

National Aeronautics and Space Administration

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EVA Operations for Artemis III External Teams

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Topics

EVA 101

EVA Hardware Design

Flight Operations

- FOD Big Picture
- Practicalities and constraints affecting an EVA
- Processes
- Training
- Real-Time Ops

Summary

EVA Basics

An EVA or Spacewalk is anytime when a crewmember is no longer protected by their home vehicle and are exposed to the external vacuum environments (Micro-gravity, Lunar, or other).

- An EVA is one of the top 3 highest risk events in Human Spaceflight

EVA's have a limited duration based on both crew and suit system consumable resources.

EVA task operations vary in both time and technique between crew members.

- Crew members interact and manipulate a suit differently due to human variations. Tasks cannot be as structured as a robotic operation.
 - Interfaces with the suited crew require intentional thought and planning with EVA experts

A spacesuit is a single person spacecraft which protects the crewmember from the external elements and provides life sustaining needs in a mobile workable volume

- Human-shaped and sized space vehicle
- Requires same key systems as other spacecraft however, it needs to be carried by a person
- Habitable pressure, breathable atmosphere, thermal control, mobility, visibility, communication, and protection from environmental concerns

The benefit of an EVA crewmember is the human ability to react to unexpected failures in real-time.

- Robotics and automation is continually growing but has not surpassed a crewmember in this aspect.

EVA's are performed in buddy pairs

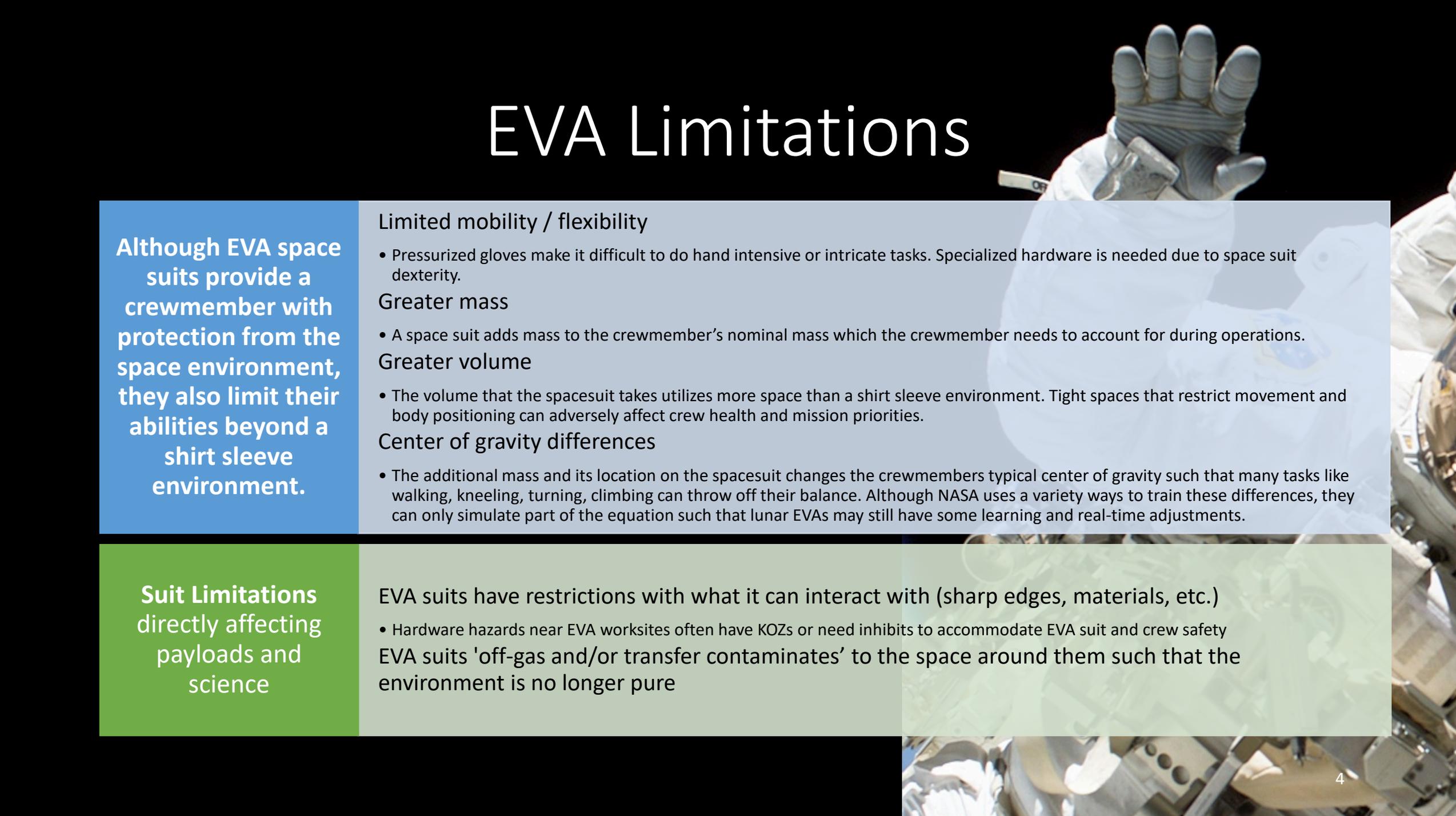
- Pairing crewmembers is to help with contingency responses. This is modeled after scuba diving and other high-risk activities.

EVA operations are planned to be as efficient as possible as time is limited and EVA is a higher risk activity.

- Goal is to reduce overall required EVA time
 - Time to effect of potentially catastrophic events can be small therefore, risk increases the further the EVA crew is from a habitable space system asset



EVA Limitations

A background image of an astronaut in a white space suit, with one hand raised, set against the blackness of space.

Although EVA space suits provide a crewmember with protection from the space environment, they also limit their abilities beyond a shirt sleeve environment.

Limited mobility / flexibility

- Pressurized gloves make it difficult to do hand intensive or intricate tasks. Specialized hardware is needed due to space suit dexterity.

Greater mass

- A space suit adds mass to the crewmember's nominal mass which the crewmember needs to account for during operations.

Greater volume

- The volume that the spacesuit takes utilizes more space than a shirt sleeve environment. Tight spaces that restrict movement and body positioning can adversely affect crew health and mission priorities.

Center of gravity differences

- The additional mass and its location on the spacesuit changes the crewmembers typical center of gravity such that many tasks like walking, kneeling, turning, climbing can throw off their balance. Although NASA uses a variety ways to train these differences, they can only simulate part of the equation such that lunar EVAs may still have some learning and real-time adjustments.

Suit Limitations directly affecting payloads and science

EVA suits have restrictions with what it can interact with (sharp edges, materials, etc.)

- Hardware hazards near EVA worksites often have KOZs or need inhibits to accommodate EVA suit and crew safety
EVA suits 'off-gas and/or transfer contaminates' to the space around them such that the environment is no longer pure

EVA Hardware Requirements



The concept for EVA assembly and repair is to keep it simple

Plan Orbital Replacement Units vs intricate repairs
Big elements by robotics and intricate or detailed work by EV crew
Standardization of bolts, connectors across vehicles and payloads



There are a multitude of EVA documents that describe con ops and requirements

Public info at <https://www.nasa.gov/suitup/reference>
Reference Documentation list in backup slides
Early integration with EVA Operations is essential



Exceptions to requirements will be analyzed and tested by NASA EVA

Potentially granted on a case-by-case basis but not guaranteed



In no other part of space operations is the outcome as dependent on the performance of the crewmember as in EVAs. Hardware and software must be designed for ease of the user.

Operations Influencing Design

- All designs start out with a concept to build the best 'x'.
- Requirements may not design hardware that optimizes the operation of the hardware.
- Thus, it becomes very important for the operations teams to play an influential part in the design process.

Injury and Risk Prevention	<ul style="list-style-type: none">• Can this design injure or pose significant risk to crew?
Reliable	<ul style="list-style-type: none">• Where does this design need to be more robust or redundant to keep crew safe and to prevent design failures?
Efficient	<ul style="list-style-type: none">• Does this design increase crew efficiency in operations?
Reduced Workload	<ul style="list-style-type: none">• Does this design add to the cognitive or physical workload?
Upgradeable	<ul style="list-style-type: none">• If we must live with this design for the next 10, 20, 30, 40 years, can we make easy upgrades?
Maintainable	<ul style="list-style-type: none">• Does this design significantly reduce or eliminate the need for corrective maintenance requirements?
Flexible	<ul style="list-style-type: none">• Does this design lock in only one ops concept or does it allow for operation flexibility?
Testable	<ul style="list-style-type: none">• Does this design have a plan to test and evaluate prelim concepts? How early can the ops community get hands-on?
Compatible	<ul style="list-style-type: none">• Is this design compatible with the current and future ops concepts and other existing hardware?
Trainable	<ul style="list-style-type: none">• Does this design require new or modified training infrastructure? Is there a plan for early training hardware?

EVA Operations Integration into the Design Process

Flight Operations Directorate (FOD)

During the design phase, FOD EVA is involved in early design reviews to evaluate the crew – hardware interactions.

- FOD EVA will provide the hardware team with assessments of the compatibility of the design to EVA operations. There may be required changes (safety) and desired changes (EVA efficiency and ops ease).
- Early crew evaluations and crew office hours are encouraged

After a tool, payload, or hardware has a preliminary design, FOD EVA and the crew office will test these Operations.

- Hardware will be rated: Acceptable, Unacceptable (design changes required), or Inconclusive

EVA is a unique skill and does not always align to defined actions

- The crew office and FOD (Flight Operations Directorate) EVA assess hardware and develop procedures and will incorporate workarounds if required.

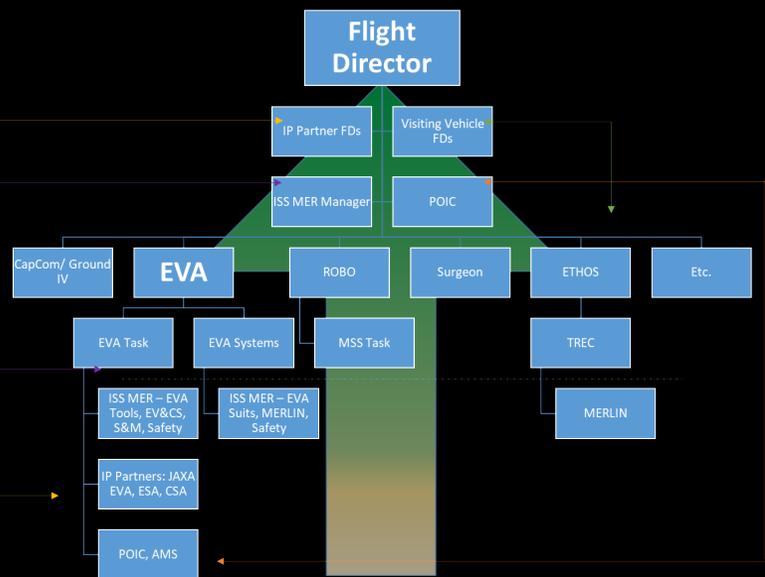
FOD – Training and Flight Control

- The Flight Operations Directorate (FOD) is responsible for the training and mission control of the USOS ISS and Artemis crewmembers.
 - The Flight Operations Directorate (FOD) at NASA's Johnson Space Center touches every program and part of sending humans to space.
 - Plan, Train, Fly
 - <https://www.nasa.gov/johnson/nasa-flight-operations-directorate/fod-who-we-are/>
 - FOD will provide the real-time operations expertise on the operation of the USOS systems as defined by Flight Rules.
- Overall priorities of the Mission and the EVA
 1. Crew safety
 2. Vehicle, suit, & hardware safety
 3. Mission Success
 - PAO, Payloads, Sampling, etc.



Flight Control Team Overview

- The Flight Control Team is led by Houston Flight from MCC-H
 - HOUSTON FLIGHT has the overall responsibility for mission integration and execution and has the authority to make any real-time decision required to ensure the safety of the crew and ISS.
 - HOUSTON FLIGHT is also responsible for providing recommendations and/or options to the IMMT, with concurrence from the IPs, when operating outside of the flight rules.
- EVA is one discipline of FOD
 - EVA flight control team will lead any external task
- The strategies, function, and setup of the Space Shuttle and International Space Station (ISS) Flight Control teams were based on predecessor NASA missions including Apollo.
 - Flight Operations Directorate (FOD) uses Lessons Learned and Best Practices post each mission and EVA (Extravehicular Activity) series to continue to refine the Flight Control Team (FCT) and its actions.
- As the vehicle and stakeholders expanded so has the Flight Control Team.
 - Integration of International partners, Payload specialists, and hardware owners.



Practicalities and Constraints

EVA Planning incorporates many aspects.

- Hardware Capabilities
 - Comm/video range
 - Emergency Return
 - Real-time Suit health
- OCADs and Flight Rules
 - Governing documents that constrain operations; normally a safety of crew or vehicle condition
 - Go/No-Go, EVA duration, distance allowed, failure response
 - Violating or Waiving a FR is a big deal

Priorities & Objectives

FOD does not own the mission objectives;
we implement them

- Objectives owned by controlling Program
- Many parties vying for same resources

Pre-flight

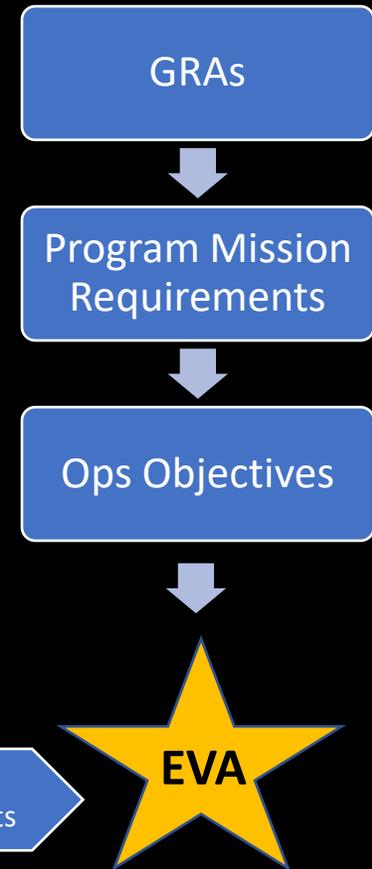
- FOD EVA (includes NASA Internal Science Team) will be handed a list of objectives/tasks in priority order and duration of EVA available
 - Process of vendors, disciplines submitting objectives, approval and prioritization to make this list is still being developed
- FOD EVA will utilize all resources to plan the safest, most efficient EVA with the goal of getting as many objectives as possible and focusing on the highest priority ones
 - Expect ratio of science/utilization and other tasks vehicle/PAO to be set by program
- Iterative process to determine final EVA
 - Unofficially (working level) and Officially at programmatic boards which will include objective owners, crew training, and hardware testing

Real-time

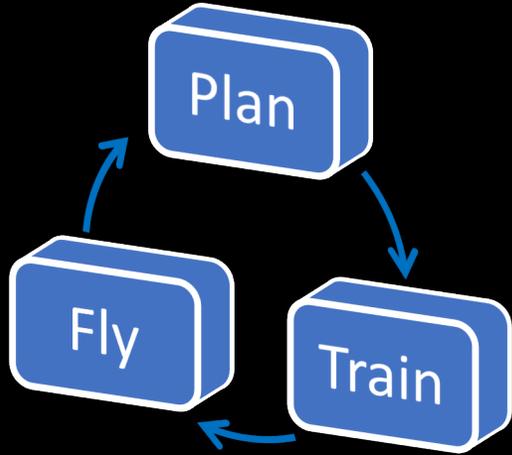
- Variations are possible but will need rationale
- We saw X at site A which makes site D a much higher priority
- Pre-planned EVAs are estimates on times; sometimes accurate and sometimes not
 - If ahead of timeline, we will have “Get Aheads” ready to do more tasks instead of coming in early
 - If behind on the timeline, be prepared for us to start deleting tasks. Mostly based on priority but can also depend on location and other factors.

Pre-Flight Processes

- FOD EVA works with hardware experts to take drawings and Con Ops and develop into EVA Procedures and training documents
 - Build/accept training mockups, flight and test article hardware viewings
- During lead time to planned EVA (1 month to 2 years prior)
 - JOPs (Joint Operations Panel), NBL (Neutral Buoyancy Laboratory) runs,
 - Allows for the entire team to shape products
 - Currently hosted on an internal NASA page
 - Forward work how to interface with Science team outside NASA
 - Hardware Owner Deliverables
 - Analysis, Hazard Reports and Ops Constraints, Procedure Reviews, Analysis, Integrated Testing
 - CEIT (Crew Equipment Interface Test) and other hardware evals
- All before final approval of products
 - Flight Note system allows parties to sign approval or comment with changes (if items were not caught earlier)
 - Goal is to reduce the time spent real-time on conversations if things are agreed to discussed prior
- Pre-planning is so important to drive a successful EVA



EVA Training



- FOD EVA Team is responsible for crew and flight controller training on all EVA hardware
- Hardware owners, payload specialists and subject matter experts are all integral to the training process
- FOD EVA conducts many types of training events in which key Subject Matter Experts (SMEs) attend
 - NBL runs, ARGOS, 1g reviews, simulations
 - Nominally reviews on flight hardware are conducted by the hardware owner with FOD leading relative training
- EVA Assessment Team (EVAAT)
 - Comprised of FOD, Engineering, Hardware SMEs, Safety, etc.
 - Team reviews the EVA procedures and the crew training to verify all constraints are followed, and operations occur effectively and safely to both crew and hardware

Products

- FOD wide
 - Daily Summary / Execute Package
 - Mission Timeline
 - Flight Notes, CHITs, Anomalies
- EVA
 - Briefing Package
 - Procedures / EVA Timeline, Cuff Checklist
 - “Cribsheet”
 - Anything we (EVA community/hardware owners) can think of what will go wrong with pre-coordinated troubleshooting steps that can be executed immediately.
 - A plan for when things don’t go according to plan – to speed up the process when operating outside of nominal.
- Shuttle and ISS use “Gateway” an electronic application to create/distribute Ops Products
 - TBD for Artemis but we expect something similar
- Most products baselined pre-mission, but expect real-time changes and adaptations



Real-Time Operations

- Goal is to allow crewmembers to perform as trained
 - Simple and efficient procedures
 - Expect minimal comm from ground to crew when things are going well
 - Flight control integration and communication is important when things are off nominal
 - Stated recommendation and rationale should be clear and concise
- Understand that any single position or task is not the only player
 - There will be compromises!
 - Know and communicate items that are absolute and where you can give some up.
- A successful EVA is one that brings the crew back inside safely no matter time spent or objectives reached
 - Although we all want the EVAs to complete as many objectives as possible be it a vehicle repair or a certain sample mass, crew safety remains first priority

*To always be aware that, suddenly and unexpectedly,
we may find ourselves in a role where our performance has ultimate consequences.*

Summary

- Keep It Simple
 - Standardization
- Design with EVA Requirements from the beginning
 - Although we often can make it work later; it costs significant more money and EVA time thus more risk (to both crew and mission success)
 - Don't focus only on the desired plan of your hardware concept but also on the "what if"
- Integrate EVA experts from the beginning



Questions?

- Additional Resources:
 - <https://www.nasa.gov/suitup/reference>
 - Links to published EVA documents
 - <https://www.nasa.gov/jsc/procurement/xevas>
 - xEVAS RFP



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Foundations of Flight Operations

1. To instill within ourselves these qualities essential to professional excellence:
 - *Discipline*: Being able to follow as well as lead, knowing that we must master ourselves before we can master our task.
 - *Competence*: There being no substitute for total preparation and complete dedication, for flight will not tolerate the careless or indifferent.
 - *Confidence*: Believing in ourselves as well as others, knowing that we must master fear and hesitation before we can succeed.
 - *Responsibility*: Realizing that it cannot be shifted to others, for it belongs to us; we must answer for what we do or fail to do.
 - *Toughness*: Taking a stand when we must; and to try again and again, even if it means following a more difficult path.
 - *Teamwork*: Respecting and using the abilities of others, realizing that we work toward a common goal, for success depends upon the efforts of all.
 - *Vigilance*: Being always attentive to the dangers of flight; never accepting success as a substitute for rigor in everything we do.
2. To always be aware that, suddenly and unexpectedly, we may find ourselves in a role where our performance has the ultimate consequences.
3. To recognize that the greatest error is not to have tried and failed, but that, in trying, we do not give it our best effort.



EVA Reference Document List

- EHP-10028 - EVA Compatibility document
- EHP 10033 - EHP Integrated Concept of Operations
- EVA-EXP-0042 - xEVA System Concept of Operations
- JSC-35191 - Artemis Flight Operations Standards"
- JSC-35199 - MCC Interface Specification"
- JSC-35194 - Mission Training Center Generic Training Simulation Interface Specification

Acronyms

- CAPCOM
 - Capsule Communicator
- CEIT
 - Crew Equipment Interface Test
- CHIT
 - Abbreviation for a formal Mission Action Request between program/engineering/ops
- EMU
 - ExtraVehicular Mobility Unit
- EVA
 - ExtraVehicular Activity (Spacewalk)
 - May also refer to EVA Officer
- EVAAT
 - EVA Assessment Team
- FCR
 - Flight Control Room
- FCT
 - Flight Control Team
- FD
 - Flight Director
- FOD
 - Flight Operations Directorate
- FR
 - Flight Rule
- GW
 - Gateway (lunar space station)
- JOP
 - Joint Operations Panel
 - AOP – Artemis Operations Panel – not in charts but new name for Artemis
- IMMT
 - ISS Mission Management Team
- ISS
 - International Space Station
- IV
 - Intravehicular (references crew or activities internal to vehicle, unsuited)
- NBL
 - Neutral Buoyancy Laboratory
- OCAD
 - Operational Control Agreement Database
- PAO
 - Public Affairs Officer, sometimes
- SA
 - Situational Awareness
- STS
 - Shuttle/Space Transportation System
- USOS
 - United States Operational Segment (US part of the ISS)