Infrastructure and Process Improvements After LADEE

Flight Software Workshop
Dec 16, 2014

Common Avionics & Software Technologies
(CAST)

Software Lead: Karen Gundy-Burlet, Ph.D.

Avionics Lead: Craig Pires

Group: Nathan Benz, Pat Castle, Scott Christa, Greg Limes, Mike Logan, Greg Orzech

Lunar Atmosphere and Dust Environment Explorer

Objectives
- Measure Lunar Dust
- Examine the Lunar atmosphere
- 100 days in a low-equatorial lunar orbit

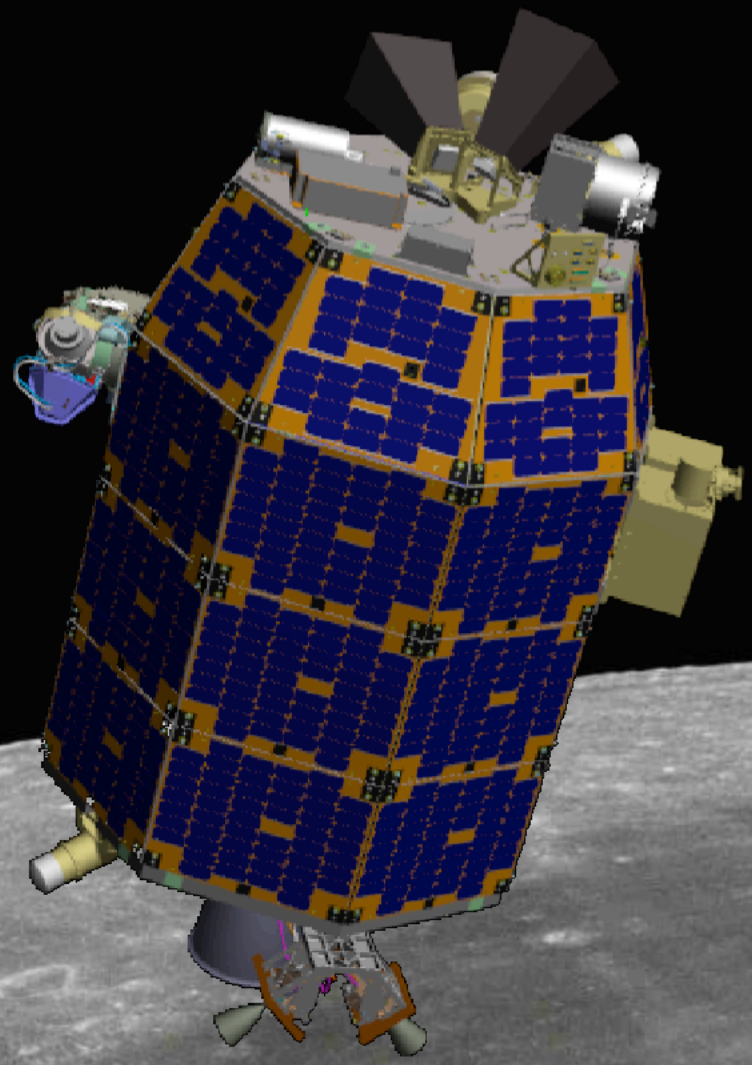
Key parameters
- Launched Sept 6, 2013
- Lunar Impact April 18, 2014

Spacecraft
- Type: Small Orbiter - Category II, Enhanced Class D
- Provider: NASA ARC and NASA GSFC

Instruments
- Science Instruments: NMS, UVS, and LDEX
- Technology Payload: Lunar Laser Communications Demo

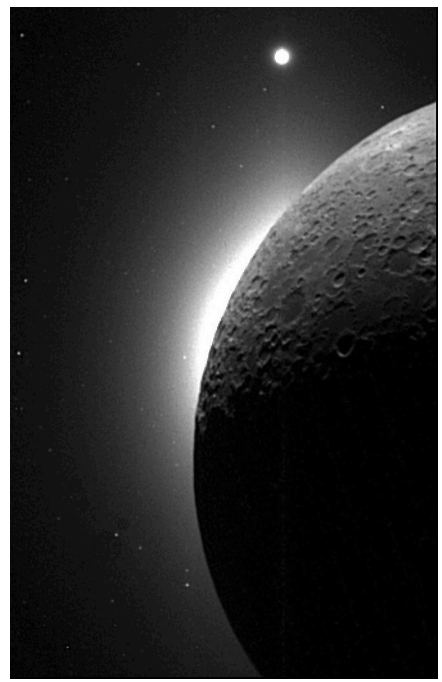
Launch Vehicle: Minotaur V

Launch Site: Wallops Flight Facility

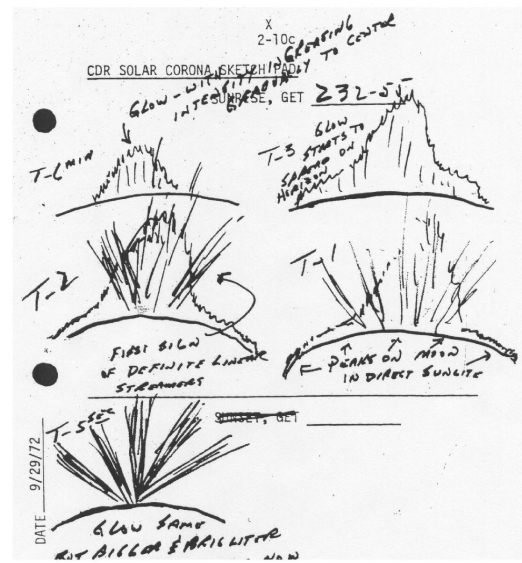


Star Tracker Images

- A series of star tracker images taken by LADEE. The lunar horizon is ahead, a few minutes before orbital sunrise.



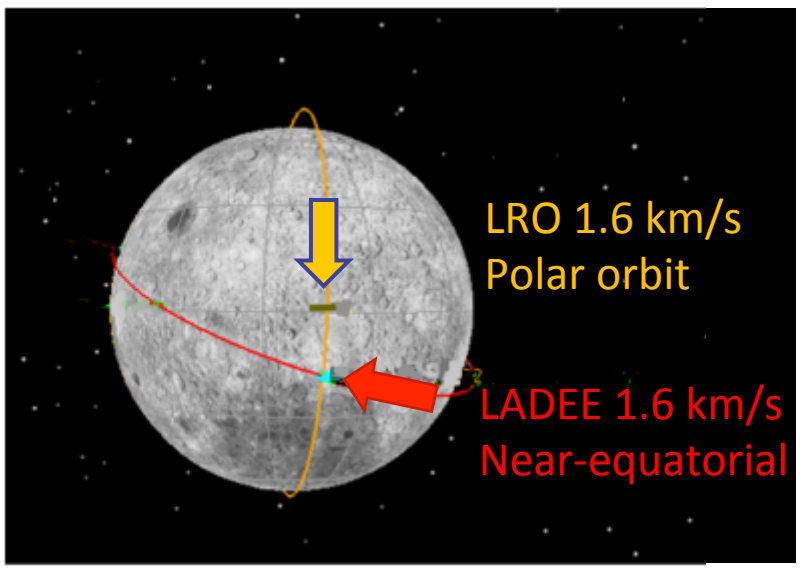
Clementine spacecraft image of moon dust corona

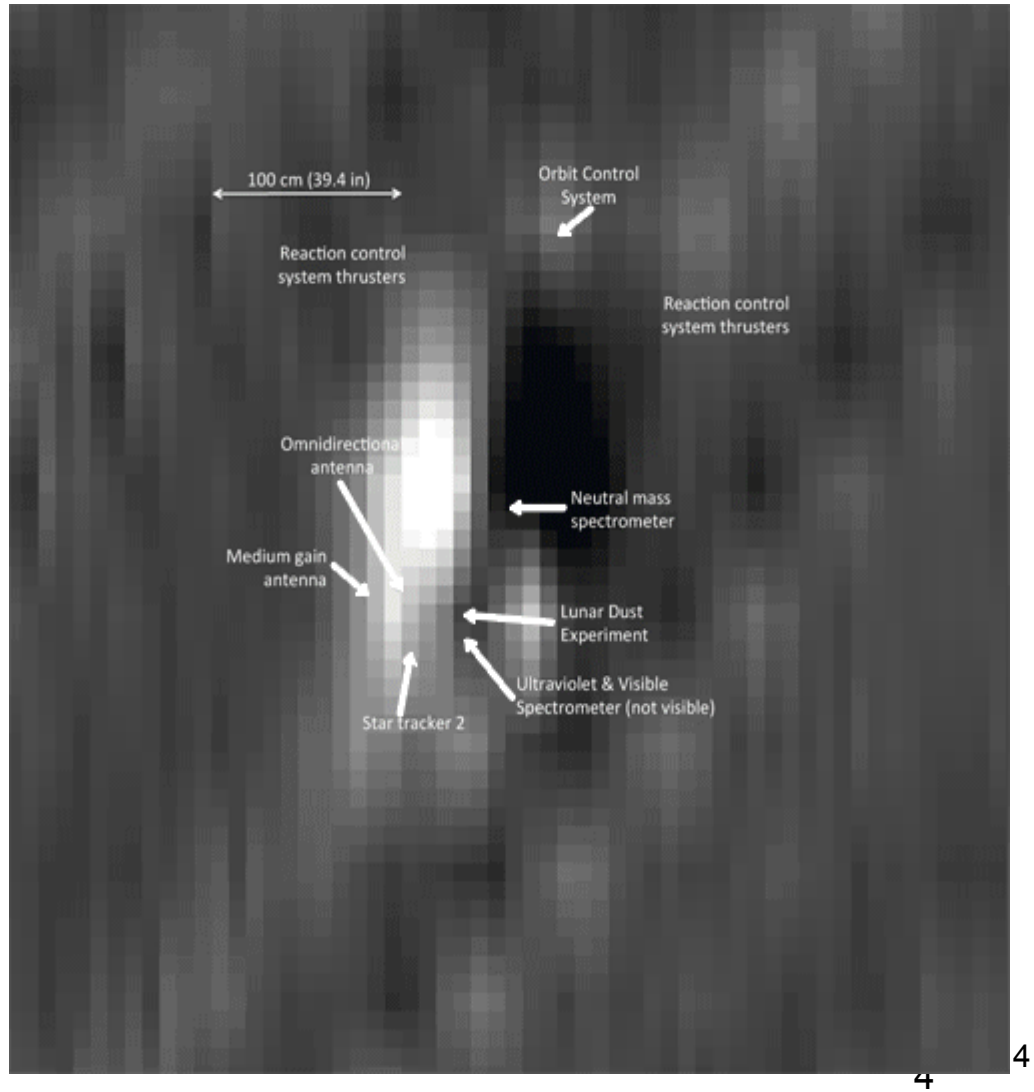


Gene Cernan's drawings of the lunar sunrise

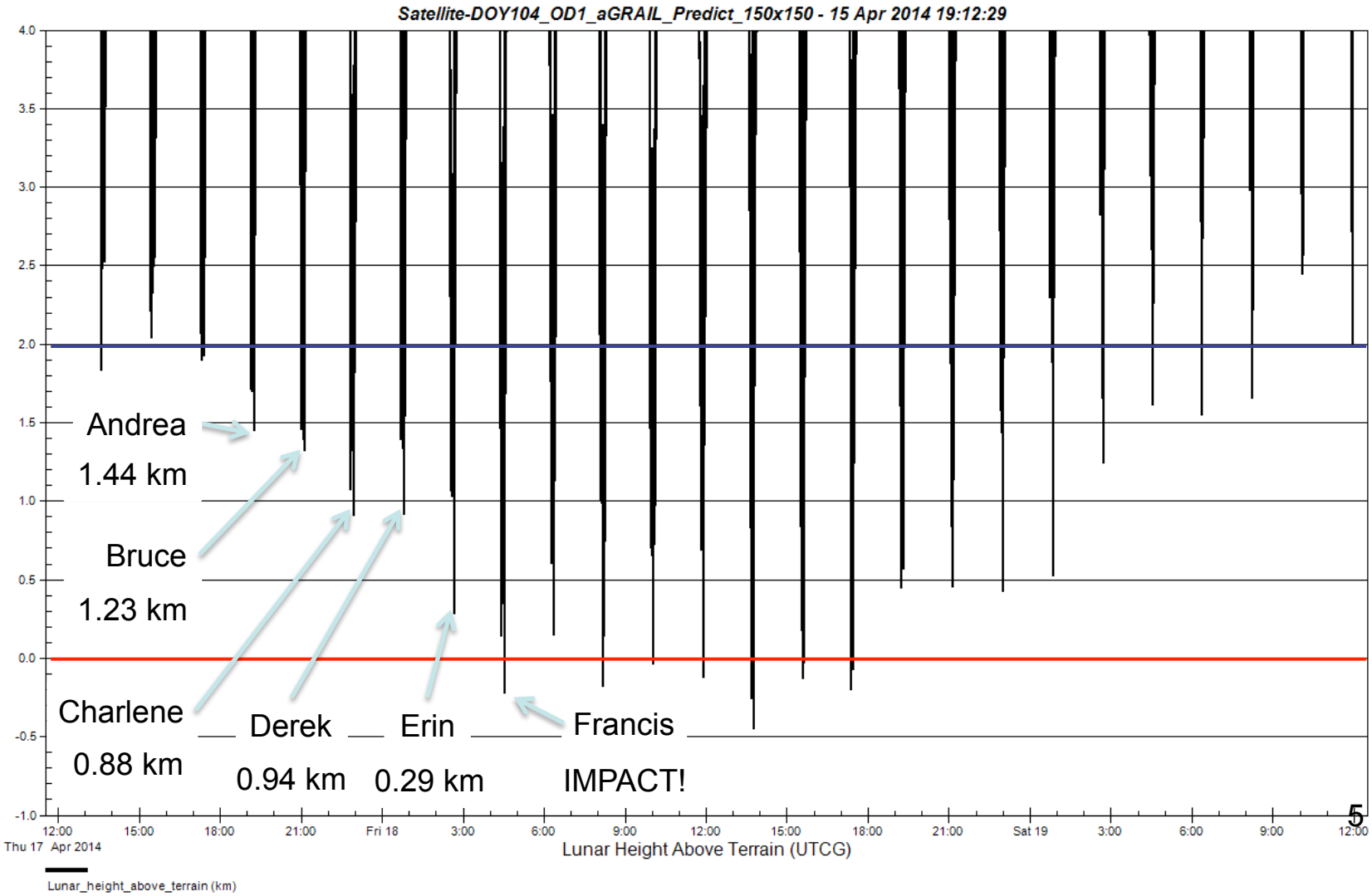
High Precision in Predicted Position

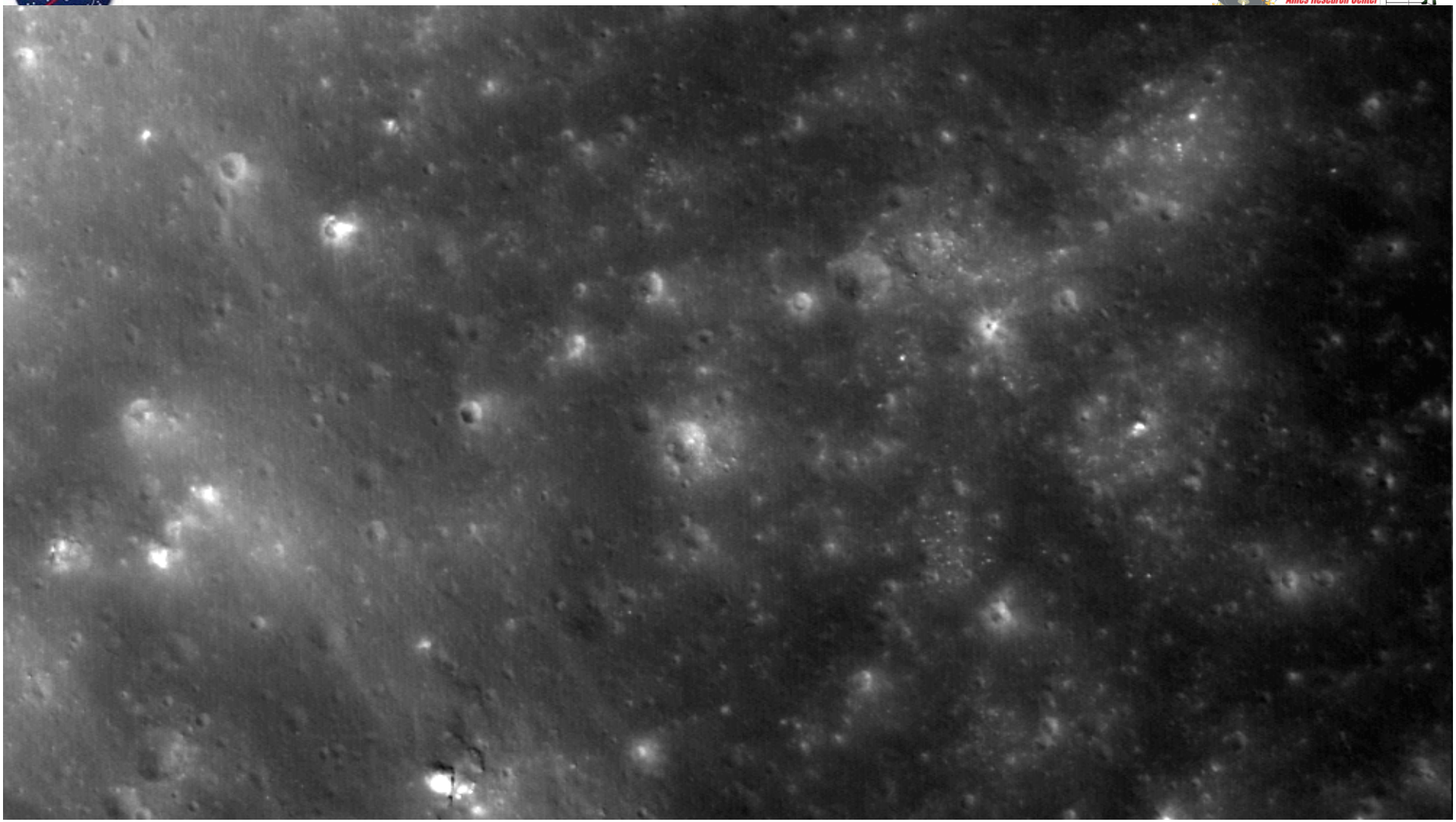
- LADEE Orbit Determination team predicted the location of the spacecraft precisely enough for an LROC photo at a high velocity fly-by
  - Two spacecraft at a nearly perpendicular orbit crossing
  - Both travelling at 1.6 km/sec





Predicted Height Above Lunar Terrain





Final Resting Place

LADEE Final Status

LADEE Flight Software

- On orbit table uploads regularly performed (ATS, RTS, FM, Thermal updates & defect reduction)
- 2 software patches to account for emergent star tracker behavior
- 1 unanticipated reboot (Interrupt Handling)
- Upload and reboot into new software load. Approximately a month's continuous operation on the new load with no defects found.
- Team recertified for CMMI level 2 in May 2013

LADEE Mission

- Successful de-orbit 4/18/2014
- Lowest science operations conducted under 2 Km over the moon's surface
- Successful Laser Communications demonstration: 622Mbs downlink rate. Very useful to be able to download a SDRAM partition in less than 2 minutes.
- Survived an eclipse!
- 188 days of lunar orbit, with approximately 200% of planned science data returned to the earth. All science goals met.

CAST

We have observed several new-start spacecraft projects at Ames abandon their efforts to utilize cFE/OSAL

- Difficulties absorbing extensive documentation
- Need experienced consultants.
- Unrealistic budget, schedule and expectations

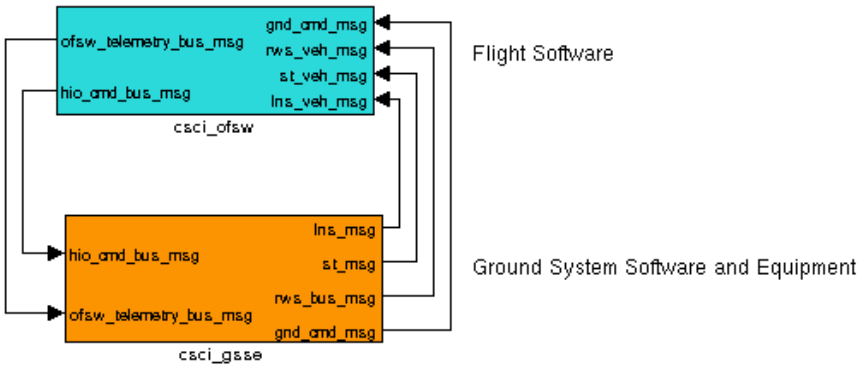
Current Effort: Common Avionics & Software Technologies

- Goal: A consulting group that provides a modular and customizable software with support for common spacecraft functions.
- Software based on the LADEE architecture, but with core components updated to modern standards
    - OSAL (based on open source 4.1.1)
    - cFE (based on open source 6.3.2)
    - cFS (LADEE version, awaiting open source)
    - vxWorks 6.9
    - Matlab/Simulink 2014a
    - Additional RTOS: Linux/Xenomai, RTEMS

Flight Software Overview

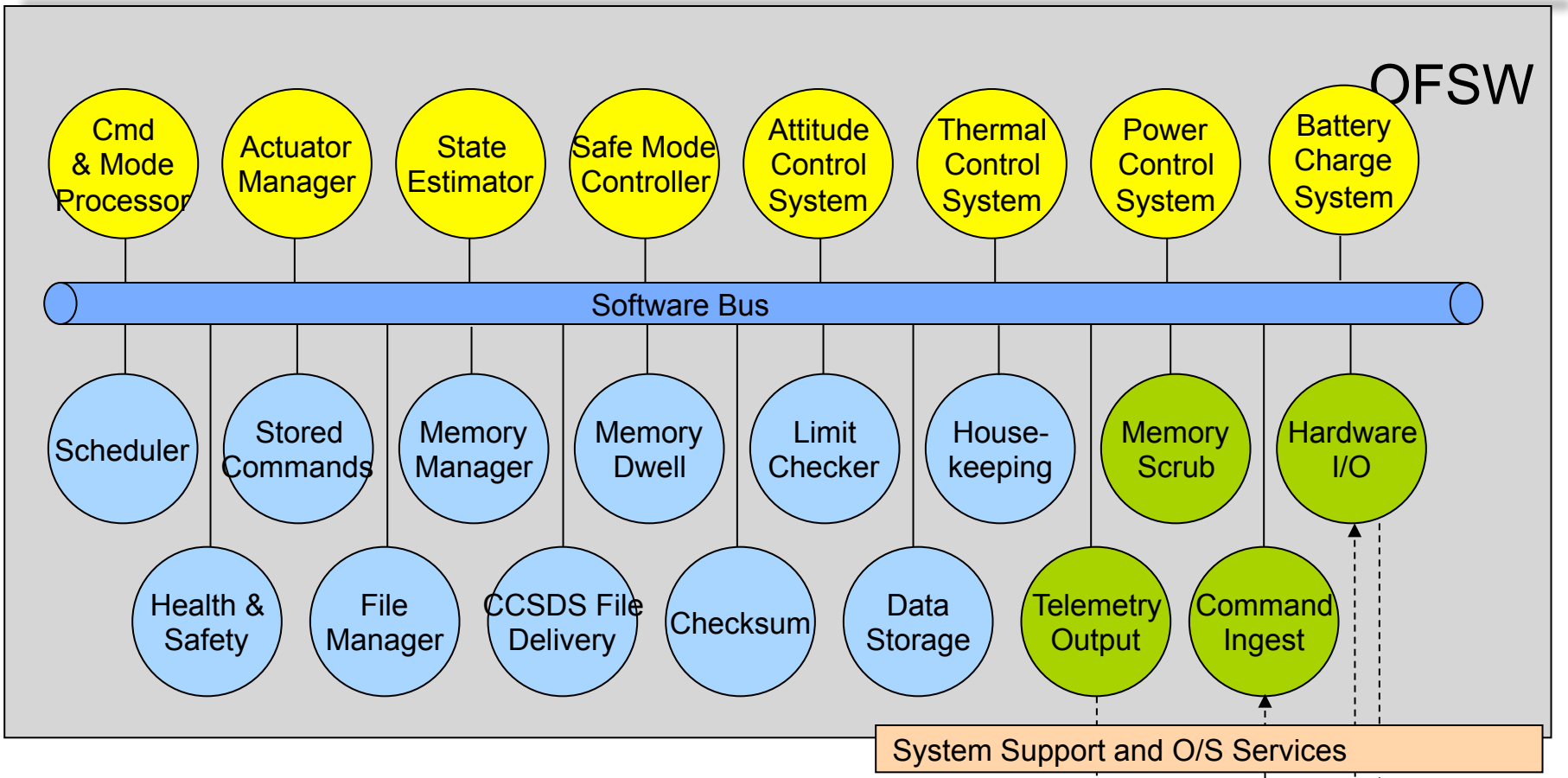
- Scope
  - Onboard Flight Software (Class B)
  - Support Software and Simulators (Class C)
  - Integration of FSW with avionics
- Guiding Documents
  - NPR7150.2 Software Engineering Requirements
    - CMMI Level 2 or Equivalent
  - NASA-STD-8739.8 NASA Software Assurance Standard

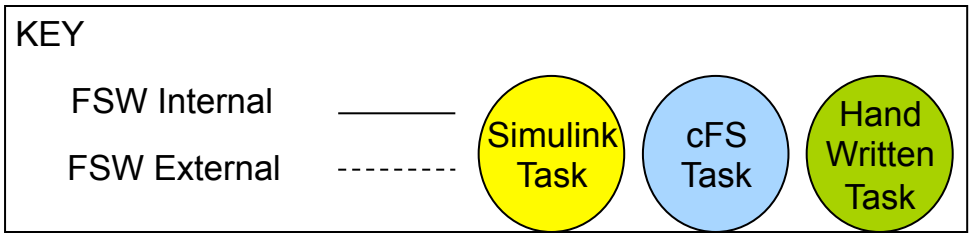
LADEE



- Development Approach
  - Model Based Development Paradigm (prototyped process using a "Hover Test Vehicle")
  - 5 Incremental Software Builds, 2 Major Releases
- Leverage Heritage Software
  - GSFC OSAL, cFE 5.2.0, cFS, ITOS
  - Broad Reach Drivers, VxWorks 6.8
  - Mathworks Matlab/Simulink 2010b & associated toolboxes
- Heritage Software Components frozen ~ 2011.

FSW Architecture





Telemetry
Gnd Cmds
Hdwr Cmds
Sensor Data

GSFC OSAL, cFE, cFS, ITOS (GOTS)
Broad Reach Drivers (MOTS)
Simulink/Matlab, VxWorks (COTS)

Processors and Practices

Integrated with a range of processors

- Trade study to make it easier for spacecraft to identify acceptable processors with necessary performance and budget constraints.
- Initial Processors targeted:
  - Beagle Bone Black
  - Zynq
  - PowerPC 750
  - LEON

- Provide a set of Software Engineering Practices and Documentation to quick start spacecraft software development effort
  - Git
  - Confluence/JIRA
  - Bamboo Continuous Test
  - NPR 7150.2 required plans
  - Extensive Test Suite
  - Peer Review/Formal Inspection

Collaborations

The CAST group is in the process of Open Sourcing the “Simulink Interface Layer for cFE/cFS”

- Sample Simulink model and interface wrappers with detailed instructions for integration with cFE.
- Currently consistent with the open source 6.3.2 version of cFE
- Updating to 6.4.0 and will ensure that it is consistent with the open source version of cFS when GSFC is able to release it.
- Extensive legal process… no firm date for open source at this point, but it is available under a software usage agreement

We are participating in the cFS Working Group

- Several NASA centers collaborating on cFS development to avoid duplication of effort and speed updates to the open source code-base.

Proposing the new software and avionics base as a core for many upcoming missions:

- Resource Prospector, CubeSat line, LADEE follow-on…