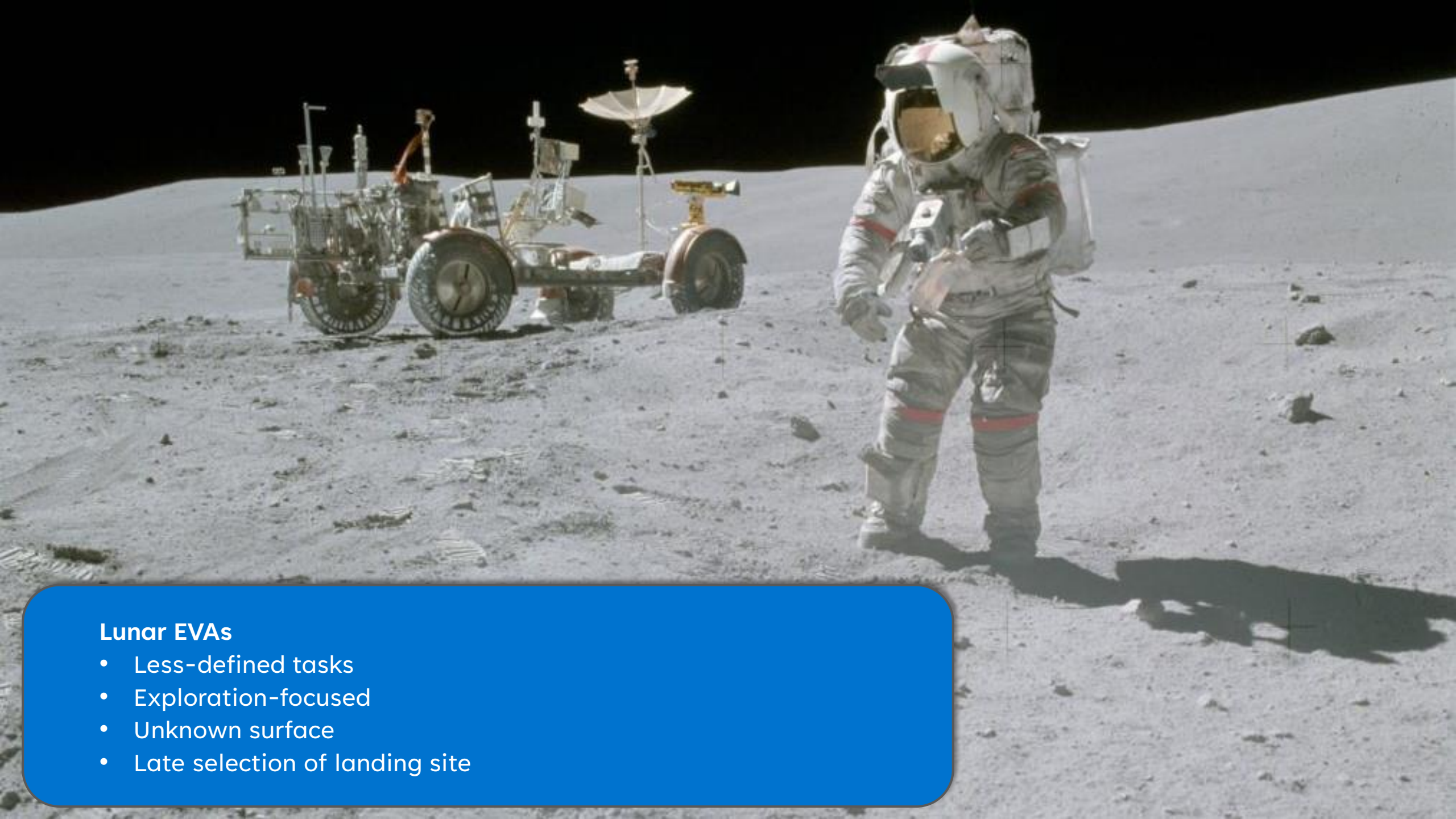
EVA Development in Exploration-Driven Human Spaceflight

KBR/Caroline Kostak
KBR/Dr. Tess Caswell
NASA/Dr. Kelsey Young

ISS EVAs

- Engineered surface
- Can precisely plan EVAs
- EVAs are mostly for ISS assembly, maintenance, and hardware upgrades
- Crew can often (but not always) train for exact tasks



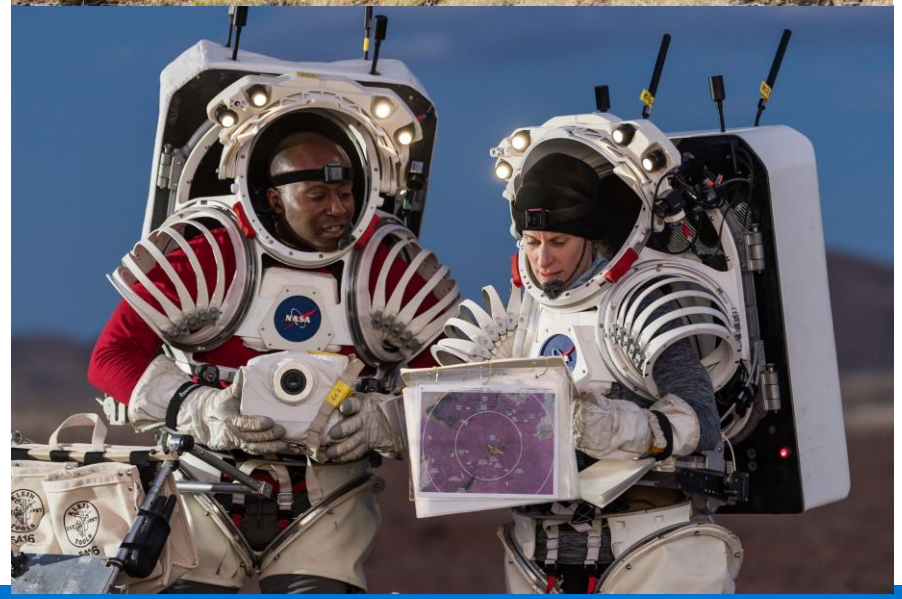
Lunar EVAs

- Less-defined tasks
- Exploration-focused
- Unknown surface
- Late selection of landing site

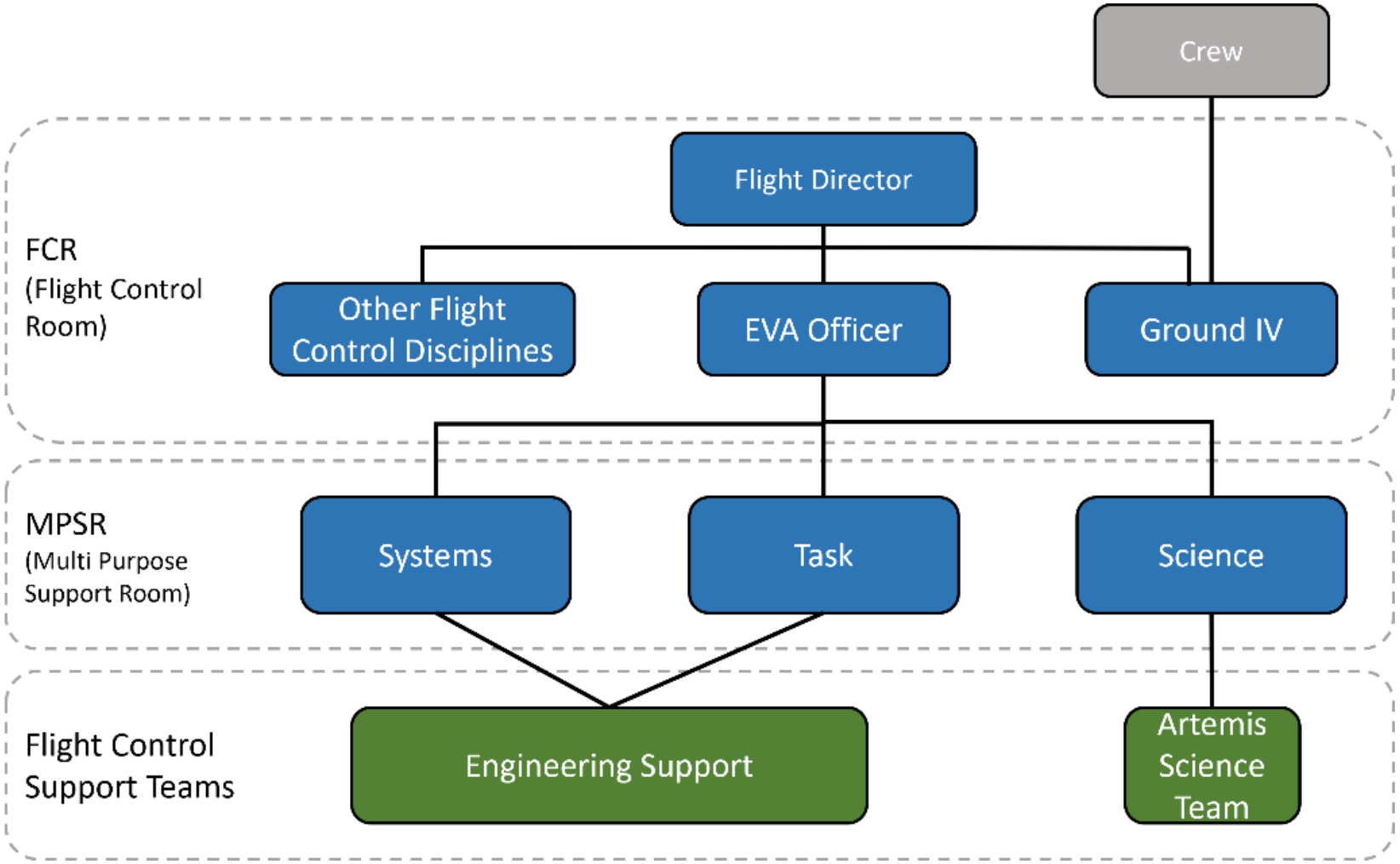
EVA Work Instruction Development Process

NASA has been using test events to develop the EVA Traverse Development Process

- Joint EVA Test Team Field Test 3 (JETT3)
  - https://www.youtube.com/watch?v=ebtTgwxAnZk
  - https://ntrs.nasa.gov/api/citations/20230000146/downloads/Caswell_et_al_LPSC_2023_RevA.pdf
- Joint EVA Test Team Field Test 5 (JETT5)
  - https://www.youtube.com/watch?v=eypu-HXMpNU
  - https://www.nasa.gov/humans-in-space/meet-the-teams-leading-moonwalking-test-mission/
- Virtual Reality Testing
  - https://science.nasa.gov/uncategorized/how-nasa-is-using-virtual-reality-to-prepare-for-science-on-moon/



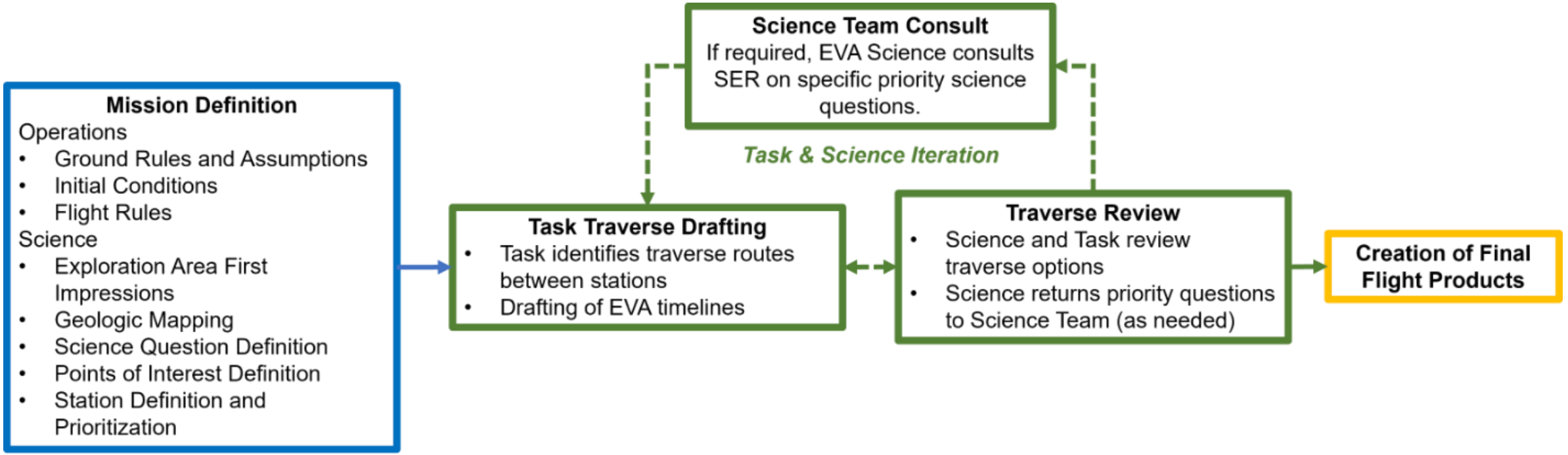
Flight Control Team Players



Flight Control Room (FCR)

Science Evaluation Room (SER)

Lunar EVA Development: Mission Definition



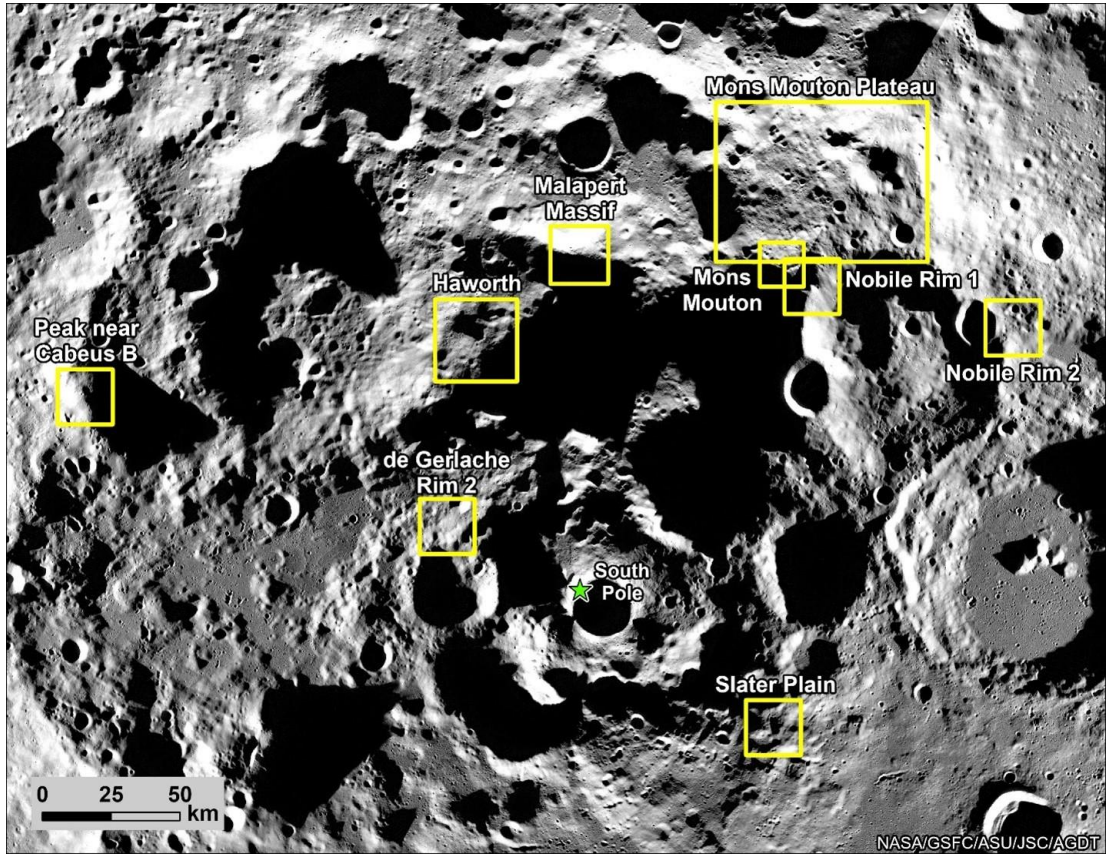
Mission Objectives and Priorities are developed by NASA's Moon to Mars (M2M) Program

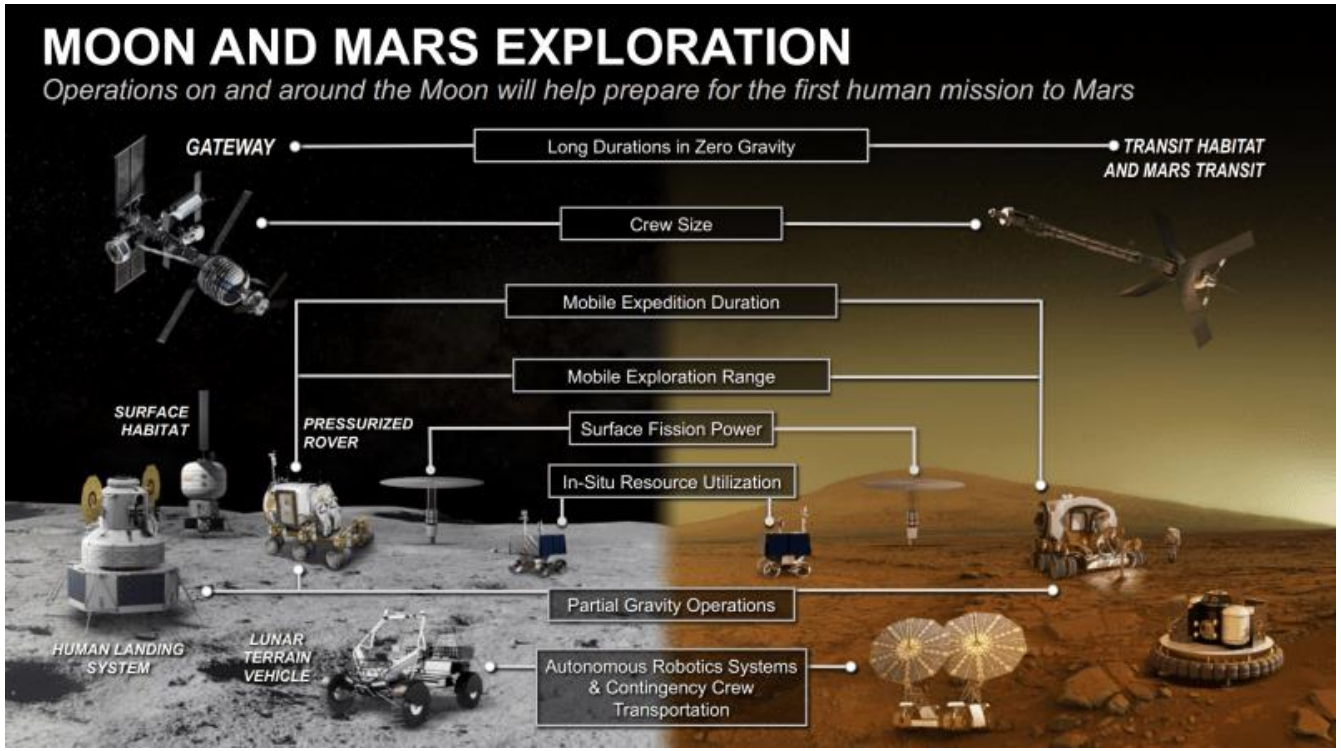
SCIENCE and TASK Flight Controllers iterate to develop EVA Traverse Plans that incorporate M2M Objectives with Science Objectives in a safe manner within the technological constraints of the hardware

Final Products are created and Crew is trained

Lunar EVA Development: Mission Definition

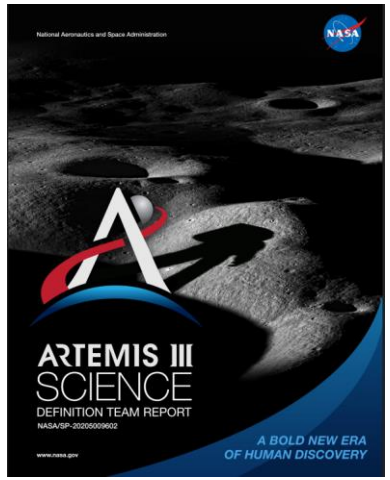
Stakeholder	Operational Contribution to Mission Definition
Moon to Mars	Mission priorities, landing site, duration of stay, number of EVAs, available surface assets, etc.

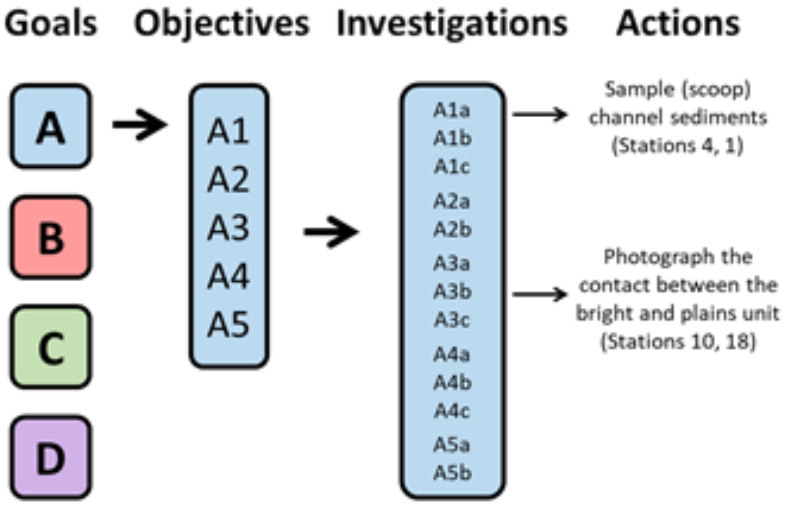




Lunar EVA Development: Mission Definition

Stakeholder	Operational Contribution to Mission Definition
SMD	Scientific/geologic priorities, sample mass priorities, payloads to be deployed, deployment specifications, terrain hazards, geologic maps





Geology

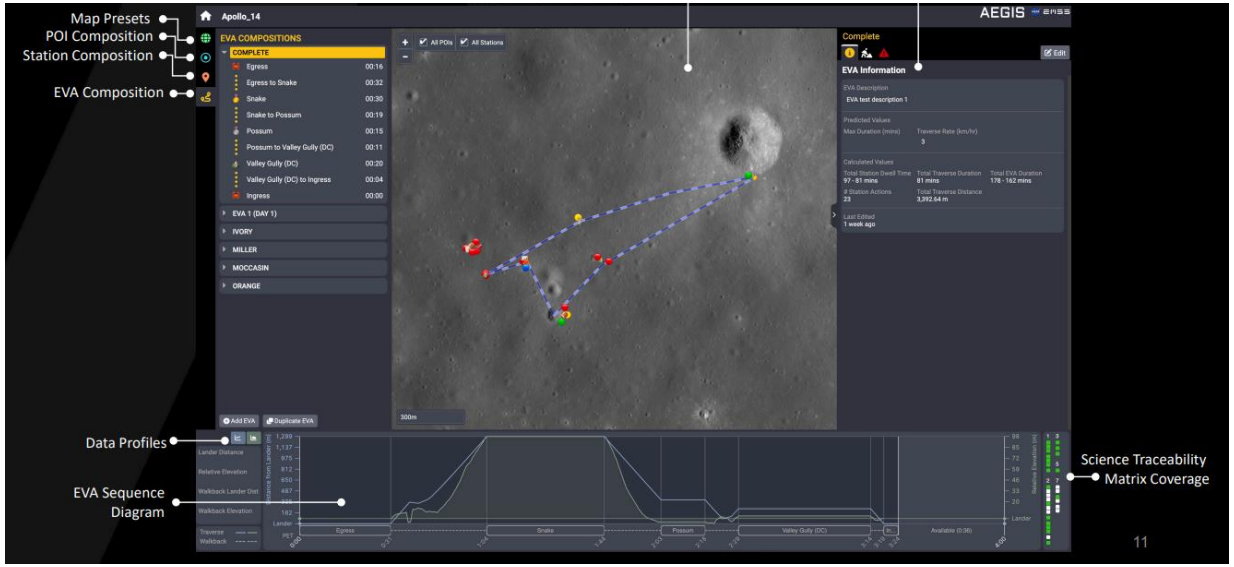
ARTEMIS

Artemis Deployed Instruments Program
Proposal Information Package

Deployed Instruments

Lunar EVA Development: Mission Definition

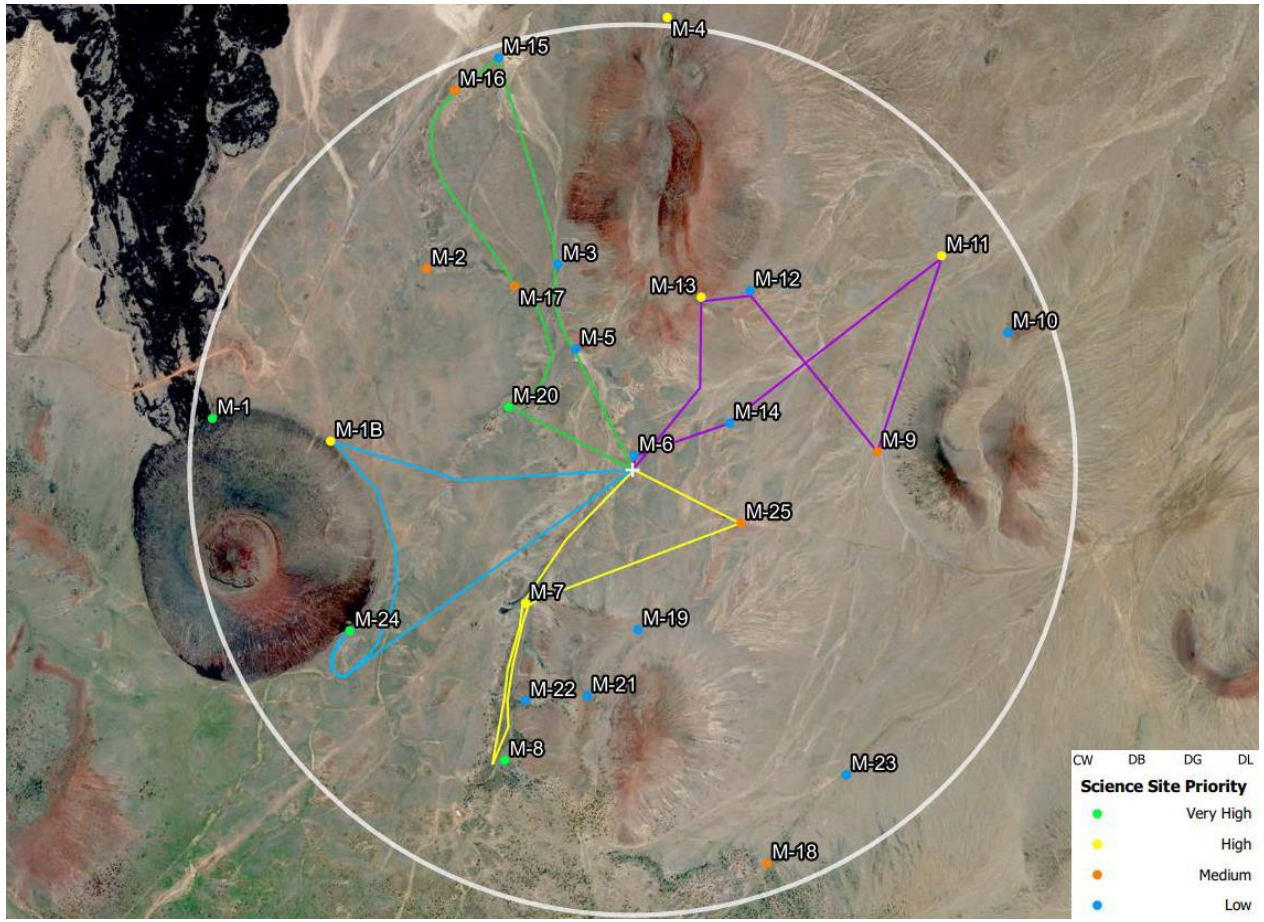
Stakeholder	Operational Contribution to Mission Definition
FOD	Operational risk mitigations; maximum traverse distance, maximum distance from lander, traverse lighting requirements, maximum safe slope for walking, maximum time without line of sight to lander, consumables redlines, etc.



Artemis EVA Geographic Information System (AEGIS)

Lunar EVA Development: Flight Operations Integration

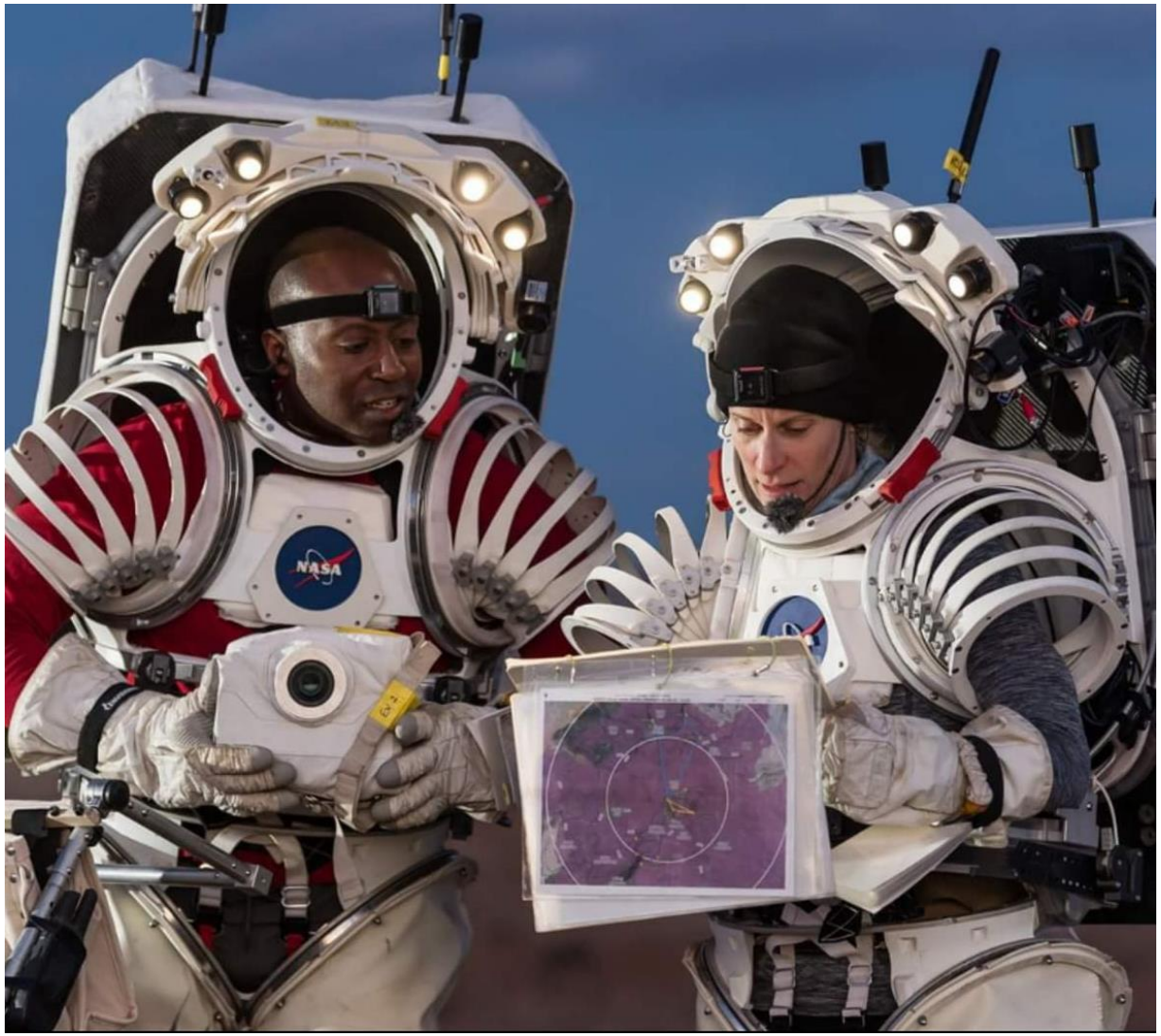
GOAL: generate an EVA plan that maximizes scientific return while keeping astronauts safe & productive



Overview EVA Plan from JETT3 Test in Arizona

1. Collect list of Objectives & Priorities
2. Locate & Prioritize Science Points of Interest (POIs)
3. Identify Constraint-driven Operational range
4. Group POIs and other objectives into EVAs
5. Iterate with Stakeholder Community

Creation of Flight Products: Map Book



Map Book will contain a variety of maps that will help the crew understand the lunar environment

- Slope
- Lighting
- Comm Coverage
- Horizon views
- Geologic Map
- Geologic Unit Descriptions
- Traverse Maps
- Point of Interest (POI) Descriptions

Map Book may include instructions on geologic sampling directed at each POI

Creation of Flight Products: Cuff Checklist

EVA 4: Station 27

Map Book Page 30

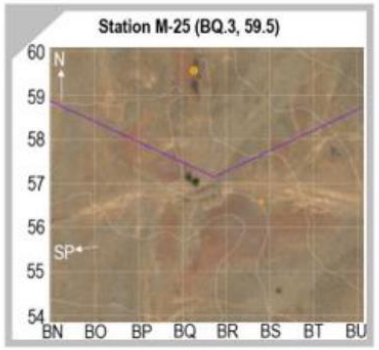
Distance to Lander: 850 m (25 min)
Lander Visible

Time at Station	EV1	EV2
	A. Station Characterization Station Description	A. Station Characterization Pano Photos
00:10	B. Chip, Ridge Outcrop	E. Describe, Photo plains contacts
00:15	C. Desc, Photo transition, ridge to plains Looking North from ridge	F. Scoop, Light Plains Unit 3x Sample Markers Check MCC
00:20	D. Scoop, Mottled Plains ~20 m north of ridge	G. Scoop, Intermed. Plains
00:25	H. Tool Audit EV1 Tool Belt EV2 Tool Belt	H. Tool Audit EV1 Tool Belt EV2 Tool Belt
00:30	Cart – No empty spots	Cart – No empty spots

3

Creation of Flight Products: EVA Procedures

10 EVA 4 Replan - Station M-25 - Copy (00:17)

IV/SSRMS/MCC	EV1	EV2
		  *Map not in cuff - ref map bag page 8*
		SITE DESCRIPTION/360 PANO (00:10) 1 SAMPLE (00:06) a. Lava flow chip 1. Perform _____ sampling at marker _____ ❑ Pre-sample photo and/or helmet camera ❑ Retrieve tools: _____ ❑ Perform sample into Bag ID _____ ❑ Post-sample photo and/or helmet camera NOTE 1. If this outcrop is not available, make descriptions of area and continue to M6 or lander DESCRIBE AND PHOTOGRAPH (00:05) b. If see any basaltic outcrop in this area, report specific observations about age relationships and contacts CLEANUP (00:00) c. Verify tools and sample markers stowed

EVA Procedures are developed by the EVA Task Flight Controllers

Used by ground teams to define the sequence of events that will occur during the EVA

Used as communication tool to explain the EVA detail to other Stakeholders and as guidance that Ground IV will use for communication with crew during EVA

Level of detail depends on activity

Creation of Flight Products: Flight Rules

Set of guidelines determined prior to flight

Document Operational Considerations, Safety, Hardware Constraints

Controlled by Flight Director Office, agreed to by all Stakeholders

EVA MISSION RULES

9/1/72

REV

LUNAR SURFACE EVA (CONTINUED)

9. OPERATIONAL PGA

MUST PASS EMU INTEGRITY CHECK AND HAVE ALL CONNECTORS LOCKED AND ALL RESTRAINTS CABLES EXCEPT GLOVE OR NECK CABLES INTACT. NOTE ONLY A SINGLE LOCKING MECHANISM IS REQUIRED FOR EACH CONNECTOR.

10. TERMINATE EVA--THE CREW WILL BE ALLOWED SUFFICIENT TIME TO CLOSE OUT THE ACTIVITY IN WHICH THEY ARE ENGAGED (5 TO 10 MINUTES) AND WILL THEN RETURN TO THE LM AND EXPEDITIOUSLY COMPLETE CLOSEOUT ACTIVITIES AS REQUIRED.

11. TERMINATE EVA IMMEDIATELY--THE CREW WILL CEASE THEIR SURFACE ACTIVITIES AND IMMEDIATELY RETURN TO THE LM, INGRESS, AND REPRESSURIZE.

12. CRITICAL INSTRUMENTATION

D

MEAS DESCRIPTION	PAM FM/FM	ONBOARD	
PGA PRESS GAGE		CUFF GAGE	1 OF 3 M
PGA PRESS	GT8168P/GT8268P		
LOW PGA PRESS TONE		TONE	
LOW VENT FLOW TONE		TONE	1 OF 2 M
PLSS BAT CURRENT	GT8140C/GT8240C		

E

CMP EVA

1. CMP EMU PRESSURE INTEGRITY

A. ABLE TO MEET MAX 0.8 PSID/MIN DECAY CRITERIA DURING EMU PRESSURE INTEGRITY CHECK.

B. CMP EMU REGULATED PRESSURE NOT LESS THAN 3.70 PSID (CREWMAN) AND DECREASING OR GREATER THAN 4.0 PSID (CREWMAN) AND INCREASING DURING CMP EVA.

2. ADEQUATE O_2 FLOW FROM SCU

CMP EMU O_2 FLOW INTO SUIT GREATER THAN 6.0 LBS/HR (60 TO 65 PSI UMBILICAL PRESS)

3. TERMINATE CMP EVA--THE CREWMAN WILL CEASE PLANNED EVA ACTIVITIES, TRANSFER TO THE CM, INGRESS AND REPRESSURIZE.

4. CRITICAL INSTRUMENTATION

PGA PRESS GAGE LOW PRESS WARNING SWITCH	CUFF GAGE ONBOARD (CMP ONLY)	1 OF 2 M
LOW FLOW WARNING SWITCH CM PRESS GAGE	ONBOARD (CMP ONLY) ONBOARD	1 OF 2 M

GO/NO-GO CRITERIA/SPECIFIC RULES

REV

LUNAR SURFACE EVA

GO/NO-GO ITEM	IF NO-GO		NOTES
	TERMINATE EVA IMMEDIATELY	TERMINATE EVA	
PROPER VENTILATION	X		①
PLSS POWER	X		②
CONTAMINATION CONTROL	X		①
EMU PRESS INTEGRITY			③
A. PRESS <3.4 PSID	X		
B. 3.4 <PRESS <3.5 PSID		X	
THERMAL CONTROL		X	②
PRIMARY O_2 SUPPLY		X	③④
CRITICAL INSTRUMENTATION		X	
OPERATIONAL OPS		X	
OPERATIONAL PGA		X	

NOTES:

① ACTIVATE OPS: OPEN PGA PURGE VLV -- LOW FLOW.

② ACTIVATE BSLSS AND/OR OPS PURGE AS REQUIRED.

③ ACTIVATE OPS

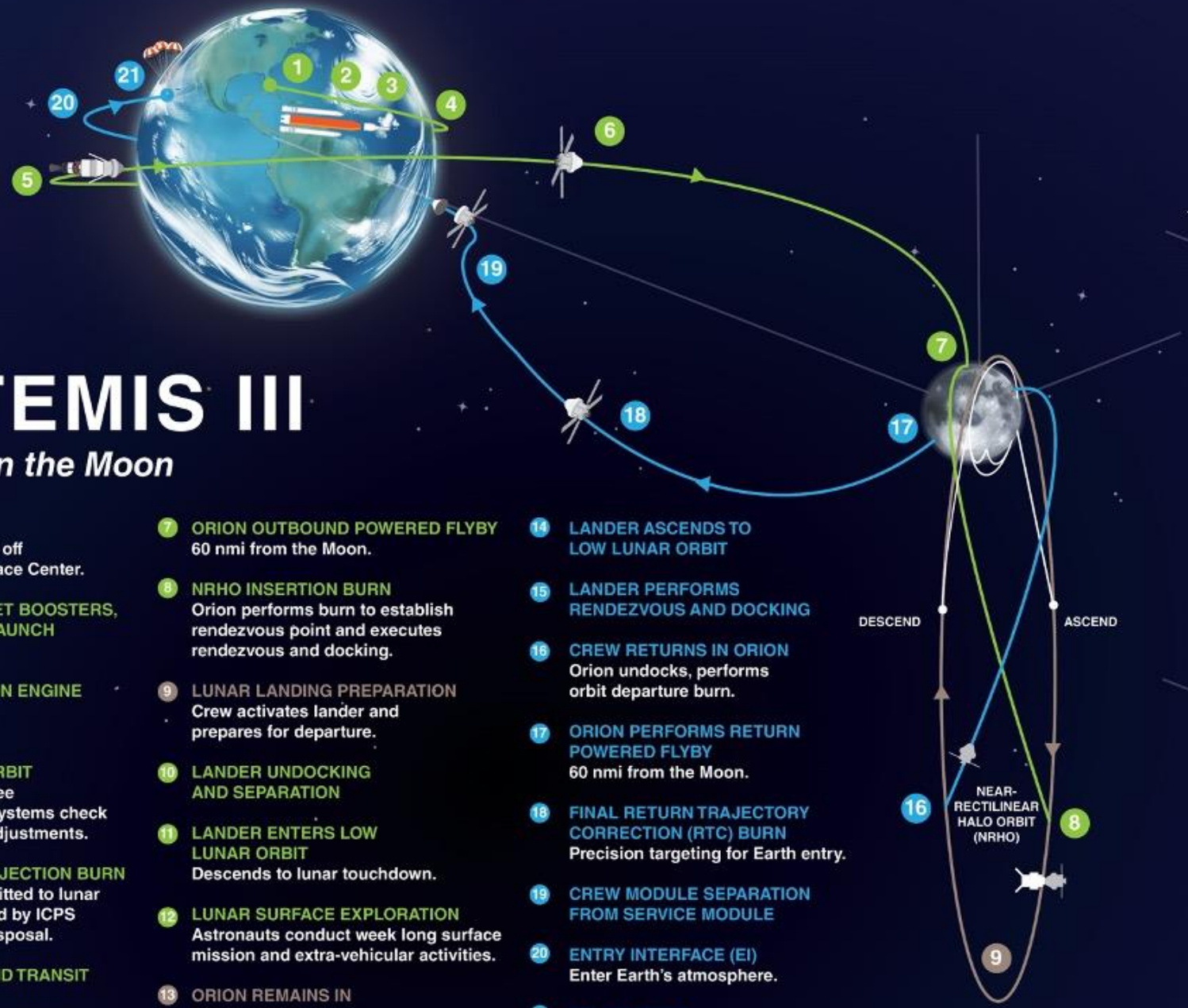
④ IF EMU REG PRESS GREATER THAN 4.05 PSID, CLOSE POS SHUTOFF VLV AFTER ACTUATING OPS.

CMP EVA

GO/NO-GO ITEM	IF NO-GO	
	TERMINATE EVA	

Excerpt from Apollo 17 Mission Rules

Backup



ARTEMIS III

Landing on the Moon

1. **LAUNCH**
   SLS and Orion lift off from Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **ENTER EARTH ORBIT**
   Perform the perigee raise maneuver. Systems check and solar panel adjustments.
5. **TRANS LUNAR INJECTION BURN**
   Astronauts committed to lunar trajectory, followed by ICPS separation and disposal.
6. **ORION OUTBOUND TRANSIT TO MOON**
   Requires several outbound trajectory burns.
7. **ORION OUTBOUND POWERED FLYBY**
   60 nmi from the Moon.
8. **NRHO INSERTION BURN**
   Orion performs burn to establish rendezvous point and executes rendezvous and docking.
9. **LUNAR LANDING PREPARATION**
   Crew activates lander and prepares for departure.
10. **LANDER UNDOCKING AND SEPARATION**
11. **LANDER ENTERS LOW LUNAR ORBIT**
    Descends to lunar touchdown.
12. **LUNAR SURFACE EXPLORATION**
    Astronauts conduct week long surface mission and extra-vehicular activities.
13. **ORION REMAINS IN NRHO ORBIT**
    During lunar surface mission.
14. **LANDER ASCENDS TO LOW LUNAR ORBIT**
15. **LANDER PERFORMS RENDEZVOUS AND DOCKING**
16. **CREW RETURNS IN ORION**
    Orion undocks, performs orbit departure burn.
17. **ORION PERFORMS RETURN POWERED FLYBY**
    60 nmi from the Moon.
18. **FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN**
    Precision targeting for Earth entry.
19. **CREW MODULE SEPARATION FROM SERVICE MODULE**
20. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
21. **SPLASHDOWN**
    Ship recovers astronauts and capsule

7/13/22

Resources

- EHP-20021 JETT3 Test Report Baseline: https://ntrs.nasa.gov/api/citations/20230010686/downloads/EHP-20021_JETT3_Test_Report_Baseline_20230010686.pdf
- NASA Image and Video Library: https://images.nasa.gov/
- Intro to EVA Ops Products: https://ntrs.nasa.gov/api/citations/20240002135/downloads/SMD_Intro_to_EVA_Ops_Products_Feb2424.pdf
- Artemis III Science Definition Report: https://www.nasa.gov/wp-content/uploads/2015/01/artemis-iii-science-definition-report-12042020c.pdf?emrc=841cb1
- Moon to Mars Architecture Definition Document: https://www.nasa.gov/wp-content/uploads/2024/12/esdmd-001-add-rev-b.pdf?emrc=5ffbf4
- Supporting Exploration Missions by Enabling Exploration Mission System Software: https://ntrs.nasa.gov/api/citations/20230010012/downloads/EMSSPaper_ICES2023_242_Final.pdf
- Tenets of Lunar EVA for Artemis III: https://ntrs.nasa.gov/api/citations/20230008183/downloads/Tenets%20of%20Lunar%20EVA%20for%20Artemis%20III_Public%20Release.pdf