



Extravehicular Activity (EVA) Hardware & Operations Overview



UTMB - Galveston
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Objectives and Overview



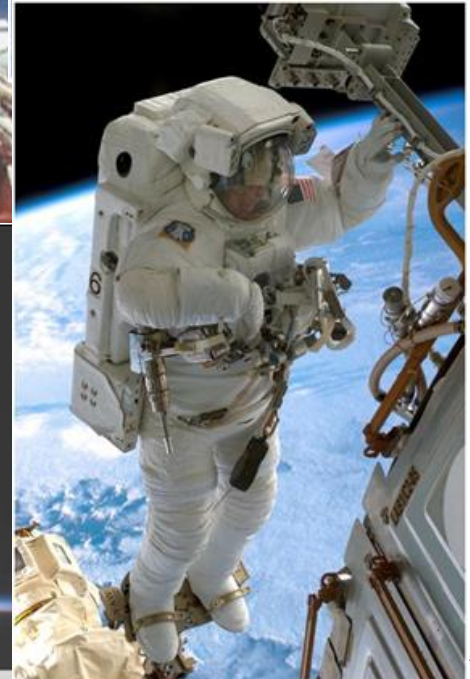
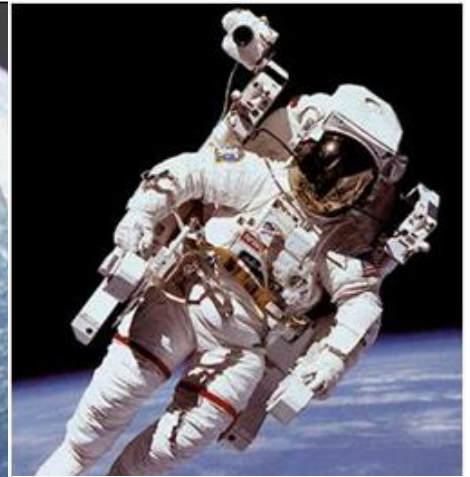
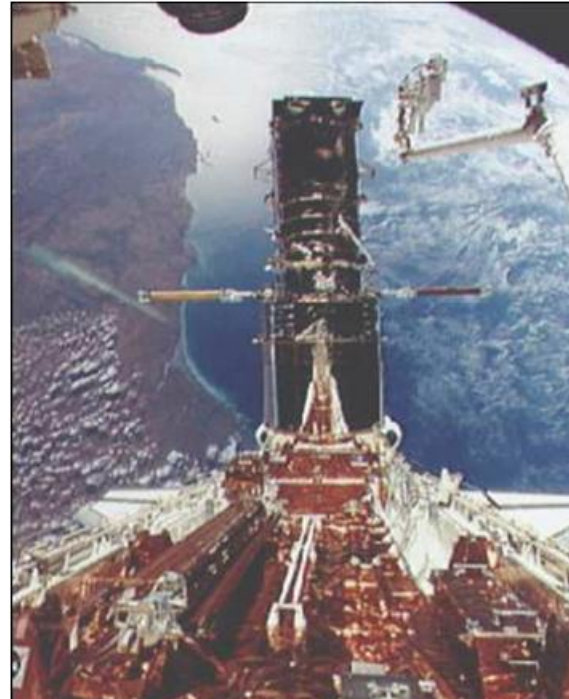
- Define Extravehicular Activity (EVA), identify the reasons for conducting an EVA, and review the role that EVA has played in the space program
- Identify the types of EVAs that may be performed
- Describe some of the U.S. Space Station equipment and tools that are used during an EVA
 - Extravehicular 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



EVA Suit

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



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

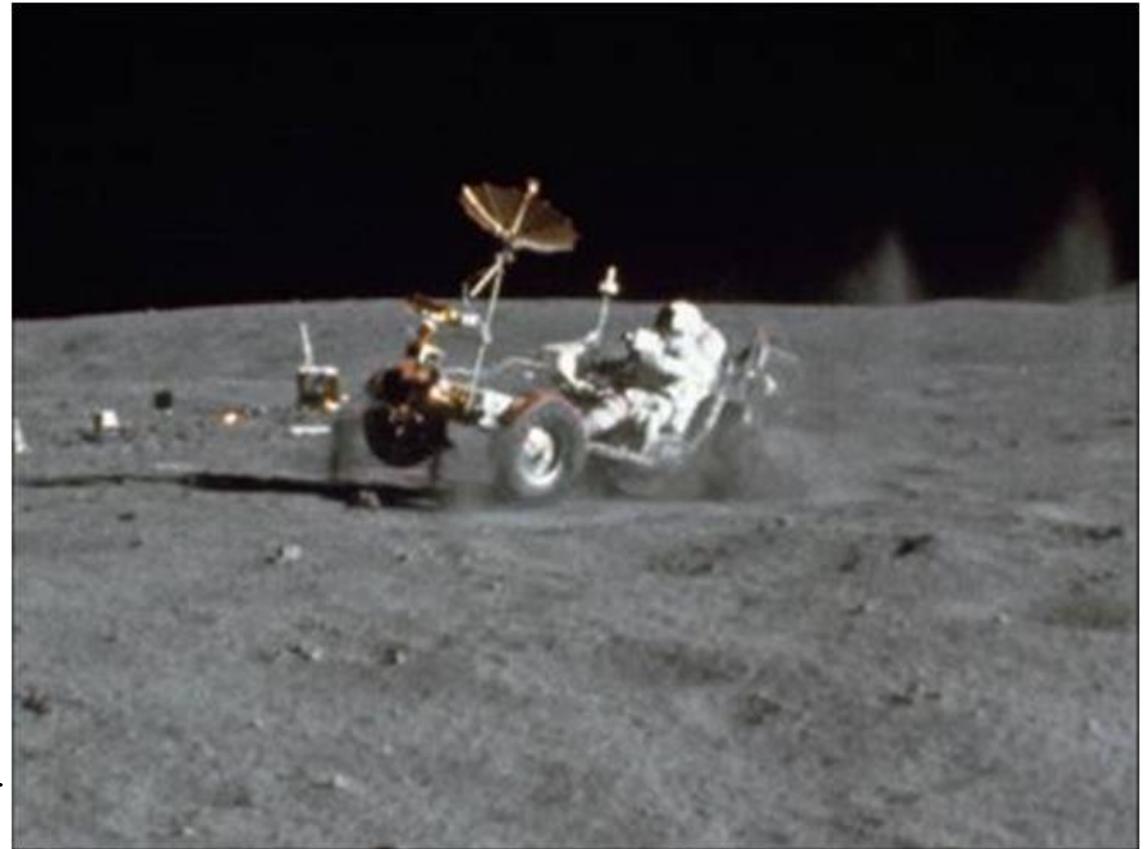
- Gemini EVA Experience -
 - Astronaut Edward White II performed first U.S. EVA during Gemini IV June 3, 1965.
 - Start of EVA program was excursion to perform a special set of procedures in a new and hostile environment.
 - Proved EVA to be a viable technique for operations outside the spacecraft crew 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.



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:

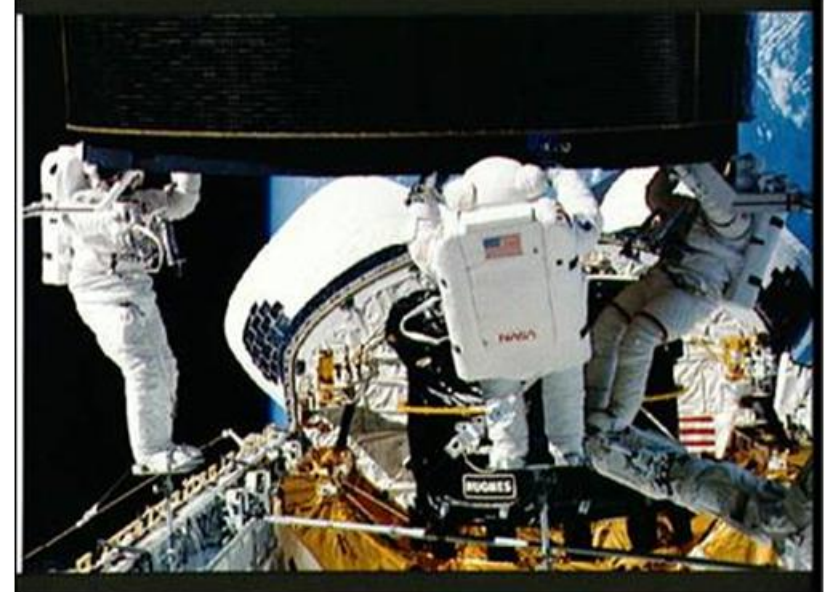
EVA, although trained, not included in the scheduled mission activities, but which may be required to achieve mission or operational success.

- 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





EVA Systems

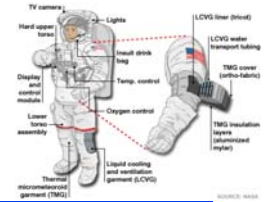


- Extravehicular Mobility Unit (EMU)
- ISS Joint Airlock
- Equipment & Tools (including Simplified Aid For EVA Rescue (SAFER))





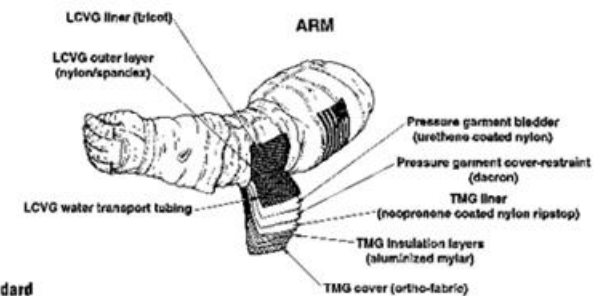
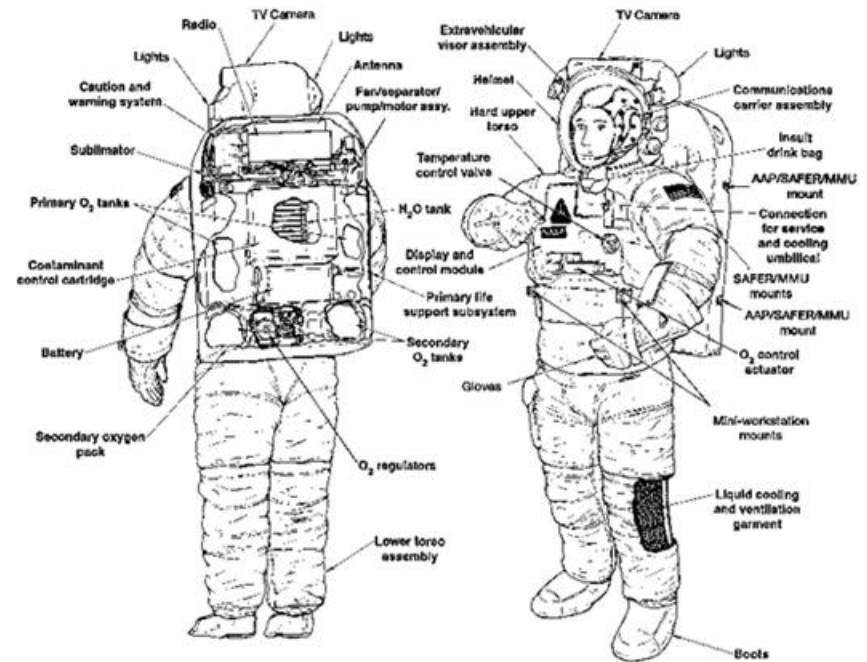
EVA Systems - EMU



- 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)

EXTRAVEHICULAR MOBILITY UNIT



Hamilton Standard
A Lockheed Martin Company

Rev 2/95

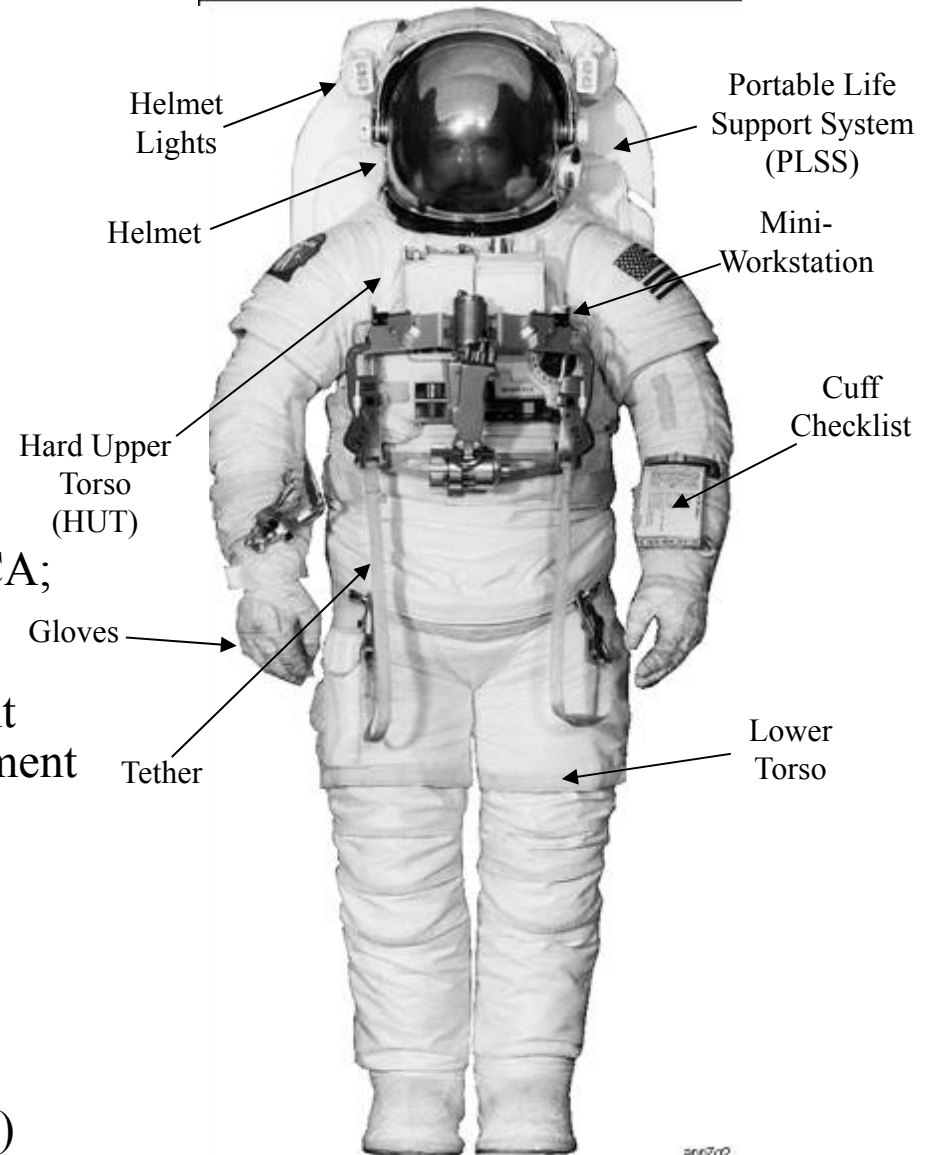


EVA Systems – Space Suit Assembly



- 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)



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EVA Systems – Space Suit Assembly



- Extravehicular (EV) gloves

- Extravehicular (EV) boots (and insert)

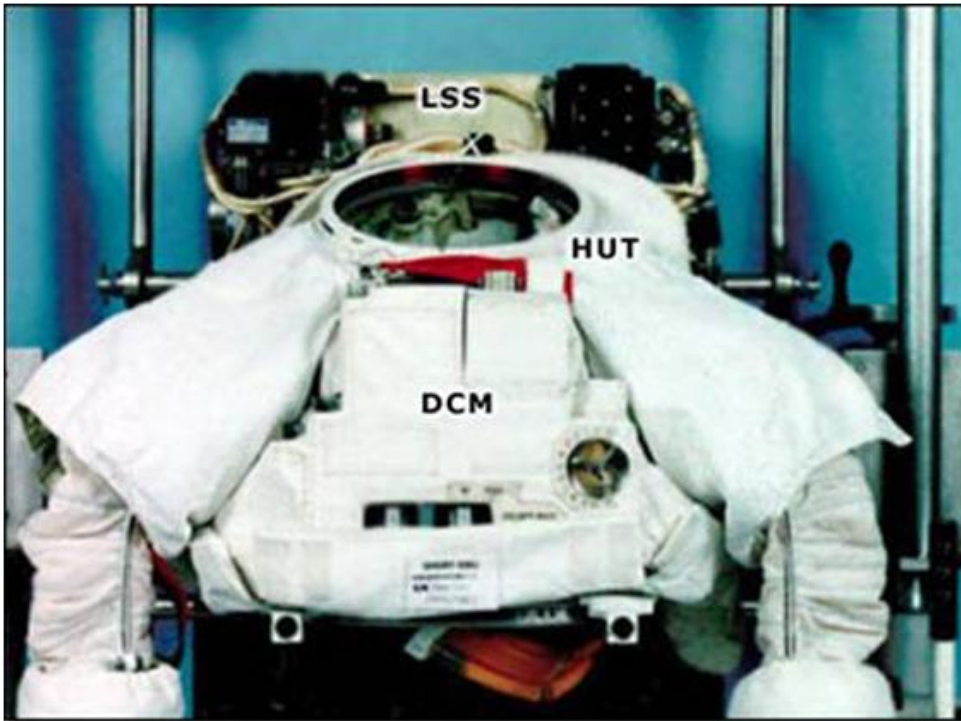
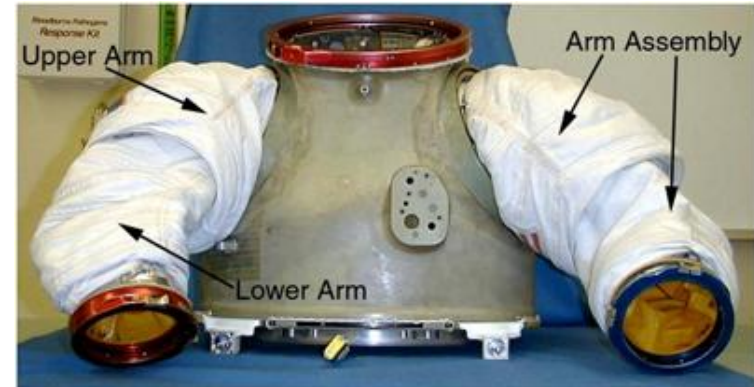




EVA Systems – Life Support



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

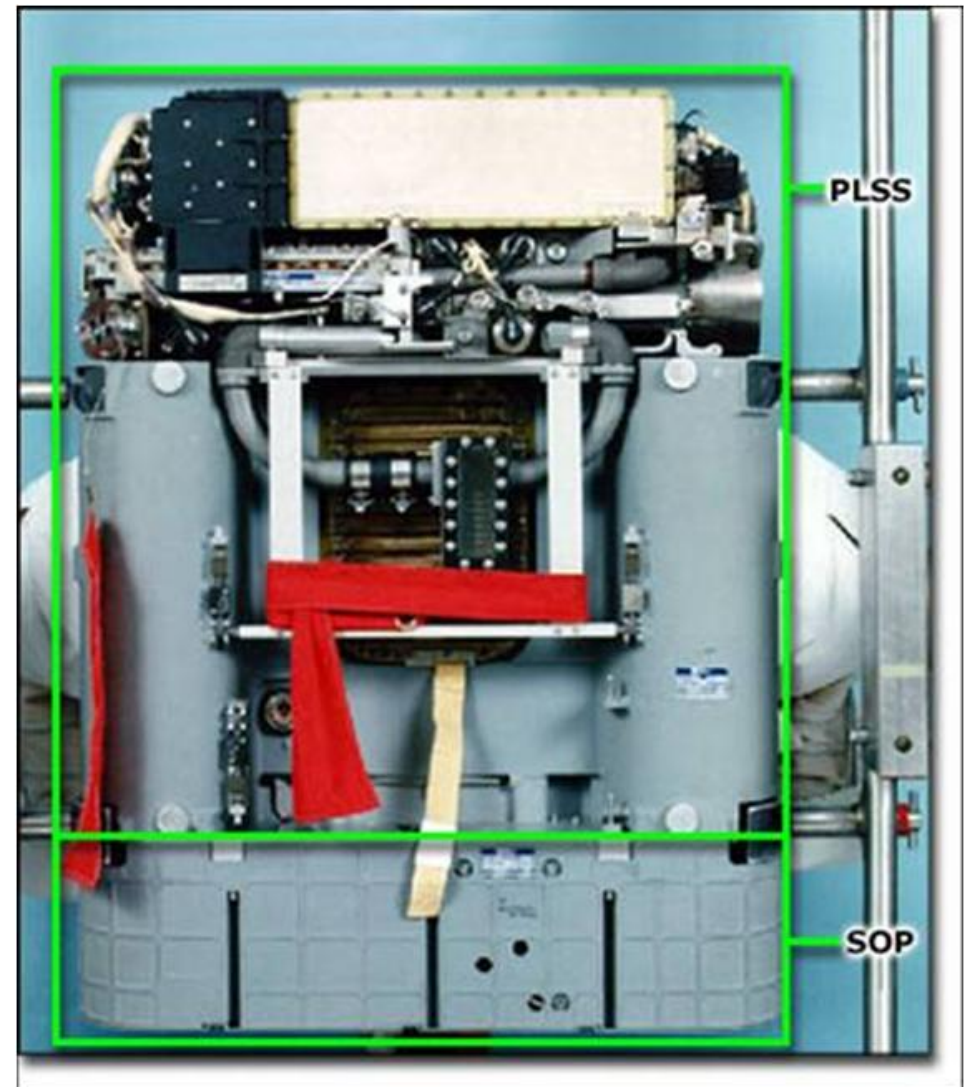




EVA Systems – Life Support



- 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



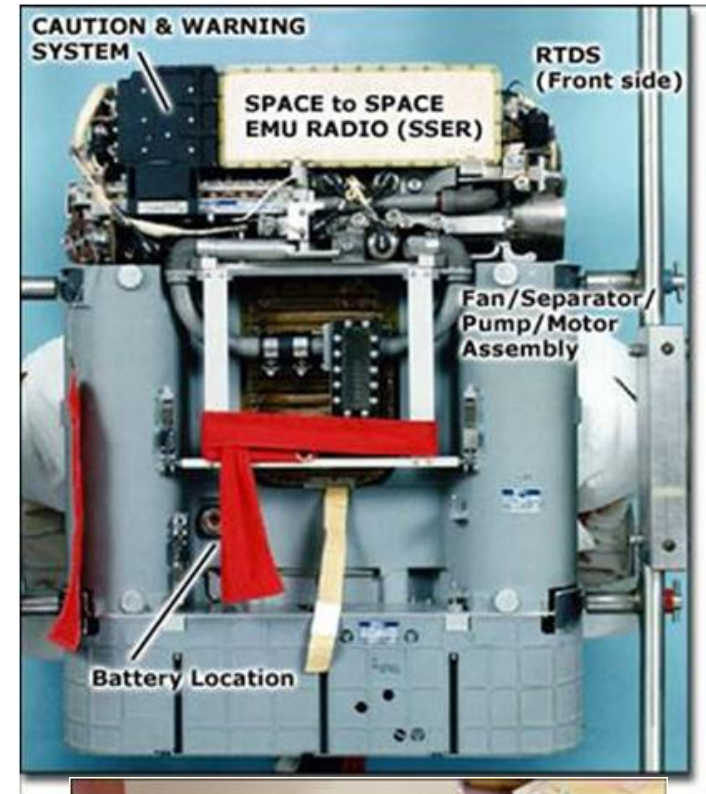


EVA Systems – Life Support



• 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 CO₂ 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:
 - CO2 cartridge (non-regenerable LiOH)
 - Oxygen
 - Potable water (for drink bags)
 - Feedwater (or sublimator water)
 - Power
 - Battery chargers

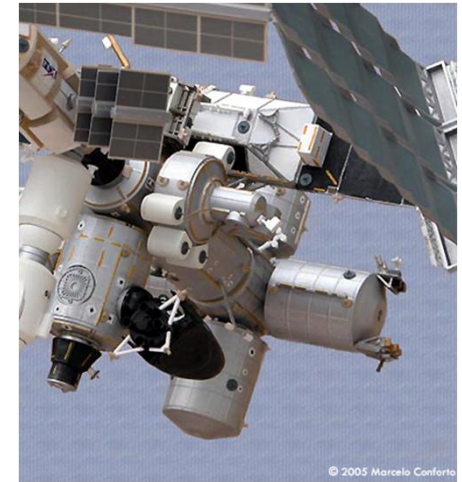
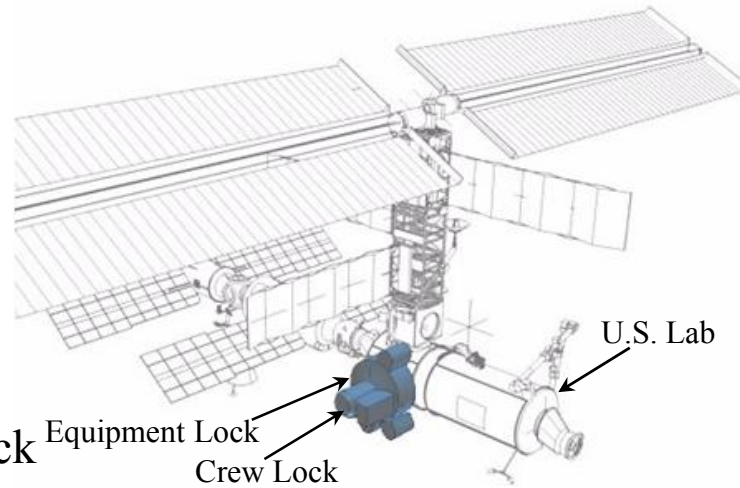
- International Space Station (ISS)
 - 4 - EMUs are, typically, kept on board to support EVAs
 - Sufficient consumables allow a large number of EVAs to be performed
 - Consumables provided include:
 - CO2 cartridge (metal oxide) and regenerator
 - Oxygen
 - Potable water (for drink bags)
 - Feedwater (or sublimator water)
 - Power
 - Battery chargers



EVA Systems - ISS Joint Airlock

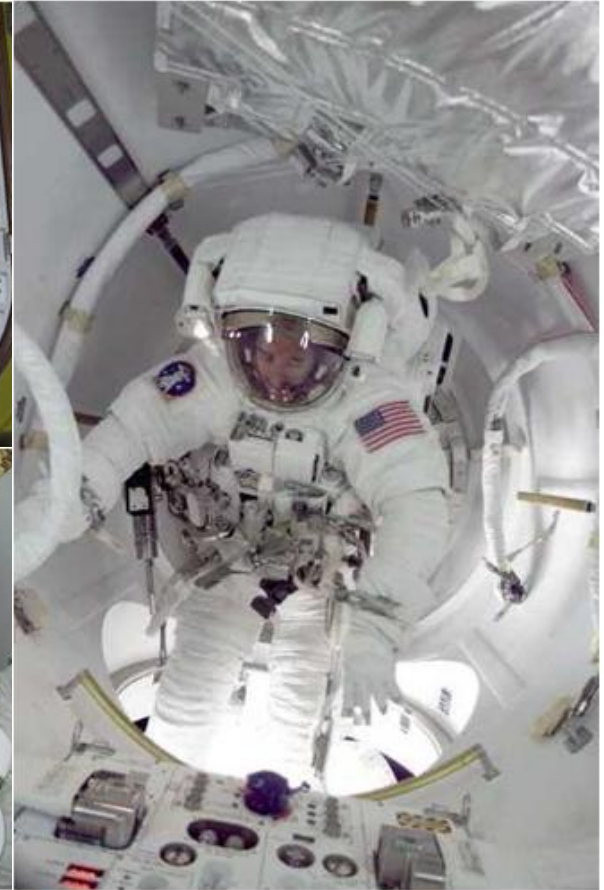


- ISS Joint Airlock:
 - Primary for U.S. ISS EVAs (both Orbiter and Station-based)
 - Compatible for use with Russian Orlans
 - Made up of two parts: Crew Lock and Equipment Lock
 - Equipment Lock is used for stowage, recharge and servicing of EMUs and to don/doff the EMUs
 - Crewlock is the volume nominally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





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

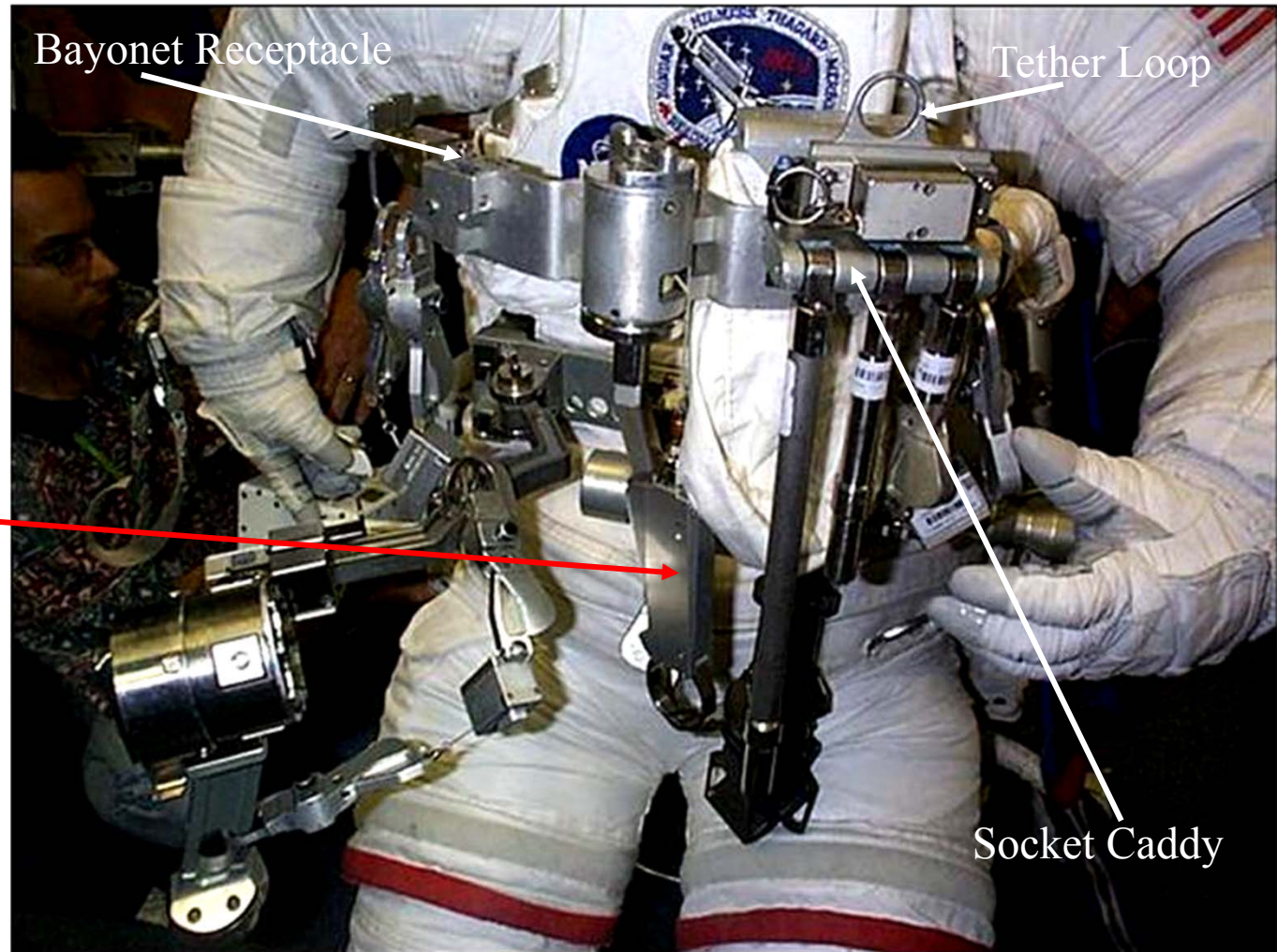




EVA Equipment & Tools



- 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



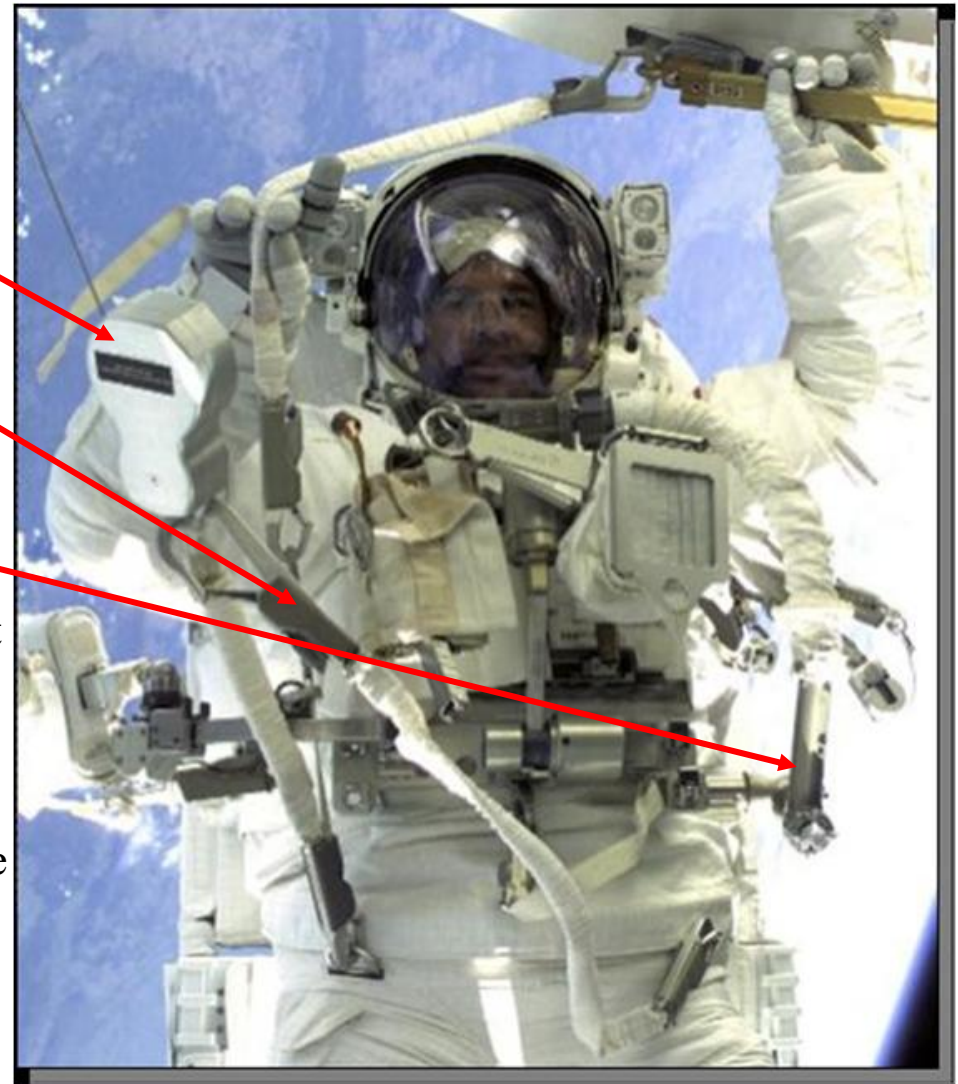
- Note: “Drop-proof tether” PIP pins are used to secure certain items such as a socket onto a tool caddy.



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 **make** a connection before you **break** a connection.

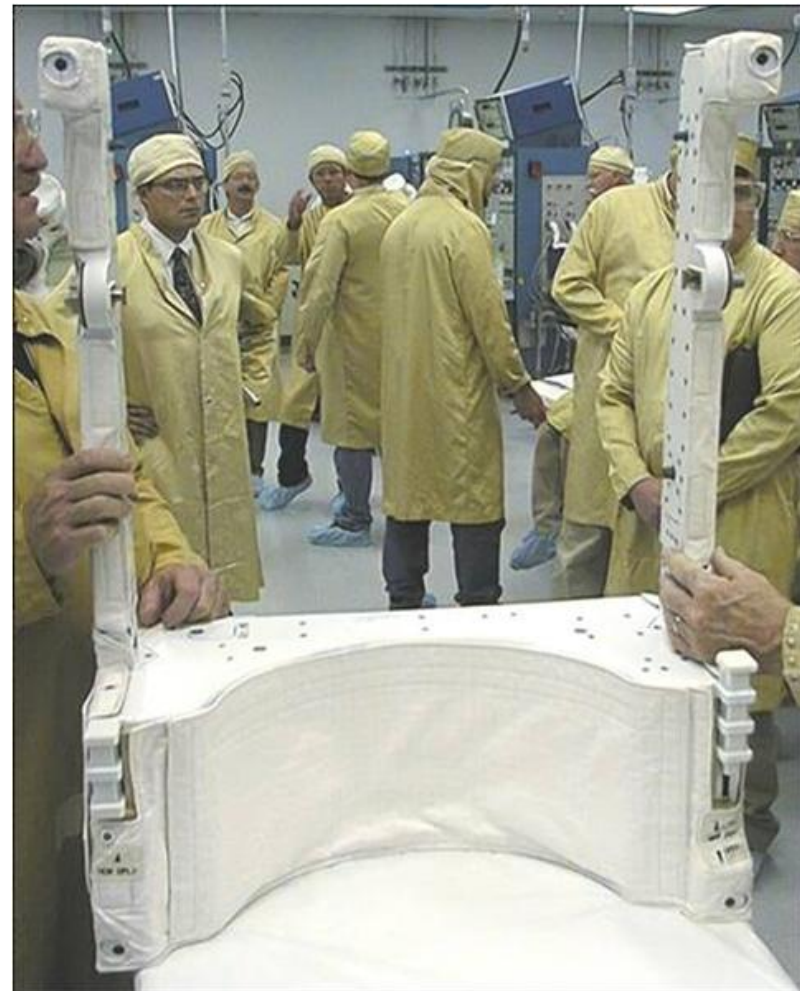




EVA Systems - SAFER (Simplified Aid for EVA Rescue)

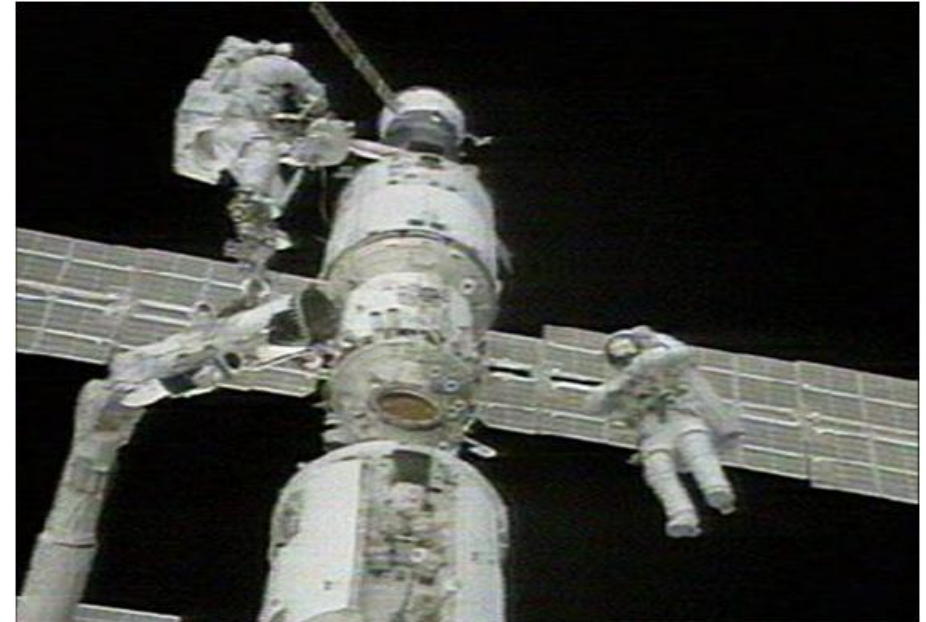
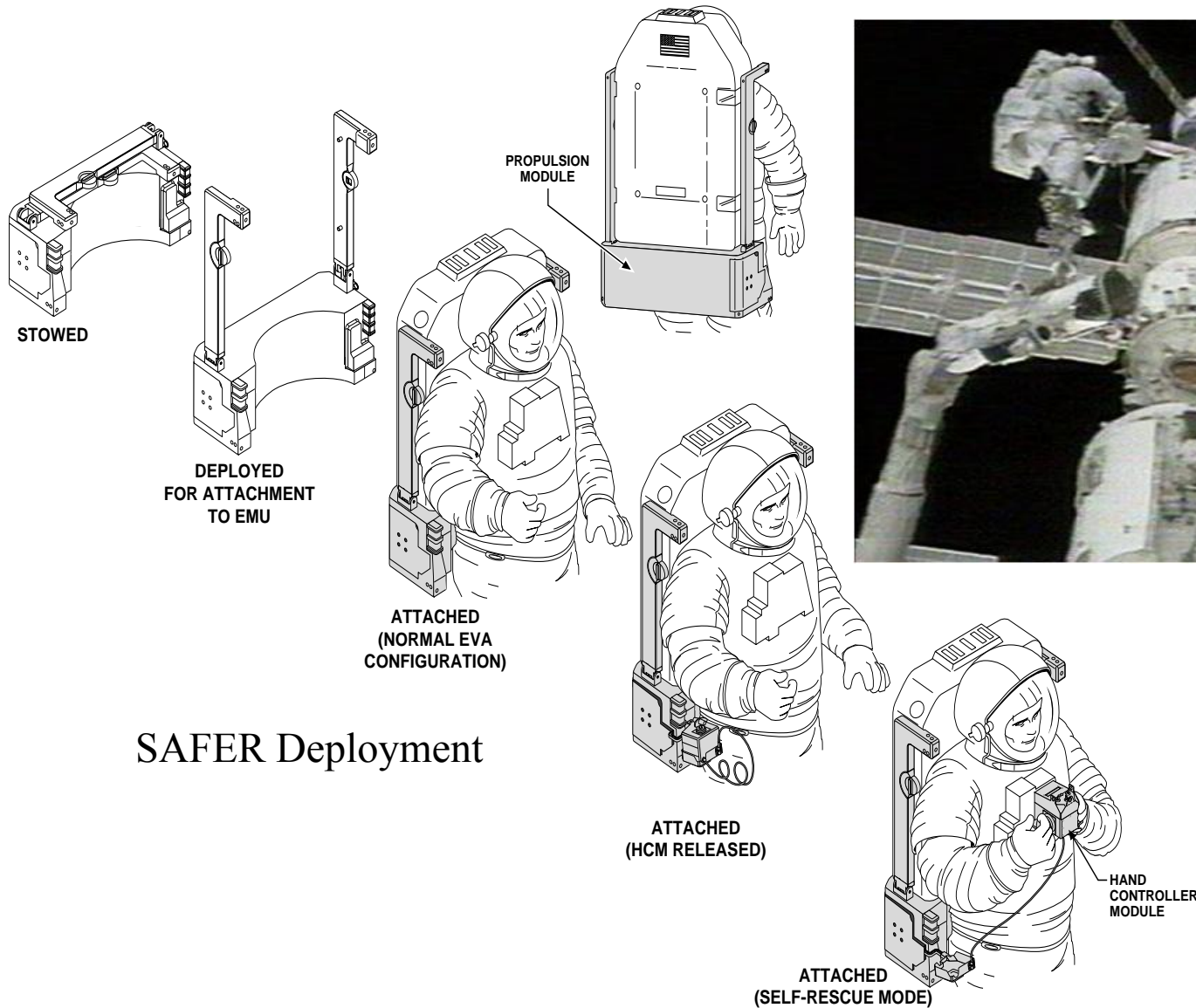


- SAFER is a self-contained, propulsive backpack self-rescue system that provides the EV crewmember with self-rescue capability when the orbiter is not present or cannot immediately perform EVA rescue.
 - Propellant: Pressurized nitrogen gas
 - Controlled by a single hand controller
 - Stowed in ISS 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)



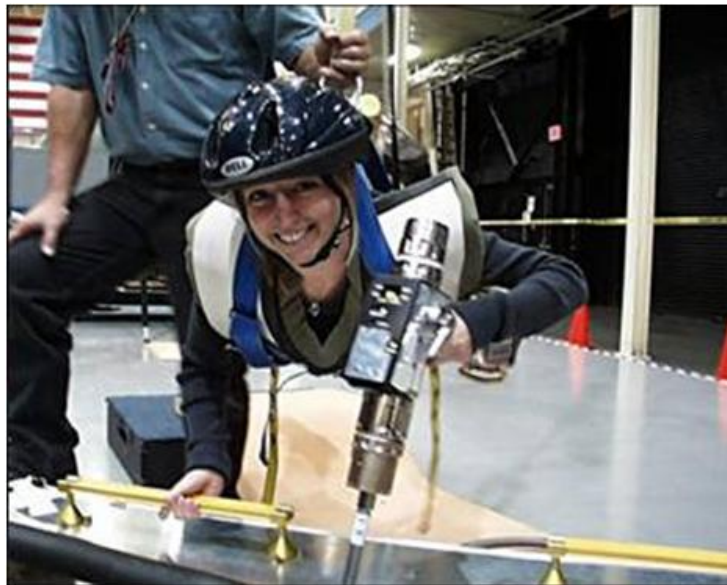
SAFER Deployment



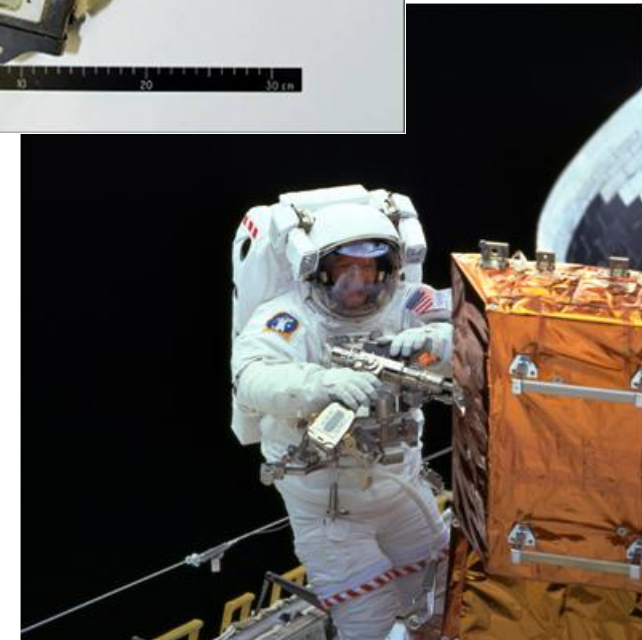
EVA Equipment & Tools



- 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*)

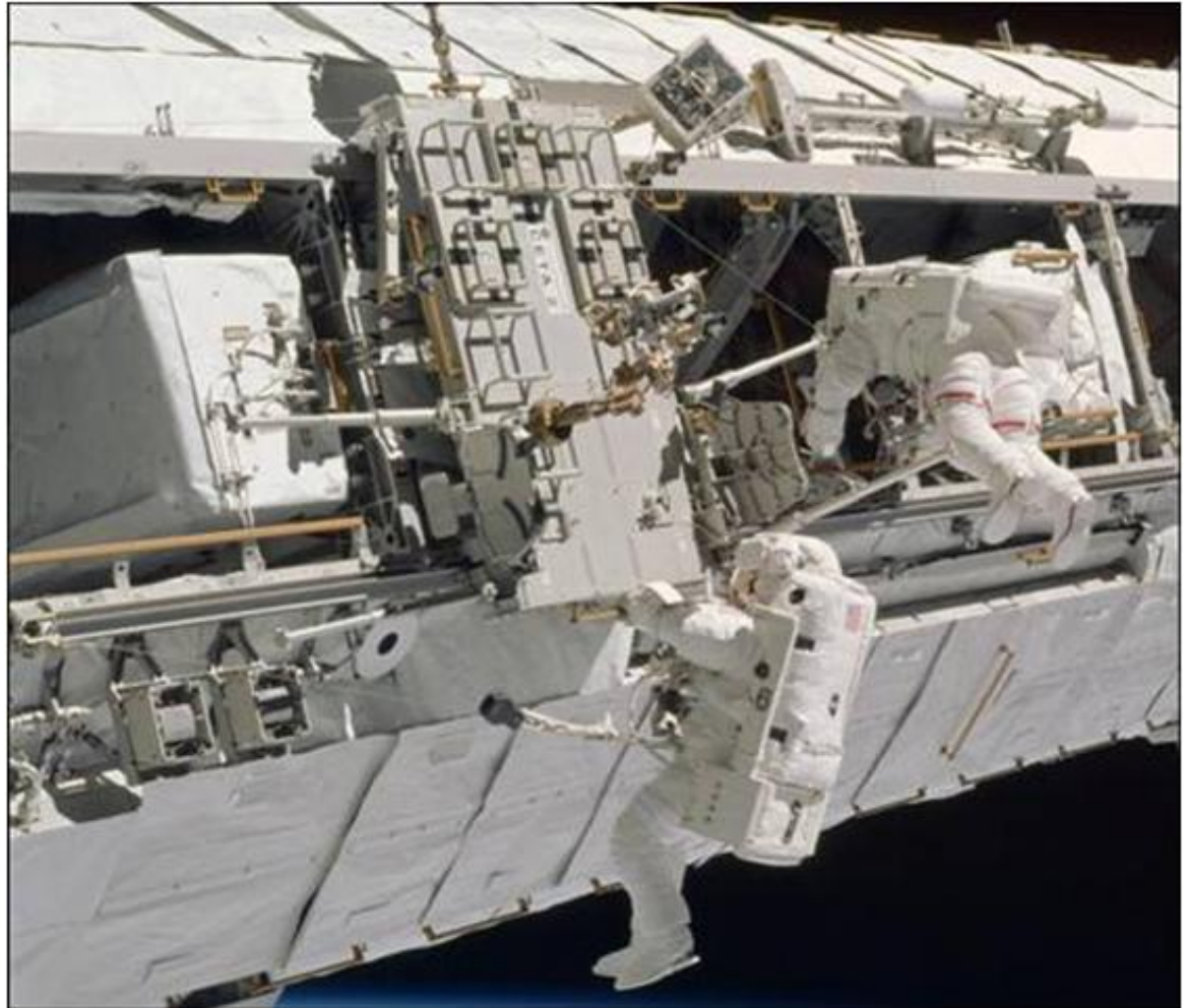




EVA Equipment & Tools



- 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



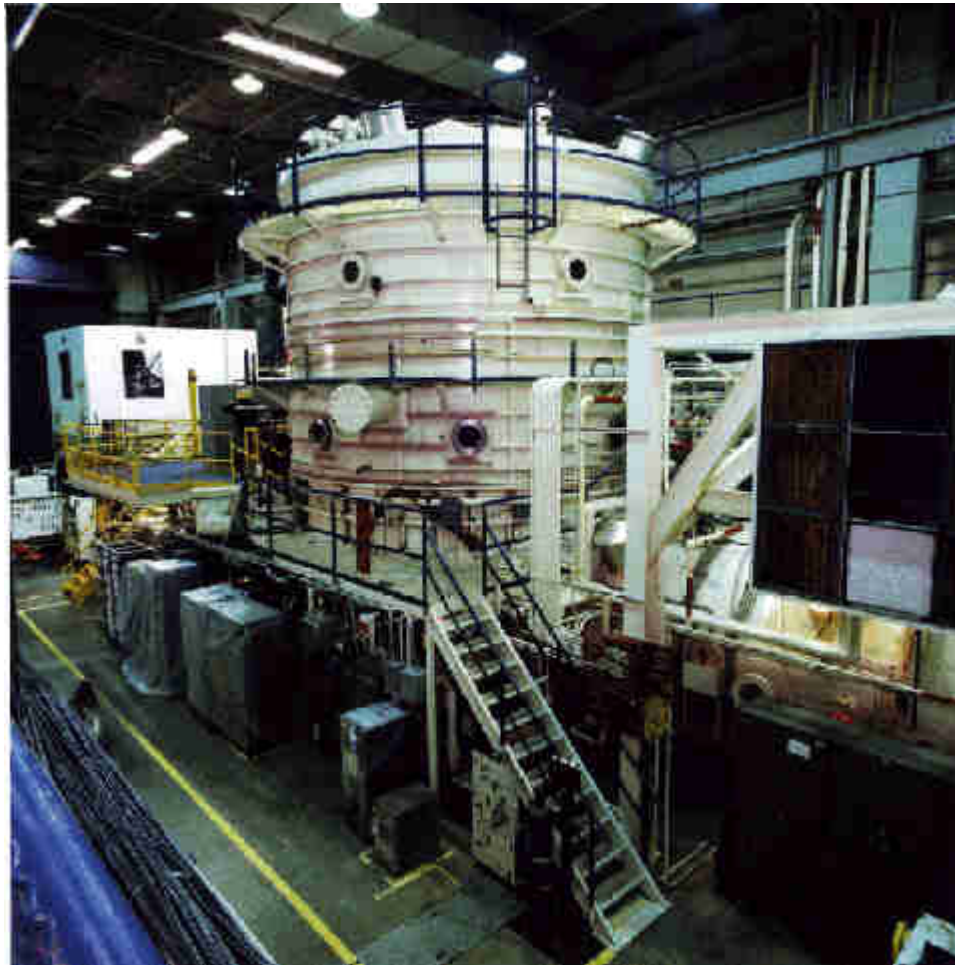
O₂ Prebreathe reduces the risk of Decompression Sickness (DCS)

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 (1 st day)	80 minutes
In-suit prebreathe time	4 hours	100 min	50 min (2 nd day)	1 hour
Ops Overview <i>(Details of EVA Prebreathe protocols are in the Aeromed Flight Rule #B13-107)</i>	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% O ₂), 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.



20-Foot Chamber



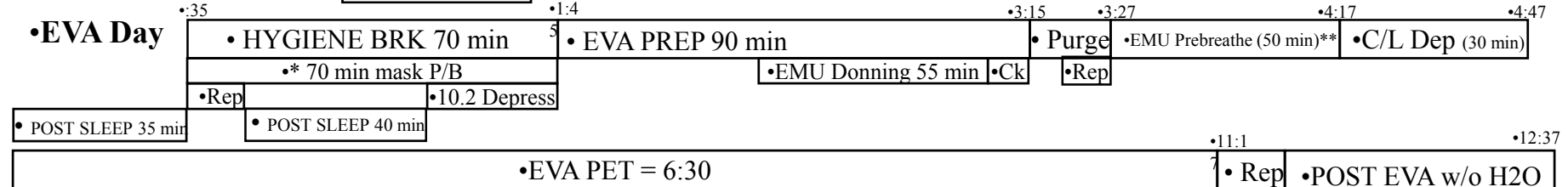
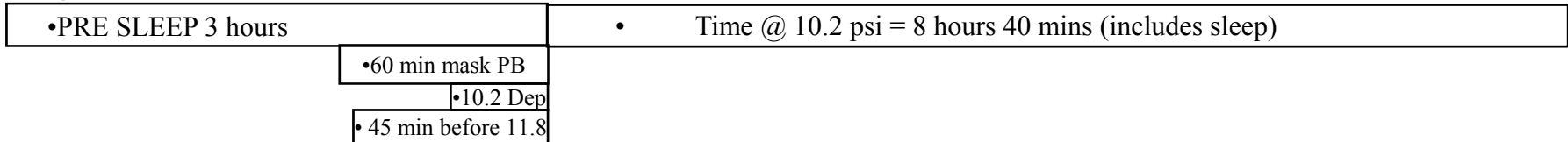


Overhead of an EVA

(EVA Campout – Times Approximate)



•Night Before EVA



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 EVA Tasks



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: <ul style="list-style-type: none">• 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
 - O₂ tank recharge
 - Battery recharge
 - H₂O tank refill
 - METOX regeneration/ LiOH swap
 - Suit cleaning
 - Suit resize (if required)



Comparison of Russian & U.S. EVAs

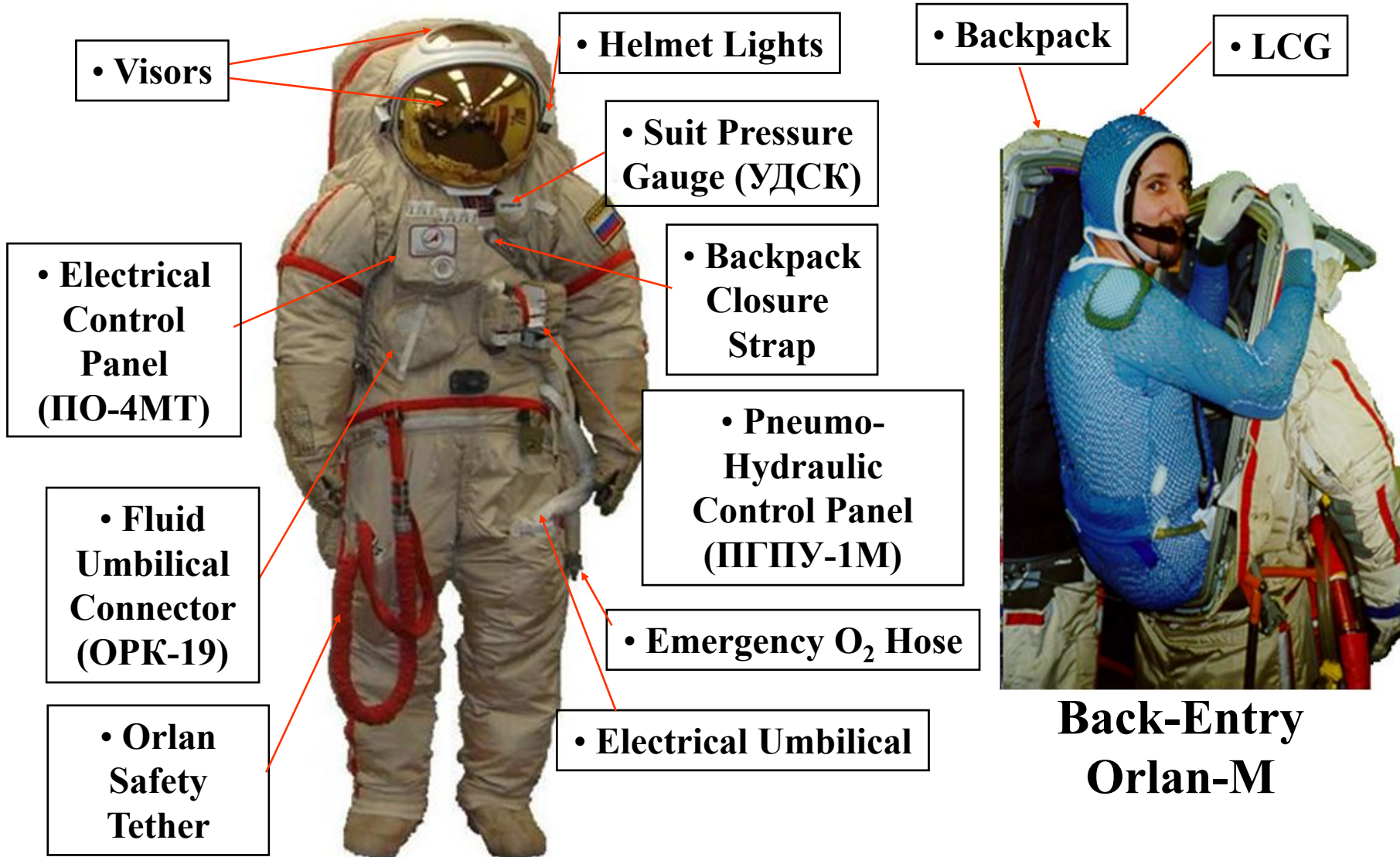


- Russian Orlan-M Spacesuit
- U.S. Extravehicular Mobility Unit (EMU)



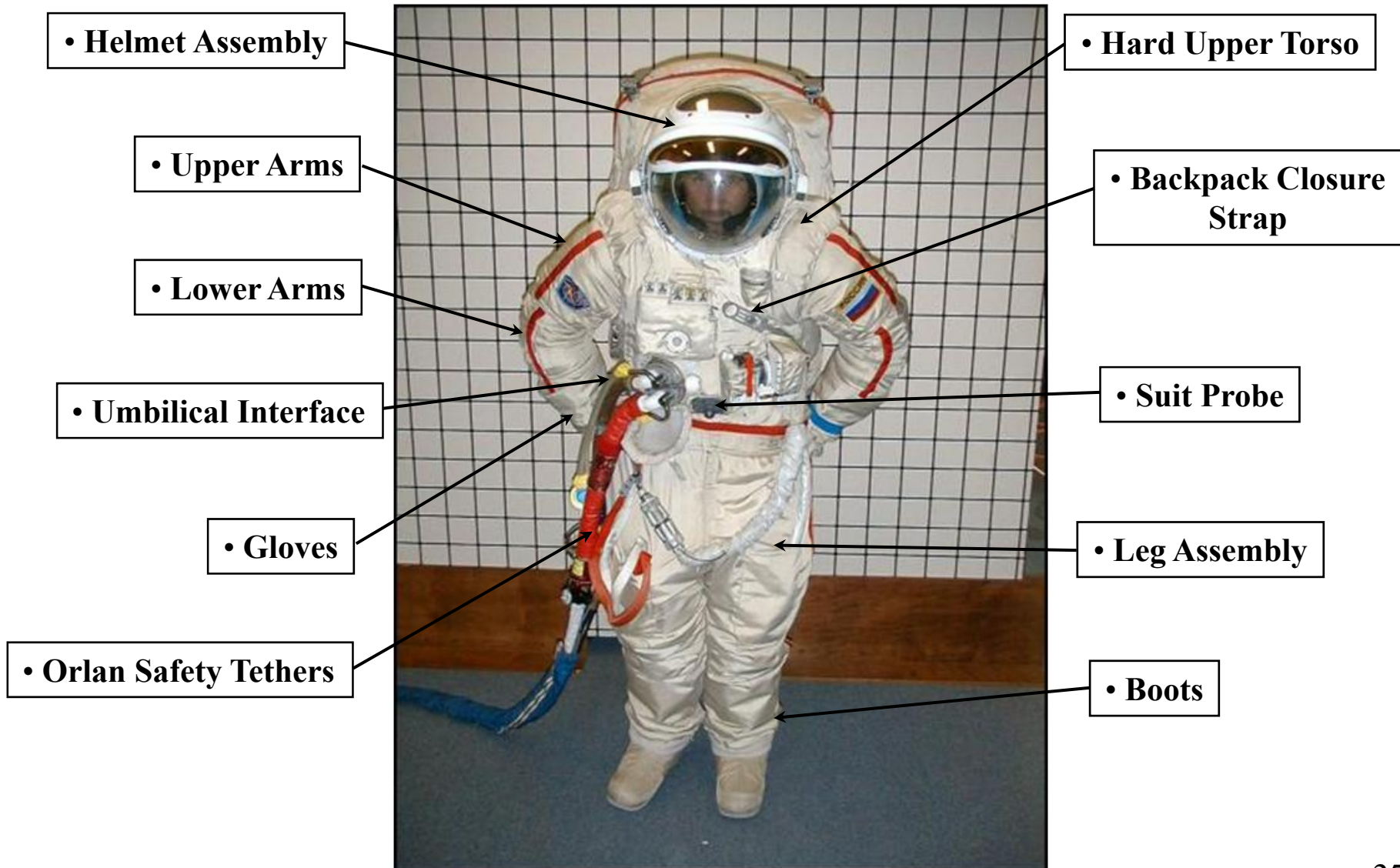


•Orlan-M Spacesuit





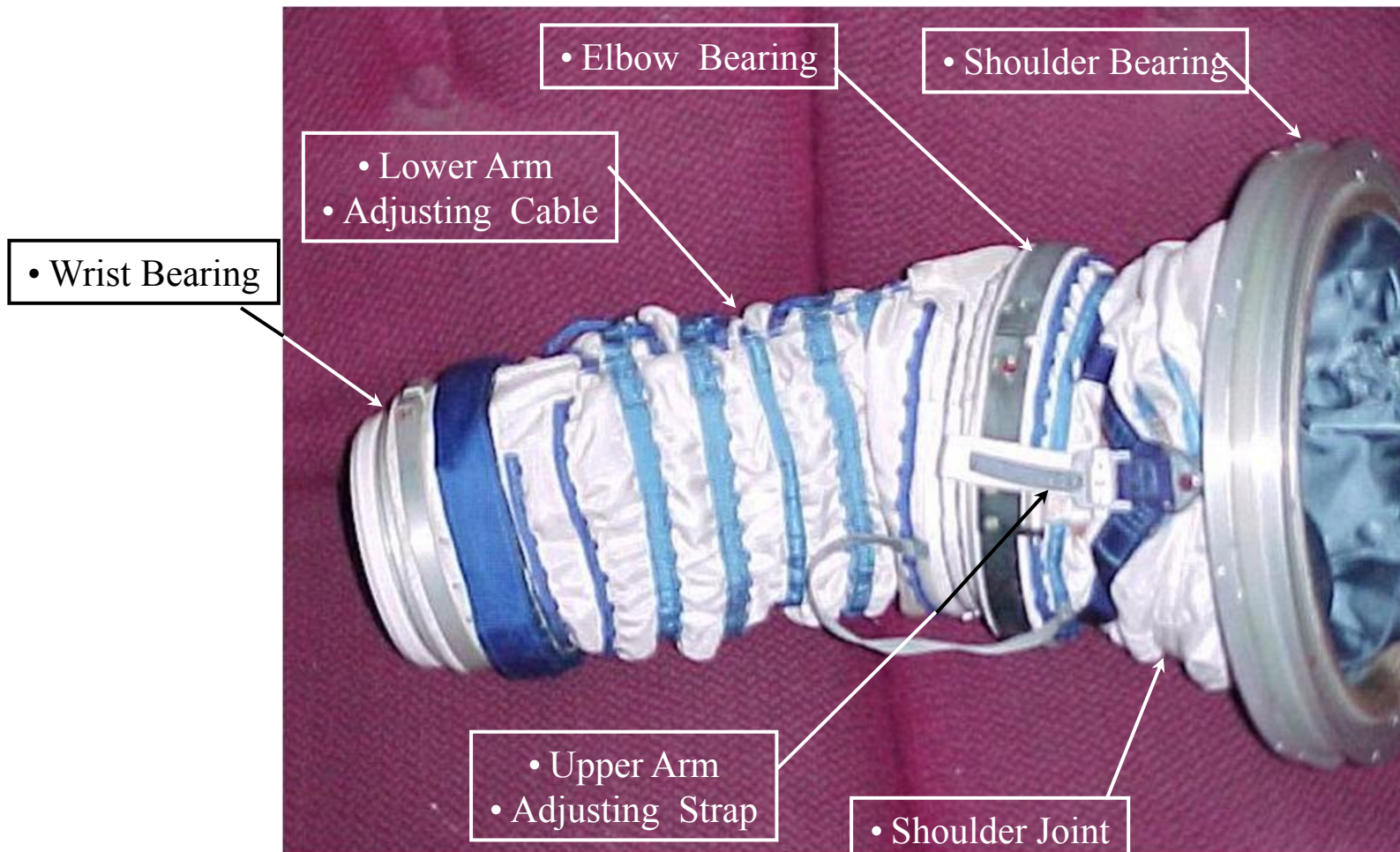
• *Suit Enclosure*





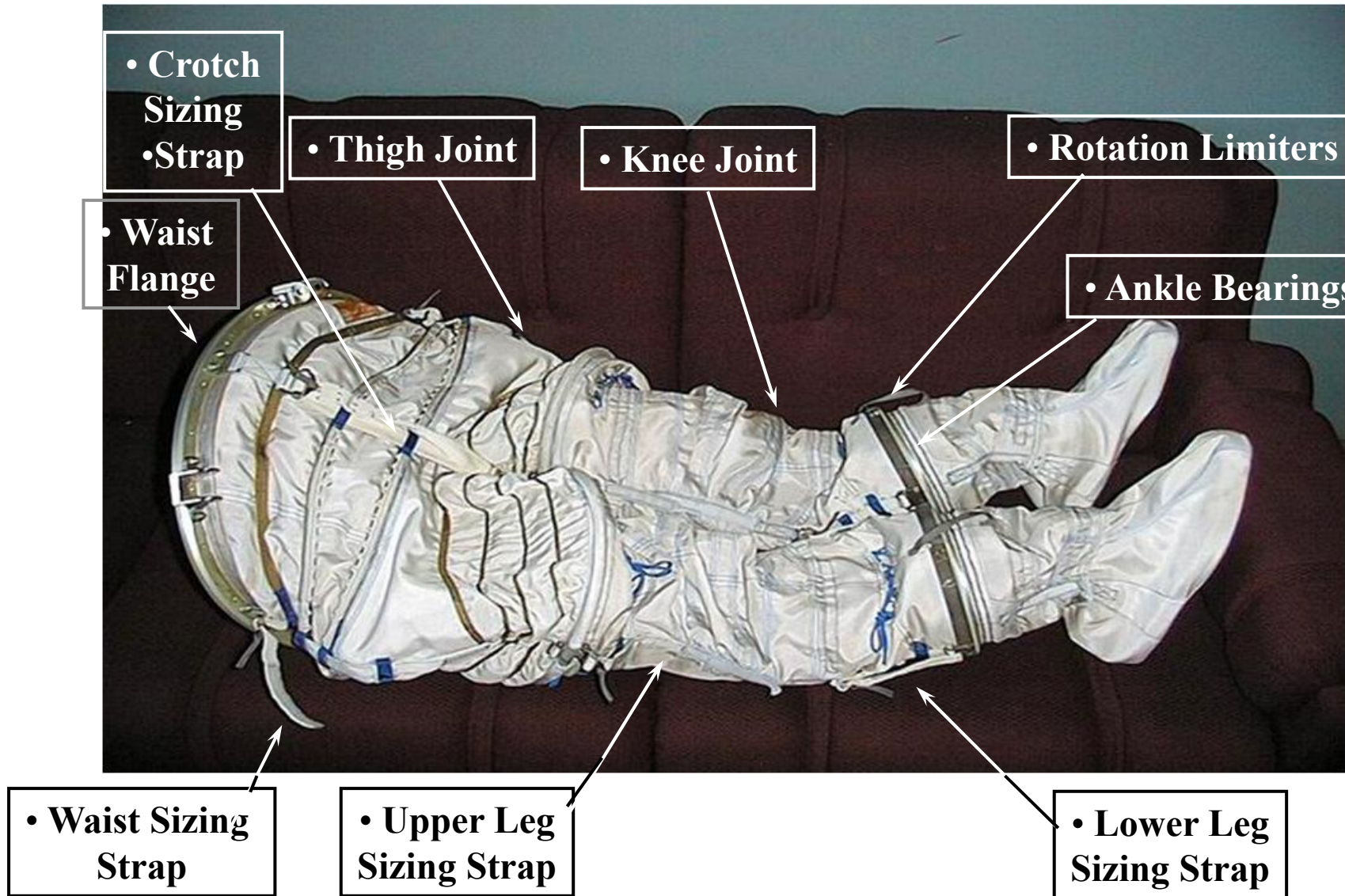
• *Arm Assembly*

(Thermal Micrometeoroid Garment "TMG" Removed)





• *Leg Assembly* (*TMG Removed*)





Orlan-M Glove





Electrical Control Panel (ΠΟ-4MT)



• Battery Voltage/Oxygen Tank Pressure Display

• Liquid Crystal Display



• Primary Pump Switch

• Primary Fan Switch

• Reserve Fan Switch

• Reserve Pump Switch

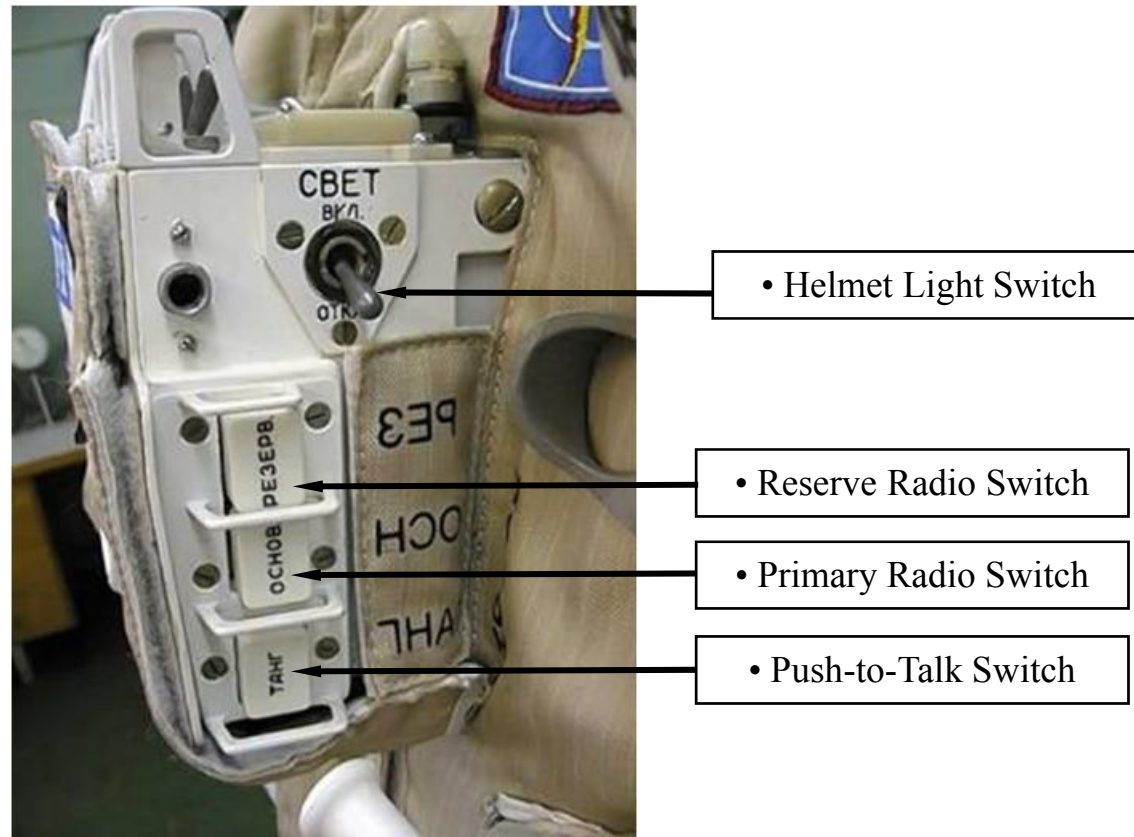
• Volts/Tone Mute Button

• Power Switch

Orlan-M Electrical Control Panel (ΠΟ-4MT)



Electrical Control Panel (ΠΟ-4MT)



•Orlan-M Electrical Control Panel (ΠΟ-4MT) (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 (TA-237)
 - Transmitter (ША-347)
 - Battery (autonomous power supply)
 - Current and Power Measurement Unit (БКНТЗ)
 - High-Frequency Filter (ФП (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

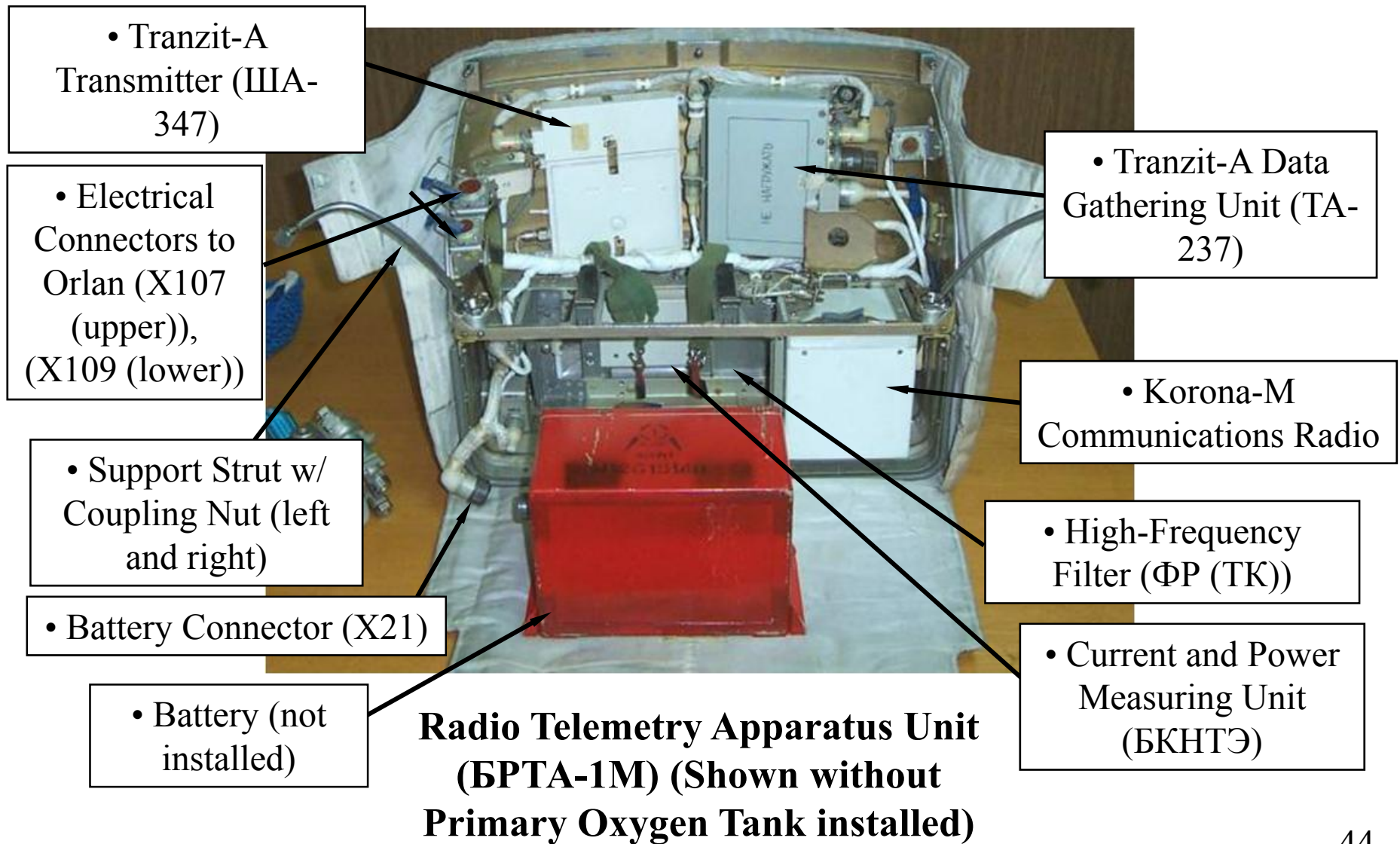


• Life Support System Backpack

• БРТА-1М



Radio Telemetry Apparatus Unit (БРТА-1М)





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 to be delivered to the 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 BPTA) 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 foot restraints, etc.
 - Simplified Aid For EVA Rescue (SAFER)
 - Donning stations
- Orlan-M
 - Compatible with:
 - Mini-work station
 - EVA tools including foot 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 (ESL) chamber
 - Space Station Airlock Test Article (SSATA)





EVA Training Facilities



- Virtual Reality Lab





EVA Training Facilities Charlotte for Low Gravity Mass Ops



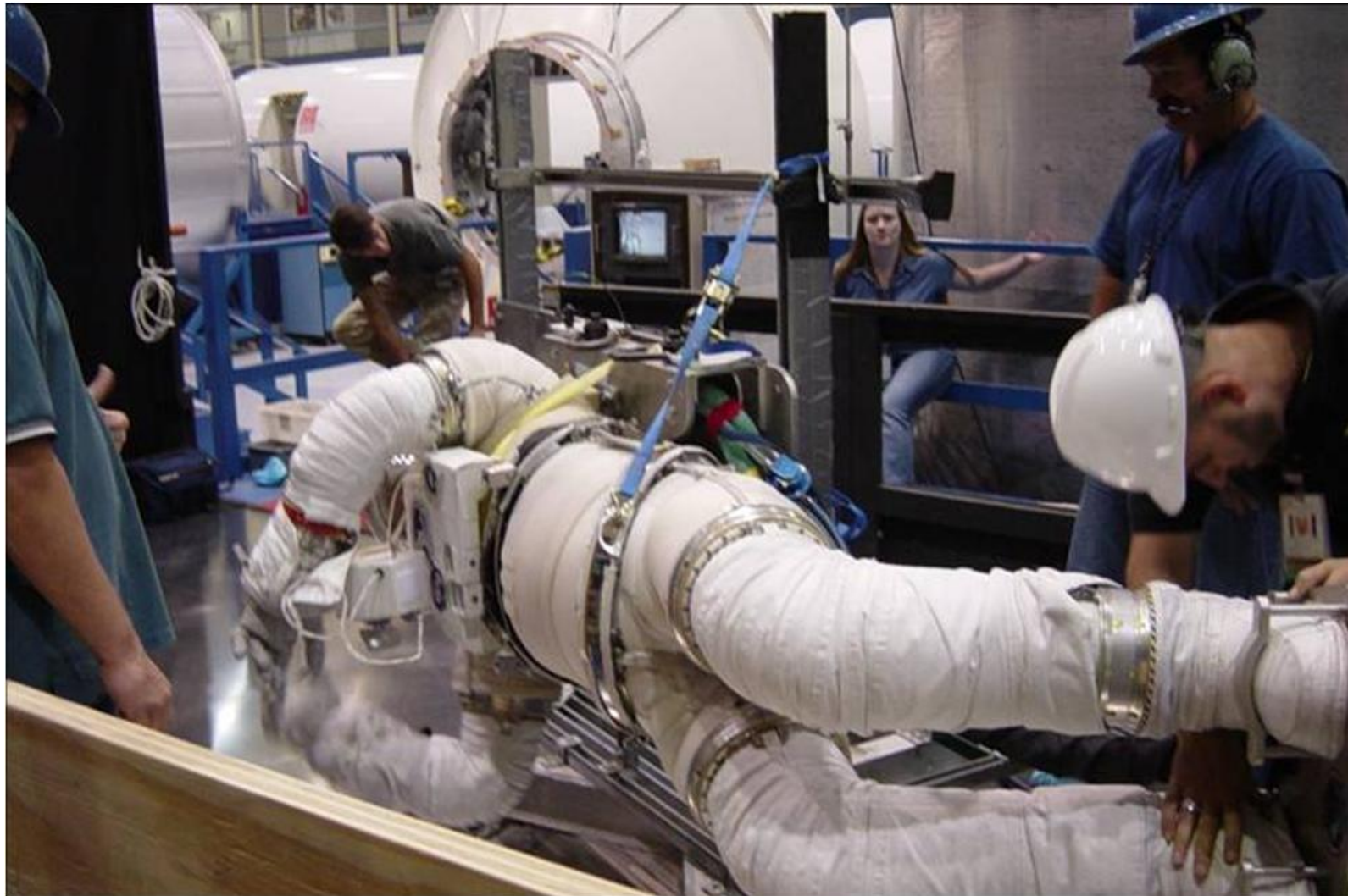
Source : Osterlund, J. & Lawrence, B. 2012



EVA Training Facilities



- Precision Air-Bearing Floor (PABF)





EVA Training Facilities



- Neutral Buoyancy Laboratory (NBL)





EVA Training Facilities



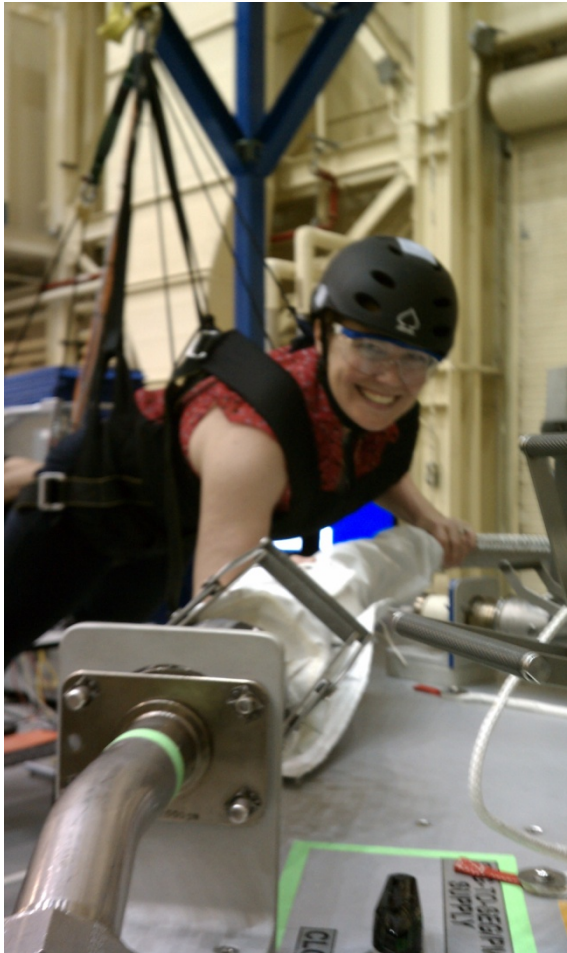
- Micro-gravity via DC-9 (KC-135 below retired)





EVA Training Facilities

The Active Response Gravity Offload System (ARGOS)



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



WEB Links

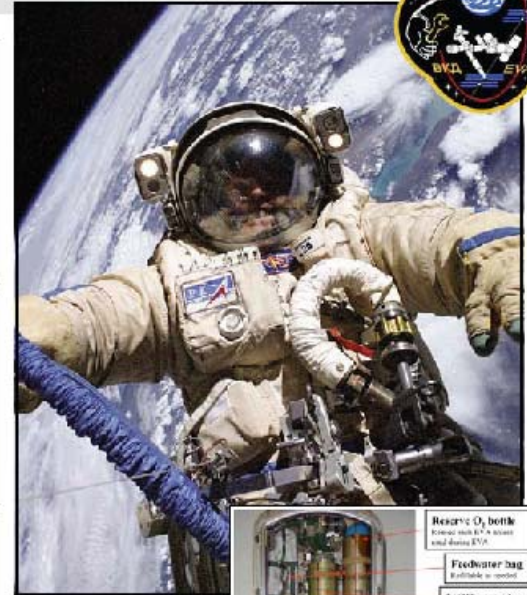


- EVA History/Advanced suit program –
<http://www.jsc.nasa.gov/xa/advanced.html>
- Hamilton Sunstrand(designers of the EMU) -
<http://www.hsssi.com/Applications/SpaceSuits/>
- DX32/35 Home page –
<http://mod.jsc.nasa.gov/dx/dx32/evahp.htm>
- EC5 Homepage –
<http://ctsd.jsc.nasa.gov/ESS/index.html>
- Osterlund and Lawrence, B., “Virtual reality: Avatars in human spaceflight training.” *Acta Astronautica*, Vol. 71, 2012, pp. 139-150.
<http://dx.doi.org/10.1016/j.bbr.2011.03.031>



Backup Material

Extravehicular Activity Suits For ISS



EMU General Reference Data

Part Number -	SEG13101492
Life -	2 years after PIA
Autonomous Operation -	7 hours
Weight wet <	350 lbs 160 kg
Avg. Metabolic Rate -	1000 BTU 290 W
Max. Metabolic Rate -	2000 BTU 580 W
Nominal Pressure -	4.3 psi 0.29 atm
Max Nom. Leak (bottle) -	0.82 cfm 0.7 atm/min
Prebreathe from 40 minutes to 4 hours	

Oxygen Supply

EMU Primary Oxygen Circuit

Circuit Contains 2 Primary Bottles

Pressure ~	900 psi	61 atm
Volume -	240 in ³	6.9 L
Contents of O2 ~	1,317 lb	0.6 kg
Burst Pressure -	2100 psi	143 atm

Secondary Oxygen Pack

SOP Contains 2 O2 Bottles

Pressure ~	6000 psi	410 atm
Volume -	89.2 in ³	1.5 L
Contents of O2 ~	2,631 lb	1.2 kg
Burst Pressure -	14800 psi	1000 atm

Regulator maintains suit pressure in nominal mode to compensate oxygen consumption and leakage.

Gas Recovery System

CO2 Removal - LiOH or Metox

Absorption Capacity -	1.48 lbs	0.67 kg
LiOH Limit - 7 hours at	1000 Btu/hr	290 W
Metox Limit - 8 hours at	850 Btu/hr	250 W

LiOH Recharge on Ground

Metox Recharge on ISS (55 cycles)		
Min Flow Rate -	6.0 cfm	170 L/min
Low Vent Signal at <	3.7 cfm	100 L/min

Gas flows through the helmet and is returned to life support system through ducting in the arms and legs

Cooling Supply

Feedwater - 3 Tanks

Tank Capacity -	10 lbs	4.2 kg
Tank Water ΔP:	15 psi	1.03 atm
15 min Max Heat Use ~	2000 Btu/hr	585 W
30 min Min Heat Use ~	400 Btu/hr	115 W
Water Temp at Outlet	53 oF	12 oC
Gas Temp at Outlet	57 oF	13 oC
Cooling Water Rate >	240 lb/hr	110 kg/hr

Single tank for cooling water and feedwater cycles water through the LCVG and provides water for sublimation.

Orlan-M General Reference Data

Part Number -	2MO-9000-00 T4
Life -	4 years or 12 EVA
Autonomous Operation -	6-1 hours
Total Operation with A/L ops -	9 hours
Glove Uses -	2-1 EVA
Weight with EPTA <	247 lbs 112 kg
Avg. Metabolic Rate -	1025 BTU 300 W
Max. Metabolic Rate -	2050 BTU 600 W
Nominal Pressure -	5.7 psi 0.40 atm
Emergency O2 Pressure -	3.9 psi 0.27 atm
Max Nominal Leak -	0.04 cfm 1.0 L/min
Prebreathe for 30 minutes during A/L ops	

Oxygen Supply

EK-3 High Pressure Oxygen Bottle

Part Number:	2AK-7850-3000
Pressure ~	5700 psi 400 kg/cm ²
Volume ~	123 in ³ 2 liters
Contents of O2 ~	2.2 lbs 1 kg
Burst Pressure ~	17000 psi 1200 kg/cm ²

Primary located in EPTA (1 time use)
Emergency located in HUT backpack

Regulator maintains suit pressure in nominal mode when O2 consumption and leakage is less than 3.2 L/min

Gas Recovery System

CO2 Removal -	LiOH (1 time use)
LiOH Part Number -	2AK-7851-2850
LiOH Max Operating -	9 hours
Absorption Capacity -	1.63 lbs 0.74 kg CO2
Min Flow Rate ~	5.65 cfm 160 L/min
Min Flow Rate <	0.78 cfm 22 L/min
CO2 Sensor Filter -	3 times use
Feedwater Filter -	1 time use
Moisture Collector/Separator -	1 time use

Gases drawn through vents in arms, legs, and helmet, passes through filters, and returns through outlet duct in helmet

Cooling Supply

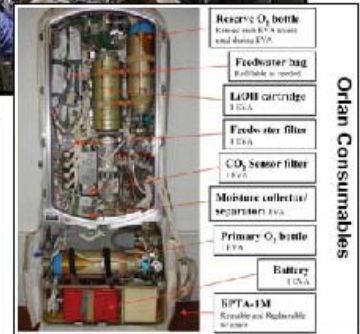
Feedwater Tank -	Collapsible
Tank Capacity -	245 in ³ 4.0 L
Nominal Tank Fill ~	220 in ³ 3.6 L
Tank Water ΔP:	2.8-3.3 psi 0.2-0.22 atm
Sublimator Cooling -	2400 BTU/hr 700 W
Water Temp Out	43-59 oF 6-15 oC
Gas Temp Out	46-61 oF 8-16 oC
Cooling H2O Flow >	330 lb/hr 2.5 L/min

Cooling water and feedwater tank are independent.
Cooling water cycles through the LCG and heat exchange; the feedwater tank provides water for sublimation.

Power Supply

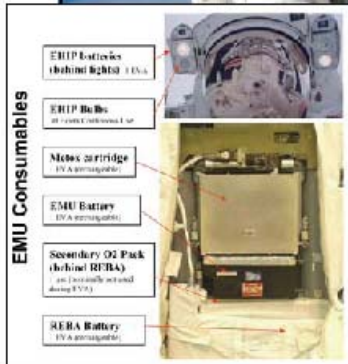
Rechargeable Battery 825M3 - 5 cycle use

Part Number 4III3.585.887-02	
Nominal Voltage -	27 V
Minimum Capacity -	13.12 Amp*Hours
Life -	360 days (240 charged days)
Duration:	7 hour EVA at 54.5 W nominal draw



Radio and Telemetry

Radio Range -	40 meters
Voice/Telem Freq (Red) -	121.125 / 231.0 MHz
Voice/Telem Freq (Blue) -	121.75 / 247.1 MHz
Receiver Frequency -	130.167 MHz
Measured Telemetry Parameter -	27



Power Supply

2 Version of Battery: 2000 and LIB Series

Duration:	7 hour EVA at 3.8 amp draw
Minimum Capacity -	26.6 Amp*Hours
2000 Series Life -	300 days (12 cycles)
Battery Consists of 11 Silver Zinc Cells	
Nominal Voltage -	16.8 V
LIB Series Life -	1825 days (150 cycles)
Battery Consists of 5 Lithium Polymer cells	
Nominal Voltage -	16 to 20.5 V

Radio and Telemetry

Radio Range -	75 meters
Voice and Telem Frequency -	417.1 or 414.2 MHz
Sampling Rate -	500 samples/sec
C&WS Measured Parameters -	25

Extravehicular Mobility Unit



Orlan-M

For Reference Only
Chris Vando Zande
July 2006

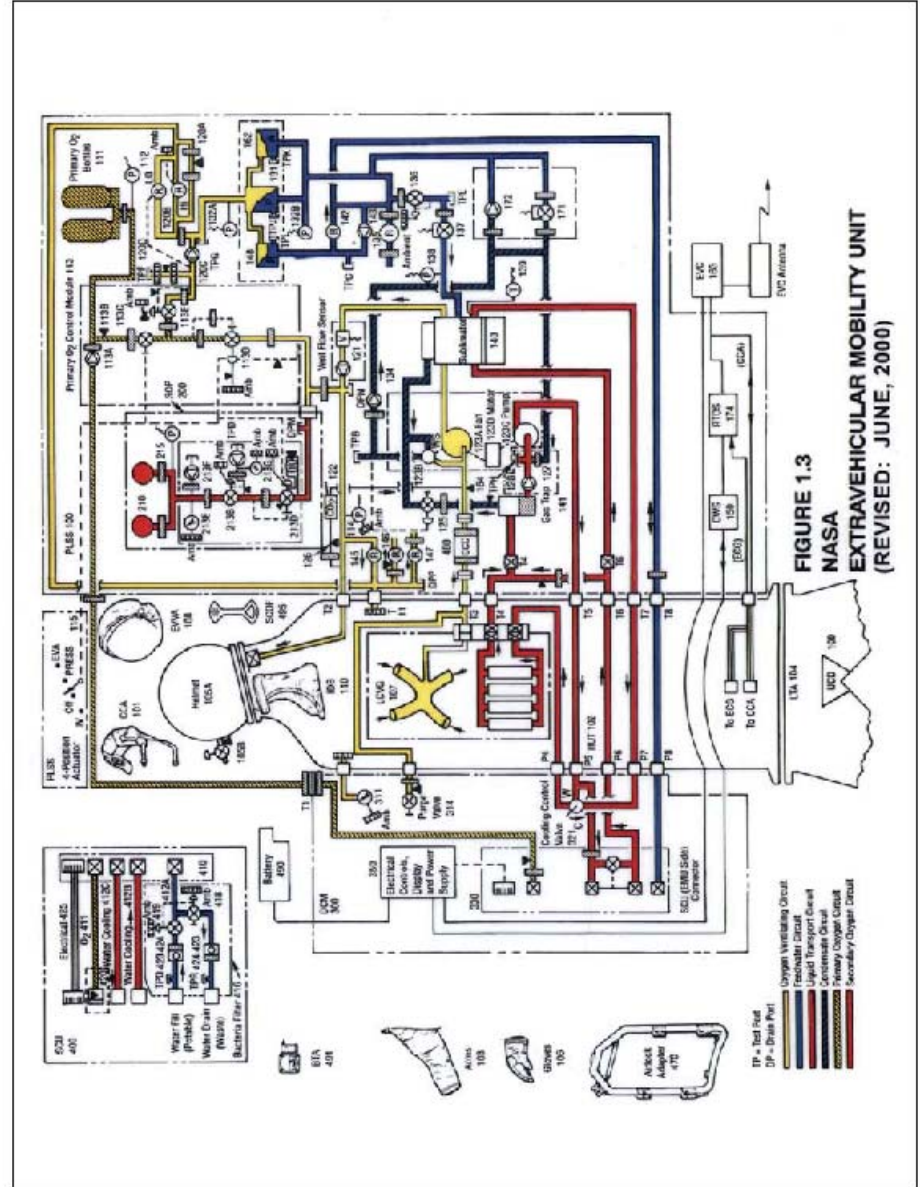
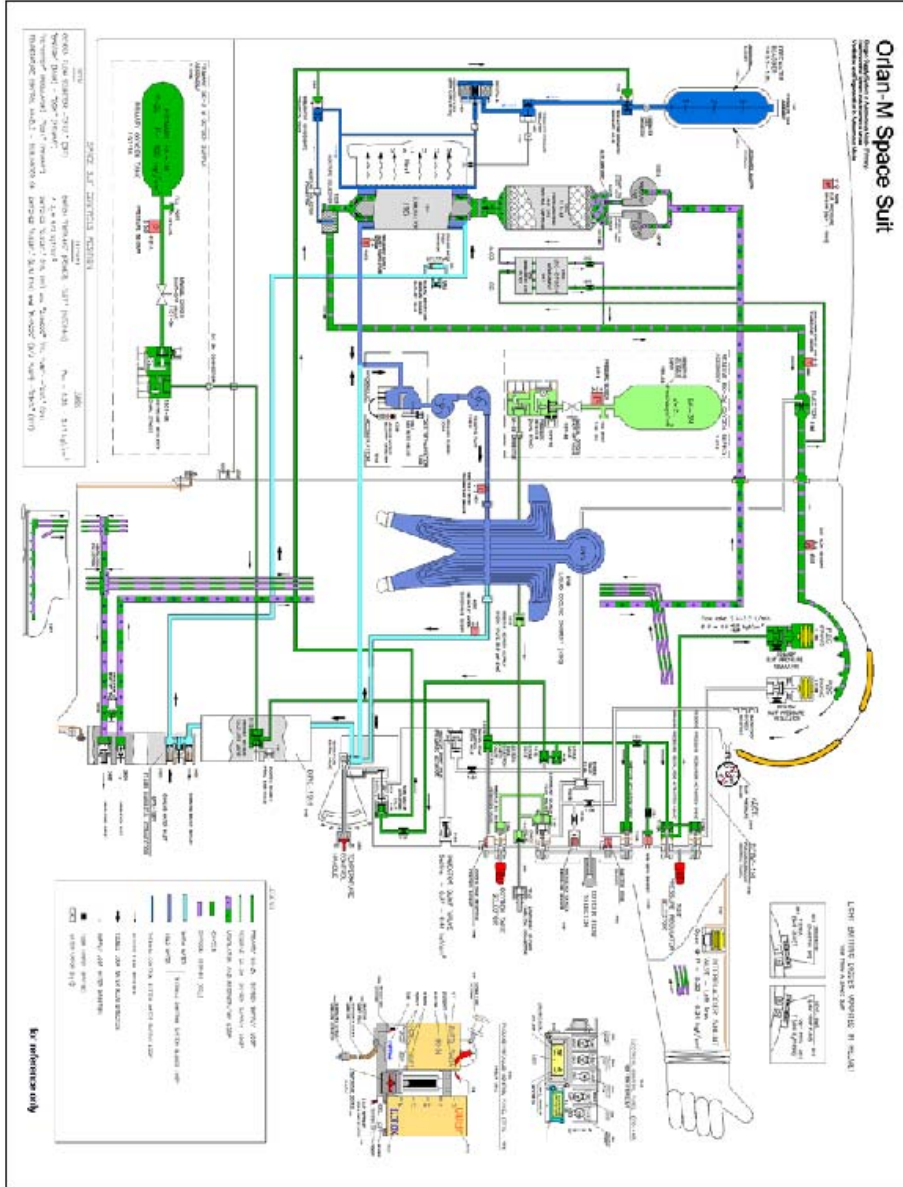


Pressures



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)

Life Support Schematics





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



Thermal Micrometeoroid Garment

