An Alternative Approach to Human Servicing of Crewed Earth Orbiting Spacecraft

Brian Alpert, NASA Johnson Space Center
John Mularski, Stinger Ghaffarian Technologies
EVA Operations Branch

Topics

- Why are EVAs (Spacewalks) required?
- ISS EVA Preparation & Comparison to Shuttle EVAs
    - Ground Training
    - On-orbit Training
    - Hardware Prep
    - Hardware Maintenance
    - Hardware Logistics
- Alternatives

Why Perform EVAs?

- EVA repair of orbiting outposts has been required of every US or Russian station since Skylab and Salyut 6.
- These stations have maintained their own on-board facilities to perform EVAs for maintenance, upgrade, and science.
  - MIR and the International Space Station (ISS) have also seen EVAs from visiting Space Shuttle crews using the Shuttle airlock
- EVAs are time- and resource-intensive but are a necessary part of any long duration spacecraft
- EVA objectives fall broadly into the following categories:
  - Spacecraft Assembly or Upgrade
  - Routine or Planned Maintenance
  - Unplanned or Unforeseen Maintenance
  - Science Experiments
- Other than science or customer satellite upgrade objectives, EVA will likely be taking resources from the prime objective of the orbiting outpost

Orbiting Outpost EVA Examples

- Spacecraft Assembly or Upgrade
  - ISS Assembly
  - International Docking Adapter Installation
  - Hubble Space Telescope Servicing
- Routine or Planned Maintenance
  - Orbital Replacement Unit change-outs
- Unplanned or Unforeseen Maintenance
  - Skylab Stuck Solar Array
  - MIR / Soyuz TM-9 Insulation Blankets
  - ISS Torn Solar Array
  - ISS Critical Contingency EVAs
- Science Experiments
  - Materials Science
  - Payload Transfers

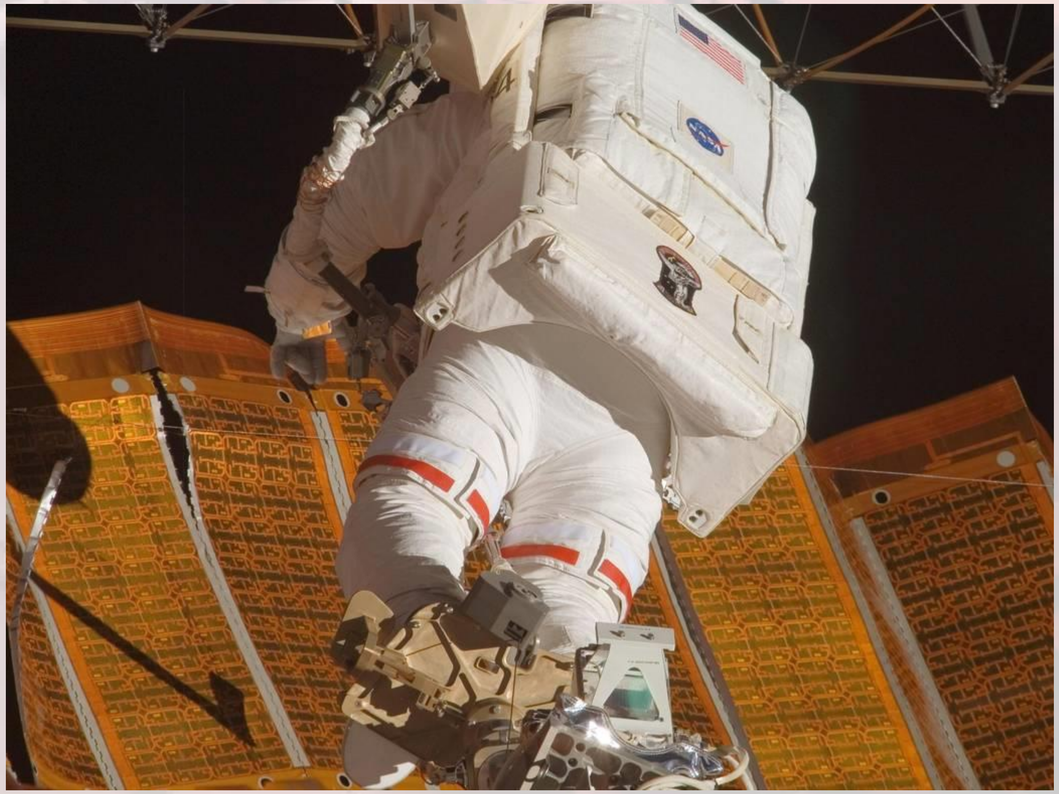

Image Credit: NASA

EVA Training & Prep Overview

- EVAs are short duration (~7 hour) missions conducted in a self-contained spacecraft (spacesuit) on the exterior of the parent spacecraft that exposes the crew to increased risks as compared to life inside the station:
  - Micrometeoroids and Orbital Debris (MMOD)
  - Radiation
  - Risk of separation from station
  - Medical (decompression sickness or other time critical issues)
- To accomplish a successful EVA, significant training is required in both the spacesuit and airlock systems for the crew's safety as well as training in the EVA tasks themselves to make the best use of the time spent outside.
- During long-duration missions refresher training is required prior to an EVA.
    - Additionally, the EVA content is often not known before launch, so detailed task training occurs on-orbit
- EVA hardware requires periodic maintenance to keep it ready for use in addition to prep for a specific EVA

EVA Ground Training

- The ISS training flow takes approximately 2 years to complete
  - EVA training is 220 hours per crew
  - EVA training is 10-15% of a NASA astronaut's training for an ISS mission
- EVA Training consists of the following topics
  - EMU (spacesuit) Systems
  - EMU & Airlock Maintenance and Repair
  - Prebreathe and Suit Up Protocols
  - Emergency Scenarios
  - Vacuum Chamber Run
  - EVA Task Training

Image Credit: NASA

EVA Ground Training

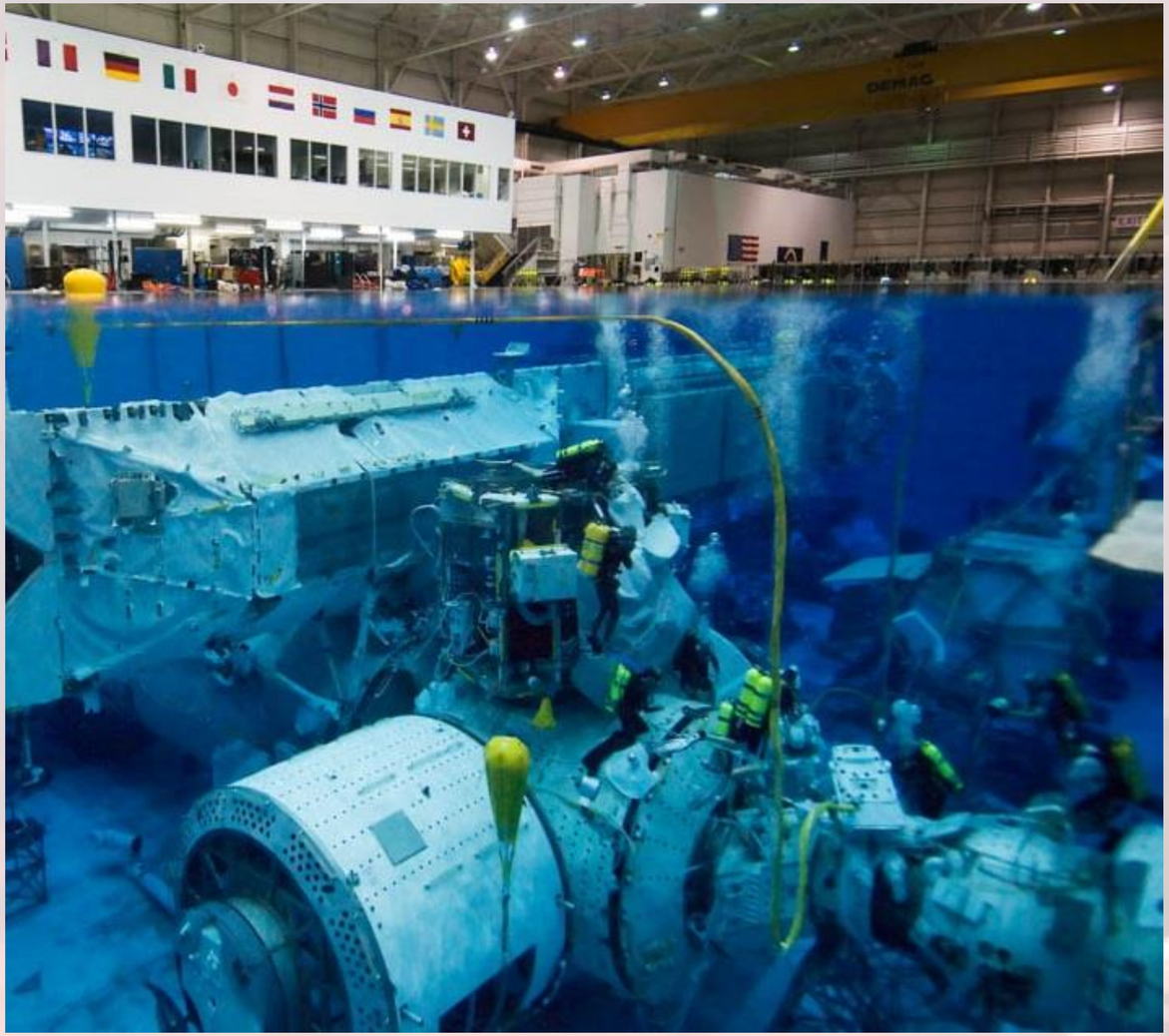

Image Credit: PADI

- EVA Task Training consists of the following topics
  - EVA Tools Training
  - 9 Skills Based Neutral Buoyancy Suited Runs
    - Focused on providing the Astronaut with the skills to perform an ISS EVA
    - Space Shuttle EVA crew would have twice the NBL runs in half the training time and would practice the specific EVAs they would perform on orbit
    - ISS crew are estimated to take 25% longer on a given task than Shuttle crew
  - These training flows occur after the pre-assignment training of 9 NBL runs to learn how to operate in a spacesuit

On-orbit Training

- Between Crew Training and Hardware Preparation over 120 crew hours spread across 3 crew are required to prepare for a single ISS EVA
- EMU Systems
  - Simplified Aid For EVA Rescue Trainer
    - Practice jet-pack rescues using Virtual Reality Trainer
  - EMU Caution & Warning Trainer
    - Refresher on the EMU and crew response to suit emergencies
  - On-orbit Suited Fitcheck
- EVA Task
  - Procedure, Briefing Package, and Tool Reviews
  - Conferences with EVA specialists
- Since EVAs are finalized with the crew already on-orbit this may be the only time they see the procedures they will execute. Crews have reported using additional time for studying and tool preparation

Hardware Prep & Maintenance

- With all of the hardware to perform an EVA residing on ISS that hardware must be maintained and prepared on-orbit for each EVA
  - EMU Loop Scrub & Checkout
    - Every 90 days each of the 4 EMUs has its water system scrubbed
    - Within 2 weeks before an EVA the 2 EMUs to be used also have a Loop Scrub and Checkout. The EMUs are scrubbed again after the EVA.
  - Battery Charging
    - Batteries for helmet lights, EMU cameras, glove heaters, tools, and the EMUs themselves must be charged prior to the EVA
    - Periodic maintenance is also performed on the batteries
  - CO_2 Scrubbing Canister Regeneration
- Maintenance accounts for ~50 hours of crew time

Hardware Logistics

- 4 EMUs are kept on-orbit to provide the needed sizing and redundancy to maintain EVA capability
  - Water, Oxygen, Internal Volume and Crew Time are required to maintain the suits and airlock in working order
- Approximately 200 ft^3 of ISS is used for storing EVA hardware including tools, suit parts, batteries, and ancillary equipment
  - This does not include the hardware the EVA crew is fixing or upgrading on ISS which is stowed both inside and outside of the station
  - There are ~70 spare parts outside waiting for installation after a failure
    - These parts do not typically receive periodic maintenance or health & status checks while being subjected to the space radiation and MMOD environment
- Each EMU EVA trained crewmember is flown prime and backup personal hardware including gloves, cooling garment, and communication cap (~10 ft^3 of cargo)

ISS EVA Summary

- Crew Time
  - 220+ hours Ground Training x 3 crew (10-15% of training)
  - 120+ hours of On-orbit Training and Preparation spread across 3 crew
  - ~50 hours spent on hardware maintenance per year
  - Crew time to unpack and pack EVA hardware being rotated for life limits or different crew
- Over 200 ft^3 of ISS volume used for EVA specific stowage on top of the replacement hardware
- 25% increase in the number of EVAs required to perform the same amount of EVA tasks as a specific ground based crew

Alternatives

- Reducing maintenance or upgrade EVAs by long duration crew in order to focus resources on the objective of the outpost can be addressed in 2 major ways.
  - Reduce the number of EVAs to maintain the outpost
  - Use Launch on Need (LON) supplemental crew to perform EVAs when required

Alternatives: EVA Reduction

- Pros/Cons
  - Reduces the amount of time spent preparing for EVAs
  - Does not eliminate the ground training, logistics, or on-orbit maintenance penalties

- Method
  - Increase robotic repair compatibility
  - Move components into the IVA environment leaving less items requiring an EVA
  - Move components into an environment that is not fully habitable but allows for ingress without a full pressure suit
    - Areas pressurized to ~1/3 of an atmosphere to allow the crew to wear only O_2 masks during the repair

Alternatives: LON

- Pros/Cons
  - Eliminates ground training of long duration crews allowing shorter training flow or additional mission specific training
  - Only hardware actually needed for EVAs has to be manifested saving space and crew time
  - Eliminates on-orbit hardware maintenance to maintain EVA capability
  - Allows more on-orbit productivity but adds risk of launch to LON crew
  - More efficient EVAs leading to overall reduction in EVAs for the same architecture

Alternatives: LON

- Requirements
  - Increased fault tolerance to allow outpost to function until visiting crew arrival
    - ISS currently has a selection of items that must be replaced rapidly via EVA. These are designated Critical Contingency EVAs.
  - Reliable methods to timely launch crew to the outpost
    - Dissimilar redundancy both of launch vehicle and crew vehicle would be highly desirable

- As a backup, on-orbit EVA capability could be maintained. This would still have the benefit of eliminating the on-orbit training and crew time used for the majority of EVAs

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Questions?

Brian.K.Alpert@nasa.gov

John.R.Mularski@nasa.gov