National Aeronautics and Space Administration

Artemis EVA Flight Operations

Preparing for Lunar EVA Training & Execution

EVA Exploration Workshop

Alex Kanelakos, *EVA Operations Chief Engineer*

February, 2020

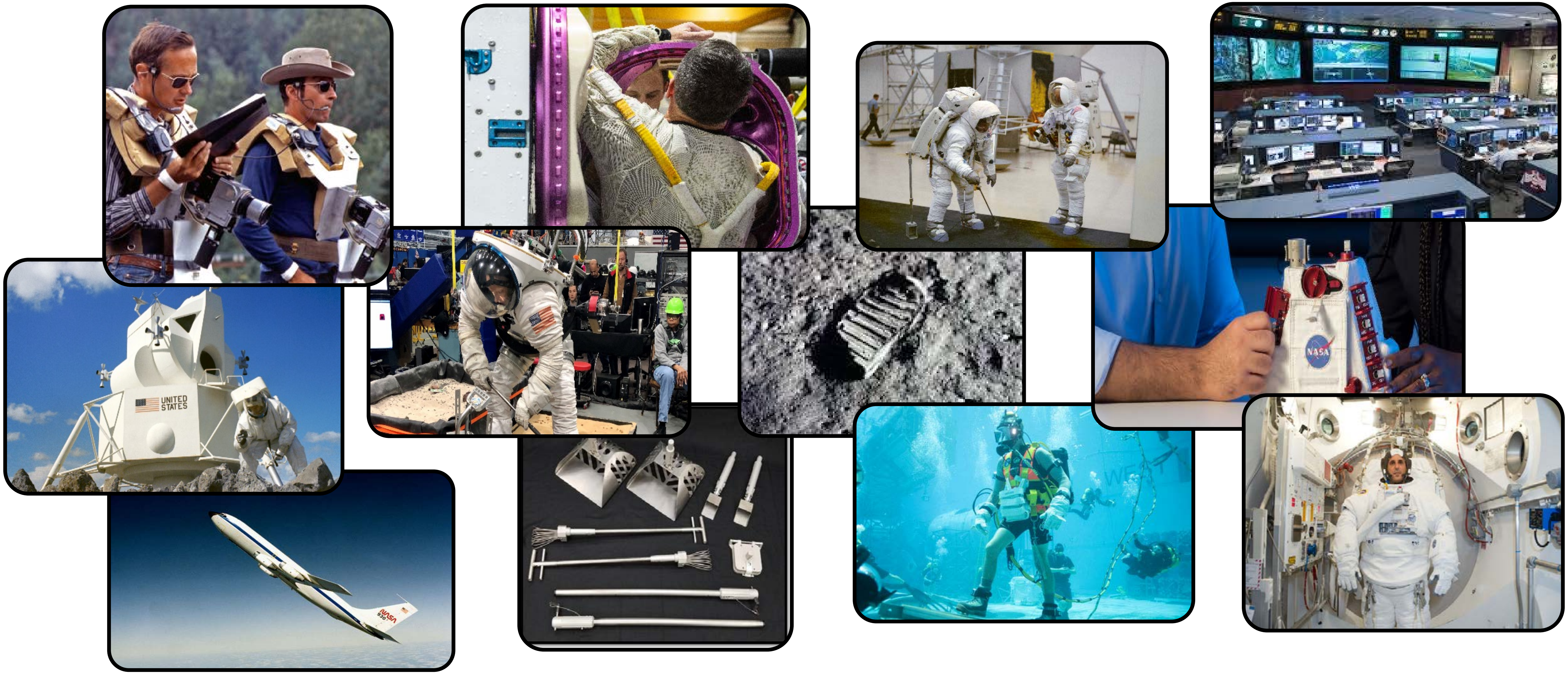
Agenda

- Role of EVA Flight Operations
- Process of Designing a New Flight Operations System for Lunar EVAs
- Capturing Historic EVA Lessons Learned
- Influencing EVA Hardware Design from an Operations Perspective
- Structured Analog Testing
- Designing Lunar EVA Training Flows using a Risk-Based Approach
- New Methods in Procedure Authoring
- Designing Lunar EVA Execution Systems

Role of EVA Flight Operations

- To protect our astronauts and to plan, train, and fly humans in space.
- Plan
  - Build execution and training operation concepts and mission requirements
  - Influence and evaluate hardware designs
  - Develop operation products: lesson plans, EVA timelines, procedures, flight rules, etc.
- Train
  - Astronauts, flight controllers, and other groups (engineers, safety and program personnel, etc.)
  - Use diverse facilities, laboratories, and analog environments to train EVA operations
- Fly
  - Execute missions from Mission Control Center – Houston
  - Perform real-time troubleshooting and risk assessments for off-nominal operations

EVA Operations



Organization Structure

EVA Systems

- Airlock systems
- Depress/repress
- xEMU operations
  - Pre EVA operations and prebreathe
  - Post EVA operations and maintenance
  - Resize
- xEVA vehicle interface equipment

EVA Task

- Suit mobility and translation
- Ingress/egress
- Tool and timeline management
- Exterior vehicle maintenance
- Electrical, fluid, and structural mechanisms for construction and deployment
- Crew rescue

EVA Science

- Site and sample characterization
- Sample collection and curation
- Science instrumentation

xEVA Operations Team

A. Kanelakos – FOD xEVA

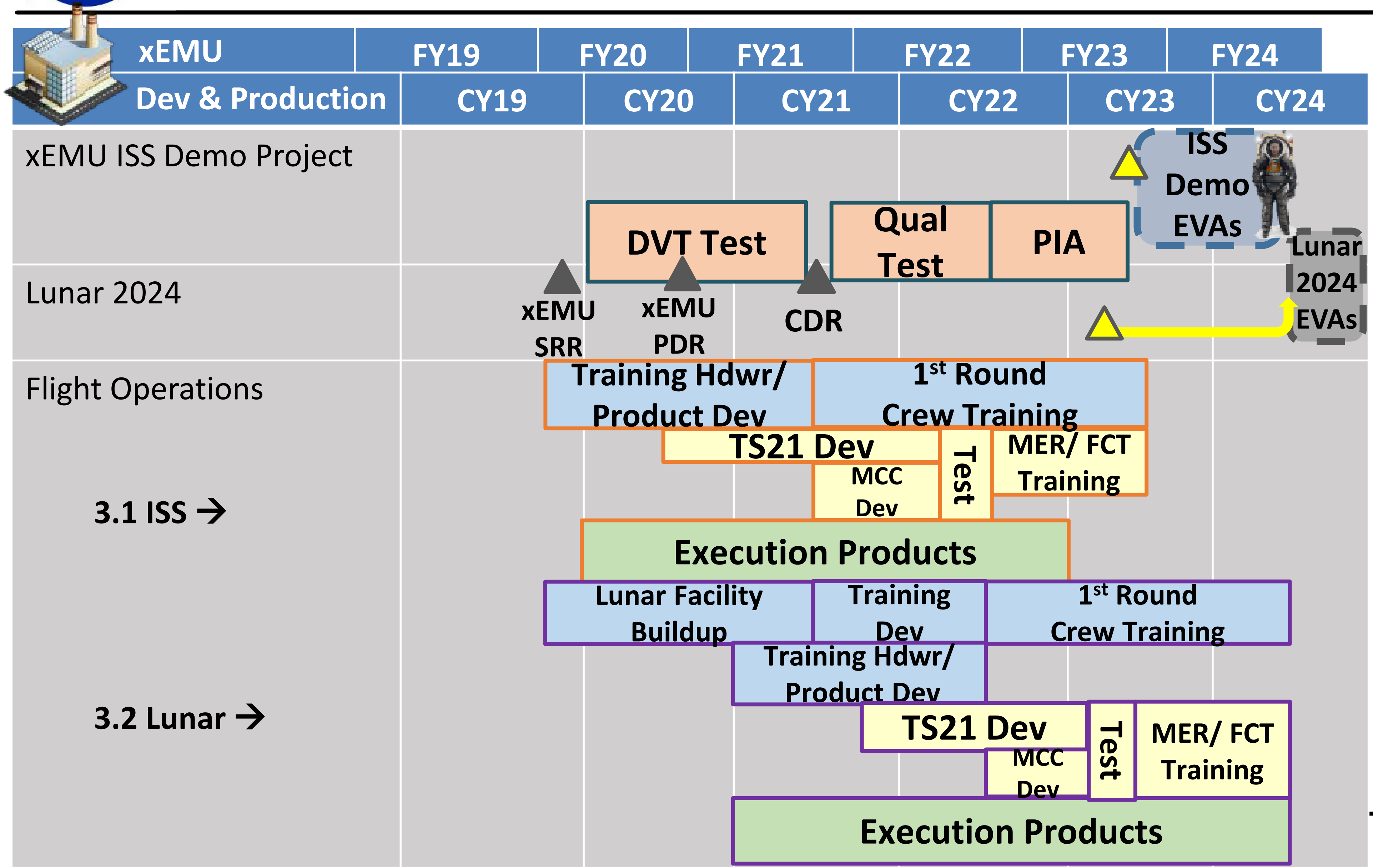
S. Korona – xEMU Lead
- J. Gaustad – xPLSS, A/L
- C. Mavridis – xPGS
- M. Dino – xInfo, xSPCE
- M. Russell – CWS
- D. Simon – Avionics
- D. Barrett – ORU
- C. Murphy – Safety/ OCADs

S. Wray – xEVA Training Lead
- T. Graff – Science Training
- TBD – Tools
- B. Scheib – xPGS
- S. Mulhern – Simulators
- I. Theriot – Tools
- V. Brooks – Data Mngt
- O. Koehler – Mockups

D. Welsh – Testing Lead, Jarvis

J. Kagey – xEVA Ops Architecture Lead
- K. Young – Science Execution
- TBD – HLS Integration
- J. Montalvo – Lunar - EOS
- B. Smith-Sparks – MCC Displays
- E. Matula – P/B
- N. McHugh – Stowage

xEVA Schedule



How do you build your operations systems for Moon and Mars?

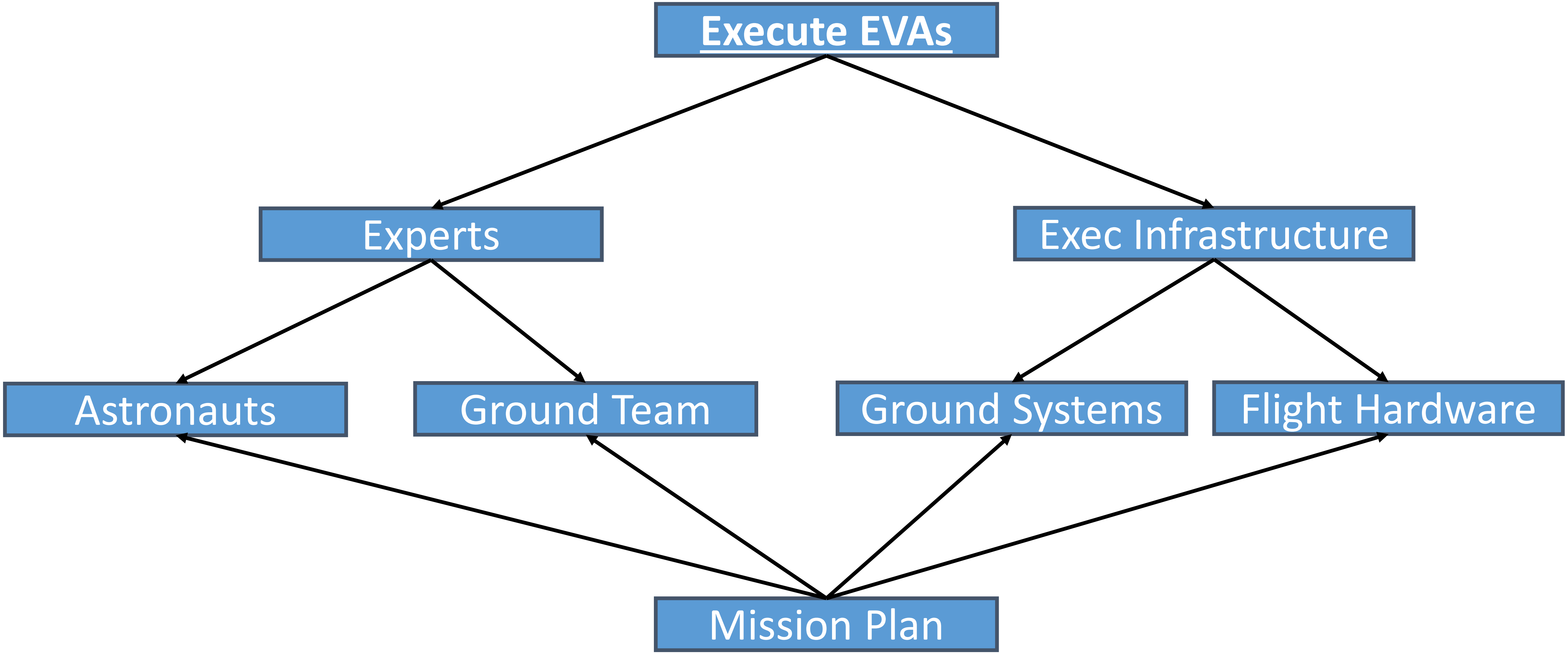
Process:

- Develop a robust set of lessons learned from previous programs
- Assess training and execution systems from a risk perspective
- Produce products and processes that increase efficiency
- Leverage existing facilities and capabilities for training and execution
- Develop new processes, facilities, and tools for operations

Training Timeframe:

- Develop training (generic and assigned) and execution infrastructure for xEMU EVAs on ISS, Moon, Gateway, and Mars
  - ISS goal of 2023 for Demo EVAs and ready to support a mid 2020's EMU → xEMU transition
  - Moon and HLS/Gateway 2024
  - Mars 2033?

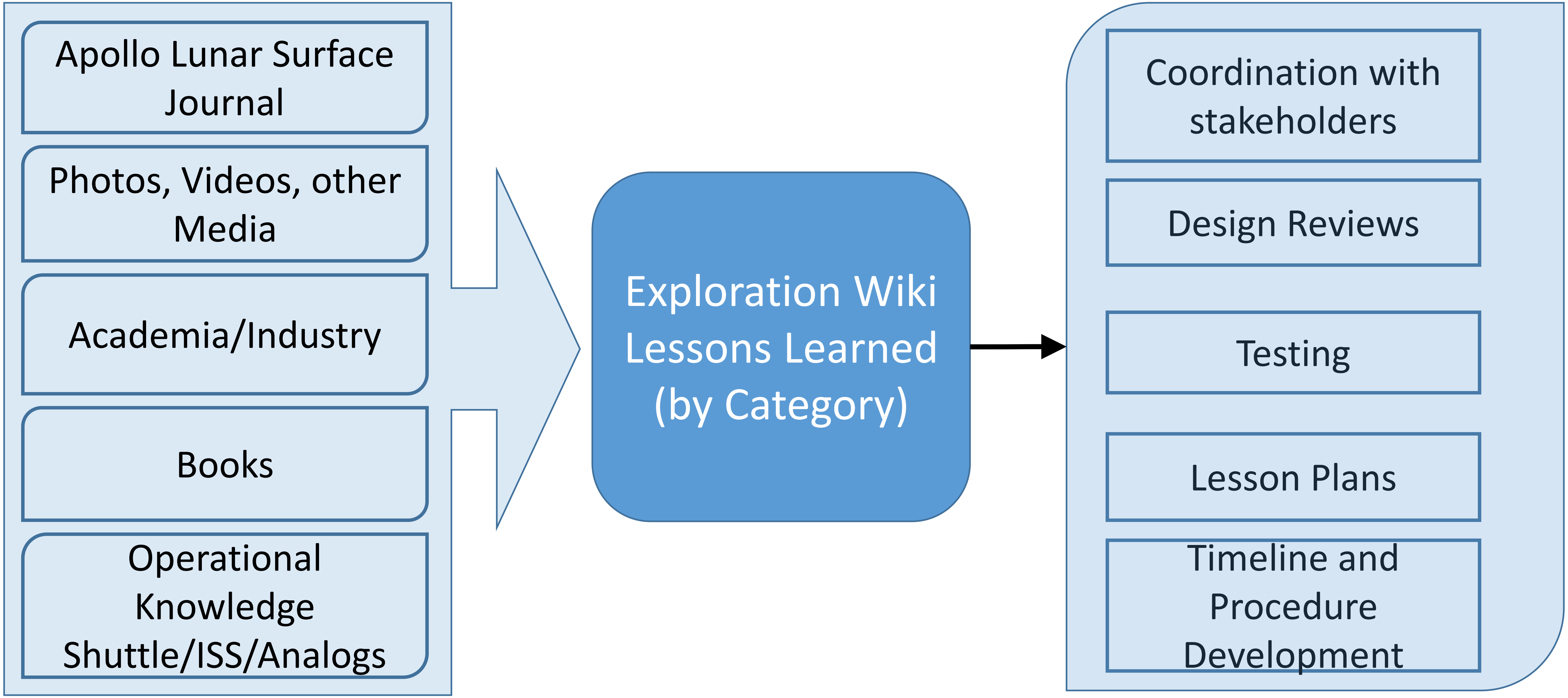
Operation Deliverables



Capturing Historic EVA Lessons Learned

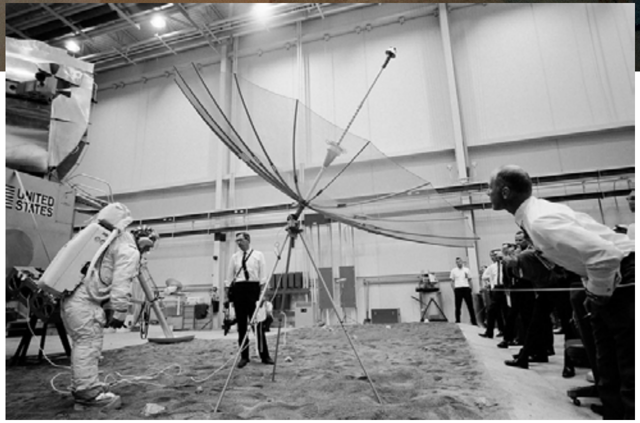
Ike Theriot – *xEVA Task Instructor*

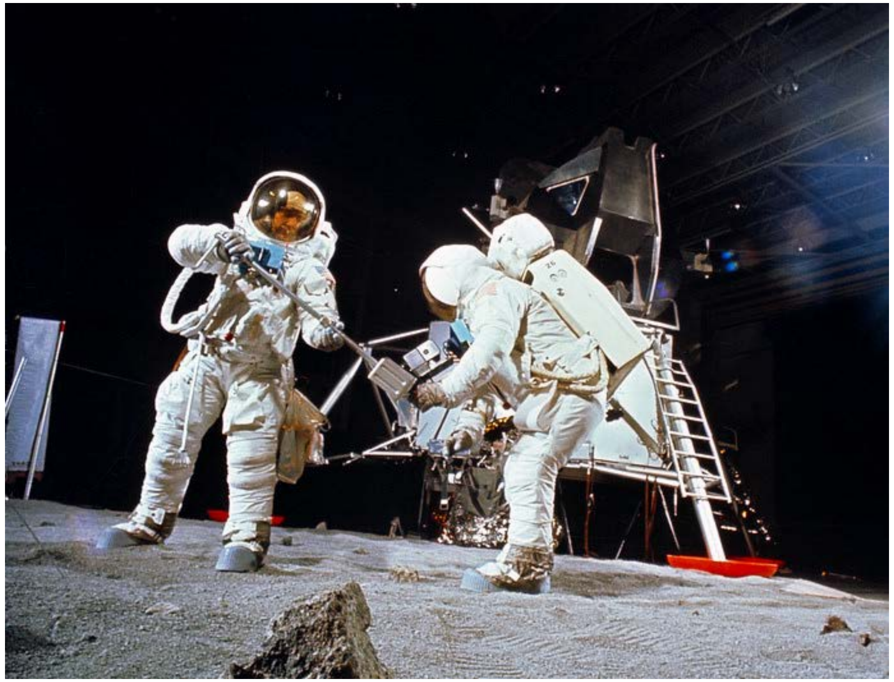
Capturing Lessons Learned



Example: EVA Crew Training and Facilities

- Various Training Facilities
  - B29 Centrifuge
  - POGO
  - Parabolic Aircraft
  - Vacuum Chambers
- Requirements for Artemis training facilities pulled from relevant lessons
  - Crew feedback
  - Facility layout and support equipment
  - Current capabilities
  - Shuttle/ISS crew training lessons learned





Sharing Knowledge

- EVA Operations is leveraging our current Wikimedia platform of resource management to inform and share information to the broader NASA EVA community

Page | Discussion | Read | Edit | Edit source | View history | More | Search Exploration Wiki

All Wikis
Add an action
Wiki Cheatsheet
Tutorial 1: Welcome!
Personnel
Recent changes
Random page
Help

Forms
Person
Meeting Minutes
xEVA Component
Hardware
Test objective
Test event

Tools
What links here
Related changes
Upload file
Special pages
Printable version
Permanent link
Page information
Page values
Browse properties

Lessons learned

1.1 2

Lessons learned capture knowledge gained through experiences in planning for, training for, and executing missions (vehicles, increments, EVAs, etc). This serves as a repository of knowledge from experience to take forward to future exploration missions. The mission leads (vehicle, increment, or EVA lead as appropriate) are responsible for gathering and presenting lessons learned in a timely manner so that others can learn from their experience and apply the lessons they've learned to future, similar operations.

Use the button below to add a new lesson learned to the Wiki

Add lesson learned

Contents [show]

CX Lessons Learned [edit | edit source]

Lessons Learned [edit | edit source]

Show 10 entries | Search: | Export

	Subject	Status	Type	Intended audience	Event date	Mission	Author	Organization	Related article
Lesson learned 1968/06/11-015	NBL training	Preliminary	Lesson learned	Internal	1968/06/11	Apollo 11	Ike Theriot	CX3 : FOD EVA	Lunar Assigned Crew Training NBL
Lesson learned 1968/06/11-010	Lunar surface navigation	Preliminary	Lesson learned	Internal	1968/06/11	Apollo 11	Ike Theriot	CX3 : FOD EVA	Lunar Assigned Crew Training
Lesson learned 1968/06/11-005	Lunar EVA depress training	Preliminary	Lesson learned	Internal	1968/06/11	Apollo 11	Ike Theriot	CX3 : FOD EVA	Lunar Assigned Crew Training
Lesson learned 1968/06/11-016	1G classes	Preliminary	Lesson learned	Internal	1968/06/11	Apollo 11	Ike Theriot	CX3 : FOD EVA	Lunar Assigned Crew Training

Influencing Hardware Design from an Operations Perspective

Costa Mavridis – *xEVA PGS Operations Lead*

Influencing EVA Designs from an Operations Perspective

- *“It’s our job to fully grasp the needs of people using our products and be the spokesperson for them”**
  - Available unassigned crew prevents astronaut office from supporting all design meetings and/or testing.
  - ISS Ops team has the best collection of crew feedback (direct and indirect) on current and past EVA hardware
- Ensure hardware is not over constrained
  - Crew can be very creative and think of new ways to use the hardware to get the job done
- Keep the bigger picture in mind
  - SE&I Teams can help design integration from a requirements stand point, but ops team can help by keeping the ‘realistic’ use of the hardware in perspective.

*Catherine Courage: VP, Ads & Commerce User Experience (UX) Design at Google

Influencing EVA Designs from an Operations Perspective: Questions to ask on a Design

- **Reliable** – Where does this suit, hardware, or tool need to be more robust or redundant to keep crew safe and to prevent failures?
- **Injury Prevention** – Can this design injure the astronaut or suited subject?
- **Efficient** – Does this design increase crew efficiency in EVA operations?
- **Reduced Workload** – Does this design add to the cognitive or physical workload?
- **Upgradeable** – If we have to live with this design for the next 40 years, can we make easy upgrades?
- **Maintainable** – Does this design significantly reduce preventative and corrective maintenance requirements compared to current EVA hardware?
- **Flexible** – Does this design lock in only one operations concept or does it allow for operation flexibility?
- **Compatible** – Is this design compatible with the current and future operation concepts and other existing hardware?
- **Trainable** – Does this design require new or modified training infrastructure?

If crew and flight controllers could change one item of the current EMU:

Hardware Efforts in Development

- Incapacitated Crew Rescue (ICR)
  - Lunar lander designs with high platforms may require lifting operations for ICR scenarios, as well as, for science return mass. Hardware may need to be developed on both the xEMU and lander to raise a crewmember that cannot climb the ladder and assist in returning the crew to the lander.
- Dust mitigation
  - Many Apollo crew comments on the quantity of dust that returned into the vehicle after the EVAs, which created operational and health challenges. How do we remove dust from suits and tools in an effective and <u>timely</u> process.
- Science, Tools, and Equipment
  - There is a need to correctly stow and carry science samples to preserve qualities and characteristics of the samples, especially for volatiles.
  - As seen from ISS, suit components fail, and many of theses failure can preclude an EVA (NO-GO for EVA). It is imperative to design for quick reparability.
  - With the ever increasing sharp edges on ISS and the very sharp regolith and rock on the Moon, there is a need to ensure our xEMU design is at an appropriate risk level for leak penetration and we optimize a design that can sustain crew life in a feed-the-leak scenarios if a hole does penetrate the pressure garment.

Designing Lunar EVA Training Flows using a Risk-Based Approach

Scott Wray – *xEVA Training Lead*

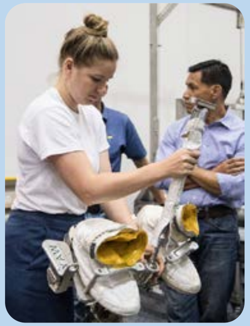
Trevor Graff – *Exploration Scientist*

EVA Skills Training –Phased Approach

EVQ
Initial Training

During astronaut candidacy

- Systems
  - Basic, working knowledge of EMU
  - Caution & Warning interface and boldface response
  - Suit-IV role, understanding of Road-to-EVA activities
- Task
  - Optimize suit fit, safely performing basic skills and proficiency to complete 6.5-hour spacewalk
  - Mastery in self-care and ability to rescue partner within 30 minutes
- Plan/Ops
  - Basic execution and participation in EVA development as EV crew and Ground IV.
  - Assist with crew suit donning/doffing




Proficiency
Intermediate Training

Between completion of initial training & flight assignment

- Maintain EV-Q Proficiency
  - Periodic NBL Runs to maintain EV-Q skills
  - Periodic Systems courses to maintain Suit-IV skills
- EVA Development
  - EVA Hardware review
  - NBL Development tests
- Leadership and Ground-IV development
  - Optional EV-L flow to increase leadership skills and mentor rookie crew
  - Ground-IV training and execution of EVA from MCC


Assigned
Intensified Training

Mission specific EVA training

- ISS Maintenance
  - Focus on Critical Contingency EVA tasks
  - Skills based for both Nominal and Contingency EVAs
  - Evaluation from EVA Evaluation Board
- EMU & A/L Systems
  - Road-to EVA and EMU Maintenance
  - EVA Prep & Post (EV and Suit-IV roles)
- EVA Specific Training
  - Training Specific EVA content which is scheduled within Increment timeframe
  - Develop crew preferences for EMU and EVA timeline
  - Evaluation from EVA Evaluation Board


EVA Science Training – Phased Approach

PHASE 1: ASCAN | Proficiency | Assigned

Initial Training

During astronaut candidacy
(plus Engineer/Manager Courses)

- JSC Classroom Training Modules
  - Geo-Science Fundamentals
  - Earth Systems
  - Planetary Science & SMD Missions
- Field Training
  - Geologic Mapping & Traverse Planning
  - Sampling & Instrumentation
- Expeditionary Components
  - Team Experiences & Leadership Opportunities

Intermediate Training

Between completion of
initial training & flight assignment

- Advanced Field Opportunities
  - Astronaut Field Assistant Program
  - Additional exercises in observation & problem solving
- ISS Specific Training
  - Ex. Crew Earth Observations
- Analog Mission Operations
  - Science in relevant environments under operational conditions (e.g. NEEMO, CAVES, etc.)
  - Additional leadership and teamwork opportunities

Intensified Training

Mission specific science training
(patterned after Apollo J-missions)

- Destination-Specific Training
  - Target-specific approach
  - Detailed focus on science objectives & operations
- Extensive Field Experiences
  - Numerous geologic/operational training trips
    Variety of relevant terrains
- Extensive Geologic Education
  - Masters Degree proficiency level
  - Proficient in multiple geo-science disciplines

xEVA Training Philosophy

- Our success in EVAs over the past 20+ years in ISS construction and maintenance can be attributed to our End-to-End Training philosophy. End-to-end Training was also used from Apollo-Shuttle Training:
  - A two-member, gravity off-loaded, pressurized suited test environment with the highest fidelity mockups, tools, and hardware capable of running the entire duration of an EVA (6-8 hours).
- Approach to assigning risk
  - For every identified lunar task, a risk must be assessed to the task if no training is performed.
  - The FOD training system and flow is developed around performing training events that reduce the risk of loss of crew, injury to crew, and loss of mission objectives.

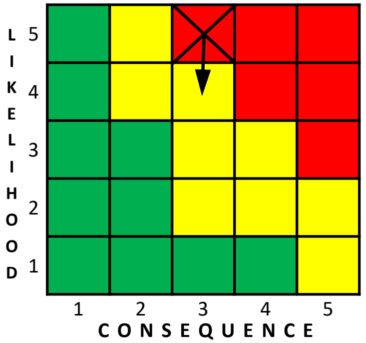
Example Risk: Medium-Long Distance Ambulation

Current Risk:

*With **NO** Training*

Very High/Severe

(Falling, Fatigue, Injury)



Current Facilities:

Risk: High/Critical

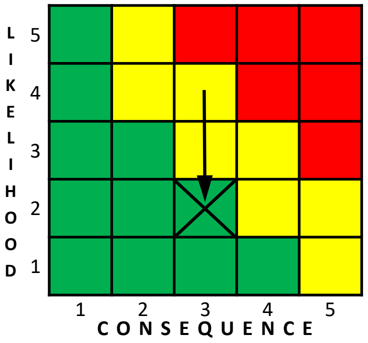
- ARGOS (Horse Treadmill)
  - 1/6g Pressurized walking suit
- NBL*
  - 1/6g SCUBA
  - 1/6g Pressurized walking suit

*Not recommended for evaluation/verification of suit ambulation due to water drag effect

Example Risk:
Medium-Long Distance Ambulation

Risk Buy-down

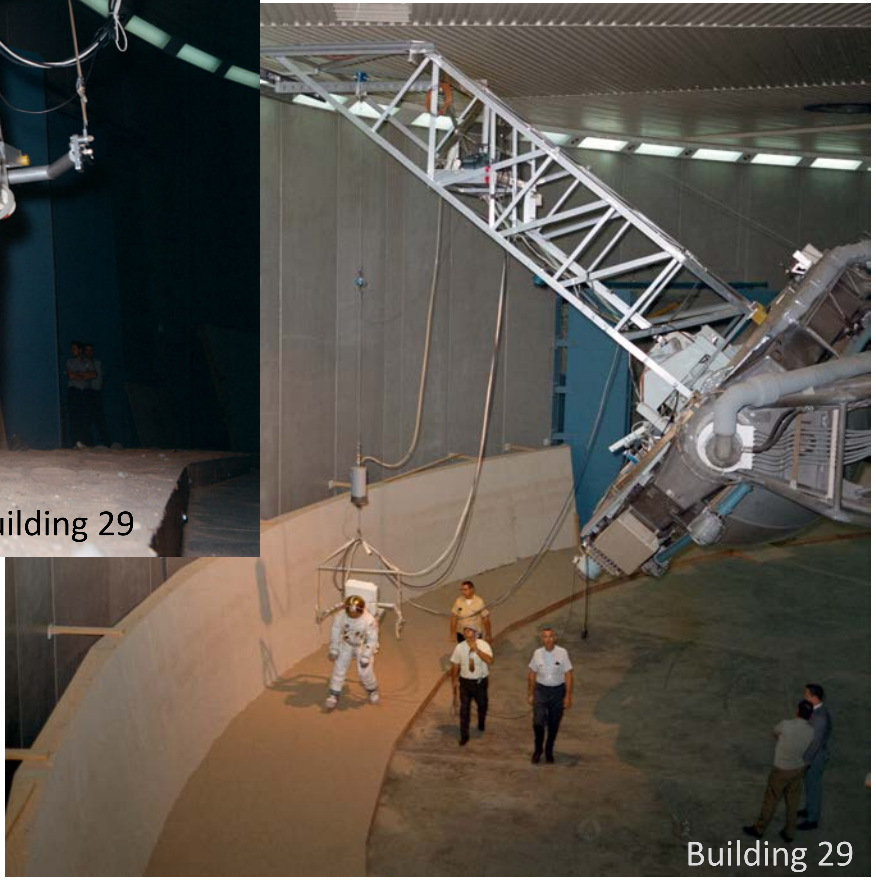
Low/Severe



Future Facility:

- Hi-Bay AXES facility
  - Large Circular or Oval Track
    - 100 ft minimum diameter corners to minimize impacts to momentum management and gait
  - 1/6g off-load
  - Hi-Fi Pressure Suit (xEMU)
  - Simulated Lunar Lighting
  - Simulated Lunar Topography

Building 29



Building 29

EVA Training Risk: One of Many Conclusions

- NASA is missing a large facility to train end-to-end EVA timeline operations, manage metabolic rate while translating and performing other operation, characterize and collect diverse science samples, practice crew-MCC communications, and complete crew rescue, all while maintaining a diverse topography, oblique lighting angles, and active xEMU Caution & Warning System.

Structured Analog Testing

Daren Welsh – *xEVA Operations Test Lead*

We need a unified, structured approach

- Tests are performed in multiple environments, with different configurations, to address lots of objectives
- A unified test structure will foster collaboration, improve work efficiency, and unify data so we can agree upon results
- A single, unified set of test objectives ensures we are working to the same goals
- Collocation of test documentation provides transparency for inter-team awareness

Test Environment Configurations

Test Environments

- NBL
- ARGOS
- VR
- Parabolic flight
- NEEMO and other field tests
- Shirt-sleeve (APACHE, NBL 1-G room, etc)
- More …

- Considerations
- Each test environment can have multiple configurations
- Mockups of flight hardware and tools
- Method of providing Lunar weigh-out
  - Different ARGOS gimbals
  - Different NBL weigh-out systems
- Subjects can have different configurations
  - Suit type
  - Dive helmet
- Methods to record data (more on this later)

New Test Structure: Test Objectives

"We don't just perform tests to perform tests. We do it to answer questions."

Determine xEMU interfaces needed for carrying tools.

2.4 1

Test Objective:12

Contents [hide]

Operational Relevance [edit source]

A small contingent of tools will need to be carried on the xEMU. Need to evaluate methods for connecting/attaching these tools to the suit.

Related Test Events [edit source]

The following Category:Test events included this objective:

Overview [edit | edit source]

The following is a notional list of the tools anticipated to be carried on the suit: point and shoot camera, sample bags, bulk sample container, hammer, chisel, scoop, various tools for powered drilling (maybe none but not sure), special tools for PSR ops (maybe none but not sure).

At this point we need to figure out how those tools would best be carried on the suit with the goal of getting to a PDR level in time for the xEMU delta-PDR in July.

Data Parameters

Data Parameter(s)	Data Collected	Metric	Hardware Required	Data Product
Subject Task Acceptability	Subject feedback	PACES Task Acceptability Rating Scale		
Subject Discomfort	Subject feedback	PACES Discomfort Scale		
Subject Perceived Exertion	Subject feedback	PACES Perceived Exertion Scale		

Determine xEMU interfaces needed for carrying tools.	
Moon-to-Mars Element: EVA	
Sponsors	• EC7 : EVA Tools Engineering
Stakeholders	• CX3 : FOD EVA • EC7 : EVA Tools Engineering • EC5 : EVA Suit Engineering • NBL • ER5 : ARGOS • XI : ARES • Crew Office
Related EVA Gaps:	• EVA Gap: Tool Transport on Surface EVAs
Target test environments:	• NEEMO • NBL • ARGOS
Target activity modules:	• Activity Module: Geology Traverse and Sampling (Lunar Surface)
Tools	
Required	• Scoop (Artemis) • Documented Sample Bag (Artemis) • Hammer (Artemis)
PACES	

New Test Structure: Test Objectives Form

Infobox | General Information | Data Parameters

Title:*

Determine xEMU interfaces needed for carrying tools.

Operational Relevance

A small contingent of tools will need to be carried on the xEMU. Need to evaluate methods for connecting/attaching these tools to the suit.

Sponsors (responsible authority and funding source)

× EC7 : EVA Tools Engineering

Stakeholders (those interested in the results)

× CX3 : FOD EVA × EC7 : EVA Tools Engineering × EC5 : EVA Suit Engineering × NBL × ER5 : ARGOS × XI : ARES × Crew Office

Moon-to-Mars Element

EVA

Related EVA Gaps

× Tool Transport on Surface EVAs

Related articles

Target test environments

× NEEMO × NBL × ARGOS

Target activity modules

× Activity Module: Geology Traverse and Sampling (Lunar Surface)

New Test Structure: Standard Measures

Some test objectives can be used generically across all tests

Objective	Data Parameter(s)	Operational Relevance	Sponsors	Stakeholders	Target Environments	EVA Gaps	Moon-to-Mars Element
Compare human health and performance data across analog environments, e.g. ARGOS and NBL	Heart Rate Subject Perceived Exertion Subject Task Acceptability Gait Tracking Subject Discomfort Subject Sim Quality	Gait analysis; physical workload; functional task decomposition; subjective feedback with standard methodology	• SK : H-3PO	• CX3 : FOD EVA • SK : H-3PO	• NEEMO • APACHE • ARGOS • JSC Rock Yard • NBL	• EVA Gap: EVA Informatics for Health & Performance • EVA Gap: EVA Conops for Human Health & Performance	• HHP
Characterize acceptability of an activity	Subject Task Acceptability	By measuring the acceptability of an activity (as reported by the subject), we can determine which factors have positive and negative effect.	• SK : H-3PO	• CX3 : FOD EVA • SK : H-3PO	• APACHE • ARGOS • JSC Rock Yard • NBL	• EVA Gap: EVA Conops for Human Health & Performance	• HHP

New Test Structure: Test Events

2019/12/19 ARGOS MKIII Test

Test Event:1

Geology Traverse and Sampling (1:00)

Procedures:

Completed	Objectives	Sponsors	Stakeholders	Data Parameters
✅	Characterize physical workload for an activity	• SK : H-3PO	• CX3 : FOD EVA • SK : H-3PO	• Heart Rate • Gait Tracking • Metabolic Rate
✅	Characterize simulation quality for an activity	• SK : H-3PO	• CX3 : FOD EVA • SK : H-3PO	• Subject Sim Quality

Data Products:

Geophone Deployment (1:55)

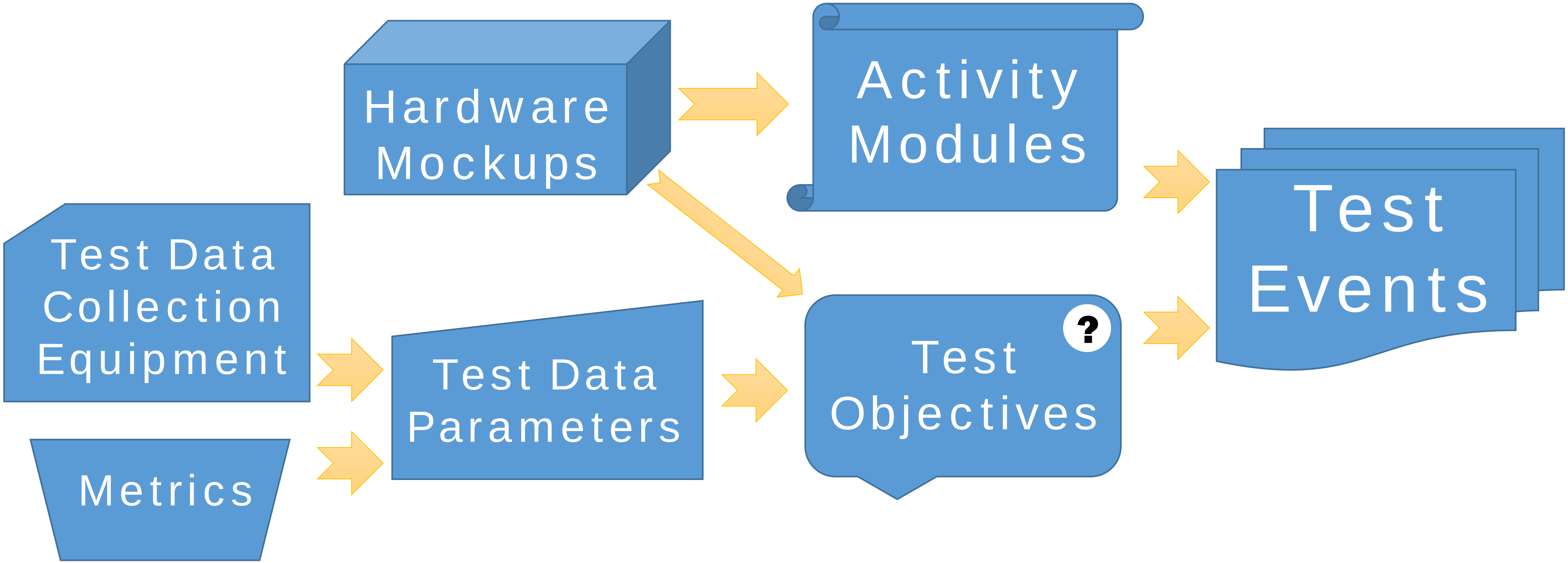
Procedures:

- Procedures[file info]
- Layout and Traverses[file info]
- Treadmill Protocol[file info]

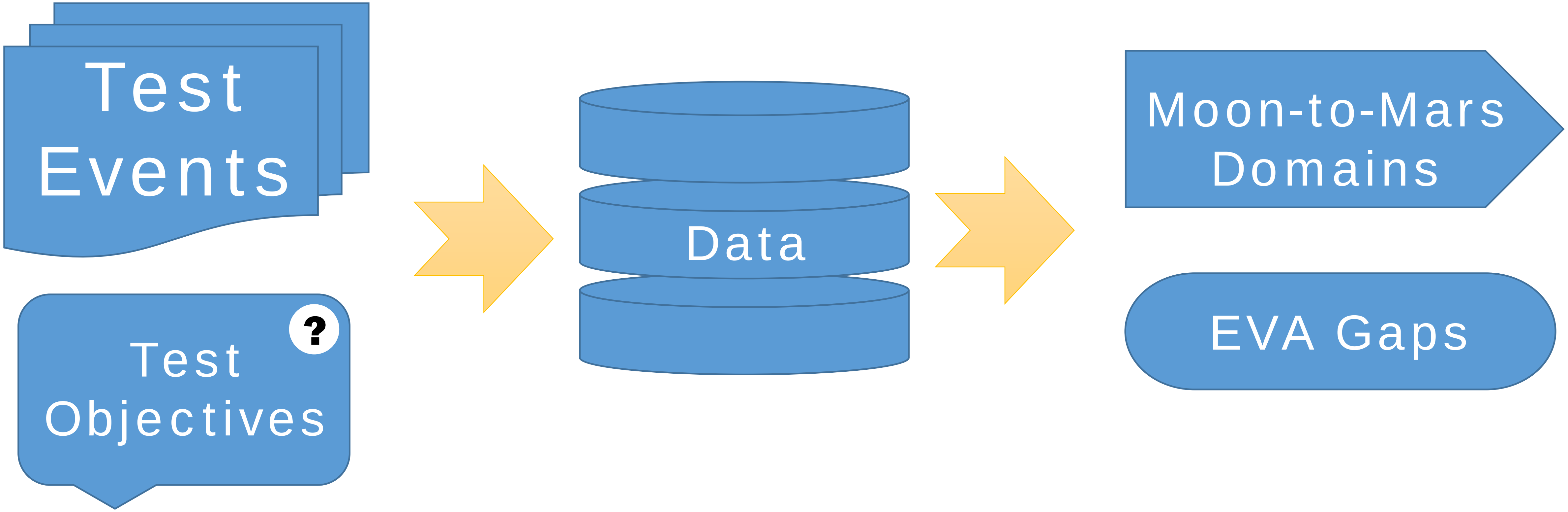
Completed	Objectives	Sponsors	Stakeholders	Data Parameters
✅	Characterize physical workload for an activity	• SK : H-3PO	• CX3 : FOD EVA • SK : H-3PO	• Heart Rate • Gait Tracking • Metabolic Rate
✅	Characterize simulation quality for an activity	• SK : H-3PO	• CX3 : FOD EVA • SK : H-3PO	• Subject Sim Quality

Test Event:1	
Date	2019/12/19
Flight Environment	Lunar Surface
Test Environment	ARGOS
Subject Environment	MKIII
Subject Environment Details	
Sponsors	• SK : H-3PO • CX3 : FOD EVA
Stakeholders	• CX3 : FOD EVA • SK : H-3PO • XI : ARES
People	
Subject(s)	• Drew Feustel
Test Director(s)	• Mike Amoroso
Test Conductor(s)	• Omar Bekdash • Jocelyn Dunn
IV(s)	• Andrea Meado • Daren Welsh
Sensors(s)	• Jenny Sullivan
Hardware	
Test Data Collection Equipment	• PACES Heart Rate Monitors

New Test Structure: Overall Structure



New Test Structure: Overall Structure



Designing Lunar EVA Execution Systems

Jaclyn Kagey – *xEVA Lunar Architecture Lead*

EVA Execution

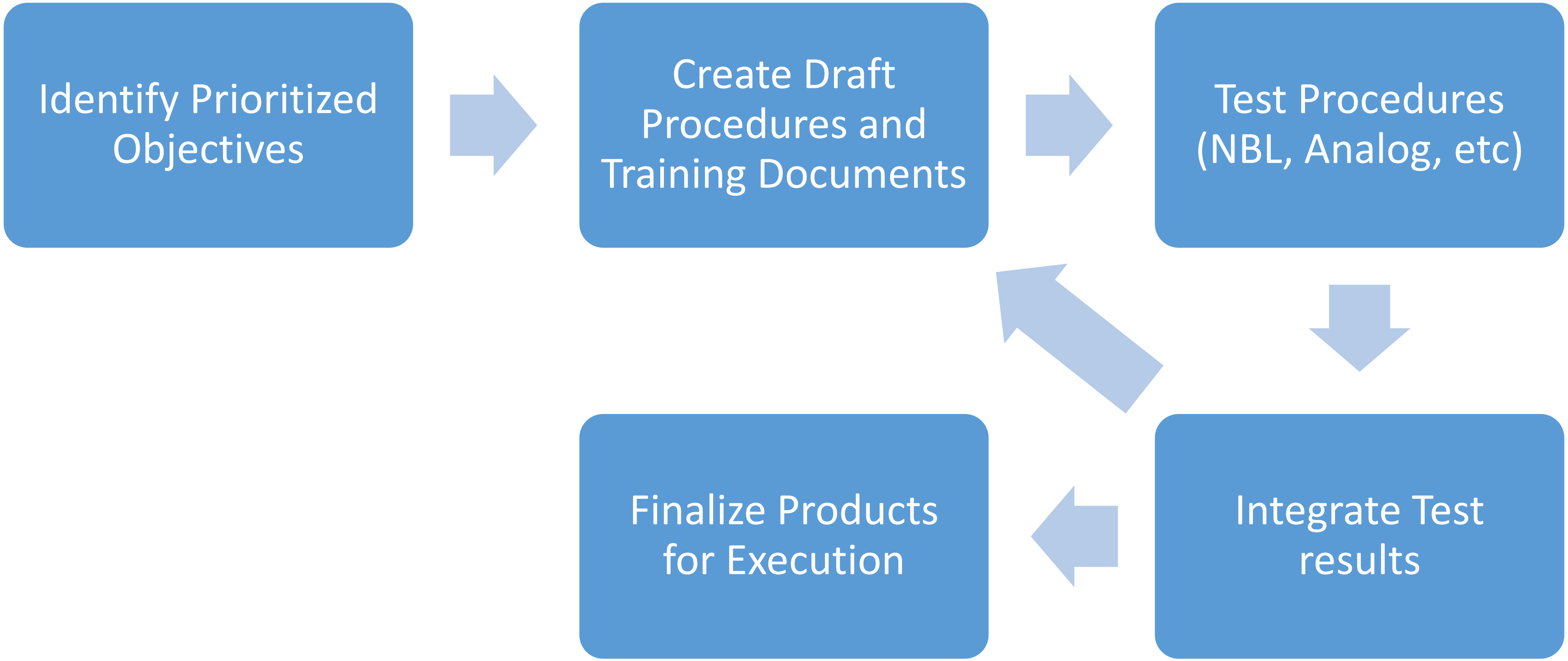
- FOD EVA is developing operational concepts for the future execution of lunar EVAs.
  - These concepts utilize lessons learned from the success of both Apollo and International Space Station EVAs.
    - Integrate lunar science experts into the flight control team and planning/training process.
      - More efficient to the mission to have a science expert integrated into the FOD EVA team (including physical location during execution)
      - With additional experts in the "Science Support Room" (Apollo SSR) interacting with the Flight Control Team, just like ISS Flight Controllers interact with the Mission Evaluation Room (MER)
    - Plan to test ops concepts during analog missions (NEEMO)
  - Communication and timely response are critical for the safety of the crew and mission success.
- Current challenges include undefined vehicles, tools, and rover access and unknown landing site.

Criticality of Communication during Ops

Clear and timely communication is critical during real-time EVA operations. Past experiences have demonstrated that delays in information can cause teams to go down paths not intended by all teams.

- Example from US EVA 32 – Water Switch flip during depress

EVA Development Process



Notional EVA Timelines

- FOD EVA is already working with ARES to identify potential objectives and their priorities.
- These have been formulated into Summary EVA Timelines which can be used for testing and requirements development.

Artemis 3 EVA 1 (6:00) (edit this summary timeline)

Dependencies: **Artemis 3**

Color key: Safety | Dust Removal | Science | Lander Ops

PET: 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00

EV1

Egress (0:45)	[2]	PAO (0:15)	Experiment Package Deploy (0:45)	Traverse (0:30)	Presampling (0:30)	Sampling (0:45)	[8]	Sampling (0:30)	[10]	Tool Stow (0:15)	Dust Removal Cleanup (0:30)	Ingress (0:30)

EV2

Egress (0:45)	[2]	PAO (0:15)	Experiment Package Deploy (0:45)	Traverse (0:30)	[6]	Instrument Use (0:30)	Sampling (0:30)	[9]	Sampling (0:30)	[11]	Tool Stow (0:15)	Dust Removal Cleanup (0:30)	Ingress (0:30)

EV1:

[2] Contingency Sample (0:15)

[8] Return traverse (0:15)

[10] Return Traverse (0:15)

EV2:

[2] HLS Inspect (0:15)

[6] Presampling (0:15)

[9] Return Traverse (0:15)

[11] Return Traverse (0:15)

EVA Operations Continuing Work

- xEVA FOD has completed it first Artemis Flight Control Test
  - Several outcomes and lessons learned came out of the event that will be used to build on future test events

- Risk
  - Method to improve crew autonomy due to ≥8 sec delay
    - Real-time independent procedure tracking as locations start having longer comm delays.
    - Verbal note taking paired with imagery for downlink and analysis.
    - Ability to give crew real-time procedures, data, pictures, or diagrams during the EVA to assist the crew with questions or obstacles.
    - Navigation and Location tracking are new needs as we venture further from our how vehicle, into PSRs, and other limited visibility areas.

- Open Work
  - Expand communication and integration methods for ground teams
    - Inclusion of science community, VIPER, CLIPS, and other outside of NASA players
    - Integration between NASA and hardware owners (vehicle, payload, etc.)
    - Will need planning data transfer and real-time communication means

New Methods in Procedure Authoring

James Montalvo – *xEVA Flight Controller*

How we currently author and execute EVA procedures

- Procedures authored in heavily-formatted Word documents
  - Cumbersome to make changes
  - Multiple authors collaborating difficult
  - More cumbersome to review changes someone else has made
- Procedures executed from printed versions of the Word documents
  - Location in procedure (which steps are active) communicated verbally throughout team
  - Notes tracked by hand on paper copy
  - Times tracked on paper copy or in separate application (Excel)

P3/P4 JUMPER STOW (00:15/00:35)

<table>
<tr><th>IV/SSRMS</th><th>EV1 (Drew)</th><th>EV2 (Spanky)</th></tr>
<tr><td>Planned PET 03:15 (EV1), 02:55 (EV2)

MCC-H: Report if NH3 Inspection reqd</td><td colspan="2">CAUTION
Use caution when translating near SARJ ring with open covers

NOTE
On **MCC-H GO:** Perform NH3 Inspection of EMU at earliest convenient opportunity, shade as reqd during day (For inspection description see 4.141 ISS EVA AMMONIA DECONTAMINATION, note 2 (SODF: ISS EVA SYS)</td></tr>
<tr><td>1. EV1 Tool Inventory:
☐ MWS
☐ BRT (L)
☐ RET (sm-sm)
☐☐ Wire Tie (2 short)
☐ T-Bar
☐ RET (Lg-sm) (R)
☐ RET (Lg-sm) (L)
☐ Adj Equip Tether (R)
☐ Adj Equip Tether (L to TB)
☐ Small ISS Trash Bag (R, inbd)
☐ Swing Arm (R)
☐ EVA Camera w/bracket (int RET)
☐ RET w/PIP pin

2. EV2 Tool Inventory:
☐ MWS
☐ BRT (L)
☐ RET (sm-sm)
☐☐ Wire Tie (2 short)
☐ T-Bar
☐ RET (sm-sm) (L)
☐ RET w/PIP pin (R)
☐☐ Wire Tie (2 short)
☐ Adj Equip Tether (R)
☐ Small ISS Trash Bag (R, inbd)
☐ Wire Tie (from P3/P4 temp stow)
☐ Swing Arm (R)
☐ RET (sm-sm)
☐ PGT w/7/16 socket 6" ext</td><td>P3/P4 JUMPER STOW (00:15)
1. Temp stow VTEB as reqd on HR_____
2. Assist EV2 as reqd
3. Retrieve RET from P3 HR 3860

CLEANUP (00:05)
4. Retrieve and stow Lube C/L bag on BRT w/RET
5. Verify Port SARJ interface is clear of all tethers and tools
6. Perform MWS tool inventory
7. Glove and Gauntlet Check</td><td>P3/P4 JUMPER STOW (00:30)
1. Translate to QD M2 on P3 outbd panel A502 (face 6)
2. Close and demate QD F2 at M2 per BLOCK D and BLOCK A
3. Install cap on M2
4. Close MLI on pnl A502

5. Translate to P4 inbd bulkhead with QD F2, tend line
6. Mate QD F2 to dummy male M2 per BLOCK B

7. Translate to P4 QD M15
8. Close and demate QD F15 per BLOCK D and BLOCK A
9. Install cap on M15

10. Translate to inbd bulkhead with QD F15
11. Mate QD F15 to dummy male M15 per BLOCK B
12. Stow jumper cable (close line in all outbd TA clamps and, as reqd, inbd TA clamps to ensure line is fully clear of SARJ)
13. WVS survey

CLEANUP (00:05)
14. Retrieve and stow VTEB on BRT w/RET
15. Verify Port SARJ interface is clear of all tethers and tools
16. Perform MWS tool inventory
17. Glove and Gauntlet Check</td></tr>
</table>

FS 7-82 EVA/134/FIN A

Source: FOIA'd STS-134 Procedures (https://www.nasa.gov/centers/johnson/pdf/539922main_EVA_134_F_A.pdf)

Maestro: short-term objectives

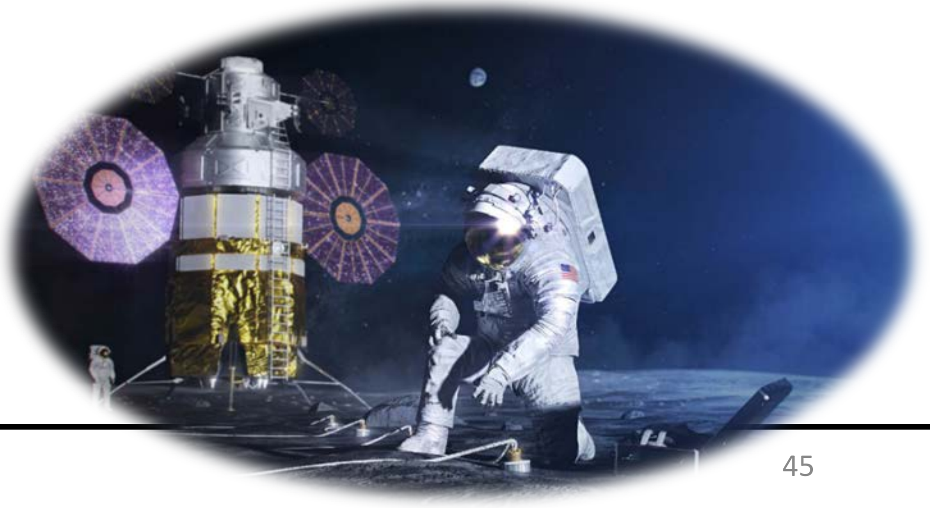
1. Make raw procedure data both **machine readable** and **human readable**
2. Render that raw data into a document that looks nearly identical to current EVA procedures (and optionally into other formats)
3. Authors don’t have to worry about formatting
4. Authors should be able to easily receive changes from contributors and accept, reject, or request updates
5. Authors should be able to easily diff changes between non-sequential versions of procedures
6. Editing a procedure should have a simple user interface

Maestro prototype

- In-house developed
- Out and in beta
- Tech used:
  - Written in Node.js
  - Editor UI in React framework
  - Desktop app in Electron
  - Isomorphic code for terminal, web, and Electron

Maestro: long-term objectives

- Machine readable means the procedure isn't tied up in an inaccessible format
  - Can query, restructure, and analyze easily
- Complicated time math: Maestro generates a Simple Temporal Network (STN) to perform calculations on time constraints
- Perform procedure verifications (glove/HAP checks placed appropriately, CETA brake release, thermal cover, SAFER checks, …)
- Maestro can generate multiple versions of a procedure. In the future could generate a public version with sensitive info redacted
- Create output to existing solutions (ProX, PRIDE)
- Currently Maestro just an editor. Later: allow real time execution tracking:
  - Take data on how and when steps performed
  - Correlate exact steps to met rate and other data
  - Record how long certain types of steps generally take
- Tracking state
  - Calculate in-EVA and post-EVA config
  - Summing result of multiple EVAs to see config in future



Maestro: Who else should be interested

- IV procedure authors – FOD’s OSO group is working on making Maestro work for IV procedures
- Electronic crew displays, AR, VR – Maestro could output content for next gen formats. Write one procedure, output to multiple formats.
- Engineering, Safety – better procedure review process
- Life sciences – Better tracking of steps performed for synchronizing met rate data with procedures
- Researchers – With machine-readable procedures, the sky is the limit on what can be done

Collaborative Forum

Please join us on Thursday for our Collaborative Forum to discuss the following question:

- What hardware and systems should be made available to the operations team to reduce risk to loss of crew and loss of mission from an operations perspective?
  - Training systems, knowledge capture and sharing, procedure editors, execution systems and hardware, contingency operations, etc.
  - Are these hardware and systems ready to go or need to be developed more?