely new type of space transportation system designed to help transform the space frontier of the 1970's into familiar territory, easily accessible for human endeavor in the 1980's and '90's.

This system will center on a space vehicle that can shuttle repeatedly from Earth to orbit and back. It will revolutionize transportation into near space, by routinizing it. It will take the astronomical costs out of astronautics. In short, it will go a long way toward delivering the rich benefits of practical space utilization and the valuable spinoffs from space efforts into the daily lives of Americans and all people. " Richard M Nixon

Space Shuttle Design Evolution



Awesome Technical Challenges to Overcome

- MSFC—Structures and Materials, testing and certification, Reusable SSME & RSRM/SRB, ET
- SSC—SSME testing and certification test stands
- KSC—New and modified Launch and Landing facilities, Shuttle element and payload processing & checkout, SRB recovery and Orbiter post landing safing and OPF processing
- JSC—Mission Operations, Crew Training, Orbiter systems with life support, FOFS avionics, RMS integration, reusable TPS, System Integration, Program Management

“It worked…the damn thing worked!”

Frank Buzzard, MCC Guidance Support to Jim I’anson, Entry Guido and WW2 B-17 pilot

- Full up crewed mission April 12-14, 1981 STS 1

Jim and Pert l'anson

STS 1 Crew

Keys to Success

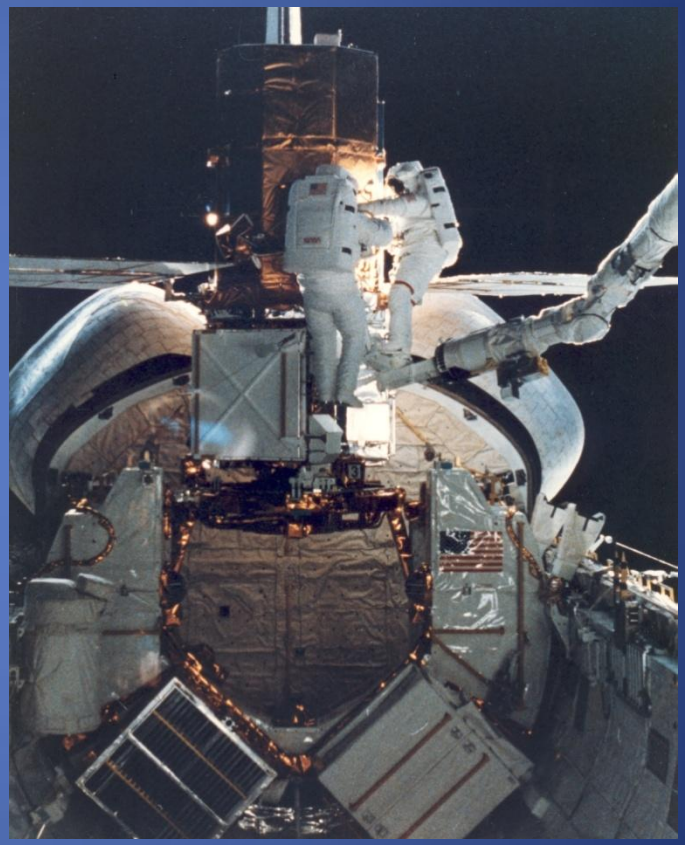
- A clear objective and a common goal
- Division of labor aligned with NASA center core competencies and expertise
- Engineering excellence and outstanding people building on past successes
- Facilities, tools, and budget to do the job
- Building multi-center and contractor relationships based on humility, trust, sincerity, and commitment to the mission
- Acceptance of a better idea is a strength, not weakness
- Lead from the front and by example
- Communicate, Communicate, Communicate. Tindelgrams

Attitudes to avoid

- Arrogance. I am in charge! I know it all!
- Organizational “stove-pipes”. Not consulting other centers or other organizations
- Not Invented Here—NIH
- Restricted or suppressed flow of information. I would look bad if I disclosed that. Public belittling of an opposing or conflicting view.
- Misunderstanding of cultures. Not recognizing that they are different. And different is OK!

Shuttle Amazing and Unique capability Solar Max Satellite Repair and Servicing

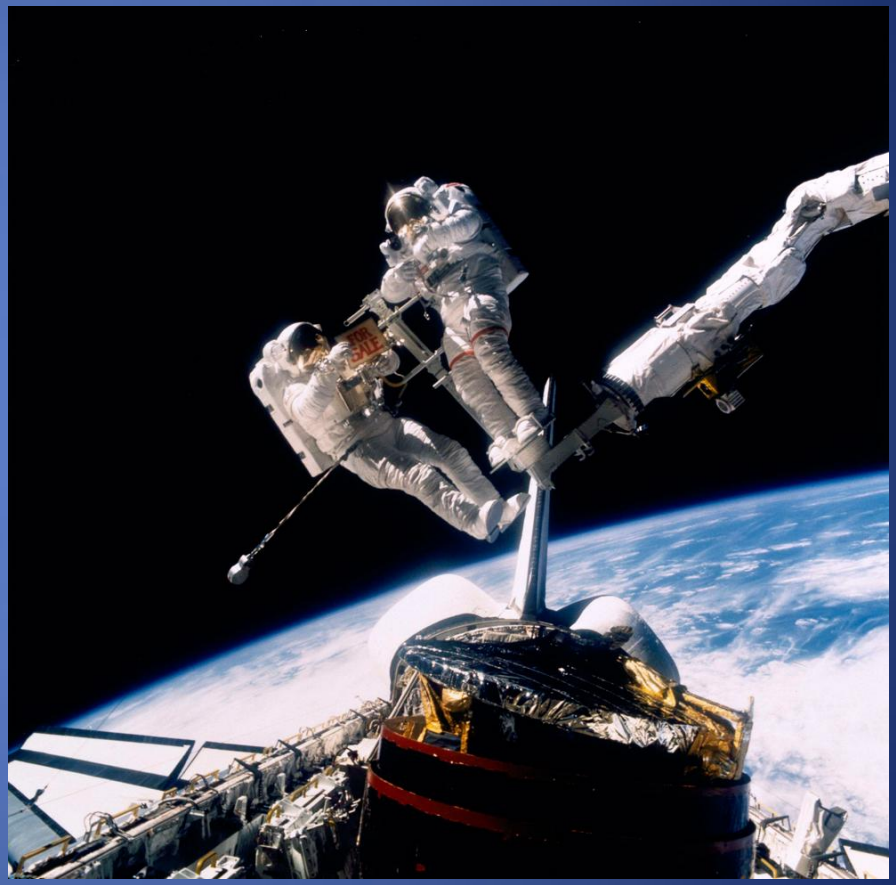
George “Pinky” Nelson attempts capture of Solar Max Satellite on STS 41-C April 1984



Astronauts repair Solar Max in Shuttle Cargo Bay and special cradle

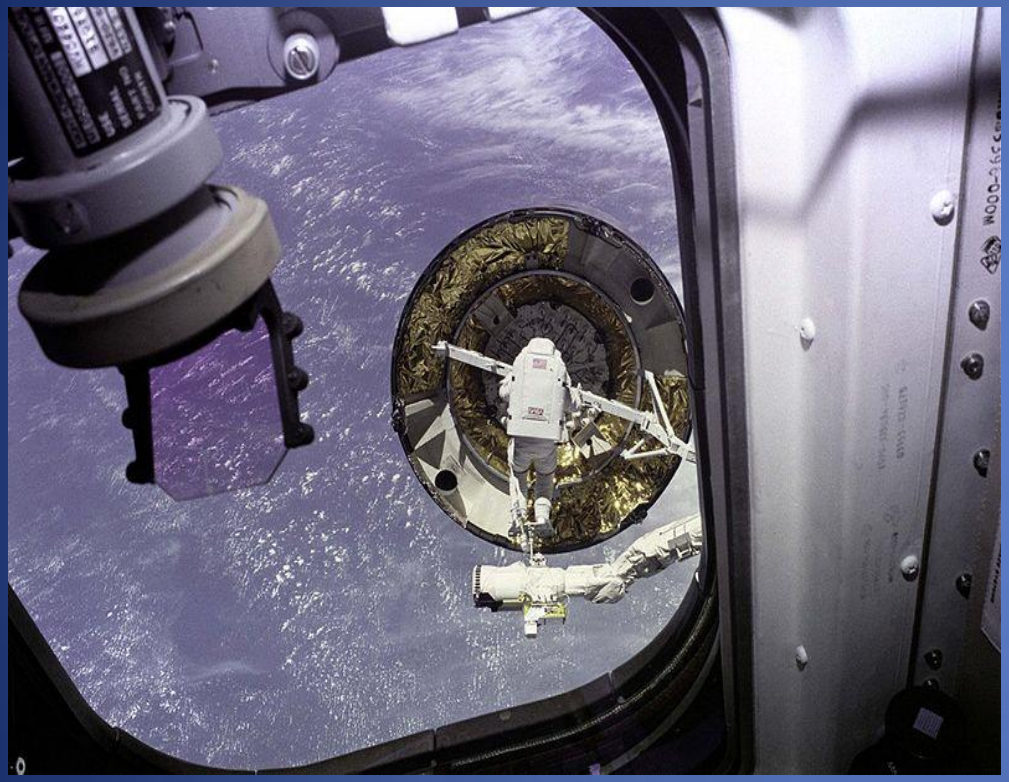
ST 51-A Westar 6 and Palapa B-2 Satellite Retrieval and Return, Nov 1984

Dale Gardner in MMU captures Westar 6 with the Stinger



Dale Gardner and Joe Allen hold a "For Sale" sign for the Westar 6 and Palapa B-2 satellites

STS 49 Intelsat VI Repair



Pierre Thout attempting capture bar snag of Intelsat VI stranded in LEO by March 1990 Titan launch. STS 49 May 1992

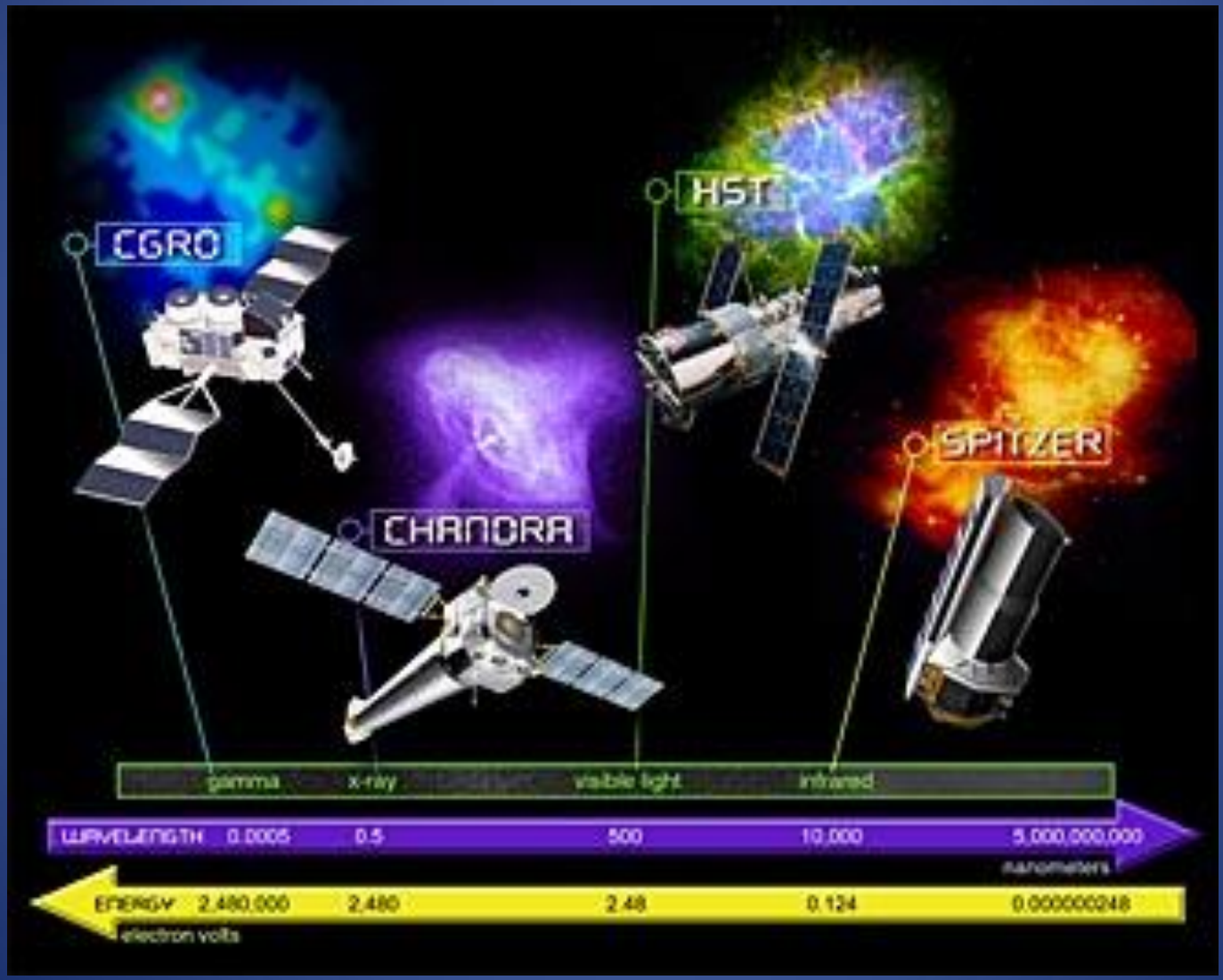
Risky hand grasp succeeded by 3 EVA crew Thout, Heib, Akers with Dan Brandenstein formation flying on 3rd rendezvous

STS 49 Intelsat VI Repair

Installing the capture bar after hand capture

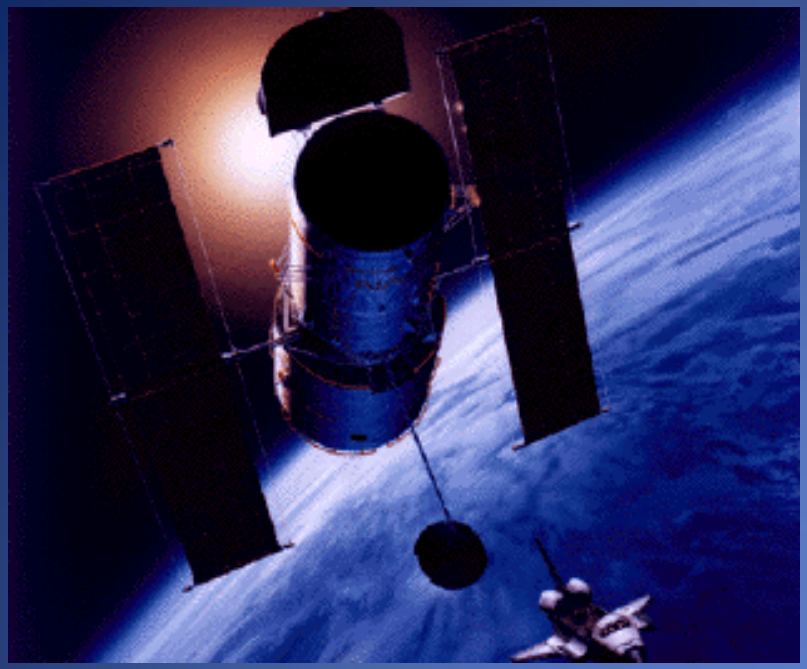
Intelsat VI deploy with new Perigee kick motor

We launched NASA's Great Observatories

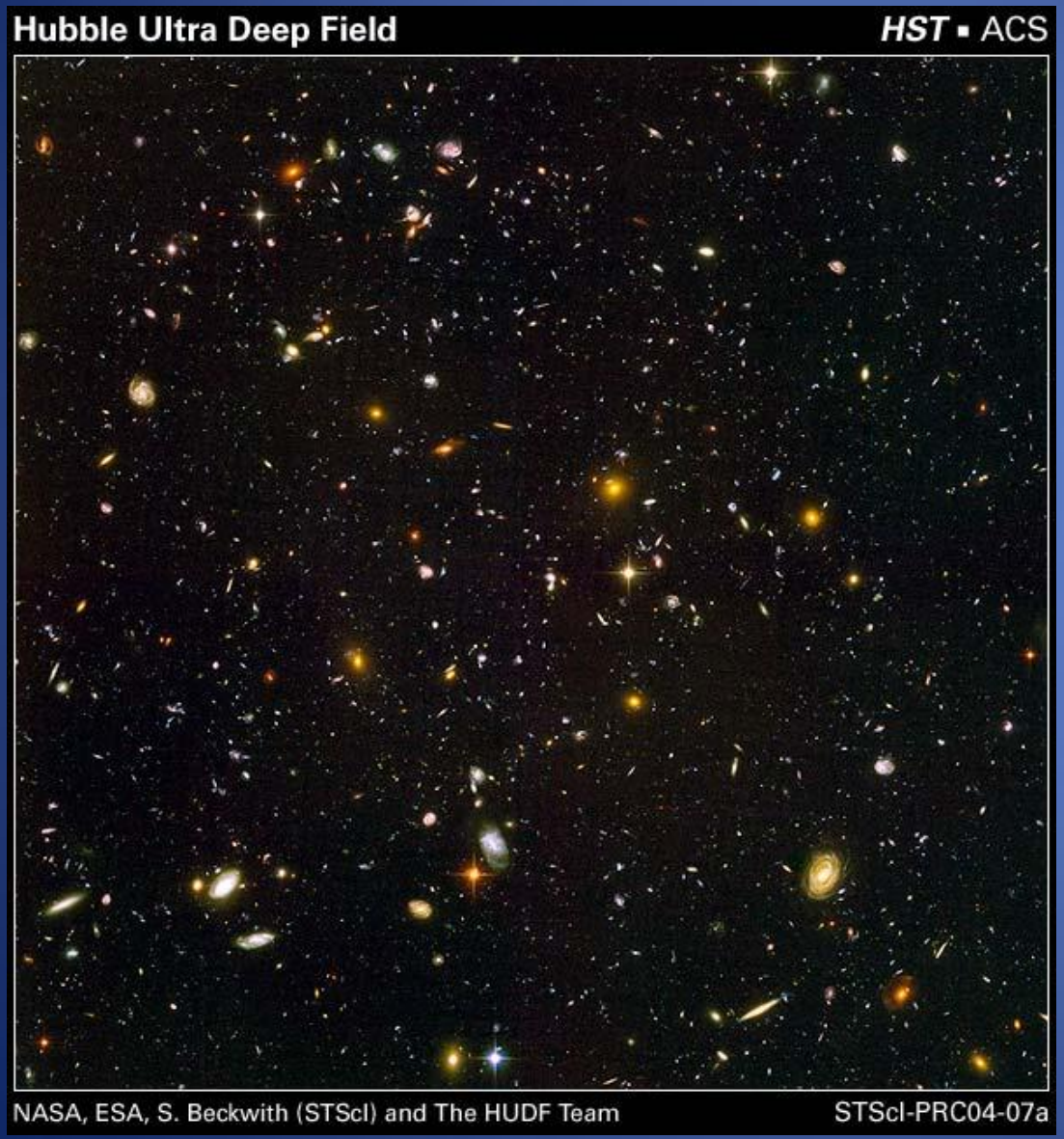


Hubble Space Telescope—An upgradable Window on the Universe

- **STS 31 April 1990 launched the Hubble Space Telescope (HST)**
- **STS-61 Dec 1993 serviced the space observatory with a record 5 EVAs and installed corrective optics**
- **STS-82 Feb1997 upgraded its scientific capabilities by installing two state-of-the-art instruments STIS and NICMOS and replaced failed hardware**
- **STS-103 Dec 1999 replaced 3 gyros, fine guidance sensor, HST computer , S-Band, and installed new solid state recorders.**
- **STS-109 Mar 2002 installed the Advanced Camera for Surveys, reactivated the infrared camera NICMOS with new cyro unit, installed rigid solar arrays, and a new power controller unit**
- **STS-125 May 2009 installed new Wide Field Camera 3 and Cosmic Origins Spectrograph, replaced 6 gyros and aging batteries, replaced insulation.**

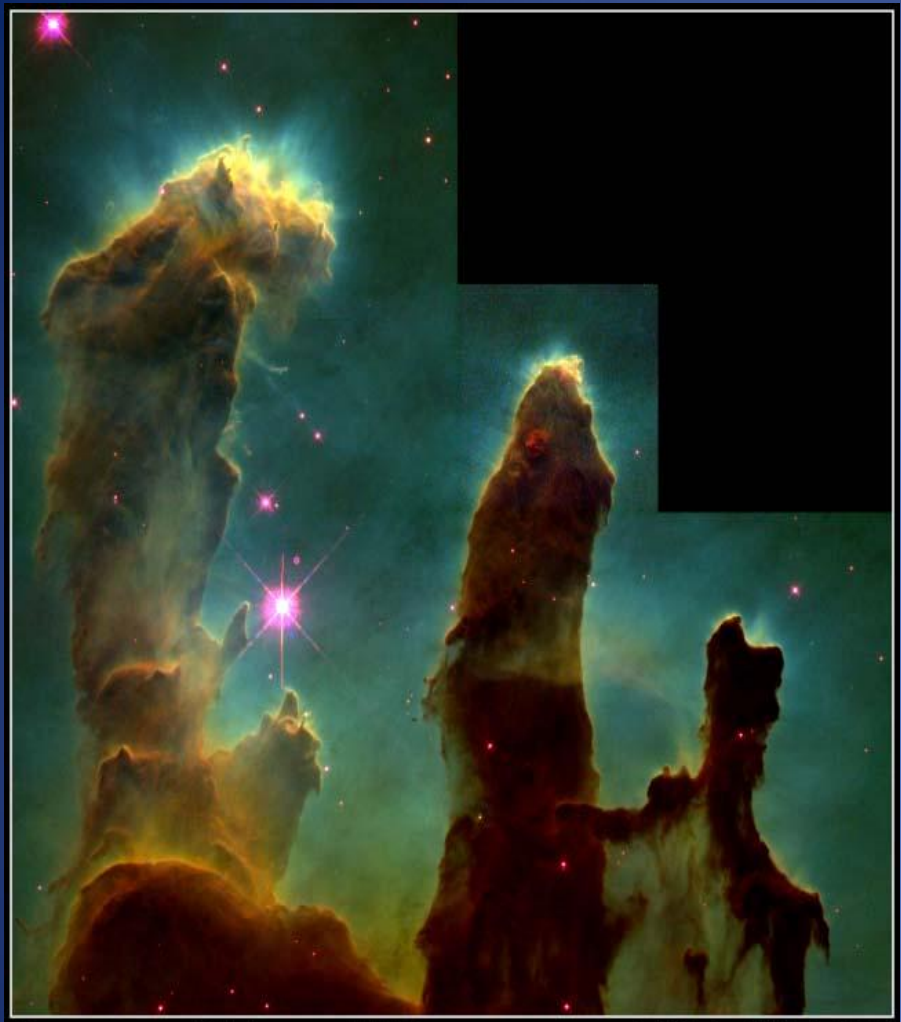


The Heavens Declare the Glory of God-Psalms 19:1



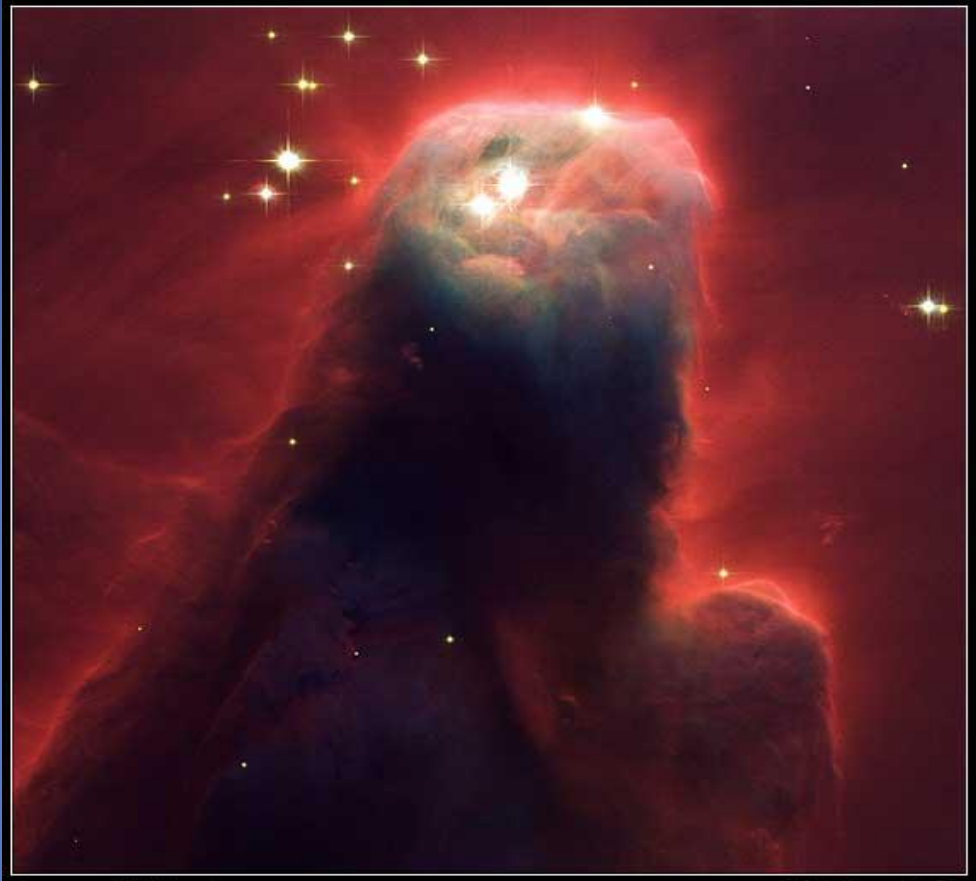
Galaxies, galaxies everywhere - as far as NASA's Hubble Space Telescope can see. This view of nearly 10,000 galaxies is the deepest visible-light image of the cosmos. In ground-based photographs, the patch of sky in which the galaxies reside (just one-tenth the diameter of the full Moon) is largely empty located in the constellation Fornax. The image required 800 exposures taken over the course of 400 Hubble orbits around Earth. The total amount of exposure time was 11.3 days

Andromeda Galaxy

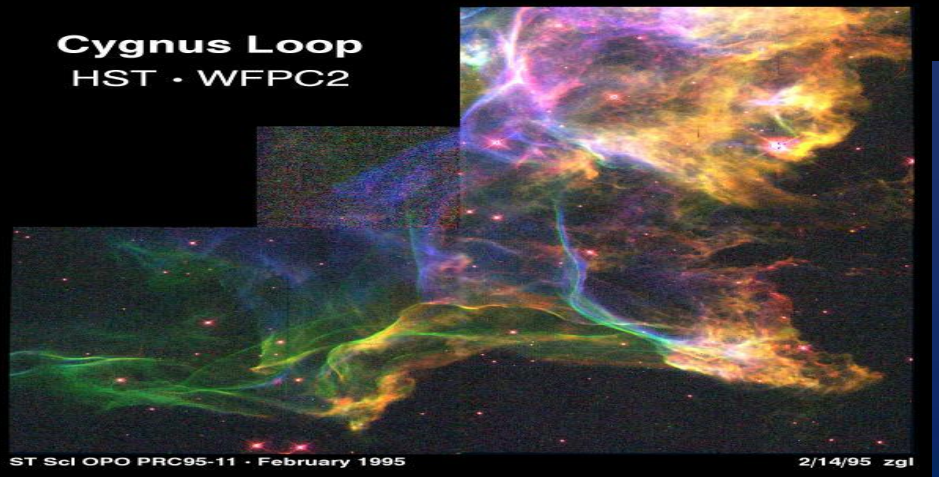


Gaseous Pillars · M16 HST · WFPC2

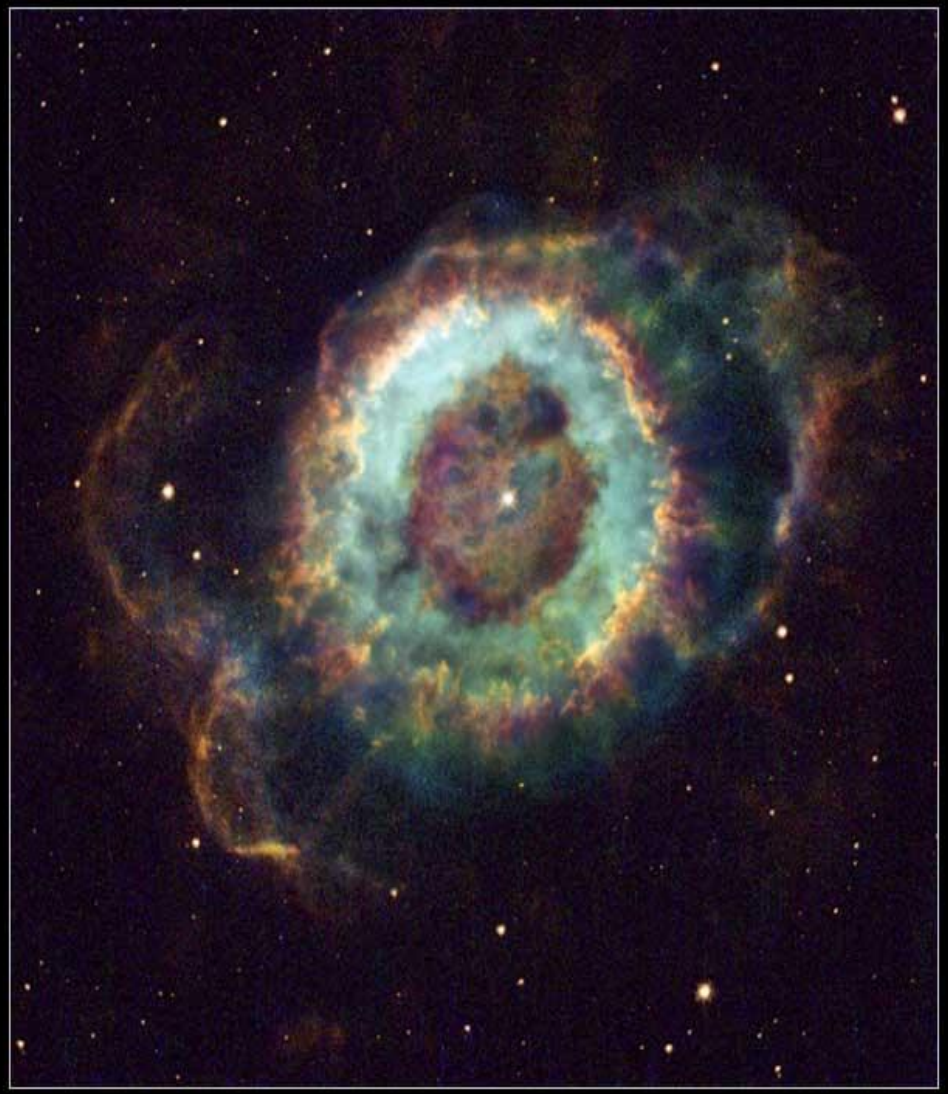
PRC95-44a · ST ScI OPO · November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA



Cone Nebula **HST • ACS**

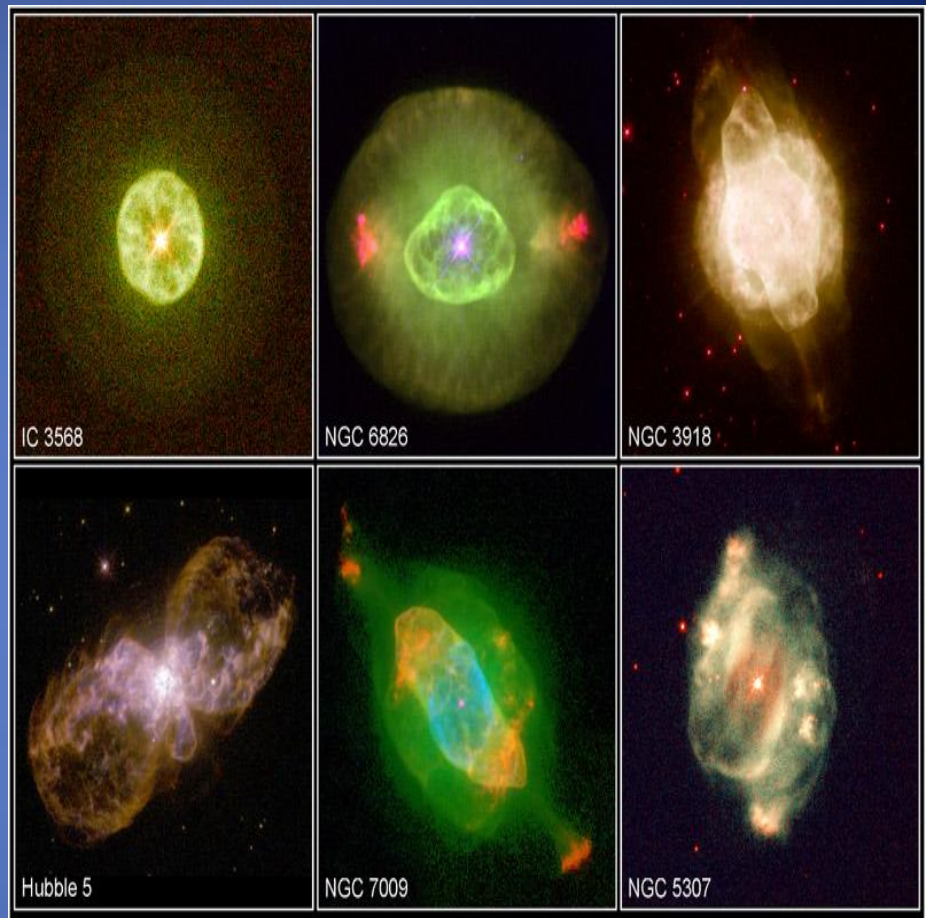


Planetary Nebula NGC 6369 • The Little Ghost



Hubble Heritage

NASA and The Hubble Heritage Team (STScI/AURA) • Hubble Space Telescope WFPC2 • STScI-PRC02-25



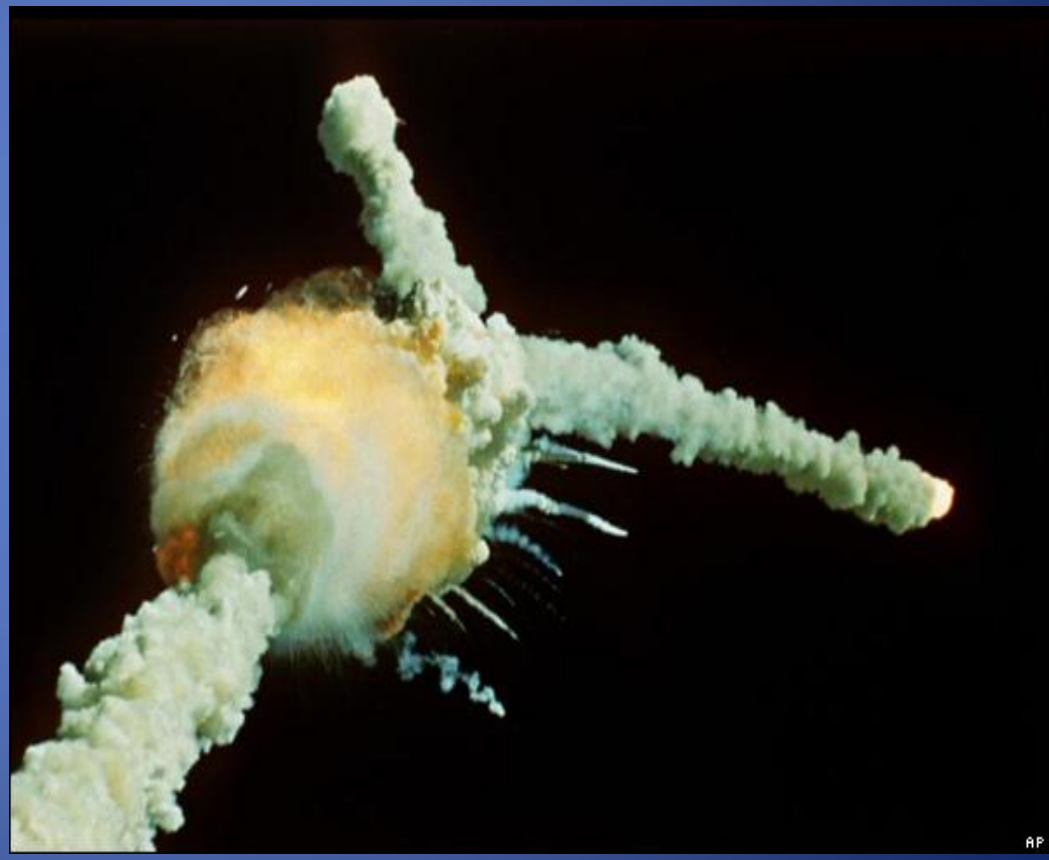
Planetary Nebula Gallery

HST • WFPC2

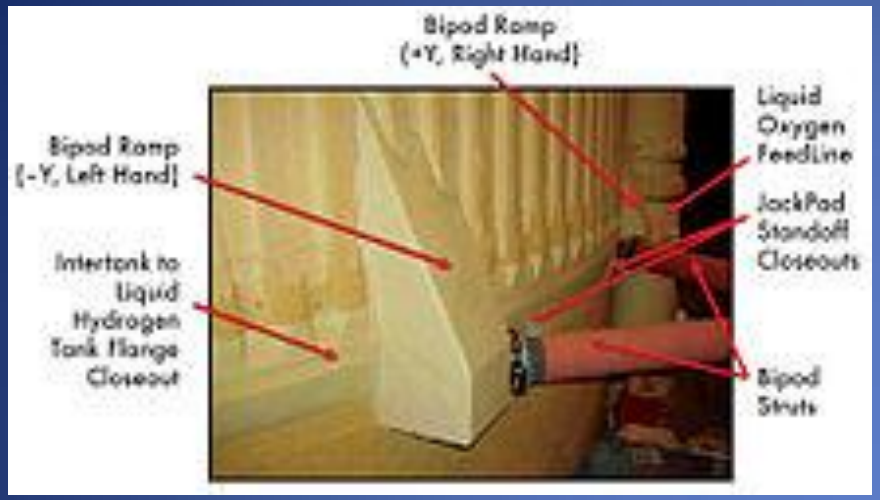
PRC97-38b • ST ScI OPO • December 17, 1997

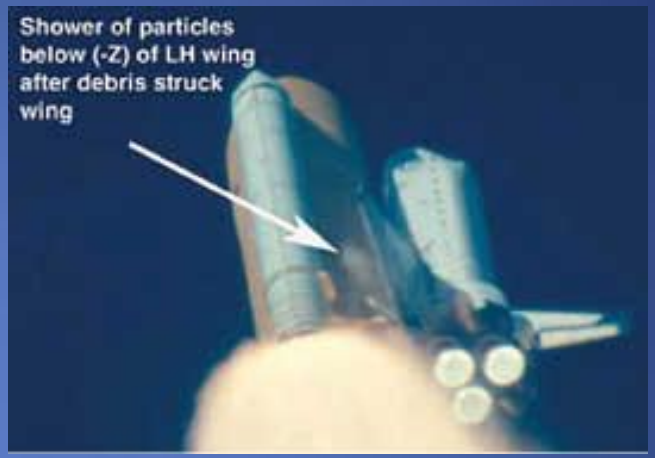
H. Bond (ST ScI), B. Balick (University of Washington) and NASA

We flew and learned, but we paid a painful price. We fixed it and kept flying to honor our fallen and their sacrifice.
Challenger STS 51-L, January 28, 1986



STS 107 Columbia February 1, 2003





Breakup over Texas

RCC panel foam impact test

Flight Experience leads to successful, safety improvements

- Dramatically improved SRB field joint design post Challenger
- Two GPC failures on STS-9 due to generic age related dendrite growth on computer boards solved by AP101B GPC upgrade
- STS-9 APU fuel line cracks/hydrazine leak and APU turbine blade cracks initiates IAPU safety enhancements for Orbiter and SRB
- Redesigned Pratt and Whitney SSME HPFTP, HPOTP, Block 2 SSME Controller, and Large Throat MCC program provides significant safety margin improvements.
- Evolved External Tank design improves payload to orbit and enables ISS at 51.6 deg inclination. LWT, SLWT, Aluminum Lithium tank
- Haines IMU upgrade solves life issues and improves performance.
- Continuous improvement in space suits, gloves, and onorbit tools.
- ET insulation shedding reduction and design changes post Columbia

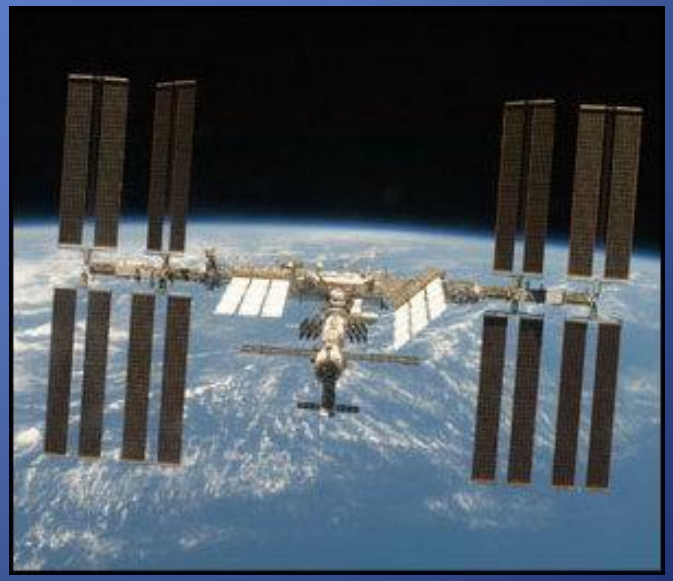
Reflections on Improvement Process

- Flying with design deficiencies you think you understand completely requires extreme caution. Challenge the test data and modeling. Have a healthy skepticism. Be highly aware of success induced complacency
- Deciding between necessary redesigns and 'better is the enemy of good enough' improvements is difficult. Quantitative risk assessment of before and after change is vital

And then we used the unique Shuttle capabilities to learn to work with our Russian colleagues to support MIR and then redesign and build the International Space Station with 16 nations cooperating together.

Building the International Space Station 1998-2001

Building the International Space Station 2002-2010



Make sure you have fun along the way

Some things are better left in the ocean rather than eaten raw!

Our Japanese ISS partners at Japanese Launch site

Parting Thoughts

- Future Space Exploration will and should be an International effort
- We should build on the ISS relationships and proven worldwide space industry expertise
- Commercial transportation initiative to LEO is vital. Building the Transcontinental Railroad (not government subsidized Amtrak) and 1930s Airline industry expansion/government cooperation models worked for major transportation infrastructure change
- NASA should transition from designing and operating new LEO rockets to designing new Lunar/Mars habitats and beyond
- Will America lead space exploration or go the way of Portugal? Henry the Navigator 1394-1460. Leadership in ship design, sails and navigation. Portugal explores Africa in 15 century. Explores Asia, Indonesia, China, and Japan in early 16th century. Gives up exploration leadership to Spain, England, and Dutch