Preliminary Design of Robotic Control Software for Mars Sample Return – Capture, Containment, and Return System

Presentation Author/Presenter:

Jacob Taylor Cassady

NASA Langley Research Center

AIAA SciTech, 6-10 January 2025

Contributors:

Ashok K. Prajapati, Elizabeth J. Geist
NASA Goddard Space Flight Center

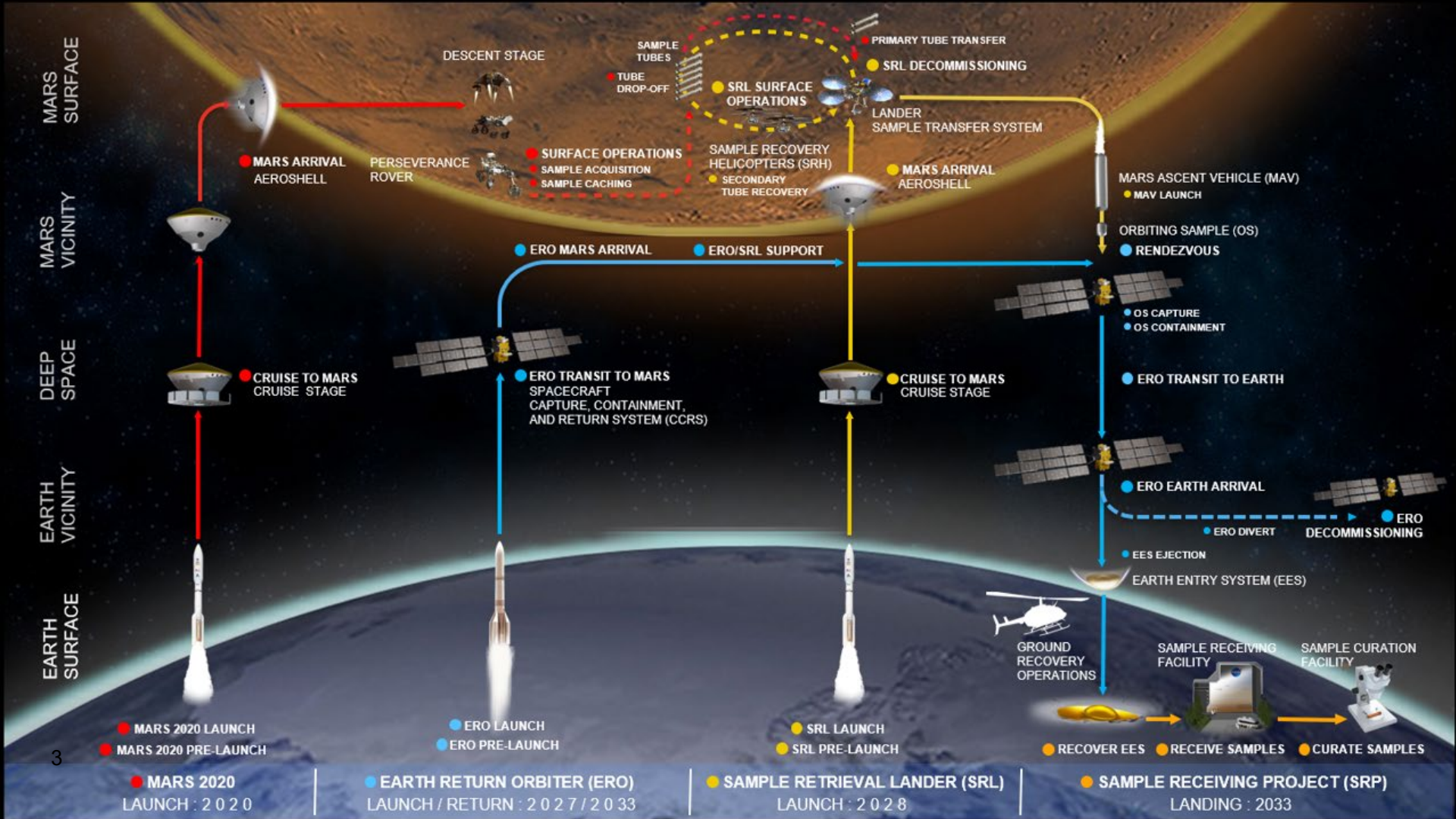
Bradley C. Tse, Benjamin L. Osborne
Microtel LLC

Jeffrey A. Angielski
HII Mission Technology Corporation

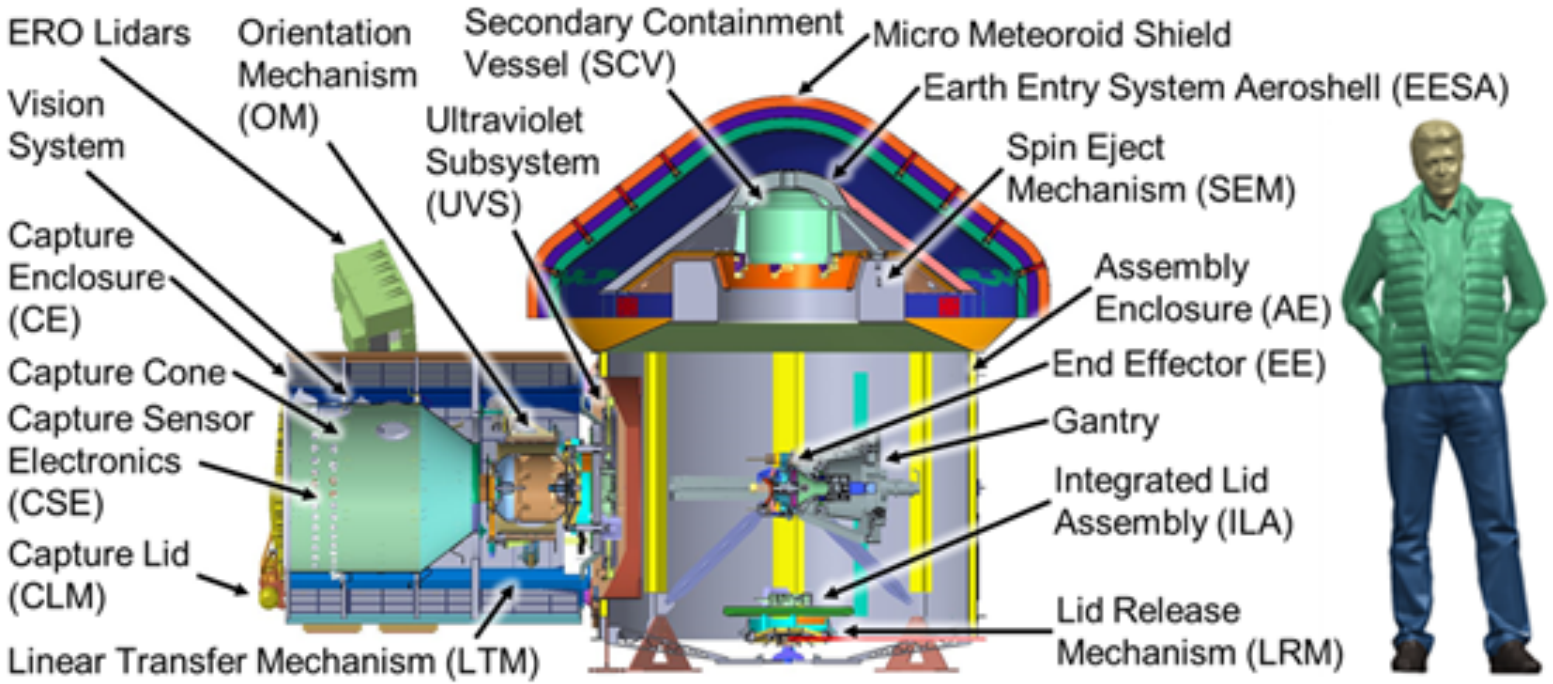
Joseph B. Lattisaw, Francis B. Hallahan
Embedded Flight Systems Inc.

Agenda

- Mars Sample Return (MSR) Campaign Overview
- Capture Containment and Return System (CCRS) Hardware
- Robotic Transfer Assembly System (RTAS) Conops
- Avionics
- Flight Software (FSW)
- Robot Software (RSW)
- Conclusion

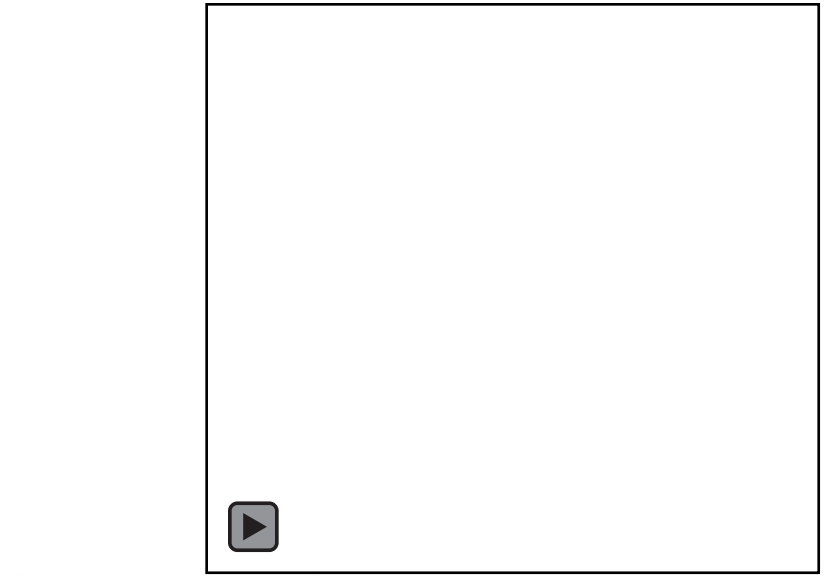

MARS SURFACE
MARS VICINITY
DEEP SPACE
EARTH VICINITY
EARTH SURFACE
DESCENT STAGE
SAMPLE TUBES
TUBE DROP-OFF
PRIMARY TUBE TRANSFER
SRL DECOMMISSIONING
SRL SURFACE OPERATIONS
LANDER SAMPLE TRANSFER SYSTEM
MARS ARRIVAL AEROSHELL
PERSEVERANCE ROVER
SURFACE OPERATIONS
SAMPLE ACQUISITION
SAMPLE CACHING
SAMPLE RECOVERY HELICOPTERS (SRH)
SECONDARY TUBE RECOVERY
MARS ARRIVAL AEROSHELL
MARS ASCENT VEHICLE (MAV)
MAV LAUNCH
ORBITING SAMPLE (OS)
RENDEZVOUS
ERO MARS ARRIVAL
ERO/SRL SUPPORT
OS CAPTURE
OS CONTAINMENT
CRUISE TO MARS CRUISE STAGE
ERO TRANSIT TO MARS SPACECRAFT CAPTURE, CONTAINMENT, AND RETURN SYSTEM (CCRS)
CRUISE TO MARS CRUISE STAGE
ERO TRANSIT TO EARTH
ERO EARTH ARRIVAL
ERO DIVERT
ERO DECOMMISSIONING
EES EJECTION
EARTH ENTRY SYSTEM (EES)
GROUND RECOVERY OPERATIONS
SAMPLE RECEIVING FACILITY
SAMPLE CURATION FACILITY
MARS 2020 LAUNCH
MARS 2020 PRE-LAUNCH
ERO LAUNCH
ERO PRE-LAUNCH
SRL LAUNCH
SRL PRE-LAUNCH
RECOVER EES
RECEIVE SAMPLES
CURATE SAMPLES
MARS 2020
LAUNCH : 2020
EARTH RETURN ORBITER (ERO)
LAUNCH / RETURN : 2027/2033
SAMPLE RETRIEVAL LANDER (SRL)
LAUNCH : 2028
SAMPLE RECEIVING PROJECT (SRP)
LANDING : 2033

Capture, Containment, and Return System Hardware

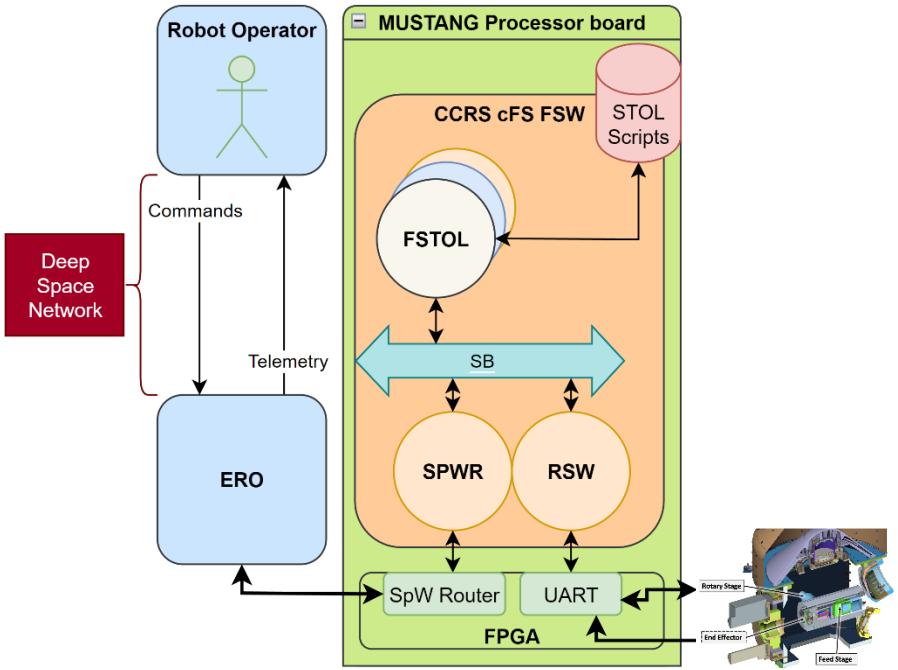


Robotic Transfer Assembly System Con-ops

- RTAS has atomic actions called **motion primitives**
  - Position, active hold, active limp, etc.
- Motion primitives are combined to create **behaviors**.
  - Open-Loop Actuator with Contact Switch Post-Motion Confirmation, etc.
- RTAS is controlled by software called Robot Software (RSW)



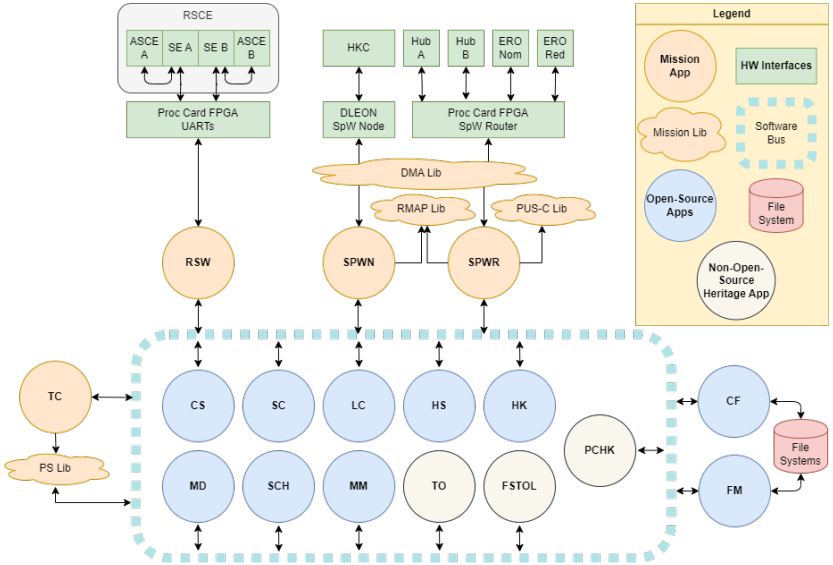
Avionics

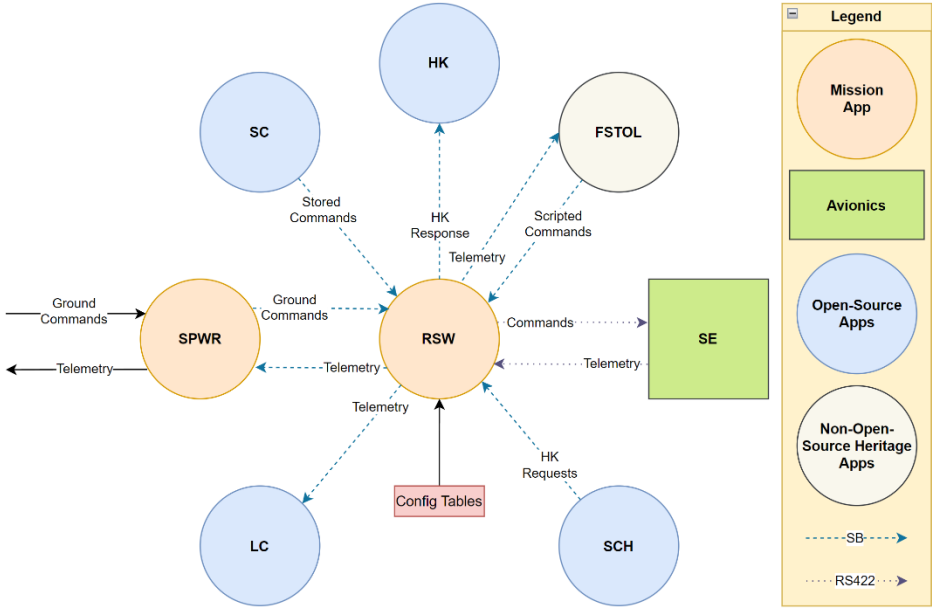


- Modular Unified Space Technology Avionics for Next Generation (MUSTANG) Processor Board
  - Spaceflight heritage: Magnetospheric Multiscale Mission, Global Precipitation Measurement Mission and more.
  - Includes RTG4 FPGA supporting SpaceWire and UART.

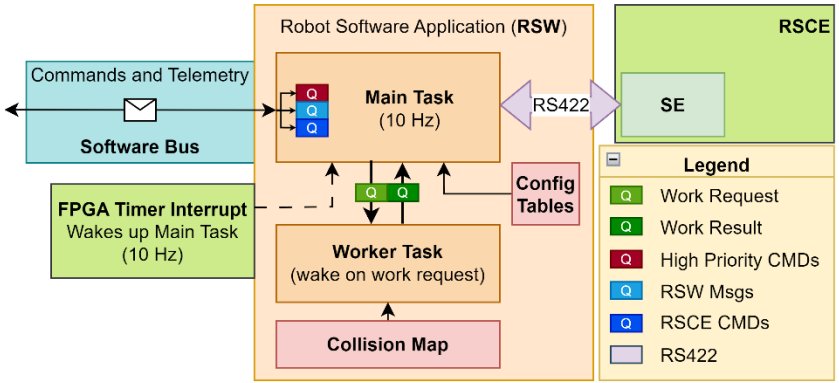
Flight Software

- Built upon the open-source core Flight System (cFS) framework developed by NASA Goddard Space Flight Center.



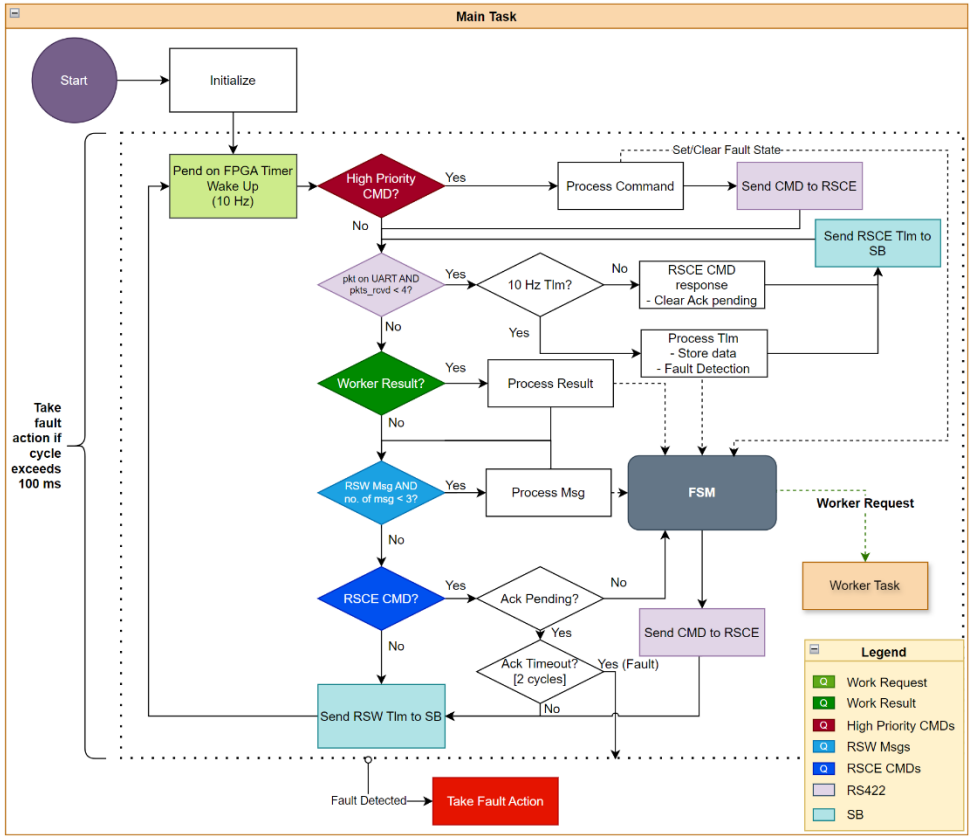


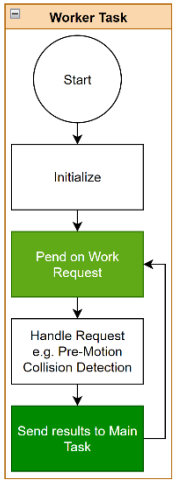
RSW



- Main Task
  - Core logic and FSM
  - Interfaces with hardware and software bus.
- Worker Task
  - For offloading expensive operations
- Message queues used for prioritizing messages and inter-task communication.

RSW Task Design





Conclusion

NASA Office of Inspector General:

“before the MSR Program is approved to proceed from formulation into development, viable alternatives to the Program’s mission architecture considered – including mission launch and sample return alternatives”

Consequently, CCRS development was stopped after Preliminary Design Review.

https://oig.nasa.gov/wp-content/uploads/2024/03/ig-24-008.pdf

Thank You!

- Questions?
- Refer to paper for more on:
  - Command and Telemetry definitions
  - Operation Phase specifics
  - Motion Primitives and Behavior definitions
  - Software Engineering and Testing
    - Functional Testing
    - Static Analysis
    - Unit Testing

AMERICAN INSTITUTE OF
AERONAUTICS AND ASTRONAUTICS