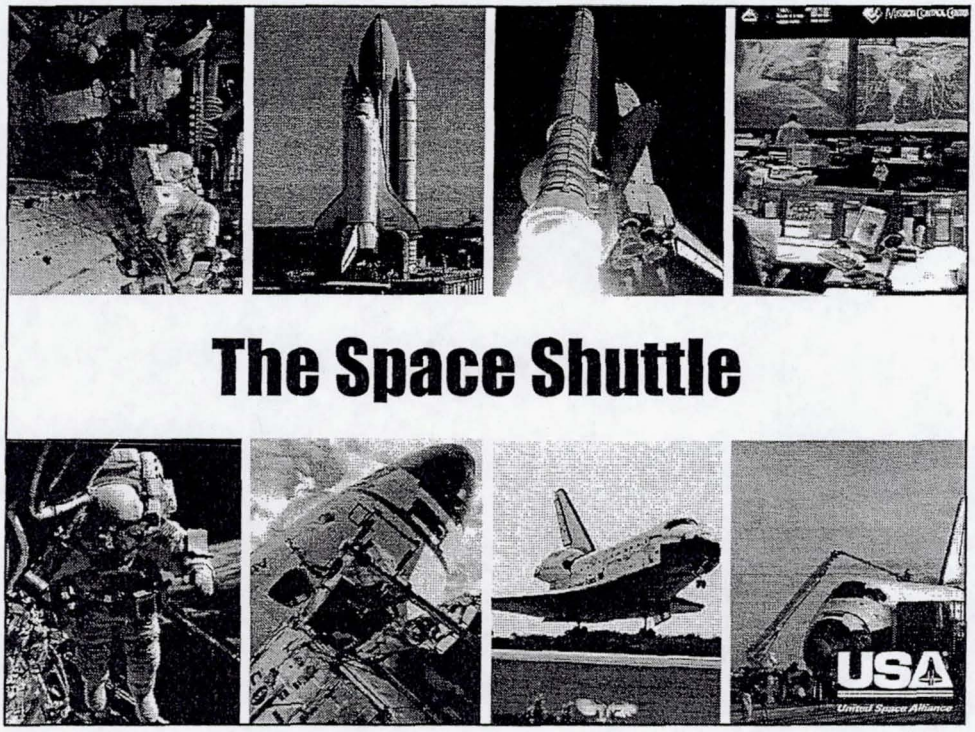

What is the Space Shuttle?

The space shuttle is the world's first reusable spacecraft and the first spacecraft in history that can carry large objects both to and from space.

The shuttle launches like a rocket, maneuvers in Earth orbit like a spacecraft and lands like a airplane – though many times more complex and robust.

Each space shuttle has a design life of 100 missions. So far, the combined fleet has flown 113 missions.

The space shuttle is the most capable, versatile and reliable space vehicle in the world today – a unique national asset.

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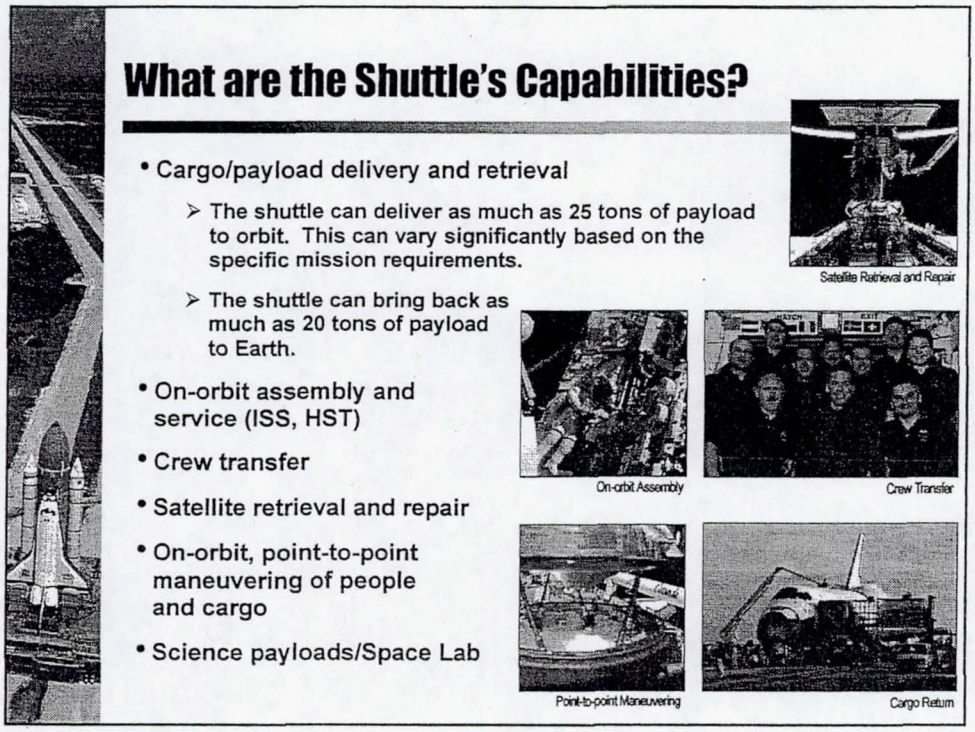
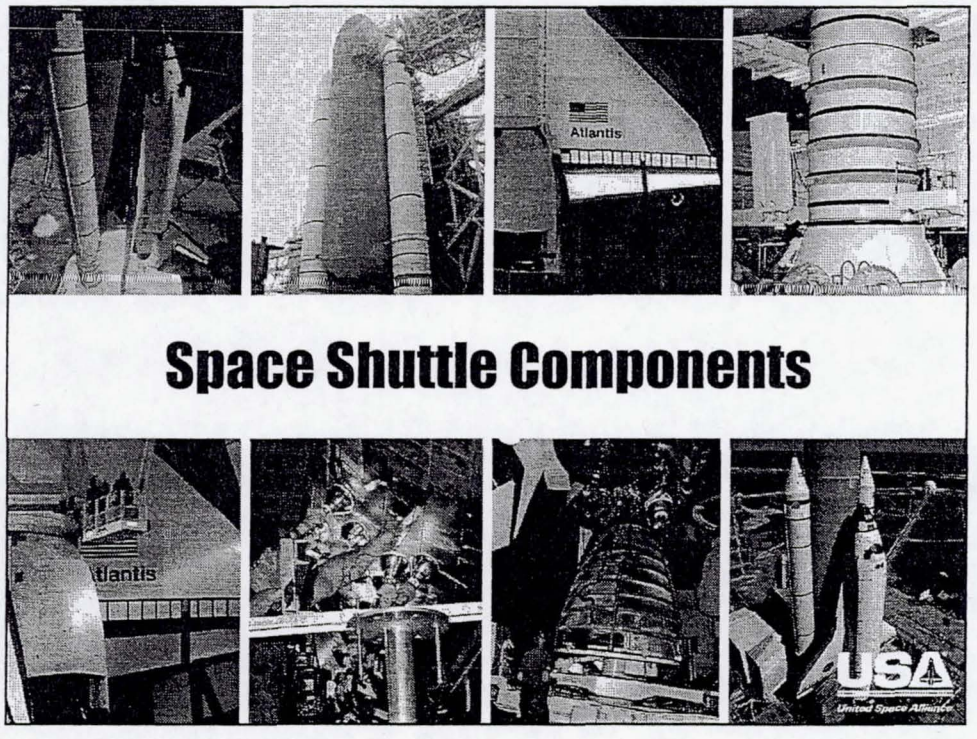
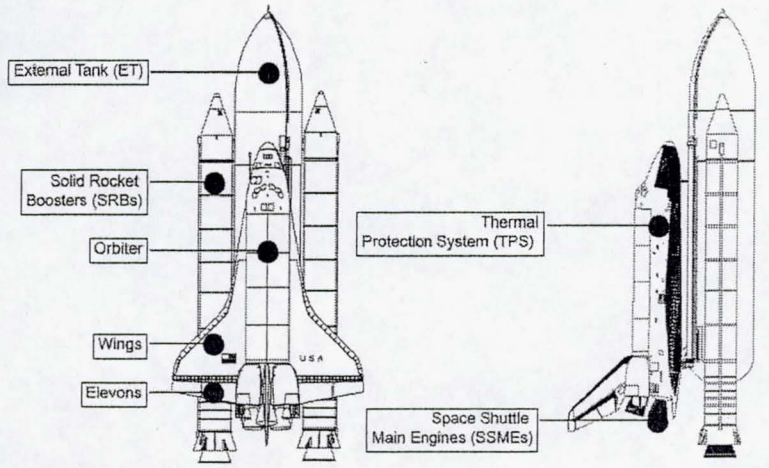

What are the Shuttle's Capabilities?
• Cargo/payload delivery and retrieval
➢ The shuttle can deliver as much as 25 tons of payload to orbit. This can vary significantly based on the specific mission requirements.
➢ The shuttle can bring back as much as 20 tons of payload to Earth.
• On-orbit assembly and service (ISS, HST)
• Crew transfer
• Satellite retrieval and repair
• On-orbit, point-to-point maneuvering of people and cargo
• Science payloads/Space Lab
Satellite Retrieval and Repair
On-orbit Assembly
Crew Transfer
Point-to-point Maneuvering
Cargo Return


Atlantis
Space Shuttle Components
USA
United Space Alliance

Space Shuttle Components



For a full description, "click" on a component (●) or name

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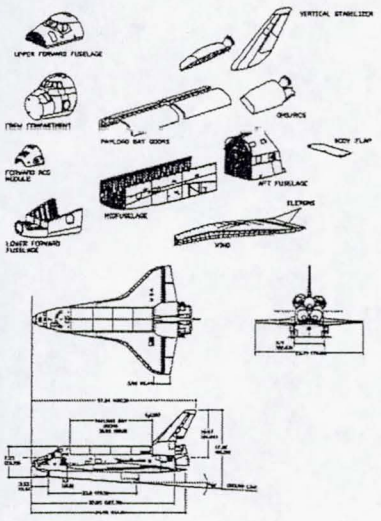
Orbiter



- Each orbiter is 121 feet long with a wingspan of 78 feet – about the size of a DC-9 commercial airliner.
- The payload bay measures 60 by 15 feet.
- The forward fuselage houses the pressurized crew cabin including the cockpit and crew working and living areas.
- The mid-body consists of the payload bay, the wing, and main landing gear attach points.
- The aft fuselage holds the main engines, the orbital maneuvering system (OMS), the reaction control system (RCS) and the vertical tail.

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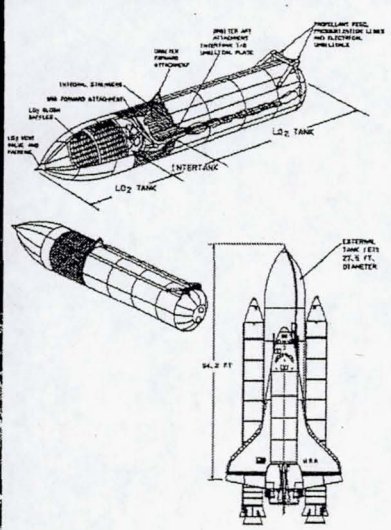
External Tank (ET)



- The external tank (ET), which is the only major component of the space shuttle that is not reusable, is 154 feet long and 28.6 feet in diameter.
- For flights to the International Space Station, a new super lightweight tank was recently developed that incorporates aluminum-lithium in its internal structure, reducing the overall tank weight by 7,500 pounds.
- Weighing slightly more than 71,000 pounds without fuel, the ET weighs 1.67 million pounds with a full load of liquid propellant and oxygen. Thousands of gallons of liquid hydrogen and oxygen are drawn from the tank by the shuttle's main propulsion system during ascent.
- Once orbit is achieved, the ET is jettisoned and disintegrates in the Earth's upper atmosphere.

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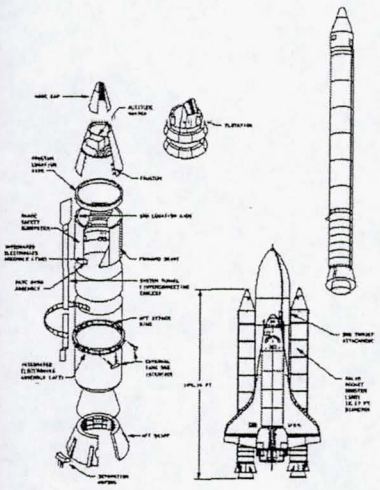
Solid Rocket Boosters (SRB)



- Each shuttle is equipped with two solid rocket boosters (SRB) that provide the initial thrust and acceleration to allow the main engines to carry the orbiter into space.
- The boosters are 116 feet long, 12 feet in diameter and contain more than one million pounds of solid propellant.
- The propellant burns at 5,800 degrees and each SRB delivers 2.65 million pounds of thrust at liftoff.
- After two minutes, at an altitude of about 24 miles, the SRBs separate from the ET and descend by parachute into the ocean where they are collected for refurbishment and reuse.
- The shuttle SRBs are the largest solid rocket propellant motors ever built and the first to be used on human-rated spacecraft.

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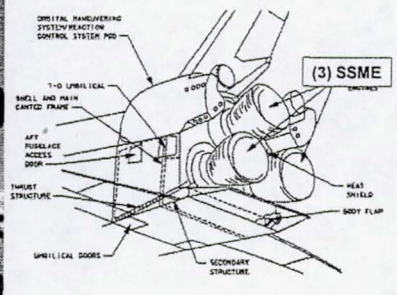
Space Shuttle Main Engines (SSME)



- The space shuttle main engines (SSME) are the most reliable and highly tested large rocket engines ever built.
- With a maximum thrust at sea level of more than 418,000 pounds each, they work in tandem with the SRBs from liftoff until separation, about two minutes after launch, after which they are the sole means of propelling the orbiter into space.
- The engines are gimbaled to steer the shuttle during the climb to orbit.
- Normal engine operating time during ascent is about 8.5 minutes and each engine has a designed operating lifetime of about 7.5 cumulative hours.

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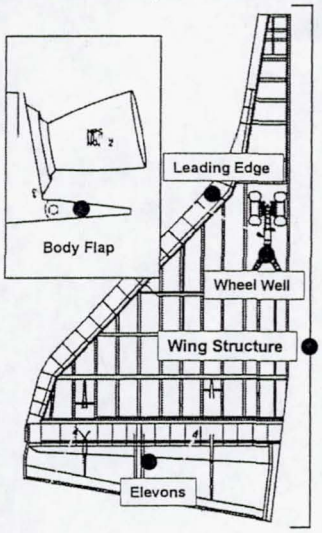
Space Shuttle – Wing Structure



- The wing is an aerodynamic lifting surface that provides conventional lift and control for the orbiter.
- The two wings (left and right) consist of the wing glove, the intermediate section (which includes the main landing gear wheel well), the torque box, the forward spar for mounting the reusable reinforced carbon-carbon leading edge structure thermal protection system, the wing/elevon interface, elevon seal panels, and the elevons.
- Each wing is approximately 60 feet long at the fuselage intersection and has a maximum thickness of approximately 5 feet.
- The two-piece elevons provide orbital flight control during atmospheric flight.
- The body flap thermally shields the three SSMEs during entry and provides the orbiter with pitch control.

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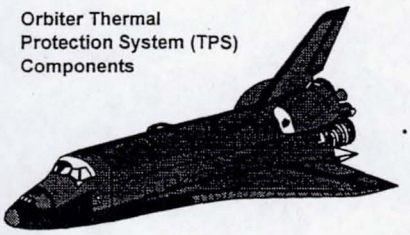
Space Shuttle – Thermal Protection System

Orbiter Thermal Protection System (TPS) Components



- Reinforced Carbon-Carbon (RCC)
- High Temperature Reusable Surface Insulation (HRSI) Tiles
- Low Temperature Reusable Surface Insulation (LRSI) Tiles
- Advanced Flexible Reusable Surface Insulation (AFRSI) blankets
- Flexible Reusable Surface Insulation (AFRSI) blankets

- There are about 25,000 tiles and thermal blankets on the outside of each orbiter and about 6,000 thermal control blankets on the inside used to protect the vehicle against the harsh elements of space flight.
- When the orbiter re-enters the Earth's atmosphere, it is traveling in excess of 17,000 mph. To slow down to landing speed, friction with the atmosphere produces external surface temperatures as high as 3,000 degrees Fahrenheit – well above the melting point of steel.
- Five basic materials are used for Obiter TPS – reinforced carbon-carbon (RCC), low and high temperature reusable surface insulation tiles (LRSI and HRSI), advanced flexible reusable surface insulation (AFRSI) and flexible reusable surface insulation (FRSI) blankets.

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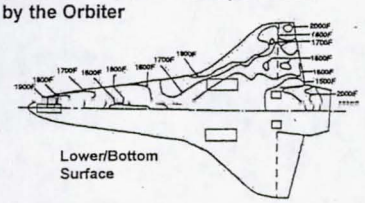
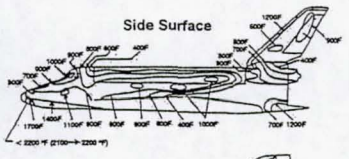
Thermal Protection System *(cont...)*

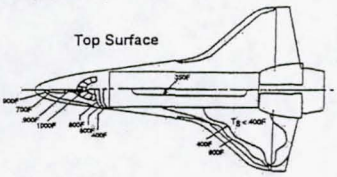
Surface Temperatures Experienced by the Orbiter



Lower/Bottom Surface



Side Surface



Top Surface

- The purpose of the thermal protection system is not only to protect the orbiter from the searing heat of reentry, but also to protect the air frame and major systems from the extremely cold conditions experienced when the vehicle is in the night phase of each orbit.
- The external temperature fluctuates from –200 degrees F to +200 degrees F during each 90 minute orbit.
- There are approximately 23,500 black tiles, used primarily on the undersurface of the vehicle and a few other key areas that require more strength and experience the highest temperatures during reentry.
- There are approximately 800 white tiles , used around the windows and front of the orbital maneuvering system (OMS).

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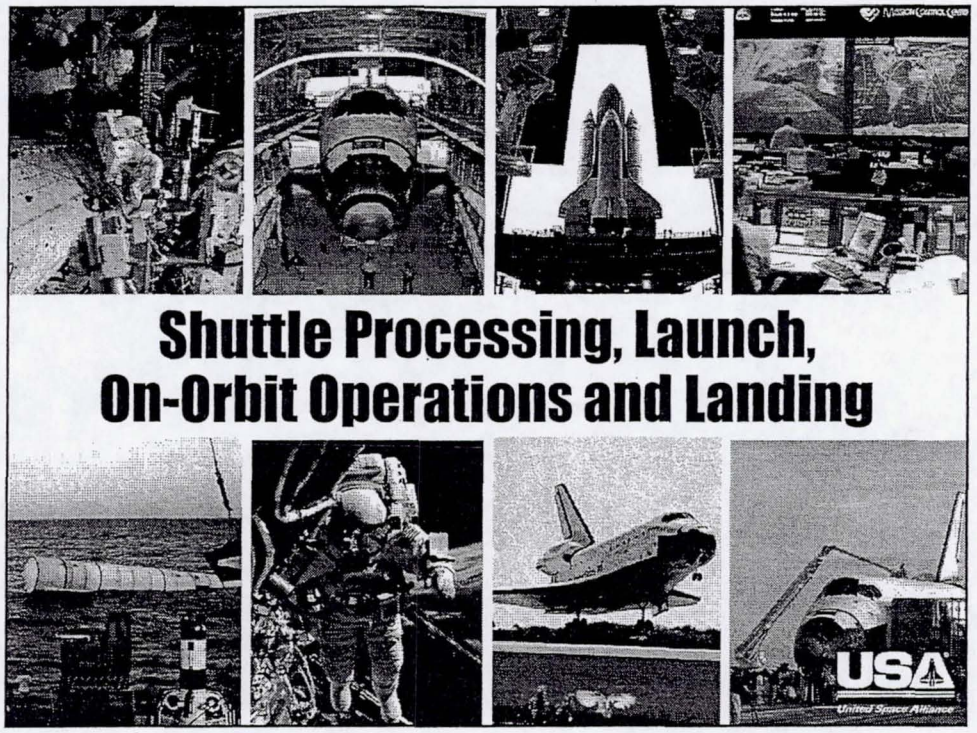
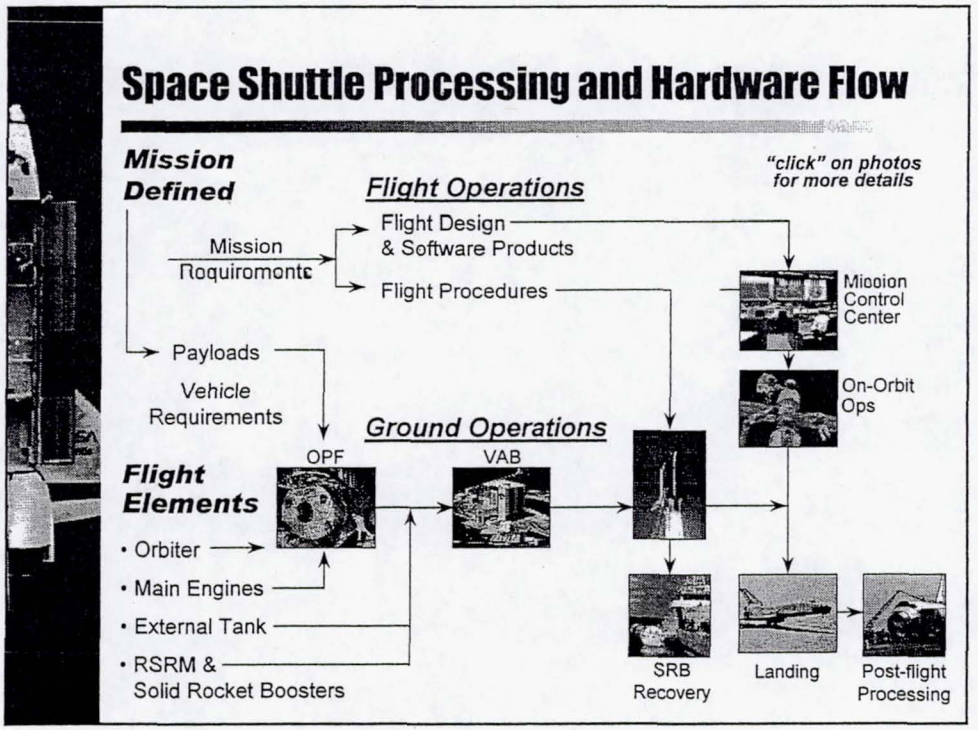
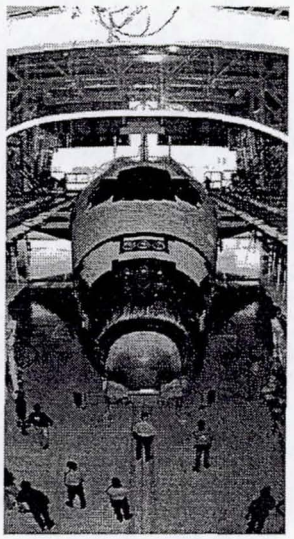

Shuttle Processing, Launch,
On-Orbit Operations and Landing
USA
United Space Alliance

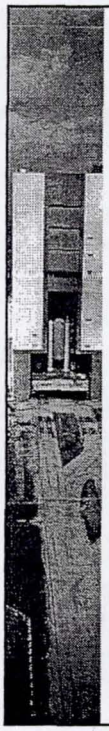

Space Shuttle Processing and Hardware Flow
Mission Defined
"click" on photos for more details
Flight Operations
Mission Requirements
Flight Design & Software Products
Flight Procedures
Mission Control Center
Payloads
Vehicle Requirements
On-Orbit Ops
Ground Operations
OPF
VAB
Flight Elements
• Orbiter
• Main Engines
• External Tank
• RSRM & Solid Rocket Boosters
SRB Recovery
Landing
Post-flight Processing

Go Back

Orbiter Processing Facility (OPF)

- After the orbiter has landed and returned to the OPF, numerous retesting and vehicle checks are conducted.
- Detailed visual inspections are made of the orbiter's thermal protection system (TPS), selected structural elements, landing gear, and other systems to determine if they sustained any damage during the mission.
- Except during hazardous operations, routine pre-flight servicing can begin while deservicing activities are still underway. This includes: reconfiguring orbiter systems for flight, performing routine maintenance, replacing parts and installing new mission flight kits and payloads.
- Consumable fluids and gases are loaded aboard, and the auxiliary power unit (APU) lube oil system is serviced.
- The final step in OPF orbiter processing is weighing the orbiter and determining it's center of gravity. Vehicle performance is affected by both the orbiter's weight and the center of gravity – accurate measurements are critical to flight programming.
- Orbiter processing generally takes less than 100 days.





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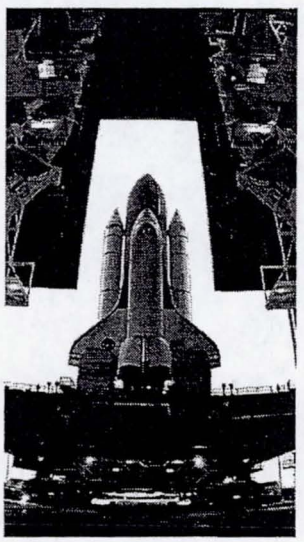
Vehicle Assembly Building (VAB)

- After the vehicle has been prepared for flight in the OPF, it is ready to be mated to the ET and SRBs in the VAB.
- In the VAB, the orbiter is raised to a vertical position and is lifted several hundred feet above the VAB floor and slowly lowered beside the waiting ET and twin SRBs.
- The vehicle is "mated" or bolted to the ET and platforms are moved into place to provide access for integration and final testing.
- Electrical and mechanical verification of the mated interfaces are performed while in the VAB.
- After checkout is complete, the VAB doors are opened to permit the tracked crawler-transporter vehicle (CTV) to move under the mobile launch platform (MLP) and the assembled vehicle or "space shuttle stack."
- The CTV then rolls the MLP and stacked vehicle out to the launch pad.
- It takes about six hours for a space shuttle, aboard the CTV, to make the trip to the launch pad.



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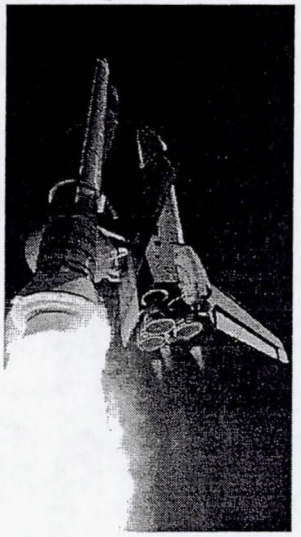
Space Shuttle Launch – Ascent/1st Stage

- The space shuttle is launched vertically with thrust provided by two solid rocket boosters (SRB), called the first stage, and three space shuttle main engines (SSME), called the second stage.
- At liftoff, both the boosters and main engines are operating. To achieve orbit, the shuttle must accelerate from zero to a speed of almost 18,000 mph.
- At liftoff, the shuttle weighs more than 4.5 million pounds.
- At one minute, the shuttle is traveling more than 1,000 mph and has consumed more than 1.5 millions pounds of fuel.
- At two minutes, when the shuttle is about 28 miles high and traveling more than 3,000 mph, the propellant in the two boosters is exhausted and the booster casings are jettisoned, a stage called "SRB sep."



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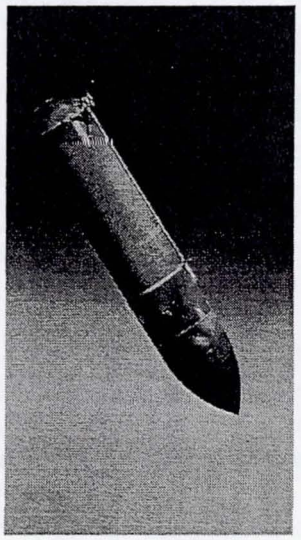
Launch – Ascent/2nd Stage

- The three space shuttle main engines (SSME), attached to the rear of the shuttle orbiter, fire until about 8.5 minutes after liftoff, burning a half-million gallons of liquid propellant from the large, orange external fuel tank (ET) as the shuttle accelerates.
- The main engines burn liquid hydrogen – the second coldest liquid on Earth at minus 423 degrees Fahrenheit – and liquid oxygen.
- The engines' generate over 37 million horse-power as they push the space shuttle to orbit.
- 8.5 minutes after launch, with the shuttle traveling 5 miles a second, the engines shut down as they use the last of their fuel, this is called main engine cutoff or "MECO."
- The only part of the shuttle that is not reused, the ET re-enters the atmosphere and burns up over the Indian Ocean.
- By this time, the shuttle has consumed more than 3.5 million pounds of fuel.



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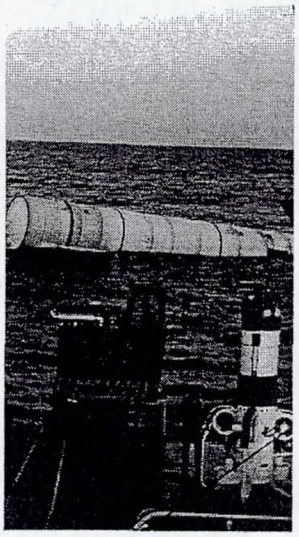
Solid Rocket Booster (SRB) Recovery

- At about two minutes into the launch, the shuttle's SRBs separate and fall into the ocean.
- The SRB casings and associated flight hardware are recovered at sea after each launch and recycled in order to reduce the cost of launches.
- The expended boosters are disassembled, refurbished and reloaded with solid propellant for reuse.
- The two NASA retrieval ships that perform the SRB recovery, named Liberty Star and *Freedom Star, were specifically designed* and constructed for this task.
- After retrieval and return to the Kennedy Space Center (KSC), the disassembly and refurbishment process begins.



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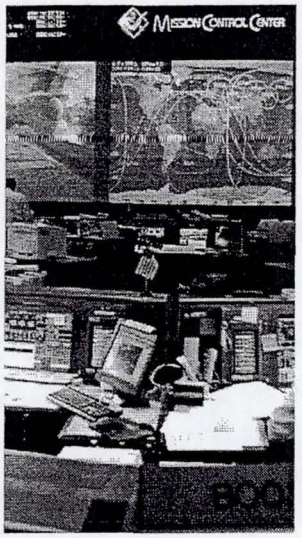
Mission Control

- Since 1965, the Mission Control Center (MCC) has been the nerve center for America's manned space program.
- These teams of experienced engineers and technicians monitor systems and activities aboard the spacecraft 24 hours a day during missions, using sophisticated communications, computer, data reduction and data display equipment.
- Once the orbiter lifts off the pad, the launch and mission are controlled from the Johnson Space Center (JSC) MCC.
- Each console or central position has a "call sign," the name the controller uses when talking to other controllers over the various communication circuits, i.e., Flight Director = "Flight."
- The space shuttle Flight Control Room and the International Space Station Flight Control Room are basically identical in their equipment and supporting structure.



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On-Orbit Operations

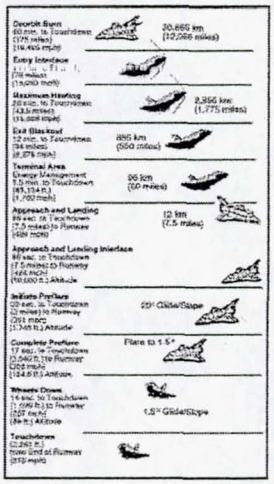
- The versatility of the orbiter provides the astronaut crews with extensive use of the payload bay, middeck, and other areas of the orbiter.
- On-orbit operations include:
  - Payload deployment/retrieval
  - Payload assembly/maintenance
  - Microgravity research and experimentation
  - Crew transfer
  - International Space Station (ISS) resupply
  - Extravehicular activity (EVA)
  - Technology test-bed
  - Cargo return

Go Back

Landing/Descent – Shuttle Flight Profile

- A returning orbiter's glide to KSC begins on the opposite side of the planet. The deorbit burn that will bring to orbiter back to Earth occurs about an hour before landing.
- Approximately 30 minutes before touchdown, the orbiter begins entering the atmosphere at an altitude of about 400,000 feet.
- At approximately 45,000 feet, the orbiter starts maneuvers that enable it to intercept the landing approach corridor at the desired altitude and velocity.
- As the orbiter nears the landing site, the commander takes manual control to line up the spacecraft with the center line of the runway and land.
- Depending on the mission and its orbital parameters, the path the vehicle takes as it enters the atmosphere and land can vary greatly.

The diagram illustrates the space shuttle's deorbit maneuvers for approach and landing events



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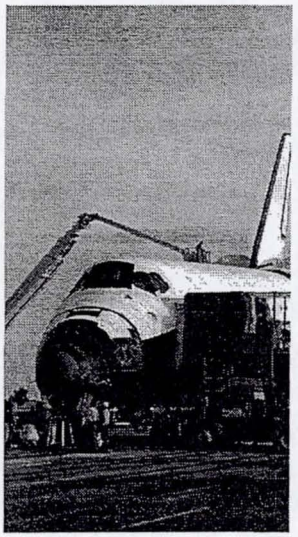
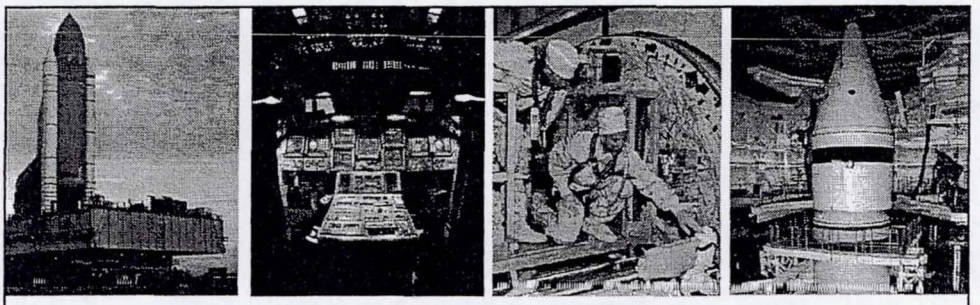
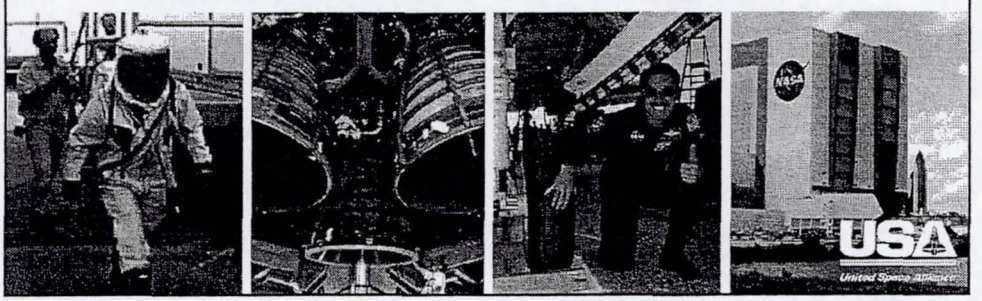
Post-flight Processing

- After the shuttle has landed, the vehicle is inspected right on the landing strip or Shuttle Landing Facility (SLF).
- Safety Assessment Teams, dressed in protective gear, quickly begin the processes necessary to "safe" the orbiter and prepare it for towing to the OPF.
- After the process is complete and it is determined that the area in and around the orbiter is safe, the crew prepares to leave.
- After the crew has left the orbiter, the JSC MCC Team "hands over" responsibility of the vehicle to Kennedy Space Center (KSC).
- After KSC vehicle ground personnel make numerous preparations, the vehicle is towed to the OPF.
- Turnaround processing procedures on the orbiter include various post-flight deservicing and maintenance functions, which are carried out in parallel with payload removal, and the installation of equipment needed for the next mission.





Improving the Shuttle with Modifications and Upgrades



Orbiter Modifications

- NASA has made literally thousands of major and minor modifications to the original design that have made the space shuttle safer, more reliable and more capable today than ever before.
- There are different types of space shuttle modifications conducted routinely during normal vehicle processing and during scheduled Orbiter Major Modification (OMM) periods.
  - During OPF processing, any required vehicle modifications, in addition to routine post-flight deservicing/servicing and checkout, are performed.
  - Planned modifications are typically put into work as soon as practical after the orbiter returns and are generally completed in parallel with pre-launch servicing.
  - Modifications to orbiters may be performed to meet future mission requirements, resolve an identified deficiency, enhance vehicle safety and performance, or reduce cost.

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Space Shuttle Upgrades

- Several years back, NASA began improving the shuttle with goals of increasing its safety by improving the highest risk components.
- In managing and operating the space shuttle, NASA holds the safety of the crew as the highest priority.
- The space shuttle is an integral part of NASA's Integrated Space Transportation Plan (ISTP).
- Space shuttle safety, supportability and technology upgrades are a critical step in the ISTP and will assure the orbiter continues to perform its role optimally, through 2020, when a next-generation reusable launch vehicle (RLV) is planned to be operational.
- The primary goal of a next generation RLV is to increase safety and reliability, and reduce the overall cost of human access to space.
- New technologies must be developed or evolved from existing technologies in order to reach this goal.

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Status of the Space Shuttle Upgrades

- Significant technical and planning progress has been made for multiple projects
- Upgrade projects have met their contractual budget and schedule requirements to date, resulting in an aggregate cost under-run
  - ➢ Total project costs and schedules have been updated from early estimates
- Requirements definition and trade studies completed
- Operational concepts defined
- Engineering 'brassboard' units manufactured and delivered
- Hardware and software prototypes completed that demonstrate key architectural components and functionality
- Dynamic testing demonstrated project designs that meet or exceed top-level requirements
- Infrastructure construction companies put under contract

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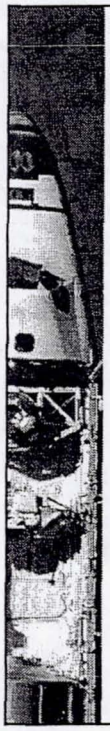

Upgrades Projects Currently Underway

- Advanced Health Management System (AHMS) Phase 2B.2
- Long Life Alkaline Fuel Cell (LLAFC)
- SRB Altitude Switch Assembly (ASA)
- Infrastructure (selected projects)
- SRB Command Receiver Decoder (CRD)
- Main Landing Gear Tire and Wheel (MLGTW)
- Advanced Health Management System (AHMS) 1
- ET Friction Stir Weld Implementation (1st flight)
- Industrial Engineering for Safety (selected projects)
- Cockpit Avionics (CAU)
- SRB Integrated Electronic Assembly (IEA)

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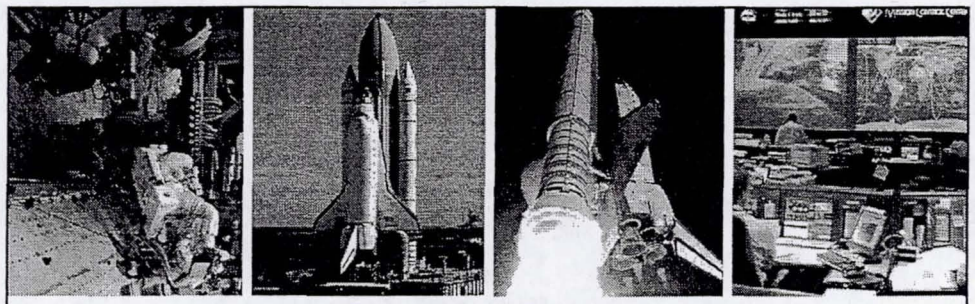
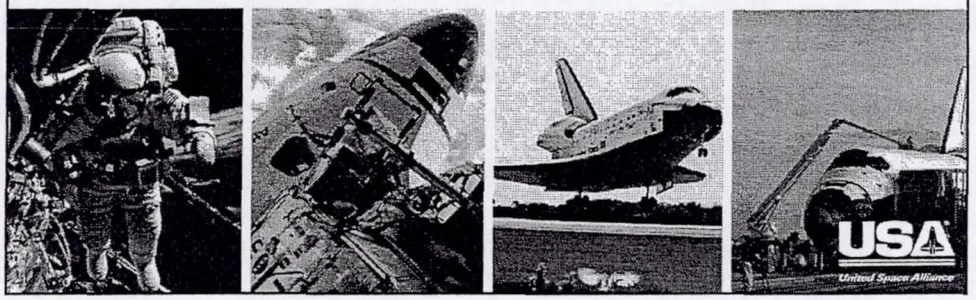
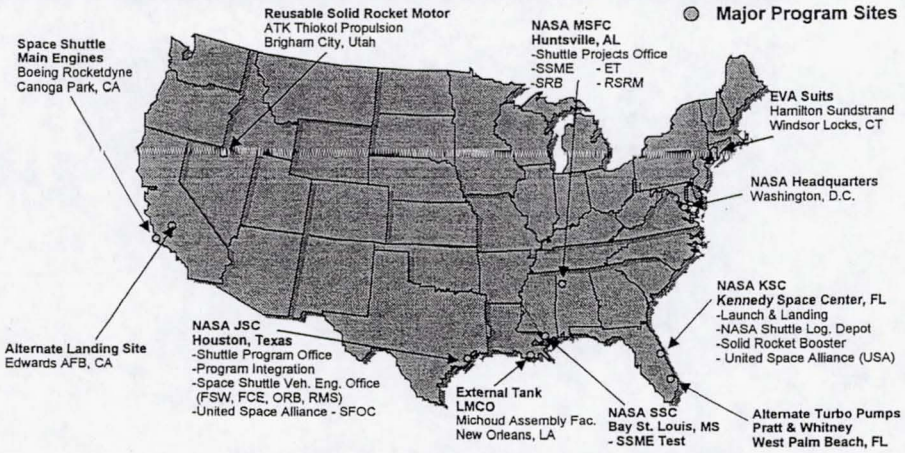


Space Shuttle Background Information



SSP Major Sites and Funding Spent at State-Level



2002 Space Shuttle Program Funding at State-Level *(shown in millions)*

AK - 71,500	CT - 66,075,953	IA - 675,228	LA - 350,903,711	MO - 2,342,068	NH - 650,857	OK - 367,313	TN - 595,428	WI - 1,343,105
AL - 43,727,530	DC -193,353,239	ID - 0	MA - 3,606,895	MS - 32,507,072	NJ - 11,467,261	OR - 330,934	TX - 711,575,763	WV - 8,720
AR - 154,153	DE - 45,378	IL - 18,142,974	MD - 26,155,545	MT - 62,935	NM - 341,075	PA - 17,826,855	UT - 416,748,438	WY - 0
AZ - 11,140,224	FL - 674,570,102	IN - 40,731	ME - 29,973	NC - 2,031,043	NV - 128,690	RI - 98,185	VA - 17,227,358	
CA - 592,410,204	GA - 4,798,304	KS - 412,564	MI - 1,902,708	ND - 7,666,460	NY - 40,328,853	SC - 85,876	VT - 30,000	
CO - 5,747,579	HI - 6,280	KY - 1,447,948	MN - 679,033	NE - 53,810	OH - 8,123,537	SD - 48,046	WA - 4,755,379	

Design, Development and Flight History

- September 1969 – Space Task Group recommends "development of a new space transportation capability..."
- January 1972 – President Nixon announces development of low cost reusable space shuttle system.
- March 1972 – Rockwell Rocketdyne Division selected to design and develop main engines.
- July 1972 – Rockwell Space Transportation Systems selected to design and develop orbiter.
- August 1973 – Martin Marietta awarded external tank contract.
- June 1974 – Morton Thiokol awarded contract for solid rocket boosters.
- September 1976 – Enterprise, the first orbiter spacecraft is rolled out. Test vehicle is never flown in space.
- January 1979 – Rockwell contracted to manufacture two additional orbiters – Discovery and Atlantis.
- March 1979 – The Columbia orbiter is delivered to Kennedy Space Center.

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Design, Development and Flight History *(cont..)*

- April 1979 – Enterprise is mated with external tank and solid rocket boosters for test purposes.
- April 1981 - Space Shuttle Columbia lifts off and is the first orbiter in space (STS-1).
- July 1982 The Challenger orbiter is delivered to Kennedy Space Center.
- October 1983 – Lockheed Space Operations awarded contract for shuttle processing at Kennedy Space Center.
- November 1983 – The Discovery orbiter is delivered to Kennedy Space Center.
- April 1985 – The Atlantis orbiter is delivered to Kennedy Space Center.
- January 1986 – Shuttle Challenger explodes and crew perishes 73 seconds after liftoff.
- September 1988 – Discovery lifts off marking return to flight status of Shuttle Program.
- October 2000 – Space Shuttle makes 100th space flight.

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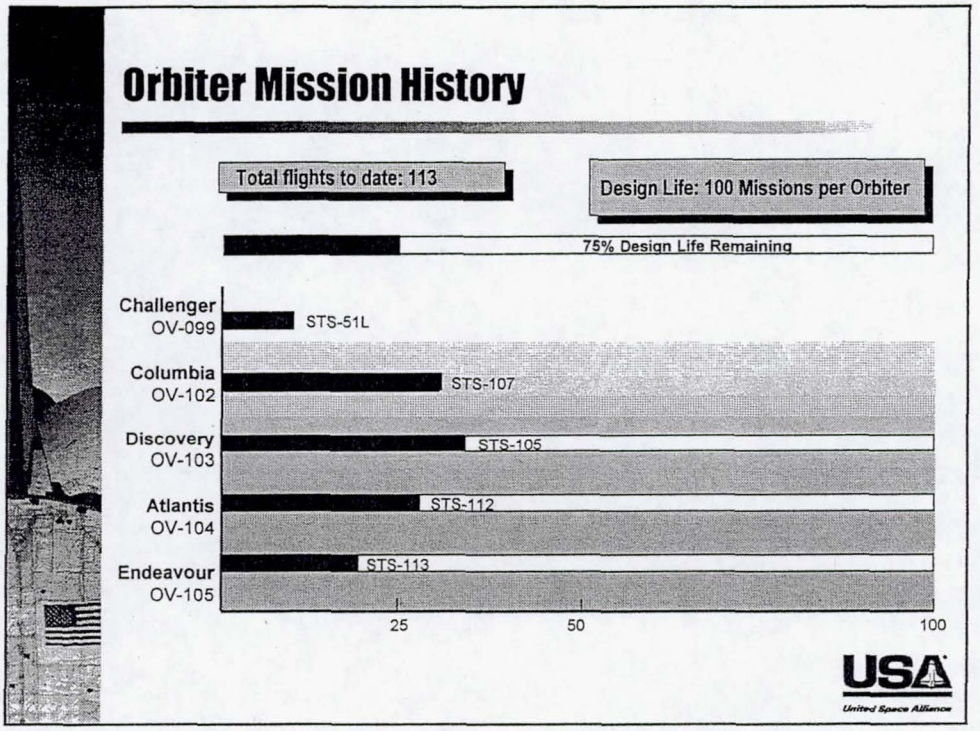
Orbiter Mission History
Total flights to date: 113
Design Life: 100 Missions per Orbiter
75% Design Life Remaining
Challenger OV-099
STS-51L
Columbia OV-102
STS-107
Discovery OV-103
STS-105
Atlantis OV-104
STS-112
Endeavour OV-105
STS-113
25
50
100
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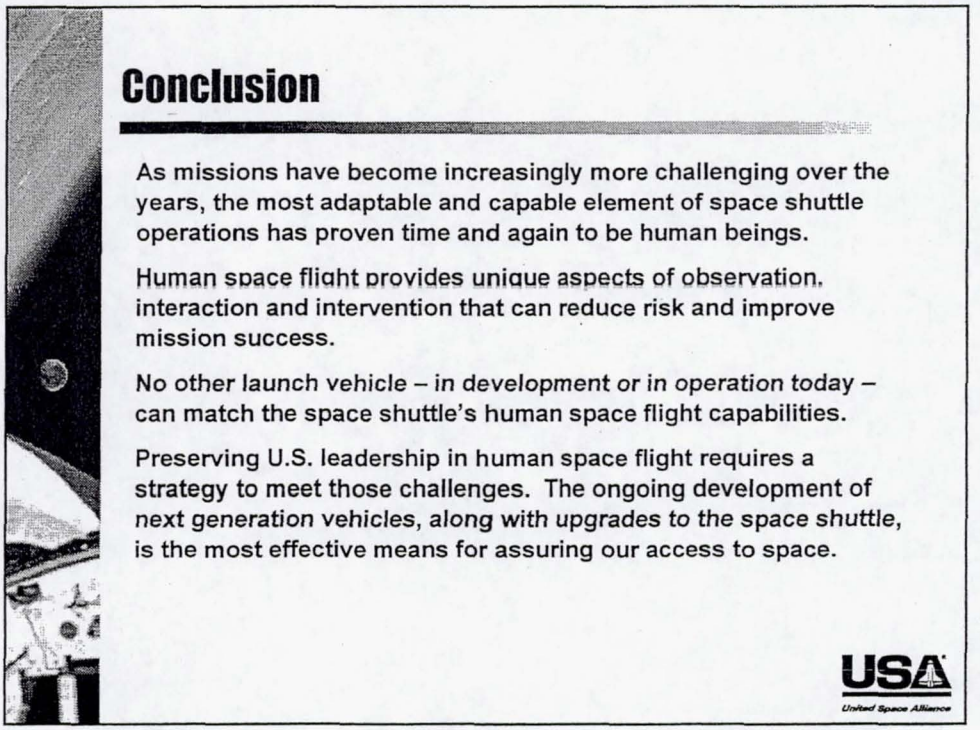
Conclusion
As missions have become increasingly more challenging over the years, the most adaptable and capable element of space shuttle operations has proven time and again to be human beings.
Human space flight provides unique aspects of observation, interaction and intervention that can reduce risk and improve mission success.
No other launch vehicle – in development or in operation today – can match the space shuttle's human space flight capabilities.
Preserving U.S. leadership in human space flight requires a strategy to meet those challenges. The ongoing development of next generation vehicles, along with upgrades to the space shuttle, is the most effective means for assuring our access to space.
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