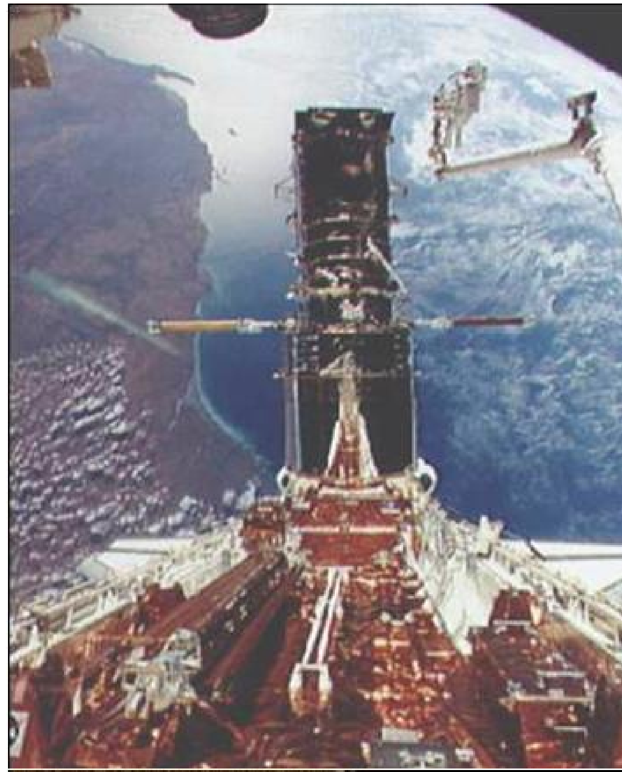
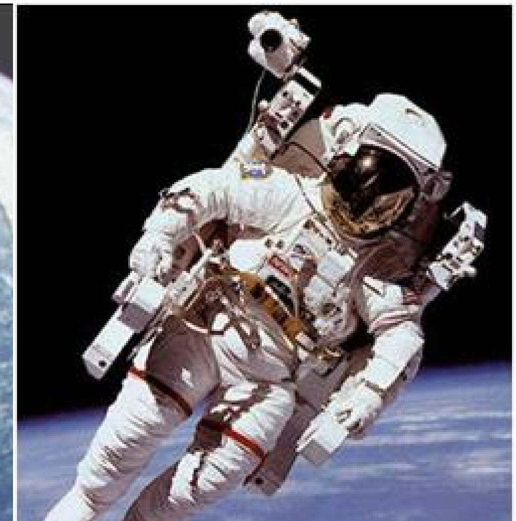
Extravehicular Activity (EVA) Hardware & Operations Overview

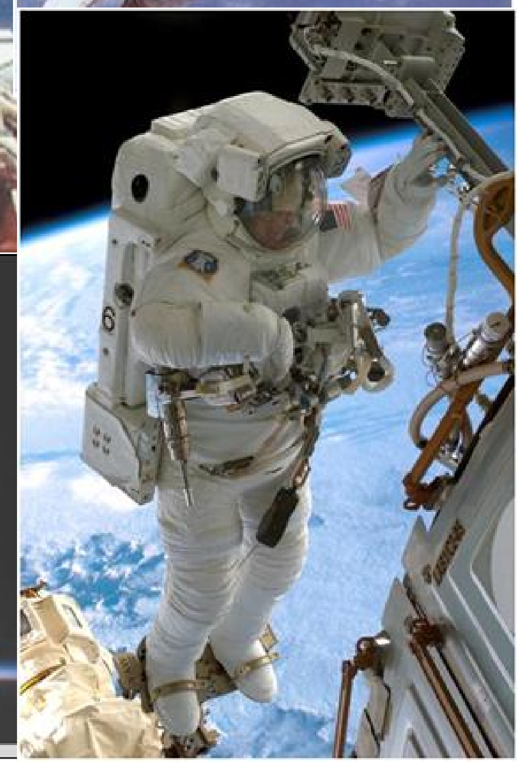
Objectives and Overview

- Define Extravehicular Activity (EVA), identify the reasons for conducting an EVA, and review the role that EVA has played in the space program
- Identify the types of EVAs that may be performed
- Describe some of the U.S. Space Station equipment and tools that are used during an EVA
  - Extravehicular Mobility Unit (EMU)
  - Simplified Aid For EVA Rescue (SAFER)
  - International Space Station (ISS) Joint Airlock and Russian Docking Compartment 1 (DC-1)
  - EVA Tools & Equipment
- Outline the methods and procedures of EVA Preparation, EVA, and Post-EVA operations
- Describe the Russian spacesuit used to perform an EVA
- Provide a comparison between U.S. and Russian spacesuit hardware and EVA support
- Define the roles that different training facilities play in EVA training

Definition of EVA

- Extravehicular Activity (EVA)
  - Definition: Crewmember leaves the protective environment of a pressurized spacecraft cabin and ventures out into vacuum of space wearing an extravehicular spacesuit.
  - Purpose
    - Contingency or Mission Success Repairs
    - Experiments or Testing
    - Spacecraft Servicing
    - Space Structure Construction [e.g., International Space Station (ISS)]



Definition of Spacesuits

- Spacesuits
  - Typically, 2 types of pressurized “spacesuits’ have been constructed to support our space programs
    - Launch, entry, and abort (LEA) spacesuit
      - Used to protect crewmembers from launch, ascent, abort, landing and other dynamic loading.
      - Capable of providing protection from loss of cabin pressure and crew rescue following landing.

Launch/Entry Suit

→

- Extravehicular Activity (EVA) spacesuit
  - Used to allow crewmembers to work effectively in the harsh external space environment (provides protection from vacuum, thermal, mircrometeoroids, radiation, etc.).

EVA Suit

Historical Overview

- First EVA was conducted by USSR/Alexi Leonov on March 18, 1965.
  - Many EVAs have since been accomplished by the Soviet Union & Russia continuing into the International Space Station era.

U.S. EVA Experience

- Gemini EVA Experience -
  - Astronaut Edward White II performed first U.S. EVA during Gemini IV June 3, 1965.
  - Start of EVA program was excursion to perform a special set of procedures in a new and hostile environment.
  - Proved EVA to be a viable technique for operations outside the spacecraft crew compartment.
  - Problems encountered: helmet fogging, overheating due to high metabolic activity (primarily due to suit constraints and lack of training).
  - Gemini Extravehicular Spacesuit and Life Support
    - 5-layer Gemini spacesuit was intended primarily for Intravehicular Activity (IVA).
    - 2 additional layers were added for EVA (making 7 layers total).
    - An umbilical was used to tether the EVA crewmember to the spacecraft and to supply breathing oxygen.
  - 5 Gemini missions involved nine EVAs for a total of **12 hours and 22 minutes** of EVA.

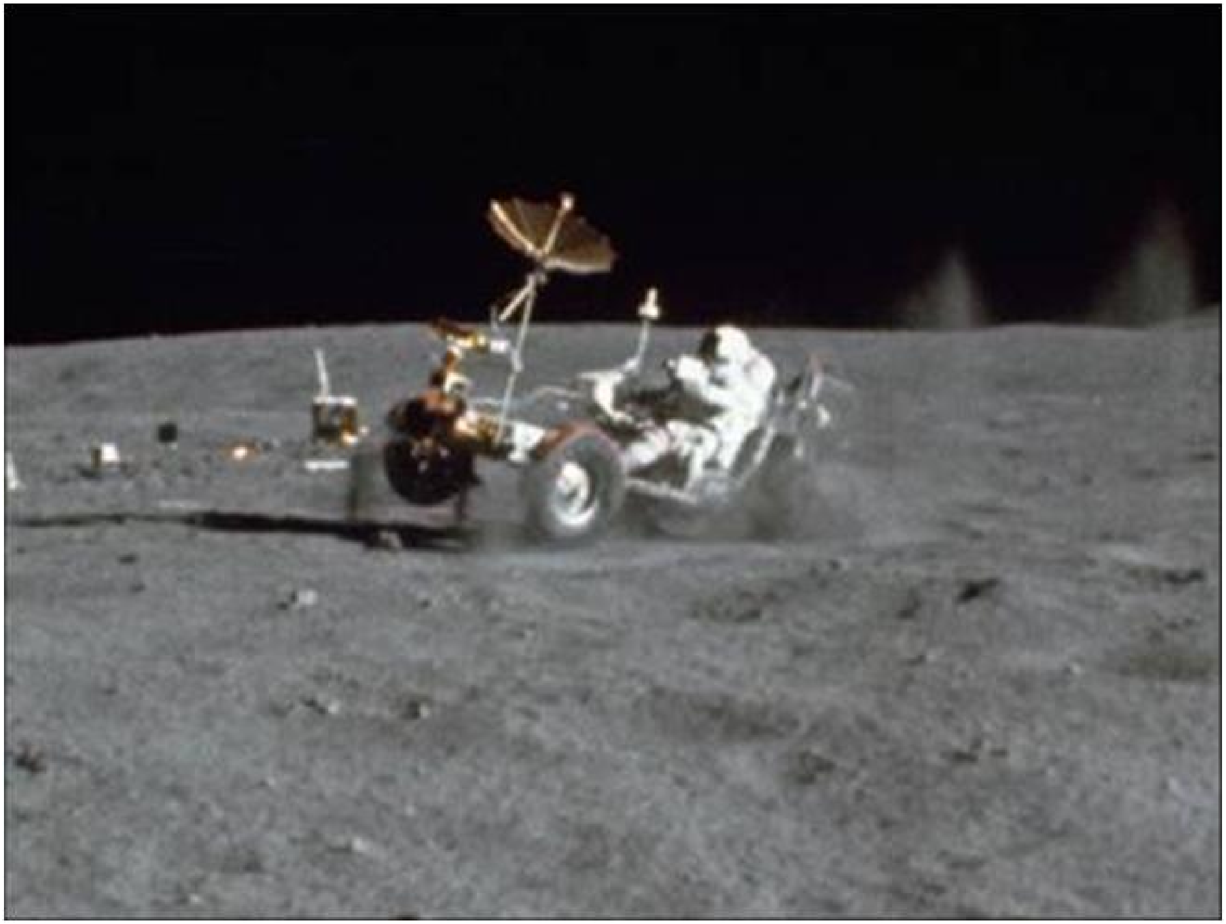
Russian Voskhod 2
1st EVA (Alexi Leonov)

- http://images.search.yahoo.com/search/images;_ylt=A2KJkPo2y.xPWkgAsWOJzbkF?p=voskhod+airlock&fr=yfp-t-701&ei=utf-8&n=30&x=wrt

U. S. Gemini Program
1st American EVA (Ed White)

Historical Overview

- Apollo EVA Experience
  - Spacesuit was redesigned to allow greater mobility.
  - Suit used for lunar and in-space EVAs.
  - Suit was configured with its own portable life support system providing:
    - Pressurization & Atmosphere
    - Communication
    - Ventilation
    - Cooling
    - Waste management system
  - 7 EVA missions totaling **170 hours** of EVA (15 on lunar surface, 5 outside Crew Module).
  - Last 3 Apollo missions (15, 16, & 17) utilized the lunar rover vehicle for greater range in lunar exploration.



Historical Overview

- Skylab EVA Experience
  - Apollo-style suit used.
  - Umbilical replaced portable life support system and provided breathing oxygen, cooling, and served as a tethering device.
  - 10 EVAs were performed during the 3 Skylab missions totaling 82.5 hours.

- Space Shuttle EVA Experience
  - New space suit design for additional mobility and modularity.
  - Portable life support system designed for microgravity operation.
  - Increased operational capability from orbiter.
  - Accumulated 1000s of hours of EVA experience over 200+ EVAs.

- Space Station EVA Experience
  - EMU certified for extended duration on-orbit operations (25 EVAs).
  - Orbital Replacement Unit (ORU) capability added.
  - Accumulated 1000s of hours of EVA experience over 150+ EVAs.

EVA Categories

ISS & Shuttle Terminology

- Three basic categories of EVA:

1. Scheduled EVA:

   EVA planned and trained prior to launch and included in the mission timeline.

   - Both 'skills-' and 'task-based' training used

2. Unscheduled EVA:

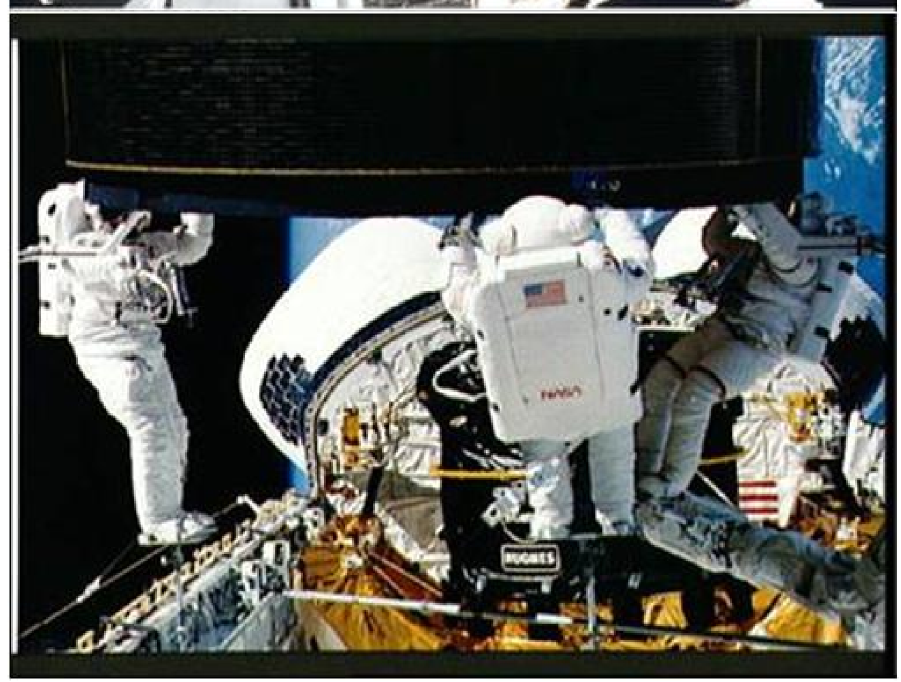
   EVA, although trained, not included in the scheduled mission activities, but which may be required to achieve mission or operational success.

   - Both 'skills-' and 'task-based' training used

3. Contingency EVA:

   EVA required to effect the safety of the crew and vehicle.

   -'Skills-based' training used



US EVA Systems

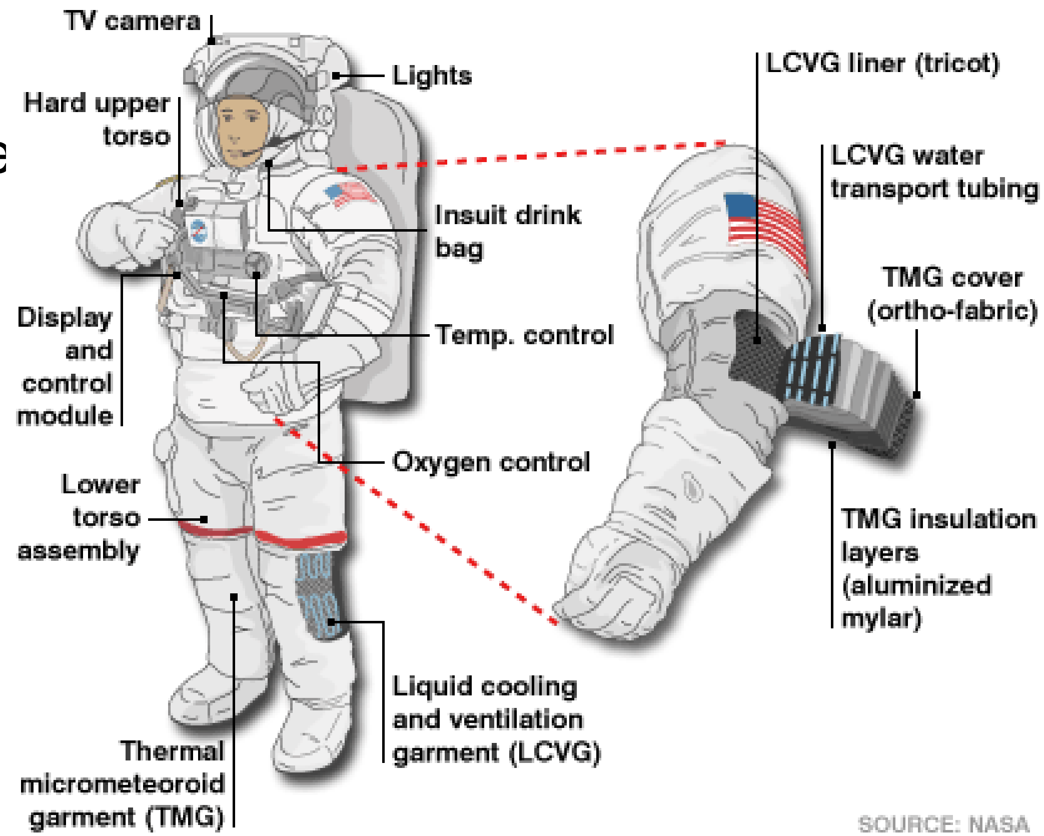
- Extravehicular Mobility Unit (EMU)
- ISS Joint Airlock
- Equipment & Tools (including Simplified Aid For EVA Rescue (SAFER))

EVA Systems - EMU

- The EMU is an independent system that provides the crewmember with environmental protection, mobility, life support, and communications during EVA.

- EMU provides consumables to support an EVA of 7 hours maximum duration.
    - 15 minutes for egress
    - 6 hours for useful work
    - 15 minutes for ingress
    - 30 minutes for reserve

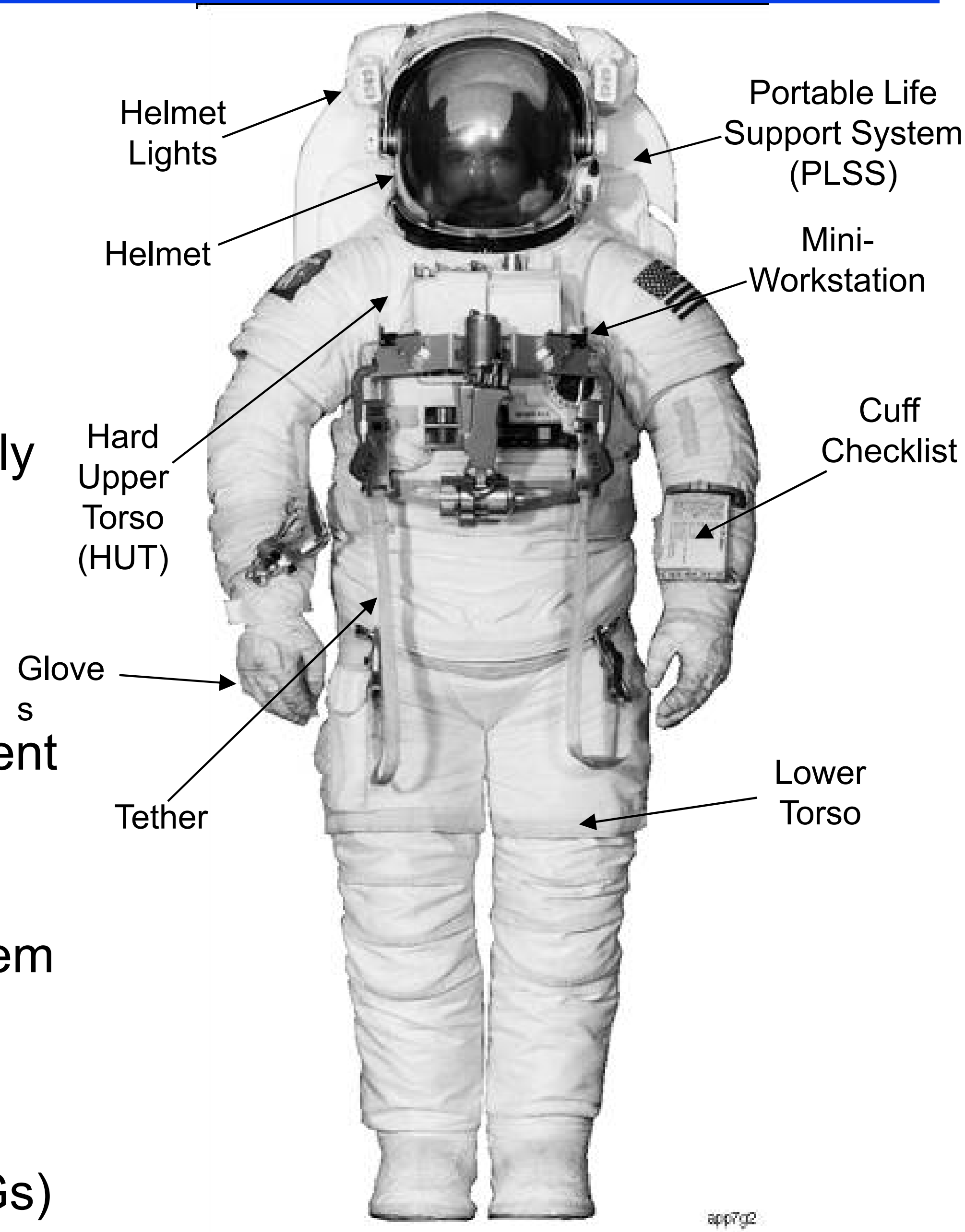
- EMU is an integrated system consisting of two subassemblies:
    - Space Suit Assembly (SSA)
    - Portable Life Support System (PLSS)



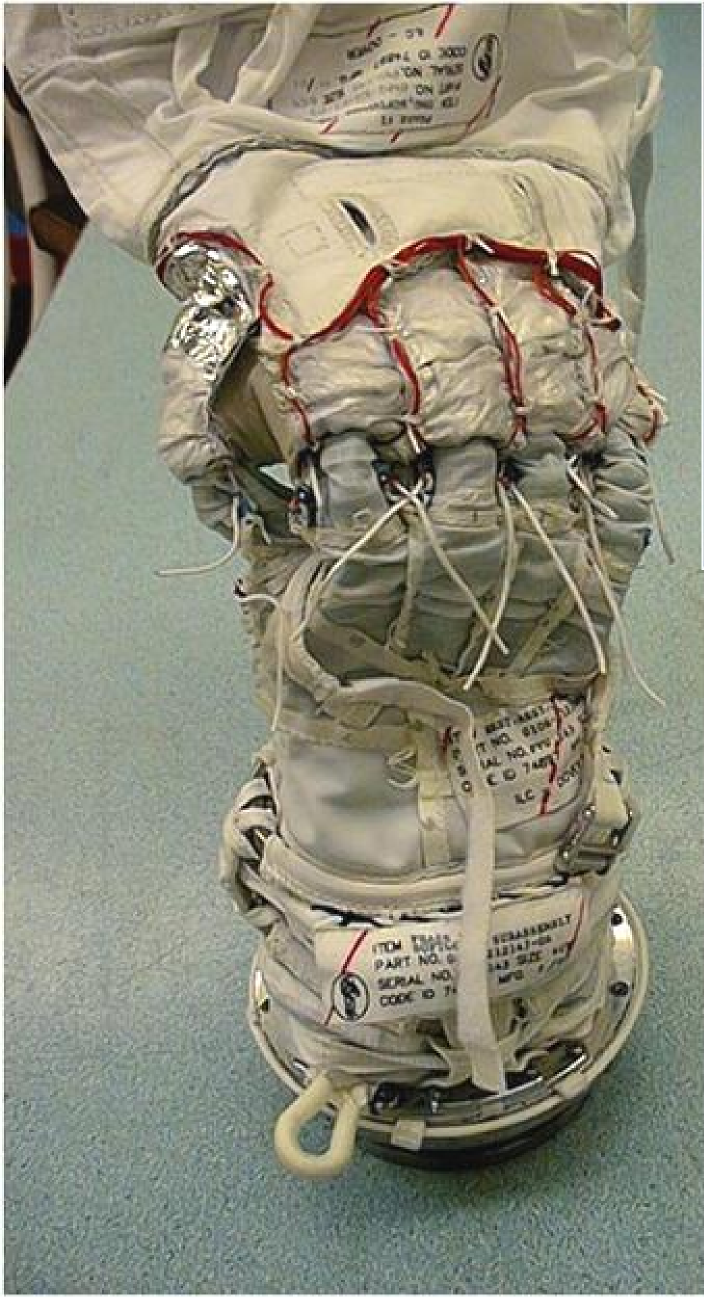
•orbiterchspacenews.blogspot.com

EVA Systems
Space Suit Assembly

- Space Suit Assembly Components:
  - Hard Upper Torso (HUT)/arms
  - Lower Torso Assembly (LTA)
  - Extravehicular (EV) gloves
  - Helmet/Extravehicular Visor Assembly (EVVA)
  - Communications Carrier Assembly (CCA; Comm Cap)
  - Liquid Cooling and Ventilation Garment (LCVG) / Thermal Cooling Under-Garment (TCU)
  - Operational Bioinstrumentation System (EKG)
  - Disposable In-Suit Drink Bag (DIDB)
  - Maximum Absorption Garment (MAGs)



EVA Systems
Space Suit Assembly

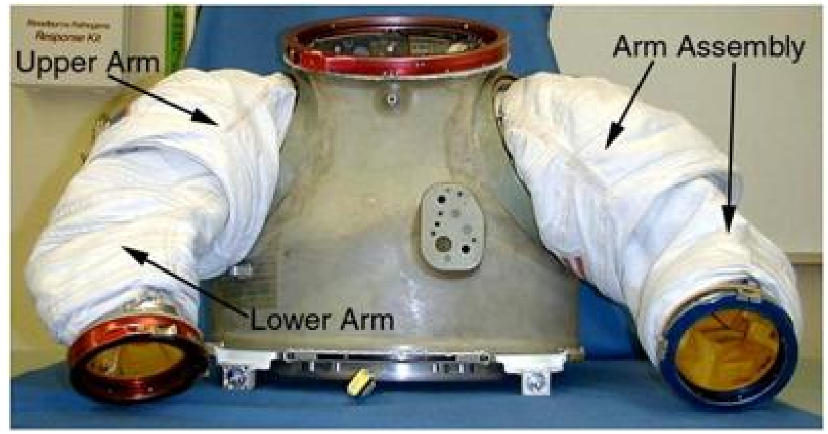


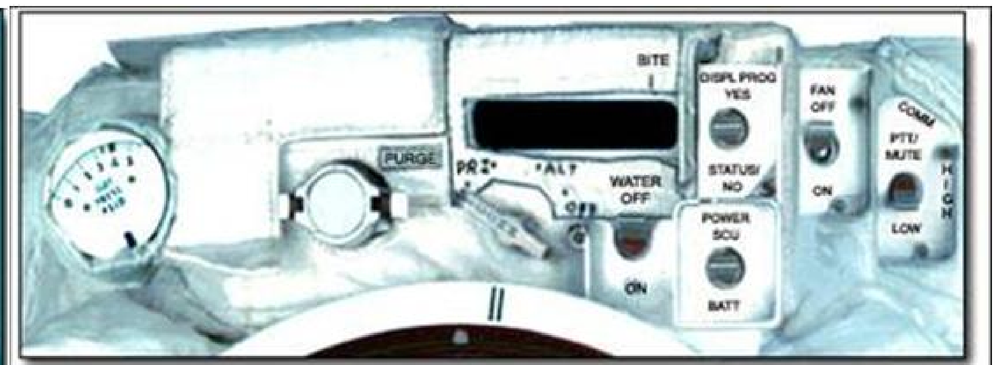
• Extravehicular (EV) gloves

• Extravehicular (EV) boots (and insert)

EVA Systems – Life Support

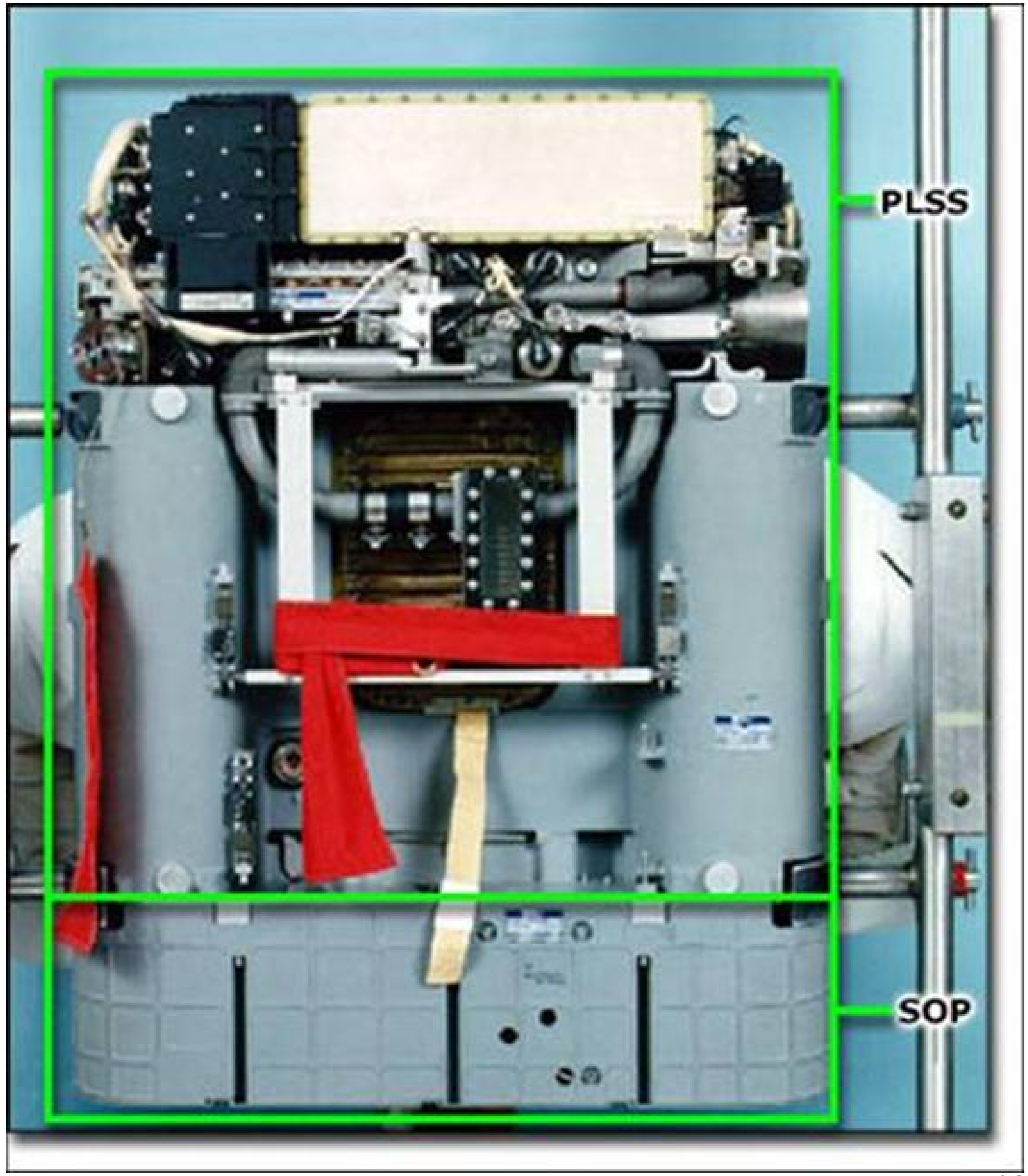
- Life Support System Components:
  - Display and Control Module (DCM)
    - Provides Caution & Warning System (CWS) messages, EMU parameters, and EMU controls to crewmember





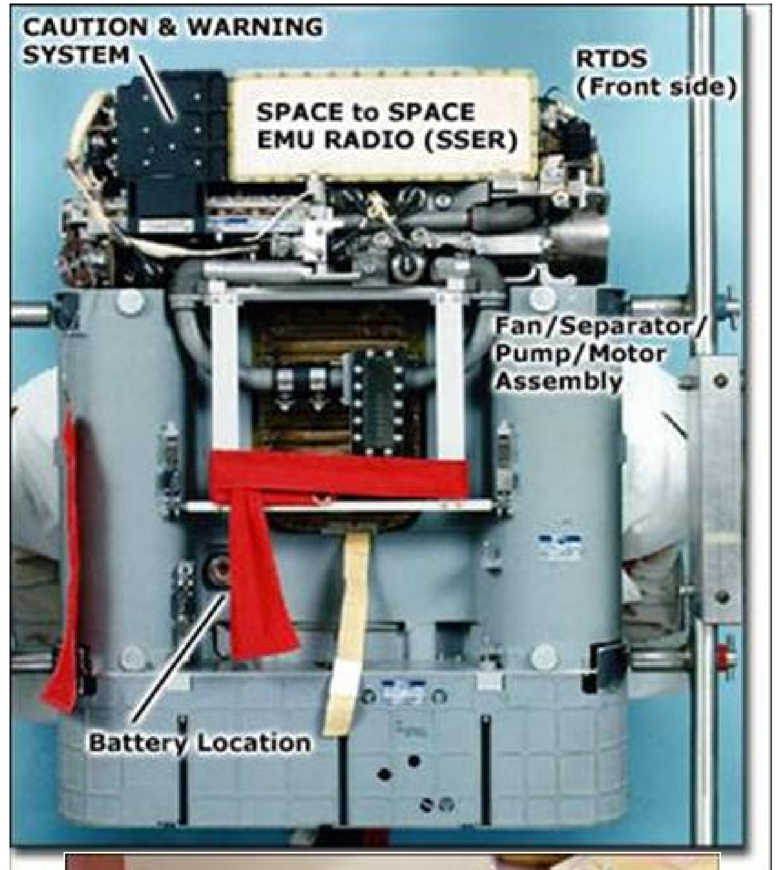
EVA Systems – Life Support

- Life Support System Components:
  - Portable Life Support Subsystem (PLSS)
    - Provides breathing O_2, electrical power, communications, cooling
    - Responsible for suit pressure control
    - Circulates O_2 and removes CO_2, humidity and trace contaminants
    - Controls thermal environment
  - Secondary Oxygen Package (SOP)
    - Provides a minimum of 30 minutes of emergency O_2 in open-loop purge mode
    - Activated automatically during EVA, if necessary



EVA Systems – Life Support

- Life Support System Components (Cont'd):
  - Space-to-Space EMU Radio (SSER)
  - Caution and Warning System (CWS)
  - Early Caution and Warning System (ECWS)
    - Provides EMU status parameters and biomedical data for transmission to Mission Control
  - Battery
    - Primary
    - Rechargeable EVA Battery Assembly (REBA)
  - Contaminant Control Cartridge (CCC; LiOH Cartridge or Metal Oxide (METOX) Cartridge)
    - Removes CO_2 and trace contaminants



•METOX Cartridge

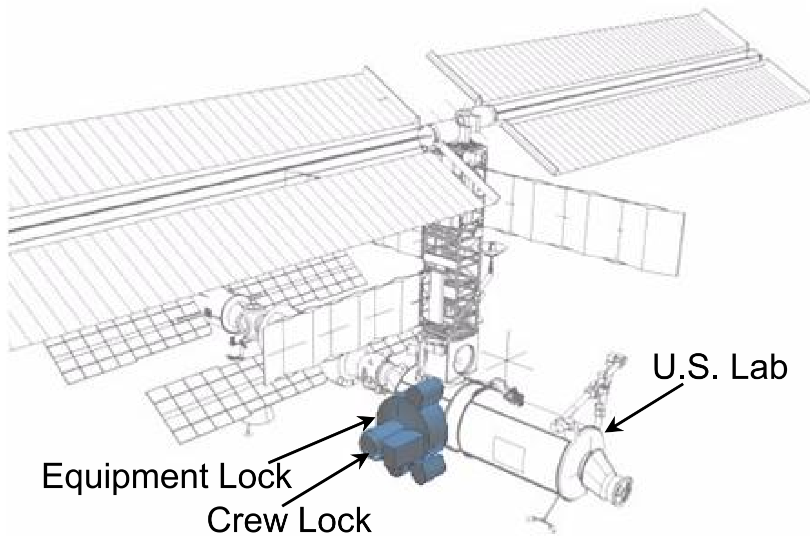
EMU Quantity & Consumables

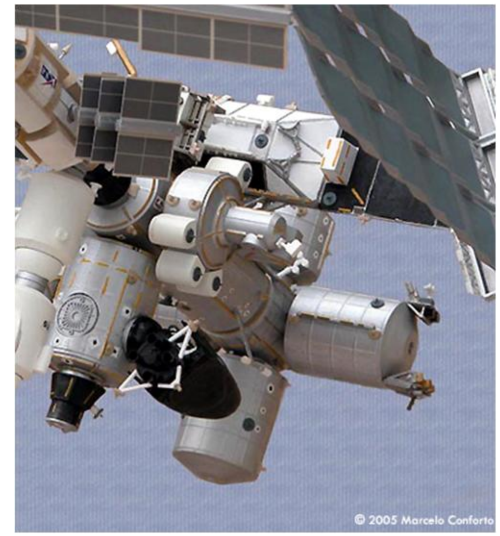
- Space Shuttle
  - Two (2) EMUs are baselined on each Shuttle flight with enough consumables to support three (3), two-crewmember EVAs. Of these 3 EVAs,
    - One 7-hour EVA may be supported.
    - Two EVAs of 3-hours and 4-hours respectively may be supported for Orbiter contingency EVA operations.
  - Consumables provided include:
    - CO_2 cartridge (non-regenerable LiOH)
    - Oxygen
    - Potable water (for drink bags)
    - Feedwater (or sublimator water)
    - Power
    - Battery chargers

- International Space Station (ISS)
  - 4 - EMUs are, typically, kept on board to support EVAs (sizes available: M, L, XL)
  - Sufficient consumables allow a large number of EVAs to be performed
  - Consumables provided include:
    - CO_2 cartridge (metal oxide) and regenerator
    - Oxygen
    - Potable water (for drink bags)
    - Feedwater (or sublimator water)
    - Power
    - Battery chargers

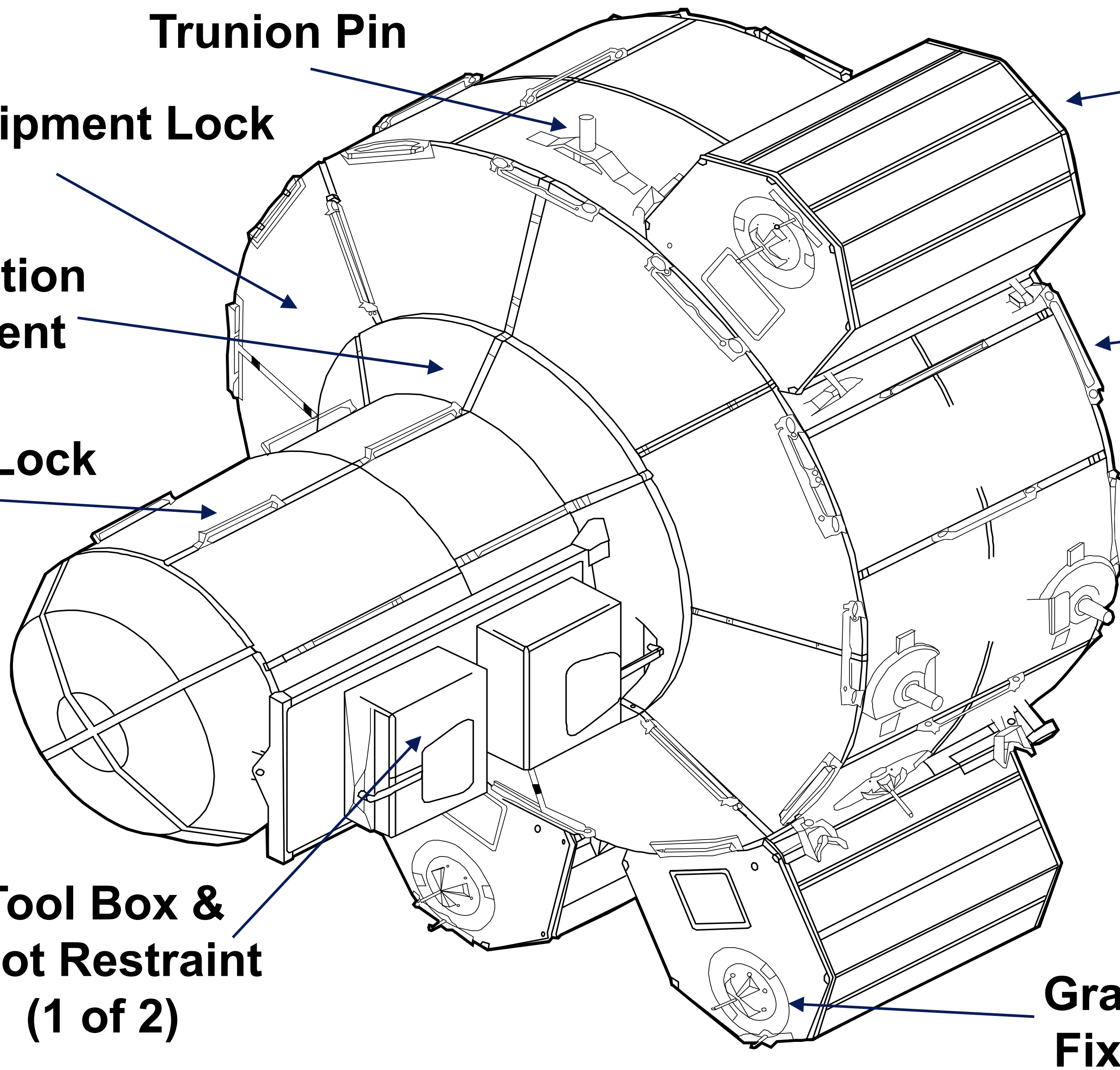
EVA Systems - ISS Joint Airlock

- ISS Joint Airlock:
  - Primary for U.S. ISS EVAs
  - Compatible for use with Russian Orlans
  - Made up of two parts: Crew Lock and Equipment Lock
    - Equipment Lock is used for stowage, recharge & servicing of EMUs, and to suit don/doff
    - Crewlock is the volume nominally depressed to vacuum for EVA

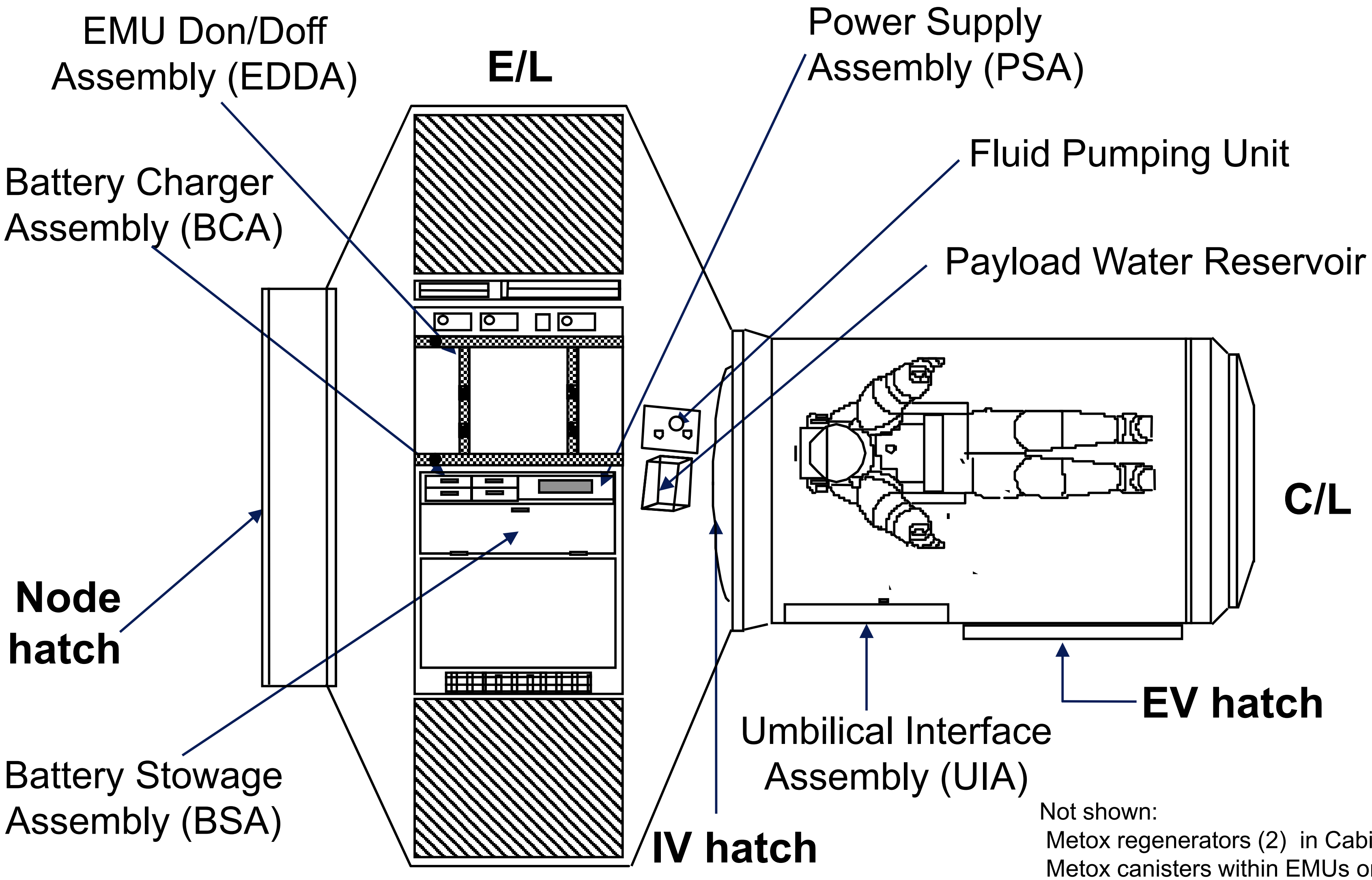




International Space Station (ISS)
Joint Airlock

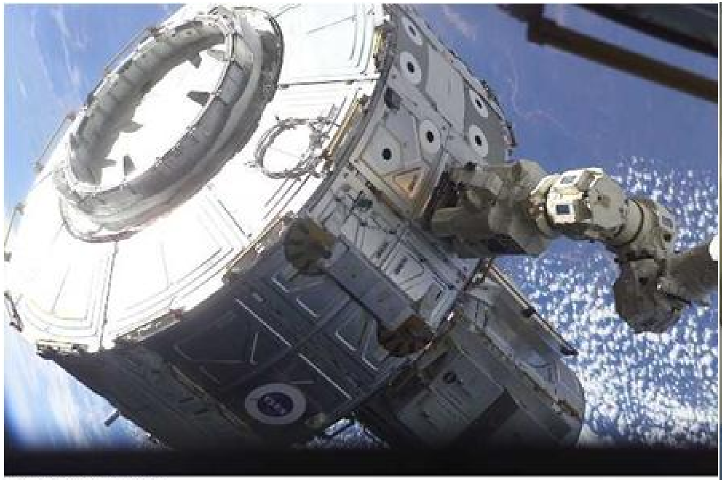


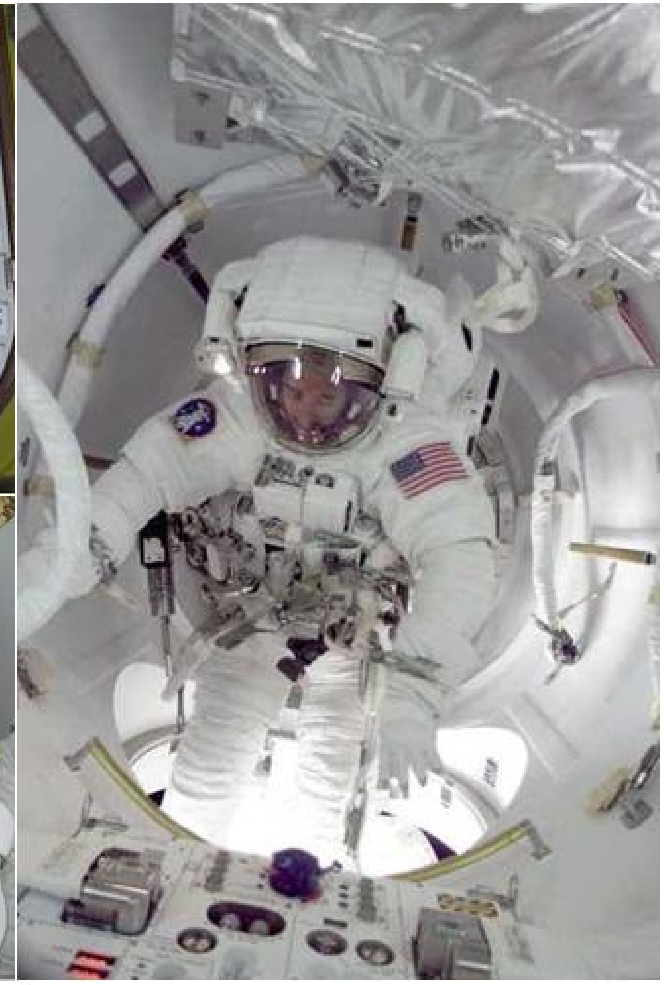
ISS Joint Airlock



Not shown:
- Metox regenerators (2) in Cabin Air Rack
- Metox canisters within EMUs or Metox regenerators
- Oxygen Recharge Compressor Assembly (ORCA) in overhead platform
- Russian Depressurization Pump

EVA Systems - ISS Joint Airlock





STS-104 / Flight 7A

(Summer 2001)

EVA Systems - ISS Joint Airlock

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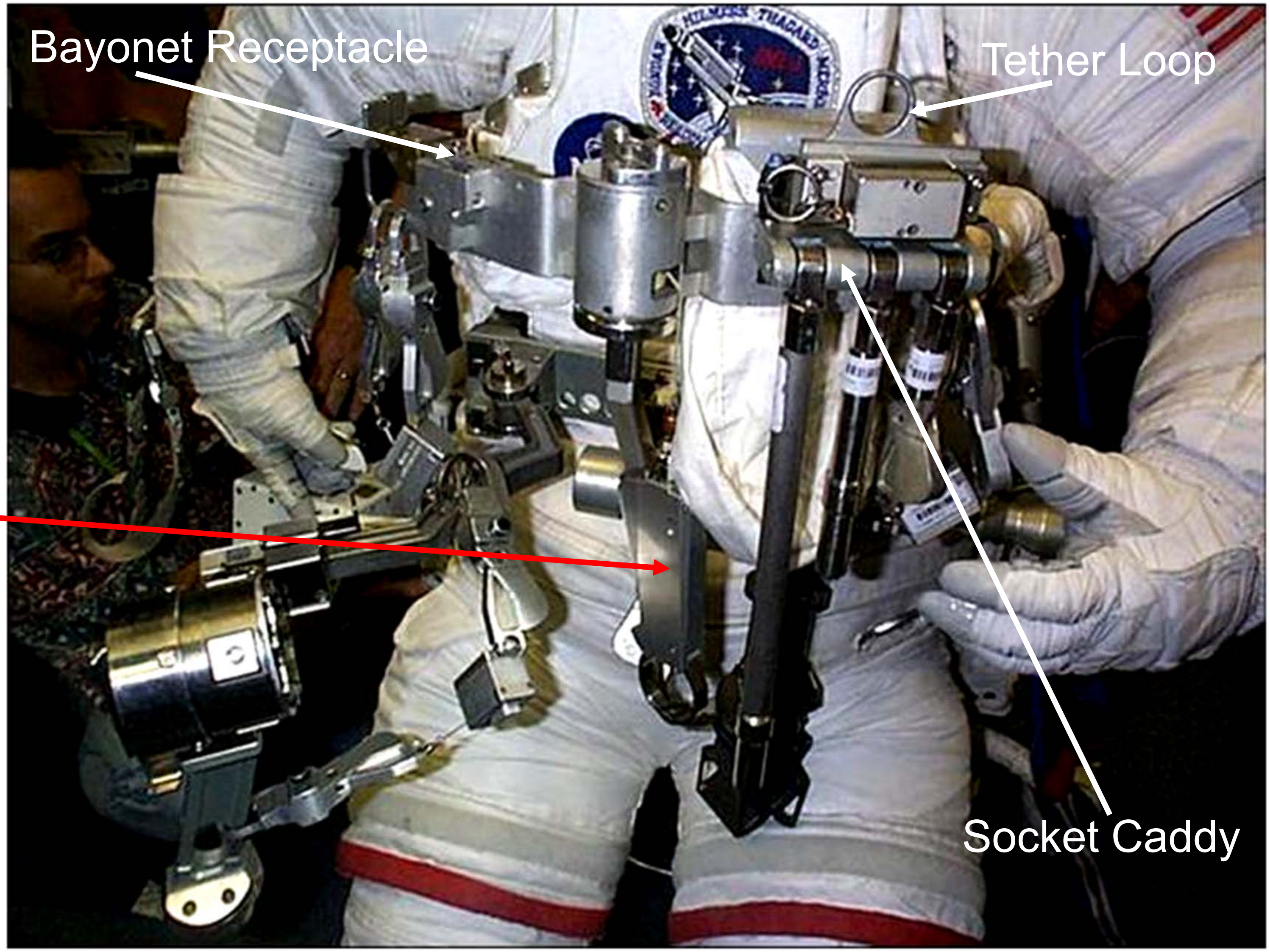
EVA Equipment & Tools

- EMU-mounted tools & equipment
  - TV Camera
  - Lights
  - Mini-workstation
  - Waist tethers
  - EVA Cuff Checklist
  - Wrist mirror
  - Body Restraint Tether
  - Pistol Grip Tool (PGT)
  - ISS Small Trash Bag

EVA Equipment & Tools

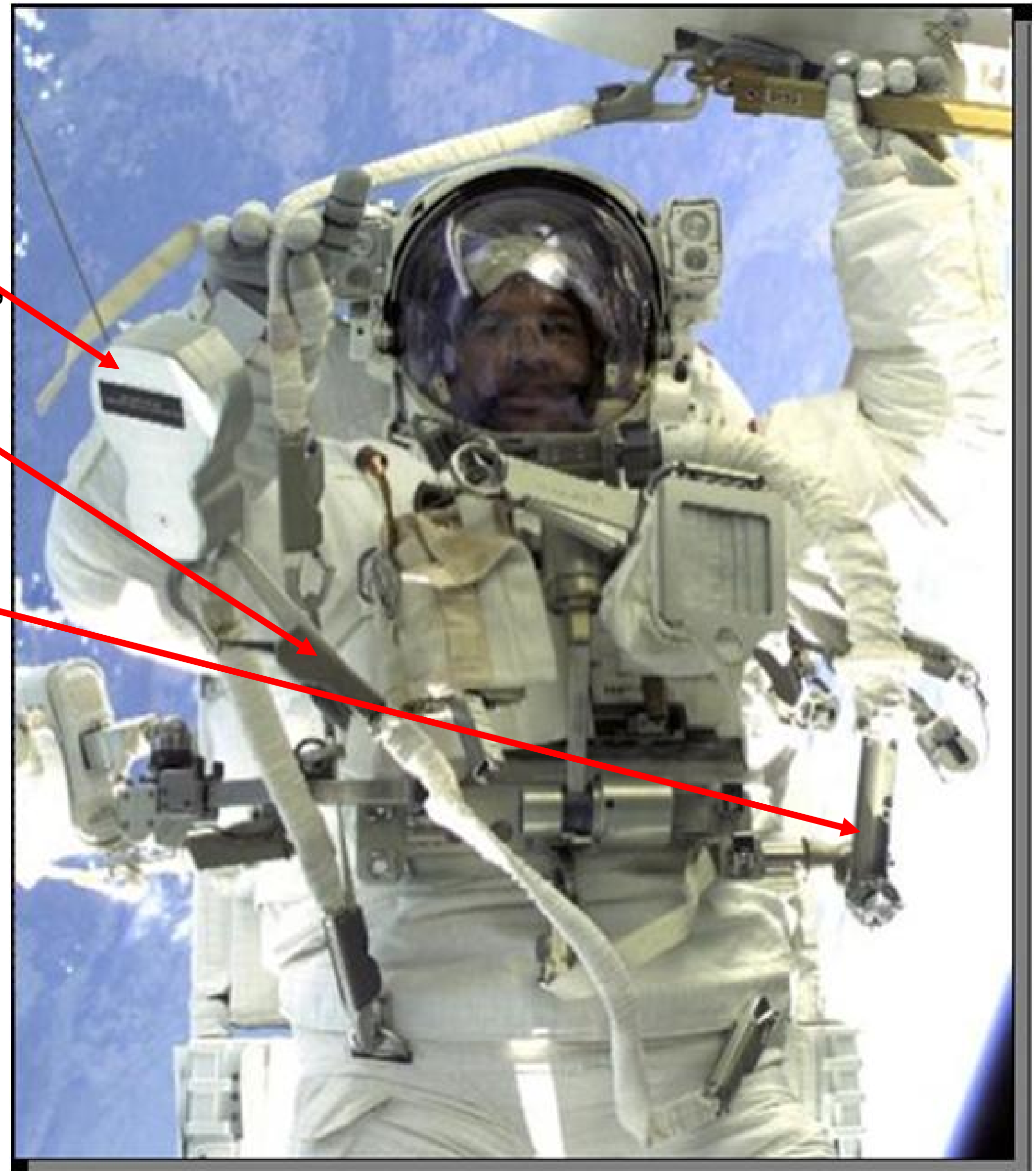
- Mini Work Station (MWS)
  - Attaches to front of the EMU
  - Used to carry small tools
  - Tools are secured via tether rings or via bayonet receptacles
  - MWS end-effector with retractable tether provides restraint to EVA Crewmember at worksite



- Note: "Drop-proof tether" PIP pins are used to secure certain items such as a socket onto a tool caddy.

EVA Equipment & Tools

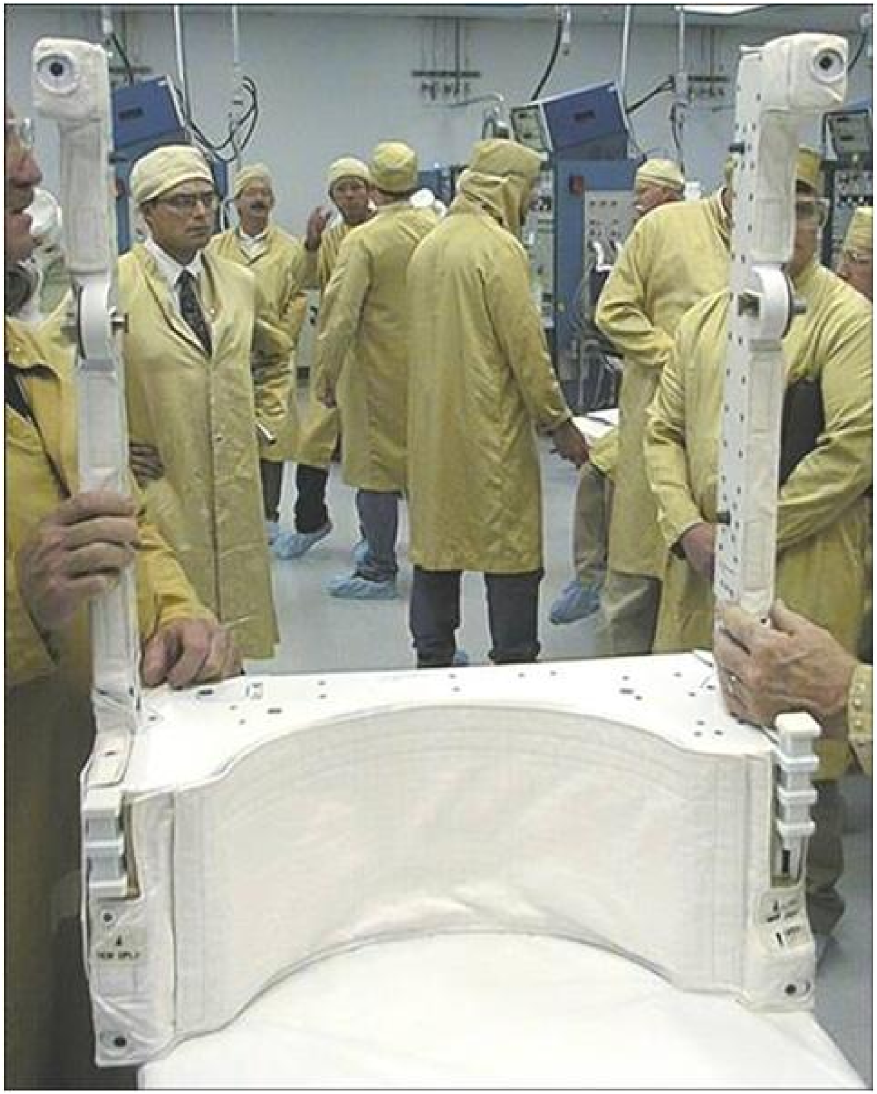
- Commonly Used Tethers
  - Safety Tether (55’ and 85’)
    - Used to secure the EVA crewmember to the vehicle
  - Suit tethers (Waist, Wrist)
    - Used to secure small items to the suit, usually for transfer
  - Retractable EVA Tether (RET)
    - Used to secure small items, usually while item is in use
  - Body Restraint Tether (BRT)
    - Attaches to the Mini-Work Station (MWS)
    - End-effector provides semi-rigid restraint to EVA crewmember at worksite via handrail (also used for translating small objects)
    - Requires less time than setting up a Portable Foot Restraint and is more stable than a MWS end effector
  - Note: EVA tether protocol is that crewmembers and equipment must be tethered at all times
    - **Always <u>make</u> a connection before you <u>break</u> a connection**.



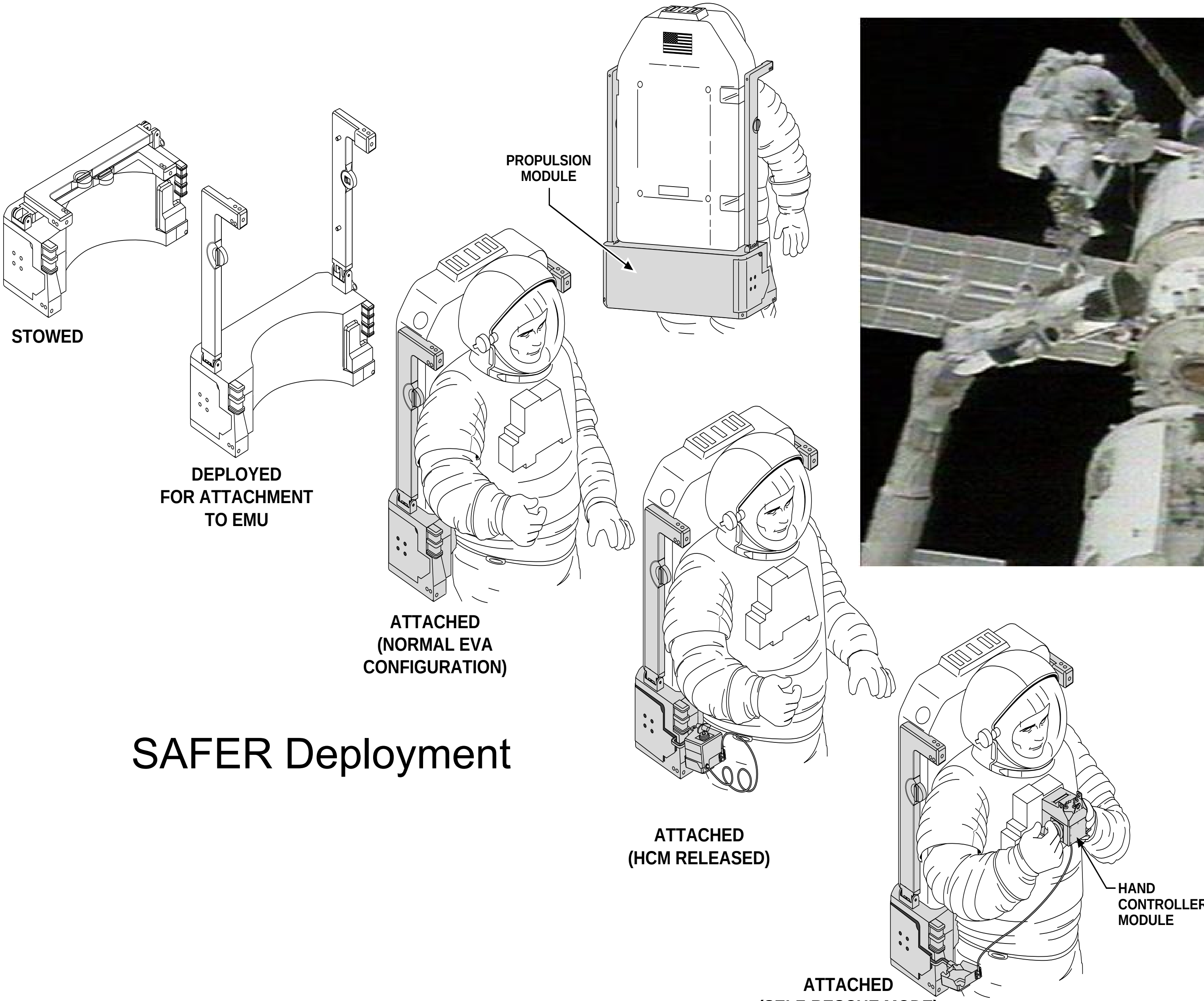
EVA Systems - SAFER (Simplified Aid for EVA Rescue)

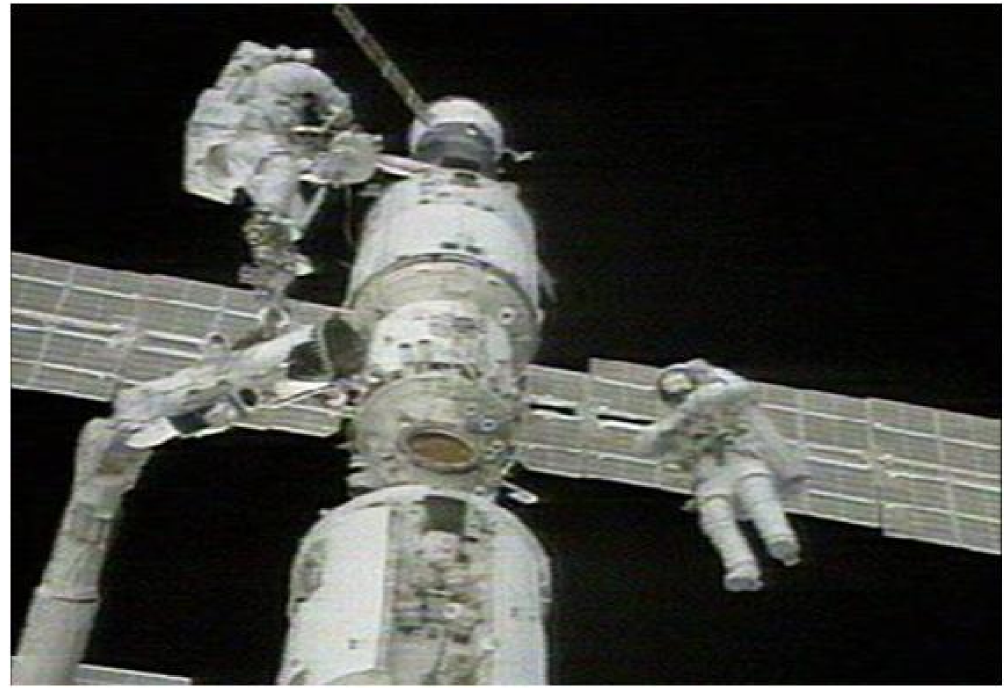
• SAFER is a self-contained, propulsive backpack self-rescue system that provides the EV crewmember with self-rescue capability when the orbiter is not present or cannot immediately perform EVA rescue.

- Propellant: Pressurized nitrogen gas
- Controlled by a single hand controller
- Stowed in ISS Airlock, used on ISS EVAs
- Sufficient propellant and power for one self-rescue (~13 min)
- Test flight on mission STS-64; self-rescue capability on STS-76
- Power up of production model SAFER on STS-86
- Tethered test flight of production model SAFER on Flights 2A and 3A



EVA Systems - SAFER (Simplified Aid for EVA Rescue)

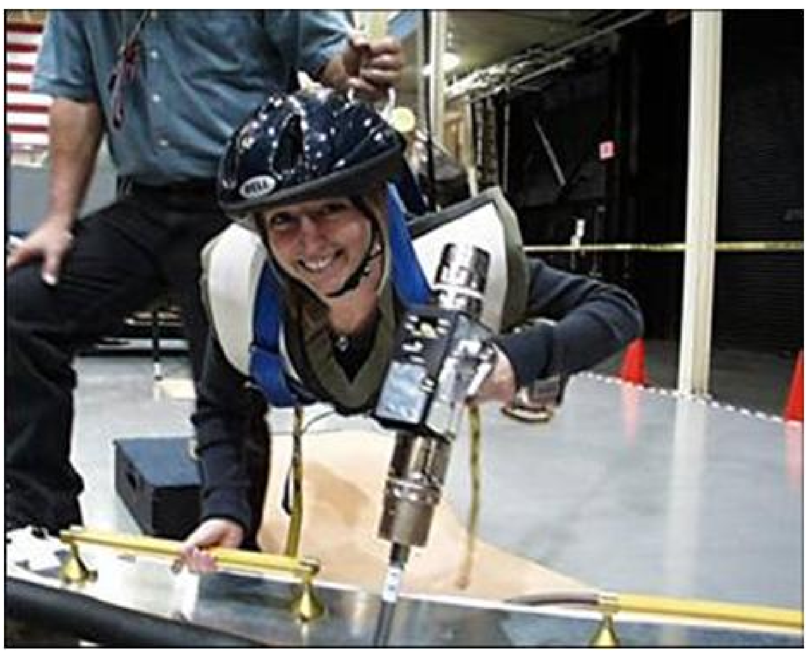




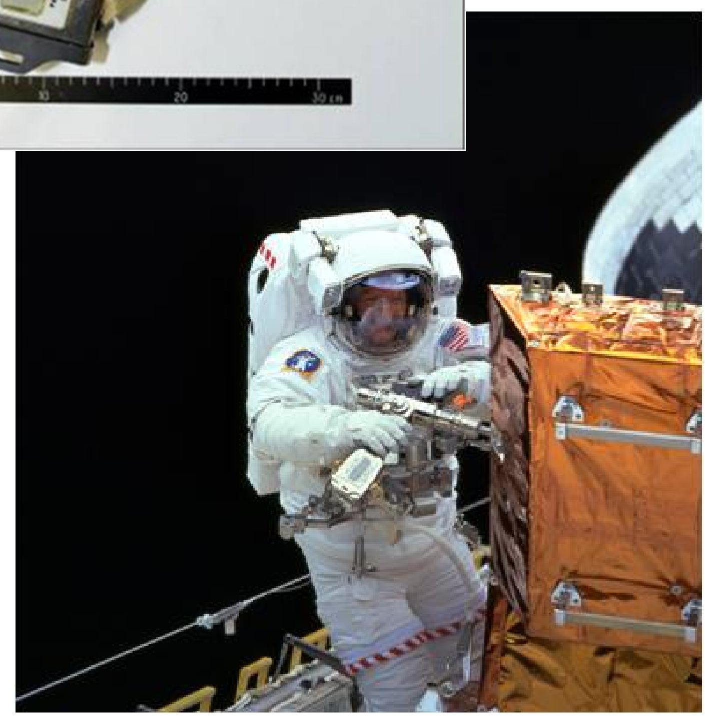
SAFER Deployment

EVA Equipment & Tools

- Pistol Grip Tool (PGT)
  - EVA torque wrench (i.e., a bolt turner)
    - Has a programmable torque limiter and turn limiter
    - Crewmember needs to be secured depending on amount of torque required
    - 2ft-lbs to 25ft-lbs of torque available
    - Generally used for ISS assembly missions and maintenance EVAs



← 1-G Testing of the PGT

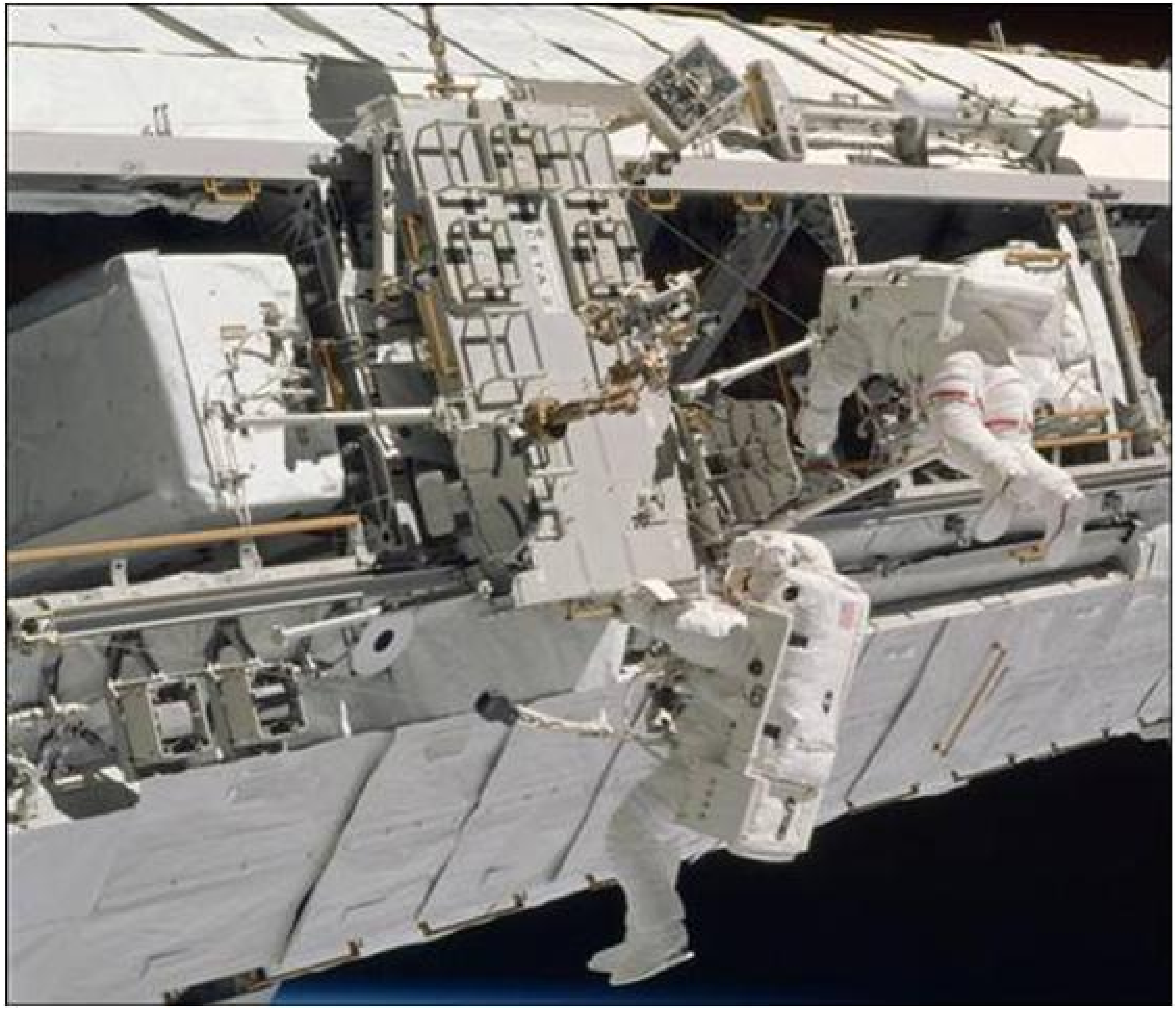


EVA Equipment & Tools

- Foot Restraints
  - Attach to structure via a socket
  - Provides EVA crewmember rigid restraint at a worksite (Newton's 3rd Law)
  - Different types:
    - Portable foot restraint (PFR) *(Shuttle)*
    - Articulating PFR (APFR) *(U.S. ISS)*
    - Interoperable APFR (IAPFR) *(U.S. & Russian ISS)*

EVA Equipment & Tools

- Crew and Equipment Translation Aid (CETA) Cart
  - Essentially an EVA equipment cart
  - Translates by CM manually pulling it along truss
  - Use brakes to stop and stay parked
  - Typical use: small ORU replacement on front truss face



EVA Operations Overview

EVA operations can be divided into three phases:

Pre-EVA

EVA

Post-EVA

Pre-EVA: Preparation & Checkouts

- Equipment Prep
  - Prepares the airlock and the EMUs to be checked out before EVA.
    - This is normally performed a few days before the EVA or before the Orbiter docks to the Station.
- EMU Checkout
  - Checks all EMU systems.
    - Performed a few days before the EVA or before the Orbiter docks to the Station.
- EVA Prep
  - All steps performed the day of the EVA prior to going EVA, including:
    - EMU Donning
    - Prebreathe with 100% oxygen

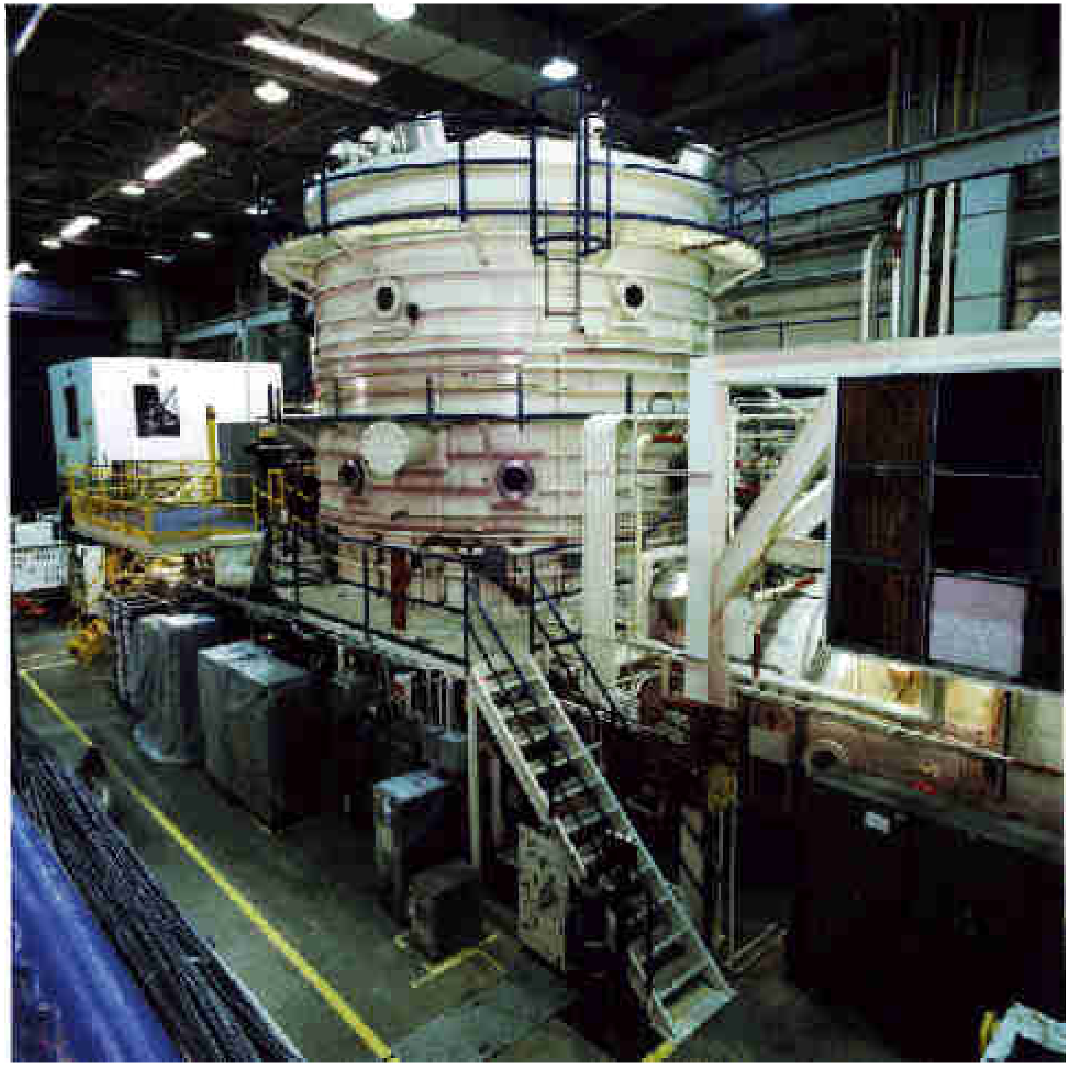
Pre-EVA: Prebreathe

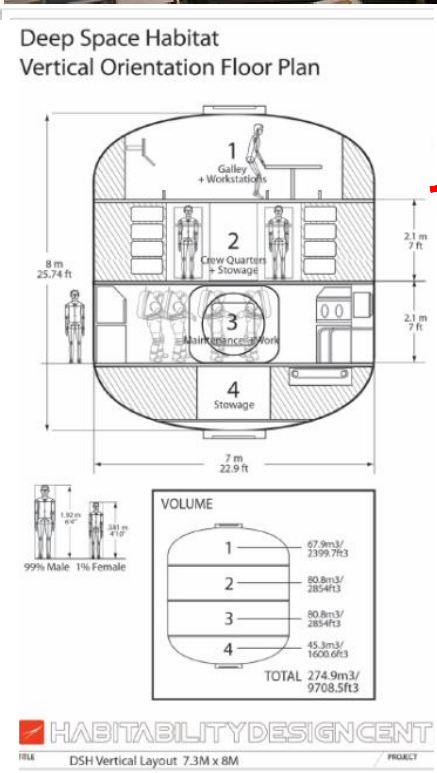
O_2 Prebreathe reduces the risk of Decompression Sickness (DCS)

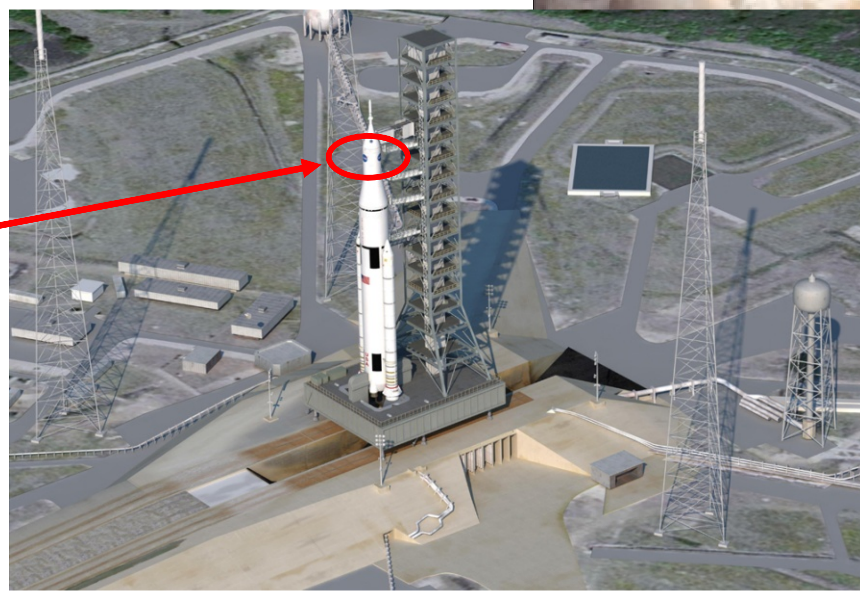
Protocol	In-Suit	In Suit Light Exercise (ISLE)	Campout ~ 8 hours 40 min @ 10.2 PSI	Exercise
Mask prebreathe time	None	1 hour	1 hour (1st day)	80 minutes
In-suit prebreathe time	4 hours	100 min	50 min (2nd day)	1 hour
Ops Overview *(Details of EVA Prebreathe protocols are in the Aeromed Flight Rule #B13-107)*	Breathe 100% O_2 in-suit for 4 hours while cabin is at 14.7, go out the door.	In Suit prebreathe light exercise totals 90 min; 50 min light exercise, 40 min Metox change out	Breathe 100% O_2 on mask while depressing cabin to 10.2, wait approx. 9 hours before in-suit prebreathe, go out the door.	Exercise on ergometer (i.e., bike) for 10 minutes at beginning of mask prebreathe (100% O2), depress airlock to 10.2, breathe in-suit for 1 hour, go out the door.
Total EVA prep & P/B time:	5:42 hrs	3:12 hrs	13:12 hrs	4:02 hrs

- Note: Long-duration exploration vehicles plan to utilize 8 psia / 32% O2 atmosphere.

NASA / JSC 20-Foot Chamber Facility Research







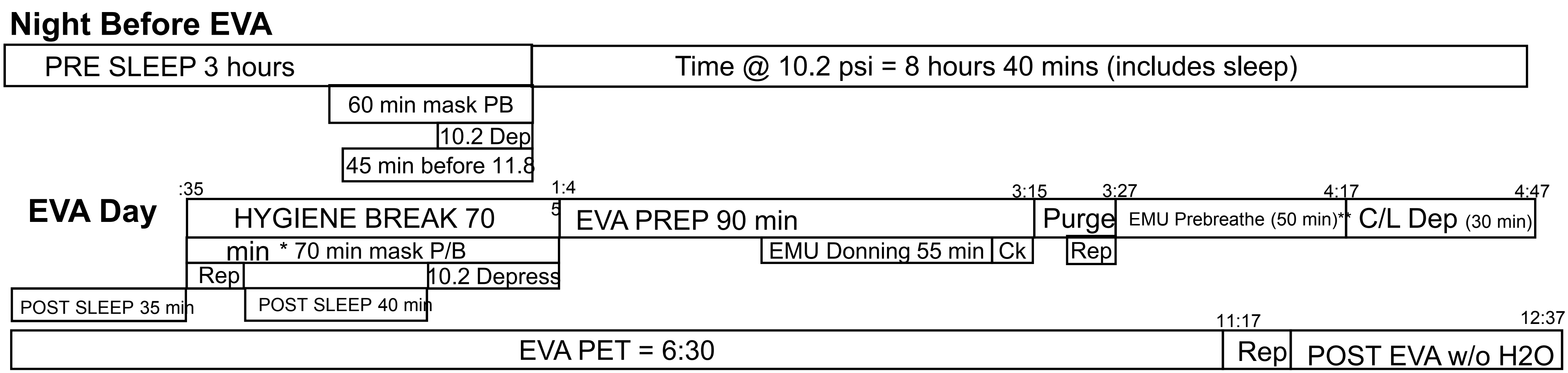
Deep Space Habitat Aboard Heavy Lift Launch Vehicle

Validation

8 psi 32% protocols

Overhead of an EVA

(EVA Campout – Times Approximate)



NIGHT BEFORE EVA SUMMARY
- Pre Sleep (3 hours total)
- Mask Prebreathe (1 hour)
  - 10.2 psi Airlock Depress (20 mins)
- 10.2 psi Overnight Campout (8 hours 40 mins minimum)

EVA DAY SUMMARY
- Post Sleep (1 hour 15 mins total)
- Mask Prebreathe (1 hour 10 mins)
  - Airlock Repress
  - Hygiene Break/Post Sleep activities
  - 10.2 psi Airlock Depress
- Mask Prebreathe Termination

- **EVA DAY SUMMARY (continued)**
- EVA Prep (~1 hour 30 mins)
  - EVA Prep for Donning (30 mins)
  - Suit Donning at 10.2 (1 hour)
- Suit Purge (12 mins)
  - Airlock Repress to 14.7
- In-suit Prebreathe (50 mins)
- Crewlock Depress to vacuum (30 mins)
- EVA tasks (6 hours 30 mins)
- Airlock Repress (20 mins)
- Post EVA without EMU H2O Recharge or METOX Regeneration (1 hour)
- Pre Sleep (2 hours)

EVA Operations: Overview of Typical EVA

30 min	Airlock depress
15 min	Airlock egress
6 hours	Worksite operations: Shuttle and ISS-based – All Shuttle EVA crewmembers are trained to perform the following Orbiter contingency tasks (if necessary) for each flight: • Failed airlock hatch latches or actuator tasks • Failed Remote Manipulator System (RMS) tasks • Manual stowage of radiators or Ku-band antenna • Manual closure of payload bay doors • Installation of payload bay door latch tools • Manual separation of Shuttle from ISS (96 bolt task) – EVA crewmembers assigned to a flight are also trained for scheduled, unscheduled, or contingency tasks.
15 min	Airlock ingress
30 min	Airlock repress

Post-EVA Operations

- EMU Doffing
- EMU Maintenance and Recharge
  - O_2 tank recharge
  - Battery recharge
  - H_2O tank refill
  - METOX regeneration/ LiOH swap
  - Suit cleaning
  - Suit resize (if required)

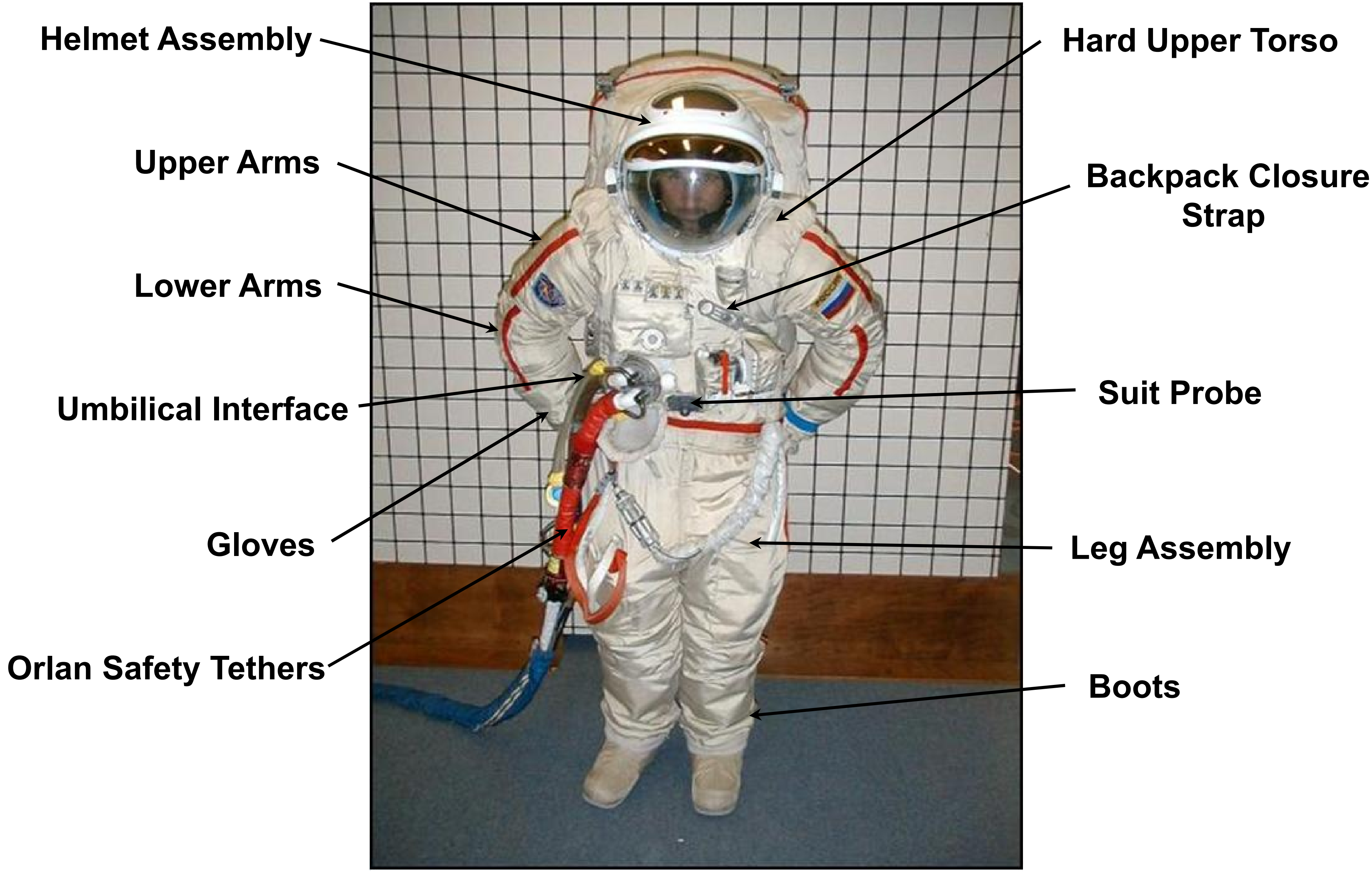
Comparison of Russian & U.S. EVAs

- Russian Orlan-M Spacesuit
- U.S. Extravehicular Mobility Unit (EMU)

Orlan-M Spacesuit

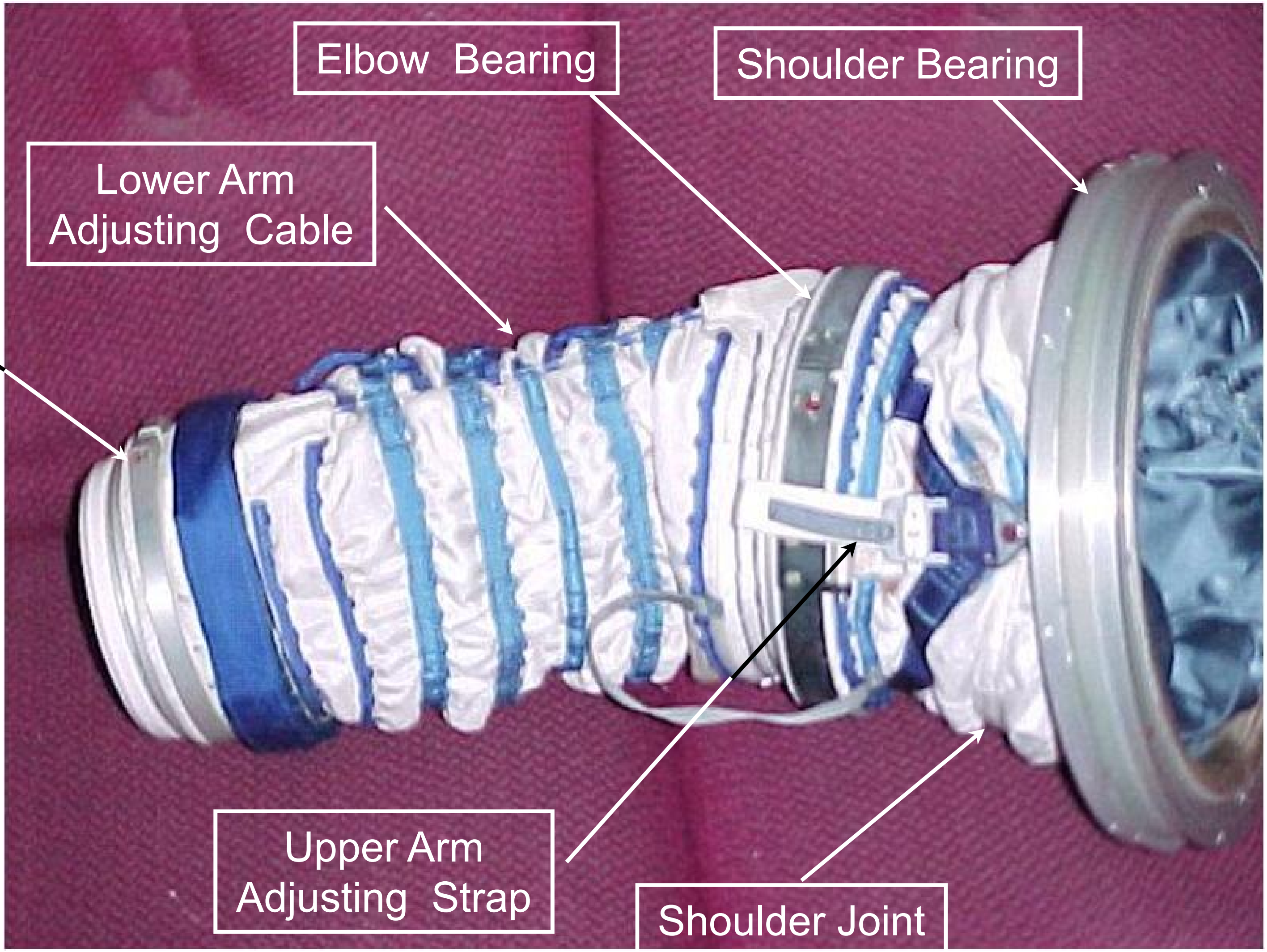
Back-Entry Orlan-M

Suit Enclosure



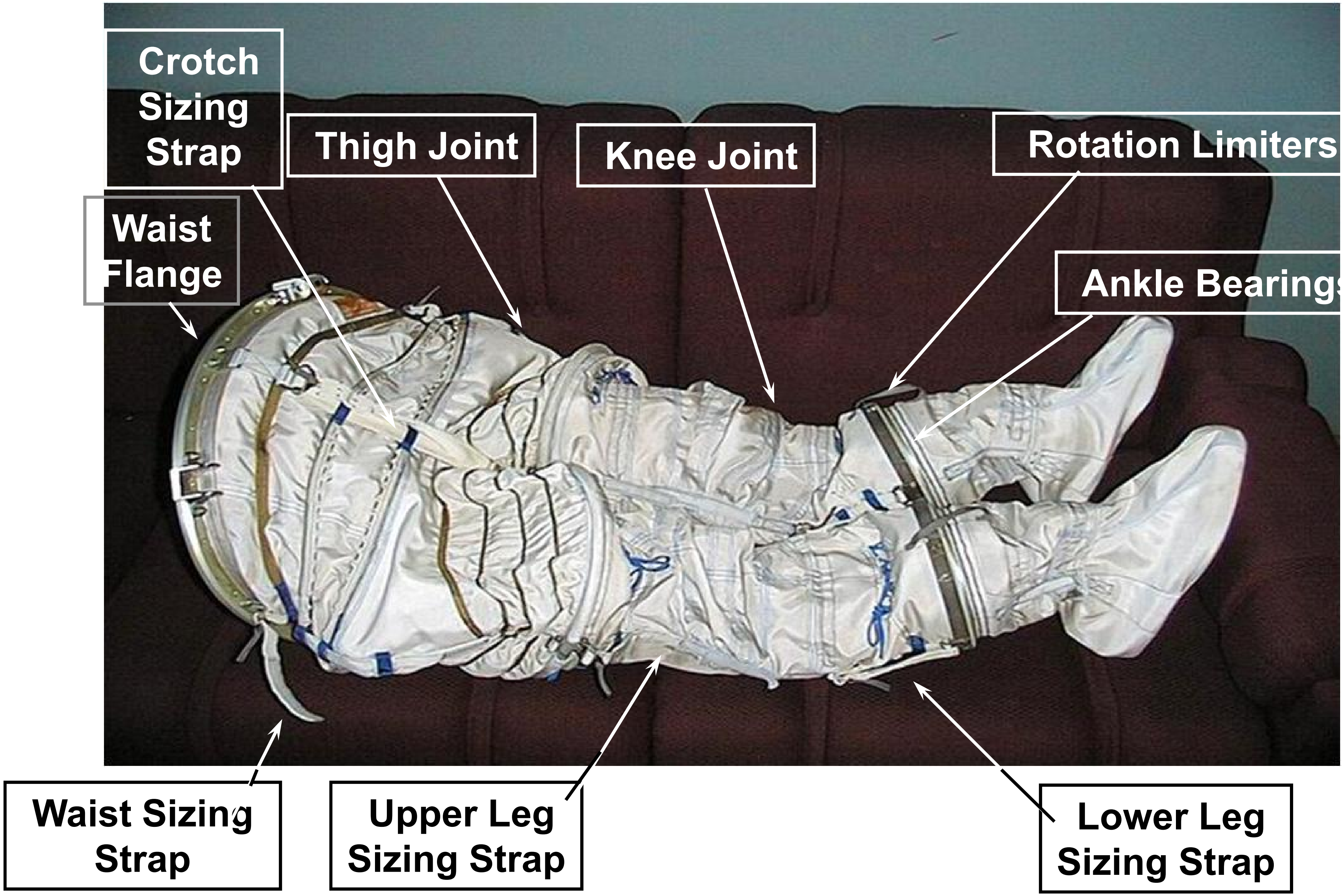
Arm Assembly

(Thermal Micrometeoroid Garment "TMG" Removed)



Leg Assembly

(TMG Removed)

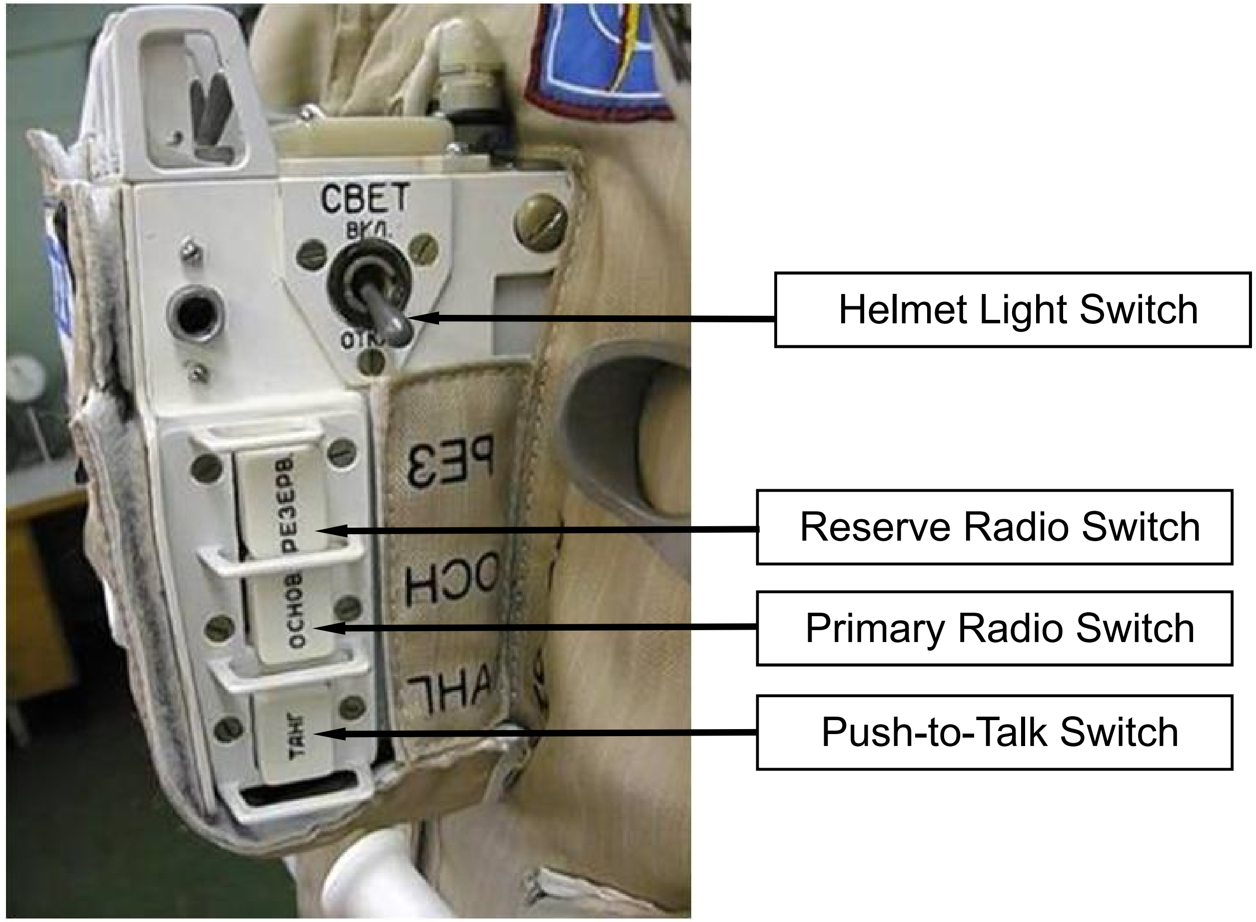


Orlan-M Glove

Electrical Control Panel (ПО-4МТ)

Orlan-M Electrical Control Panel (ПО-4МТ)

Electrical Control Panel (ПО-4МТ)



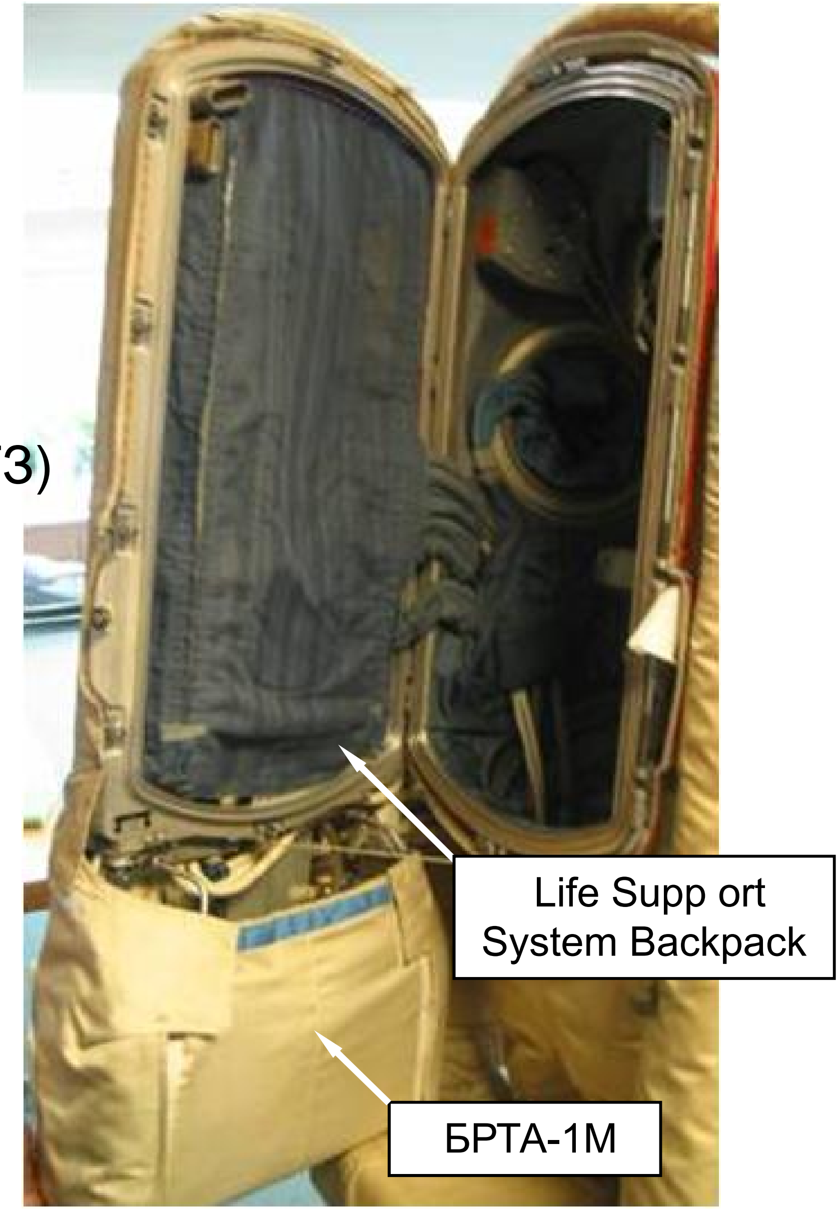
Orlan-M Electrical Control Panel (ПО-4МТ) (side view)

Radio Telemetry Apparatus Unit (БРТА-1М)

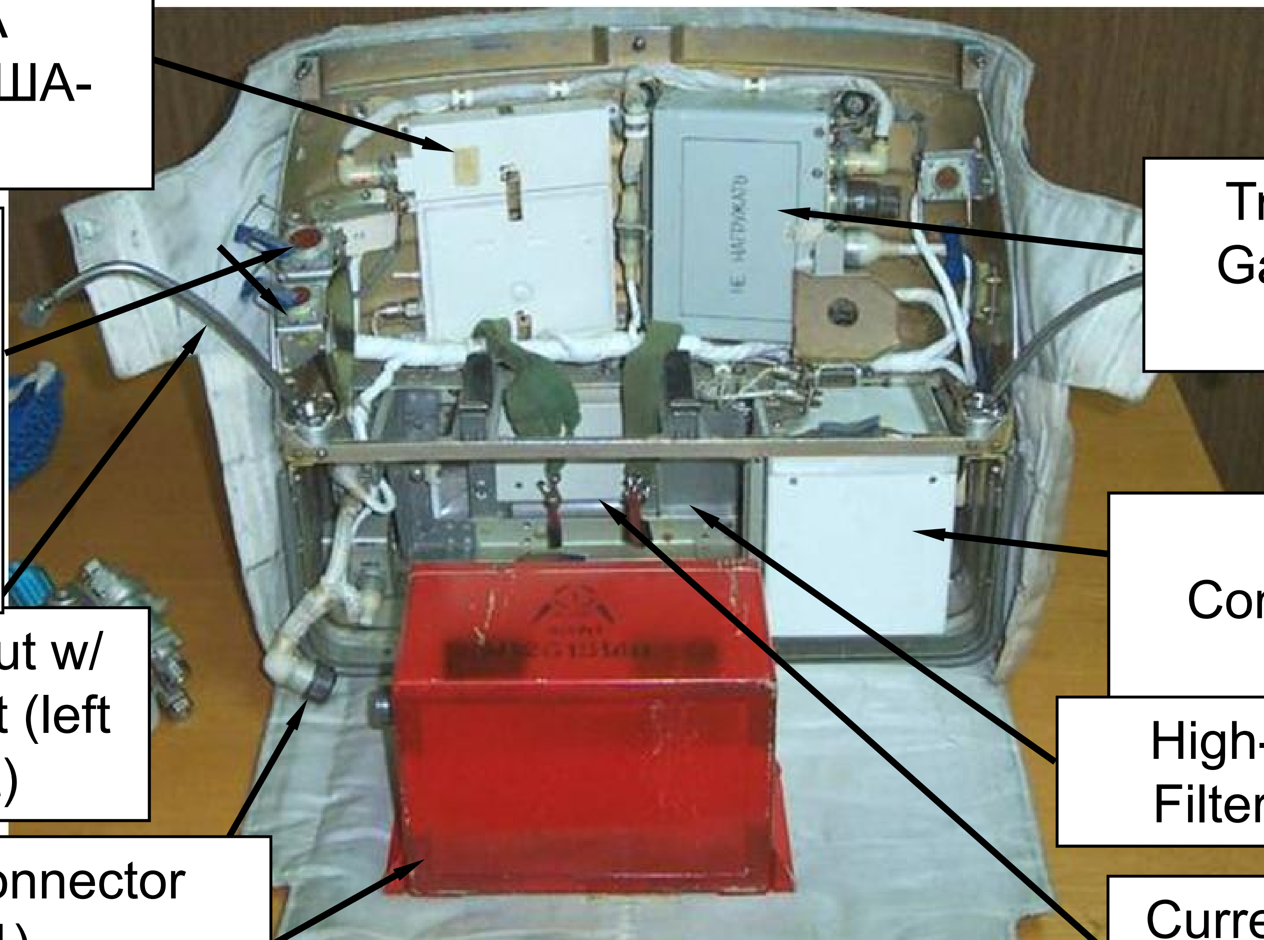
- Contains the following electrical assemblies:
  - Korona-M Communications Radio
  - Tranzit-A Telemetry Radio (2 parts)
    - Data Gathering Unit (ТА-237)
    - Transmitter (ША-347)
  - Battery (autonomous power supply)
  - Current and Power Measurement Unit (БКНТЗ)
  - High-Frequency Filter (ФР (ТК))
  - Annunciation Unit (БС-1М)
  - Relay Module (МР)

- БРТА-1М attaches to bottom of backpack enclosure (not pressurized)

- Easily attached to and removed from suit



Radio Telemetry Apparatus Unit (БРТА-1М)



Radio Telemetry Apparatus Unit (БРТА-1М) (Shown without Primary Oxygen Tank installed)

Safety Tethers

- Two Safety Tethers attached on the right HUT/Leg Assembly flange
  - Not designed for EVA removal
  - One Tether is fixed length
  - One Tether is variable length
  - Both tethers share an attaching strap
  - Tether hooks
    - One fault tolerant
    - Titanium construction
    - Certified for 600 kg (1320 lbs)

Variable Length Safety Tether

EVA Tools and Crew Aids

- Orlan Tether Adapter (OTA)
  - Provides interface points for U.S. tools
  - Provides various equipment tether loops
- OTA Interface Block
  - Permanently mounted to the waist flange of the Orlan suit
  - Provides load support to the OTA
  - Provides one crew safety tether loop
- Standard U.S. Tool Configuration
  - OTA
  - Right Swing Arm
  - Retractable Equipment Tethers (RET)
  - EVA Camera (Digital or F5)

Orlan Tether Adapter (OTA)

Comparison with Russian EVAs
EMU vs. Orlan - Manufacturers

- EMU

  United Technologies, Hamilton-Sundstrand, Windsor Locks, CT

- Orlan

  Zvezda Research, Development, and Production Enterprise, Tomilino (Moscow Region), Russia

Comparison with Russian EVAs
EMU vs. Orlan - Applications

- EMU – Space Shuttle and International Space Station (ISS)
  - In operation since 1981 to present
    - Several upgrades have been made

- Orlan-M – Mir Space Station and ISS
  - In operation since 1997 (replaced Orlan-DMA)
    - Upgraded Orlan-MK delivered to ISS in 2008

Comparison with Russian EVAs
EMU vs. Orlan – General Characteristics

- EMU
  - Suit operating pressure: 4.3 psi
  - Mission duration: 6.5 hours + 30-minute contingency
  - Weight: ~280 lbs
  - On-Orbit Service life: 25 uses/2 years (with maintenance)
    - **Returned for refurbishment**

- Orlan-M
  - Suit operating pressure: 5.8 psi
  - Mission duration: 6.5 hours + 30-minute contingency
  - Weight: ~230 lbs
  - On-orbit Service life: 12 uses/4 years (with maintenance)
    - **Not returned for refurbishment**

Comparison with Russian EVAs
EMU vs. Orlan – Spacesuit Assembly

- EMU Construction
  - Semi-rigid construction; aluminum hard upper torso
  - Urethane-coated nylon pressure bladder
  - Orthofabric and aluminized mylar thermal/meteoroid garment
  - Ball-bearing joints
  - Liquid-cooling and ventilation undergarment
  - Display & Controls Module (DCM)
  - Polycarbonate helmet and polysulfone visors; helmet lights
  - Location for attachment of mini-work station, etc.
- Orlan-M Construction
  - Semi-rigid construction; aluminum hard upper torso
  - Urethane-coated nylon pressure bladder
  - Orthofabric and aluminized mylar thermal/meteoroid garment
  - Liquid-cooling undergarment
  - Electrical Control Panel / Pneumo-Hydraulic Control Panel
  - Polycarbonate helmet and visors; helmet lights
  - Probe provided for attachment of mini-work station, etc.

Comparison with Russian EVAs
EMU vs. Orlan – Spacesuit Assembly Differences

- EMU
  - Sizing: Medium, large, and extra large size modular components and the use of sizing inserts (legs and arms) allow a fairly large population range to be accommodated
    - Multiple glove sizes including some custom-sized gloves
  - Gloves are heated to provide protection from cold environment; wrist disconnect is on suit side
  - Suit Donning: Bottom entry
  - Helmet is removable
  - Waist tether(s) removable
  - Includes provisions for TV camera
- Orlan-M
  - Sizing: One size with adjustable sizing axial restraint cable in arms/legs
    - 2 glove sizes
  - Glove wrist disconnect is on glove side
  - Suit Donning: Back entry
  - Helmet integrated into suit
  - 2 Waist tethers (fixed and variable length); not removable
  - Orlan-MK includes provisions for U.S. TV camera

Comparison with Russian EVAs
EMU vs. Orlan – Portable Life Support Assembly

- EMU
  - Closed-loop, 100% oxygen
  - Expendables replaced or recharged on-orbit
  - Primary & secondary oxygen tanks
  - Liquid cooling via garment and use of sublimator
  - Carbon Dioxide and trace gas scrubber
  - Average/Max metabolic rates: 1000 BTUs (290 W) / 2000 BTUs (580 W)
  - Primary battery Li-ion
  - Radio for voice, data, and medical information; use of headset
- Orlan-M
  - Closed-loop, 100% oxygen
  - Expendables replaced or recharged on-orbit
  - Primary & secondary oxygen tanks
  - Liquid cooling via garment and use of sublimator
  - Carbon Dioxide and trace gas scrubber
  - Average/Max metabolic rates: 1025 BTUs (300 W) / 2050 BTUs (600 W)
  - Primary battery is zinc-silver-oxide (rechargeable)
  - Radio for voice, data, and medical information; use of headset

Comparison with Russian EVAs
EMU vs. Orlan – Portable Life Support Assembly Differences

- EMU
  - Primary O2 pressure: 2 tanks @ 900 psi (rechargeable); Secondary O2 pressure: 2 tanks @ 6000 psi (non-rechargeable)
  - Most electronics located in life support backpack @ vacuum
  - Crewmembers communicate between each other
  - Single fan-pump-water separator
  - Liquid cooling and ventilation garment; biocide: iodine
  - CO2 scrubber: silver oxide or lithium hydroxide
  - Additional rechargeable battery used for glove heating (nickel-metal-oxide)
  - Prebreathe: 4-hour in-suit, 10.2 psi, and 14.7/10.2 psi & ergometer protocols available
- Orlan-M
  - Primary and Secondary O2 pressure: 6000 psi; both removable and non-rechargeable
  - Electronics (except for БРТА) located in life support backpack @ 100% O2
  - Crewmembers communicate via the vehicle (signal is relayed)
  - Redundant fans and pumps
  - Liquid cooling garment; biocide: silver ions
  - CO2 scrubber: lithium hydroxide
  - Prebreathe: 1-hour @ 550 torr

Comparison with Russian EVAs
EMU vs. Orlan – Work Aids

- EMU
  - Compatible with:
    - Mini-work station
    - Numerous EVA tools including foots restraints, etc.
    - Simplified Aid For EVA Rescue (SAFER)
    - Donning stations

- Orlan-M
  - Compatible with:
    - Mini-work station
    - EVA tools including foots restraints, etc.
    - REBA – helmet lights
    - Donning stations (however, rarely used on orbit)

Comparison with Russian EVAs
EMU vs. Orlan – Crew Preference Items

- EMU
  - Comfort gloves
  - Eyeglass holder
  - Fresnel lens (various strengths)
  - In-suit drink bag
  - Maximum absorbent garment (MAG)
  - Socks
  - Valsalva device
  - Wristlets
  - Miscellaneous: Lint free wipes, Anti-fog wipes, Comfort pads, Moleskin tape, Stericide sanitizer
- Orlan-M
  - Comfort gloves
  - Dosimeter (passive)
  - Socks

Comparison with Russian EVAs
EMU vs. Orlan – Operations Differences

- Russian EVA crewmembers talk directly to engineers on ground
- U.S. EVA crewmembers talk through Capcom

- Russian EVA training is more skills based
- U.S. EVA training is more task based

- Russian EVA crewmembers have little or no Intravehicular (IV) interaction
- U.S. EVA crewmembers work with an IV crewmembers before, during, and after an EVA

- Russian EVA crewmembers use a hand-over-hand tether protocol
- U.S. EVA crewmembers use a safety tether (ISS & shuttle) and a slidewire (Shuttle)

EVA Training Facilities

- Shuttle Full-size Mockup Trainers (historical)
  - Crew Cabin Trainer (CCT) and CCTII
  - Full Fuselage Trainer (FFT)

EVA Training Facilities

- Space Station Mockup Training Facility (SSMTF) Airlock Mockup

EVA Training Facilities

- EMU Caution and Warning System (ECWS) Trainer

EVA Training Facilities

- Vacuum chambers
  - 11-foot chamber
  - Environmental Test Article (ETA) chamber
  - Space Environment Simulation Lab (SESL) chamber
  - Space Station Airlock Test Article (SSATA)

EVA Training Facilities

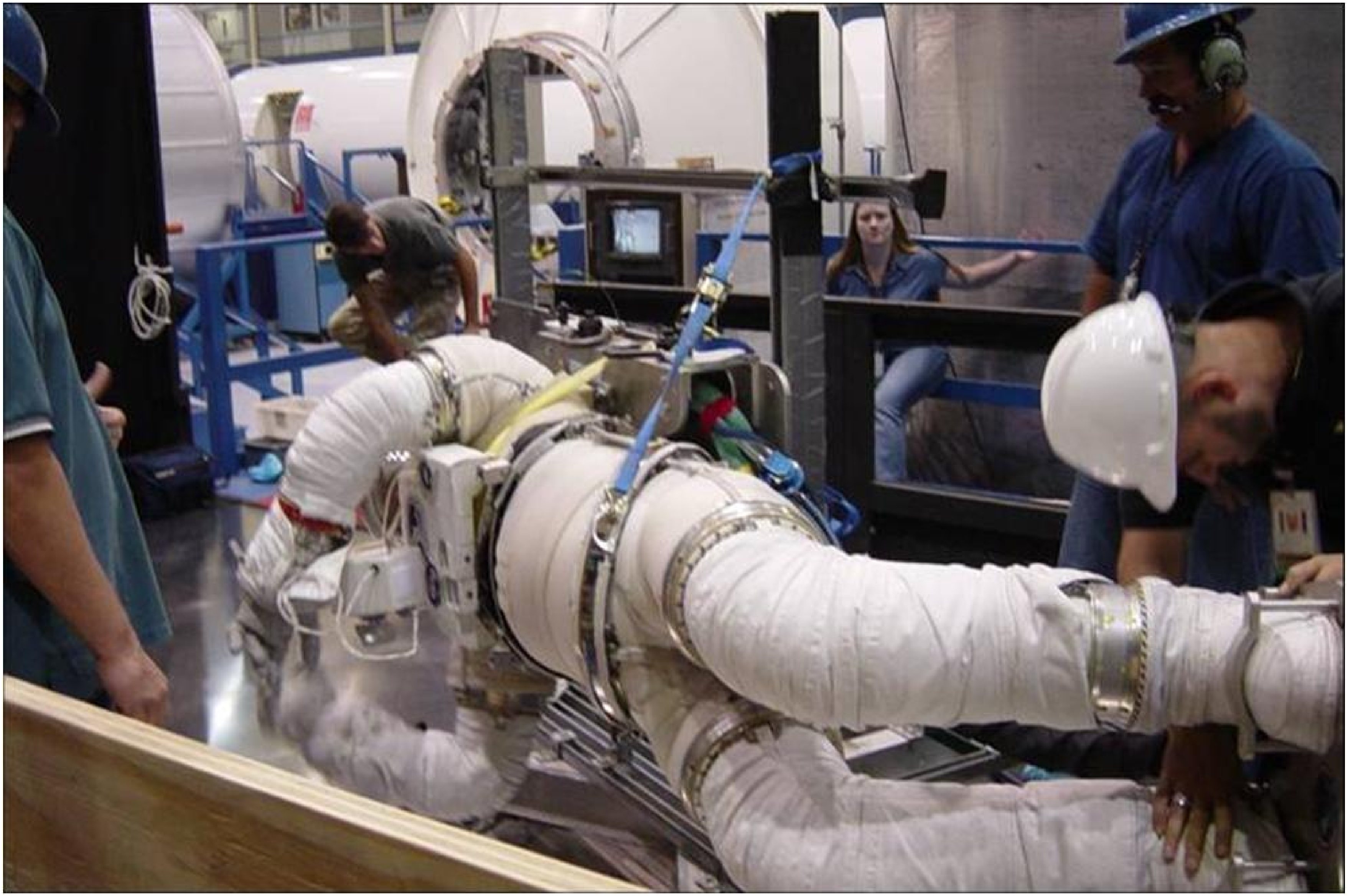
- Virtual Reality Lab

EVA Training Facilities
Charlotte for Low Gravity Mass Ops

Source : Osterlund, J. & Lawrence, B. 2012

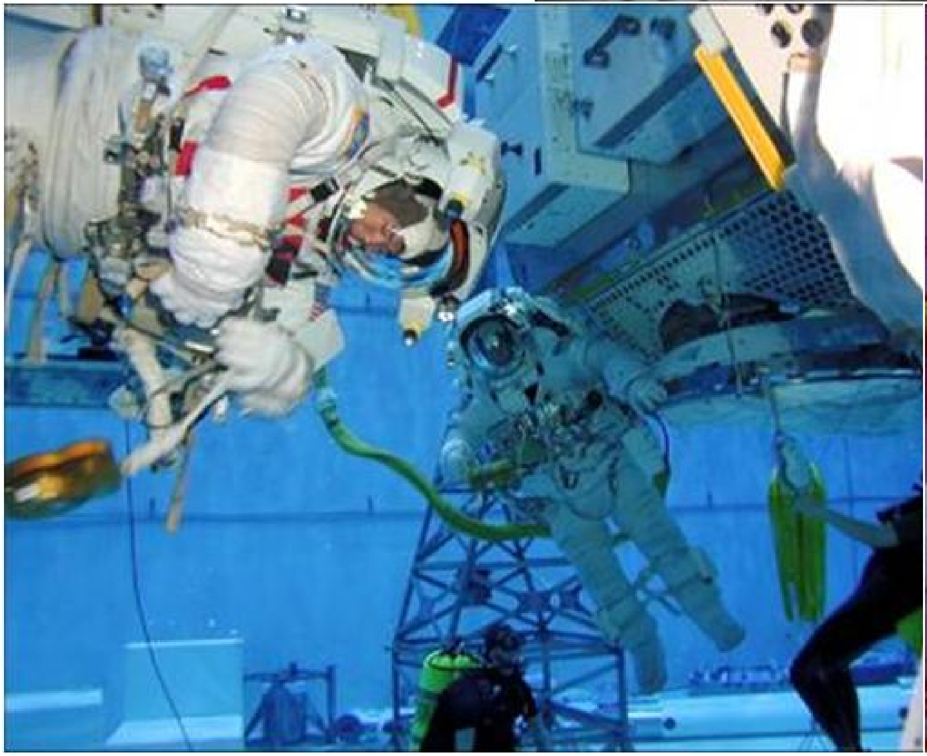
EVA Training Facilities

- Precision Air-Bearing Floor (PABF)



EVA Training Facilities

- Neutral Buoyancy Laboratory (NBL)

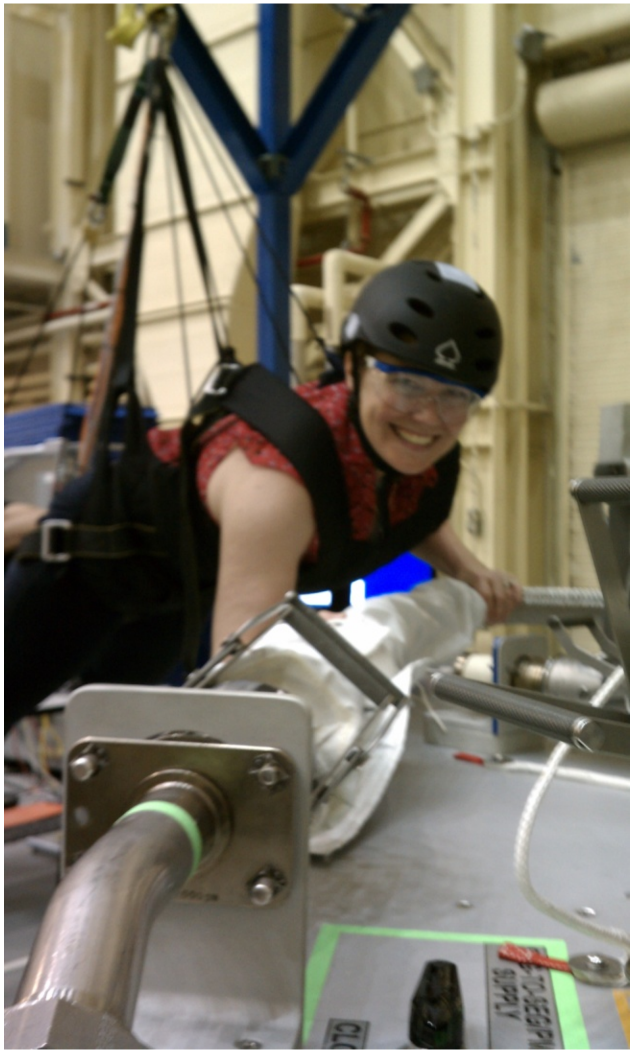


EVA Training Facilities

- Micro-gravity via DC-9 (KC-135 below retired)

EVA Training Facilities

The Active Response Gravity Offload System (ARGOS)



- ARGOS uses an inline load cell to continuously offload of a portion of a human or robotic subject's weight during all dynamic motions

Backup Material

Pressures

Altitude (ft)	Atmospheric Pressure (psi)	Oxygen Concentration (%)	Comments
Sea Level	14.7	20	Nitrogen Concentration is 80%. 1 atmosphere (1 atm). 101.325 kPa.
10,000	10.11	70% of Sea Level	Early signs of hypoxia (shortage of oxygen in the body)
15,672	8.3	56% of Sea Level	Exploration Atmosphere recommended pressure
18,000	7.34 or (14.7 / 2)	51% of Sea Level	½ atm
23,500	5.8	40% of Sea Level	Russian Orlan operating pressure
30,250	4.3	30% of Sea Level	U.S. EMU operating pressure
34,000	3.62 or (7.34 / 2)	25% of Sea Level	¼ atm
101,381 (19.2 miles)	0.147 or (14.7 / 100)	≈1% of Sea Level	1/100 atm
283,076	0.000147 or (14.7 / 100,000)	0% of Sea Level	ISS (220 miles or 1,161,600 ft)

Comparison with Russian EVAs
EMU vs. Orlans

Suit Feature	Orlan - M	EMU
Entry Method	Rear Entry: Self-donning typical Easy suit ingress/egress	Waist Entry: Self-donning possible More difficult in/egress
Pressure	5.7 psid nominal	4.3 psid nominal
Pre-breathe	30-minute nominal	40 min. nominal from 10.2 psi cabin 4 hour nom from 14.7 psi
Sizing	One size Adjust lengths of arms and legs	Modular 137 measurements made
Useful Life	4 years or 12 EVAs Burns on re-entry in Progress vehicle	2 years or 25 EVAs Refurbished and recertified on ground
Displays	C&W lights on front of suit and in helmet; can send suit data to ground	CWS, DCM display: msg and status; can send suit data to ground

Comparison with Russian EVAs EMU vs. Orlans

- Resupplying/Recharging
  - Orlan H2O tank refilled and O2 tanks replaced after each EVA
  - EMU H2O and O2 tanks resupplied via umbilical
- Orlan and EMU coolant operation similar
  - Both Orlans and EMUs use sublimators
  - Liquid Cooling (and Ventilation) Garments [LC(V)Gs] are similar
- Umbilicals
  - Orlan umbilical provides power, comm, and pre-breathe O2
  - EMU umbilical provides power, comm, O2, recharge H2O and cooling H2O
- Gloves
  - Orlan gloves used for two EVAs
  - EMU gloves used multiple times, electrically powered glove heaters
- Emergency procedures
  - Orlan: Few simple messages, gloves have reference tables on them
  - EMUs have Caution and Warning System, combined with a cuff checklist
- Both Orlans and EMUs have duplex comm