



Supporting Exploration Missions by Enabling Exploration Mission System Software

ICES 2023 Conference; Track 506: Human Exploration Beyond Low
Earth Orbit: Missions and Technologies

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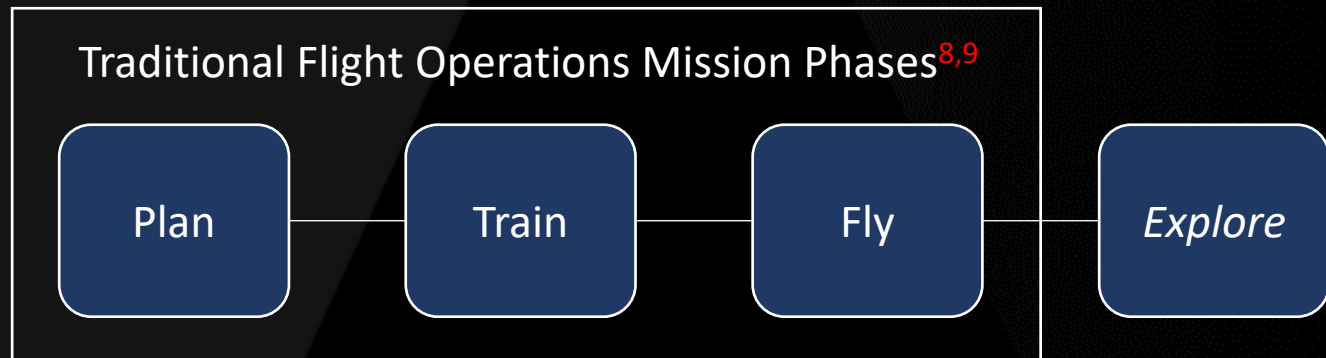
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Rynearson, Jackie Vu, James Montalvo, Katie Heinemann, Trey
Davis, Stephen Lin, Omar Baig

Artemis missions face an unprecedented data management challenge



- At present, there is a noticeable absence of contractual mechanisms in place to ensure seamless interoperability of data sets from a myriad of mission assets with the purpose of supporting mission operations personnel.
- We assert in this paper that mission data are at risk for becoming siloed, being in inconsistent and incompatible formats, and requiring custom tooling to manipulate.
- These risks result in limiting mission data utility and delaying the acquisition of actionable information within mission operations workforce unless there is a deliberate effort to create **temporally** and **spatially** integrated data management systems

Artemis missions should design software solutions that align with mission operations work needs



Explore examples include:

- Continued scientific learning from Apollo.^{10,11}
- Mishap reporting such as ISS EVA Suit Water Intrusion Mishap Report¹²

This paper describes a specific set of tools, known collectively as the Extravehicular Activity (EVA) Mission System Software (EMSS), to transform the EVA *plan, train, fly, explore* work processes.

EVA Mission Software System (EMSS) Initiative Overview

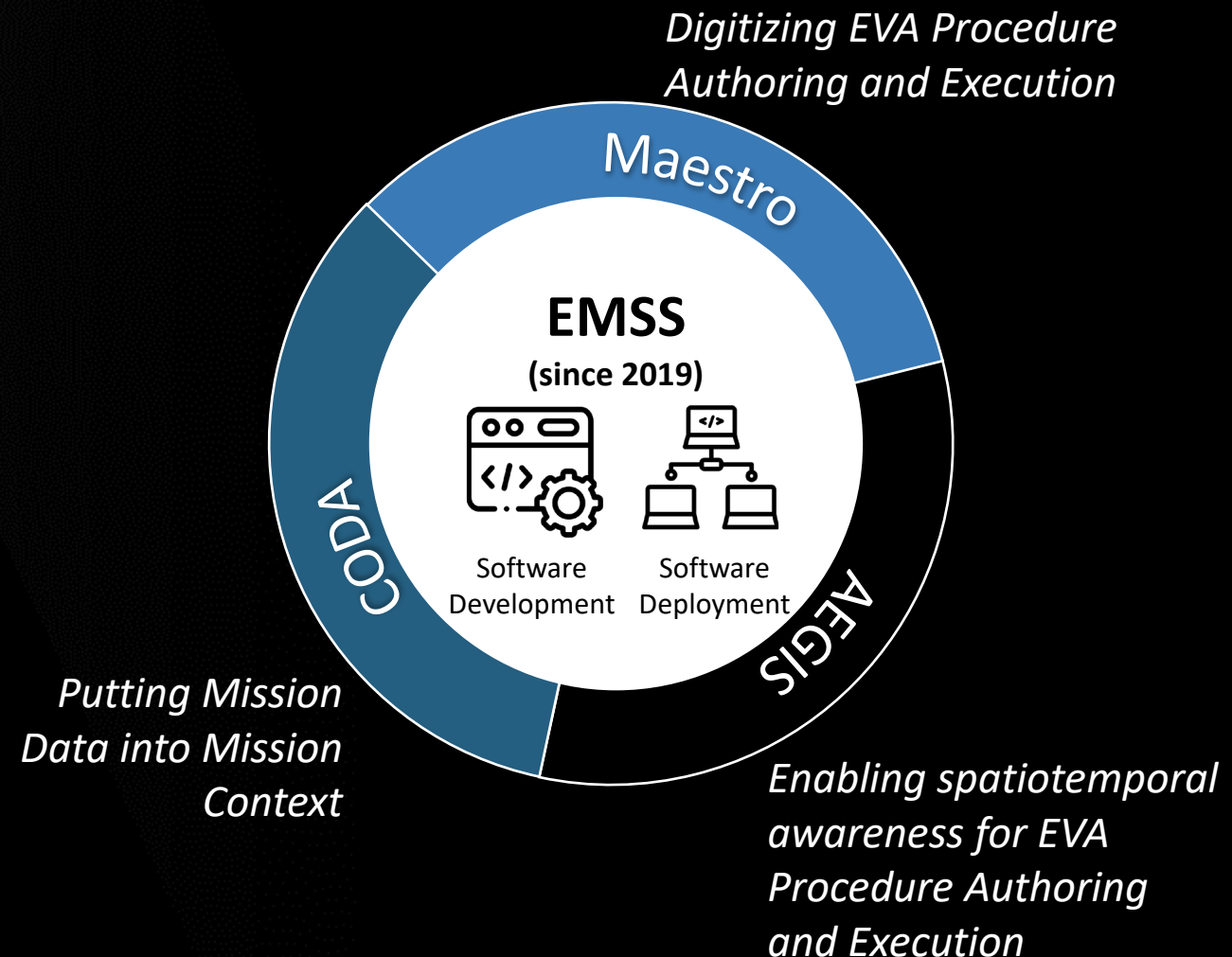


In 2013, Montalvo began working Maestro, an EVA procedure execution and authoring tool to reimagine ISS EVA.^{8,13}

In 2013, Miller and Pittman apply cognitive systems engineering methods to the EVA work domain to design and develop novel decision support systems for EVA operations.¹⁵

In 2015, Feist launched Apollo 17 in Real-time and later Charney joined to support the launch of Apollo 11 and 13 in Real Time.¹⁴

In 2018, crew health and performance personnel joined the first integrated effort known as EVA Operations System.¹⁹





EMSS Development Methods

- The EMSS suite of applications leverage a common architecture.
 - *React.js* is used as the front-end framework for creating dynamic user interfaces.
 - The back-end consists of Node applications that communicate with data sources and provide data to the front-end.
 - The applications are deployed into the Flight Operations Directorate's secure server environment using Docker containers, which are like lightweight and portable virtual machines that isolate the application from the host environment.
 - The suite also leverages continuous integration and continuous delivery (CI/CD) tools to automate the testing, building, and deployment of code changes.
 - This enables ongoing rapid development and deployment of new features and ensures that the systems are always up-to-date.

Collectively, these software development and deployment efforts bring modern software capabilities to allow EMSS team to support EVA plan, train, fly, explore for both ISS and future Artemis missions.

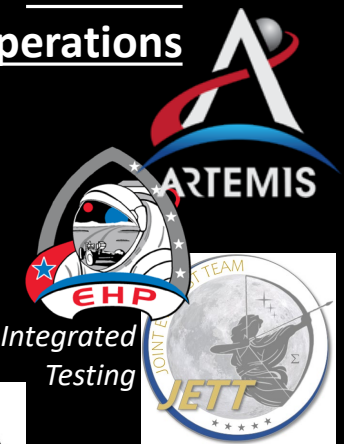
ISS Operations



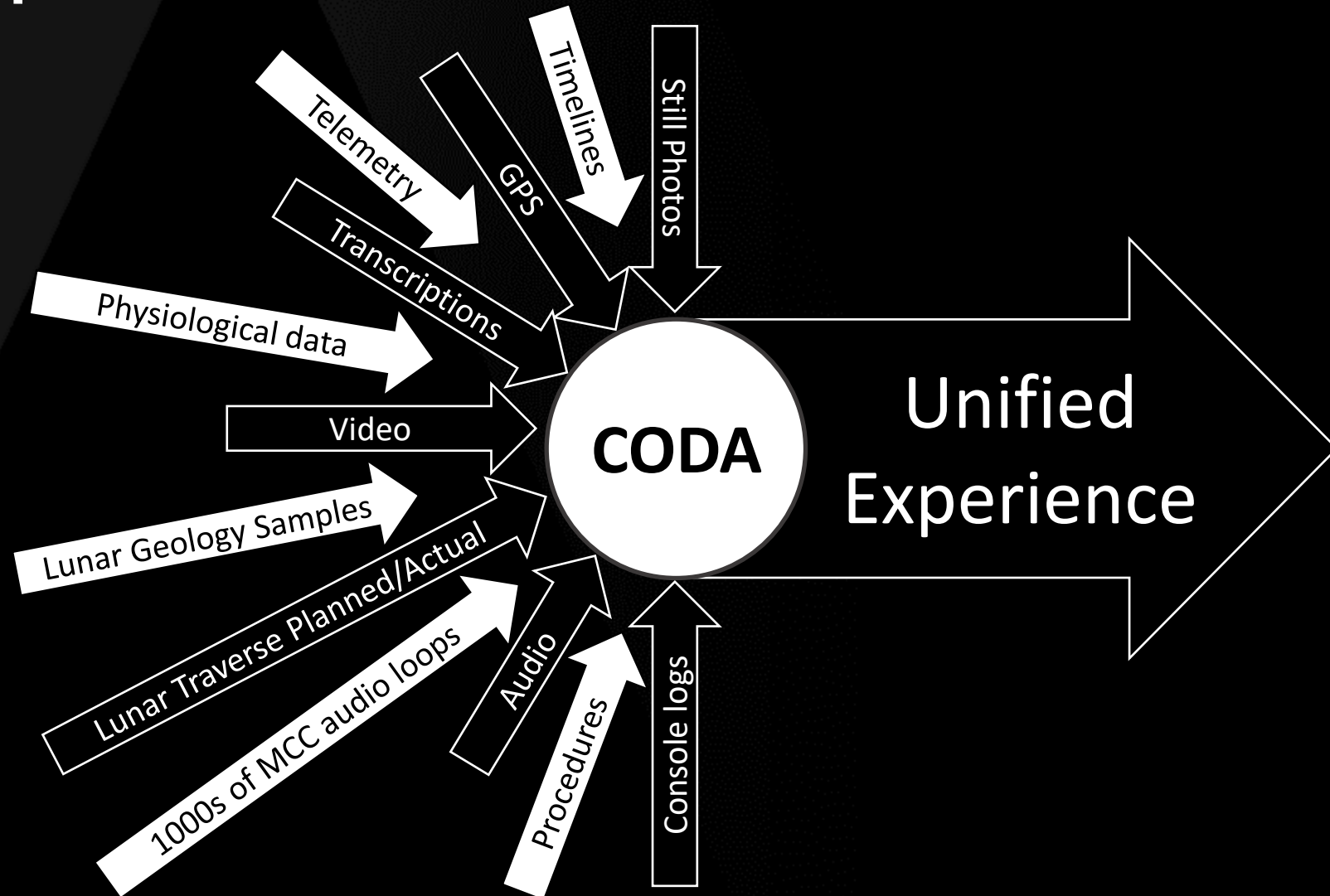
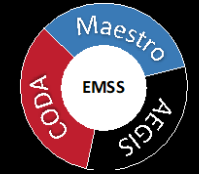
Crew and Flight
Controller Training Flow



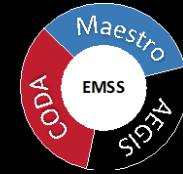
Artemis Operations



Collaborative Operations Data Activation (CODA) as a concept



Collaborative Operations Data Activation (CODA) as it exists today



Choose a data source Choose a data and time or event Load Preset Choose a Display layout Share current day and time

Choose a type for each frame

The screenshot displays the CODA interface with the following components:

- Top Bar:** ISS, 2021-06-25, 13:17:26 Z, US EVA 76 - P6 IROSA Install EV...
- Video Channels:** Three video feeds showing the ISS structure and solar panels.
- Current Photo:** A large photo of the ISS exterior.
- SELECT DISPLAY TYPE Menu:**
 - VIDEO CHANNELS
 - VIDEO OTHER
 - CURRENT PHOTO
 - ALL PHOTOS
 - ISS POSITION
 - GPS POSITION
 - EVA INFO
 - COMMUNICATIONS
 - GRAPH
- ISS POSITION:** A map of the North Atlantic Ocean showing the ISS location.
- EVA INFO:**

Event: US EVA 76 - P6 IROSA Install EVA 3	
Timing: PET Start: 11:52Z Duration: 06:45:00	
Timeline	
EV1: Thomas Pesquet	EV2: Shane Kimbrough
11:52:00: Egress	11:52:00: Egress
12:04:00: Worksite Prep / SSRMS Ingress	12:04:00: Worksite Prep
13:55:00: IROSA Release from FSE	13:08:00: IROSA Release from FSE
14:23:00: IROSA Install	14:23:00: IROSA Install
17:15:00: IROSA Deploy	17:15:00: IROSA Deploy
17:50:00: Cleanup	17:23:00: Cleanup
18:05:00: Ingress	18:03:00: Ingress
- COMMUNICATIONS:**
 - 13:17:22 copy you can translate to Charlie, 11.
 - 13:17:32 Big picture for you both. We are more or less on timeline. PGT one hour, 25 minutes an hour limiting consumable is 7 hour, 10 minutes from EV2 Madox.
 - 13:17:49 But PGT.
 - 13:17:53 At this point, Shane, we're going to have you hold position. I have a couple of steps for you, but primarily we will be waiting to release Charlie, 11, once Thomas has configured the arm. In the meantime, I'll take a glove inspection and a check for me.
 - 13:18:11 EV1 Glass cloth no change, no. Typekit.
 - 13:18:28 I.
 - 13:18:46 I mean, position for of 11.
 - 13:18:50 Copy same settings. Bravo 3 counter to and you'll just be breaking talks.
 - 13:18:58 Other 3 counter to. OK talking broken on Sol EV1
 - 13:19:25:26 5 copy will now be releasing the A-Rosa FCU bolts, so starting with Charlie 11, so in your current location will be releasing 27 turns only, which is just halfway, so not fully
- ALL PHOTOS:** A grid of small photo thumbnails.
- Timeline:** A horizontal timeline at the bottom with a play/pause button and a red marker at 13:17:26Z.

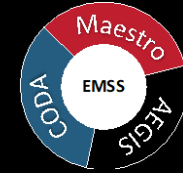
Move timeline

Maestro as a concept



- The Purpose of Maestro:
 - consolidate the authoring and execution process within a dedicated tool that can handle the interconnected and unique constraints of EVA procedures.
- Note: Maestro enables custom capabilities that are different from existing ISS planning and execution tools such as Optimis^{21,22} and PRIDE.^{23,24}
- What Motivates Maestro Development?
 - EVA requires the choreography of at least two EVA crew members and support personnel, therefore necessitating the need to handle in parallel the sequence of events for two or more agents at a granular level of detail.
 - Crew work both in tandem and independently, depending on the needs of the EVA tasks.
 - Crew procedures must be inherently associated and tracked to ensure overall EVA objectives are effectively managed and achieved.
 - In addition to simultaneously handling the planning of at least two agents, EVA procedures for ISS are highly proceduralized, demarcating minute details that must be accomplished at specific moments.
 - Maestro enables users to coordinate activities with minute precision while also fully describing the necessary actions with dependencies to be accomplished for two crew members who need to perform hours of work

Maestro as it exists today



IV Procedure
EV1 Procedure
EV2 Procedure
Actual Phased Elapsed Time (PET)

Procedure Tabs

Completed Tasks

In Progress Tasks

Input Fields

The screenshot displays the Maestro interface with the following components:

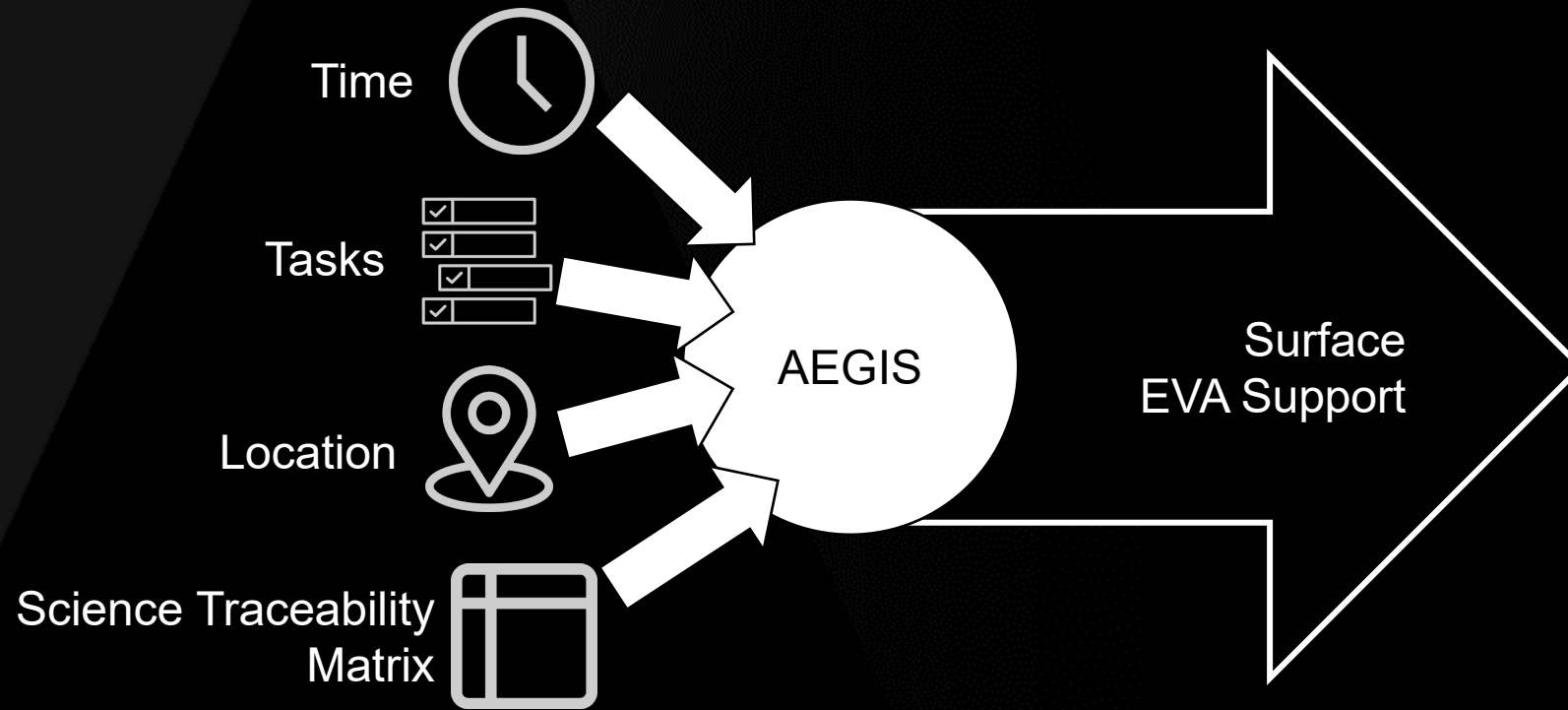
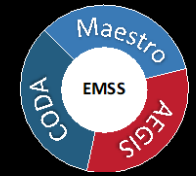
- Procedure Tabs:** MAINT 1, MAINT 2, MAINT 3, MAINT 4 (active), MAINT 5, NEW PROCEDURE +
- Task Lists:**
 - IV/SSRMS/MCC:** 1. Instructor: Cannon Connector Tool cannot be installed due to zip tie through primary power connector.
 - EV1 (crewA):** 2. Pre-eclipse checklist: Retrieve P1-T (size 25, medium) Terminator Cap from CL bag #1; Retrieve 1 size 37 (large) Cannon Connector Cap from receptacle on P5 (J45, J44, J46) and temp stop on MWS; PGT settings for vise clamp: [A7, CCW2]; (9.2 ft-lb, 30RPM, MTL 30.5); 3. Perform: Gloves inspection; HAP check.
 - EV2 (crewB):** 4. Pre-eclipse checklist: Configure Adj Equip Tether on J1 cable (large connector); Retrieve Cannon Connector Tool from C/L Bag #1; Install Cannon Connector Tool on J1 (large, Size 37); PGT-awake check; 5. Perform: Gloves inspection; HAP check.
- Actual Phased Elapsed Time (PET):** Airlock Thermal Cover, 07:23 remain of 30:00. Gantt chart shows tasks from 00:00 to 06:30, including EGRESS / SETUP, ESP-2 SPARE FHRC REMOVAL, MATE AND OPEN HOUSE BOX QDS, and WORKSITE / SSRMS CLEANUP.

Enter Edit Mode

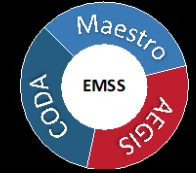
Adjust Layout

Follow Execution

Artemis EVA Geographic Information System (AEGIS) as a concept



Artemis EVA Geographic Information System (AEGIS) as it exists today



- Map Presets
- POI Composition
- Station Composition
- EVA Composition

Apollo_14
AEGIS

EVA COMPOSITIONS

COMPLETE

- Egress 00:16
- Egress to Snake 00:32
- Snake 00:30
- Snake to Possum 00:19
- Possum 00:15
- Possum to Valley Gully (DC) 00:11
- Valley Gully (DC) 00:20
- Valley Gully (DC) to Ingress 00:04
- Ingress 00:00

EVA 1 (DAY 1)

IVORY

MILLER

MOCCASIN

ORANGE

Annotated Map

Summary Statistics

Complete

EVA Information

EVA Description

EVA test description 1

Predicted Values

Max Duration (mins)	Traverse Rate (km/hr)
	3

Calculated Values

Total Station Dwell Time	Total Traverse Duration	Total EVA Duration
97 - 81 mins	81 mins	178 - 162 mins
# Station Actions	Total Traverse Distance	
23	3,392.64 m	

Last Edited

1 week ago

Data Profiles

EVA Sequence Diagram

Science Traceability

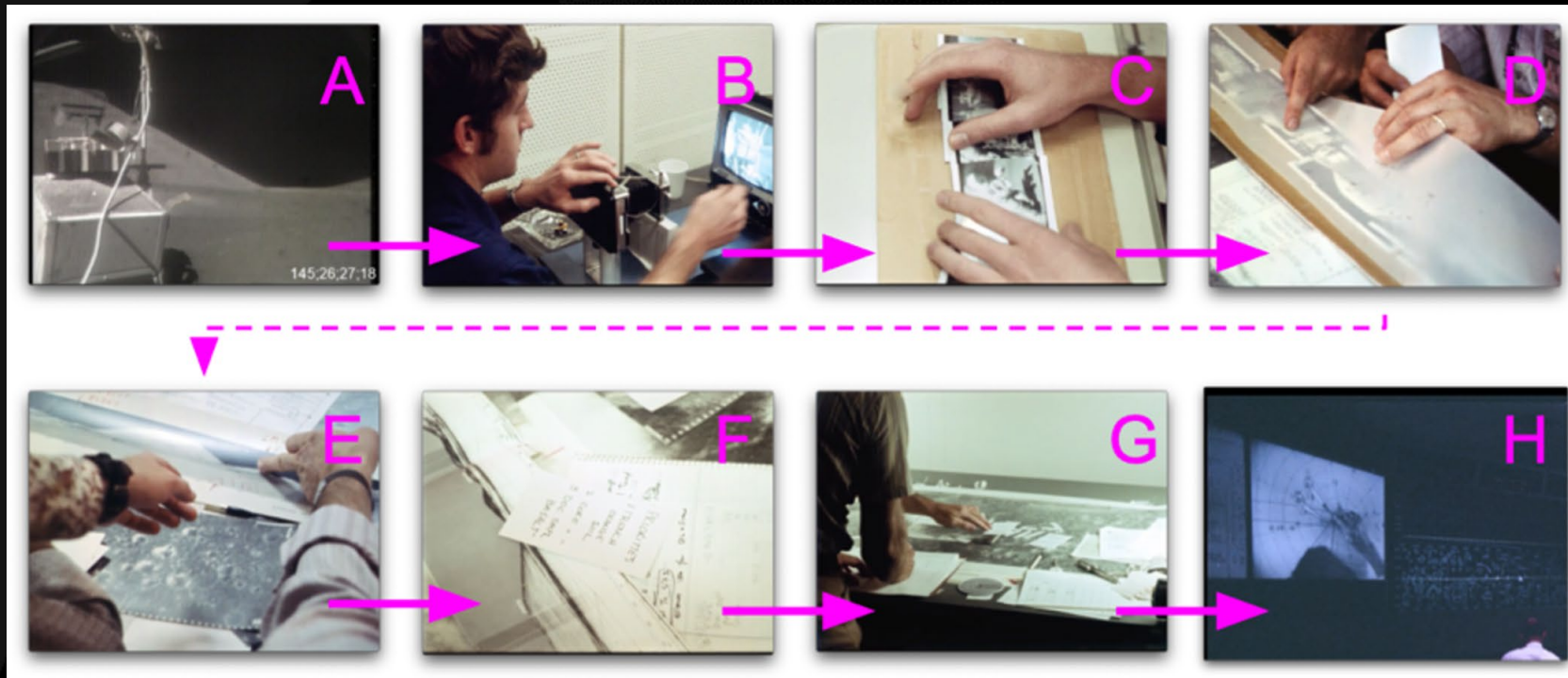
Matrix Coverage

Areas of Integration between EMSS and Mission Operations Work Efforts



- Actively supporting ISS operations and NBL training:
 - Maestro has successfully been deployed in 6+ ISS EVAs to-date and is now actively used in the support of planning and training activities at the NBL.
 - CODA is routinely used in support of anomaly reporting for on-going ISS operations and there is active development underway to align NBL data streams to bring similar CODA capabilities to review all NBL EVA training activities.
- Integrated into Artemis development:
 - Dr. Miller has been named the NASA Science Mission Directorate - Artemis Internal Science Team Software Systems Lead
 - Integrated component of the NASA EVA and Human Surface Mobility Program (EHP)³⁰ and leverages NASA Joint EVA Test Team (JETT) events to inform Artemis functionality across the EMSS tools.
 - Supported the JETT3 field test in October 2022, that included the most complete Artemis flight team surface EVA planning and execution activities performed to-date.^{28,31}
 - Close engagement with with the Artemis Geospatial Data Team³² so that EMSS tools can leverage the most relevant lunar surface map data for EVA FOD utilization.
 - Active support is ongoing for JETT5.
- EMSS Awards include:
 - CODA was awarded the JSC Software Excellence Award and subsequently received the NASA agency-wide Major Space Act Award in 2022.
 - Maestro has received numerous acknowledgements within the FOD for helping pave a modern way of enabling the flight team to conduct EVA and has also been awarded the 2023 JSC Software Excellence Award and the 2023 EVA and Human Surface Mobility Program Recognition of Excellence Award

Conclusion: Supporting human spaceflight operations requires the seamless integration of temporal and spatial data to enable mission operations personnel to make timely and accurate decisions



Snapshots taken from 16mm film shot during Apollo 17 EVA. Video feed from the lunar surface (A) was transferred to Polaroid still photography (B) and collated into panoramas (C) that were overlaid with precursor imagery to estimate crew location and facilitate scientific interpretation (D). These images were compared with other map products (E) to synthesize and articulate real-time science priorities that were passed along the chain of command to impact crew behavior (F). Additionally, estimates of crew location were indicated using icons moved manually on a map alongside operations relevant data such as clock time and event markers (G), which were all shared among the flight team via overhead projector (H).



Questions and Contact Information

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