2.11 EXTRAVEHICULAR ACTIVITY (EVA)

CONTENTS

Description

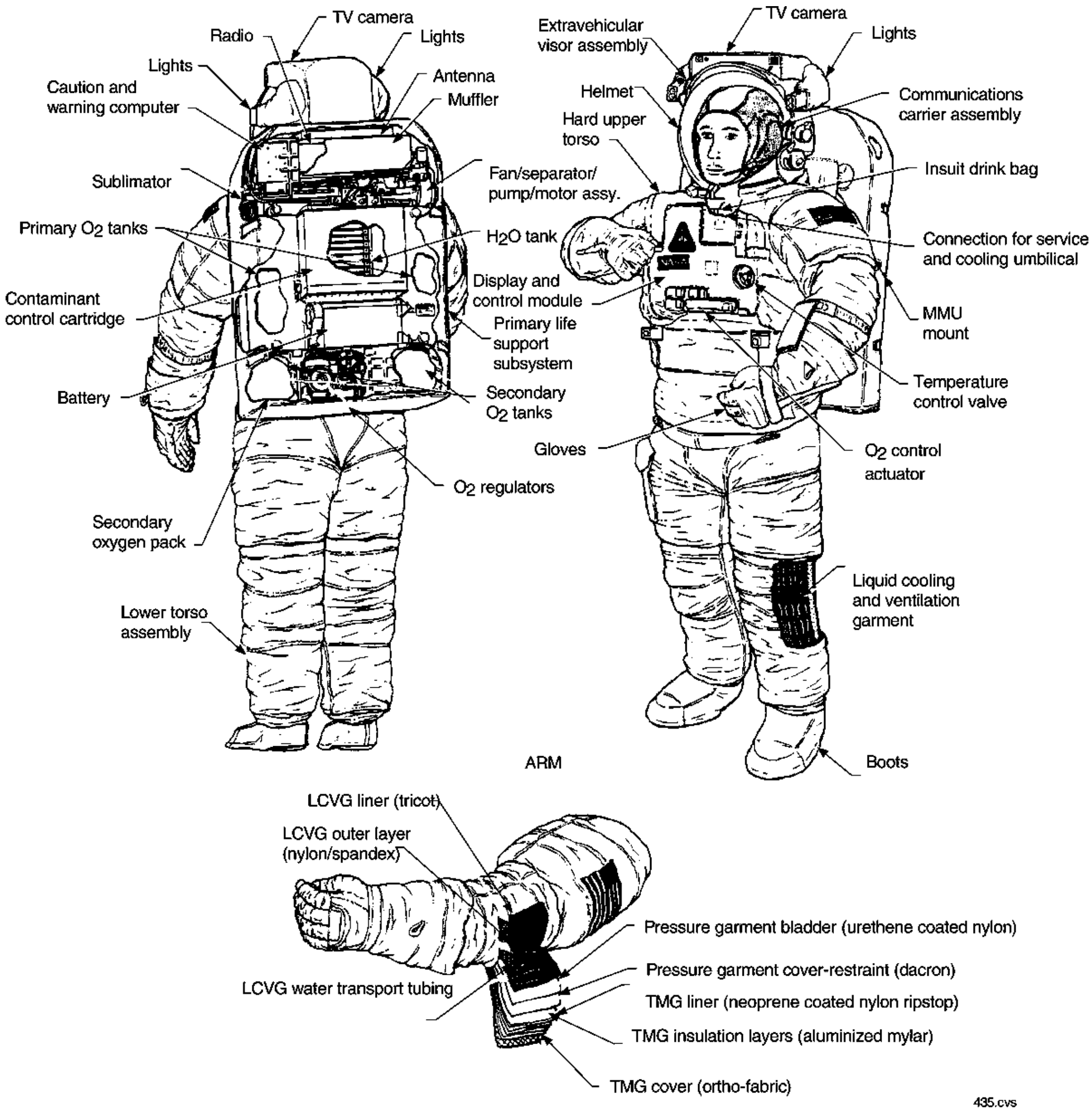
An EVA occurs when a crewmember leaves the protective environment of a spacecraft's pressurized cabin and ventures out into the vacuum of space wearing a space suit. An EVA is commonly referred to as a spacewalk. The current space suit, designed for a total maximum duration of 7 hours, provides environmental protection, mobility, life support, and communications. Two suits are included in each baseline orbiter mission, and consumables are provided for three two-person, 6-hour EVAs. Two EVAs are available for payload use, with the third reserved for orbiter contingency operations. EVA has been demonstrated to be useful in satellite repair, retrieval, and refueling as well as with space station development.

There are three basic categories of EVA: scheduled, unscheduled, and contingency. A scheduled EVA is defined as any EVA incorporated into the nominal flight plan in order to complete a specific mission objective. An unscheduled EVA is not part of the flight plan; rather, it is conducted to achieve payload operation success or to advance overall mission accomplishments. A contingency EVA is also unscheduled, but is required to ensure safe return of the orbiter and flight crew.

A subcategory of scheduled EVA is the quick-response EVA. A quick-response EVA must be performed within a few hours after a problem is discovered, and it is usually associated with payload deployment. Quick-response EVAs are planned pre-flight, and the crew prepares for the EVA even though it may not be performed.

Mission	Date	Purpose of EVA	EVA crew	No. EVA/ mission	Duration, man-hours
STS-6	Apr 4-9, 83	System Functional Demo	Musgrave/Peterson	1	8 hr, 34 min
STS-41B	Feb 3-11, 84	MMU Capability Demo	NcCandless/Stewart	2	23 hr, 14 min
STS-41C	Apr 6-13. 84	Solar Max Satellite Repair	Van Hoften/Nelson	2	20 hr, 12 min
STS-41G	Oct 5-13, 84	Orbiter Fuel Transfer Demo	Leestma/Sullivan	1	6 hr, 58 min
STS-51A	Nov 8-16, 84	Westar/Palapa Satellite Retrieval	Allen/Gardner	2	24 hr, 28 min
STS-51D	Apr 12-19, 85	Syncome F3 Satellite Repair	Griggs/Hoffman	1	6 hr, 20 min
STS-51I	Aug 27-Sep 3, 85	Syncome F3 Satellite Repair	Fisher/Van Hoften	2	23 hr, 42 min
STS-61B	Nov 26-Dec 3, 85	Large Structure Assembly	Spring/Ross	2	24 hr, 40 min
STS-37	Apr 5-10, 91	GRO Satellite Repair/Locomotion Studies	Ross/Apt	2	20 hr, 58 min
STS-49	May 10-14, 92	Intelsat Repair and Assembly of Station by EVA Methods (ASEM)	Thuot, Hieb, Akers, Hornton,	4	59 hr, 51 min
STS-54	Jan 17, 93	First EVA Detailed Test Objective (DTO 1210)	Harbaugh, Runco	1	8 hr, 56 min
STS-57	Jun 25, 93	EURECA Antenna Stow and Second EVA DTO (1210)	Low, Wisoff	1	11 hr, 40 min
STS-51	Sep 16, 93	Third EVA DTO (1210)	Walz, Newman	1	14 hr, 10 min
STS-61	Dec 4-8, 93	Hubble Space Telescope Repair Mission	Musgrave, Hoffman, Akers, Thornton	5	70 hr, 58 min
STS-64	Sep 16, 94	SAFER First Flight	Lee, Meade	1	13 hr, 42 min
STS-63	Feb 9, 95	First EVA Development Flight Test (EDFT) (Spartan Mass Handling)	Foale, Harris	1	13 hr, 18 min
STS-69	Sept 16, 95	Second EDFT (Task board with station EVA interfaces)	Voss, Gernhardt	1	13 hr, 32 min
STS-72	Jan 14-16, 95	Third EDFT (Station assembly and maintenance hardware)	Chiao, Barry, Scott	2	26 hr, 4 min
STS-76	Mar 27, 96	Fourth EDFT (MEEP - Mir Environmental Effects Payload)	Godwin, Clifford	1	12 hr, 4 min

Space Shuttle EVA Chronology



Extravehicular Mobility Unit

Extravehicular activities are classified according to level of complexity: simple, intermediate, or complex. A simple payload EVA requires minimal unique tools, mockups, or mobility aids. Existing procedures and techniques may be adapted to particular EVA needs, thus requiring minimal crew training. An intermediate payload EVA requires development of new tools and equipment. Some procedure and technique development is required, with more extensive training necessary. A complex payload EVA requires the design and development of complex or elaborate tools and equipment. The tasks require extension of basic capabilities and may pose difficulty in access or restraint. Procedure and technique development is extensive, as are crew training requirements.

Extravehicular Mobility Unit

The extravehicular mobility unit (EMU) is an independent anthropomorphic system that provides environmental protection, mobility, life support, and communications for the crewmember to perform EVA in Earth orbit. For EMU design considerations, an EVA is defined as any time the EMU external environmental pressure is below 4.0 psia. The EMU is designed to accommodate an EVA mission with a total maximum duration of 7 hours, consisting of 15 minutes for egress, 6 hours for useful EVA tasks, 15 minutes for ingress, and a 30-minute reserve. The EMU also accommodates specific metabolic rate limits, including (1) an average metabolic rate not exceeding 1600 Btu/hr in any given EVA hour and not exceeding 1000 Btu/hr for the entire duration, (2) a peak metabolic rate not exceeding 2000 Btu/hr for a period of 15 minutes, and (3) a minimum metabolic rate not less than 400 Btu/hr for a period of 30 minutes. The EMU is an integrated assembly, primarily composed of the space suit assembly, life support system, and numerous items of associated support and ancillary equipment.

Space Suit Assembly

The space suit assembly (SSA) is the anthropomorphic pressure vessel that encloses the crewmember's torso, limbs, and head. The SSA provides a variety of functions while the crewmember performs an EVA, including suit pressure retention, crewmember mobility, crewmember liquid cooling distribution, oxygen ventilation gas circulation, downlink of crewmember's electrocardiogram data via EMU radio, crewmember interface with EMU radio, crewmember in-suit drinking water, and urine containment. The SSA operates under specific pressure requirements and leakage criteria.

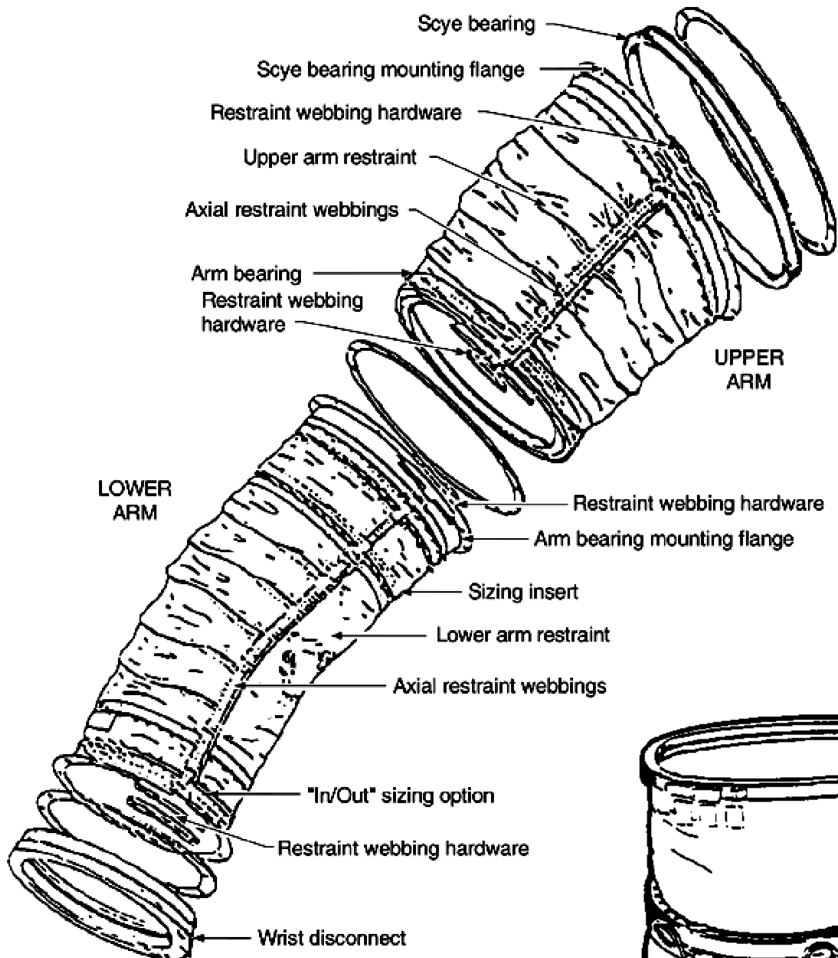
The space suit assembly consists of the following:

- Hard upper torso/arms
- Lower torso assembly
- Extravehicular gloves
- Helmet/extravehicular visor assembly
- Liquid cooling and ventilation garment
- Operational bioinstrumentation system
- Communications carrier assembly
- In-suit drink bag
- Urine collection device
- Maximum absorption garment.

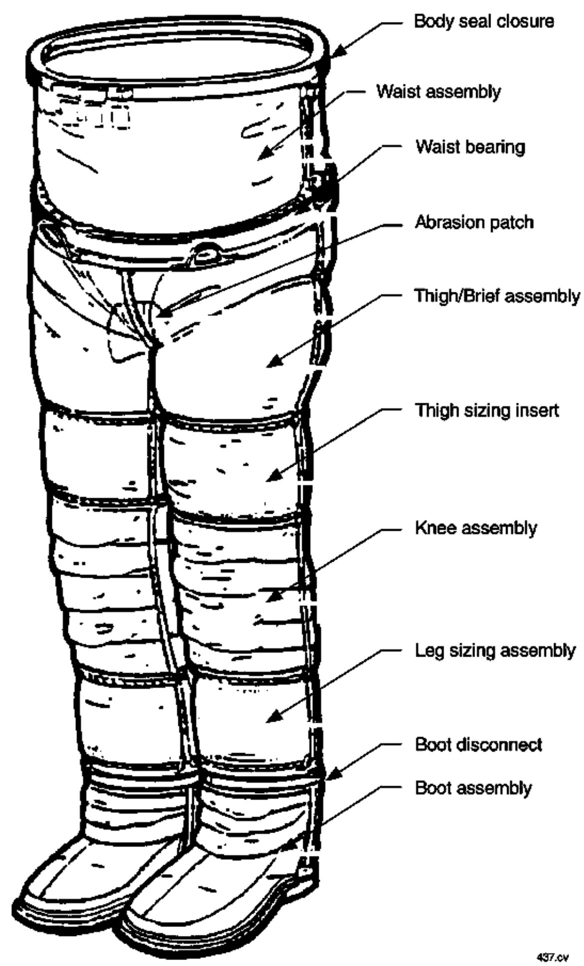
The hard upper torso (HUT) provides pressure containment for the upper torso as well as being the central component from which the mechanical, electrical, and fluid interfaces of the EMU branch. The HUT is available in four sizes to accommodate 5th through 95th percentile-sized crewmembers. The planar HUT, which deletes the arm gimbal and bellows assembly, will be available in two sizes. The HUT includes the following components: fiberglass shell (with water tubes and oxygen ducts), assorted mounting brackets, waterline and vent tube assembly, multiple water connector, EMU electrical harness, shoulder bearing assemblies, waist disconnect ring (passive half), helmet disconnect ring, and thermal micrometeoroid garment (TMG). The right and left arm assemblies are flexible, anthropomorphic pressure vessels that encompass the arms. Each arm assembly includes the following components: upper arm assembly, rotating scye bearing, lower arm assembly, rotating arm bearing, wrist disconnect ring, urethane pressure bladders, cloth restraint systems, and TMGs for the upper and lower arm assemblies.

The lower torso assembly (LTA) consists of a flexible anthropomorphic pressure vessel that encompasses the waist, lower torso, legs, and feet. The LTA includes the following components: waist assembly, waist disconnect ring, trouser assembly, rotating waist bearing between the waist and trouser assemblies, boot assembly, urethane pressure bladders, cloth restraint systems, and TMGs for the waist, trouser, and boot assemblies.

The current sizing of the arm/leg assemblies is accomplished on the ground using different sizes of each assembly for a particular crewmember. An enhanced EMU has been developed to provide an on-orbit capability of EMU resizing by using various arm/leg segments and sizing rings. The on-orbit quick-sizing capability, uses threaded quick-disconnects, softgood sizing elements, aluminum sizing rings, and adjustable-length restraint lines. This suit incorporates dual lip seal mobility bearings and low-torque fabric joints. The enhanced EMU will phase out the current space suit for future station and shuttle operations.

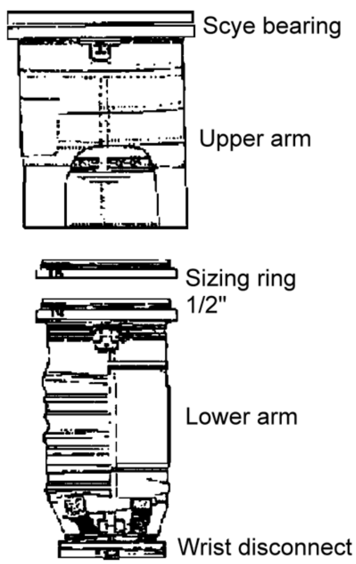


SSA Arm Assembly



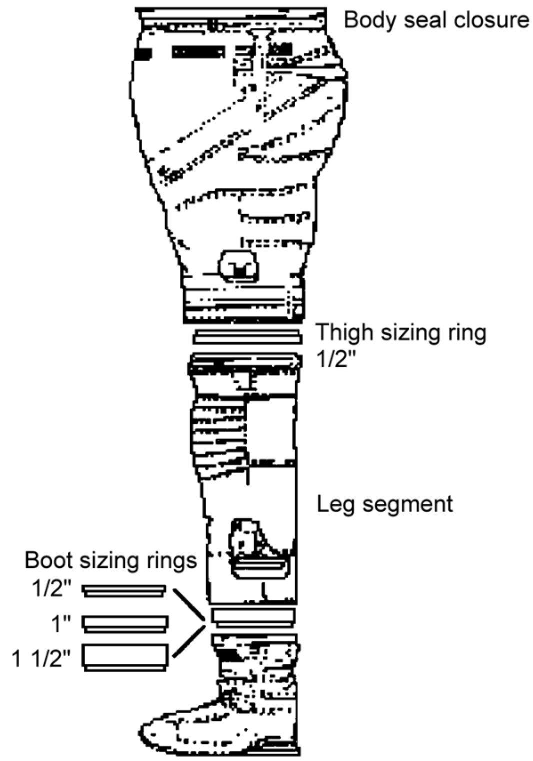
Lower Torso Assembly with TMG Removed

The extravehicular gloves consist of a detachable, flexible pressure vessel, encompassing each hand for use during EVA. The extravehicular gloves include the following components: urethane pressure bladder and cloth restraint system, wrist disconnect ring with rotating wrist bearing, wrist gimbal ring, adjustable palm restraint bar/strap, wrist tether strap, and TMG with palm restraint bar. The current 4000 series gloves incorporate a standard nine-size system to size the gloves for a comfortable fit. The glove fingers use a sizing feature that consists of a pair of polyester dacron cords to provide finger length adjustments. Customized gloves can be manufactured for the crewmember if a proper fit cannot be obtained from the standard size glove.



Enhanced Arm Assembly

The helmet, a "one-size-fits-all" model, consists of a detachable, transparent, hard pressure vessel encompassing the head. The helmet includes the following components: hard transparent bubble, helmet disconnect ring, helmet purge valve, and vent pad. Two crew optional items are also available for the helmet. One of these items is the Fresnel lens, which is mounted to the lower front inside of the helmet to improve display control module visibility for the crewmember. The other item is the valsalva device, attached to the inside of the bubble, which allows the crewmember to clear his or her ears during pressure changes. The extravehicular visor assembly (EVVA) attaches to the helmet to provide the crewmember with visual, thermal, impact, and micrometeoroid protection. The EVVA includes the following components: clear protective visor, sun visor, center and side eyeshades, fiberglass shell, and latch mechanisms and supporting structure for the visor and eyeshades.



Enhanced Lower Torso Assembly

The liquid cooling and ventilation garment (LCVG) is a form-fitting elastic garment worn against the crewmember's body. The LCVG includes the following components: outer restraint fabric, inner liner assembly, crew optional comfort pads, biomed pocket, dosimeter pocket, water tubing network, paramanifold assembly, ventilation ducting network, vent plenum assembly, multiple water connector, and full torso zipper. The garment supports a network of tubing that circulates water over the body to provide cooling to the crewmember. It also supports a network of ducting that draws ventilation gas from the suit extremities and routes it back to the primary life support system to complete the suit ventilation loop. Connections to the ducting in the HUT for both cooling water and ventilation flow are made at the LCVG half of the multiple water connector. The LCVG is sized to fit the crewmember based on a sizing system with six size ranges.

The communications carrier assembly (CCA) is a cloth aviator-type cap that positions and supports the electronics for interface with the EMU radio for crewmember communications. The CCA contains the microphones and earphones necessary for the EVA crewmembers to communicate with each other or with the orbiter. The CCA also allows the EVA crewmembers to talk to Mission Control via the orbiter communications system. Six sizes allow the CCA to fit 5th through 95th percentile-sized crewmembers. The CCA includes the following components: skull cap, ear cups, ear phones, ear seals, microphone modules, microphone booms, summing module, interconnect wiring, interface cable, neck strap, crew-optional chin strap, and perspiration absorption strap.

The in-suit drink bag is a dielectrically sealed bag assembly attached to the interior of the HUT that supplies drinking water to the crewmember during EVA. The drink bag is available in two sizes with the capacity for 21 or 32 fluid ounces of water. The in-suit drink bag includes the following components: bladder, inlet valve, drink valve, drink tube, and velcro attachments.

The urine collection device (UCD) is a disposable, flexible container that has the capacity to hold up to 32 fluid ounces of urine. The UCD is worn under the LCVG by male crewmembers during EVA. It is designed for one-time use, then disposed of as wet trash. The UCD includes the following components: collection bag, attachment straps, one-way check valve, and disposable roll-on cuff.

The maximum absorption garment (MAG) consists of multiple layers of material designed to rapidly absorb and store urine. The MAG is designed to be worn under the LCVG by male or female crewmembers during EVA. It has the capacity to hold 32 fluid ounces of urine and is disposable after use. The MAG includes the following components, multilayer absorbent material and tape attachment straps.

Life Support System

The life support system (LSS) provides a safe living environment inside the EMU. The LSS provides a variety of functions while the crewmember performs an EVA, including provision of breathing oxygen, suit pressurization, crewmember cooling, crewmember communications, displays and controls for crewmember operation of the EMU, and monitoring of EMU consumables and operational integrity. The life support system consists of the following:

- Primary oxygen system
- Secondary oxygen pack
- Oxygen ventilation circuit
- Liquid transport system
- Feedwater circuit
- Electrical interfaces
- Extravehicular communicator (EMU radio)
- Display and control module
- Caution and warning system.

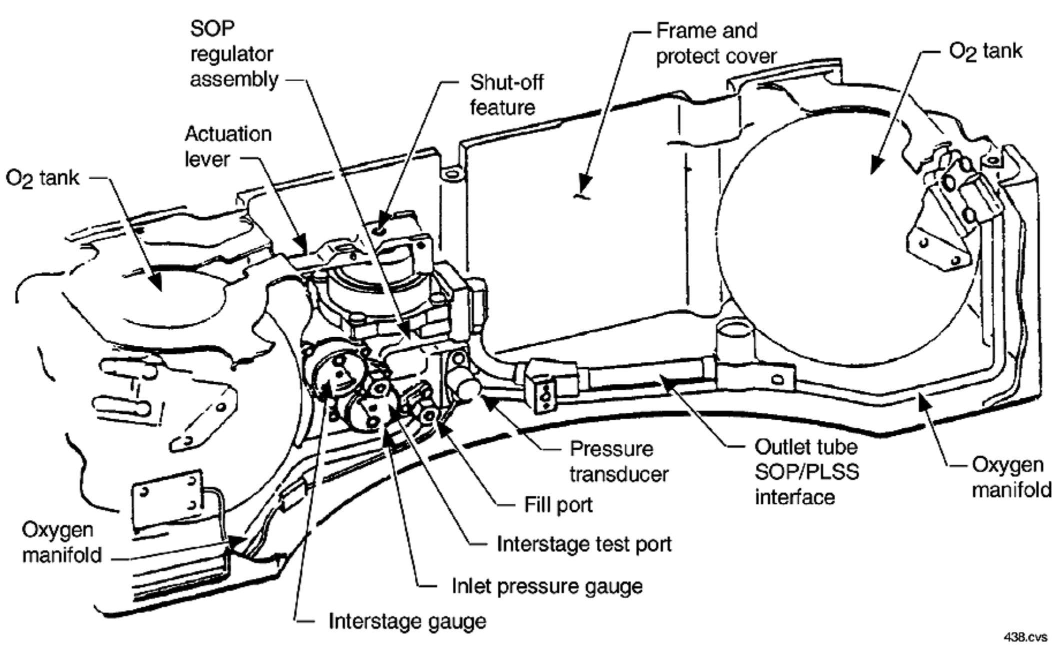
The primary oxygen system, oxygen ventilation circuit, liquid transport system, feedwater circuit, electrical interfaces, extravehicular communicator, and the caution and warning system make up the primary life support subsystem (PLSS). The secondary oxygen pack is a separate unit that is attached to the bottom of the PLSS. Together, the PLSS and the secondary oxygen pack make up the backpack of the EMU.

The primary oxygen system provides a crewmember with breathing oxygen and satisfies pressure requirements for EVA. The system stores 1.217 pounds of oxygen at 850 psia and 90° F. It delivers oxygen during EVA at 4.3 ± 0.1 psid, and maintains a metabolic use rate range of 0.02 to 0.33 lb/hr. The system is charged through a common multiple connection to the orbiter environmental control and life support system. Charging pressure is 850 ± 50 psig. The minimum usable pressure is 60 psi. The system performs various functions, including suit pressurization, provision of breathing oxygen, and water pressurization. The primary oxygen system includes the following components: oxygen tanks, oxygen tank pressure sensor, flow limiter, oxygen shutoff valve, oxygen actuator, suit pressure regulator, water pressure regulator, high mode relief valve, and low mode relief valve.

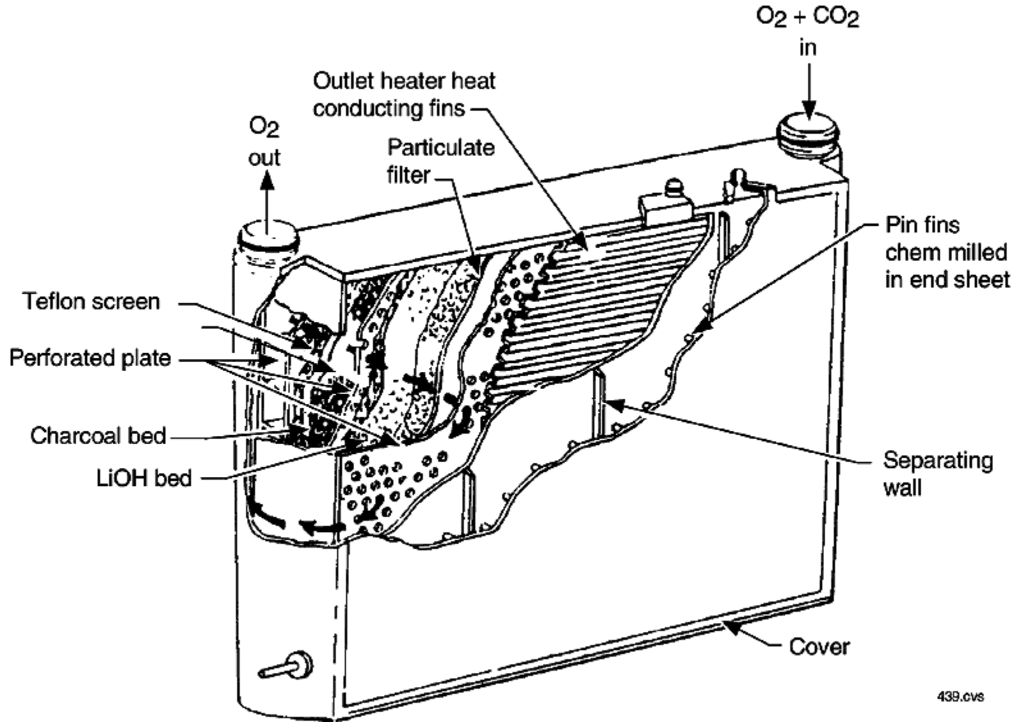
The secondary oxygen system, also known as the secondary oxygen pack (SOP), is the backup assembly to the primary oxygen system. This backup system provides a minimum of 30 minutes of emergency oxygen in the purge mode. The SOP functions include suit pressurization, provision of breathing oxygen, and some degree of cooling in the purge mode. There is no required crewmember interface to activate the SOP; it automatically activates whenever the oxygen actuator is in the EVA position and suit pressure is less than 3.9 psid. The SOP includes two oxygen tanks, containing a total of 2.65 pounds of oxygen at 5800 psia and 70° F. The system includes the following components: oxygen tanks, SOP inlet pressure gauge, first-stage regulator, interstage gauge, second-stage regulator/shutoff valve/flow restrictor, PLSS/SOP interface connector, and oxygen tank pressure sensor.

The oxygen ventilation circuit forms a closed loop with the space suit assembly. The circuit provides oxygen for breathing, suit pressurization for intravehicular activity (IVA) and EVA operation, and ventilation for cooling and elimination of exhaled gases. The oxygen flow picks up heat, humidity, carbon dioxide, and other contaminants, which are removed from the EMU by the ventilation circuit components. The system includes the following components: fan/water separator, slurper/ sublimator, vent flow sensor/backflow check valve, suit pressure sensor, suit pressure gauge, contaminant control (lithium hydroxide) cartridge (CCC), carbon dioxide sensor, display control module purge valve, helmet purge valve, positive pressure relief valve, negative pressure relief valve, SOP checkout package, muffler, and SOP checkout fixture. Ventilation flow is picked up at the body extremities and returned to the upper torso via a vent duct manifold that is part of the LCVG. From the upper torso, the gas is routed back into the PLSS and the CCC. The CCC is sized to absorb 1.48 pounds of carbon dioxide associated with 7000 Btu of metabolic activity over a 7-hour EVA period. The cartridge is installed in the back of the PLSS and is replaceable on orbit. On the ground, the used cartridge can be recharged for future use.

The liquid transport system uses the centrifugal pump to circulate approximately 240 lb/hr of water through the LCVG. The function served by the liquid transport system is to provide cooling to the crewmember. The system includes the following components: pump, temperature control valve, LCVG, gas trap, pump priming valve, pump check valve, sublimator temperature sensor, and service and cooling umbilical bypass valve. During IVA operation, the pump circulates water not only through the EMU, but also through the service and cooling umbilical to the orbiter heat exchanger.



Secondary Oxygen Pack



LiOH Cartridge

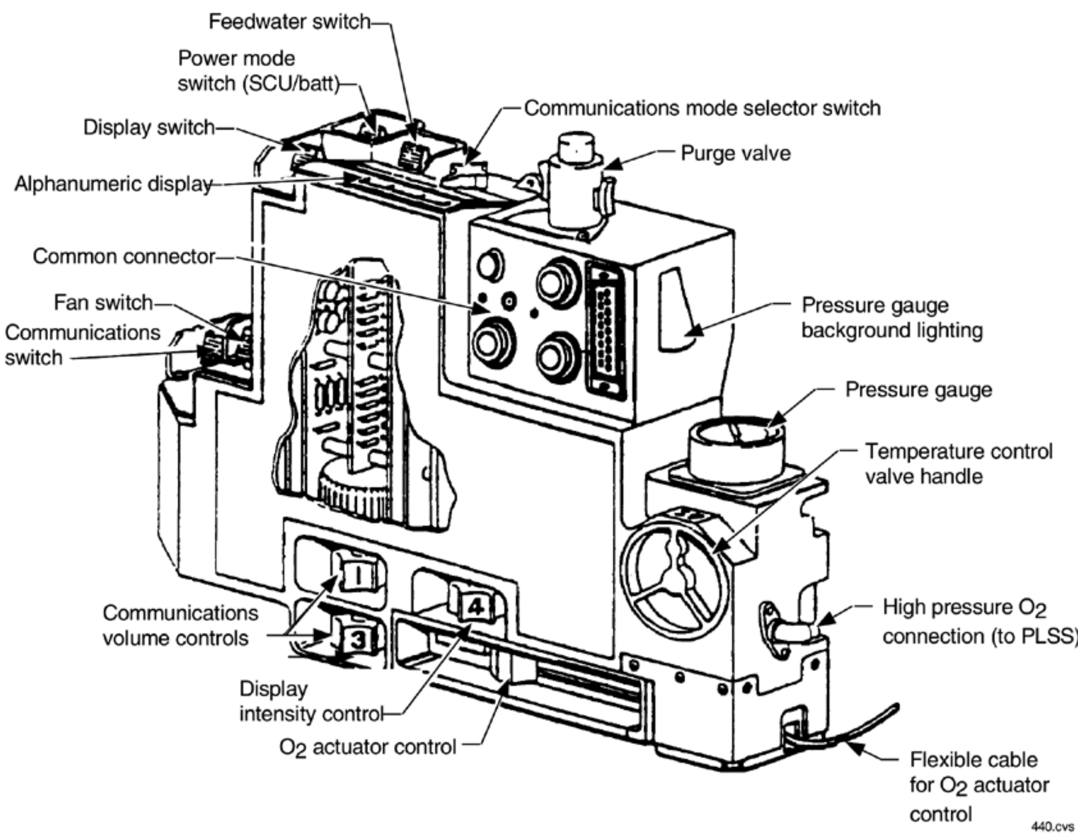
The feedwater circuit contains the equipment and water to dissipate heat loads imposed on the system by the crewmember, the PLSS, and the environment. It also contains equipment to remove moisture from the ventilation circuit and gas from the transport circuit, to separate the water and gas, and to put them back in their respective loops. The feedwater circuit functions involve heat rejection, LCVG water makeup, and vent loop condensate separation and storage. The system includes the following components: feedwater tanks (2 primary/1 reserve), feedwater tank pressure sensors, reserve feedwater tank check valve, feedwater pressure regulator, feedwater shutoff valve, feedwater pressure sensor, sublimator, feedwater relief valve, condensate water relief valve, water separator, and coolant isolation valve. The primary and reserve tanks store approximately 10 pounds of feedwater at 15 psig. The reserve feedwater tank provides 30 minutes of water for EMU cooling in the event that primary feedwater is depleted. Potable water from the orbiter ECLSS is used to fill or recharge the tanks.

The EMU electrical system is composed of the following main components: battery, feedwater shutoff valve, coolant isolation valve, motor, instrumentation, extravehicular communicator, display and control module, and caution and warning system. Electrical interfaces exist between the display and control module and parts of the PLSS, SOP, and C/W. The power supply for operation of all electrical components of the EMU is a battery installed in the back of the PLSS. The EMU battery consists of eleven sealed, silver-zinc, high current density cells connected in series. The battery provides a minimum of 26.6 amp-hr of power over a 7-hour EVA mission at a nominal voltage of 16.5 V dc.

The extravehicular communicator (EVC) is composed of two parts, the orbiter-based equipment and the EMU-based equipment. The orbiter equipment consists of the EVA/air traffic control transceivers and antennas. This configuration provides communication with the EVA crewmembers and relay between EVA crewmembers and the ground (including downlink ECG and real-time data system (RTDS) telemetry). The EMU equipment consists of the EMU radio and antenna. It provides voice communications with other EVA crewmembers and the orbiter, ECG/RTDS telemetry to the orbiter for recording and/or downlink, and caution and warning tones to alert the EVA crewmember of anomalies or other significant events. The EVC includes the following components: orbiter UHF system, EMU radio, EMU electrical harness, communications carrier assembly, biomed sensors, COMM MODE selector switch, COMM switch, volume controls, and real-time data system. Orbiter panels O6, A1R, and R10 are the crew communication interfaces. The panels control UHF operation, air-to-air or ground transmission, and biomed data downlink/recording respectively.

The display and control module (DCM) contains all controls and displays necessary for nominal operation and monitoring of EMU systems. The DCM includes the following components: POWER mode switch, DISPL switch, FAN switch, COMM switch, communications volume controls, display intensity control, oxygen actuator, temperature control valve, pressure gauge, DCM purge valve, alphanumeric display COMM mode selector, and WATER switch. The DCM is installed on the hard upper torso, with the surfaces covered with a TMG. This TMG contains the labels for the controls and displays.

The EMU caution and warning system (CWS) consists of instrumentation and a microprocessor to obtain, process, and visually display information for use by the EVA crewmember in the operation and management of the EMU. The system contains built-in test equipment (BITE), consisting of software and hardware that verify proper CWS operation. CWS serial data are also routed to the ground by the real-time data system. The CWS functions involve displaying EMU leak check procedures, monitoring and displaying EMU consumables status, monitoring EMU operational integrity, and alerting crewmembers to EMU anomalies. The system includes the following components: alphanumeric display with BITE indicator, display (DISPL) switch, alert/status/warning tones, sensors, and "black box" processor. The CWS receives inputs from EMU sensors and from the DISPL switch located on the DCM. Sensors gather information throughout the EMU system and relay it to the CWS. Information is provided on pressures, temperatures, currents, and voltages.



Display and Control Module

EMU Ancillary Equipment

The EMU ancillary equipment consists of hardware necessary to support the EMU during all phases of EVA (prep/post/operation). The following list itemizes the components with a brief description of their functions.

EMU helmet lights - attach to the helmet EVVA and provide two functionally independent sets of lights for portable lighting during an EVA task.

EMU scissors - steel cutters with one serrated edge capable of cutting anything from fabric bags and straps to lightweight steel cable and Kevlar cord.

EMU wrist mirror - attaches to the wrist of the EVA glove to allow the EVA crewmember to view the controls and displays on the front of the EMU.

EVA cuff checklist - a set of reference cards bound by an aluminum alloy bracket attached to a wrist band. The reference cards, approximately 4 inches by 5 inches in size, contain procedures and reference data for performing EVA tasks and for aiding in the diagnosis and resolution of EMU malfunctions.

Food stick - a fruit bar contained in an edible wrapper, positioned just above the neck ring adjacent to the drink valve on the in-suit drink bag.

*In-suit drink bag syring*e - a device used to remove gas from the water in the drink bag. The needle of the syringe is inserted in the inlet valve of the bag, and gas is suctioned out of the bag with the syringe.

*Thermal mitten*s - an adjustable enclosure composed of several layers of thermal blankets and aluminized Mylar with a layer of Nomex felt on the palm and undersides of the fingers that fit conformally around the EV gloves to provide greater thermal hand protection at extreme high and low temperature worksites.

Lower torso assembly donning handles - left and right handles that aid in the mating of the hard upper torso and lower torso assembly halves of the waist ring.

Contingency tool - a pry bar used to disconnect the LTA and HUT halves of the waist ring in the event that the latching mechanism becomes jammed. Operation of the pry bar may damage the latching mechanism; therefore, it should be used only if the waist ring becomes jammed and the crewmember is entrapped in the space suit.

Bends treatment adapter (BTA) - an emergency device that may be used on-orbit in the event an EVA crewmember contracts decompression sickness (bends). The BTA converts the EMU into a hyperbaric treatment chamber, pressurizing the EMU to 8.0 psid over ambient cabin pressure.

SOP checkout fixture - a flight support test item installed on the HUT half of the neck ring during pre-EVA operations.

DCM plug - a cover that attaches to the multiple connector on the DCM in the event that water begins leaking from the connector after the service and cooling umbilical multiple connector is removed.

Prep kit - items necessary for preparing the EMU for EVA, such as antifog wipes, tissue-type wipes, scissors, and urine collection device clamps.

Maintenance kit - additional equipment necessary for routine EMU maintenance, including valsalva devices, stericide wipes, lubricant wipes, antifog wipes, and urine collection device roll-on cuffs.

Bio kit - equipment associated with the biomed instrumentation, including EVA cables, overtapes, electrode placement illustration, alcohol wipes, stoma seals, and electrode paste.

Airlock stowage bag - a Nomex bag used for temporary storage and transfer of items used in prep- and post-EVA operations. When stowed in the airlock over the inner hatch, the bag and its contents are removed from the airlock prior to airlock depressurization.

EVA bag - used to stow various items (camera, thermal mittens, tool caddy) in the airlock for possible use during EVA. The EVA bag remains in the airlock during the EVA.

Airlock

An airlock on the orbiter accommodates astronaut EVA operations. The airlock permits EVA crewmembers to transfer from the mid-deck crew compartment into the payload bay in EMUs, without depressuring the orbiter crew cabin. The internal airlock provides launch and entry stowage of up to four EMUs, while the external airlock can stow two EMUs. Both types of airlock contain the interfaces and associated displays and controls for the orbiter systems that support EMU operation and servicing. Sized to accommodate a two-person EVA, the internal airlock dimensions have a diameter of 63 inches, a length of 83 inches, and two D-shaped 40-inch-diameter openings (three for external airlock). The internal airlock's volume measures 150 cubic feet, while the external airlock has a volume of 185 cubic feet. Support functions performed in the airlock include depressurization and repressurization, EVA equipment recharge, LCVG water cooling, and EVA equipment checkout, donning, and communications. All EVA gear, checkout panel, and recharge stations are located against the internal walls of the airlock.

Airlock Hatches

Two pressure-sealing hatches are mounted on the internal airlock, while the external airlock contains three of these hatches. The inner hatch is located on the exterior of the airlock opening into the middeck. The inner hatch isolates the airlock from the crew cabin. The outer hatch isolates the airlock from the unpressurized payload bay when closed and permits the EVA crewmembers to exit from the airlock to the payload bay when open. The external airlock's third hatch is an additional upper, outer hatch that will be used for docking operations. Each hatch has six interconnected latches with gearbox and actuator, a window, a hinge mechanism with hold-open device, a differential pressure gauge on each side, and two equalization valves.

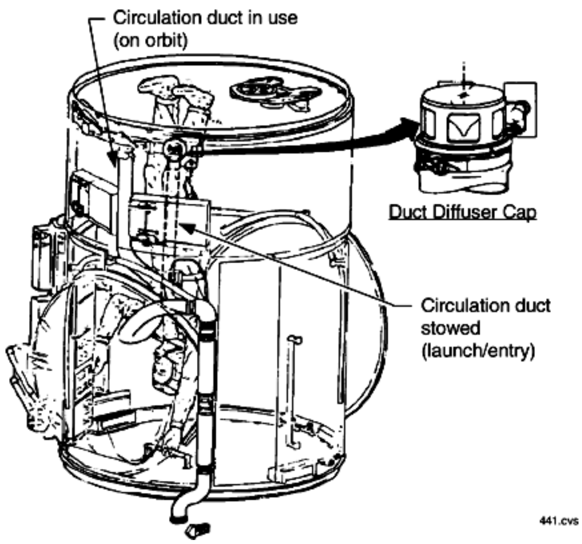
Airlock repressurization is controlled from the middeck or inside the airlock. It is performed by equalizing the airlock and cabin pressure with airlock-hatch-mounted equalization valves on the inner hatch. Depressurization of the airlock is controlled from inside the airlock. The airlock is depressurized by venting the airlock pressure overboard. The two D-shaped airlock hatches are installed to open toward the primary pressure source, the orbiter crew cabin, to achieve pressure-assist sealing when closed. Each hatch opening is 40 inches in diameter, yet with one side being flat, the minimum dimension is 36 inches.

The 4-inch-diameter window in each airlock hatch is used for crew observation from the cabin to the airlock and the airlock to the payload bay. The dual window panes are made of polycarbonate plastic and are mounted directly to the hatch using bolts fastened through the panes. Each airlock hatch has dual pressure seals to maintain the airlock's pressure integrity. One seal is mounted on the airlock hatch and the other on the airlock structure. A leak check quick disconnect is installed between the hatch and the airlock pressure seals to verify hatch pressure integrity before flight.

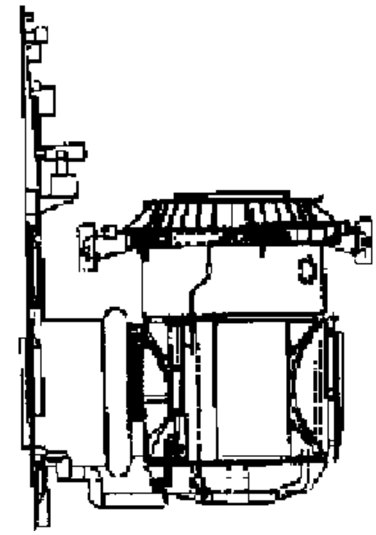
Each airlock hatch has the following design characteristics: (1) capable of being fully locked/unlocked from either side, (2) designed for 2000 open/close cycles, (3) one-handed operation by astronaut in pressure suit, (4) capable of opening against 0.2 psid maximum, (5) latches capable of withstanding 20 g's in the +X direction, and (6) actuator handle load of 30 pounds maximum.

The gearbox with latch mechanisms on each hatch allows the flight crew to open or close the hatch during transfers and EVA operations. The gearbox and the latches are mounted on the low-pressure side of each hatch, with a gearbox handle installed on both sides to permit operation from either side of the hatch. Three of the six latches on each hatch are double-acting with cam surfaces that force the sealing surfaces apart when the latches are opened, thereby acting as crew-assist devices. To latch or unlatch the hatch, the gearbox handle must be rotated 440°.

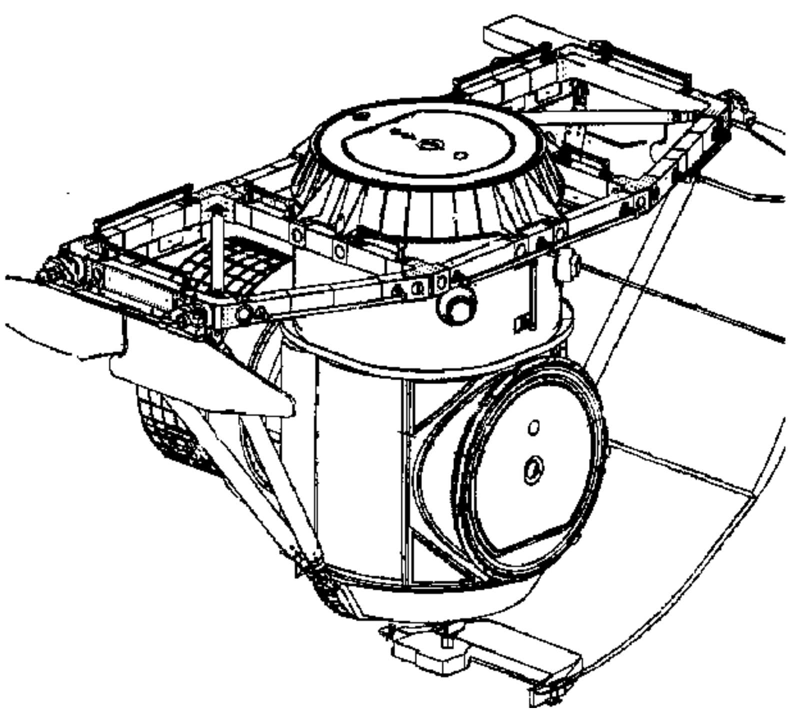
The hatch actuator/gearbox is used to provide the mechanical advantage to open and close the latches. The hatch actuator lock lever requires a force of 8 to 10 pounds through an angle of 180° to unlatch the actuator. A minimum rotation of 440° with a maximum force of 30 pounds applied to the actuator handle is required to operate the latches to their fully unlatched positions.



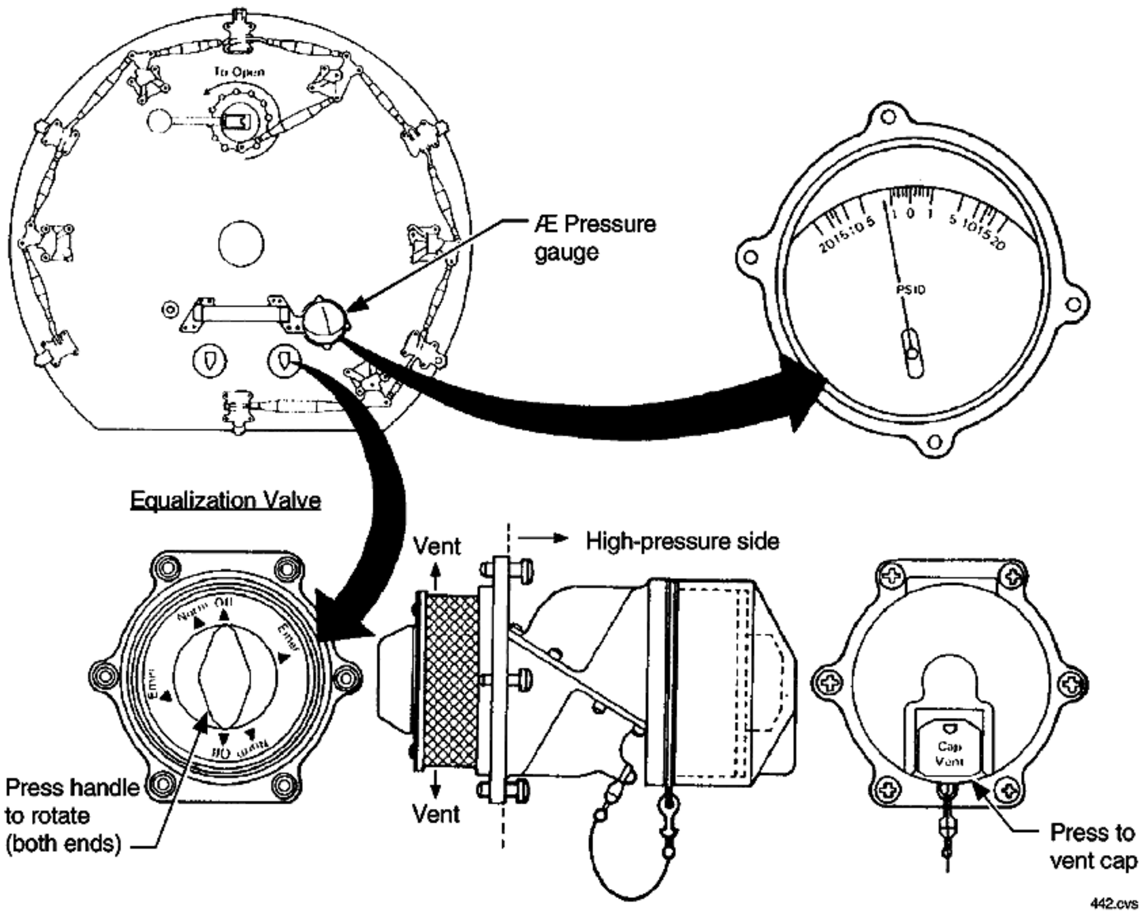
Airlock in Middeck



External Airlock
(port side view)



External Airlock ISS Configuration
(planned for OV-103, OV-104, OV-105)

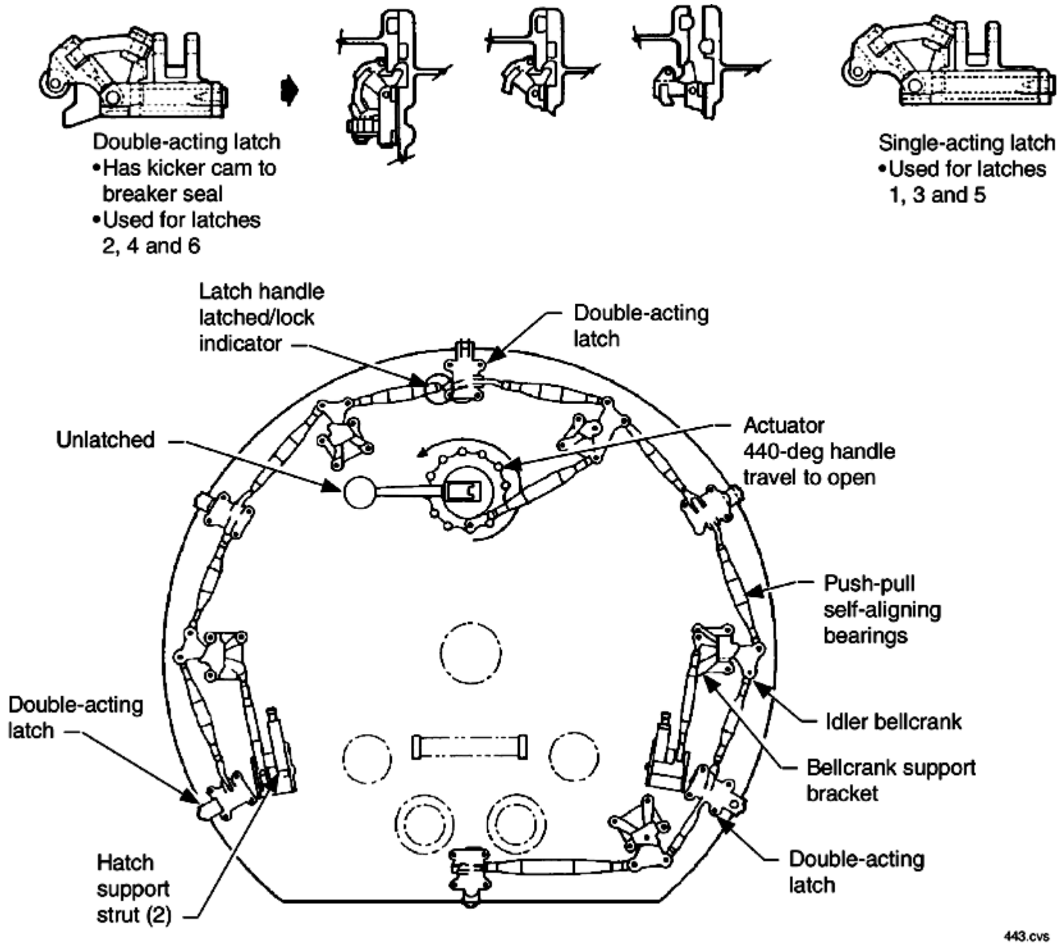


Airlock Repressurization, Schematic Diagram

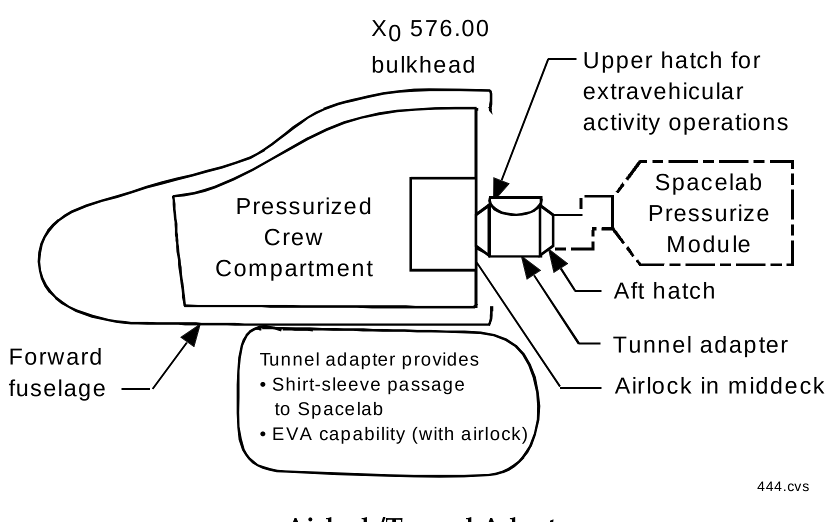
The hinge mechanism for each hatch permits a minimum opening sweep into the airlock or the crew cabin middeck.

The inner hatch of the internal airlock (airlock to crew cabin) is pulled or pushed forward to the crew cabin approximately 6 inches. The hatch pivots up and to the right side. Positive locks are provided to hold the hatch in both an intermediate and a full-open position. The outer hatch of the internal airlock (airlock to payload bay) opens and closes to the contour of the airlock wall. The hatch is hinged to be pulled first into the airlock and then forward at the bottom and rotated down until it rests with the low-pressure (outer) side facing the airlock ceiling (middeck floor). The hatch has a hold-open hook that snaps into place over a flange when the hatch is fully open. To support and protect the hatch against the airlock ceiling, the hatch incorporates two deployable struts.

The configuration of the external airlock, planned for International Space Station (ISS) operations, contains an inner hatch, an EV hatch, and a docking hatch. The inner hatch of the external airlock (airlock to crew cabin mid-deck) has the same opening mechanism as the outer hatch of the internal airlock. The hatch is hinged so that it can be pulled into the middeck and rotated down until it rests on the middeck floor. The EV hatch of the external airlock (airlock to payload bay) also opens in the same manner. The docking hatch, located on the floor of the external airlock (toward the payload bay doors), is hinged to be pulled into the airlock and then rotated until the low pressure side rests against the airlock wall facing toward the nose of the orbiter. The external airlock hatches also have hold-open protection and deployable struts for support against the airlock structure.



Airlock Hatch Latches, Schematic Diagram



Airlock/Tunnel Adapter

Airlock Subsystems

The airlock air circulation system provides conditioned air to the airlock during non-EVA periods. The airlock revitalization system duct is attached to the outside airlock wall at launch. Upon airlock hatch opening in flight, the duct is rotated by the flight crew through the cabin/airlock hatch and installed in the airlock. The duct has a removable air diffuser cap, installed on the end of the flexible duct, which can adjust the air flow from 216 pounds per hour. The duct must be rotated out of the airlock before the cabin/airlock hatch is closed for chamber depressurization. During the EVA preparation period, the duct is rotated out of the airlock and can be used for supplemental air circulation in the middeck.

To assist the crewmember before and after EVA operations, the airlock incorporates handrails and foot restraints. Handrails are located alongside the avionics and ECLSS panels, with aluminum alloy handholds mounted on each side of the hatches. Each handrail has a clearance of 2.25 inches between the airlock wall and the handrail to allow crewmembers to grip it while wearing a pressurized glove. Foot restraints, sized for the EMU boot, can be installed on the airlock floor nearer the payload bay side. The ceiling handhold is installed nearer the cabin side of the airlock. A rotation release knob on the foot restraint is designed for shirt-sleeve operation and, therefore, must be positioned before the suit is donned. The foot restraint is bolted to the floor and cannot be removed in flight.

Airlock-based EMU support components provide for EMU stowage, EMU operational support, and EMU recharge during intravehicular activity operations. These components include the EMU mount, the service and cooling umbilical, and the lower torso restraint bag. The EMU mount provides a mechanical interface between the EMU and airlock wall for EMU stowage. The mount attaches to the back side of the EMU and engages with three fixtures on the wall of the airlock. The mount is also used to maintain the EMU in a fixed position on orbit for EMU donning and doffing operations. If necessary, the EMU mount can be removed from the airlock wall while on orbit.

The service and cooling umbilical consists of three water hoses, a high pressure oxygen hose, electrical wiring, water pressure regulators, and a strain relief tether. The system is used to interconnect the EMU and the orbiter airlock for two major functions: electrical power, hardline communications, oxygen supply, wastewater drainage, and water cooling capability from the orbiter during IVA operation; and recharge capability for the PLSS oxygen tanks, water reservoir, and battery.

The lower torso restraint bag is attached to the bottom of the EMU mount and covers the lower torso of the EMU to restrain it during launch and entry. Straps on either side of the bag are attached to points on the upper part of the EMU mount and are tightened to ensure that the EMU is fully restrained.

For Spacelab/Spacehab module missions, the internal airlock is used along with a tunnel adapter that mates with the airlock and a Spacelab/Spacehab tunnel that is installed in the payload bay. The airlock tunnel adapter, hatches, tunnel extension, and tunnel permit the flightcrew to transfer from the orbiter's pressurized middeck compartment to the Spacelab/Spacehab pressurized shirt-sleeve environment. An upper hatch in the tunnel adapter provides egress/ingress for EVA operations. The external airlock is used in conjunction with the tunnel adapter during Spacelab/Spacehab missions when the orbiter is docked to Mir or the ISS. In the event of an EVA, the flightcrew is not present in the Spacelab/Spacehab.

EVA Support Equipment

A variety of equipment is available to support the EVA crewmember. Depending on the task to be performed, the proper tool is available outside the airlock. The general equipment functions include securing the crewmember to the orbiter/RMS, providing the crewmember with mechanical assistance, and assisting the crewmember in mobility. The following list itemizes the EVA support components with a brief description of their functions.

Crewmember safety tether - ensures the crewmember is positively tethered to the orbiter while providing access to all areas of the payload bay.

Before airlock egress, this 55-foot safety tether is attached to a waist tether and remains attached at all times during EVA, while the crewmember translates from one area of the payload bay to another.

Slidewires - facilitate the translation of a crewmember and equipment in the forward and aft directions of the payload bay. Two slidewires are installed for all STS flights on either side of the payload bay for a length of approximately 46 feet.

Tethers - include waist and wrist tethers. Waist tethers are used to attach the crewmember to the orbiter safety tether system and to provide additional crewmember restraint at a worksite when required. Waist tethers use a large hook to be attached to various tether points (including the crewmember safety tether) and a small hook that attaches to an EMU waist tether ring. Wrist tethers are used to secure tools and hardware to the EVA crewmember and to tether points. Wrist tethers are both fixed and adjustable, attaching to loops on the EMU glove.

Handrails - aluminum tubing strategically located to aid in crewmember translation or restraint to accomplish a specific task. Handrails are located on the forward and aft bulkheads, the hingeline of the payload bay doors, and the RMS end effector. Handrails are designed with tether attach points.

Portable foot restraint - a working platform designed to restrain the EVA crewmember while performing contingency operations on various components of the payload bay systems. The portable foot restraint stabilizes the crewmember by using a system of toe guides and heel clips designed to interface with the EMU boots.

EVA Winch - allows the EVA crewmember to close the payload bay doors in the event of a payload bay door drive system failure. Prior to launch, the winch is mounted on both the forward and aft payload bay bulkheads. The winch consists of a reel, assisted by spring energy, housing 24 feet of 3/8-inch-diameter Kevlar rope with a hook attached to the free end.

Provisions stowage assembly (PSA) - an aluminum tool stowage container mounted under the cargo bay liner, flush with the bottom of the payload bay. Tool box tether protocol: when stowing the tools in the PSA, the tools/tool caddies are tethered before they are removed from the mini-workstation and untethered only after they are securely placed in their corresponding storage cavity. The tools listed below are contained within the PSA.

Mini-workstation - a mechanical device that mounts on the front of the EMU to stow tools and to provide a means of tether restraint for an EVA crewmember at a worksite.

Tube cutter - used for a contingency door-closing operation. The tool consists of spring-loaded retention rollers, a cutter wheel mounted on a slide, a blade ratchet handle, a rotating body, a control lever, and a tube-cutter ratchet handle. It is designed to cut drive door linkages.

Payload bay doors disconnect tools - used to disengage the payload bay doors power drive unit(s) (two) from the power-drive-unit torque shaft, allowing manual closing of the doors. The tool is approximately 6-3/4 inches long from the tip of the tether ring to the end of the 3/8-inch steel square drive extension. Additional tools for disconnecting the door drive linkage system include vise-grip, ratcheting box-end wrench, adjustable wrench, loop pin extractor, Velcro/tape caddy, bolt puller, and trash bag.

Three-point latch tool - used to compensate for failed bulkhead latches. The tool consists of a stowable ratchet handle, two interchangeable tool handles, a ratchet control selection lever, a spring-loaded compensator, and two fixed-load pickup points.

Centerline latch tool - used to compensate for a failed payload bay door centerline latch. The tool consists of a fixed-load and a spring-loaded pickup point, plus a reversible ratchet with a stowable handle and a pair of trigger release buttons with a safety that prevents an accidental release.

Airlock latch disconnect tool - a common, EVA-modified, crescent wrench used to force open a jammed latch and/or latches disconnected from the rotary actuator. The other contingency airlock disconnect tool is a drive ratchet with a 7/16-inch hex socket and 4-inch extension.

RMS rope reel - used in conjunction with the snatch blocks in the event of an RMS joint failure. The reel consists of a rope spool, spool bracket, rope guide, and cam cleats. The rope reel contains approximately 80 feet of 5/16-inch-diameter Kexlon rope.

Snatch block - a common marine device used, in the event of an RMS failure, in conjunction with the RMS rope reel and EVA winch to backdrive the RMS to a stowed position.

Payload retention device (PRD) - used as an on-orbit temporary tiedown tool so that the article or payload being secured can be repositioned as necessary to prevent damage. It consists of a housing that encloses a 15-foot Kevlar webbing strap on a spring-loaded reel.

RMS manipulator positioning mechanism wrench (RMS MPM wrench) - a double-ended, open-end steel wrench used to deploy or stow the MPMs (in the event the MPM motors fail) by manually turning the drive shaft in the appropriate direction, thus allowing for payload deployment and/or payload bay door closing.

RMS shoulder brace release - a flat steel bar with an angled foot used to disengage the RMS shoulder brace locking mechanism, thus releasing the shoulder brace. If the lock is not released, the RMS is inoperative.

Grapple fixture release tools - used to remove a grapple fixture shaft should an end effector malfunction, failing to release a payload. The tools include a probe and 1/2-inch ratcheting box-end wrench.

Radiator actuator disconnect tools - A 3/8-inch drive ratchet and 1/4-inch allen wrench extension used to disconnect a failed radiator actuator and support stowage of the radiators.

External tank umbilical door tool - used to override a failed external tank door centerline latch and support ET door closure.

Generic jam removal tools - diagonal cutter, cable cutter, needle nose pliers, probe, hammer, prybar, forceps, trash bag. For use in disconnecting or dislodging jams in various orbiter mechanisms, such as PLBD hinges, latches, etc.

Portable foot restraint (PFR) bridge clamp - provides a PFR socket that mounts on the sill of the PLB in available locations on existing bridge rails.

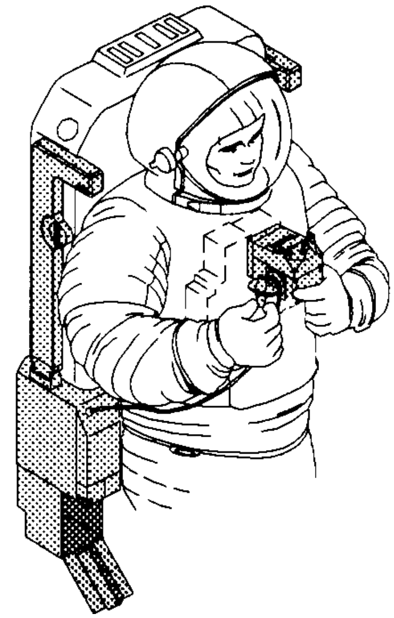
Simplified Aid for EVA Rescue

The simplified aid for EVA rescue (SAFER) is a small, self-contained, propulsive backpack system used to provide a free-flying rescue capability for an EVA crewmember. SAFER is a "simplified," single-string system that fits on the bottom of the EMU PLSS and attaches to existing mounts on the sides of the PLSS. In essence, SAFER is a small simplified version of the manned maneuvering unit (MMU). Because it is intended for self rescue use only, SAFER does not have the propellant capacity and systems redundancy that was provided with the MMU.

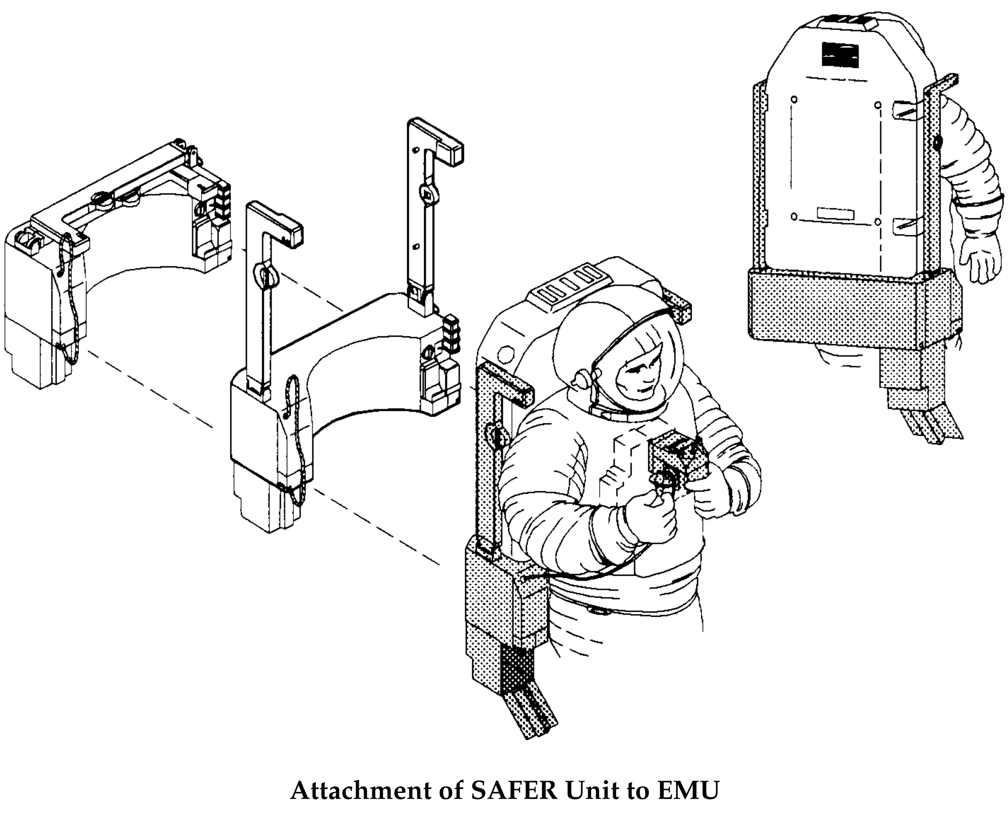
SAFER is designed to be used as a self-rescue device for a separated EVA crewmember in situations where the orbiter is unavailable to provide rescue capability. Such situations would include when the orbiter is docked to a large payload or structure, such as the Russian Mir Space Station or ISS. The SAFER will also be used during all future ISS EVA operations where the orbiter might not be present at the ISS during an EVA.

To provide self-rescue capability, the SAFER offers 13 minutes of propellant and control authority to stabilize and return a tumbling/separating EVA crewmember. The SAFER has 24 gaseous-nitrogen (GN_2) thrusters to provide 6 degrees-of-freedom maneuvering control. The SAFER is controlled by a single hand controller housed in a hand controller module box located on the bottom of the unit. The SAFER propulsion subsystem provides a total delta velocity of at least 10 ft/sec with an initial charge. The flight unit weighs approximately 85 pounds and folds for launch, landing, and on-orbit stowage.

The SAFER is the product of a Johnson Space Center (JSC) in-house project to develop, build, and produce a rescue device for the instances when the orbiter cannot provide rescue capability and for ISS EVA operations. An on-orbit SAFER detailed test objective (DTO) conducted on space shuttle mission STS-64 was very successful. This DTO demonstrated SAFER's operational capabilities and collected performance data to augment the design and development of the final operational SAFER. The STS-76 SAFER was a transitional unit between the DTO unit flown on STS-64 and the final production unit that will be manifested for ISS. The operational unit will be capable of being stationed on-orbit for 1 year; however, after use on orbit, the unit will be returned to Earth for refurbishing.



Simplified Aid for EVA
Rescue (SAFER)



Attachment of SAFER Unit to EMU

Operations

As previously discussed, there are three types of EVA: scheduled, unscheduled, and contingency. A scheduled EVA is defined as any EVA incorporated into the normal flight plan in order to complete a specific mission objective. An unscheduled EVA is not part of the flight plan; rather, it is conducted to achieve payload operation success or to advance overall mission accomplishments. A contingency EVA is also unscheduled, but is required to ensure safe return of the orbiter and flight crew.

Regardless of the EVA type, a series of procedures are required to initiate and terminate an EVA. These procedures cover an integrated timeline sequence from the EVA checklist. The detailed procedures are summarized for reference in the following steps:

1. ***Quick don mask prebreathe*** - Donning of the mask for prebreathe and cabin depressurization.

2. ***Cabin depressurization to 10.2 psi*** - Reducing the cabin pressure from 14.7 psi to 10.2 psi.

3. ***EMU checkout*** - Preliminary checkout of the EMU systems prior to EMU donning.

4. ***Middeck preparation and preparation for donning*** - Configuration of the EMU and its ancillary components for crewmember donning.

5. ***Suit donning*** - Crewmember donning of the EMU and ancillary components, approximately 40 minutes duration.

6. ***EMU check*** - Configuration and checkout of the EMU prior to EMU purge.

7. ***EMU purge*** - Nitrogen purge of the EMU prior to prebreathe.

8. ***Prebreathe*** - Crewmember acclimation to lower chamber pressure, over a period of 40 to 70 minutes.

9. ***Preparation for depressurization*** - Configuration of the airlock and closing the inner hatch prior to airlock depressurization.

10. ***Airlock depressurization*** - Configuration and checkout of the EMU, airlock depressurization to vacuum, and opening of the outer hatch.

11. ***Airlock repressurization*** - Airlock repressurization and opening of the inner hatch.

12. ***Post-EVA*** - Shutdown of the EMU systems and doffing of the EMU and ancillary components.

13. ***EMU maintenance/recharge*** - Change-out or recharge of the EMU battery and lithium hydroxide cartridge and general cleaning of the EMU for subsequent EVA; recharge of the EMU water system.

14. ***Post-EVA entry preparation*** - Reconfiguration and restowage of the EMU and airlock equipment.

A set of procedures are followed when a crewmember has contracted the bends during an EVA. The crewmember discontinues the EVA and returns to the airlock to connect to the service and cooling umbilical. The airlock is repressed to 10.2 psia, and the cabin is repressed to 14.7 psia. The helmet is doffed, and the crewmember drinks a minimum of 32 ounces of fluids. After proper EMU reconfiguration, the bends treatment adapter is installed for bends recovery.

Scheduling an EVA is a very complex and involved task. The following list outlines the general mission constraints regarding EVA, but does not attempt to define the detailed specific activities.

- The maximum scheduled duration for an EVA is 6 hours.
- All scheduled and unscheduled EVAs require two crewmembers.
- No scheduled or unscheduled EVA shall occur on flight day 1 (~24 hours MET).

- No scheduled EVA shall be planned to occur prior to flight day 4 (~72 hours MET) unless:

  i) A specific flight is dedicated to scheduled EVA activity, and

  ii) That payload customer has specifically negotiated with NASA for the early scheduled EVA capability, and an exemption is processed.

- The latest an EVA may be scheduled in preflight planning is EOM-2.

- No unscheduled EVA shall be planned to occur prior to flight day 3 (~48 hours MET) unless:

  i) A specific payload has no alternative but to utilize an EVA as its third level of redundancy for the purpose of a critical backup to deploy/operations that would prevent loss of the payload, and

  ii) That payload customer has been made aware of the inherent risk that the EVA may not be able to be performed due to crew status, and the customer has agreed to accept the risk, and

  iii) That payload customer has specifically negotiated with NASA for the early unscheduled EVA capability, and an exemption is processed.

- The following are required response times prior to an unscheduled payload EVA:

  i) Upon the discovery of a failure leading to an EVA, approximately 24 hours are allotted for EVA preparation prior to starting actual EVA maintenance on a failed component.

  ii) If the case above occurs on launch day, then approximately 44 hours are allotted prior to starting EVA maintenance.

  iii) If a payload requires a shorter EVA response time, then the requirement for that EVA must be negotiated with NASA, and an exemption must be processed.

- Payload activities that could require an unscheduled EVA at the end of a mission may only be scheduled if there are sufficient consumables and landing opportunities to extend the mission to perform the EVA and preserve 2 wave-off days.

- A minimum of 1 flight day must separate two scheduled EVAs, for any given EVA crewmember.

- A contingency EVA will be scheduled in real time whenever it is necessary to restore the orbiter to a configuration for safe return.

Contingency EVAs occur if orbiter hardware sustains a malfunction. Procedures, tools, and specified work locations are identified for practice on any STS mission. The recognized failures pertain to the following orbiter systems: radiator actuator, payload bay doors, bulkhead latches, centerline latches, airlock hatch, remote manipulator system (RMS), bulkhead camera, Ku-band antenna, and external tank doors. The corrective actions for each system failure are itemized in the following table.

FAILURE	CORRECTIVE ACTION
Radiator actuator	Radiator actuator disconnect
Payload bay door system	PDU Winch operations PLBD drive system linkage cut PLBD drive system disconnect Electrical crossover disconnect Jam removal
Bulkhead latch	3-point latch tool installation Jam removal
Centerline latch	Centerline latch tool installation Jam removal
Airlock hatch	Airlock latch disconnect Hinge disconnect
RMS	RMS joint alignment RMS tiedown MPM stow/deploy RMS shoulder brace release Grapple fixture release
Bulkhead camera	Disconnect and remove camera
Ku-band antenna fails to align for stowing	Ku-band antenna gimbal alignment
External tank door	ET door centerline latch release

System Failure Corrective Actions Table

EVA Summary Data

- EVA refers to operations performed outside the spacecraft crew compartment.

- For generic orbiter missions, two suits are included with consumables provided for three, two-person, 6-hour EVAs.

- There are three basic categories of EVA: scheduled, unscheduled, and contingency.

- The extravehicular mobility unit (EMU) is an independent anthropomorphic system that provides environmental protection, mobility, life support, and communications for the crewmember to perform EVA in Earth orbit. An EVA is defined, for EMU design considerations, as any time the EMU external environmental pressure is below 4.0.

- The EMU is an integrated assembly, primarily composed of the space suit assembly, life support system, and numerous items of associated support and ancillary equipment.

- The orbiter's airlock permits EVA flight crew members to transfer from the middeck crew compartment into the payload bay in EMUs without depressurizing the orbiter crew cabin. The airlock also provides launch and entry stowage of up to three EMUs.

- The airlock's support functions include airlock depressurization and repressurization, EVA equipment recharge, LCVG water cooling, EVA equipment checkout, donning, and communications.

- Depending on the task to be performed, the proper tool is available outside the airlock. The general EVA-support equipment functions include securing the crewmember to the orbiter/RMS, providing the crewmember with mechanical assistance, and assisting the crewmember in mobility.

- A standard series of procedures (pre and post operations) are required to initiate and terminate an EVA, regardless of the EVA type.

EVA Rules of Thumb

- Always use "make before break" tether protocol.

- Don't use the glove as a hammer.

- EVA crewmember and equipment must remain tethered at all times.

- Slow and deliberate motion provides much greater stability than quick, jerky motions.

- Body positioning is 90 percent of the task.

- Each EVA crewmember should check out his or her own EMU.