

CAIS: Crew Anomaly Investigation System

Helping future Mars crews understand spacecraft problems without immediate support from Earth

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Executive Summary

The Crew Anomaly Investigation System (CAIS) is an interactive dashboard that helps crew maintain situational awareness during a spacecraft anomaly.

On a Mars mission, one-way communication latency can reach 22 minutes. A crew that cannot consult ground in real time must respond to anomalies semi-autonomously. Over seven months, we worked with astronauts, flight controllers, and NASA experts to build CAIS: a tool that collects, organizes, and filters information across disparate sources, so crews can understand and investigate problems on their own.

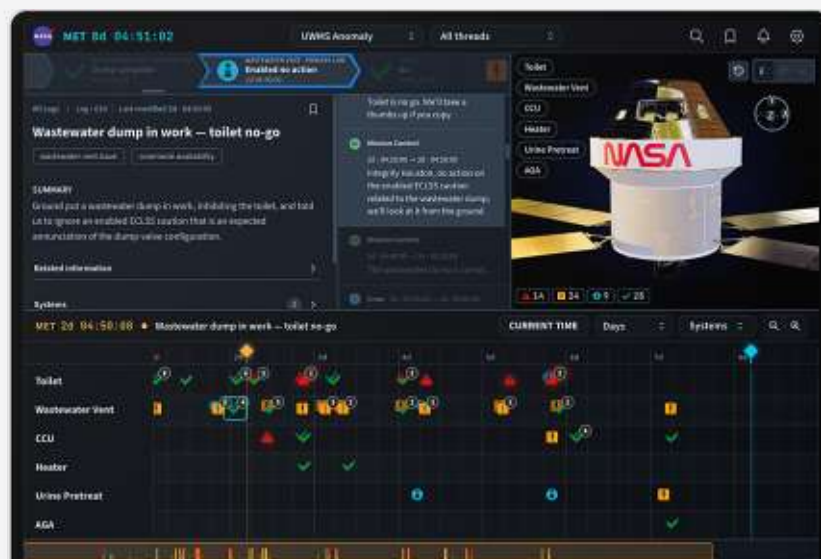
Why This Matters

Anomaly information is scattered across messages, system data, and tools the crew cannot always access, making it difficult to reconstruct what happened and why.

The Solution

CAIS brings everything about a single anomaly into one interactive workspace. It consolidates communications, system state changes, telemetry, and crew observations into synchronized views. The panels work together: a readable log of events and rationale, a 3D interior and exterior schematic to locate relevant systems, and a timeline tracing prioritized events across multiple systems over time.

Rather than searching separate tools and asking ground to fill the gaps, crew can open CAIS and reconstruct the full picture on their own.



- 1 Information Panel**
Summarizes what happened and keeps messages and rationale nearby.
- 2 3D Schematic Panel**
Shows where affected systems are located on the spacecraft.
- 3 Timeline Panel**
Maps system changes so crew can spot patterns and reconstruct the anomaly.

Approach

Research and Interview

We studied past spaceflight anomalies and interviewed retired astronauts, flight controllers, and researchers to understand how crews investigate problems.

Prototype and Build

We translated those insights into a working prototype, reimagining an Artemis II anomaly under Mars-like delay. We iterated through low- to high-fidelity designs.

Test and Validate

We tested CAIS with retired astronauts and NASA human factors experts, measuring how quickly and accurately crews reconstructed an anomaly. Their feedback shaped the design.



The framework shows the Mars mission world we built to define crew roles, information, and decision boundaries.



Captured with Kate Rubins, a retired ISS astronaut, after two testing sessions with CAIS.

Design Principles

Nine principles for any system built for time-delayed Mars operations, drawn from our research.

Asynchronous Communications Messaging built for delay	Multi-Modal Information Same info, multiple formats	Generative Visuals Telemetry made readable
Passive Logging Tools Actions logged automatically	Adaptive Information Density Detail that shifts with need	Reconfiguration Tailored to each workflow
Alerts & Highlights Cues that guide attention	Surfacing Uncertainty Nudges toward verification	Collaborative Features Shared crew context

Key insights

- 1 Efficient contextualization comes from consolidating disparate sources
- 2 Synced panels pair flexible rendering with cross-panel confirmation
- 3 Summarized rationale lets crews act autonomously under time delay

Impact

When an anomaly unfolds, CAIS gives crews back time, clarity, and confidence.

Anomalies demand time already claimed by routine operations, so every minute CAIS returns is time back for onboard science and other critical work. When communication delays leave ground and crew operating on different realities, CAIS surfaces conflicts and maintains a single onboard ground truth that is timestamped and traceable. With expert-backed information behind it, crews can confidently commit to their next course of action.