National Aeronautics and Space Administration

NASA

MSFC Flight Software

December 11th, 2019

EXPLORE MARSHALL

- Ability to go further into space for longer durations require new technologies as well as new applications of existing technologies
- Flight Software Community is at the forefront of identifying what computing technologies can enable missions to the moon, Mars, and beyond
- Proving such capabilities through ground simulation is also of paramount importance to preparing them for use in space missions

Flight Software Community

- Deep space missions increase the need for autonomous navigation and decision making within flight software
- Increasingly complex missions to deep space will require more difficult scientific investigations managed through flight software
- Constraints on project schedules and budgets make more modular, reusable software and associated artifacts more attractive
- Analysis of huge volumes of data can be better enabled by machine learning
- More robust, high-performance hardware, such as multi-core, FPGAs, and high performance space computers are also required to meet these mission needs

Enabling Technologies

Human-Rated Class A

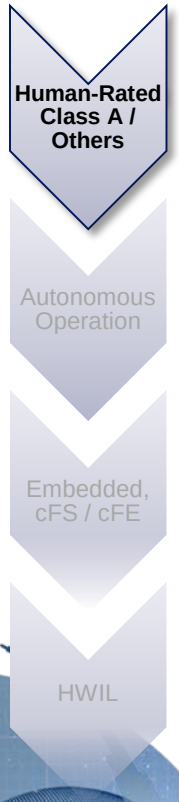
Autonomous Operation

cFS / cFE

HWIL

- Fully-qualified in developing Human-Rated Class A Software
  - CMMI Level 3 rated for Flight Software (required for Human Rated, Class A)
  - CMMI Level 2 rated for Hardware/Software Test Facilities
- 20+ years of Flight Software heritage
  - Voting Architecture
  - Autonomous and Commanded Operations
  - Sensor Data Qualification
  - Mission & Fault Management
  - Environmental Control and Life Support Systems (ECLSS)
- Leverage expertise in software development life cycle
  - ARINC 653 VxWorks
  - Modular/Layered Software Architecture
  - IBM Rationale DOORS for Requirement and Test Case management
  - Development of Planning and Technical artifacts, including ICDs, SRS, SDD
- Console-certified Engineering Support Team (EST)
- Scalable HWIL framework – from completely simulated to full HW build-up

MSFC Capabilities



- Space Launch Systems – Flight Computer Software
  - Flight Software: Utilizes a voting architecture between three (3) Flight Computers (FCOG). Employs an ARINC 653 VxWorks platform.
  - iLoad Software: Provides for day of launch and other parameter updates of the Flight Software.
- International Space Station – ECLSS/MSRR
  - Urine Processor Assembly (UPA): Performs command processing and status reporting of hardware to reclaim potable H2O from waste H2O.
  - Four Bed Carbon Dioxide Scrubber System (4BCO2): Controls the heaters, blower, air save pump, and valves, and provides telemetry back to Mission Control Center (MCC) to support venting of CO2 removal from ISS cabin air.
  - Material Science Research Rack (MSRR): Processes and monitors various materials in a high temperature / zero gravity environment.
- Modeling and Simulations
  - ARTEMIS: Robust adaptive simulation capability used to support testing and qualifications of Avionics and software systems.
  - MAESTRO: Test conductor interface to configure and execute program approved tests.

Responsible for full software development life cycle

Human-Rated Class A Flight Software

Human-Rated Class A / Others

Autonomous Operation

Embedded, cFS / cFE

HWIL

- Space Launch Systems – Flight Computer Software
  - Flight Software: Provides centralized, autonomous nominal/off-nominal operation of the SLS vehicle from Autonomous Launch Sequence (ALS) through ICPS Separation.
- Advanced Video Guidance Sensor
  - Used on Demonstration of Autonomous Rendezvous Technology (DART). For the DART mission, the AVGS was mounted on the DART chase spacecraft in a position that allowed proper viewing of the retroreflectors on the target spacecraft.
- Autonomous Systems and Operations (ASO)
  - Autonomous Fluid Transfer System (AFTS) and Smart Vehicle Management Technical Excellence (TE) - A ground demonstration of autonomous operations to reduce crew dependence on mission control.
- Machine Learning
  - Analyze Big Data with Machine Learning Technical Excellence (TE). By using machine learning, nominal flight software test data sets can be used to train machine learning models to distinguish between expected behavior and anomalies that a simulation produces.

Autonomous Experience

- Lunar CATALYST
  - Serve as subject matter experts to support commercial partners, Astrobotic, develop the flight software for their Peregrine Lunar Lander.
  - Developing cFS sensor applications (Inertial Measurement Unit, Star Tracker, Sun Sensor) for Astrobotic Peregrine Lunar Lander, as well as providing overall software process support and product reviews.
- Mars Ascent Vehicle
  - Developing prototype flight software using cFS to control IMU and Star Tracker through Marshall Technical Innovation Program award.
  - Beginning work on definition of flight software architecture.
- X- Testbed
  - Ported portions of existing Iodine Satellite (iSAT) flight software to cFS to develop a technology demonstration testbed, including camera code.
- Marshall Technical Excellence
  - Established cFS/cFE Training & Artifact Infrastructure.

cFS Experience

Human-Rated Class A / Others

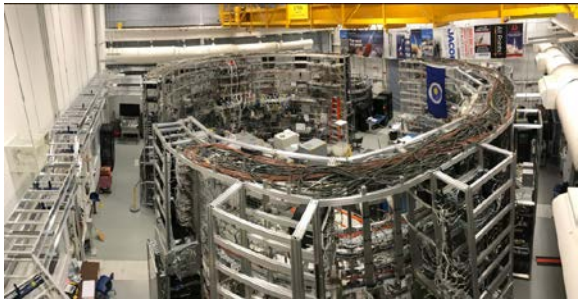
Autonomous Operation

Embedded, cFS / cFE

HWIL

HWIL Capability

- MSFC can provide integrated avionics hardware-in-the-loop (HWIL) facilities to enable an independent and trusted system integration and system test resource to provide assurance and confidence to the program that the vendor-provided avionics system meets the requirements and will accomplish the mission.
- MSFC provided integrated avionics software development and HWIL test facilities provide significant contributions to the development of avionics systems by aiding with the maturation of:
  - Interface control documents
  - Bus loading evaluation and analyses
  - “What if” mitigation assessments
  - Early integration of hardware components in a partial or full HWIL integration environment
  - Post-Test data analysis



Human-Rated Class A / Others

Autonomous Operation

Embedded, cFS / cFE

HWIL

- Configurable / Scalable HWIL framework
  - Reusable test control modules and displays
  - Proven I/O interfaces (e.g. 1553, 422, GigE, Analog, Discretes, other special IF)
  - HW/SW concepts for unobtrusive data recording of all interfaces
  - Selected real-time computing platform
  - Established architecture for test data archival and analysis
- Established relationships with numerous external test facilities (other center and vendor labs).
- Our scalable framework has been adapted to a small satellite lab using cFS; thereby demonstrating the ability to leverage our SLS capabilities to HABs or other applications.
- Relationships with design and manufacturing at MSFC for specialty HW needs (e.g. support structures, circuits, cables).


Avionics Test Facilities


Emulators

REST Satellite Lab

HWIL Capability

- Fully-qualified in developing Human-Rated Class A Software
  - CMMI Level 3 rated for Flight Software (required for Human Rated, Class A)
  - CMMI Level 2 rated for Hardware/Software Test Facilities
  - Agile Software Engineering Processes
  - Agency requirements and standards for software engineering compliance
- Invested in growing core Flight System (cFS), Autonomous Systems, and Machine Learning capabilities
- Established relationships throughout MSFC and other Centers to ensure our products and capabilities meet the needs of the program (e.g. HOSC, M&FM, GN&C, EGS)
- High performance demonstrated on SLS program
  - SLS FSW development maintained schedule with no significant findings found during FQT.
  - Demonstrated flexibility by compensating in SLS FSW for Avionics HW deficiencies.
  - Architecture, fabrication, integration, and certification of complex real-time simulation and HWIL facilities and emulators (i.e., launch vehicle in a rack)
- Experience with Public / Private partnerships (Space Act Agreement, NDA, etc.)

MSFC Capabilities Summary