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
• 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.
    • 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 -
  – 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.
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))
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)
• 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
• 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
• 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
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
• **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
• 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.
• 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.
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
SAFER Deployment

SAFER (Simplified Aid for EVA Rescue)

STOWED

DEPLOYED FOR ATTACHMENT TO EMU

PROPULSION MODULE

ATTACHED (NORMAL EVA CONFIGURATION)

ATTACHED (HCM RELEASED)

ATTACHED (SELF-RESCUE MODE)

HAND CONTROLLER MODULE

ATTACHED
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
• 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)*
• 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
• 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)

<table>
<thead>
<tr>
<th>Protocol</th>
<th>In-Suit</th>
<th>In Suit Light Exercise (ISLE)</th>
<th>Campout</th>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mask prebreathe time</td>
<td>None</td>
<td>1 hour</td>
<td>1 hour (1ˢᵗ day)</td>
<td>80 minutes</td>
</tr>
<tr>
<td>In-suit prebreathe time</td>
<td>4 hours</td>
<td>100 min</td>
<td>50 min (2ⁿᵈ day)</td>
<td>1 hour</td>
</tr>
<tr>
<td>Ops Overview</td>
<td>Breathe 100% O₂ in-suit for 4 hours while cabin is at 14.7, go out the door.</td>
<td>In Suit prebreathe light exercise totals 90 min; 50 min light exercise, 40 min Metox change out</td>
<td>Breathe 100% O₂ on mask while depressing cabin to 10.2, wait approx. 9 hours before in-suit prebreathe, go out the door.</td>
<td>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.</td>
</tr>
<tr>
<td>Total EVA prep &amp; P/B time:</td>
<td>5:42 hrs</td>
<td>3:12 hrs</td>
<td>13:12 hrs</td>
<td>4:02 hrs</td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE SLEEP 3 hours</td>
<td></td>
</tr>
<tr>
<td>60 min mask PB</td>
<td></td>
</tr>
<tr>
<td>10.2 Dep</td>
<td></td>
</tr>
<tr>
<td>45 min before 11.8</td>
<td></td>
</tr>
</tbody>
</table>

#### EVA Day

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYGIENE BRK 70 min</td>
<td>1:4</td>
</tr>
<tr>
<td>EVA PREP 90 min</td>
<td>3:15</td>
</tr>
<tr>
<td>Purge</td>
<td>3:27</td>
</tr>
<tr>
<td><em>EMU Prebreathe (50 min)</em>*</td>
<td>4:17</td>
</tr>
<tr>
<td>C/L Dep (30 min)</td>
<td>4:47</td>
</tr>
<tr>
<td>*70 min mask P/B</td>
<td></td>
</tr>
<tr>
<td>*10.2 Depress</td>
<td></td>
</tr>
<tr>
<td>POST SLEEP 35 min</td>
<td></td>
</tr>
<tr>
<td>POST SLEEP 40 min</td>
<td></td>
</tr>
</tbody>
</table>

- EVA PET = 6:30

### 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)

### 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 Operations: Overview of EVA Tasks

<table>
<thead>
<tr>
<th>Time</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 min</td>
<td>Airlock depress</td>
</tr>
<tr>
<td>15 min</td>
<td>Airlock egress</td>
</tr>
<tr>
<td>15 min</td>
<td>Airlock ingress</td>
</tr>
<tr>
<td>30 min</td>
<td>Airlock repress</td>
</tr>
</tbody>
</table>

#### 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.
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

- Visors
- Electrical Control Panel (ПО-4МТ)
- Fluid Umbilical Connector (ОРК-19)
- Orlan Safety Tether
- Helmet Lights
- Suit Pressure Gauge (УДСК)
- Backpack Closure Strap
- Pneumo-Hydraulic Control Panel (ПГПУ-1М)
- Emergency O₂ Hose
- Electrical Umbilical
- Backpack
- LCG

Back-Entry Orlan-M
- Suit Enclosure

- Helmet Assembly
- Upper Arms
- Lower Arms
- Umbilical Interface
- Gloves
- Orlan Safety Tethers
- Hard Upper Torso
- Backpack Closure Strap
- Suit Probe
- Leg Assembly
- Boots
• Arm Assembly
(Thermal Micrometeoroid Garment “TMG” Removed)
• Leg Assembly
(TMG Removed)
Orlan-M Glove
Electrical Control Panel (ΠΟ-4МТ)

- Battery Voltage/Oxygen Tank Pressure Display
- Liquid Crystal Display
- Reserve Pump Switch
- Primary Pump Switch
- Primary Fan Switch
- Reserve Fan Switch
- Power Switch
- Volts/Tone Mute Button
- Orlan-M Electrical Control Panel (ΠΟ-4МΤ)
Electrical Control Panel (ΠΟ-4МΤ)

- Orlan-M Electrical Control Panel (ΠΟ-4МΤ) (side view)

- Helmet Light Switch
- Reserve Radio Switch
- Primary Radio Switch
- Push-to-Talk Switch
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 (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)

- Tranzit-A Transmitter (ША-347)
- Electrical Connectors to Orlan (X107 (upper)), (X109 (lower))
- Support Strut w/ Coupling Nut (left and right)
- Battery Connector (X21)
- High-Frequency Filter (ФР(ТК))
- Battery (not installed)
- Tranzit-A Data Gathering Unit (TA-237)
- Korona-M Communications Radio
- Current and Power Measuring Unit (БКНТЭ)
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)
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)
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 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 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

  http://dx.doi.org/10.1016/j.actaastro.2011.03.031
Backup Material
# Pressures

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

### EMU vs. Orlans

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