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## SIGNIFICANT ENDEAVOUR PRODUCTION UPGRADES

From the outside, NASA's newest space shuttle, Endeavour, looks nearly identical to its sister ships Discovery and Atlantis. Beneath its sleek exterior, however, Endeavour truly represents the state of the art in manned space vehicle capability. Many systems onboard Endeavour have undergone design changes or have been updated from earlier equipment to incorporate new technologies as part of NASA's orbiter continuous improvement and upgrade program. The upgrades include numerous improved or redesigned avionics and mechanical systems; installation of a drag chute to aid in vehicle landings; and modifications to pave the way for possibly extending shuttle flights to as long as 28 days in the future.

Some such updated systems have already been installed in the rest of the shuttle fleet; some are being or will be installed in all orbiters in the near future; and others will be unique to Endeavour.

Some of the more significant Endeavour production upgrades follow:

### AVIONICS SYSTEMS

#### Advanced General Purpose Computers

The advanced general purpose computers (GPCs) have flown previously on Columbia, Discovery, and Atlantis and will be used on Endeavour for its first space flight. The updated computers have more than twice the memory and three times the processing speed of their predecessors.

Built by IBM, Inc., and officially designated the IBM AP 101S, they are half the size, about half the weight, and require less power than the first-generation GPCs. The central processor unit and input/output processor, previously installed as two separate boxes, are now a single unit.

The new GPCs use the existing shuttle software with only subtle changes. However, the increases in memory and processing speed allow for future innovations in the shuttle's data processing system.

Although there is no real difference in the way the crew will operate with the new computers, the upgrade increases the reliability and efficiency in commanding the shuttle systems. The predicted "mean time between failures" (MTBF) for the advanced GPCs is 6,000 hours. The flight computers are already exceeding that prediction with an MTBF of more than 60,000 hours. The MTBF for the original GPCs was 5,200 hours.

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## New GPC Specifications

Dimensions	19.52" x 7.62" x 10.2"
Weight	64 lb
Memory capacity	262,000 words (32-bits each)
Processing rate	1.2 million instructions per second
Power requirements	550 watts

## HAINS Inertial Measurement Units

The High Accuracy Inertial Navigation System (HAINS) Inertial Measurement Unit (IMU) is being incorporated into the orbiter fleet on an attrition basis as replacements for the current KT-70 model IMUs, and has already flown on two previous Atlantis shuttle missions. The three IMUs on each shuttle orbiter are four-gimbal, inertially stabilized, all-attitude platforms that each measure changes in the spacecraft's speed used for navigation and provide spacecraft attitude information for flight control.

The HAINS IMU for the space shuttle is a derivative of IMUs used in the Air Force's B-1B aircraft. It includes an improved gyroscope model and microprocessor and has demonstrated in testing improved abilities to hold an accurate alignment for longer periods of time. In addition, it has proven more reliable than the KT-70 IMUs. The new IMUs require no software changes on the orbiter or changes in power or cooling interfaces.

For Endeavour's first flight, one HAINS IMU will fly with two accompanying KT-70 IMUs to provide redundancy with proven hardware.

The HAINS IMU is manufactured by Kearfott, Inc., of Little Falls, New Jersey.

## Improved Tactical Air Navigation Systems

Two improved tactical air navigation systems (TACANs) will fly on Endeavour's first flight. The TACANs provide supplemental navigation information on slant range and bearing to the orbiter using radio transmissions from ground stations during the final phases of entry and landing.

The improved TACAN is a modified off-the-shelf solid-state unit developed by Collins, Inc., of Cedar Rapids, Iowa, for military aircraft and slightly modified for the shuttle. The improved solid-state TACAN operates on 28-volt direct current power as compared to the original TACANs that use 110-volt alternating current for power. Also, the new TACANs do not require forced air cooling as do the original TACANs and are approximately half the size and weight of the original Gould TACANs. The TACANs' interfaces to the shuttle's guidance, navigation, and control system are identical.

### Mass Memory Unit Product Improvement

Two mass memory units (MMUs) are aboard each orbiter and are a magnetic reel-to-reel tape storage device for the shuttle's onboard computer software. Improvements to the current MMUs in the form of modifications include error detection and correction circuitry to accommodate performance limitations of magnetic tape and improve overall unit performance. In addition, modifications were made to the tape drive head to extend its lifetime. The improvements have no effect on the current software or connections of the MMUs. The modified MMUs will fly on Endeavour's maiden voyage and will be incorporated into the rest of the orbiter fleet during normal maintenance activities. The upgraded MMUs have already flown on STS-44 and STS-45. The MMUs were built and upgraded by Odetics of Anaheim, Calif.

### Enhanced Multiplexer-Demultiplexer

The multiplexer-demultiplexers (MDMs), 19 located throughout each orbiter, act as a relay for the onboard computer system as it attains data from the shuttle's equipment and relays commands to the various controls and systems. The enhanced MDM uses state-of-the-art components to replace obsolete parts and improve maintenance requirements. The new components have simplified the structure of the EMDM by more than 50 parts in some instances. The EMDMs have flown in Discovery and Atlantis, but Endeavour's STS-49 flight will mark the first full use of the EMDM on an orbiter. The EMDMs are manufactured by Honeywell Space Systems Group, Phoenix, Ariz.

### Improved Radar Altimeter Antenna

A complete set of four improved radar altimeter antennas are installed for Endeavour's first flight. The new antennas are six-element microstrip phased arrays developed by Honeywell's Microwave Systems Division, Minneapolis, Minn. The upgraded antennas have reduced sidelobe pattern characteristics. Also, the design eliminates the cross-polarization inter-system noise between transmit and receive antennas that results from coverage of the antennas by the orbiter's thermal protection system. The improved radar altimeter aboard Endeavour has already been installed and flown on all other shuttle orbiters since STS-26.

### Improved Nosewheel Steering

Improvements to the nosewheel steering system include a second command channel, used as a backup in case of a failure in the primary channel, for controlling the steering through the onboard computers. In addition, a valve has been installed in the hydraulic system to switch to a secondary hydraulic pressure system in case of a failure in the primary system. Endeavour has been modified with the improved nosewheel steering system. The rest of the orbiter fleet will have the improvements made during their major modification periods. The improved nosewheel steering system control box and hydraulic switching valve were designed by Sterer Engineering and Manufacturing Components, Los Angeles, Calif. Rockwell International's Space Systems Division, Downey, Calif., designed the system modification.

### Solid-State Star Tracker

The solid-state star tracker (SSST) is an upgraded star tracker design developed for Endeavour that takes advantage of advances in star tracker technology. The two star trackers on each shuttle orbiter are used to search for, detect, and track selected guide stars to precisely determine the orientation of the spacecraft. The precise information is used to periodically update the orbiter's IMUs during flight. The SSST uses a solid-state charge-coupled device to convert light from stars into an electric current from which the star's position and intensity are determined. The solid-state design requires less power and provides greater reliability than the current star trackers. The SSSTs require no modifications to the orbiter or its software for installation. One SSST is installed on Endeavour and another is in Columbia. The SSST was developed and built by Ball Aerospace Division, Boulder, Colo.

## Mechanical Systems

### Improved Auxiliary Power Units

An improved version of the auxiliary power units, three identical units that provide power to operate the shuttle's hydraulic system, has been installed on Endeavour. STS-49 will mark the first flight of three IAPUs: one flew aboard Atlantis on STS-45. The IAPUs are installed on Columbia and will be installed on Discovery and Atlantis as each spacecraft is taken out of operation for a major modification period during the next year.

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The IAPU is lighter than the original system, saving about 134 pounds. The weight savings are due to the use of passive cooling for the IAPUs, eliminating an active water spray cooling system required by the original units. The redesigned APUs are expected to extend the life of the units from the current 20 hours or 12 flights to 75 hours or 50 flights. The increased lifetime is anticipated to result in fewer APU changeouts and improved ground turnaround time between flights.

Components of the APU that have been redesigned to improve reliability include the gas generator, fuel pump, redundant seals between the fuel system and gearbox lubricating oil, a materials change in the turbine housings, and modified turbine wheels. The IAPU's are manufactured by Sundstrand Corp., Rockford, Ill.

### Orbiter Drag Chute

During the production build, provisions for a drag chute were added to Endeavour. The drag chute will assist in stopping and add greater stability in the event of a flat tire or steering problem. The drag chute is another in a series of improvements to the shuttle's landing aids. Other improvements already in use on the orbiter fleet include reinforced carbon-carbon brakes to replace the original beryllium brakes and nosewheel steering capability.

The 40-foot diameter drag chute canopy will trail 87 feet behind the orbiter as it rolls out after landing. The main drag chute and a 9-foot diameter pilot chute are deployed by a mortar fired from a small compartment added to the bottom of the vertical stabilizer. The drag chute will be jettisoned when the spacecraft slows to less than 60 knots. The time from pilot chute mortar firing to full inflation of the main chute is anticipated to be less than 5 seconds.

The drag chute is expected to decrease the orbiter's rollout distance by 1,000 to 2,000 feet. The drag chute is deployed using two switches located to the left of the commander's heads up display, one switch arms the mortar and a second switch fires it. A third switch, located to the right of the commander's heads up display, jettisons the drag chute. A redundant set of switches is mounted beside the pilot's heads up display.

The drag chute is installed in Columbia and will be installed in Atlantis and Discovery during their upcoming major modification periods.

The drag chute system was designed by NASA's Johnson Space Center, Rockwell International's Space Systems Division, Downey, Calif., and Irvin Industries, Santa Ana, Calif.

## Extended Duration Orbiter Modifications

Although no plans are yet in place to use Endeavour for extended duration missions, the orbiter has been fitted with internal plumbing and electrical provisions needed for extended duration orbiter (EDO) mission kits that could enable the spacecraft to stay in orbit as long as 28 days. Equipment installations necessary for extended stays include an improved waste collection system that compacts human waste; extra middeck lockers for additional stowage; two additional nitrogen tanks for the crew cabin atmosphere; a regenerating system for removing carbon dioxide from the crew cabin atmosphere; and a set of supercold liquid hydrogen and liquid oxygen tanks mounted on a special pallet in the payload bay that provides supplemental fuel for the shuttle's electrical generation system.

Columbia received all the modifications necessary for a 16-day stay in orbit during its major modification/structural inspection period completed in February 1992 at Rockwell International's Space Systems Division orbiter assembly and modification facility in Palmdale, Calif. The first EDO flight is currently planned for June 1992, the STS-50 U. S. Microgravity Laboratory-1 flight aboard Columbia, which will be 13 days in length.

EDO provision modifications already made to Endeavour include the following:

### Additional Cryogenic Tanks

Endeavour has provisions to carry five liquid hydrogen and five liquid oxygen tanks. On the rest of the orbiter fleet, Columbia has five tank pairs, and Atlantis and Discovery each have four tank sets. In addition, Endeavour has the internal connections needed to hook up an EDO cryogenic payload bay pallet, containing four additional tanks of both hydrogen and oxygen. The plumbing systems onboard Endeavour could be hooked up to feed fuel from this pallet to the spacecraft's three fuel cells, which combine hydrogen and oxygen to create electricity for the shuttle as well as water. The four EDO pallet tank sets, coupled with five payload bay internal sets, provide a 16-day mission capability. For a 28-day mission, four additional tank sets would be required in the payload bay on either a second pallet or larger pallet.

### Additional Nitrogen Tanks

Endeavour does not have additional nitrogen tanks. However, the internal electrical and plumbing connections have been built into the orbiter to allow for their installation. At present, there are no plans and no timetable for installation of these tanks. If installed, they would be located near the current nitrogen tanks below the payload bay.

### Improved Waste Collection System

Provisions to accommodate an improved waste collection system are built into Endeavour. The IWCS compacts human waste and has an increased capacity for storage of waste.

### Regenerative Carbon Dioxide Removal System

Endeavour has the internal electrical and plumbing connections to be outfitted in the future with a regenerative carbon dioxide removal system that may be used in tandem with lithium hydroxide (LiOH) canisters to remove carbon dioxide from the crew cabin atmosphere. The regenerative system, if used alone, would eliminate the need to carry extensive amounts of LiOH canisters for a long flight. Currently, the crew must change out LiOH canisters daily as part of spacecraft housekeeping. The regenerative system works by removing the CO<sub>2</sub> and then releasing it to space through a vent. The regenerative system is located under the middeck floor.

### Additional Cabin Stowage

Endeavour is outfitted with brackets necessary to mount additional middeck lockers on board. About 127 cubic feet of additional stowage would be needed for an extended duration flight. The crew compartment size, however, is exactly the same as all other orbiters.

## Other Selected Significant Upgrades

### ET Umbilical Debris Container Modification

A canister with a blade valve instead of the previously used hole plugger was installed aboard Endeavour and purge line/electrical harness changes associated with the canister change were incorporated to assure that no debris escapes from the umbilical area after orbiter/external tank separation. The modification will be added to each vehicle following their major modification periods.

## Middeck Accommodations Rack

Endeavour will be the first shuttle to fly with the new middeck accommodations rack (MAR), a means of providing launch transportation to the scientific community for small payloads and experiments. The MAR, which is adaptable to several payload/experiment configurations, is located on the port side of the orbiter middeck, just aft of the relocated galley, and occupies an area of approximately 22.5" x 20" x 80". It has an internal volume of approximately 15 cubic feet and can accommodate payloads up to 300 pounds.

The MAR will accommodate payloads/experiments installed in standard orbiter middeck locker trays or on unique structural mounts or plates attached directly to the MAR structure.

The orbiter, through the middeck utility panel (MUP) located above the galley, provides electrical power to MAR payloads including 28 Vdc and 115 Vac, 3 phase, 400 hertz. In addition, either passive or active thermal control can be provided to MAR-mounted payloads/experiments. Passive cooling consists of heat dissipation through the MAR/orbiter structure. Active cooling, up to 1,200 watts, can be provided to the MAR cooling pump, using the orbiter cooling loop.

Installation and checkout of payloads/experiments into the MAR may be accomplished at the payload/experimenter's facility. The ground support equipment (GSE) console, available to MAR users, provides electrical power and cooling to the MAR for payload servicing and checkout. In addition, a transportation stand, sling, and shipping crate are also available to MAR users.

The MAR presents an opportunity to experimenters, both commercial and noncommercial, to use the middeck environment of the orbiter as an orbiting laboratory for small payloads/experiments. Further, the MAR may be used by experimenters with large payloads for storage of a variety of nontoxic/nonhazardous equipment, including, but not limited to, data tapes, small tools, experiment manuals, etc.

Rockwell International is under contract to NASA to manage the MAR equipment, including the MAR rack, MAR locker doors, GSE checkout console, GSE sling, shipping crate, and transportation stand. In addition, Rockwell provides MAR payload integration services to users. The MAR will be installed in the orbiter fleet during major modification periods.

## Tire Pressure Decay Monitoring System

Endeavour has been installed with wheel rim dedicated pressure transducer plugs and temperature transducers to more accurately monitor tire pressure, temperature and leak rate.



### Redundant Weight-on-Wheels Detector

STS-49 will mark the first shuttle program use of the redundant weight-on-wheels detector (RWOWD). The RWOWD was developed to provide a redundant indication of weight-on-wheels during landing. This redundancy is required in order to satisfy automated landing requirements for extended duration orbiter missions. System upgrades include two hardware RWOWD assemblies to process tachometer wheel speed data and software modifications to provide fault detection and selection filtering of weight-on-wheels data. A wheel speed of greater than 125 knots is used as the indication of weight on wheels.

### Upgraded MPS 750 psig Helium Regulators

Redesigned (enhanced stability, vented bellows, new bellow seals and Belleville springs) main propulsion system 750 psi regulators have been installed aboard Endeavour to eliminate failures caused by oscillation. This modification will be incorporated into the rest of the fleet in the near future.

### Thermal Protection System Modifications

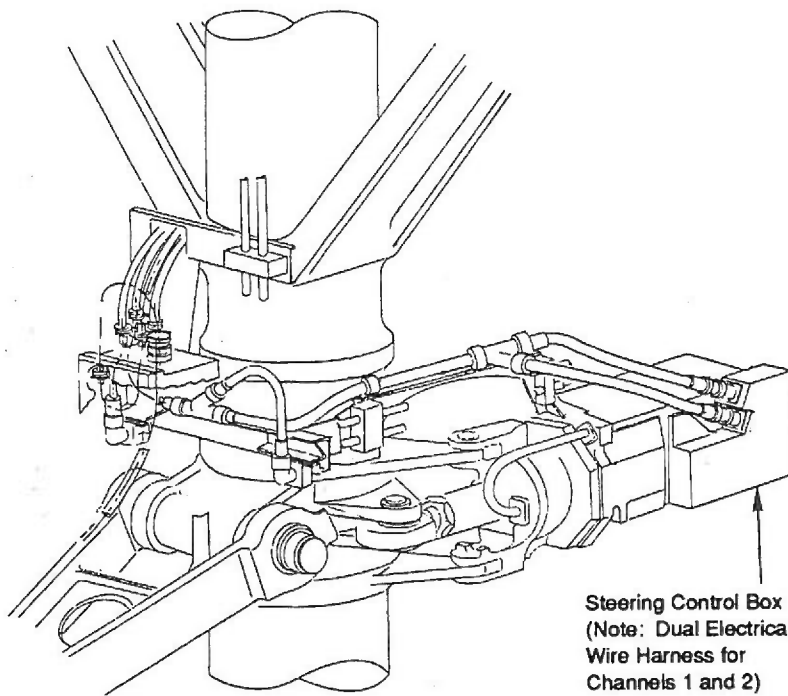
A number of modifications have been made to Endeavour's thermal protection system, among them the following (fleet effectivity indicated in parentheses):

- . Mechanically attached main landing gear thermal barriers have been redesigned with mechanical attachments versus being bonded to the structure to improve removal/reinstallation during turnaround operations (major modification period)
- . Mechanically attached external tank door thermal barriers have been redesigned (major modification)
- . Mechanically attached (versus bond-on) thermal barriers have been installed at vent doors 1 and 2 to enhance turnaround operations (Endeavour only)
- . Redesigned thermal protection system materials have been installed to eliminate the need for TPS removal when removing access doors on the upper forward fuselage (major modification)
- . C-9 coated gap fillers have been installed to improve performance (attrition)
- . Tapered room temperature vulcanizer shim on the inboard elevon has been removed; and redesigned wing/elevon hub tiles have been installed to eliminate room temperature vulcanizer shim to simplify manufacturing and installation of hub tiles and improve turnaround (attrition)
- . Redesigned TPS has been installed adjacent to the wing outboard columbium seal in the wing tip region to prevent filler bar charring (completed on remainder of fleet)

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- . New carrier panels/tiles have been installed at the top of the Xo1307 bulkhead to eliminate replacement of flexible reusable surface insulation (FRSI) at each turnaround (Endeavour only)
- . FRSI has been installed on the upper elevon/wing trailing edge forward of flipper doors and aft of rub panels to eliminate "damage prone" advanced FRSI (Columbia inboard complete, outboard TBD; Discovery partial and major modification; Atlantis complete)

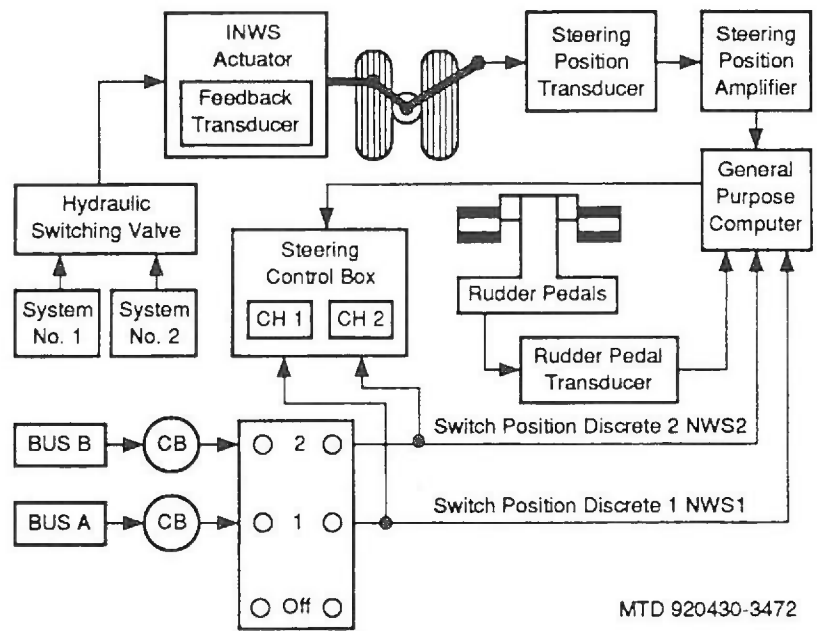
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Steering Control Box  
(Note: Dual Electrical  
Wire Harness for  
Channels 1 and 2)

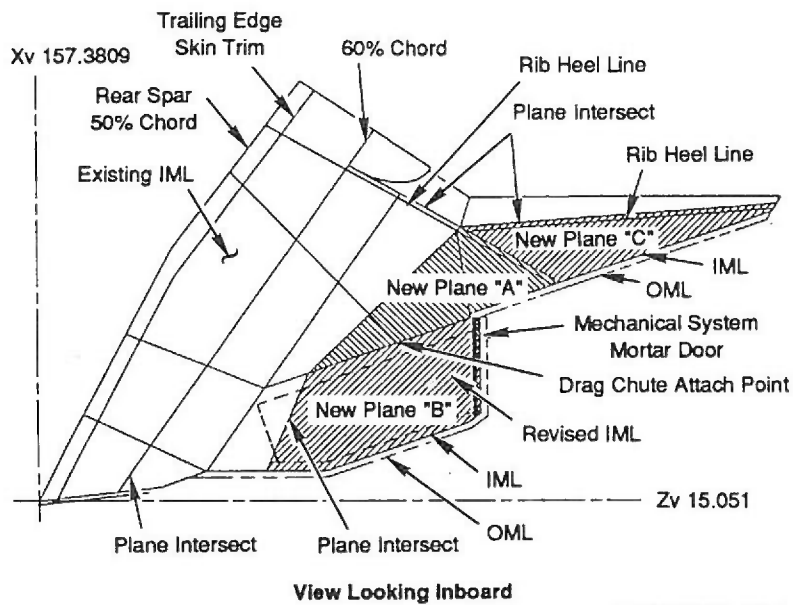
MTD 920430-3473

*Improved Nosewheel Steering System*



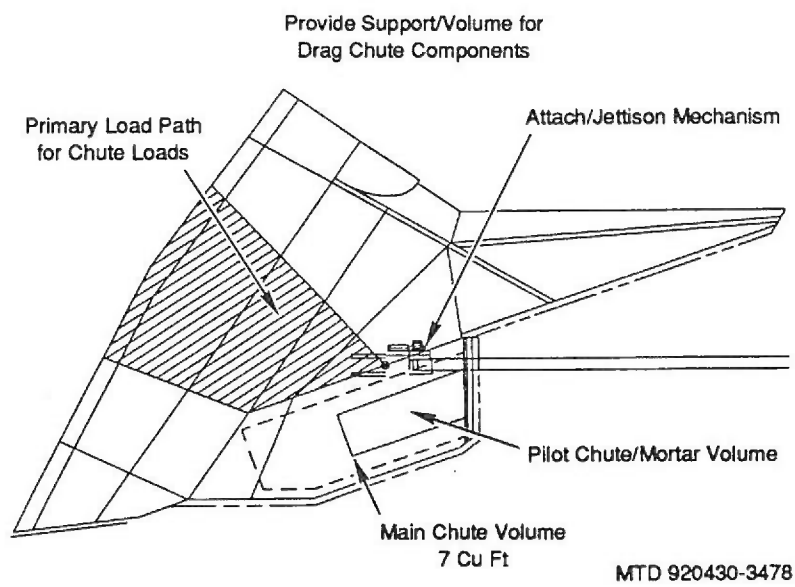
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*Improved Nosewheel Steering Block Diagram*

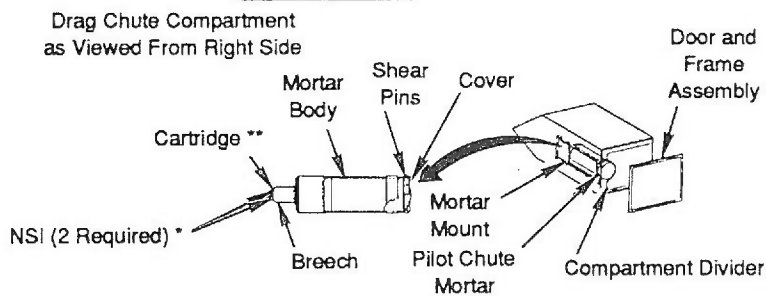
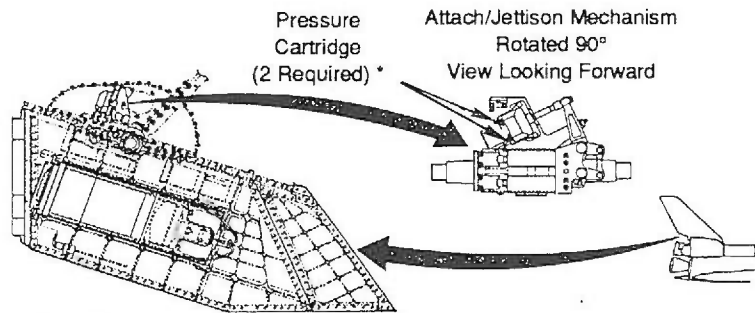


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*Vertical Stabilizer Structural Changes for Drag Chute*



*Drag Chute Volume, Load Path, and Attach/Jettison Mechanism Are Integrated*



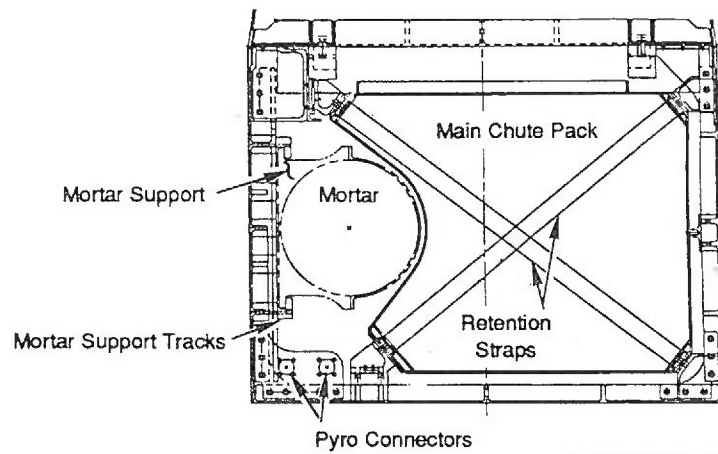
**Note**  
 Drag Chute Installed on OV-105 and OV-102. Will Be Installed on OV-103 and OV-104 During their 1992-1993 Orbiter Maintenance Down Periods

\* ICC Explosive Code Class C

\*\* ICC Explosive Code Class B

MTD 920430-3477

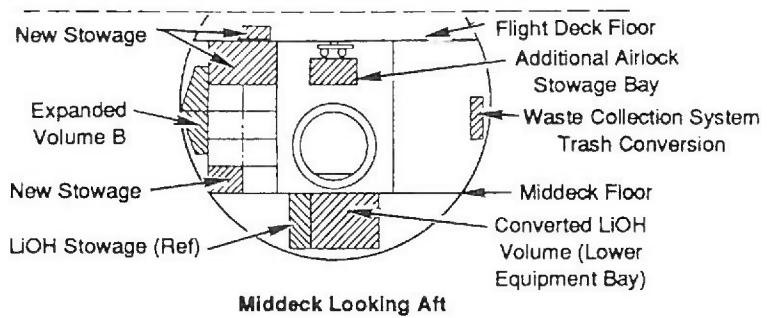
*Orbiter Drag Chute Pyrotechnics*



MTD 920430-3476

*Drag Chute Parachute Compartment - View Looking Forward*

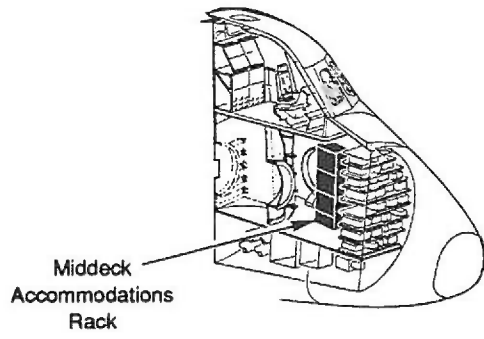




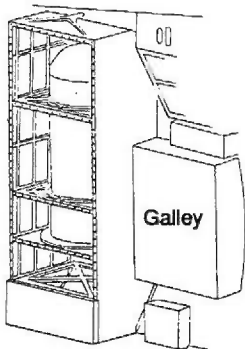
**Middeck Looking Aft**

MTD 920430-3479

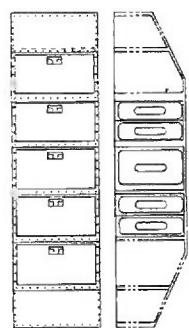
*Expanded Crew Stowage*



Middeck  
Accommodations  
Rack



MAR Payload/  
Experiment Configuration



MAR Locker Configuration

MTD 920430-3480

*Middeck Accommodations Rack*