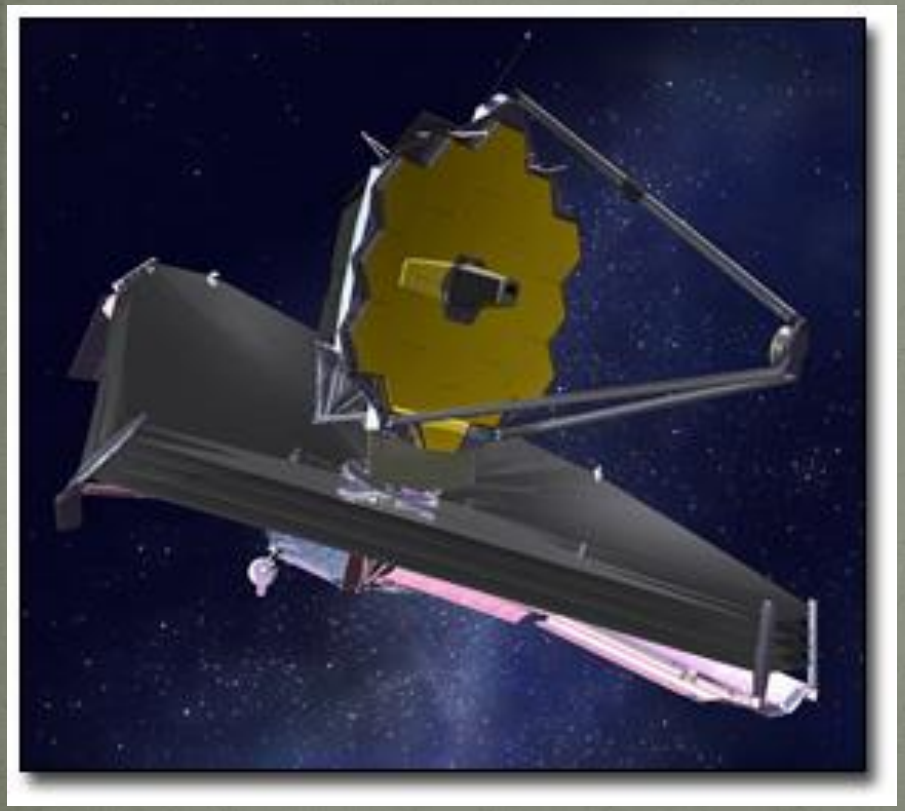
Dynamic Emulation of NASA Missions for IV&V

A case study of JWST and SLS

Steve Yokum
steven.c.yokum@ivv.nasa.gov

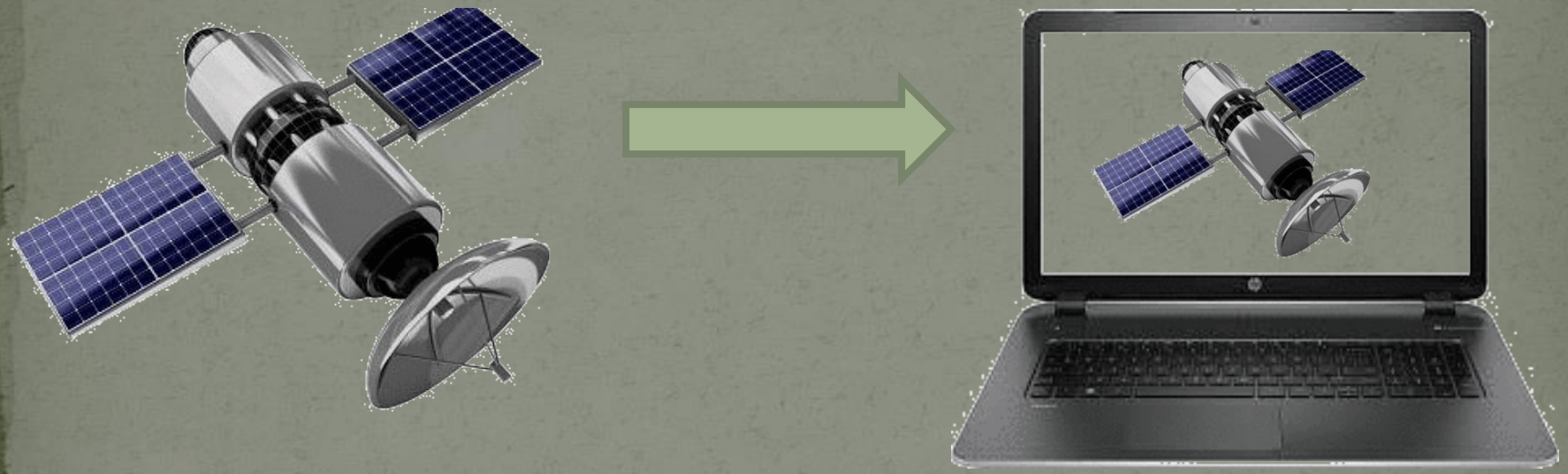
Focus Missions:



Who we are?

- Independent Test Capability (ITC)
  - develop, maintain and operate adaptable test environments for the IV&V program that enables the dynamic analysis of software behaviors for multiple NASA missions

What is Dynamic Emulation?



- Entire Flight "System" condensed to a Laptop
  - Sensors/Actuators are Simulated
  - Flight Computer Hardware is Emulated.
  - Flight Software binaries executed as delivered.
  - Ground Operations Integrated.

Why we do it…

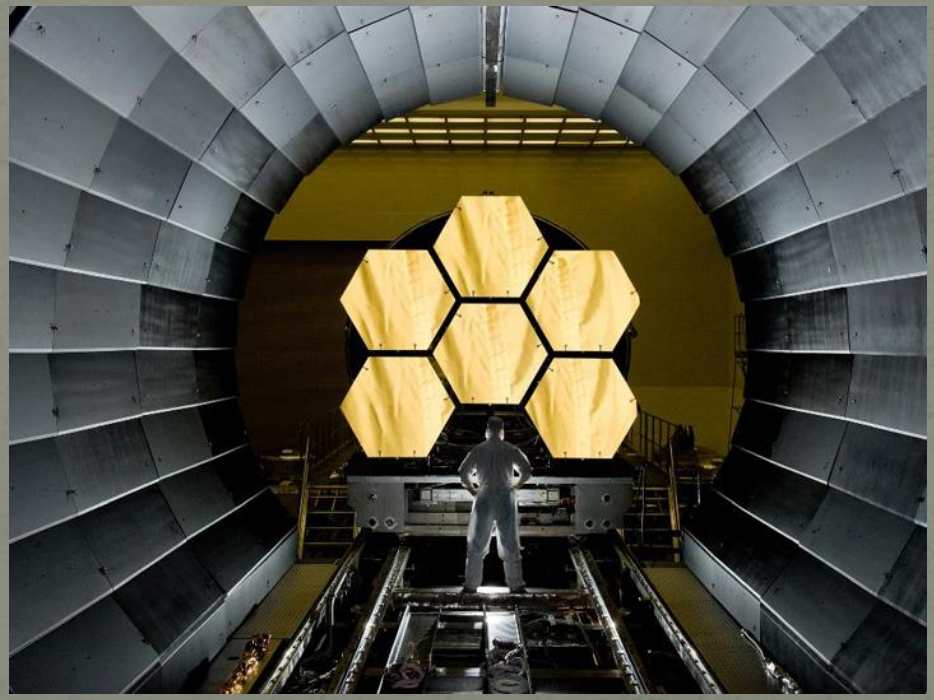
- Fault Injection
- Flexible Time
- Source Level Debugging
- Measureable V&V
- Unlimited Simulation Resources

How we do it…

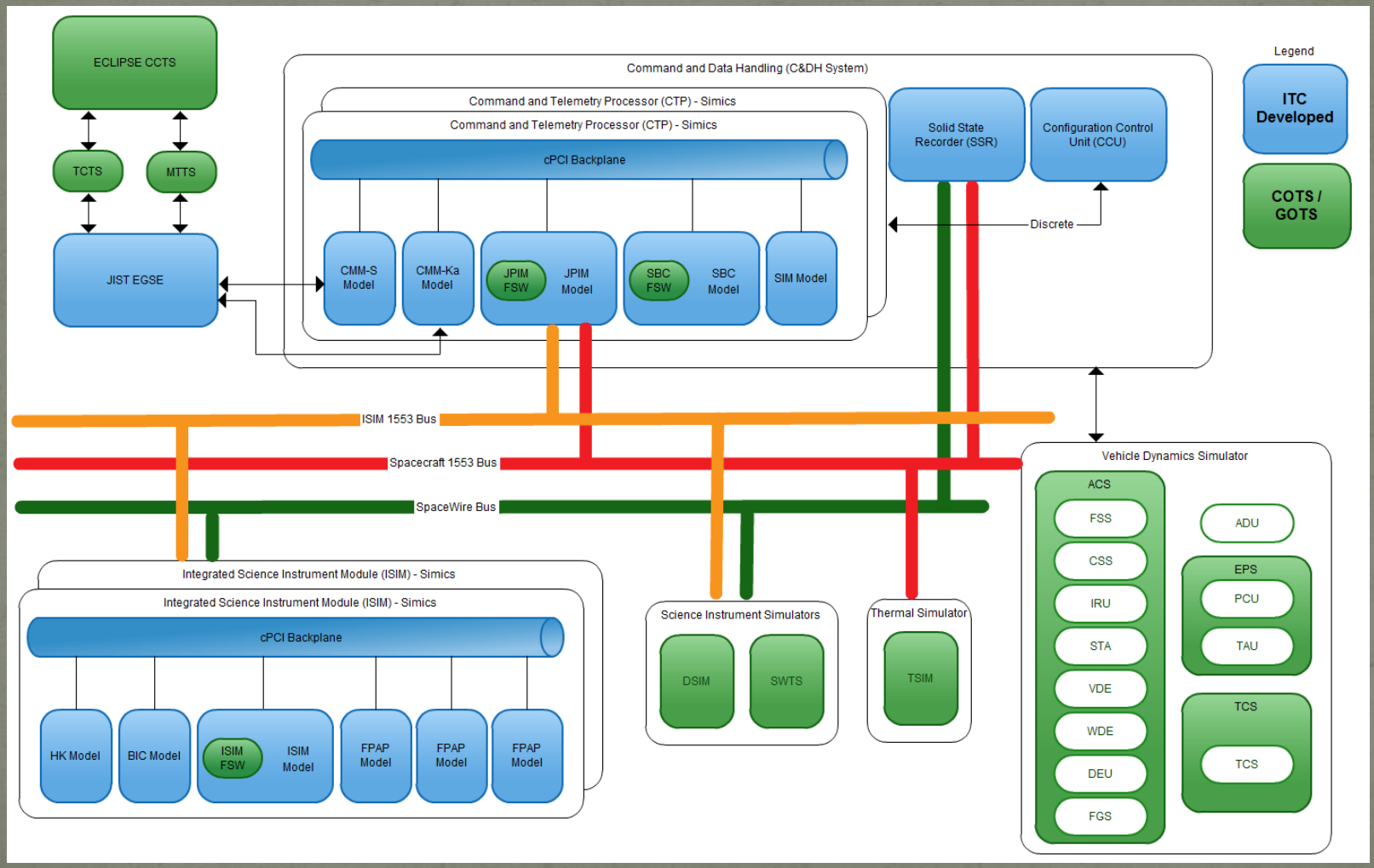
- Execute
  - Emulation software
    - assemble engine
- Construct
  - Device Modeling Language (DML)
    - registers, memory, interrupts, buses
- Connect
  - NOS Engine
    - ITC middleware product
- Integrate
  - Vendor's models and dynamics
  - Ground system software

JWST Integrated Simulation and Test

JIST



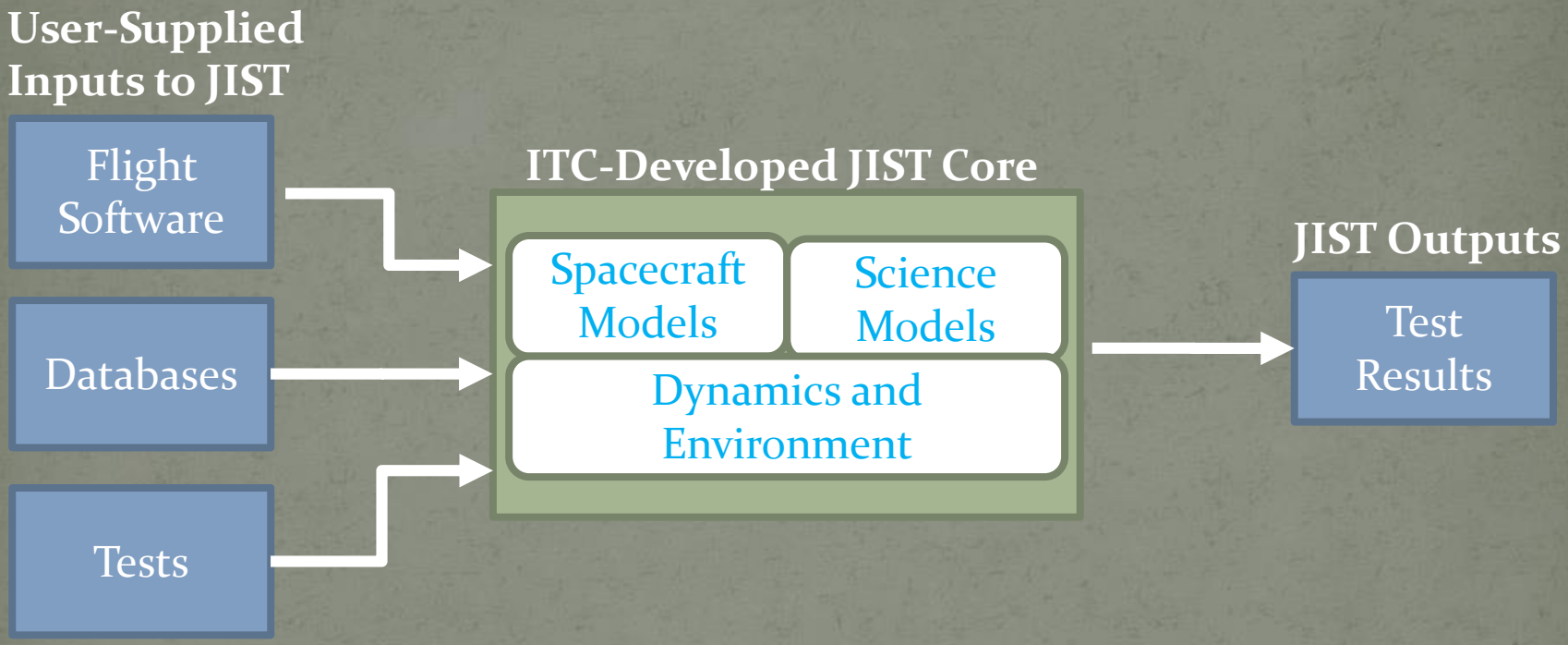
JIST ⟹ Architecture



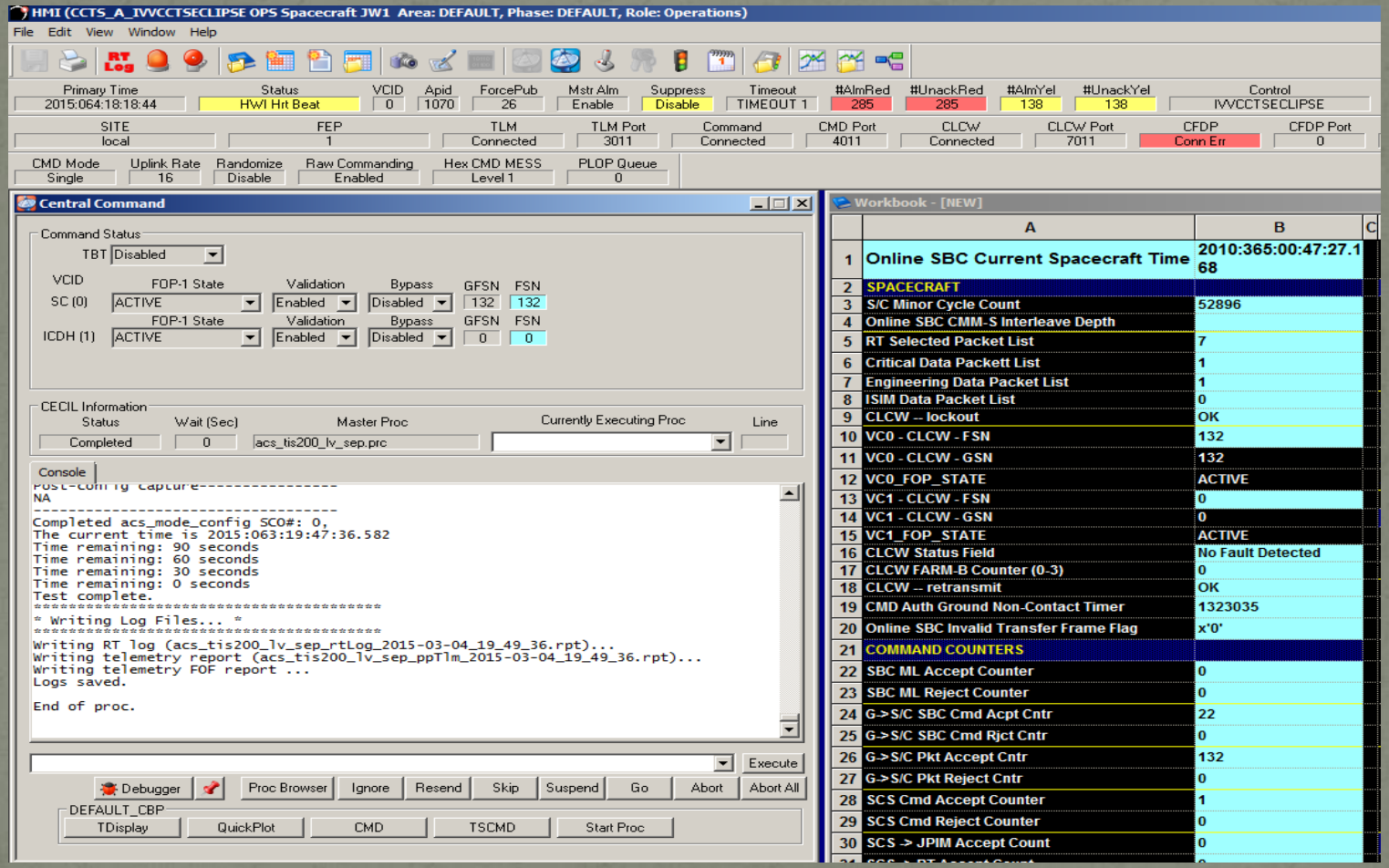
JIST ⟹ Project Unique Abilities

- Only integration of Science and Spacecraft FSW
- Faster than real-time
- Flexible hardware configurations
- Hardware fault injection
- Source-line debugging
- Complete control of all memory states

JIST ⟹ Test Cycle

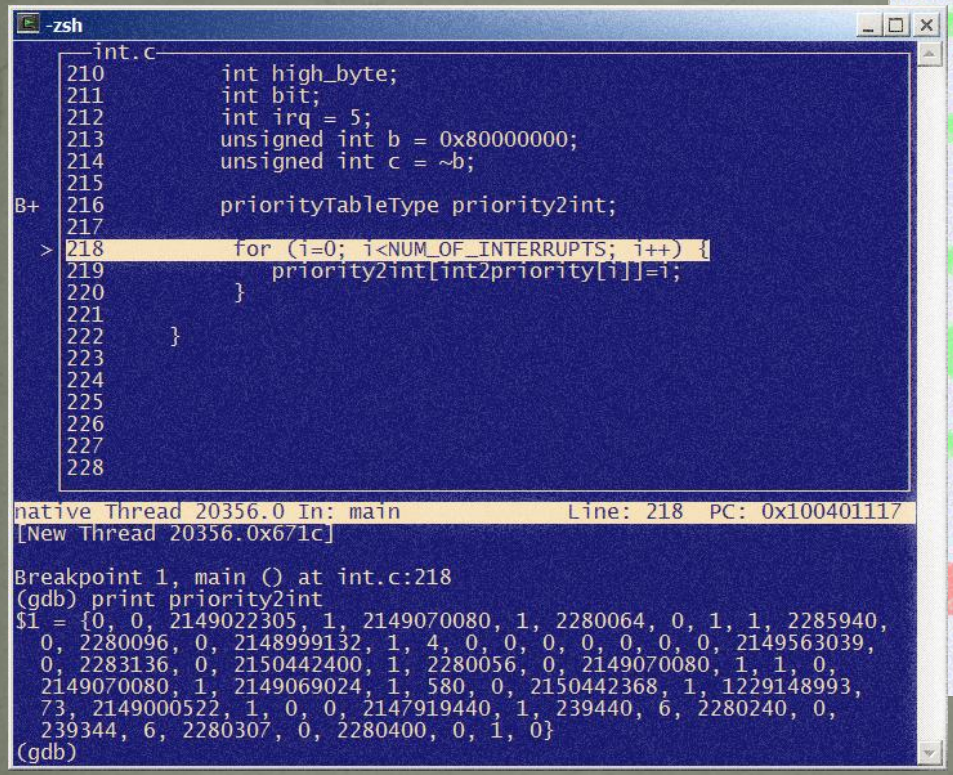


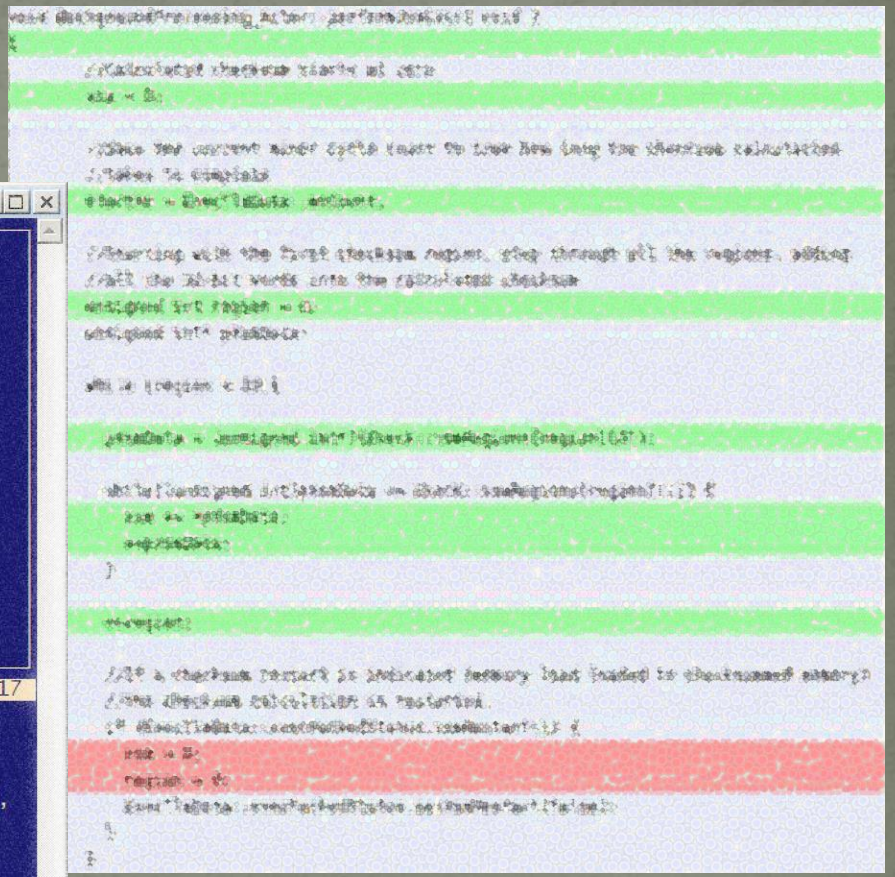
JIST ⟹ Ground System Software



	A	B
1	Online SBC Current Spacecraft Time	2010:365:00:47:27.168
2	SPACECRAFT	
3	S/C Minor Cycle Count	52896
4	Online SBC CMM-S Interleave Depth	
5	RT Selected Packet List	7
6	Critical Data Packett List	1
7	Engineering Data Packet List	1
8	ISIM Data Packet List	0
9	CLCW -- lockout	OK
10	VC0 - CLCW - FSN	132
11	VC0 - CLCW - GSN	132
12	VC0_FOP_STATE	ACTIVE
13	VC1 - CLCW - FSN	0
14	VC1 - CLCW - GSN	0
15	VC1_FOP_STATE	ACTIVE
16	CLCW Status Field	No Fault Detected
17	CLCW FARM-B Counter (0-3)	0
18	CLCW -- retransmit	OK
19	CMD Auth Ground Non-Contact Timer	1323035
20	Online SBC Invalid Transfer Frame Flag	x'0'
21	COMMAND COUNTERS	
22	SBC ML Accept Counter	0
23	SBC ML Reject Counter	0
24	G->S/C SBC Cmd Acpt Cntr	22
25	G->S/C SBC Cmd Rjct Cntr	0
26	G->S/C Pkt Accept Cntr	132
27	G->S/C Pkt Reject Cntr	0
28	SCS Cmd Accept Counter	1
29	SCS Cmd Reject Counter	0
30	SCS -> JPIM Accept Count	0

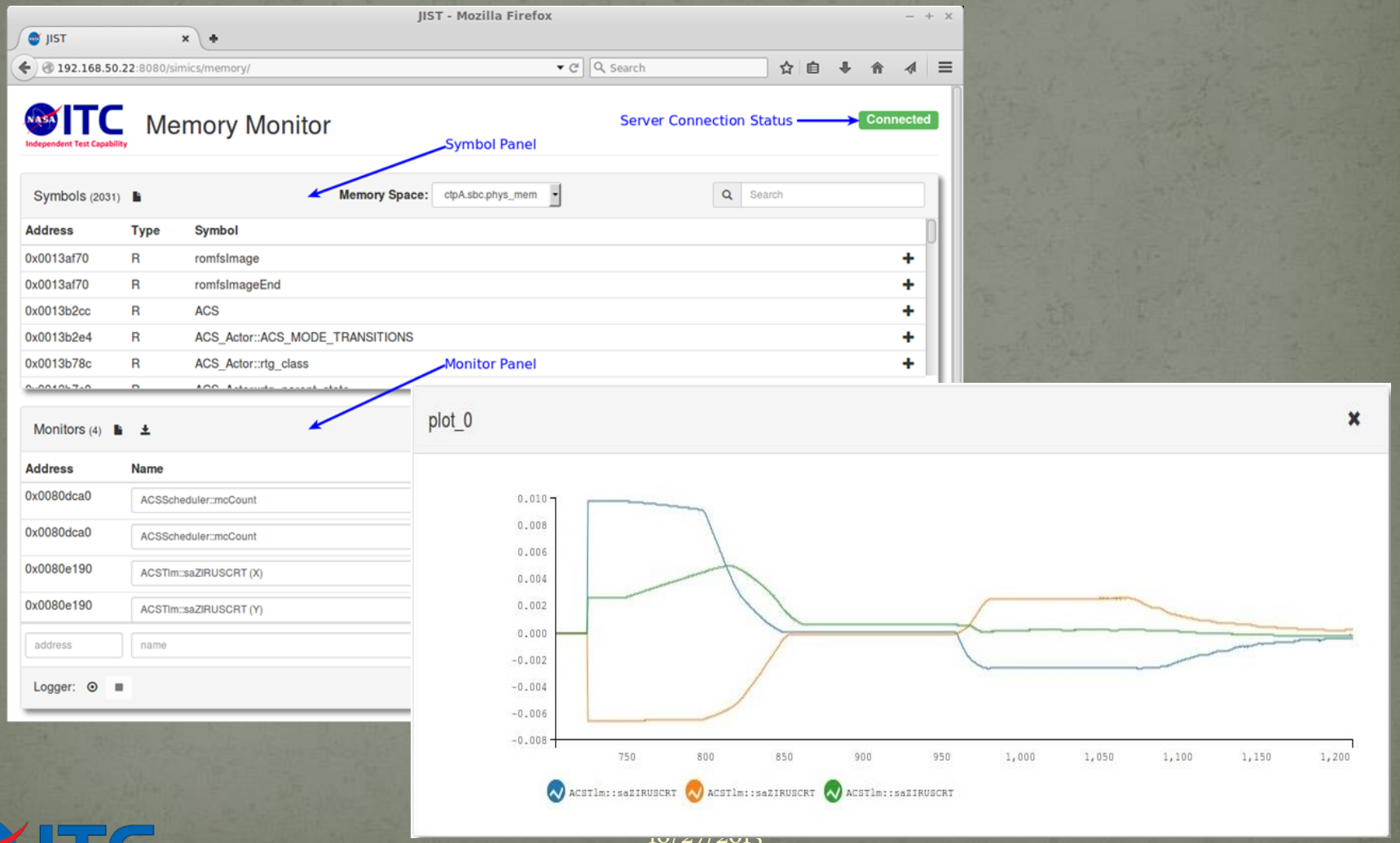
JIST ⟹ Source Analysis



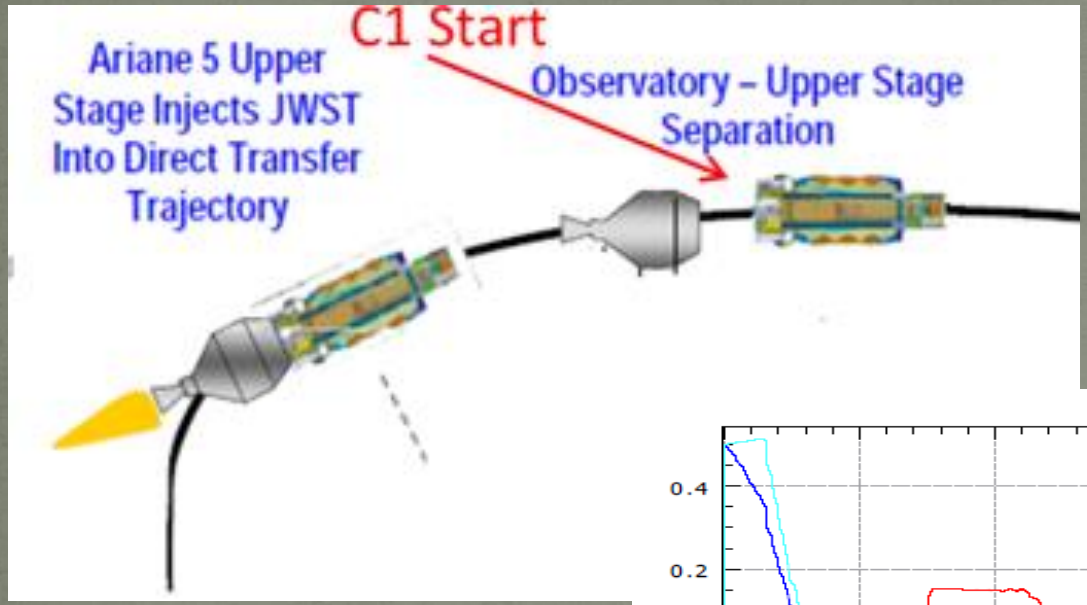


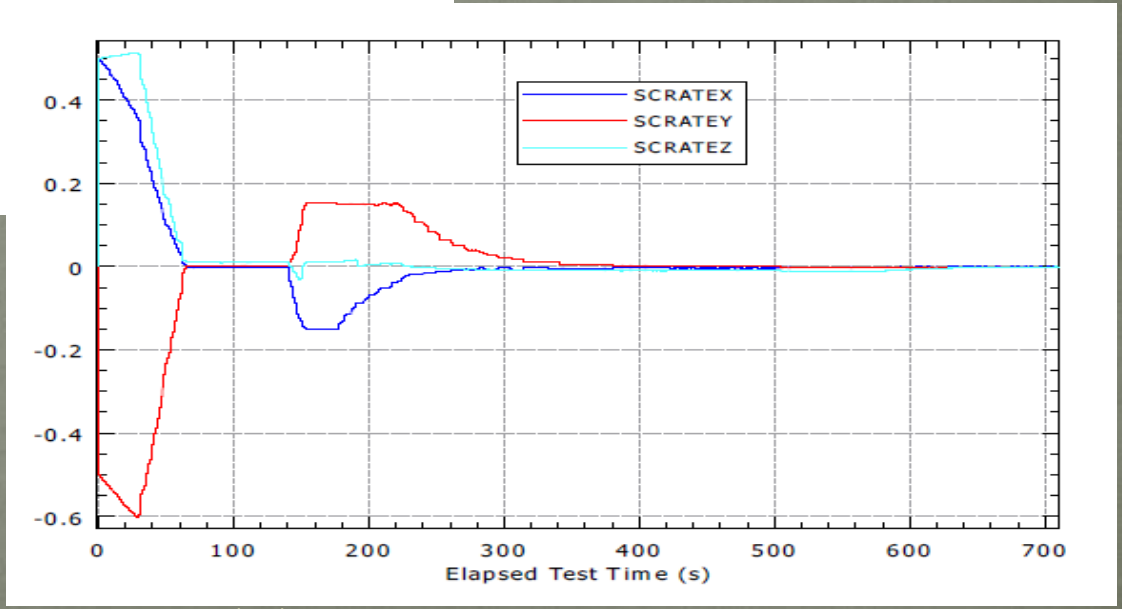
NASA ITC
Independent Test Capability

JIST ⟹ Memory Analysis



JIST ⟹ Orbit Scenarios





JIST ⟹ Utilizations

- 30 day test
- Fine-Guidance Sensor Closed-loop
- Training
- Stored Command Procedure validation
- Stuck Thruster
- PPC fault injection (Instruction faults, etc.)
- Primary/Backup Swapping
- SUROM testing

JIST ⟹ Findings

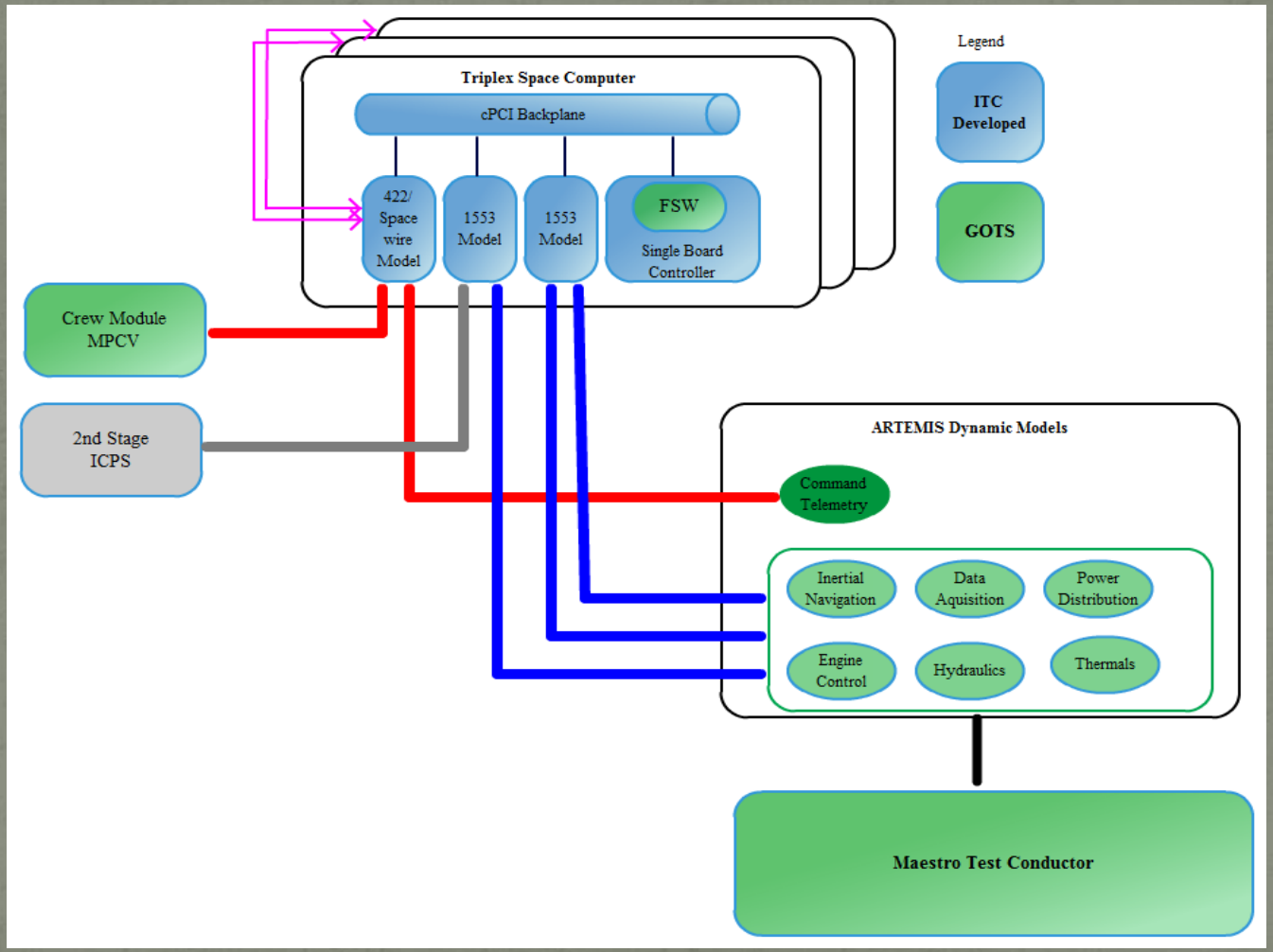
- Severity 1 issue found in Attitude Control
  - Loss of mission
- Multiple issues found in telemetry formats and processing
- Multiple issues found in test drivers when integrating them with JIST

SLS Software-only Simulation

S3

NASA ITC
Independent Test Capability

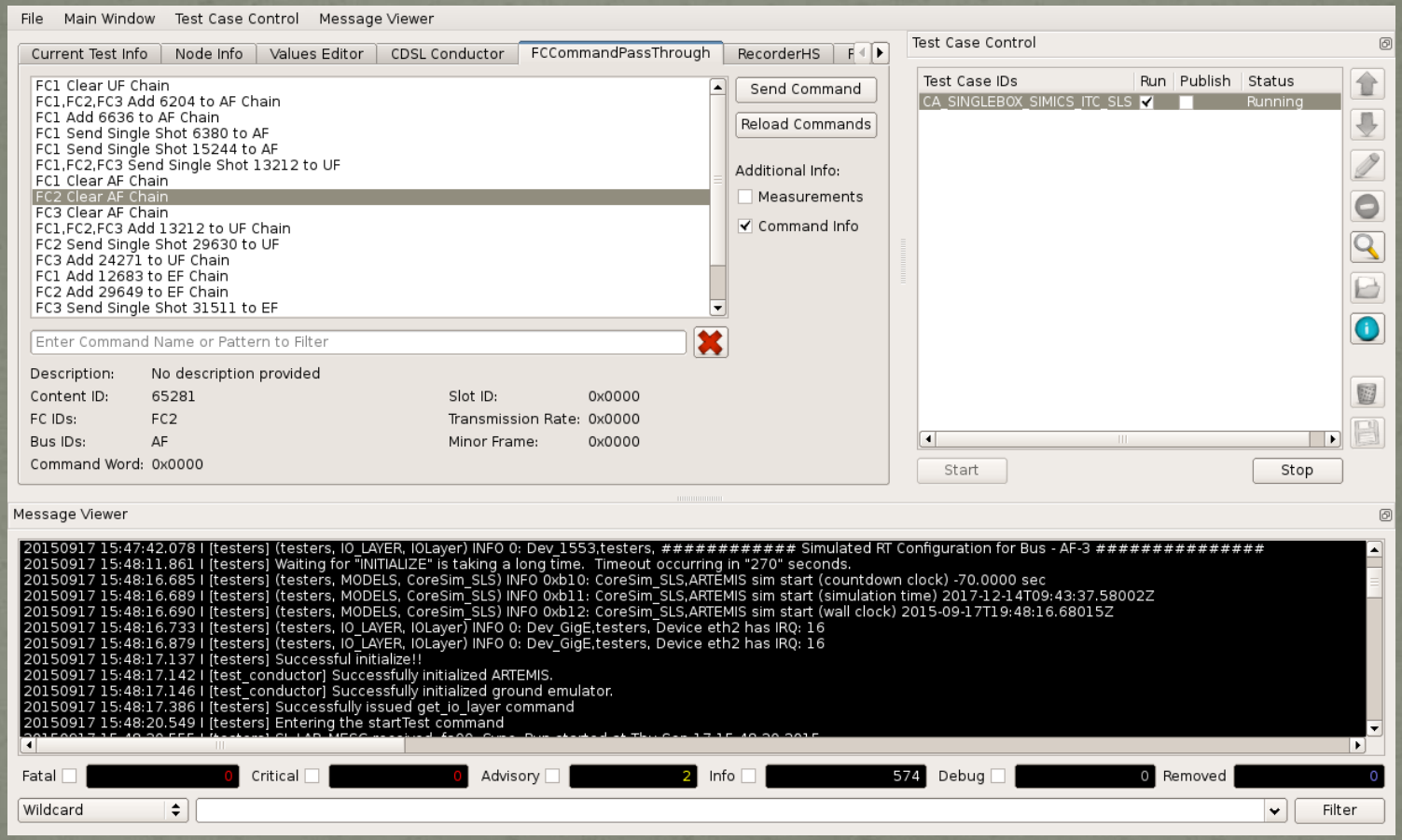
S3 ⟹ Architecture



S3 ⟹ Overview

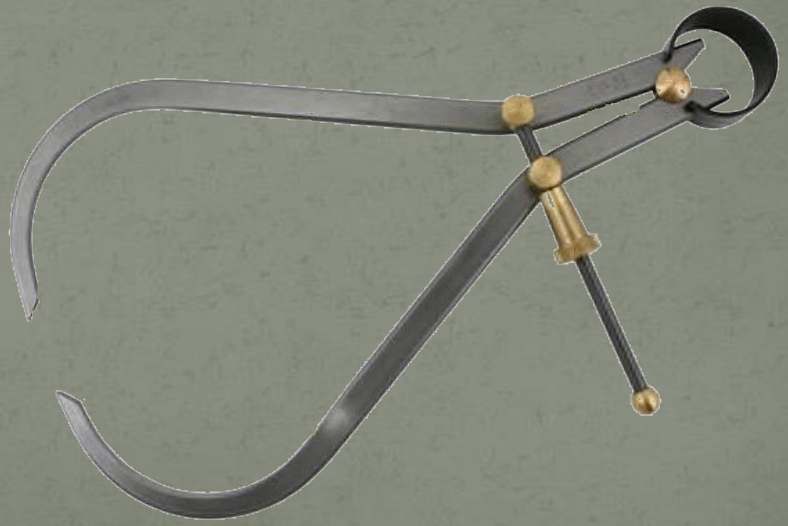
- Rolling out now to SLS IV&V Team
- Triplex Synchronization
- Integrates ARTEMIS models and dynamics
- Runs same qualification test as MSFC (Maestro)
- Similar capabilities to JIST
- Future goals:
  - Integrate GSDO and MPCV software simulators for full system simulation.

S3 ⟹ Maestro Test Scenarios



S3 ⟹ IV&V Through Construction

- S3 presented challenges due to insufficient hardware documentation
- Extensive reverse engineering of FSW was necessary to build emulator
  - Negative – Fidelity of hardware model
  - Positive – Code exposure



S3 ⟹ Findings

- No specifics allowed ☹
- 6 issues found in Board Support Package
  - Most could only be validated using an all-software emulation
    - Interrupt and timing related
    - Bad states due to hardware failures
  - IV&V is beginning test on application code now

Concluding…

- There are many ways to validate FSW
- Large NASA missions:
  - Are difficult to fully validate
  - Must work the first time

- ITC brings a unique capability to FSW testing