



Overview of Avionics and Electrical Ground Support Equipment

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49th AIAA Aerospace Sciences Meeting

Orion Pad Abort 1 Flight Test

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Avionics Overview: Relevant Test Objectives



- **Primary Objectives**

- AC01p. Demonstrate the capability of the LAS to propel the CM to a safe distance from a launch vehicle during a pad abort.
- S01p. Demonstrate abort event sequencing from abort initiation through LAS jettison.
- AC03p. Demonstrate ground-initiated abort.
- DS02p. Demonstrate stability and control characteristics of the LAV due to the LAS.
- P02p. Demonstrate the ability of the LAS to jettison from the CM.
- P01p. Determine the performance of the abort motor.
- P04p. Determine the performance of the ACM.
- S07p. Demonstrate jettison of the forward bay cover.
- S09p. Obtain data on ground impact locations for LAV modules and elements.

- **Secondary Objectives**

- R01s. Demonstrate parachute assembly system event sequencing.
- R02s. Demonstrate the deployment of the drogue parachute system.
- R03s. Obtain data on performance of the drogue system.
- R04s. Demonstrate the deployment of the main parachute pilot chute.
- R05s. Demonstrate the performance of the main parachute system.

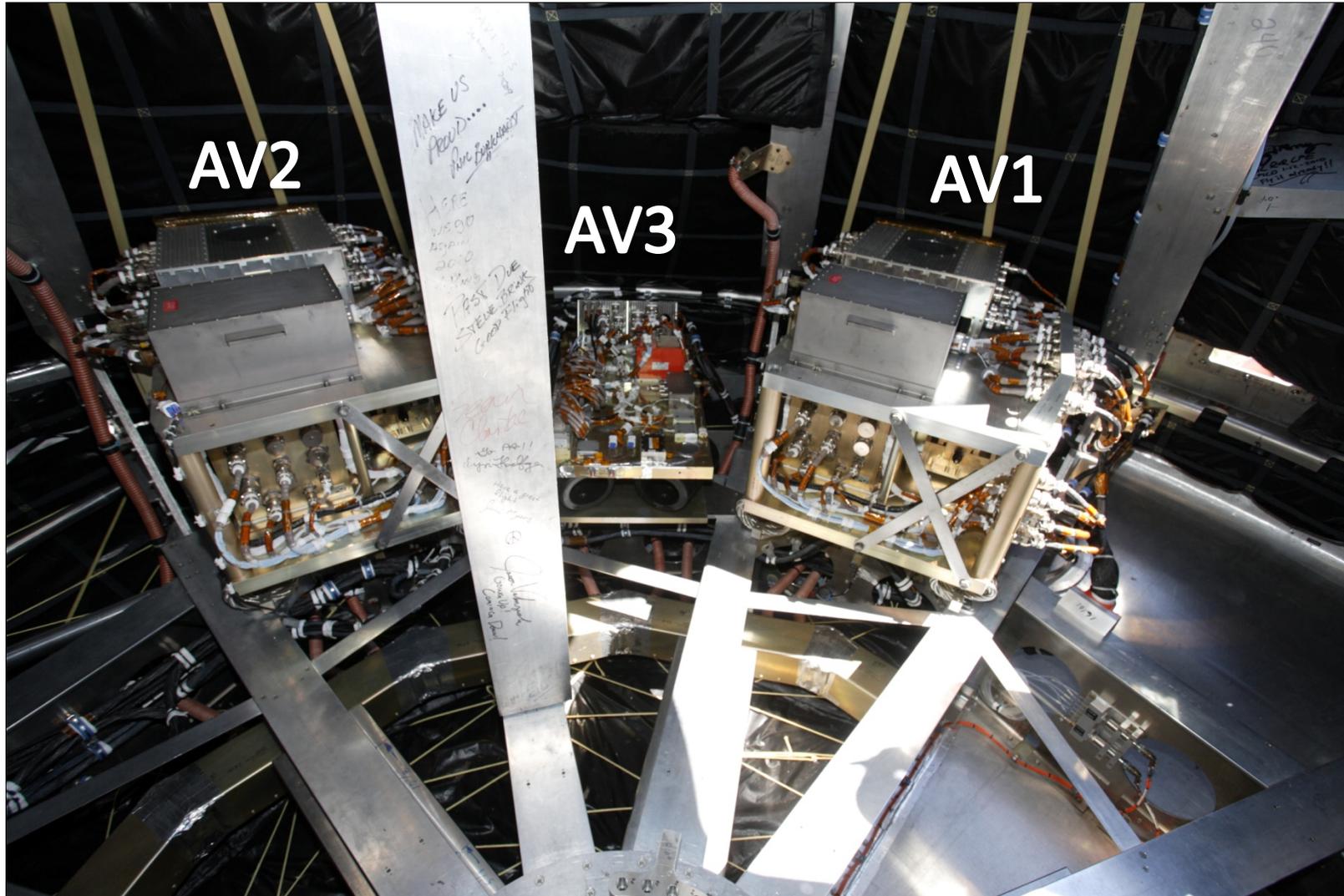
Avionics and FSW supported these objectives



Avionics Overview: Palletized Packaging



Project Orion Abort Flight Test

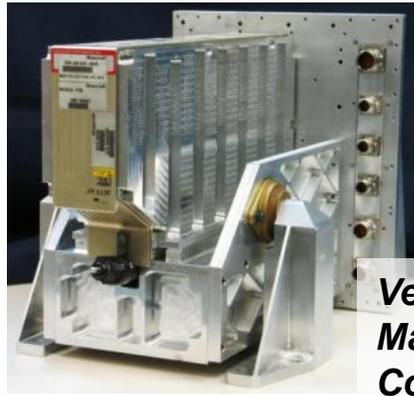




Avionics Overview: Components



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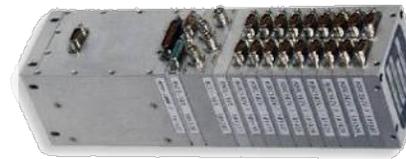
Vehicle Management Computer
(Honeywell)



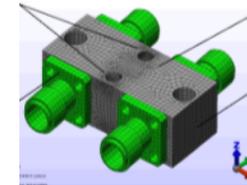
Flight Data Recorder
(Teletronics)



RF Transmitter
(Teletronics)



Master Data Acquisition Unit
(Teletronics)



RF Hybrid
(Merrimac)



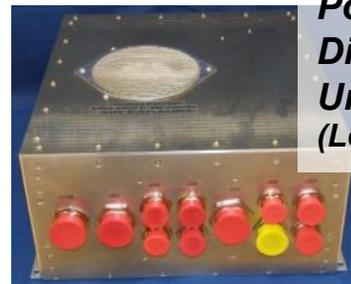
Remote Interface Unit
(Honeywell)



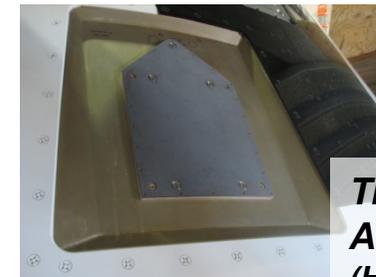
Main Vehicle Battery
(EaglePicher)



SIGI-INS unit without GPS
(Honeywell)



Power Distribution Unit
(Lockheed)



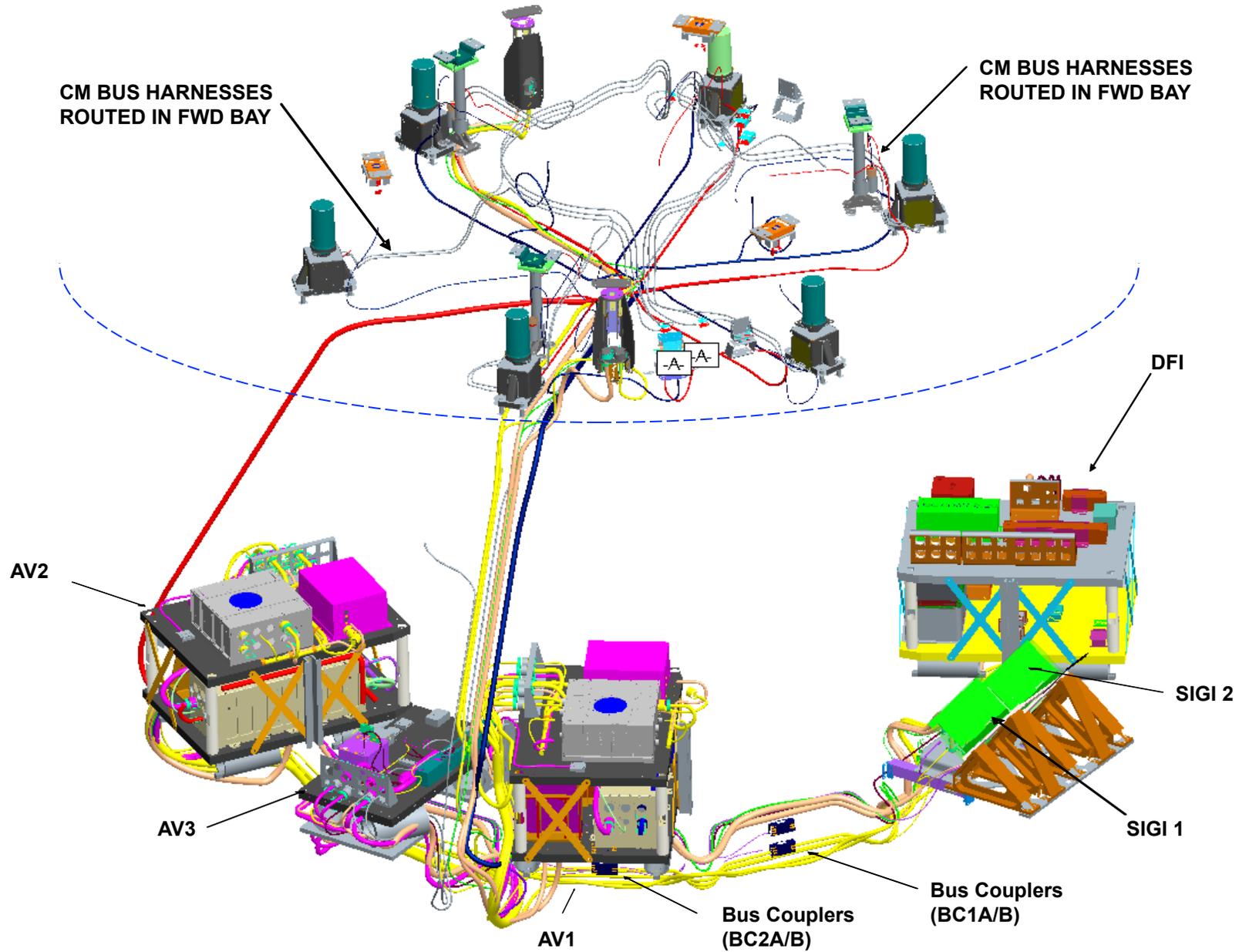
Tri-Band Antenna
(Haigh-Farr)



Avionics Overview: Component Layout



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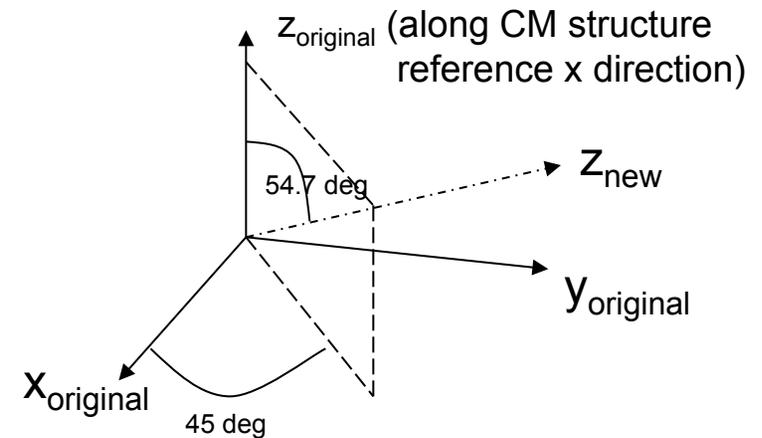
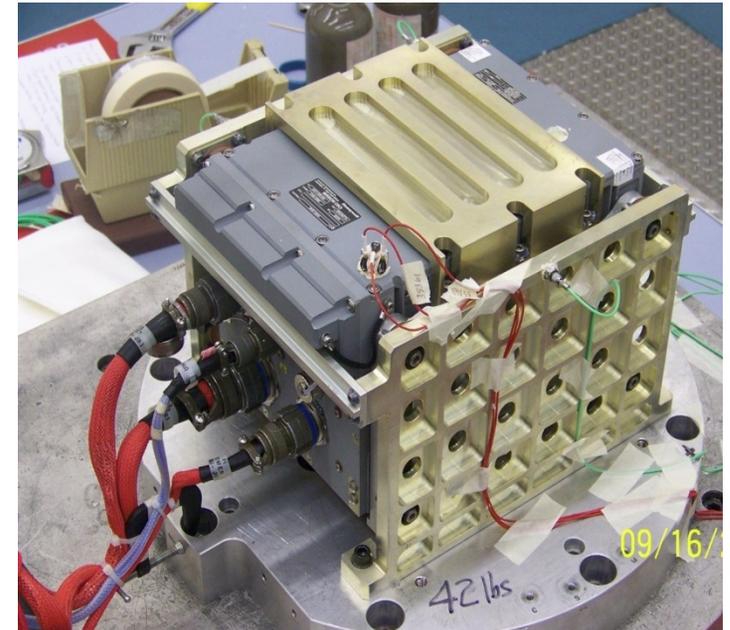




Flight SIGI



- PA-1 large angle of attack knowledge error; attributed to design of PA-1 orientation
 - Environmental testing resulted in vertical velocity and altitude errors which affected angle of attack
 - Tests at high steady g in vertical channel plus random vibration saturated sensors
- Solution: Mount SIGI with diagonal axis vertical. Instead of 19 g on a single vertical channel, 11 g will be sensed by all 3 channel

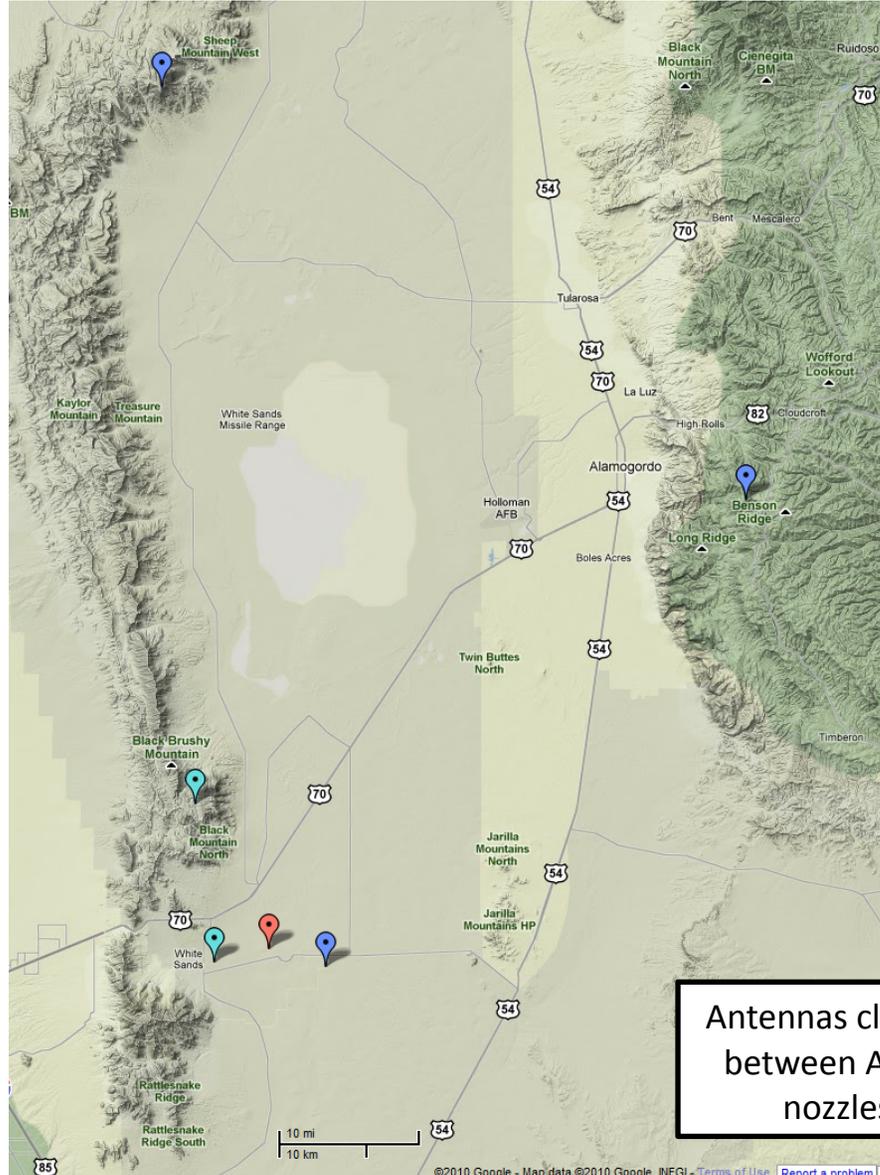




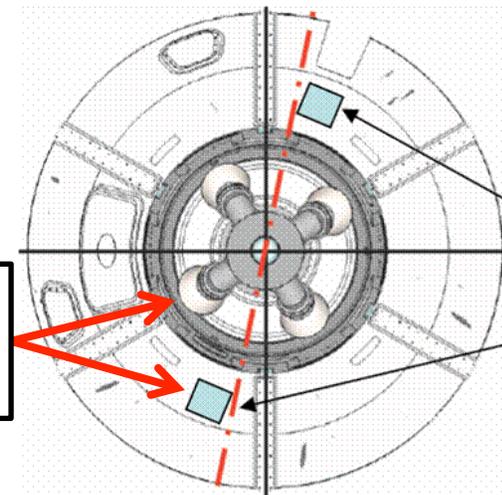
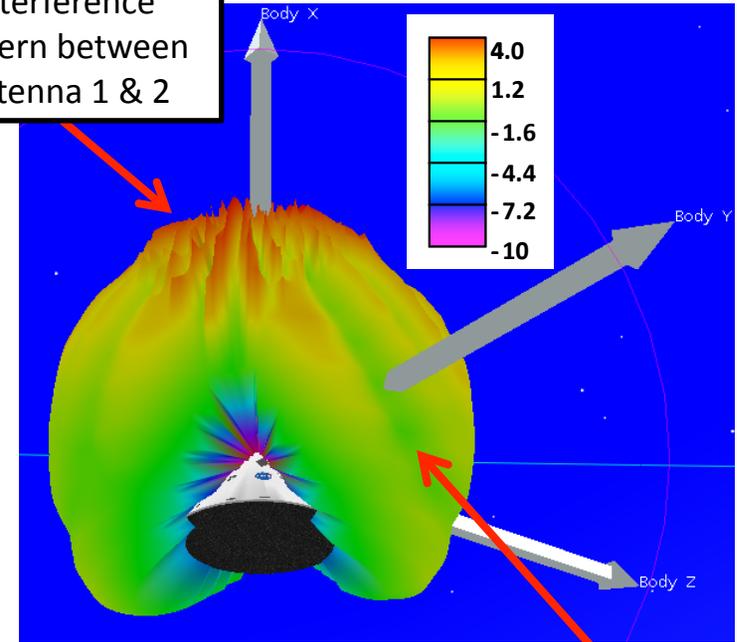
Antenna Analysis



Project Orion Abort Flight Test



Interference pattern between Antenna 1 & 2



Abort plume assumed to be opaque

Antennas clocked between Abort nozzles

Tri-Band Antennas



Battery Cycle Life / Recharge Logistics



- Vendor recommended charging algorithm: Charge at 7.5 A until battery terminal voltage reaches 38V, then reduce current limit to 2.0 A until terminal voltage reaches 38V again
- Two battery charging tests conducted; resulted in algorithm bypassing high current charge and entering top-off phase immediately
- Additional tests and consultation with EaglePicher concluded that a period of inactivity produced a passivation layer, and, combined with the high state of charge (SOC), resulted in an elevated charging terminal voltage.

Solution:

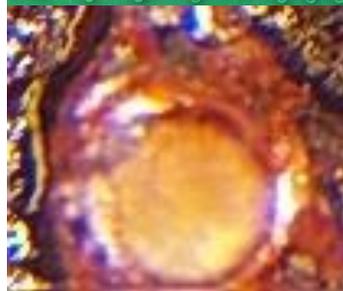
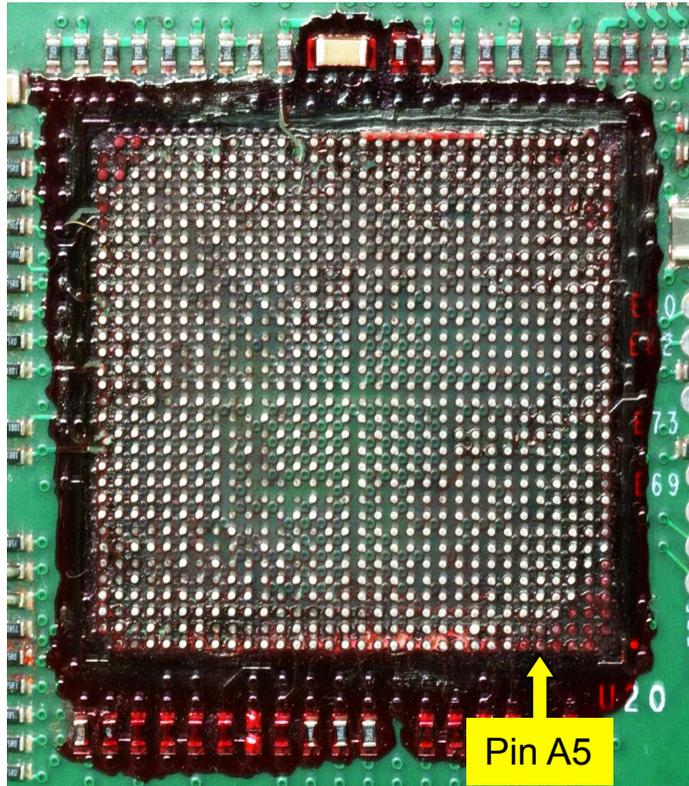
- To avoid charging, developed go/no-go SOC criteria of 25% (25AH; 200% estimated usage for day of flight). Equates to approx 4 scrubs before the batteries need to be recharged in addition to planned pre-launch tests
 - 87 AH initial SOC (after the 3 planned tests)
 - 10.6 AH used per launch scrub
 - 15.01 AH used for worst case launch scenario
- No change to battery charging algorithm. If charging is required, discharge the batteries to 25AH or less prior to charging



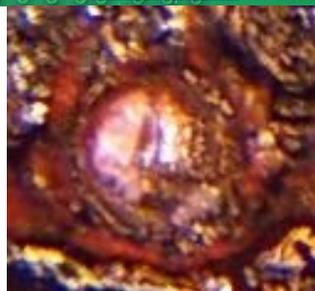
FT-VMC Issues and Resolution



U20 – CCA side



U20 Pin A5
Device side



U20 Pin A5
CCA side

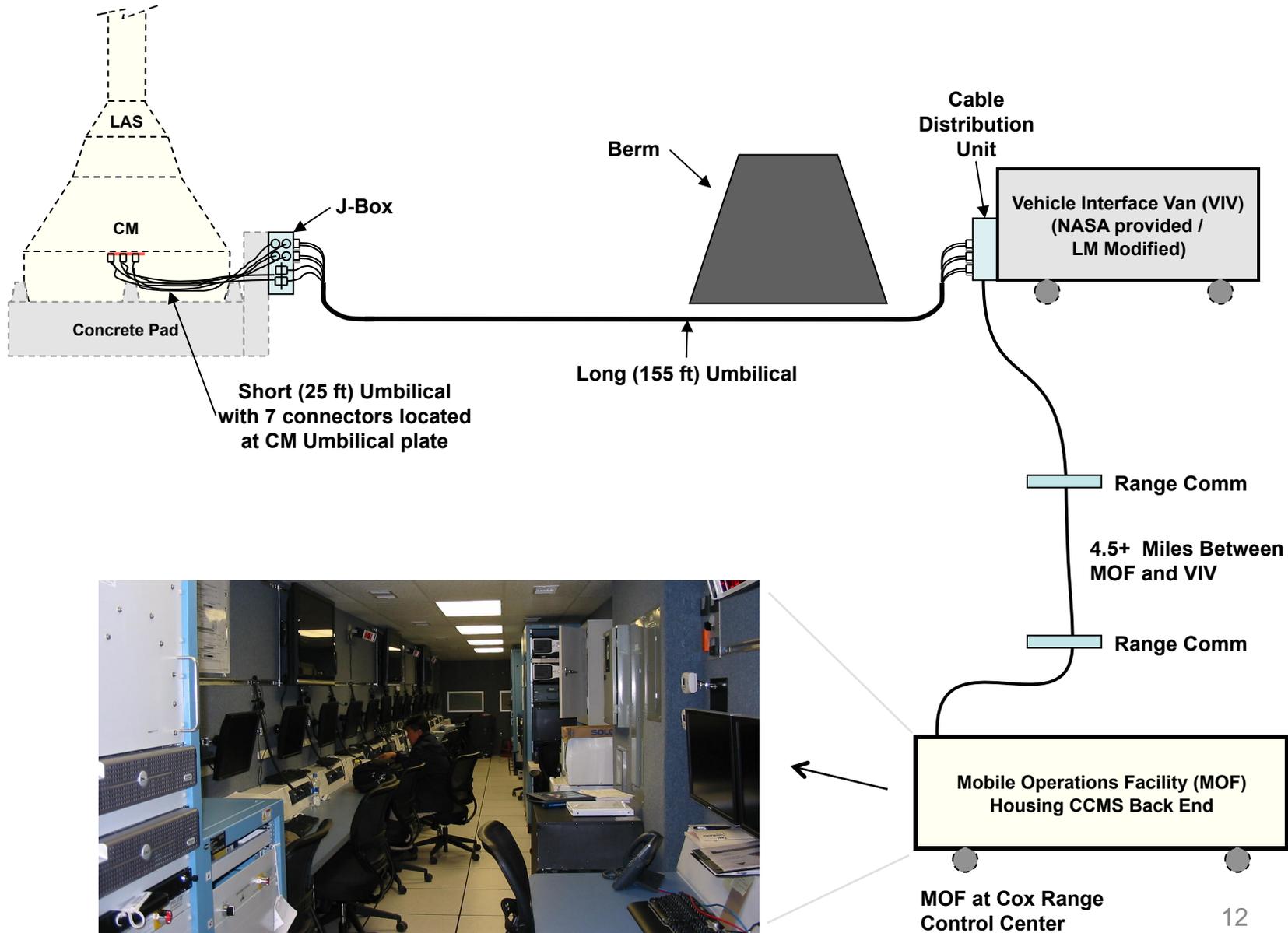
- FT-VMC BGA Black pad Issue (Risk #3941)
 - Black pad evidence on high vibration failed test unit (unmodified rugged chassis) in development testing
 - Black pad phenomenon occurs when the ball grid array on a device soldered to the printed wire board fractures or has debonded (open pads)
 - The root issue is anomalies in the inter-metallic bonds during the manufacturing process. This leads to a weakened joint and potential premature failure at these points
 - Industry phenomenon
 - Second test shows no black pad
 - Part is Altera Stratix 3 FPGA
- Conclusion: accepted risk for PA1



EGSE Overview: Launch Configuration

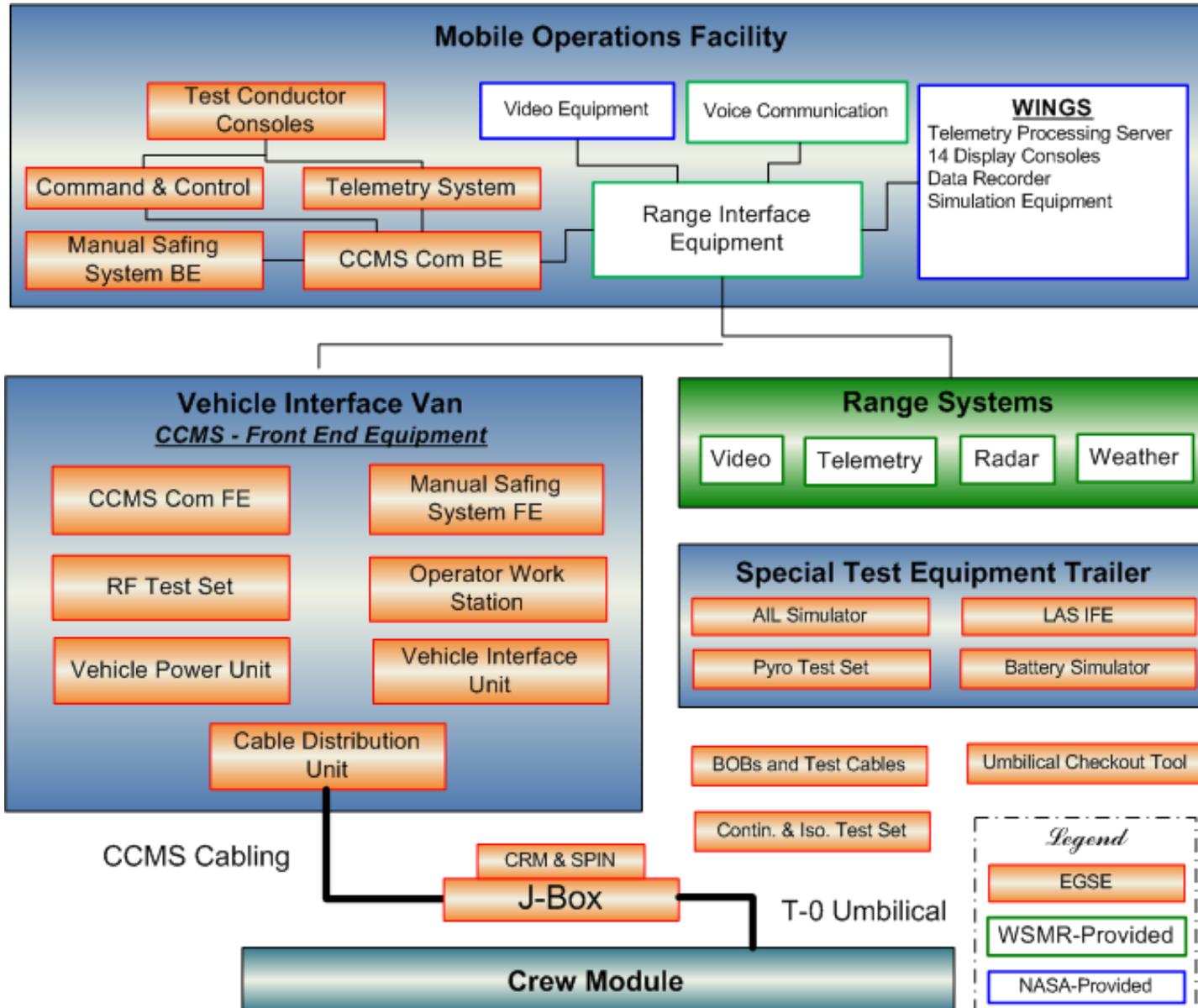


Project Orion Abort Flight Test





EGSE Overview





Open Avionics Issues at T-0



- At T-27d, Remote Interface Unit 2 (RIU2) failed to respond correctly on all interfaces upon power up.
 - Telemetry (MDAU serial link) and VMC point-to-point unresponsive
 - Ethernet interface degraded (intermittent ICMP response, no command response)
 - Voltage and Currents were nominal
 - RIU1 behaved nominally
- Lab units never showed this behavior, even after an aggressive power-cycle test (power cycled approx 100 times consecutively)
- Project team elected not to attempt the power cycle test on flight units to reduce risk of damage or further degradation.
- Root cause has not been isolated. May be grounding problem. Power cycle test was performed post-flight, no recurrence of symptoms observed.



Open Avionics Issues at T-0



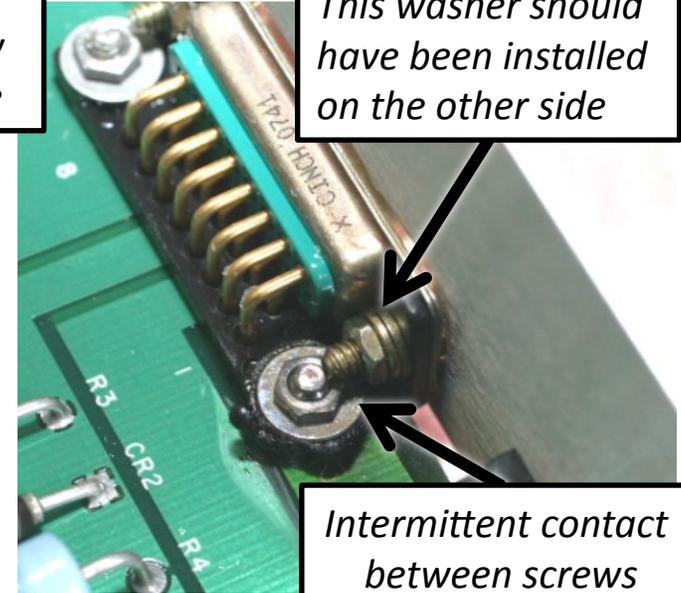
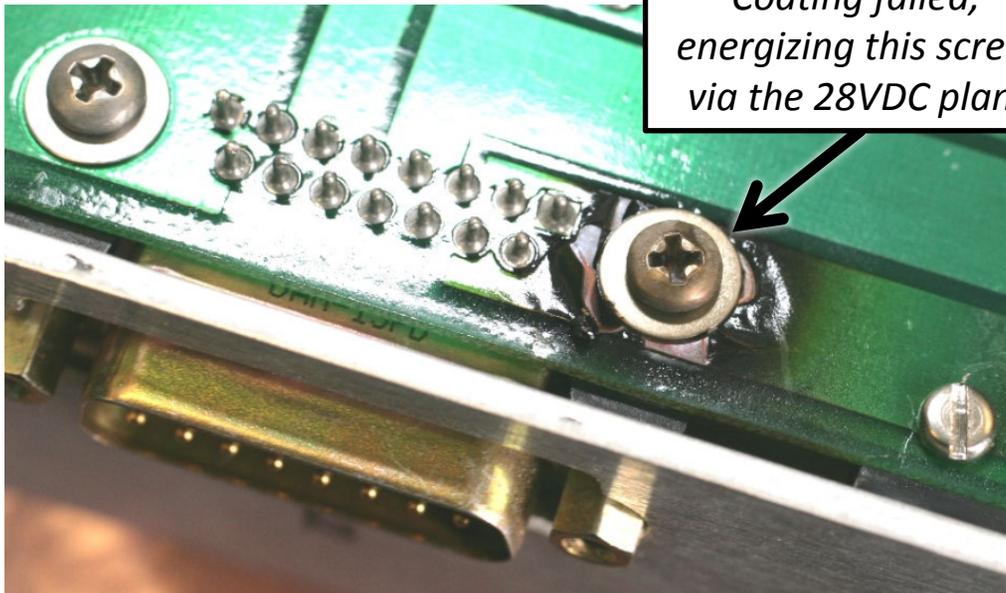
- SIGI2 exhibited increasing drift in the position solution throughout the vehicle integration and system testing phase. Requirement was “< 0.6 ft/s”
 - Altitude Go/No-Go limits exceeded (-41% margin), accepted as this is not used by the GNC control loop
 - Drift error disappeared on Day of Flight
- CM Main Vehicle Battery 1 (MVB1) voltage was slow to recover following brief (< 1 minute) load test at T-24 hours
 - Test and performance history of this battery indicated that the activation acceptance testing at the manufacturer showed similar behavior on this particular serial number. It was within acceptance criteria so it wasn't flagged.



Open EGSE Issues at T-0



- Vehicle Interface Unit 'Voter Card' shorted intermittently.
 - At T-18d, routine checks found that the CM skin had become energized by the VIV ground reference.
 - Upon investigation, root cause found to be jack screw not installed according to drawing and a failure of the PCB conformal coating.
 - Replaced failed board with spare. Inspected remaining 8 boards for similar failures, replaced all post-flight.





Open EGSE Issues at T-0



- Command and Control Server failed to enumerate RIUs correctly for the first time at T-2h25m
 - Prevented automatic verification of avionics built in test (cursory inspection found no avionics problems)
 - Analyzed all the logfiles available in real time using system experts in the Mission Engineering Room and the engineering teams standing by in Denver and Houston
 - At T-39m, decided to reinitialize the EGSE command server and rerun avionics built in test to verify no avionics issues were masked by the EGSE failure.
 - Had not happened before or since

Response notification delayed

```

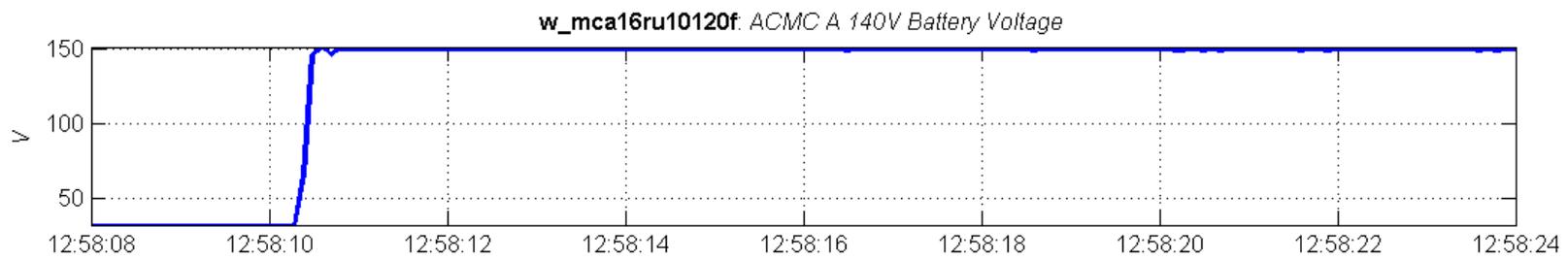
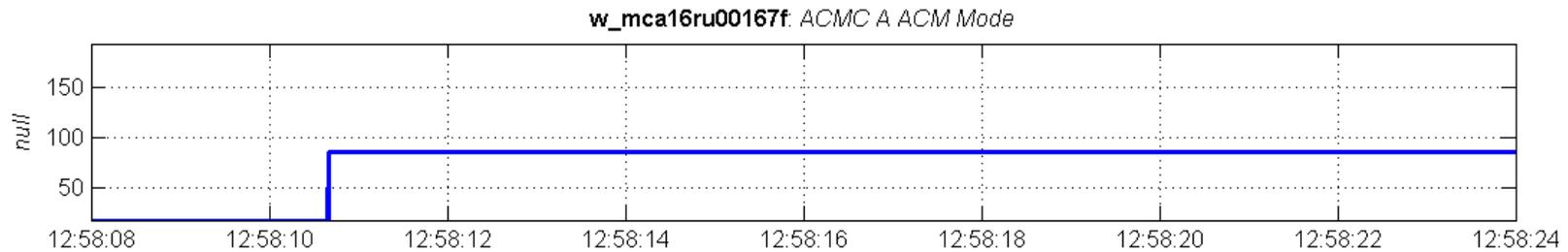
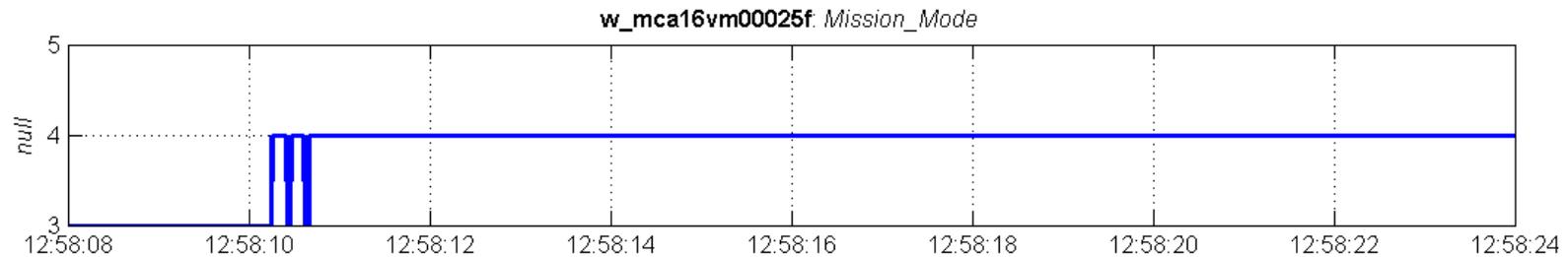
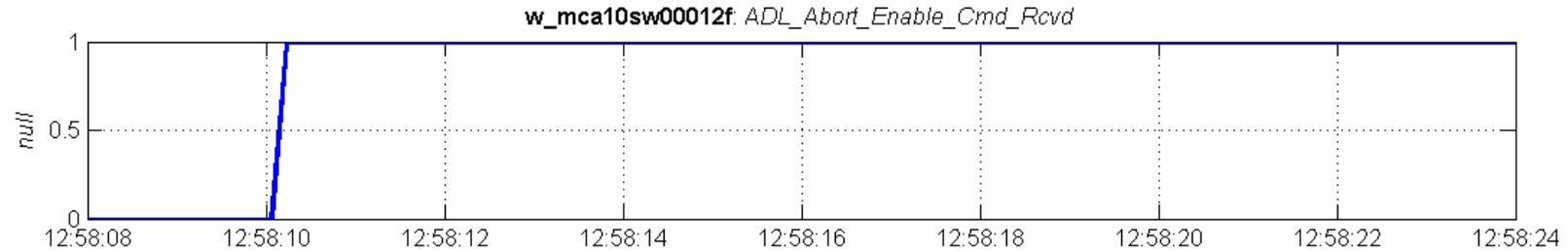
2010-05-06T10:35:05.032Z ... RIU1
2010-05-06T10:35:05.032Z ... COMMAND RESPONSE
2010-05-06T10:35:05.032Z ... Msg Num: 1
2010-05-06T10:35:05.032Z ... Packet Type: 17
...
2010-05-06T10:35:17.039Z ... RIU1
2010-05-06T10:35:17.039Z ... COMMAND RESPONSE
2010-05-06T10:35:17.039Z ... Msg Num: 1
2010-05-06T10:35:17.039Z ... Packet Type: 17
...
2010-05-06T10:35:17.071Z ... RIU1
2010-05-06T10:35:17.071Z ... COMMAND RESPONSE
2010-05-06T10:35:17.071Z ... Msg Num: 2
2010-05-06T10:35:17.071Z ... Packet Type: 17
...
2010-05-06T10:35:27.993Z ... RIU1
2010-05-06T10:35:27.993Z ... COMMAND RESPONSE
2010-05-06T10:35:27.993Z ... Msg Num: 2
2010-05-06T10:35:27.993Z ... Packet Type: 17
...
2010-05-06T10:35:28.031Z ... RIU1
2010-05-06T10:35:28.031Z ... COMMAND RESPONSE
2010-05-06T10:35:28.031Z ... Msg Num: 3
2010-05-06T10:35:28.031Z ... Packet Type: 17
...
2010-05-06T10:35:30.275Z ... RIU1
2010-05-06T10:35:30.275Z ... COMMAND RESPONSE
2010-05-06T10:35:30.275Z ... Msg Num: 3
2010-05-06T10:35:30.275Z ... Packet Type: 17 17
  
```



Avionics Flight data: Abort Enable



Project Orion Abort Flight Test



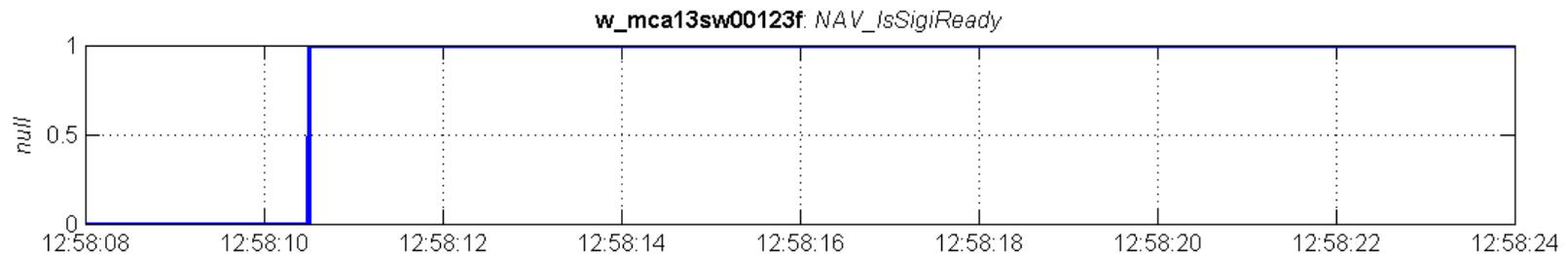
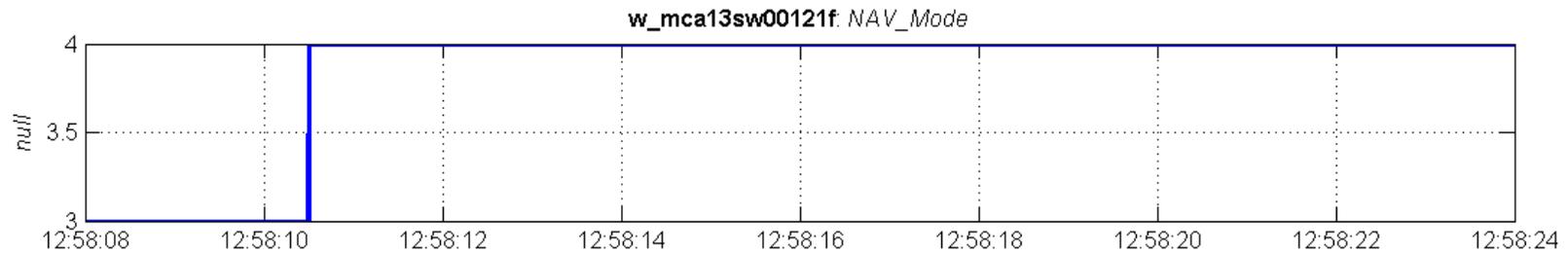
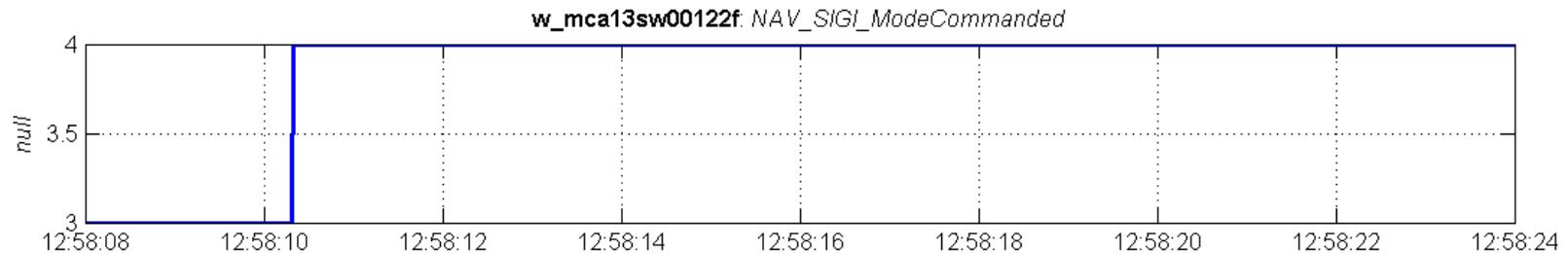
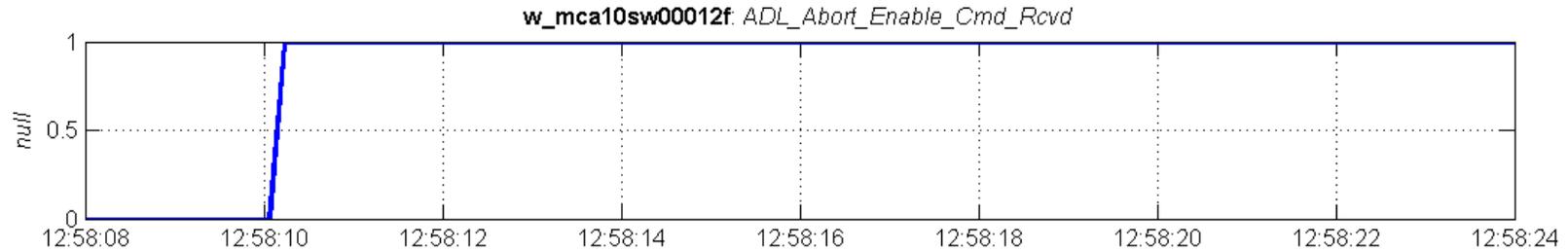
12:58:08.000 ← UTC Time (HH:MM:SS) → 12:58:24.000



Avionics Flight data: Abort Enable



Project Orion Abort Flight Test



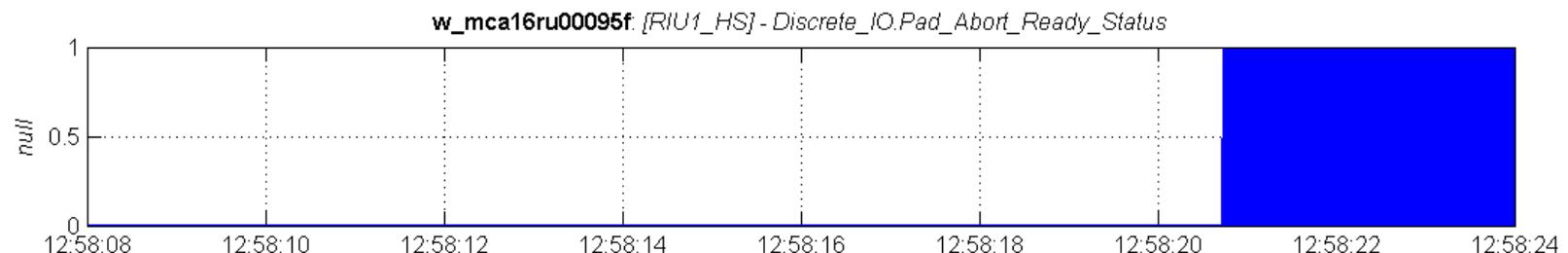
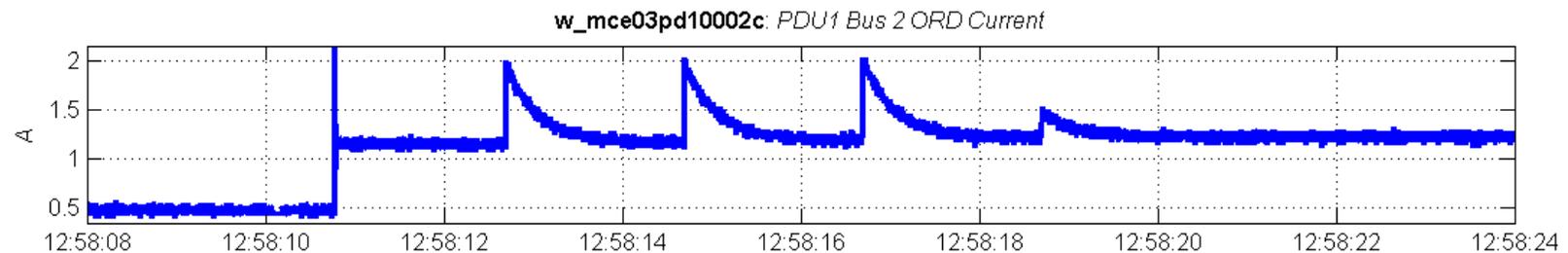
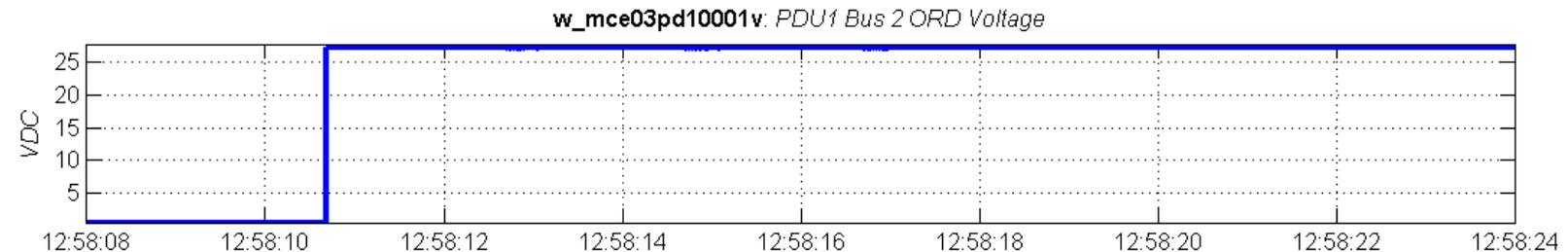
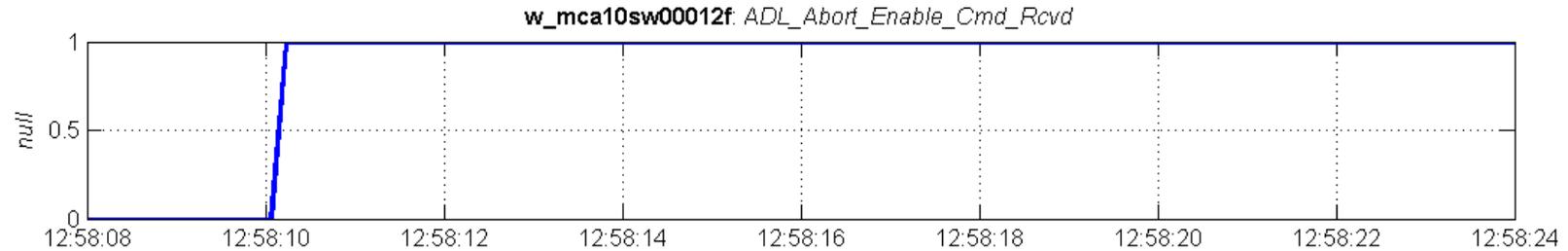
12:58:08.000 ← UTC Time (HH:MM:SS) → 12:58:24.000



Avionics Flight data: Abort Enable



Project Orion Abort Flight Test



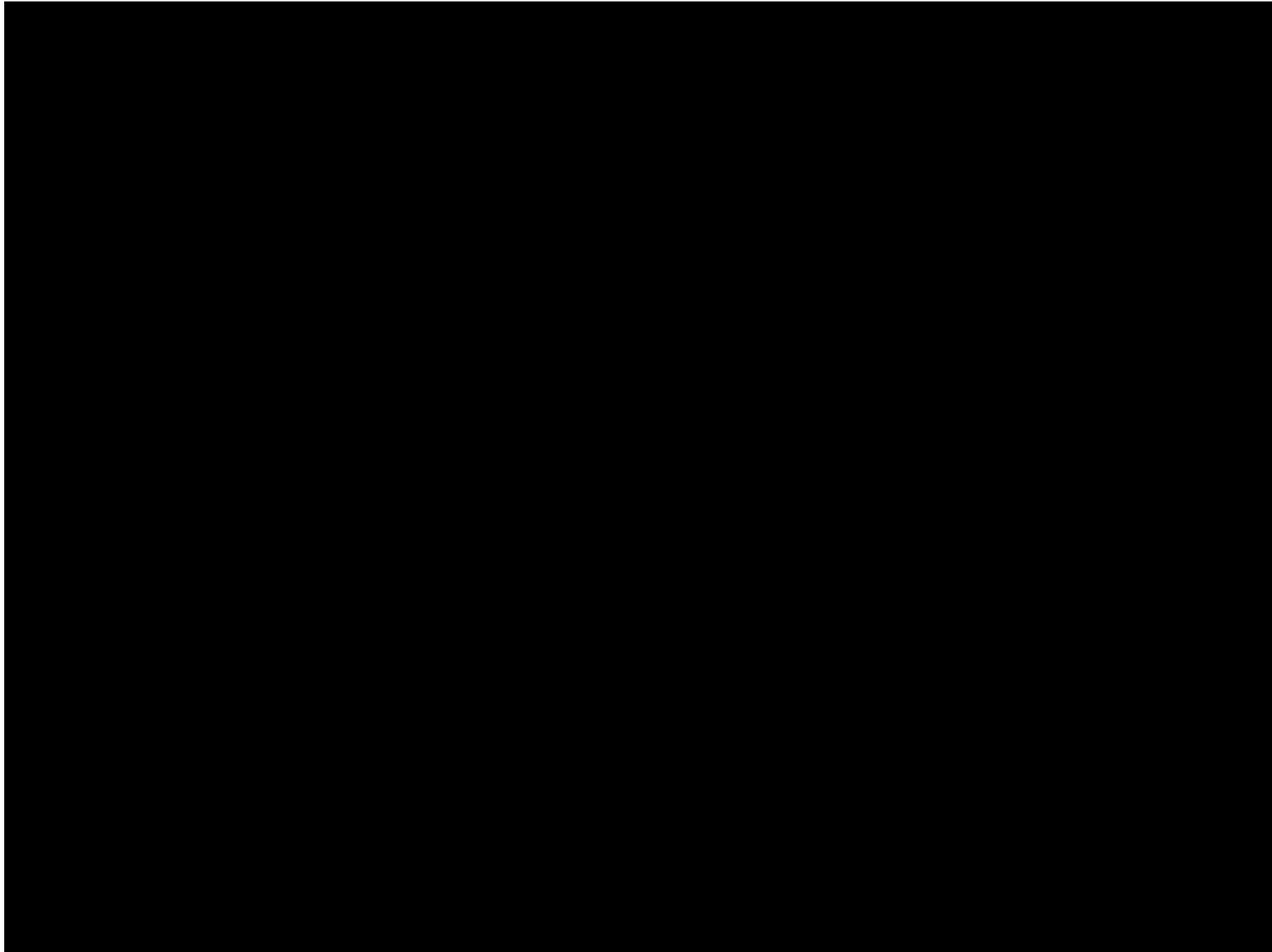
12:58:08.000 ← UTC Time (HH:MM:SS) → 12:58:24.000



Avionics Flight data: Abort Enable



Project Orion Abort Flight Test



Video from <http://www.youtube.com/watch?v=IfKzAZY2tTk>

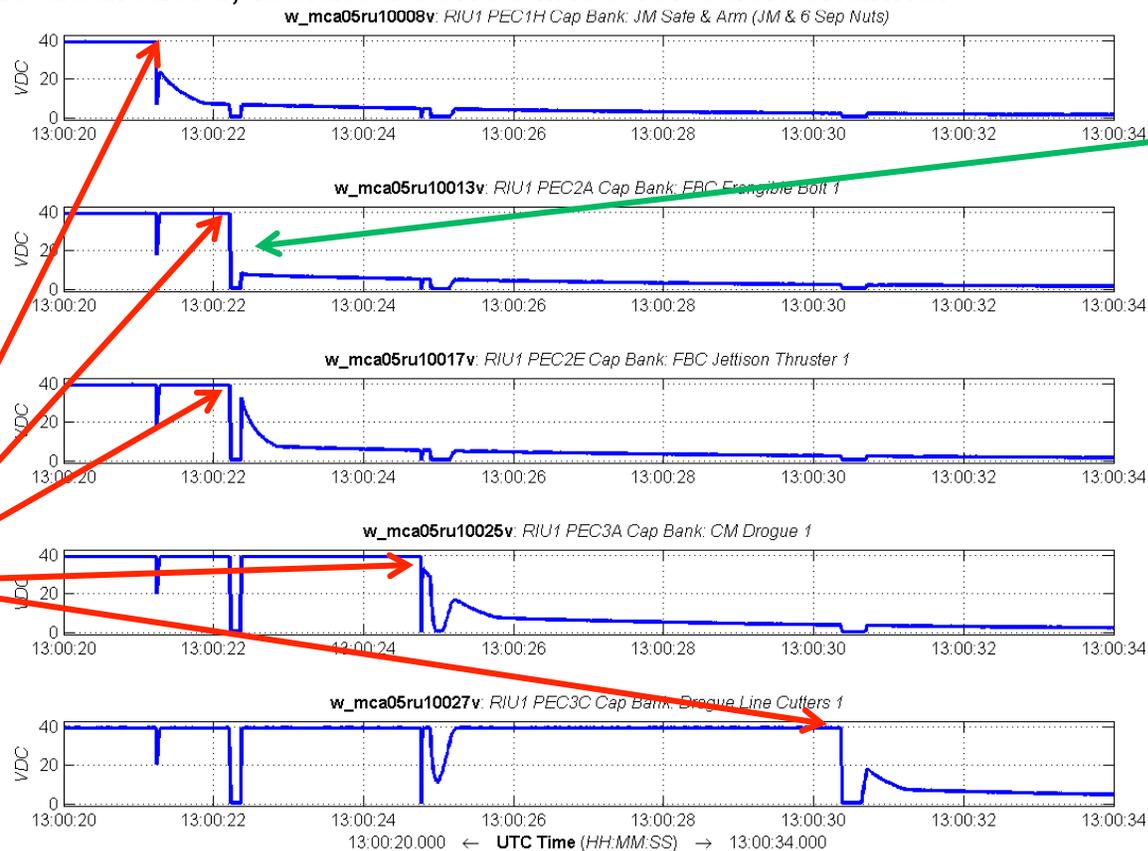


Flight Data: PEC Channel Crosstalk



Project Orion Abort Flight Test

- Due to PEC and MDAU design, erroneous telemetry can be recorded during ordnance firing events. When a channel is fired, PwrSpplly indicates 0V and all channels firing
- Similar signature observed in EDL during validation testing with live NSIs
- This does not affect the performance of the PECs themselves, all ordnance did fire as designed (verified by post-flight continuity test)
- Had there been an anomaly, the lack of telemetry would impede troubleshooting
- Solution: provide dedicated, isolated sense lines for each channel



Actual firing events

Missing Data



Data Time Tagging



- Avionics design had no true time reference; clocks were synced to free-running time signal on board
- SIGI had no GPS. Would not have improved position reckoning during boost phase of PA-1, but could have provided an accurate clock and reduced drift errors prior to launch. VIV had GPS time reference, but no IRIG signal to CM.
- WSMR data path included an RF Best Source Selector. Path delay is variable.

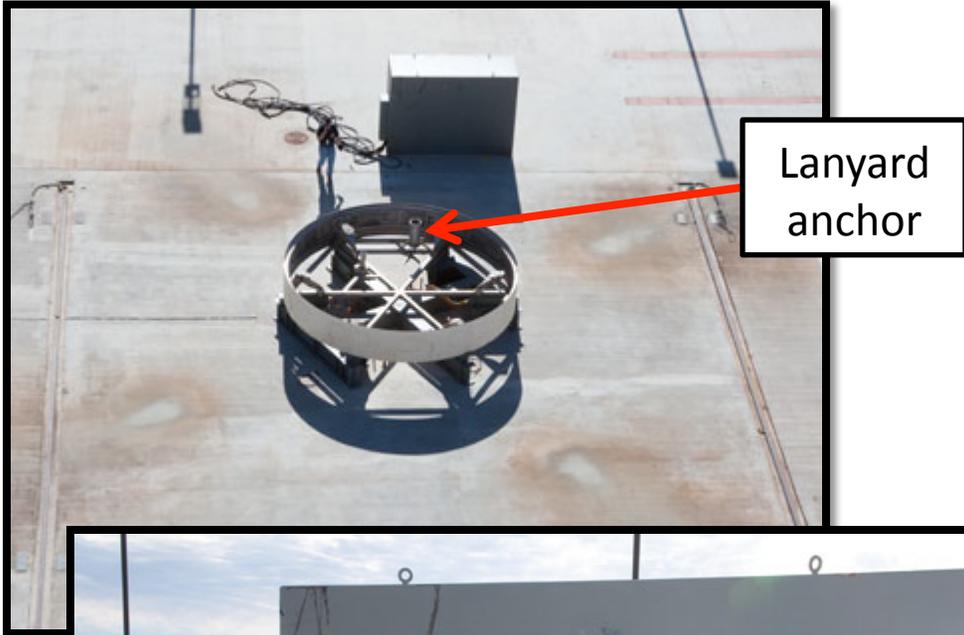
Product	Time Offset
MOF wideband recorded telemetry	≡00:00:00.000
VIV logged data files	+00:00:00.114±0.006
DFI recorder segment 1	-04:22:37.873±0.005
DFI recorder segment 2	-04:22:44.440±0.005
DFI recorder segment 3	-04:22:53.415±0.005
OFI recorder segment 1	-02:53:06.654±0.005
OFI recorder segment 2	-02:53:12.533±0.005
OFI recorder segment 3	-02:53:19.532±0.005
CM tunnel film camera	+11:20:54.963±0.006
CM tunnel video camera	+12:34:53.680±0.032
WSMR optics	+00:00:00.114±0.006
WSMR radar	+00:00:00.114±0.006
BET	+13:00:00.203 23



T-0 Cable Failure Post Launch



Project Orion Abort Flight Test



- Abort motor blast competed with vehicle motion to demate umbilical connectors from the Crew Module.
- Lanyards failed, although may have been after connectors demated.

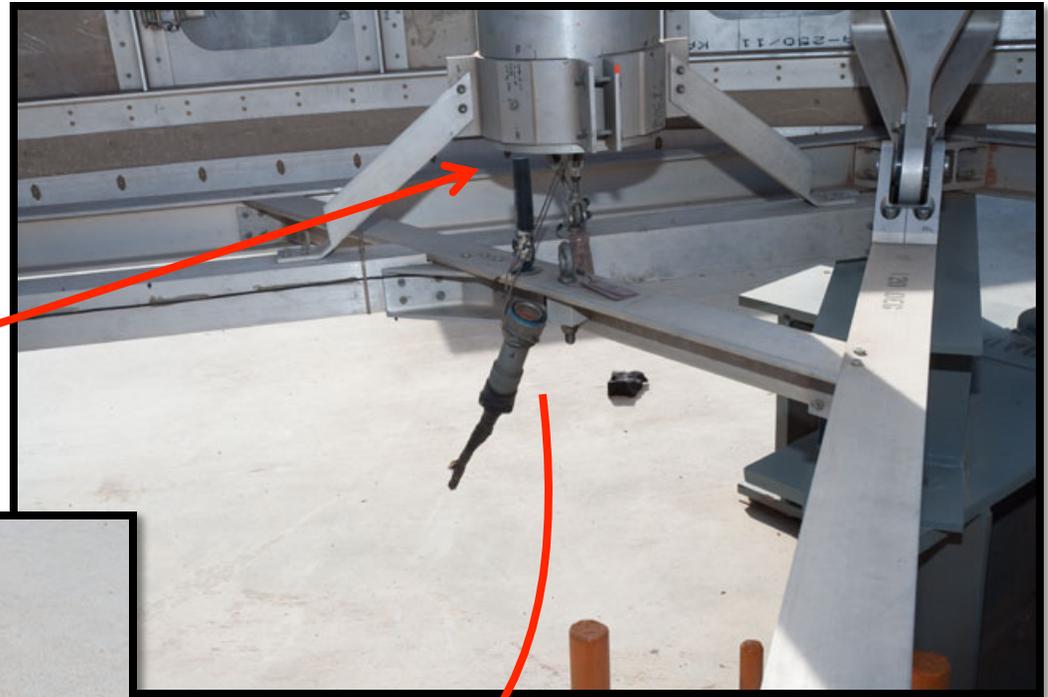


T-0 Cable Failure Post Launch



Project Orion Abort Flight Test

Lanyard anchor



Blast forces depinned the smallest connector



Conclusions / Lessons Learned



- Avionics survived the flight
 - SIGI2 position error turned out to be less than 3 ft
 - RF Telemetry Link maintained lock via at least one receiver throughout the flight (best source selector switched as needed)
 - Parachute cutters fired successfully at T+8 minutes
 - All transmitters and auxiliary systems powered down as scheduled by T +14 minutes, VMCs and RIUs powered down when ground crew removed the Battery Enable Plugs.
 - Passed full suite of post-flight tests (functional checkout and mission simulations) with no issues.
 - No evidence of BGA/Black Pad failure
- Data time tagging plan must account for entire data path, should be considered early so that post flight analysis is practical. Requirements must be clear and understood
- Launch schedule pressure can lead to sub-optimized solutions if decisions are based on unrealistic launch date (mid- or long-term solutions may be rejected unnecessarily)



BACKUP



EGSE Flight Data



Command Log (Operator Station in the MOF): PA-1 Launch command

```
SCL: send command "abortexecute"  
MSG: 05/06/2010 12:59:55:921 Sending Command CGF01GV00010B - VIU Pad Abort Execute  
RTE: Task scriptid 2881 set to ONHOLD  
RTE: Release HOLD on Task scriptid 2881 restore to COMPUTABLE  
MSG: VIU1 command accepted. MsgNum: 659 CmdId: 1033  
MSG: VIU3 command accepted. MsgNum: 659 CmdId: 1033  
ALRT: Command Response Error  
MSG: 05/06/2010 13:00:00:473 System Mode Changing From ( 4 ) to ( 5 )  
ALRT: Abort heartbeat was turned off or lost, it is ok to re-enable RIU cmding  
MSG: 05/06/2010 13:00:02:171 CMD Response Verified: VIU Pad Abort Execute
```

Vehicle Interface Unit Log (VIV): Launch Command Received

```
13:00:00.014[ericViuExec:ViuExec(241)]ViuExec processCcsCommand msgNum=659 CmdId=1033 Arg 1=276 Arg 2=277 Arg 3=0  
13:00:00.014[ericViuExec:MonCmdAbsStatus(400)]ViuExec, buildLocalCmd, pipename=/tmp/sendAbsPipe syncWord=64203 cmdId=1  
13:00:00.014[ericViuExec:MonCmdAbsStatus(422)]ViuExec, buildLocalCmd, pipename=/tmp/sendAbsPipe syncWord=64203 cmdId=1  
13:00:00.014[ViuCmdAbsLog:EricAbstractCmd(482)]viuCmdAbs readCmdIO - cmdId 1033, msgNum 659, cmdval[0]276, cmdval[1]0  
13:00:00.014[ViuCmdAbsLog:EricAbstractCmd(257)]viuCmdAbs sendToDiscreteDriver - wrote a 0, to dio brd num 0, chan num  
13:00:00.014[ViuCmdAbsLog:EricAbstractCmd(659)]viuCmdAbs readCmdIO - Send stat to viuCmdEx - num byte 16, cmdId 1033,c  
13:00:00.014[ViuCmdAbsLog:EricAbstractCmd(482)]viuCmdAbs readCmdIO - cmdId 1033, msgNum 659, cmdval[0]277, cmdval[1]0  
13:00:00.014[ViuCmdAbsLog:EricAbstractCmd(257)]viuCmdAbs sendToDiscreteDriver - wrote a 0, to dio brd num 1, chan num  
13:00:00.014[ViuCmdAbsLog:EricAbstractCmd(659)]viuCmdAbs readCmdIO - Send stat to viuCmdEx - num byte 16, cmdId 1033,c  
13:00:00.019[ericTlmMgr:OmegaClient(206)]send tlm name: MGF01GV30038K value 1  
13:00:00.019[ericTlmMgr:OmegaClient(206)]send tlm name: MGF01GV30050K value 1  
13:00:00.019[ericTlmMgr:OmegaClient(206)]send tlm name: MGF01GV30002V value 1105568640  
13:00:00.019[ericTlmMgr:OmegaClient(206)]send tlm name: MGF01GV30014V value 1105528000  
13:00:00.019[ericTlmMgr:OmegaClient(206)]send tlm name: MGF01GV30004D value 1  
13:00:00.019[Sequencer:Lcu(654)]Lcu::SetRuleFire, NORM, Fired rule 1.10_Monitor_RIU1_Enable_Execute_On_Rule1.  
13:00:00.019[Sequencer:Lcu(654)]Lcu::SetRuleFire, NORM, Fired rule 1.11_Monitor_RIU2_Enable_Execute_On_Rule1.  
13:00:00.019[ericViuExec:ViuExec(168)]ViuExec, main, From Cmd_Abs: Sync Word=64203 CmdId=1033 msgId=659 Status=0  
13:00:00.024[ericTlmMgr:OmegaClient(206)]send tlm name: MGF01GV30011D value 0  
13:00:00.024[ericTlmMgr:OmegaClient(206)]send tlm name: MGF01GV30010D value 0  
13:00:00.024[ericViuExec:ViuExec(168)]ViuExec, main, From Cmd_Abs: Sync Word=64203 CmdId=1033 msgId=659 Status=0  
13:00:00.024[ericViuExec:MonCmdAbsStatus(326)]ViuCmdEx commandSender Status to CCS: msgNum=659: cmdId=1033 status=0
```



EGSE Overview – CCMS & STE



Project Orion Abort Flight Test

