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Using CCDD to Automate Software development on AA2

Agenda

- AA2 Background
- cFS Command and Data Dictionary (CCDD) Overview
- CCDD Products used on AA2
- Development on AA2
- Next Steps

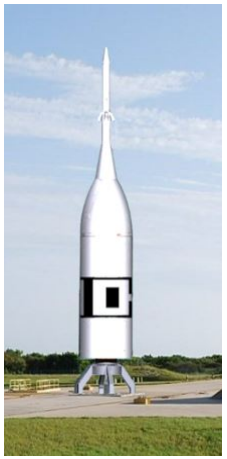
- AA-2 is a development flight test for Multi Purpose Crew Vehicle (MPCV)
  - Launch planned for May 2019 from Space Launch Complex 46
  - AA-1 test was dropped, but AA-2 was not renumbered
  - Pad Abort 1 (PA1) demonstrated similar LAS functionality from a launch pad. (May 2010)
- Largely a test of the Launch Abort System (LAS) on Orion
  - Safety system to quickly separate crew capsule from the Booster (during a failure)
  - Verify LAS works under flight-like conditions to help certify system for crewed missions
- Two identical CPU's running, only 1 is required (redundancy)
  - Each CPU is cFS instance running on vxWorks (on a PPC)
  - Each CPU has separate serial link to the LAS, but only 1 is needed (redundancy)
  - Code is essentially identical on each computer, but each computer used a different value for each MID that it sends on the Software Bus (SB)

AA-2 Background

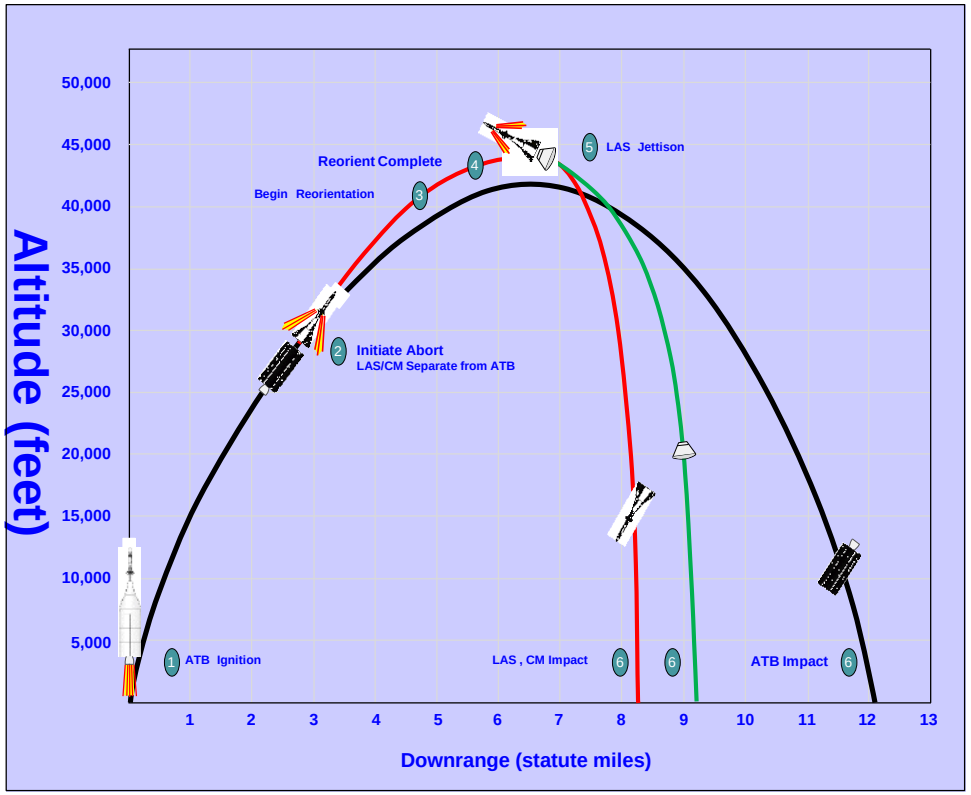
Apollo Pad Abort Test

Apollo Abort Test (Little Joe Ascent II Booster)

Orion PA-1 Test



AA-2 Flight Test Vehicle



AA-2 Avionics & Software

- Designed to use COTS avionics wherever possible
- Dual string design using cFE/CFS on VxWorks
- Reuse of ANTARES Trick Simulation
- CFS wrapped GNC Matlab/Simulink Autocode from mainline MPCV

CCDD Background

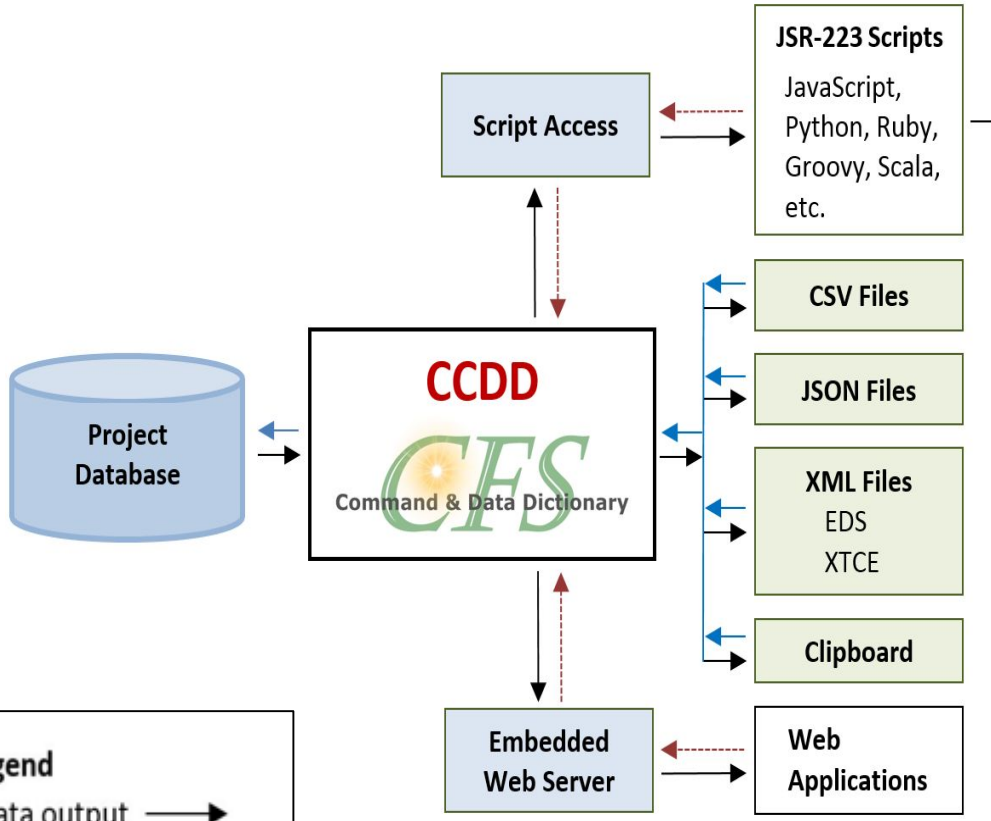
- CCDD stands for cFS Command and Data Dictionary
- Goddard's Core Flight System (cFS) has been, is, and is intended to be used by many projects
  - Examples: Lunar Reconnaissance Orbiter (LRO), Morpheus, Exploration EMU (xEMU) spacesuit, Orion Backup Flight Software (BFS)
  - Success of the cFS concept is shown by the number cFS projects at FSW-2018
- A command and data dictionary (CDD) defines telemetry/command messages
- Each cFS project must select a way to manage their CDD
  - Frequently involves using a spreadsheet, with custom SW to convert into useful files
- cFS Command and Data Dictionary utility (CCDD) was designed as a generic utility to eliminate duplication of effort in order to make CDD management easier

CCDD Goals

- Create a configurable CDD utility that runs on multiple operating systems
  - Written in Java for maximum portability
- Easy creation/modification of CDD information
  - Graphical user interface (GUI) to interact with the database
- Store all CDD information into a standard database (postgreSQL)
- Bidirectional transfer of information to/from the CCDD
  - Cut-n-paste to Excel, import/export via XTCE/CSV/JSON
- Easy access to CDD information (via scripting languages and web applications)
  - Allows user to code in various languages (ruby/python/js) and access CDD information
    - »Create vehicle and ground software products, data summary, etc
    - »Generate complicated CFS products: Schedule or network tables, copy table, etc

Data is accessible to scripting languages (JavaScript, Python, etc.)

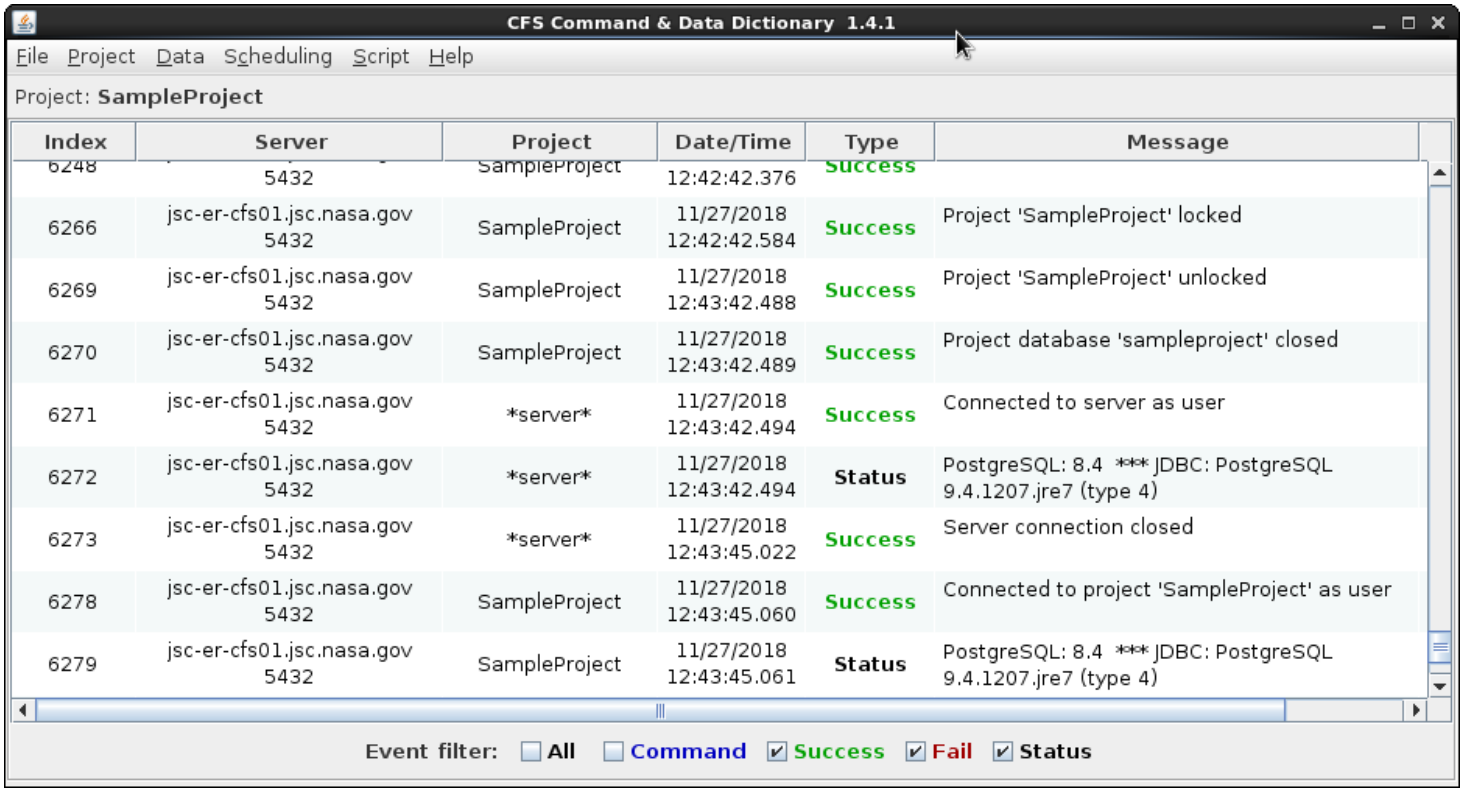
- Example scripts provided for common products



Web-based dataserver (JSON)

Imported/exported via:

- CSV (comma-separated values)
- JSON (JavaScript Object Notation)
- XML (Extensible Markup Language)
  - » EDS (Electronic Data Sheet)
  - » XTCE (XML Telemetric and Command Exchange)
- OS clipboard (“cut & paste”)


CFS Command & Data Dictionary 1.4.1
File Project Data Scheduling Script Help
Project: SampleProject
Index | Server | Project | Date/Time | Type | Message
6248 | 5432 | SampleProject | 12:42:42.376 | Success |
6266 | jsc-er-cfs01.jsc.nasa.gov 5432 | SampleProject | 11/27/2018 12:42:42.584 | Success | Project 'SampleProject' locked
6269 | jsc-er-cfs01.jsc.nasa.gov 5432 | SampleProject | 11/27/2018 12:43:42.488 | Success | Project 'SampleProject' unlocked
6270 | jsc-er-cfs01.jsc.nasa.gov 5432 | SampleProject | 11/27/2018 12:43:42.489 | Success | Project database 'sampleproject' closed
6271 | jsc-er-cfs01.jsc.nasa.gov 5432 | *server* | 11/27/2018 12:43:42.494 | Success | Connected to server as user
6272 | jsc-er-cfs01.jsc.nasa.gov 5432 | *server* | 11/27/2018 12:43:42.494 | Status | PostgreSQL: 8.4 *** JDBC: PostgreSQL 9.4.1207.jre7 (type 4)
6273 | jsc-er-cfs01.jsc.nasa.gov 5432 | *server* | 11/27/2018 12:43:45.022 | Success | Server connection closed
6278 | jsc-er-cfs01.jsc.nasa.gov 5432 | SampleProject | 11/27/2018 12:43:45.060 | Success | Connected to project 'SampleProject' as user
6279 | jsc-er-cfs01.jsc.nasa.gov 5432 | SampleProject | 11/27/2018 12:43:45.061 | Status | PostgreSQL: 8.4 *** JDBC: PostgreSQL 9.4.1207.jre7 (type 4)
Event filter: All Command Success Fail Status

CCDD Products in AA-2

- C header files defining SB command/telemetry messages
  - Define the structure for all software bus (SB) messages.
- MID file generation (Same file used by both CPUs)
  - Defines all the MIDs for each cFS message sent/received on each CPU
    - »CPU2 adds 0x100 to all the MID values sent out by CPU1
    - »Allows Ground SW to know which computer sent a message
- HK copy table generation
  - Telemetry link is constrained. Select various parts of messages to go at different rates
  - 2 separate telemetry paths (per CPU), so 4 separate messages are sent
- ITOS “rec” files (ground control system)
  - Used to define commands/messages in ITOS
- Data decom config files (post-flight data processing)
  - Provides CSV files with desired parameters to be analyzed
  - Custom built utilities to decode data from “raw” recorded telemetry files
    - »Significantly faster than data replay and seqprt utility in ITOS

- Worked to develop the CDD before the SW development was complete
  - CDD not treated as an “as built” post-development documentation effort
  - Required iterations on data structures and MIDs, but minimized interface issues
- Added ability to track ~900 DFI system parameters (in addition to OFI)
  - Allows additional insight into vehicle for all ground controllers
- Automated data processing and “quicklook” of key parameters after tests
  - Allows rapid verification of how the system performs during simulation runs
- Automated regression testing to perform SW verification activities
  - Test framework consumed CCDD-generated files to define CCSDS messages
  - Can verify any parameter (of any messages) meets expected values (at specific times)
- Automated remote control/monitoring of ground power supplies
  - Quite useful since people need to stay miles away during launch window

Future Work

- Launch (with a successful abort!) in May 2019
- Working with Education/Outreach on student outreach contest
  - Build a real-time application to show the position of the vehicle during the test
  - Winning team to view KSC launch (and see app in use)
- The CCDD tool has successfully been used to automate/autocode a large amount of software used on AA-2.
  - Pass on the lessons learned so they can be leveraged on other programs