Extravehicular Activity (EVA) Hardware & Operations

U.S. & Russian EVA Spacesuit Overview

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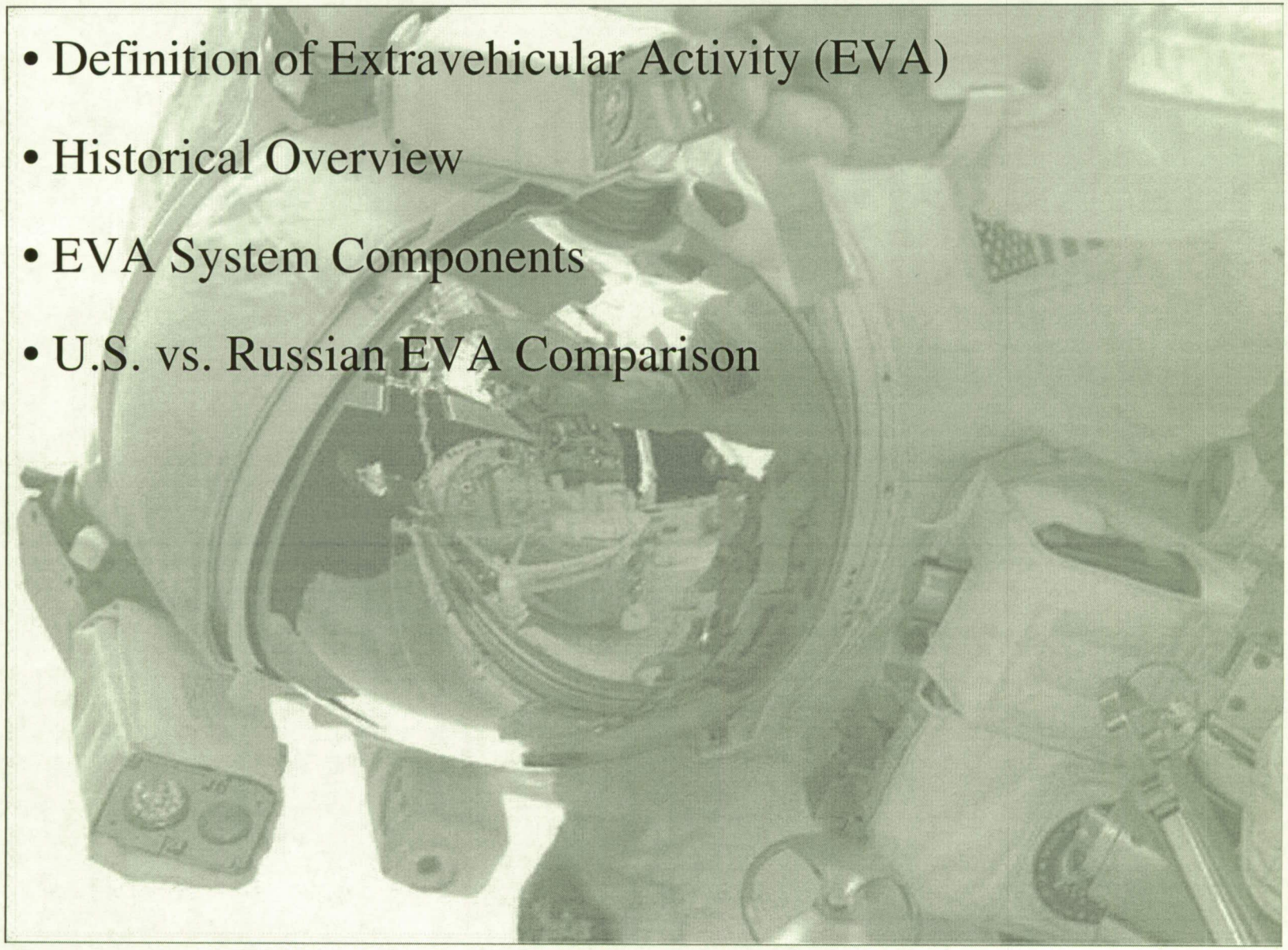
- Felix's Background

My Background

- **Name: Jose (Joey) Marmolejo**
- **Hometown**: San Antonio, Texas
- **Education**:
  - Marquette University, Milwaukee, Wisconsin. B.S., Electrical Engineering
  - University of Houston – Clear Lake, Human Factors Graduate Studies
  - International Space University (ISU) Summer Session, Adelaide, Australia, Graduate Space Studies
- **NASA Background**
  - First started in June 2001 as Cooperative Education (Co-op) student
  - Various Shuttle, International Space Station (ISS), Advanced Development assignments on U.S. and Russian Extravehicular Activity (Suits, Life Support, Tools, Airlocks and Operations)
- **Current Assignment**
  - Constellation Program – Orion Systems Manager Orion Suits, EVA, and Crew Survival
- Questions
  - Day In The Life @ NASA, What has influenced my career? Student Advice.

Introduction



- Definition of Extravehicular Activity (EVA)
- Historical Overview
- EVA System Components
- U.S. vs. Russian EVA Comparison

Definition of EVA

- Spacesuits
  - Typically, 2 types of pressurized "spacesuits' have been constructed to support our space programs

    - Launch, entry, and abort 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, meteoroids, radiation, etc.).

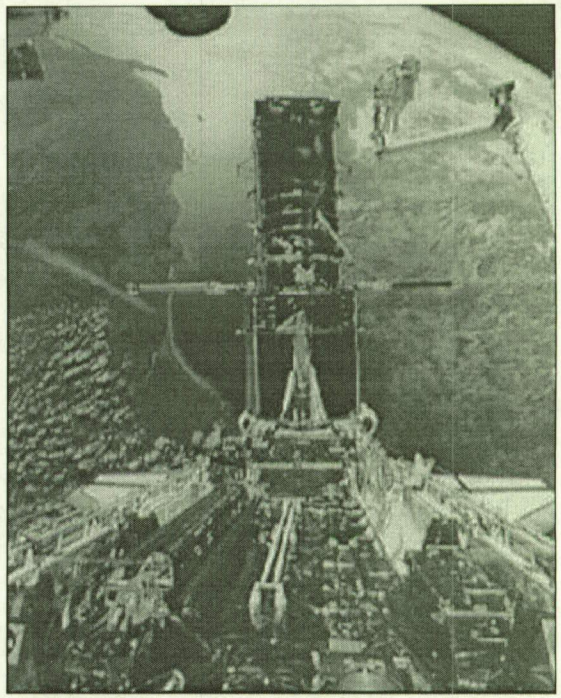
EVA Suit

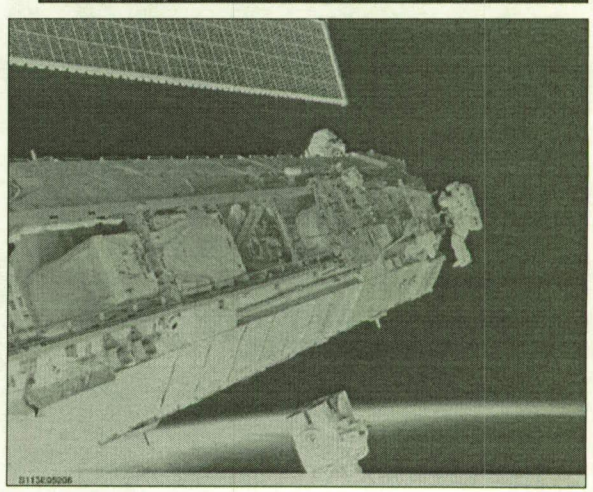
Definition of EVA

- 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 Repairs
    - Mission Success Repairs
    - Experiments or Testing
    - Spacecraft Servicing
    - Space Structure Construction [e.g., International Space Station (ISS)]





Historical Overview

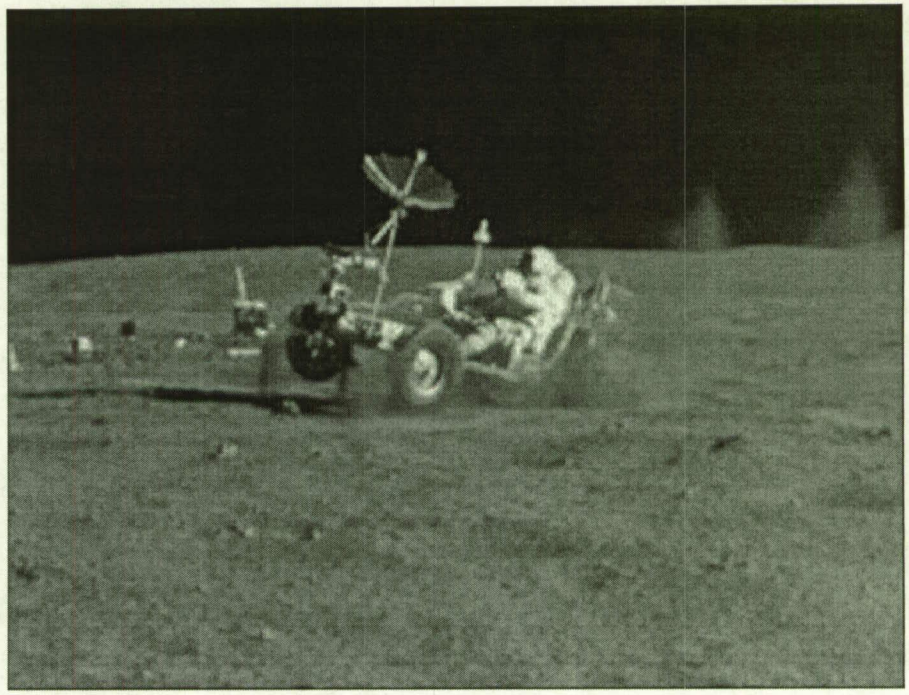
- First EVA was conducted by USSR/Alexi Leonov on March 18, 1965.
  - Many EVA have since been accomplished by the Soviet Union & Russia continuing into the International Space Station era.

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 EMU and Life Support
    - 5-layer Gemini space suit 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 crewman 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 man-hours of EVA (15 on lunar surface, 5 outside CM)
  - Last 3 Apollo missions (15, 16, & 17) utilized the lunar rover vehicle for greater range in lunar exploration



Historical Overview

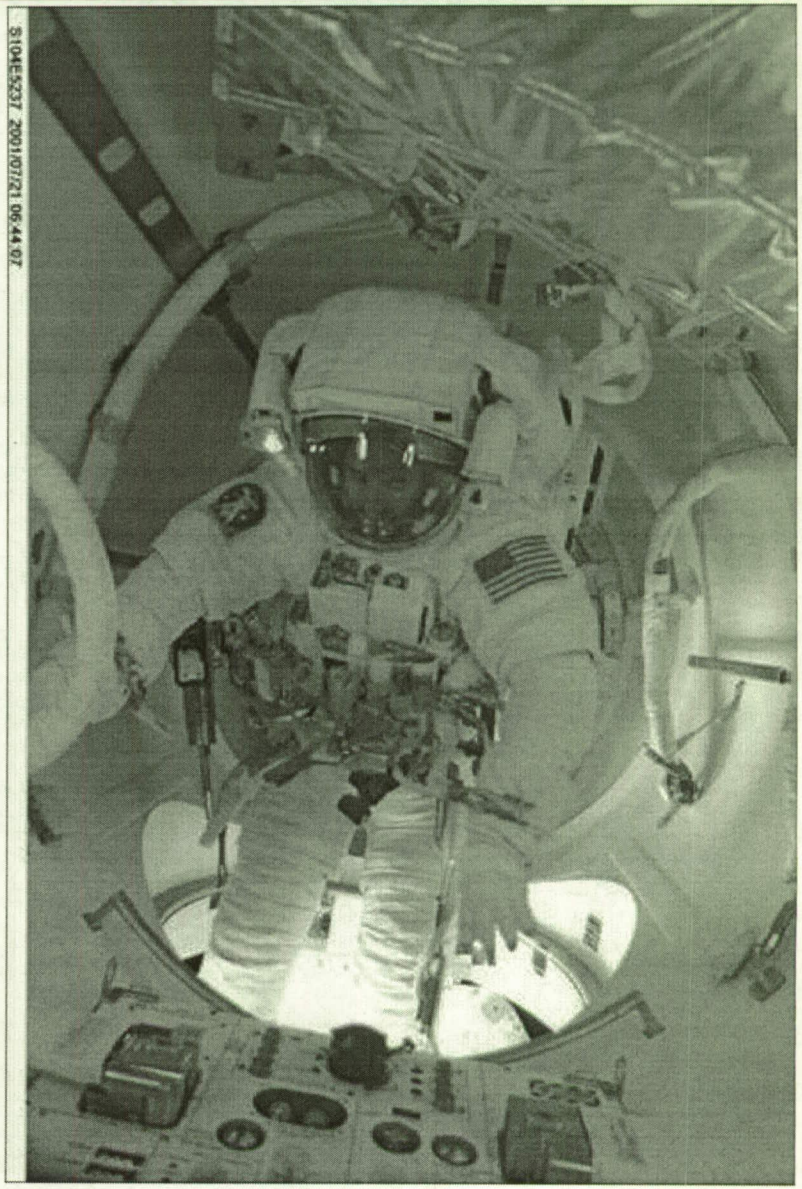
- Skylab EVA Experience
  - Apollo suit used again
  - Umbilical replaced portable life support system and provided breathing oxygen, cooling, and served as a tethering device
  - 10 EVAs were performed during the 3 Skylab missions totaling 82.5 man-hours

- 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 200+ EVAs

International Space Station (ISS)
EVA Systems

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

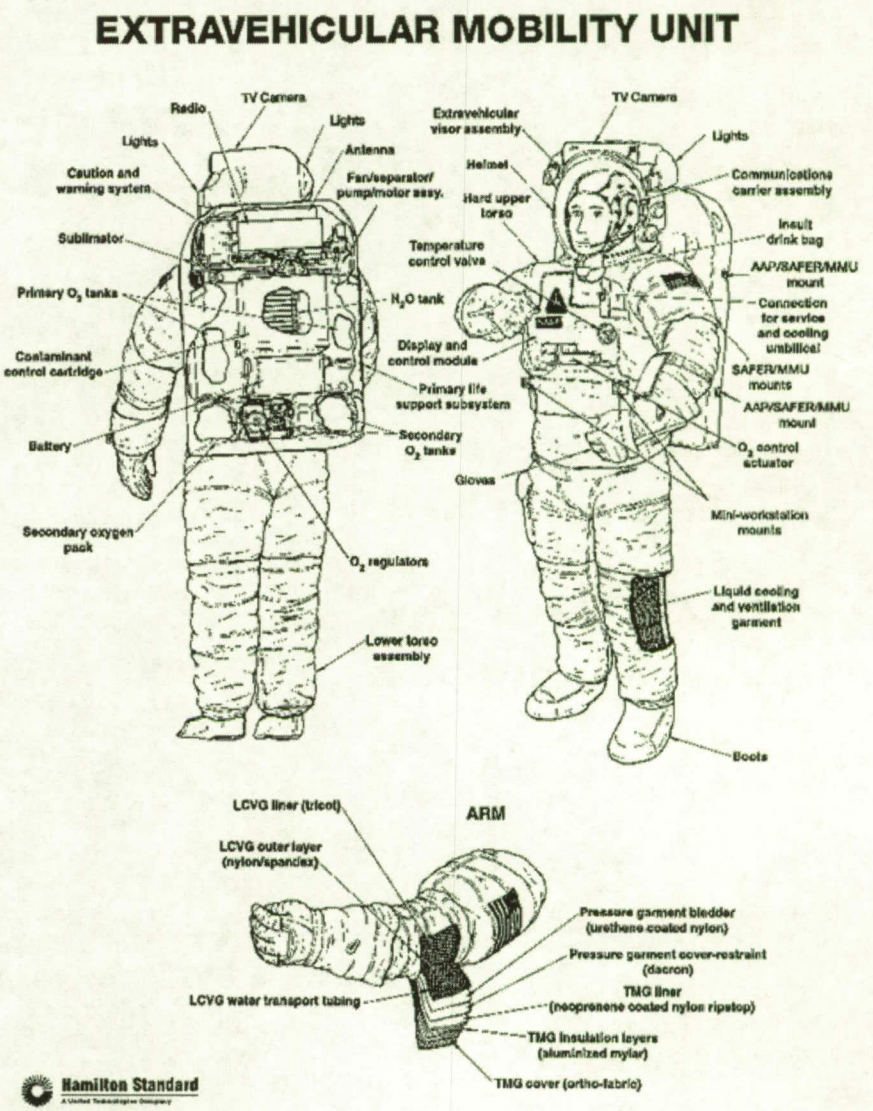


EVA Systems - EMU

• 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

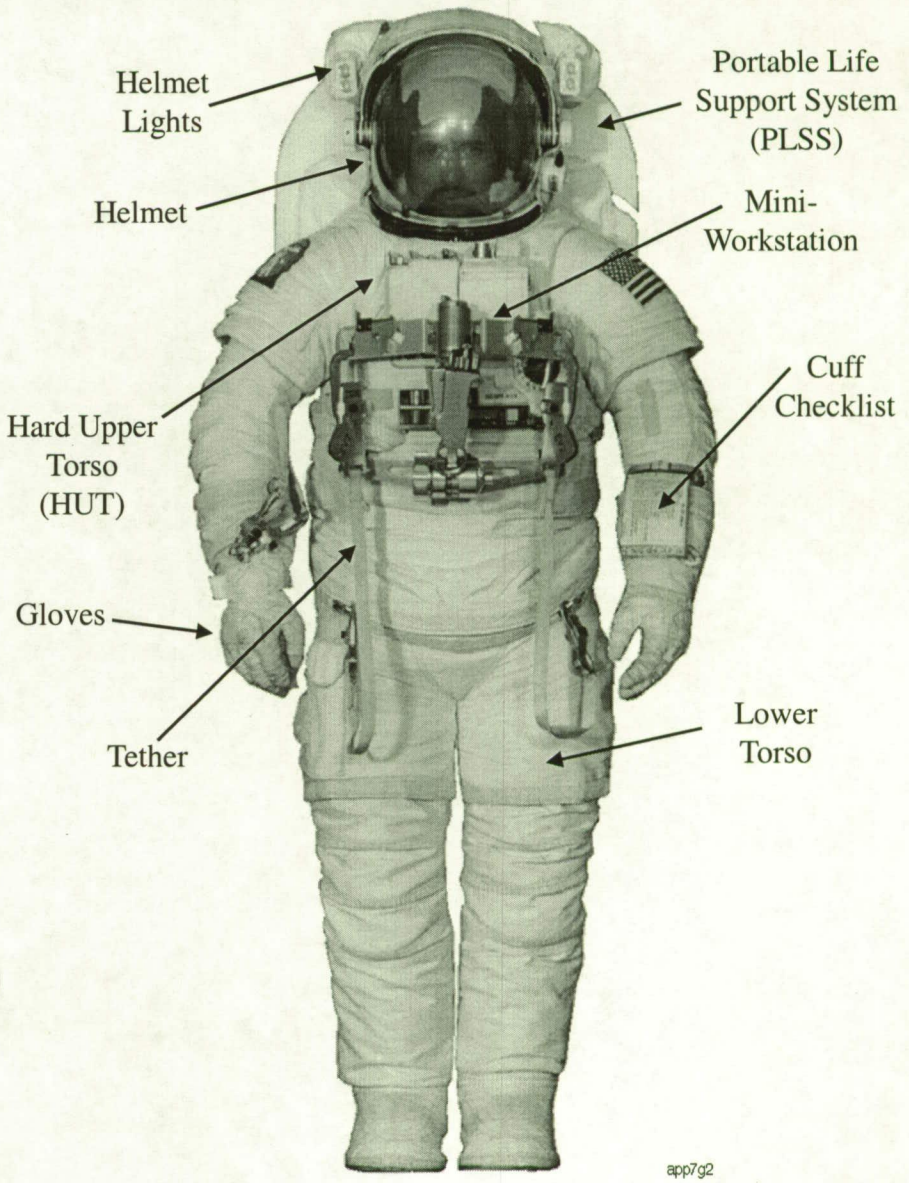
• EMU is an integrated system consisting of two subassemblies:
  - Space Suit Assembly (SSA)
  - Portable Life Support System (PLSS)



Rev 2/95

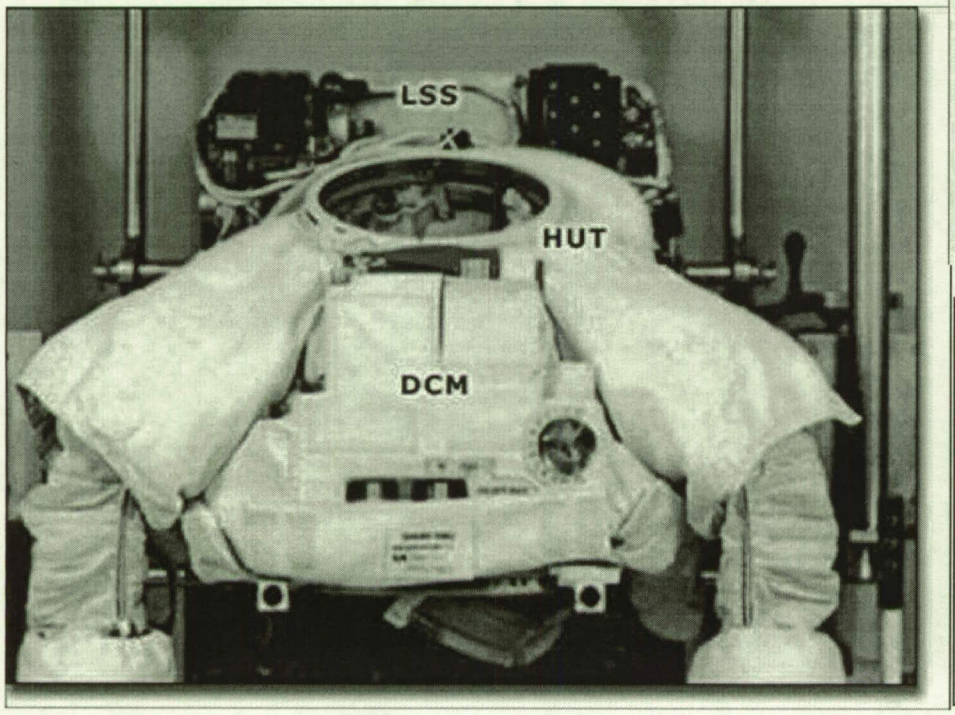
EVA Systems – Space Suit Assembly

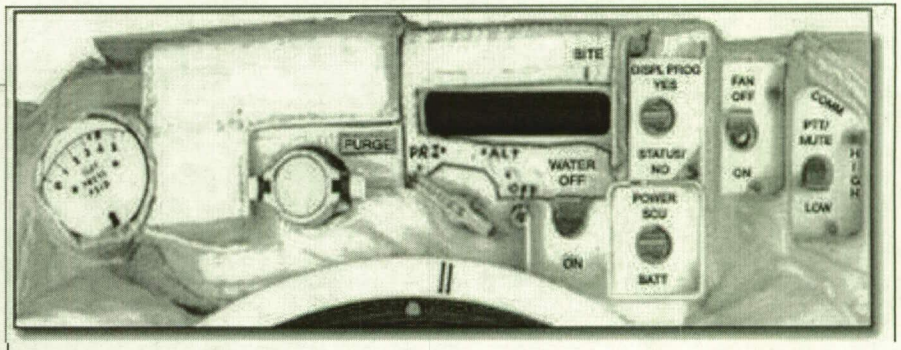
- Space Suit Assembly Components:
  - Hard Upper Torso (HUT)/arms
  - Lower Torso Assembly (LTA)
  - Extravehicular (EV) gloves
  - Helmet/Extravehicular Visor Assembly (EVVA)
  - Liquid Cooling and Ventilation Garment (LCVG)
  - Operational Bioinstrumentation System (EKG)
  - Communications Carrier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

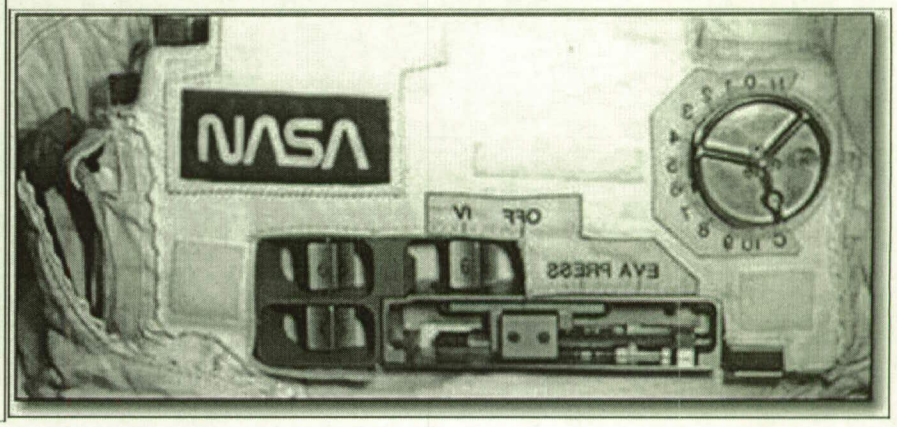


EVA Systems – Space Suit Assembly

- Space Suit Assembly Components (Cont'd):
  - Display and Control Module (DCM)
    - Provides Caution & Warning System (CWS) messages, EMU parameters, and EMU controls to crewmember

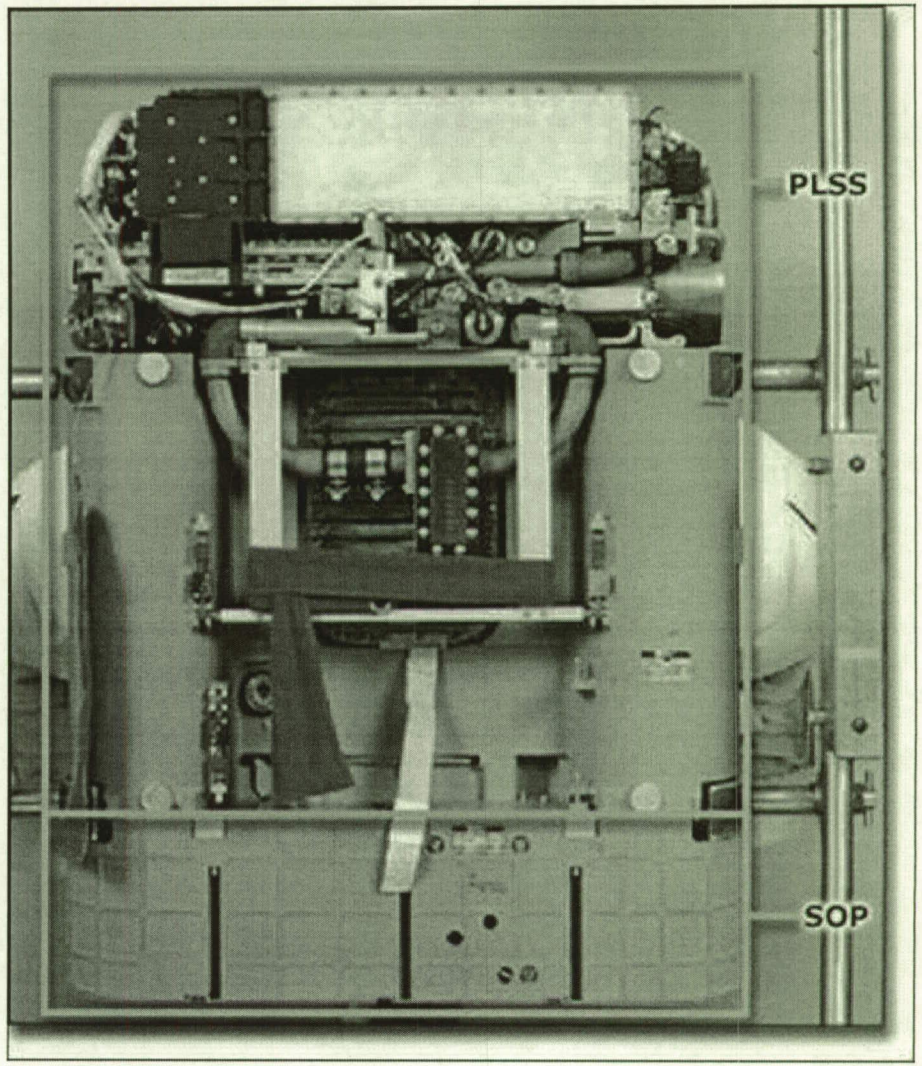






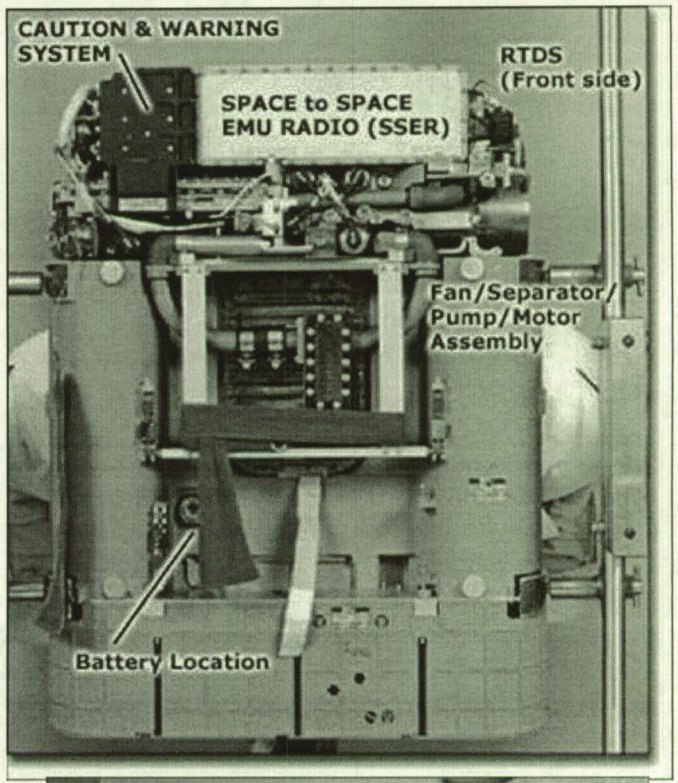
EVA Systems – Life Support

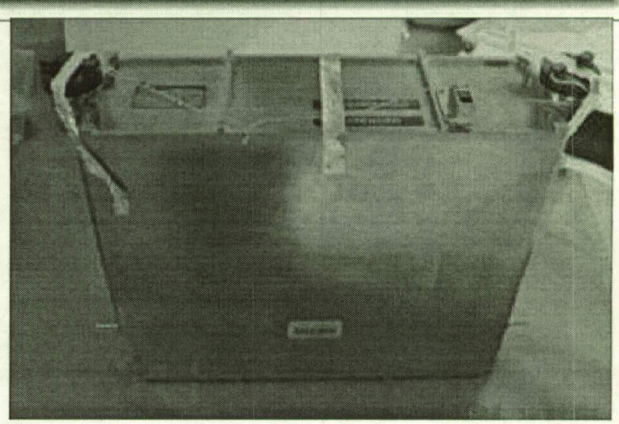
- Life Support System Components:
  - Portable Life Support System (PLSS)
    - Provides breathing O_2, electrical power, comm, cooling
    - Responsible for suit pressure control
    - Circulates O_2 and removes CO_2, humidity and trace contaminants
    - Controls thermal environment
  - Secondary Oxygen Pack (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; EMU Radio)
  - Caution and Warning System (CWS)
  - Real-Time Data System (RTDS)
    - Provides EMU status parameters and biomedical data for transmission to Mission Control
  - Battery
  - Contaminant Control Cartridge (CCC; LiOH Cartridge or METOX Cartridge)
    - Removes CO_2 and trace contaminants





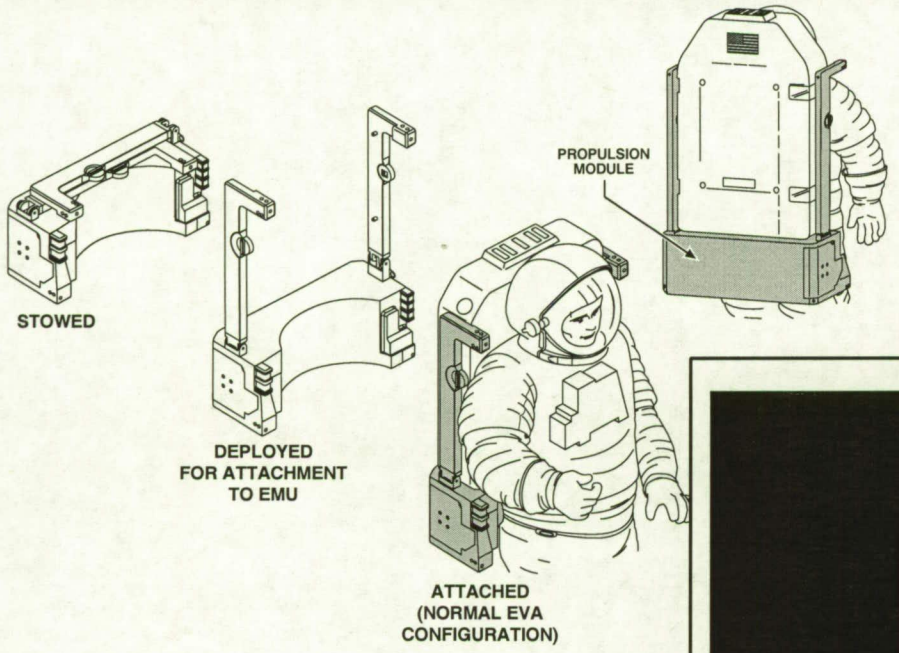
Purge/Prebreath

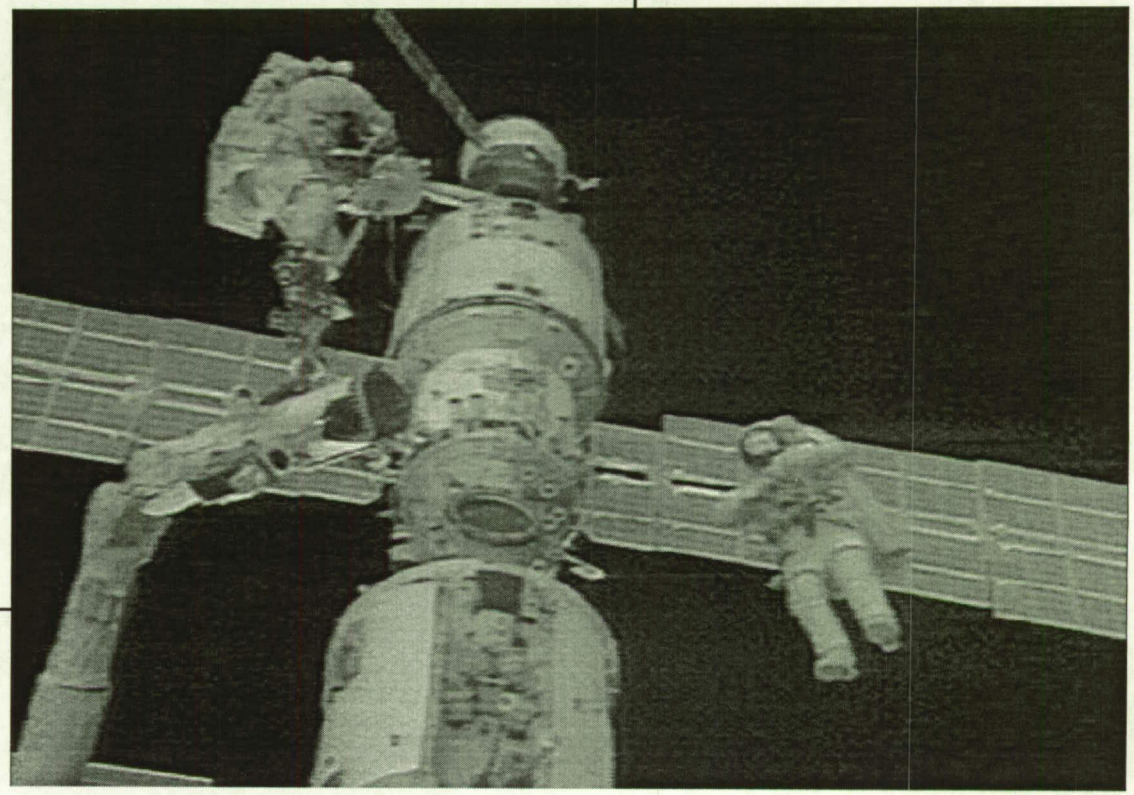
EVA Systems - SAFER (Simplified Aid for EVA Rescue)

• SAFER is a self-contained, propulsive backpack self-rescue system that provides the EV crewmember with self-rescue capability when 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 2A and 3A

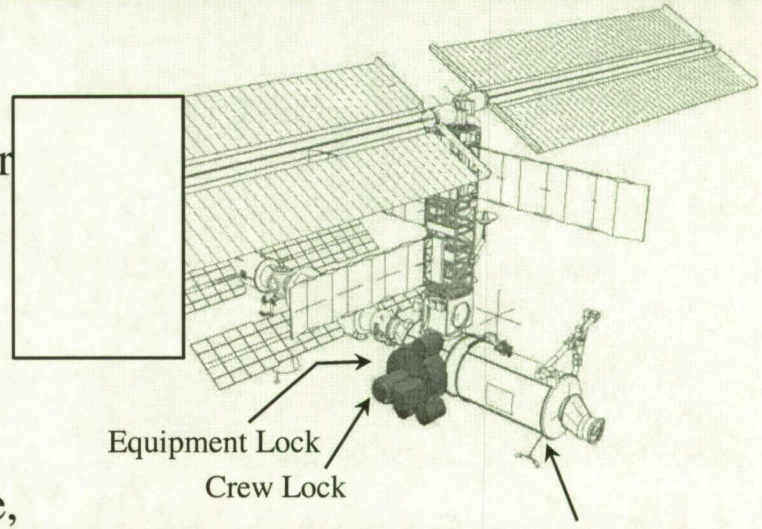
EVA Systems -
SAFER (Simplified Aid for EVA Rescue)

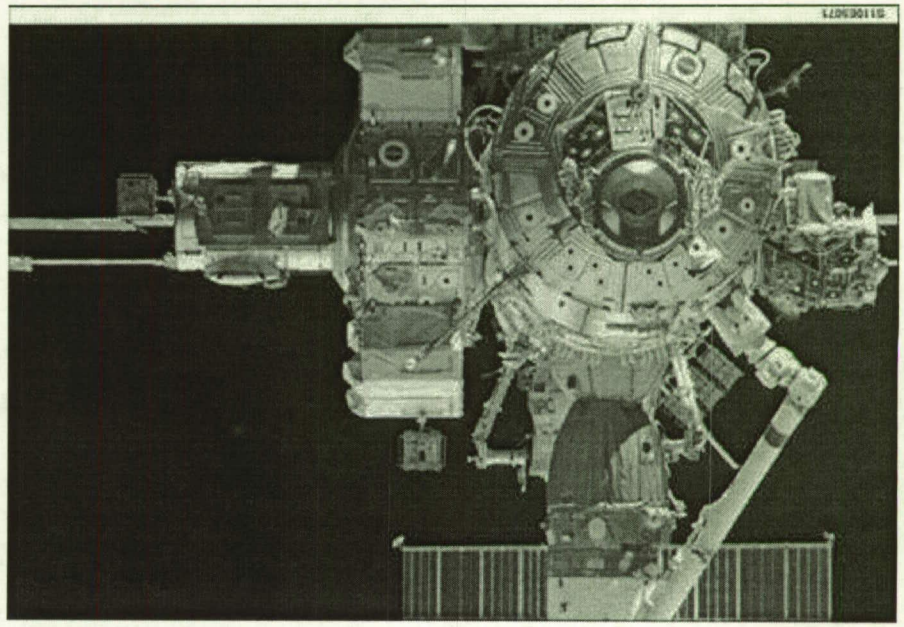




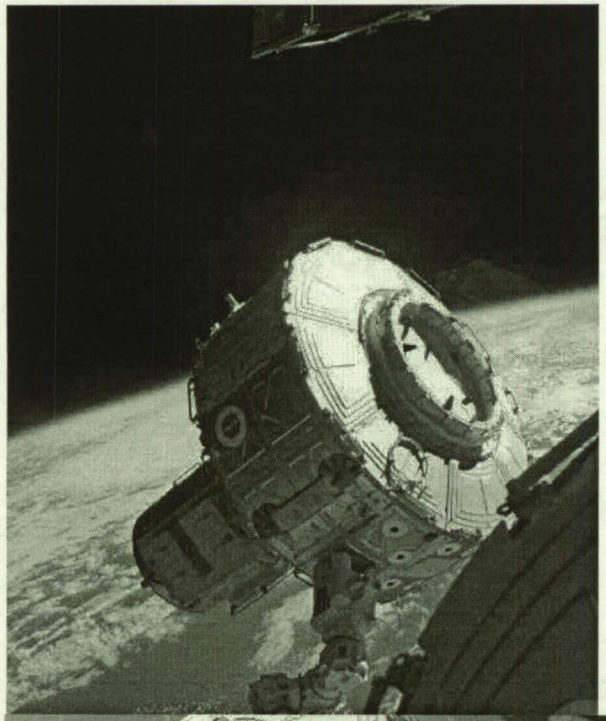
EVA Systems - ISS Joint Airlock

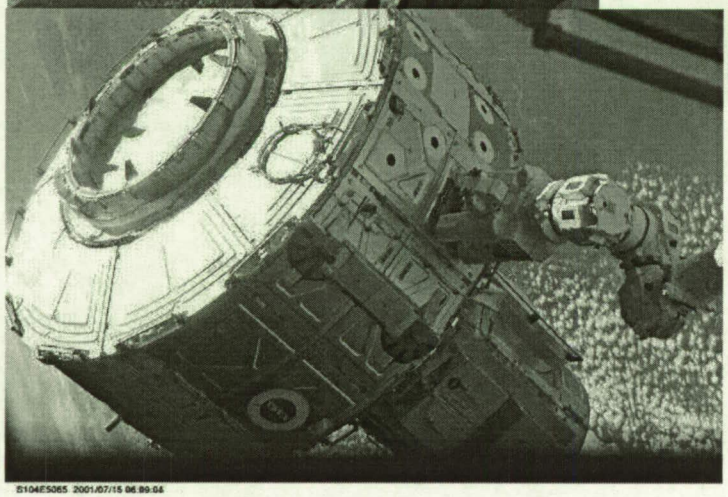
- ISS Joint Airlock:
  - Primary for U.S. ISS EVAs (both Orbiter and Station-based)
  - Compatible for use with Russian Orlans
  - Made up of two parts: Crew Lock and Equipment Lock
    - Equipment Lock is used for stowage, recharge and servicing of EMUs and to don/doff the EMUs
    - Crewlock is the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

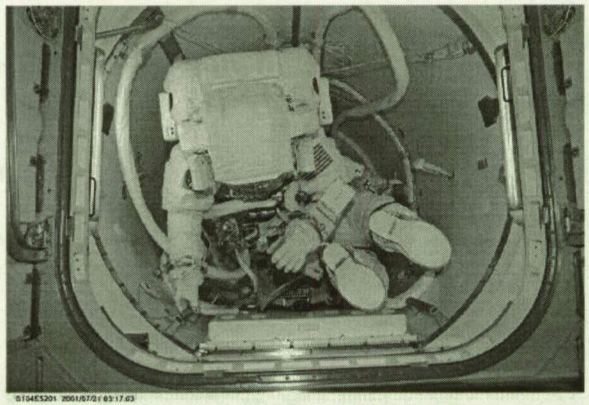


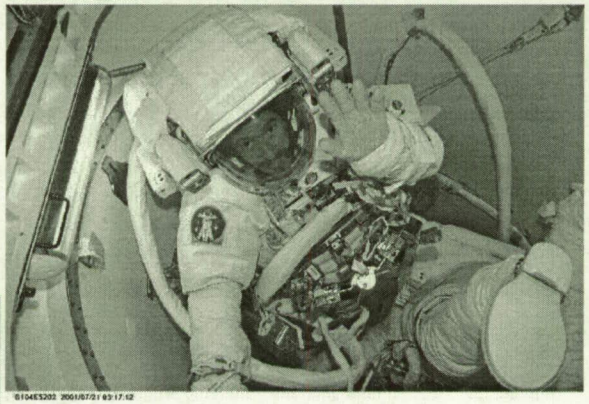


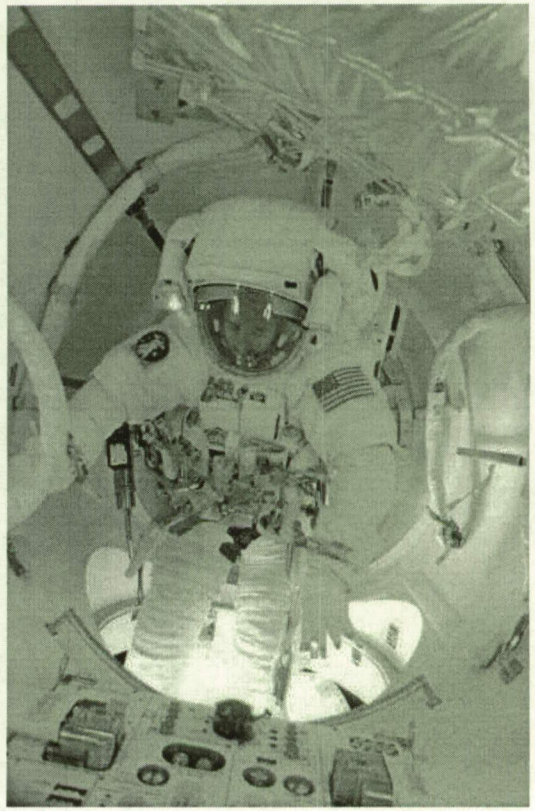
EVA Systems - ISS Joint Airlock











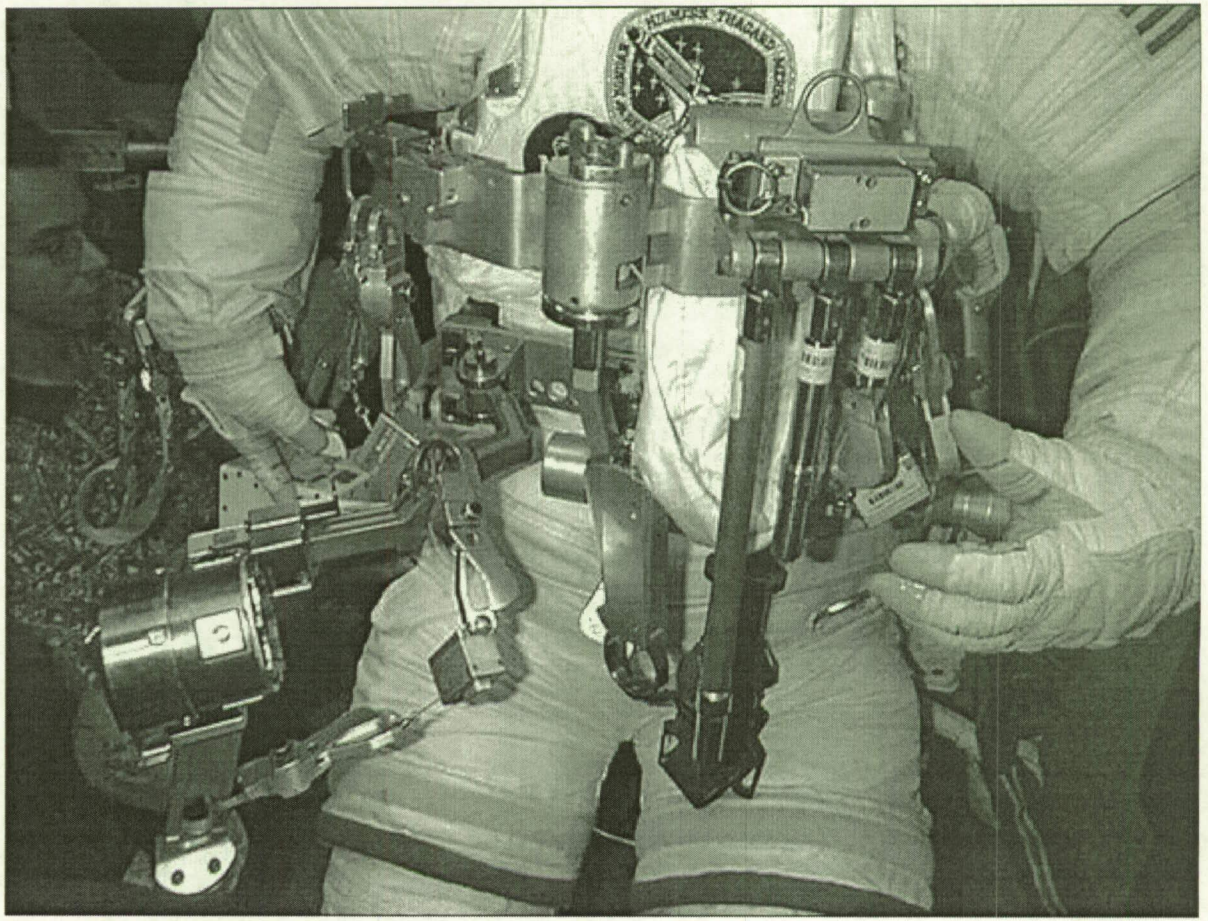
STS-114 / Flight 7A

EVA Equipment & Tools

- EVA crewmembers use specific tools for each task and this generic equipment:
  - Tethers
    - 55' safety tether, 2 waist tethers, wrist tethers
    - 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.**
  - Body Restraint Tether (BRT)
    - Attaches to the Mini-Work Station (MWS)
    - Body Restraint Tether (BRT) end-effector provides semi-rigid restraint to EVA crewmember at worksite
    - Requires less time than setting up a Portable Foot Restraint and is more stable than a MWS end effector
    - Also used for translating small objects

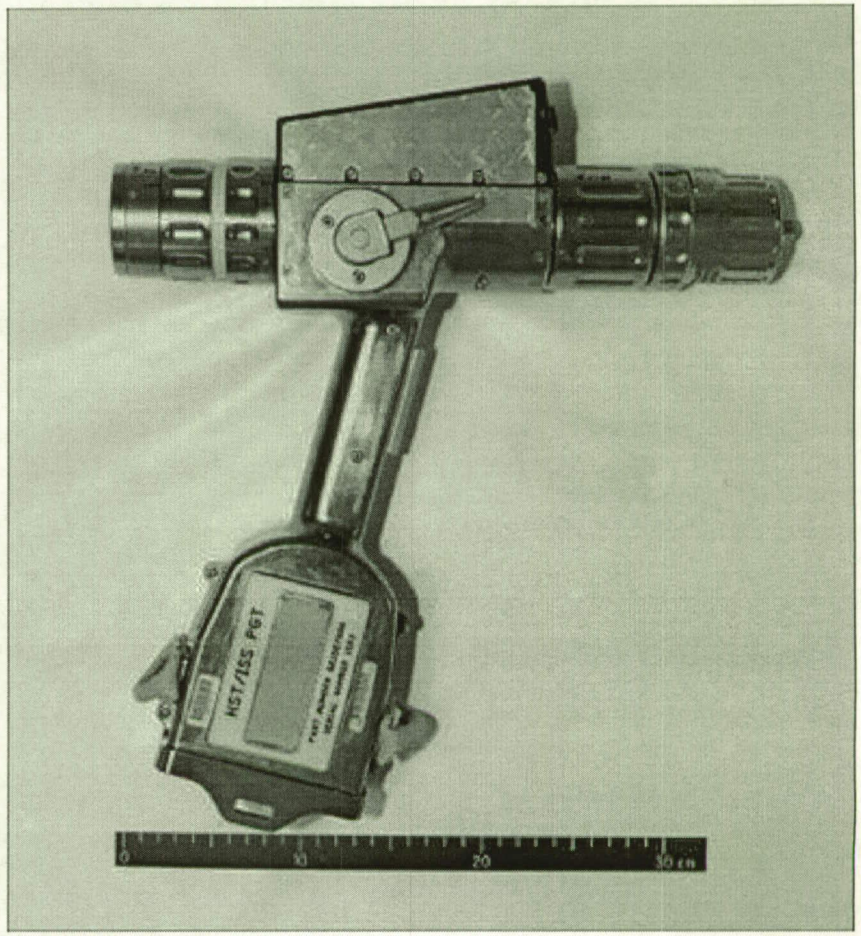
EVA Equipment & Tools

- Mini Work Station (MWS)
  - Attaches to front of the EMU
  - Used to carry small tools
  - MWS end effector and retractable tether provide restraint to EVA Crewmember at worksite



EVA Equipment & Tools

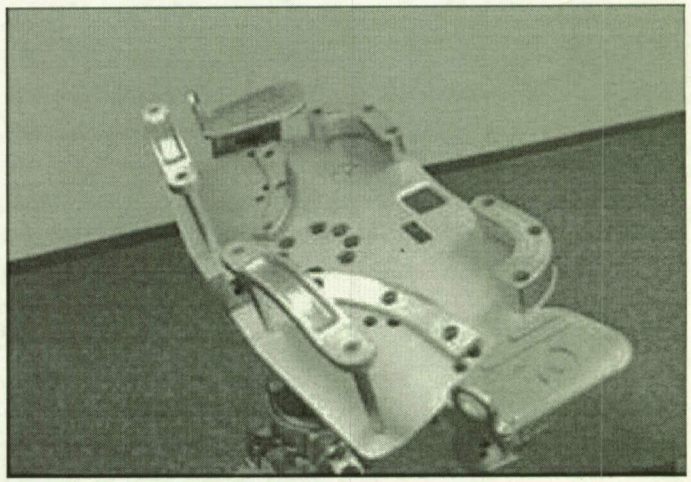
- Pistol Grip Tool (PGT)
  - EVA torque wrench (i.e., a bolt turner)
    - Has a programmable torque limiter and turn limiter
    - CM needs to be secured depending on amount of torque required
    - 2ft-lbs to 25ft-lbs of torque available
    - Generally used for ISS assembly

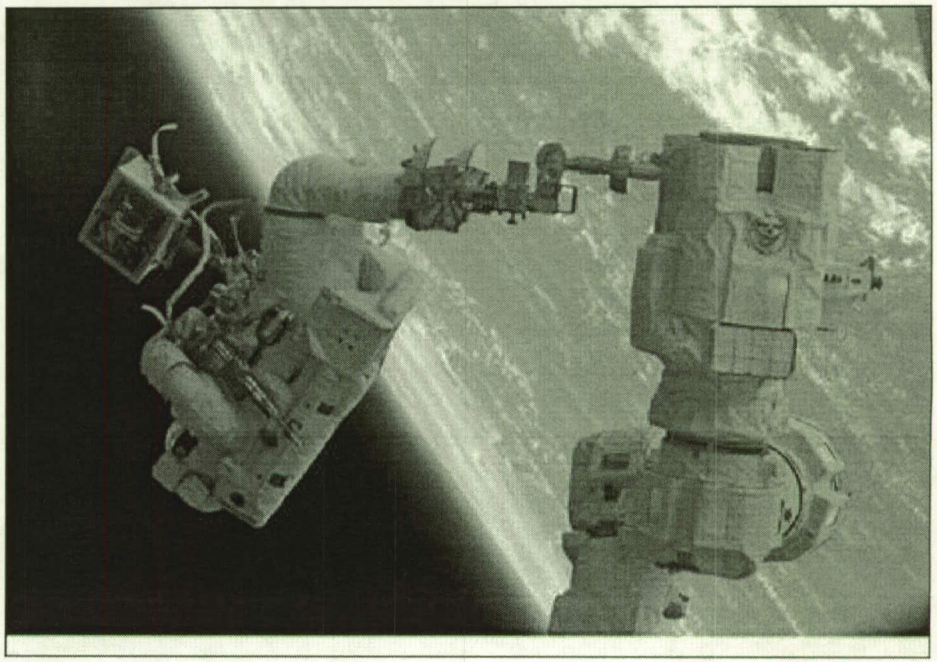


← 1-G Testing of the PGT

EVA Equipment & Tools

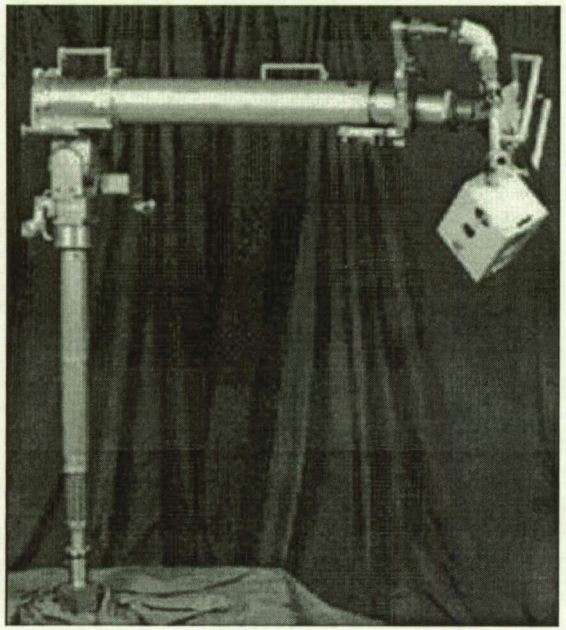
- Foot Restraints
  - Attaches to structure via a socket
  - Provides EVA crewmember rigid restraint at a worksite (Remember Newton's 3rd Law?)
  - Different types:
    - Portable foot restraint (PFR) *(Shuttle)*
    - Articulating PFR (APFR) *(U.S. ISS)*
    - Interoperable APFR (IAPFR) *(U.S. & Russian ISS)*
- Tool Stanchion *(no photo)*
  - Attaches to APFR or CETA Cart
  - Levers allow crewmember to yaw and tilt with respect to APFR
  - Holds tools and provides temporary stowage of old On-orbit Replacement Units (ORUs)

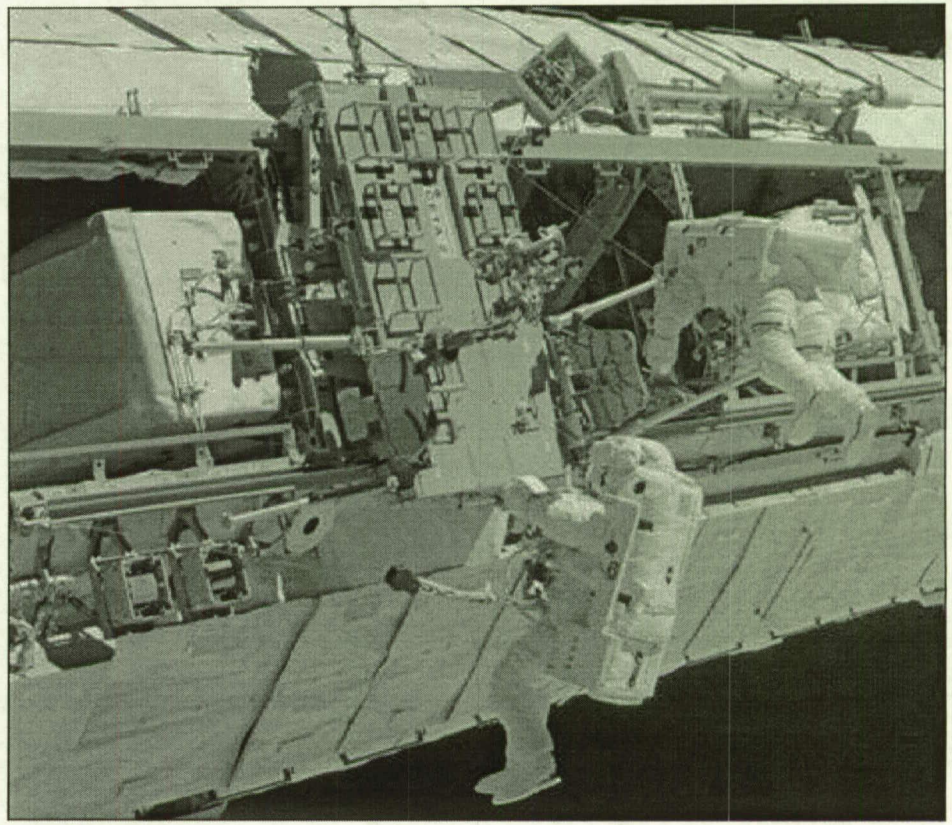




EVA Equipment & Tools

- 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





- U.S. EVA Crane
  - Used to transfer ORUs during maintenance EVAs
  - Pitch and yaw capabilities
  - Telescoping boom (18 feet)
  - Smaller than Russian crane (STRELA)

Comparison of Russian & U.S. EVAs

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

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 hours + 30-minute contingency
  - Weight: ~230 lbs
  - On-orbit Service life: 12 uses/3 years (with maintenance)
    - **Not returned for refurbishment**

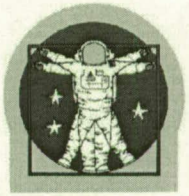
Comparison with Russian EVAs
EMU vs. Orlan – Spacesuit Assembly

- 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
  - Outer "orthofabric" and aluminized mylar thermal/meteoroid garment
  - Liquid-cooling ventilation 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
  - 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 (plus 2 glove sizes)
  - Suit Donning: Back entry
  - Helmet integrated into suit
  - 2 Waist tethers (fixed and variable length); not removable

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



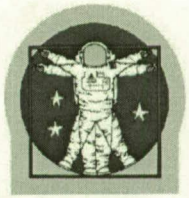
- EMU
  - Closed-loop, 100% oxygen
  - Expendables replaced or recharged on-orbit
  - Primary & secondary oxygen tanks
  - Liquid cooling via garment and use of sublimator
  - Carbon Dioxide and trace gas scrubber
  - Average/Max metabolic rates: 1000 BTUs (290 W) / 2000 BTUs (580 W)
  - Primary battery is zinc-silver-oxide (rechargeable)
  - 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: 900 psi; Secondary O2 pressure 6000 psi
  - Most electronics located in life support backpack @ vacuum
  - Crewmembers communicate between each other
  - Utilizes liquid cooling and ventilation garment; biocide is iodine
  - CO2 scrubber: metal oxide
  - 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 are silver ions
  - CO2 scrubber: lithium hydroxide
  - Prebreathe: 1-hour @ 550 torr

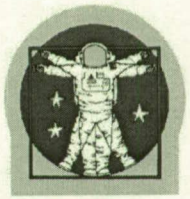
*Note: Russians prefer to verify system performance by test supported by analysis … much more than U.S.!

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.
    - Donning stations (however, rarely used on orbit)



Backup Material

EVA Operations Overview
Operations to prepare for EVA

O_2 Prebreathe reduces the risk of Decompression Sickness (DCS)

Protocol	In-Suit	10.2 (12 hr)	10.2 (24 hr)	Exercise
Mask prebreathe time	None	1 hour	1 hour	80 minutes
In-suit prebreathe time	4 hours	75 minutes	40 minutes	1 hour
Ops Overview *(Details of EVA Prebreathe protocols are in the Aeromed Flight Rule #B13-107)*	Breathe O_2 in-suit for 4 hours while cabin is at 14.7, go out the door.	Breathe O_2 on mask while depressing cabin to 10.2, wait 12 hours before in-suit prebreathe, go out the door.	Breathe O_2 on mask while depressing cabin to 10.2, wait 24 hours before in-suit prebreathe, go out the door.	Exercise on bike for 10 min. at beginning of mask prebreathe, depress airlock to 10.2, breathe in-suit for 1 hour, go out the door.