



ARTEMIS II IN-FLIGHT ANOMALY RESOLUTION TOOL DEVELOPMENT, UTILIZATION, AND OBSERVATIONS FOR FUTURE MISSIONS

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OVERVIEW



Artemis II Launch

- NASA's Artemis II Mission
- Anomaly Resolution Tools
 - ACEL-ENT
 - EPS PDA
- Data Evaluation
 - Pre-Flight Observations
 - Fishbone Screening
- Recommendations and Conclusion

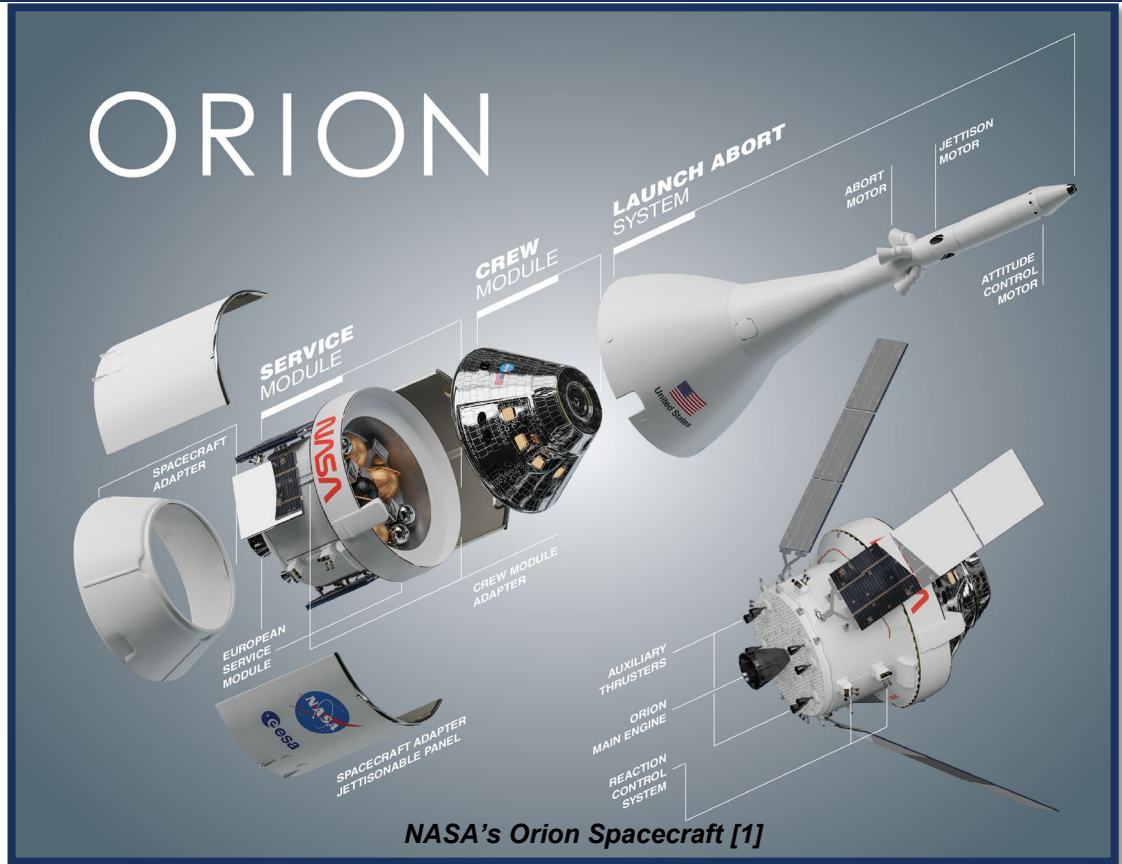


ARTEMIS II MISSION

ARTEMIS II ANOMALY RESOLUTION TOOLS

ORION SPACECRAFT

- Artemis Program initiative to return human presence to the moon
- Orion spacecraft is primary crew vehicle
 - Multi-purpose Crew Vehicle (MPCV) is comprised of Crew Module and European Service Module (ESM)
 - ESM contains:
 - Propulsion subsystem
 - Electrical Power System
 - Crew Support System
 - Thermal Control System



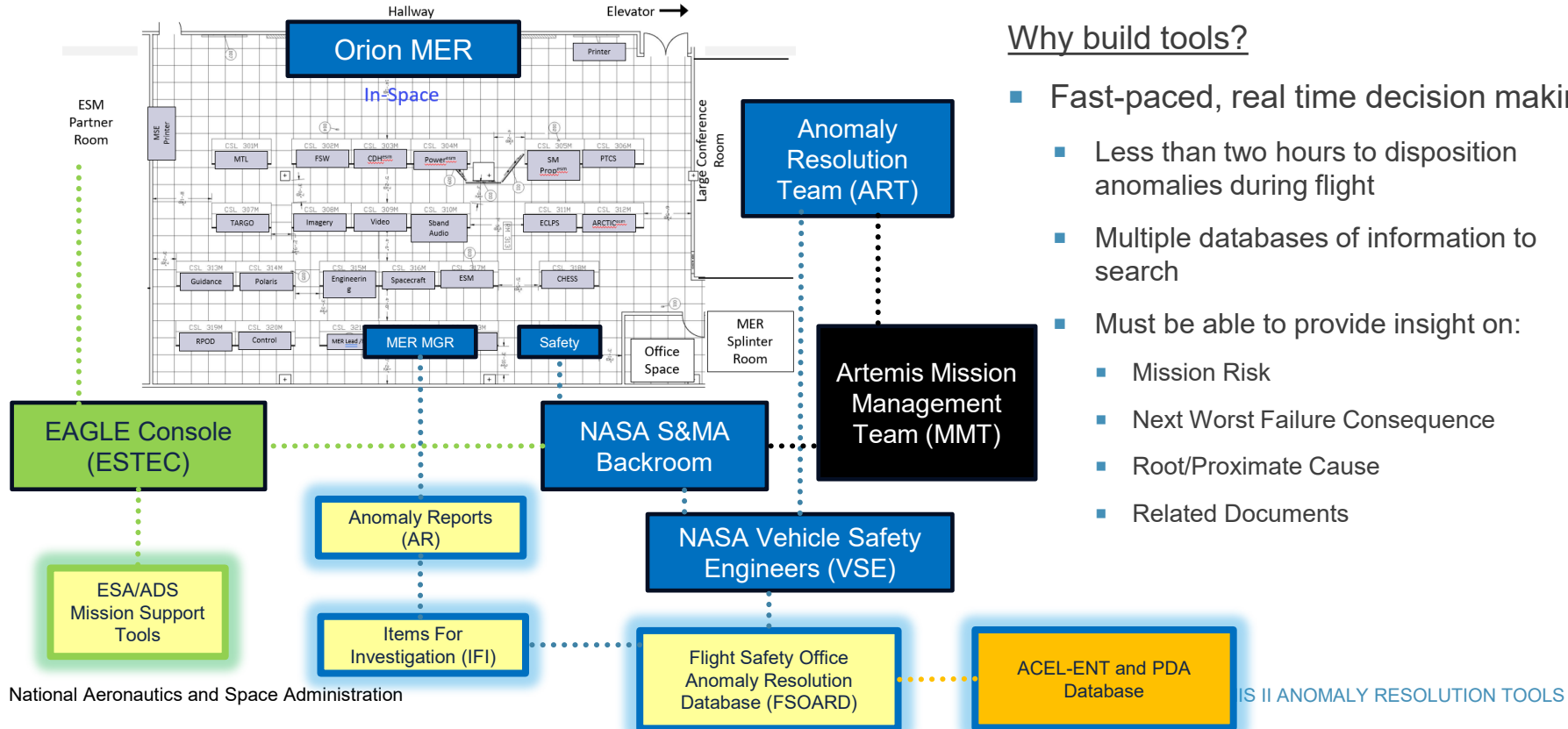
ARTEMIS II MISSION



Artemis II Mission Map [1]

- First crewed test flight of Orion
- 10 day Lunar Orbit Mission
 - Rendezvous and Proximity Operations demonstration
 - Trans Lunar Injection Burn
 - Lunar Flyby

ANOMALY RESOLUTION





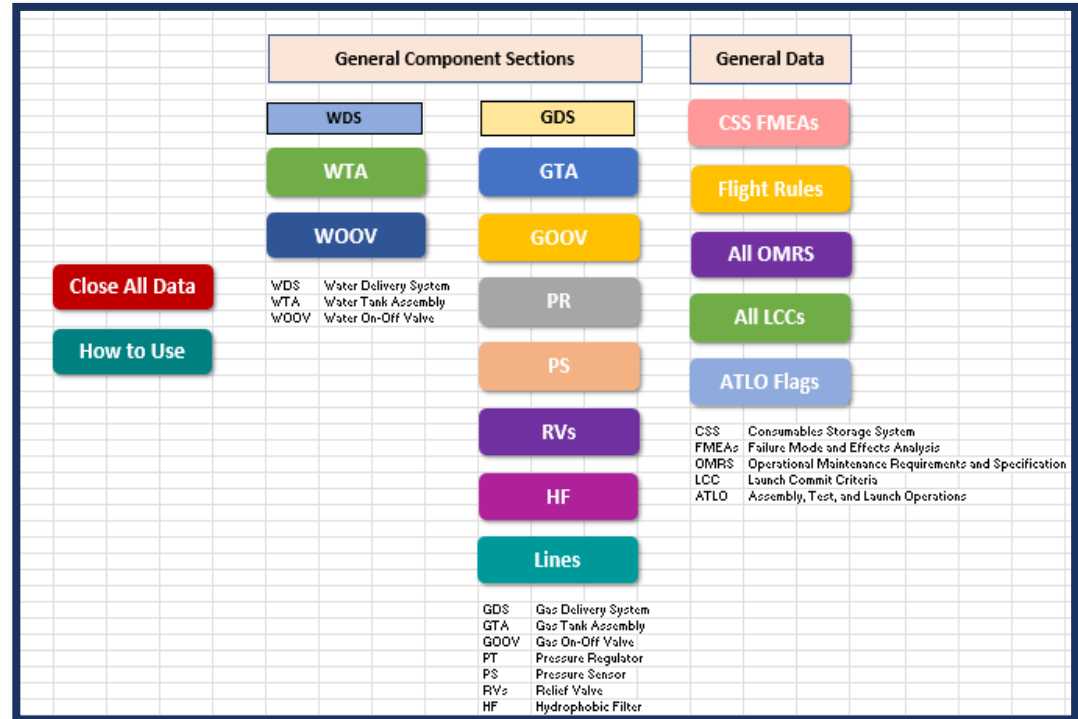
ARTEMIS COLLABORATION AND ELEVATED LOCALIZATION EFFICIENT NEXT-FAILURE TOOL (ACEL-ENT)

ARTEMIS II ANOMALY RESOLUTION TOOLS

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ACEL-ENT DATABASE OVERVIEW

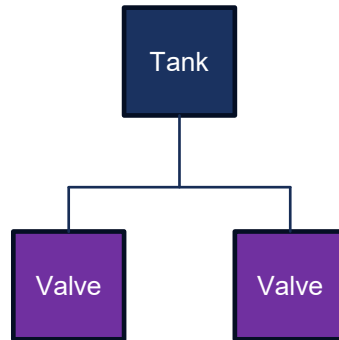
- Four ACEL-ENT Databases created in Visual Basic for Applications in Excel
 - Propulsion Subsystem
 - Active Thermal Control System
 - Crew Support System
 - Solar Generation System
- Consists of:
 - Clickable subsystem schematic
 - Three-dimensional system view
 - Searchable categories of information



Crew Support System ACEL-ENT Structure

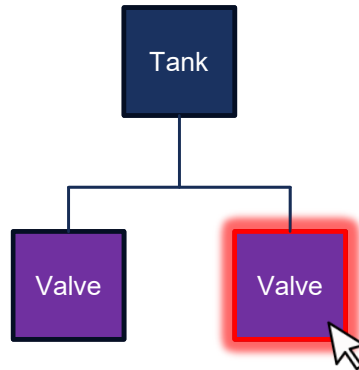
ACEL-ENT DATABASE FUNCTION

- Coded with a series of conditional statements to allow filtering of several databases of information
- Selection of general data button, component overview button, or specific schematic part opens different filters of information



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	A	B	C	D	E	F	G	H	I
1	Non Conformance Reports								
2	Reference	Status	Unit SN	Part Number (Material Number)	Description	Part Type	Corrective Action	Source of NCR/QM	
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13	Quality Notes								
14	Reference	Status	Unit SN	Part Number (Material Number)	Description	Disposition	Part Type	Source of NCR/QM	
15									
16									
17									

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Home Page

Valve Data

Valve NCRs

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ACEL-ENT DATABASE IMPACT

- Three ACEL-ENT Databases were used in flight for Items for Investigation (IFIs)
 - ACEL-ENT allowed for rapid filtration of data to find relevant information
 - NC and ADP data for possible root cause from similar failures
 - FMEA for failure modes of highest concern
 - Flight Rules for pre-declared Loss of Mission conditions
 - Efficiency of data location allowed for faster decision making on if flight could be continued safely or if abort was necessary
 - Understanding history of components allowed for recommendations of in-flight test objectives to better characterize IFIs



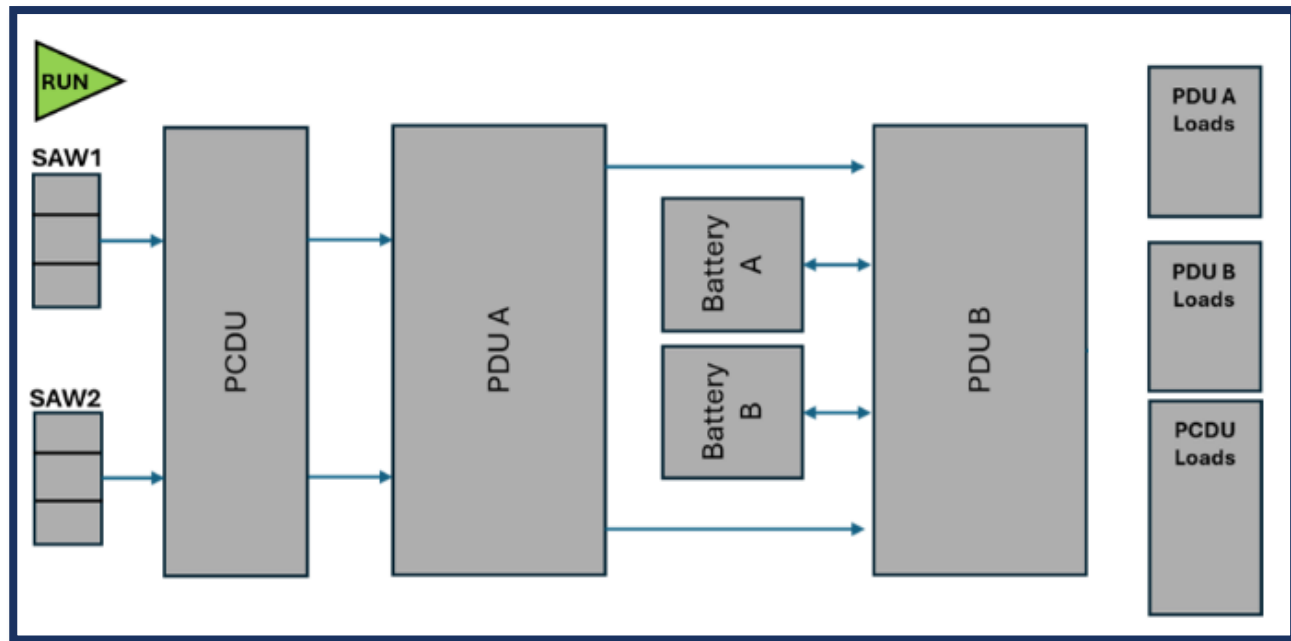
ELECTRICAL POWER SYSTEM POWER DISTRIBUTION ARCHITECTURE (PDA)

ARTEMIS II ANOMALY RESOLUTION TOOLS

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EPS PDA OVERVIEW

- Comprised of 3 major functional areas:
 - Power generation
 - Power regulation
 - Power distribution
- EPS functional areas:
 - Solar Array Wings – convert solar to 120V energy
 - Batteries – store on-board EP
 - Power Conditioning and Distribution Unit – regulates and distributes solar power to loads
 - Power Distribution Unit – further regulates and distributes PCDU power
 - Loads – end users of EP

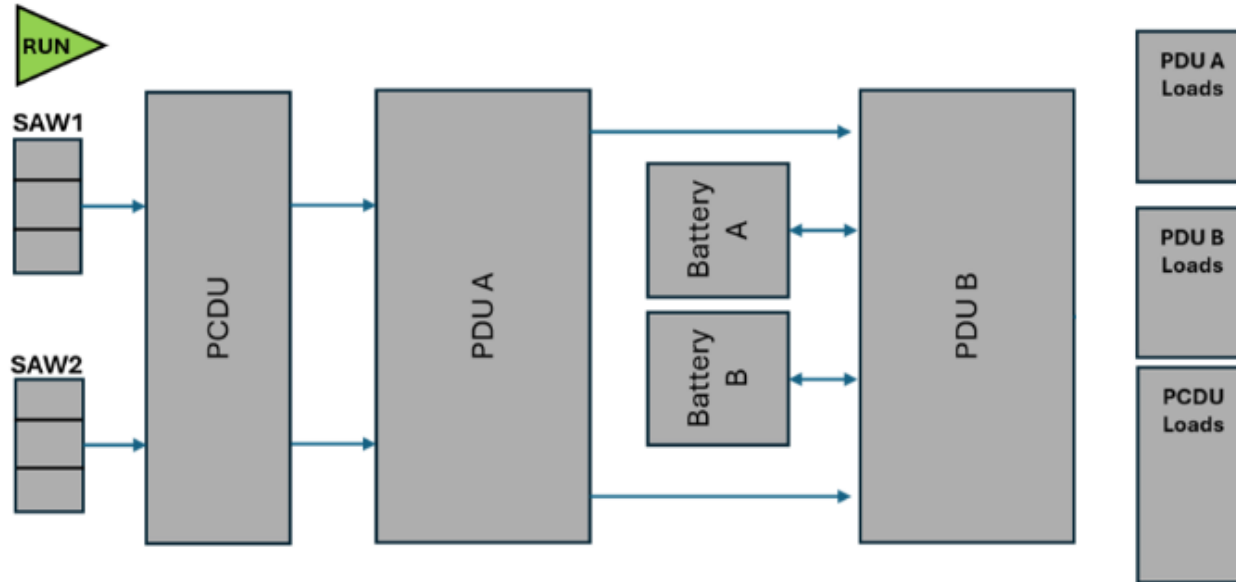


Simplified EPS PDA Schematic

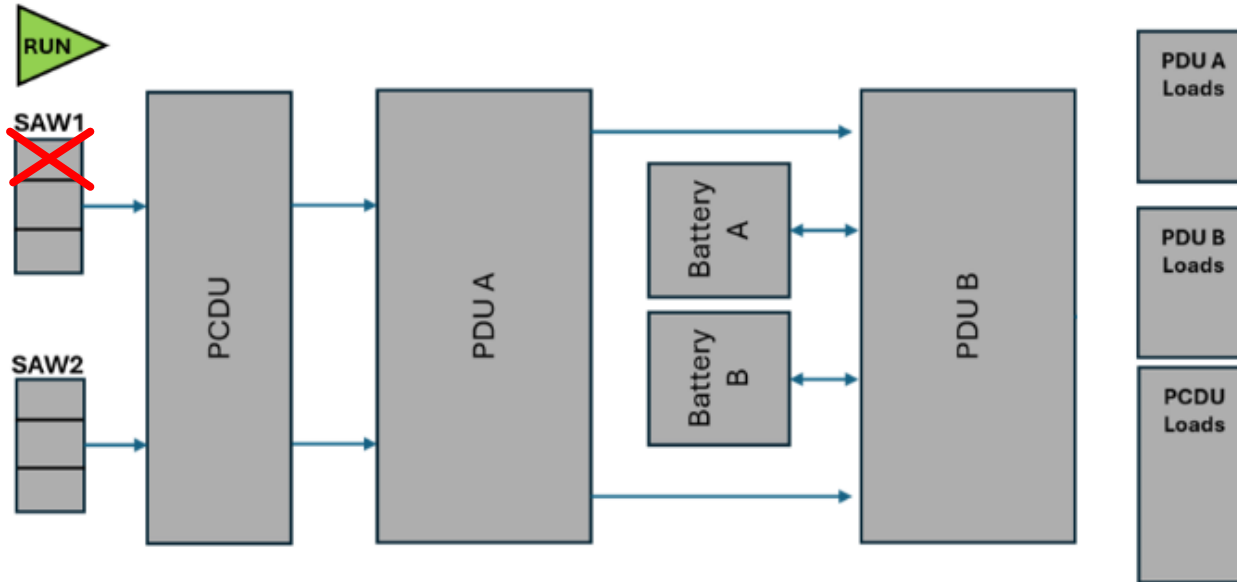
EPS PDA FUNCTION

- Operates in Microsoft Excel with VBA
 - Directed Network employs nodes and directional arrows to map EPS
 - Breadth First Search parses through power-flow of circuit paths from sources (solar and batteries) to end users (loads)
- Data table for each node, connection and switch state
 - Nodes: component where power exists
 - Edge: Data elements that link nodes and specify direction arrow
 - Switch state: combines user defined state with node properties
 - User defined states include state of switches, powered circuits, and unpowered circuits

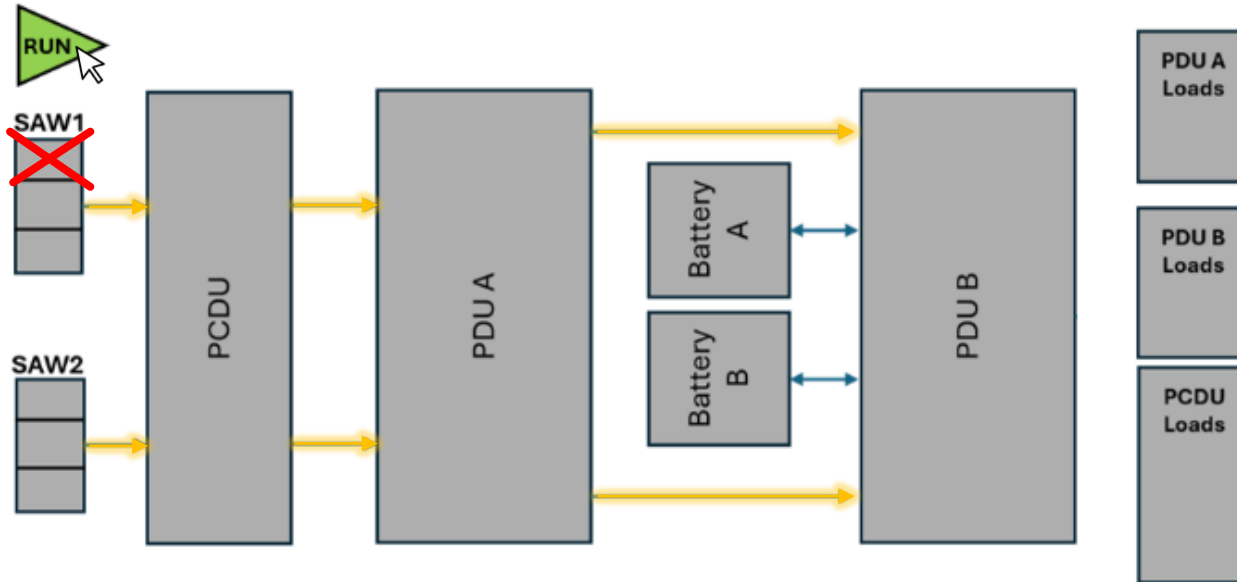
EPS PDA FUNCTION



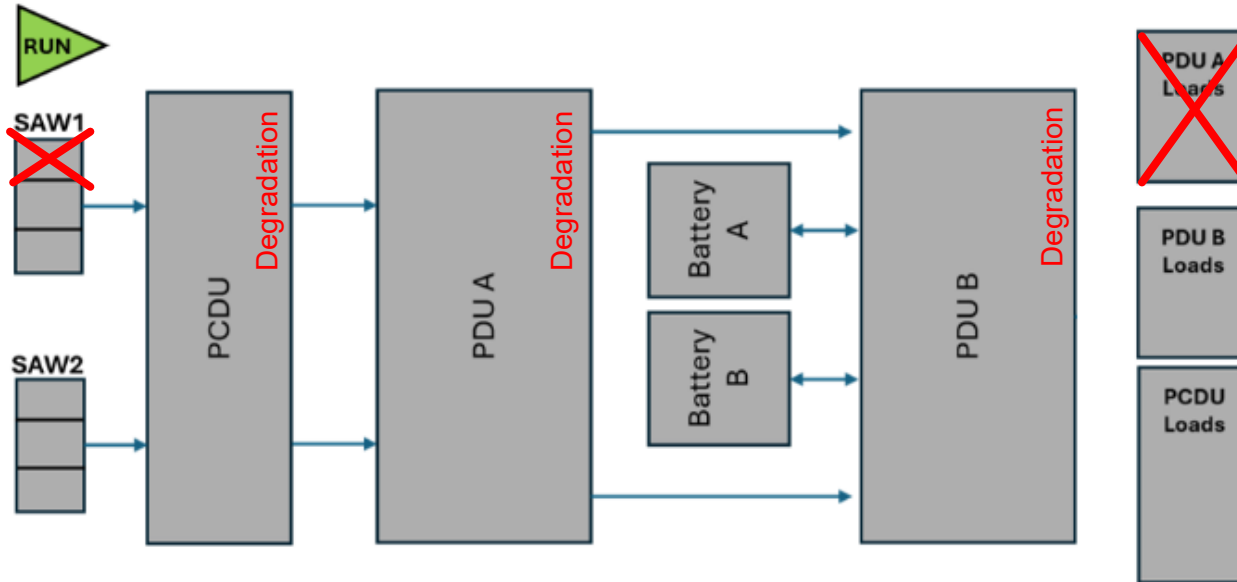
EPS PDA FUNCTION



EPS PDA FUNCTION



EPS PDA FUNCTION



EPS PDA IMPACT

- Facilitates investigation of EP nonconformances experienced in-flight
 - Configurable to reflect the current state of the vehicle and determine which loads are unpowered
 - Aids flight team in understanding:
 - Current vehicle risk
 - Next Worst Failure
 - Remaining Failure Tolerance



ARTEMIS II DATA EVALUATION

ARTEMIS II ANOMALY RESOLUTION TOOLS

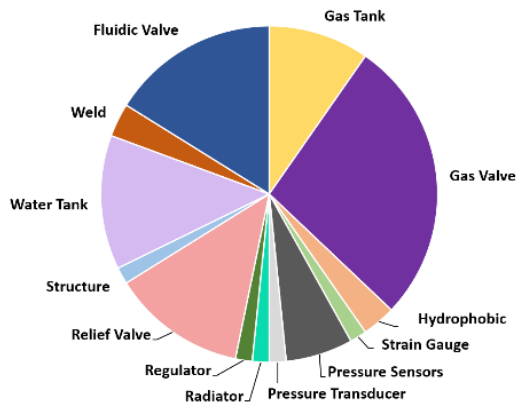
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IN-FLIGHT OBSERVATIONS

- Artemis II was the first test flight of several ESM functional elements
- Several IFIs issued, investigated, and endorsed by the Mission Management Team with authorization to continue the mission
 - Crew Support System (CSS) Finding
 - Mechanical (Mech) System Finding
 - Propulsion Subsystem (PSS) Finding
- Post Flight evaluation process examined:
 - Ground nonconformances in comparison to flight IFIs
 - Flight Fishbone assessment
 - Ground screening
 - Accessibility of data

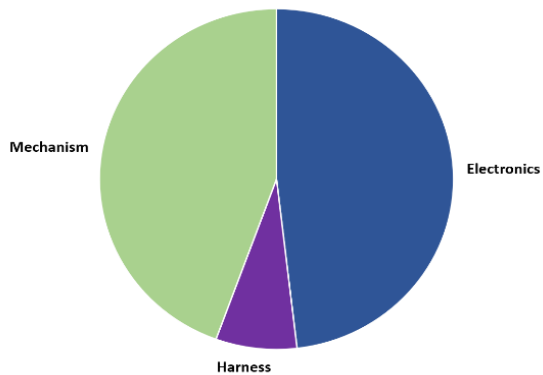
GROUND ANOMALY OBSERVATIONS

Failure Mode/Signature Frequency Count Per Component of the Artemis II Crew Support System



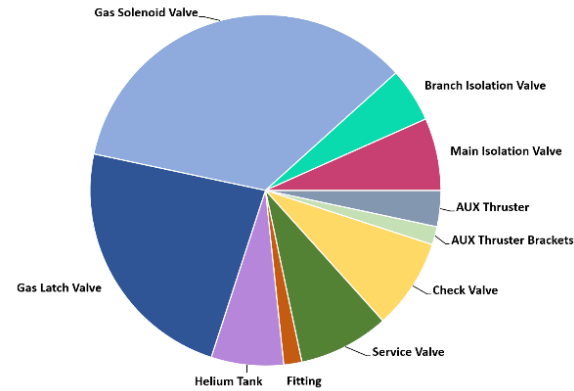
- Gas Valves: 27% CSS, 4.4% vehicle
- Fluidics Valves: 16% CSS, 2.6% vehicle

Failure Mode/Signature Frequency Count Per Component of the Artemis II Mechanisms System



- Mechanisms: 43% Mech, 3.1% vehicle
- Electronics: 11% Mech, 0.8% vehicle

Failure Mode/Signature Frequency Count Per Component of the Artemis II Propulsion Subsystem



- Gas valves: 58% PSS, 16% vehicle
- Predominant discrepant condition: Leakage (19% PSS, 5.2% vehicle)

- Ground anomalies were assessed for similarities to Artemis-2 IFIs
- Higher-frequency ground and flight failure modes are traceable to more complex systems and vehicle interactions

FLIGHT FISHBONE CONTRIBUTIONS

Legend		Formatting	
A	Possible screen via analysis		Screening currently exists
I	Possible screen via inspection		
M	Possible screen via test at material level	X	Screening does not currently exist - requires risk trade to implement
C	Possible screen via test at component level		
S	Possible screen via test at subsystem level		
V	Possible screen via test at vehicle level	X	Ground failure observed
E	Possible screen with multi-environment test		

The figure displays three fishbone diagrams, each with a set of contributors on the left and a grid of 8M categories (A, I, M, C, S, V, E) on the right. The grid cells are color-coded: yellow for 'No relationship', light blue for 'Weak relationship', green for 'Moderate relationship', and dark green for 'Strong relationship'. 'X' marks indicate specific relationships.

CSS Fishbone Contributors

Contributor	A	I	M	C	S	V	E
1	Yellow	Light Blue	Yellow	Green	Green	Green	Yellow
2	Yellow	Light Blue	Yellow	Green	Green	Green	Yellow
3	Green	Light Blue	Yellow	Green	Green	Green	Yellow
4	Green	Yellow	Yellow	Green (X)	Green (X)	Green	Yellow
5	Green	Yellow	Yellow	Green	Green	Green	Yellow

Mech Fishbone Contributors

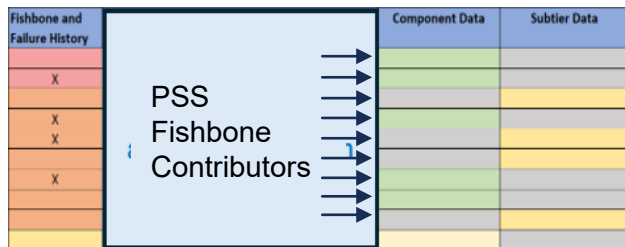
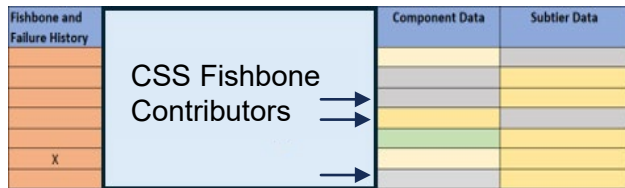
Contributor	A	I	M	C	S	V	E
1	Light Blue	Green (X)	Yellow	Green	Yellow	Yellow	Yellow
2	Yellow	Yellow	Light Blue	Green	Green (X)	Yellow	Yellow
3	Green	Light Blue	Light Blue	Green (X)	Green	Green	Yellow
4	Green	Yellow	Yellow	Green (X)	Green	Green	Yellow
5	Green	Yellow	Yellow	Green (X)	Green	Green	Yellow

PSS Fishbone Contributors

Contributor	A	I	M	C	S	V	E
1	Green	Light Blue	Yellow	Green (X)	Green (X)	Green	Yellow
2	Yellow	Yellow	Light Blue	Green	Green	Green	Yellow
3	Yellow	Yellow	Yellow	Green	Green (X)	Green	Yellow
4	Yellow	Yellow	Yellow	Green (X)	Green (X)	Green	Yellow
5	Green	Light Blue	Yellow	Green	Green	Green	Yellow
6	Green	Yellow	Yellow	Green	Green (X)	Green	Yellow
7	Yellow	Yellow	Yellow	Green	Green	Green	Yellow
8	Green	Light Blue	Yellow	Green	Green	Green	Yellow

- CSS investigation is evaluating criticality and coverage for force margin, installation damage, material integrity and corrosion
- Mech investigation is evaluating criticality and coverage for command behavior, unit specific motion, and system interactions
- PSS investigation is evaluating criticality and coverage for dimensional tolerances, material compatibility, and static seal performance

FISHBONE DATA ACCESSIBILITY



Key	Fishbone Classification	Key	Data Accessibility
	Likely Contributor		Part-specific data is impractical to generate, or not relevant
	Moderately Likely Contributor		Part-specific data available and delivered via component ADPs, NCRs referenced in ACCEL-ENT
	Somewhat Likely Contributor		Part-specific data available during the mission based on supplier reach-back
X	Ground Failure Observed		Part-specific data requires additional investigation

*requested post-flight

CSS fishbone contributions were sourced from:

- ACEL-ENT: Leakage and vibration testing, nonconformances related to loads, command sequencing, parts selection
- In-flight reach-back: Preliminary loads assessment
- Supplier reach-back*: Component testing, force margin analysis, inspections, lot data

Mech fishbone contributions were sourced from:

- ACEL-ENT: Vibration and functional testing, nonconformances related to design margin, electrical compatibility and workmanship
- In-flight reach-back: Sub-tier engagement tests, qualification unit inspections, mission-specific structural analysis
- Supplier reach-back*: Structural analysis, system analysis and testing

PSS fishbone contributions were sourced from:

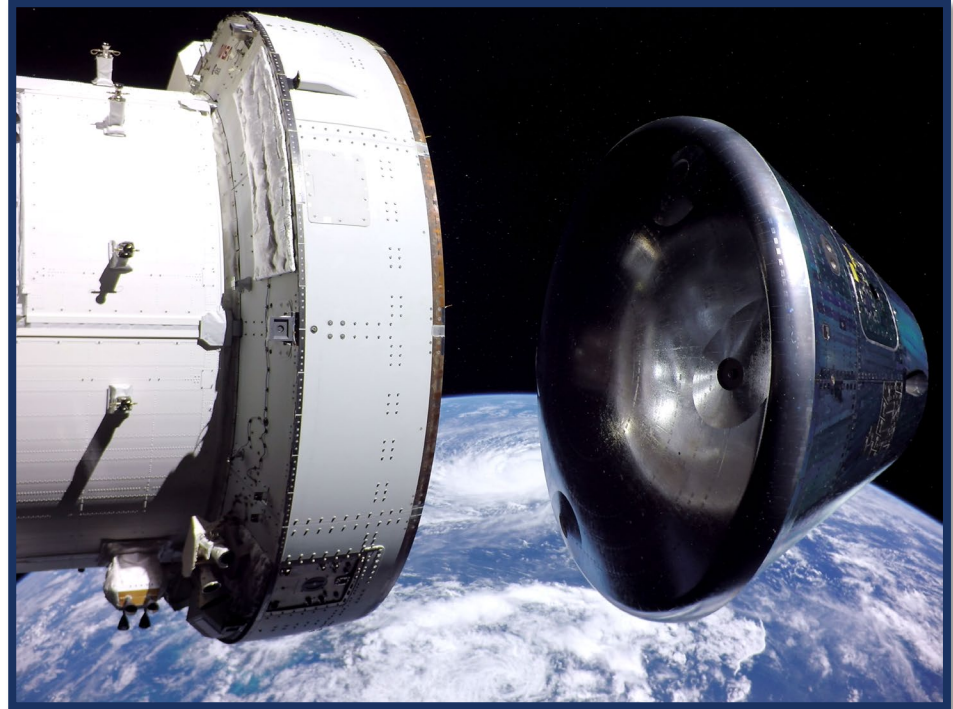
- ACEL-ENT: Leakage, vibration, and thermal cycle testing, nonconformances related to leakage risk
- In-flight reach-back: Command telemetry, dedicated low-risk assessment based on failure tolerance and benign mission profile
- Supplier reach-back*: Procurement data, material compatibility test data

FINDINGS

- Artemis component test campaigns are designed to demonstrate margin and facilitate flight rationale when individual component screening is impractical
 - Acceptance test strategy validated with no significant gaps
- Artemis vehicle human rating requires at least single failure tolerance to catastrophic hazards
 - Post flight analysis and root cause investigations will be used to reassess risk and confirm design tolerance
 - Investigation of opportunities underway to add target screening for uniquely susceptible hardware
- Artemis II succeeded based on positive agency and industry collaboration
 - ACEL-ENT identified ground anomalies related to the CSS (5), Mech (6), and PSS (17) Findings
 - Because ACEL-ENT does not include sub-tier data, required supplemental information from suppliers
- ACEL-ENT and PDA are limited by overhead
 - Excel databased require manual maintenance of massive quantities of data and must be re-populated for each mission to account for vehicle to vehicle variation
 - ADP data does not have consistent formatting between suppliers and is not always searchable

RECOMMENDATIONS

- Criticality 1/1R component sub-tier data should be made available upon request during flight to support go/no-go decisions
- Improve ability to parse ADPs
 - Improve Optical Character Recognition PDF search tool
 - Streamline ADP formatting
- Investigation Artificial Intelligence options for data compilation
 - Use AI to populate new data into existing databases
 - Create a repository of information searchable by AI for interpretation by responsible engineer



CM/ESM Separation

CONCLUSIONS



Splashdown

National Aeronautics and Space Administration

- Artemis missions will continue to increase in scope and complexity, requiring diligence in preparation to ensure adequate anomaly resolution
 - The ACEL-ENT and PDA databases were proven useful tools, with upgrades necessary to reduce labor intensity of creation
 - A retroactive assessment of safety processes used in each mission is crucial to achieve safety and mission success as Orion encounters new challenging environments

REFERENCES

1. National Aeronautics and Space Administration. (2026). *Artemis II Reference Guide*. <https://www.nasa.gov/wp-content/uploads/2026/01/a2-reference-guide-012825.pdf?emrc=979554>

