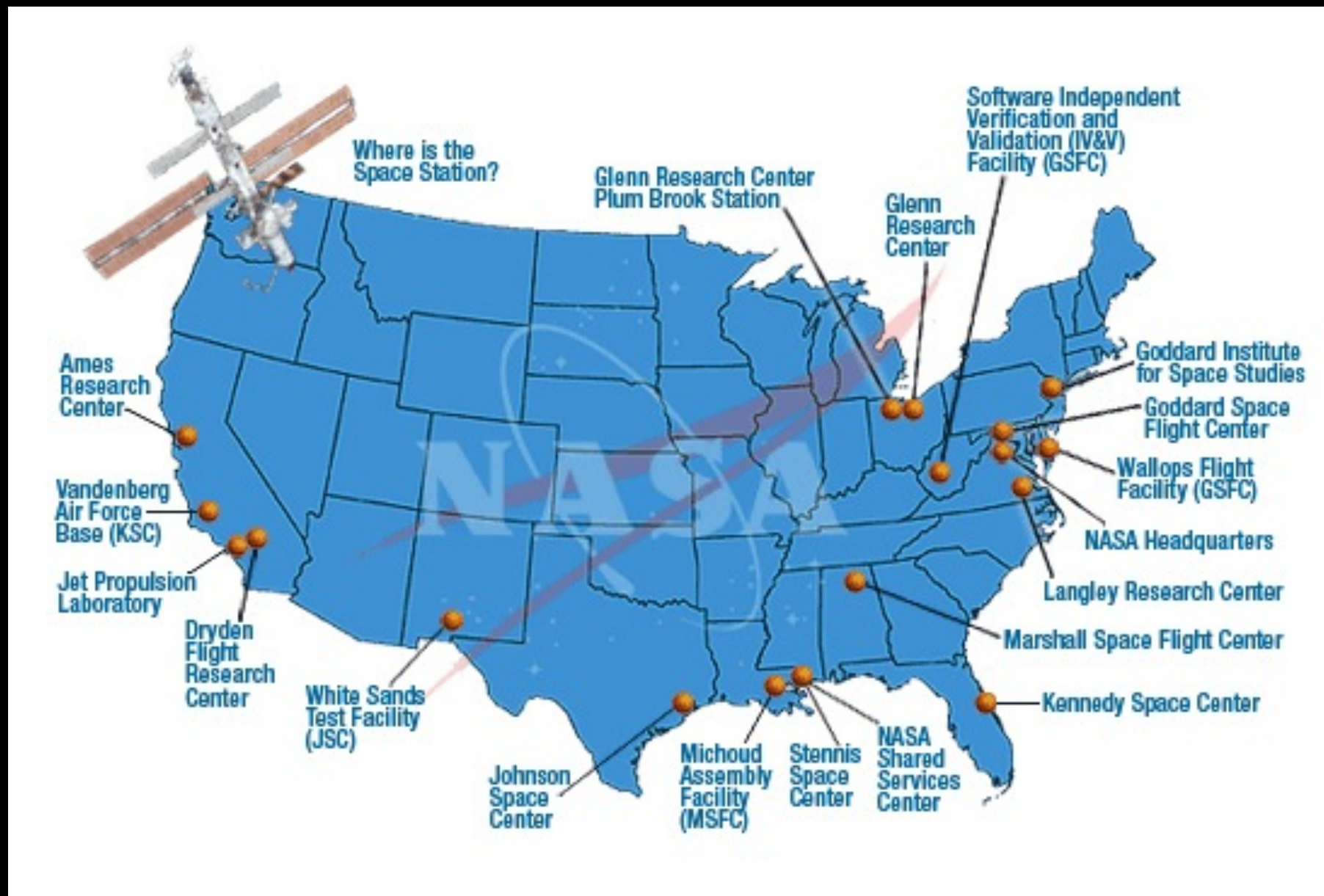


Open Source Mission Control for Chrome

Jay Trimble
NASA Ames Research Center

NASA



Missions

- Extend our senses with robots and instruments
- Extend our presence with people
- Mission Experience
 - Knowledge and perspective through data

Mission Interaction Bounded by Communication Time

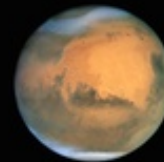
Round Trip Light Time: ~2.4 S
Comm Latency: Variable
Command to Response time range: 6 – 25+ seconds



Round Trip Light Time:
Variable 134min – 170min



Round Trip Light Time:
Variable ~10 min – 48 min



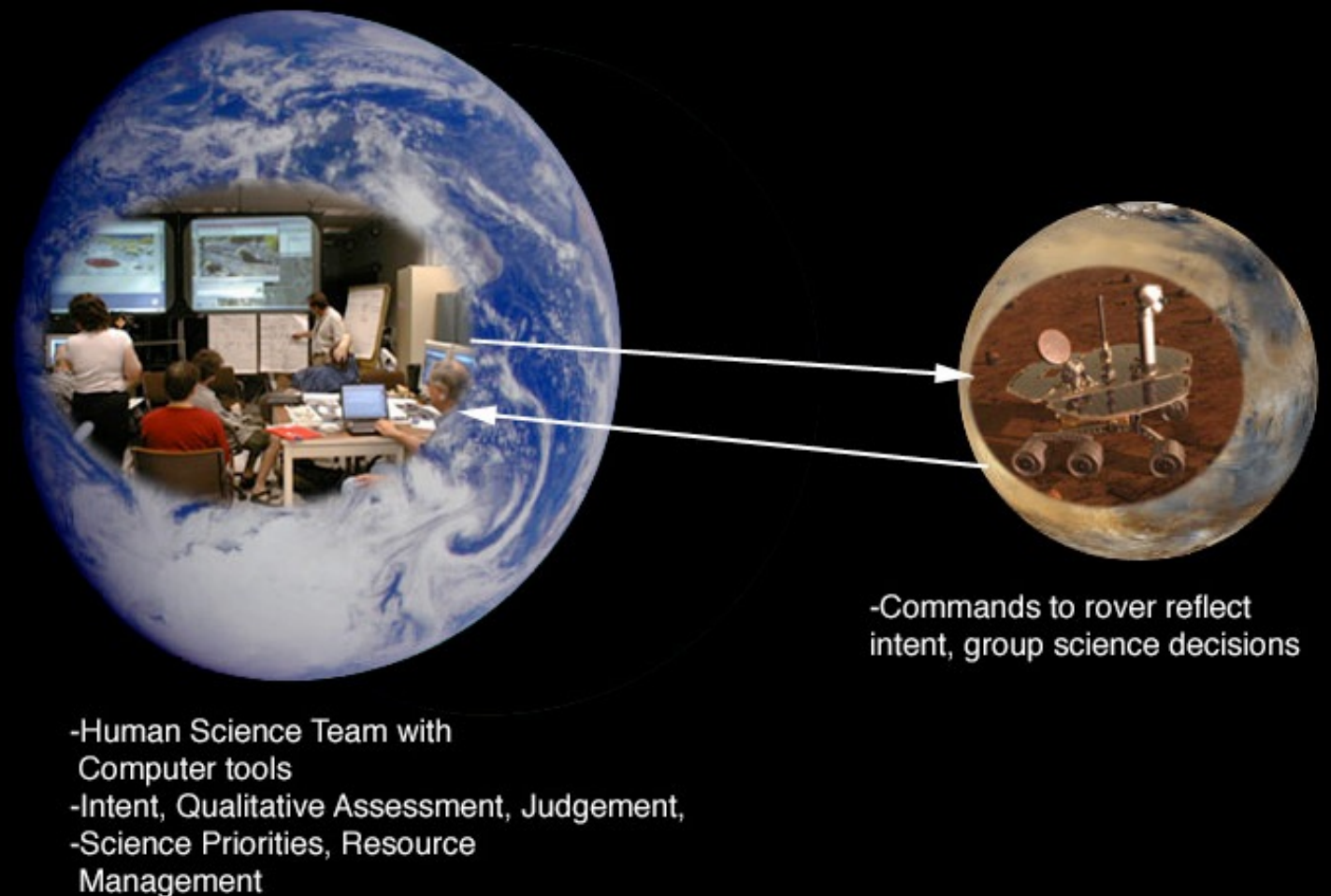
Mission Control for Crewed Missions

- What is the optimal ground/crew distribution of work?
- System status and health, housekeeping
- Planning
- Trajectory
- Authority



Mission Control: Earth to Mars (MER)

- What is the optimal ground/robot distribution of work?
- All from the ground
- Limited onboard autonomy



Control Centers



Disciplines, Call Signs Examples

- NASA
 - Flight Director
 - Systems
 - Trajectory
 - Payloads/POCC
 - INCO
- Star Trek
 - Captain (Kirk, Janeway, Picard, Cisco,...)
 - Engineering (Mr. Scott)
 - Navigation (Chekov)
 - Science Officer (Spock)

Apollo 11 - Nominal



Go for Landing

Apollo 11- Anomaly



1201 Alarm

Apollo 13



Space Shuttle ATO



What do the consoles do?



Once upon a time...



In Houston,
Summer Intern, 1981



Lead Ops Director
SRL-I, 1994

MCC Display 1984

[illegible]

MCC Display 1984

2 7 0 DAY 1 0 1

F/V 13/099 FSS CONTROL RR3408A CH044

OGMT 101:18:12:32 OMET 4:04:14:32 SITE TDR OI 188 GN 62
RGMT 101:18:12:32 U/D RATE 1 SM 64 BF 12

MECHANISM SELECTION		CONFIGURATION				TELEMETRY	
		ON		OFF		AMPS	TEMP
		A	B	A	B		
BERTH LAT	1 1	SCIU	16 *	17	*	SCIU	0.53 2
	2 2	MSB	18	19	*	MSB	0.07 0
	3 3	MPC	20 * *	21	*	MPC	4.7
UMB MAIN	4	DPC	22	23	*	DPC	0.2
HEATER	5	LCKR	24 *	25		FSS LCKR	1 26
RET LAT KEEL	6						2 13
PORT	7						
STBD	8						
ROTATOR	9	HEATERS (SSP)					
PIVOTER	10	ENA AMPS				PCU	5
TRANSLATOR	11	FSS	*	0.2	PDSU	-1	
PLAT LOCK	12	SMM		0.1			
DESELECT	13	MACS		0.1			
OVERRIDE						FMDM	0.85
ENABLE	14 *					FMDM BOX	A 26
DISABLE	15						B -55↓

DEU

1

2 RESUME

3

4 RESUME

DISP	MF
2011	SM
2011	SM
9 2011S	ONCS
9 2011S	ONCS

83

Y84

HR 1

8

MIN 1

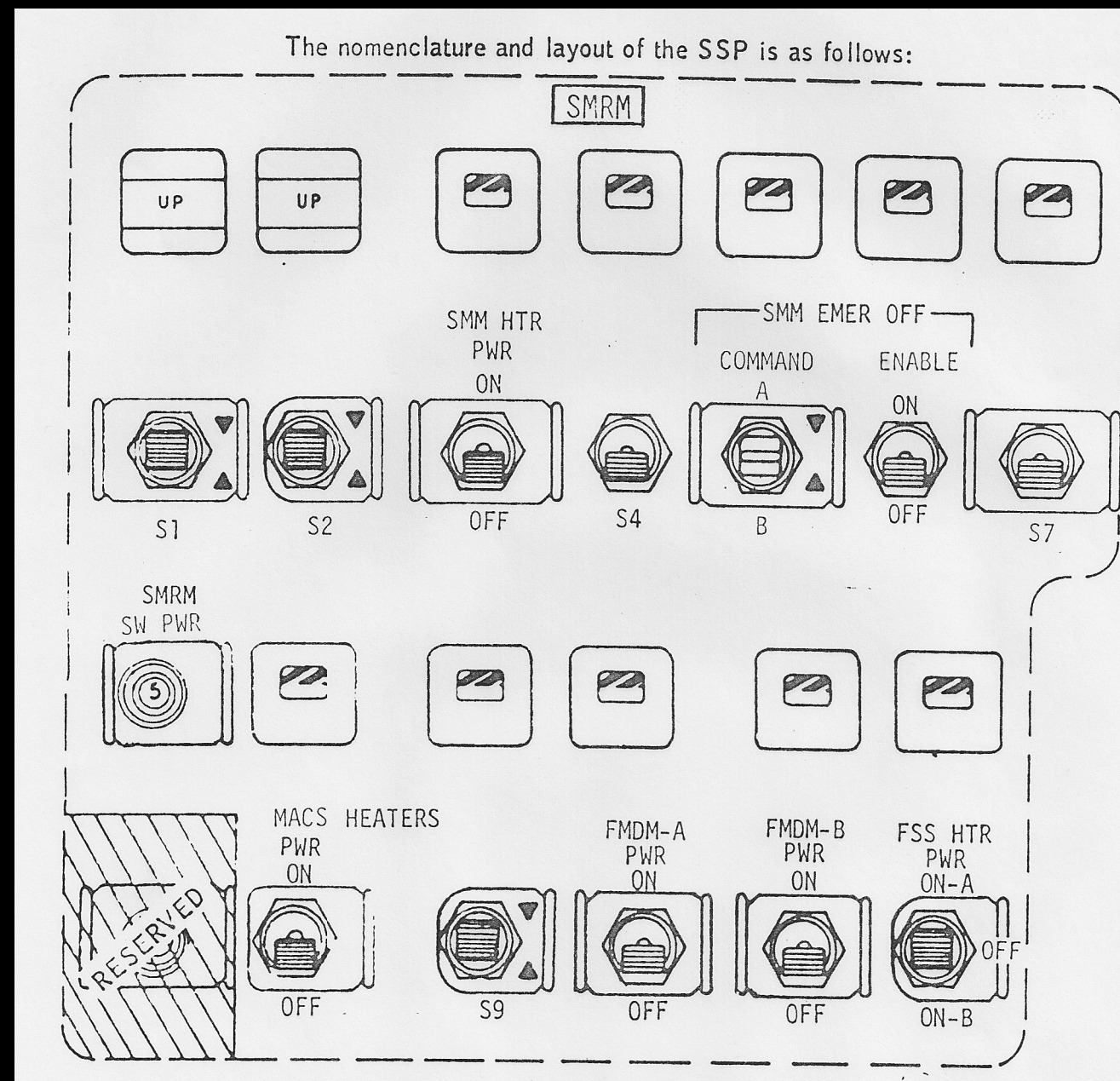
2

SEC 3

6

Mental model: Display

Shuttle Control Panel



Timeline

41-C PAYLOAD OPERATIONS SUPPORT TIMELINE					
	MET	KEY EVENT	CREW ACTION	JSC	POCC
	04:00:00	•RMS Grapples SMM	Cinema 360 Ops, (Cue Card) (90 sec of approach to SMM before grapple) Cinema 360 Ops (SMM grapple)		
		•Maneuver SMM to FSS Platform	•Reverify FSS/SMM umbilical config. for berthing and connectors powered down		
	00:10	•Berth SMM on FSS, close berthing latches, and mate umbilical connectors	Cinema 360 Ops (SMM berthing)		
			•KU-Band - COMM •Maneuver to TDRS TRK Attitude		
	00:20	•Umbilical Interface C/O (Crew)	•Configure FSS components for comm via umbilical SCIU ON •Verify SMM tlm •RMS release SMM •Position SMM/FSS for repair ops: Pivot (inform MCC when at 25 degrees), MPC ON, rotate, pivot	MCC verify SCIU voltages ASAP and verify umbilical connectors mated via FSS umbilical monitoring	
	00:30			•Confirm STS is configured for comm with SMM via PI/PDI	•POCC DIRECTOR conducts command activity briefing with HOUSTON PAYLOADS
				•POCC-to-MCC Command Flow Test	•POCC-to-MCC Command Flow Test (NOTE: JOIP proc. 11.2)
	00:40			•HOUSTON PAYLOADS inform POCC DIRECTOR ready for Umbilical Interface C/O (SMM tilted to 25 deg; MPC ON) •Command activity briefing with POCC CONTROL	•Command activity briefing with HOUSTON P/L DATA
		•S/C C/O (POCC)		•HOUSTON P/L DATA enables remote POCC command panel	•Receive "GO FOR COMMAND" from HOUSTON P/L DATA: •RF Check via PI •Send 18 CU NOOPS commands •Verify SMM status and command capability via PI/PDI •Config C&DH for comm via PI/PDI •Verify status of all subsystems •Notify MCC when finished
	00:50				
	04:01:00	•Begin SMM OBC LOAD (POCC) (completed approx. 04:05:00MET) IMU Align @ 04:06.15MET ZLV @ 04 07:00MET		HOUSTON P/L DATA will be notified by POCC CONTROL upon start and end of all bank loads	•Begin OBC LOAD (3 revs comm) initialize OBC for S/W load •CAP responses enabled •Dump verif. after each 4K bank •Halt and reconfigure OBC

Evolving the Technology

- Why evolve the current model - it works and it has worked well for decades
- Software built as traditional applications creates packaging of functionality that come with operational constraints
- Duplication, Granularity, heterogeneous environments, different UI's, "walls," bloat

Open Source Mission Control Visualisation

- Mission Control Technologies (MCT)
 - Desktop JAVA
 - Open Source
 - <https://github.com/nasa/mct>
 - <http://ti.arc.nasa.gov/OpenMCT/>
- Web Applications for Resource Prospector (WARP)
 - In development, open source coming soon
 - Check <http://ti.arc.nasa.gov/OpenMCT/>

Why Open Source

- Enables collaboration
- Share ground system technology
- Build a community
- Create a pathway for outside in innovation

A User Perspective

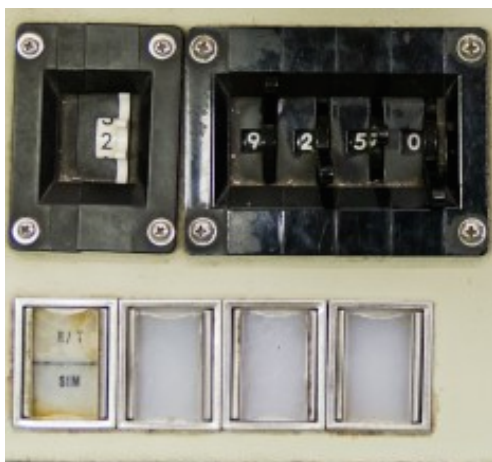
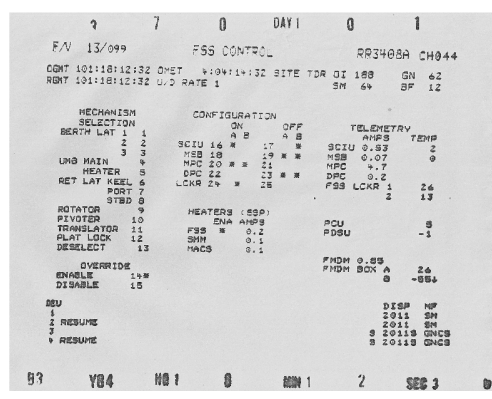
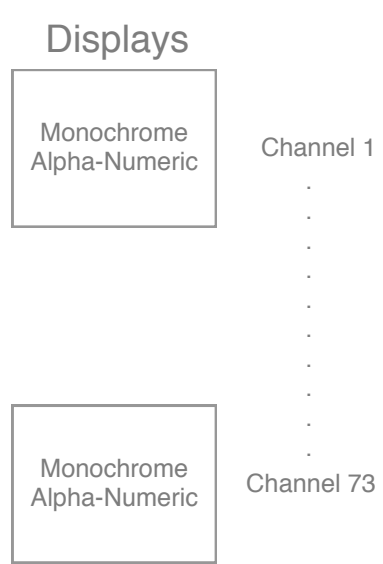
- Displays (no concept of applications)
- Applications
- Objects and Compositions - most users don't get this
 - Things you can manipulate and views - more users seem to get this
- Depending on your mental model, these could all be viewed as displays

Interacting with our Digital Stuff

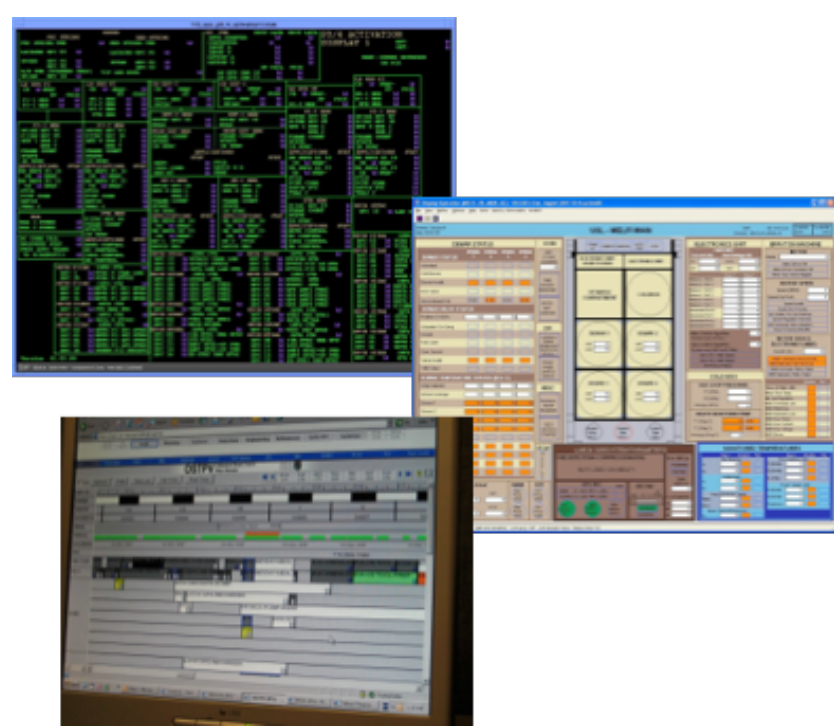
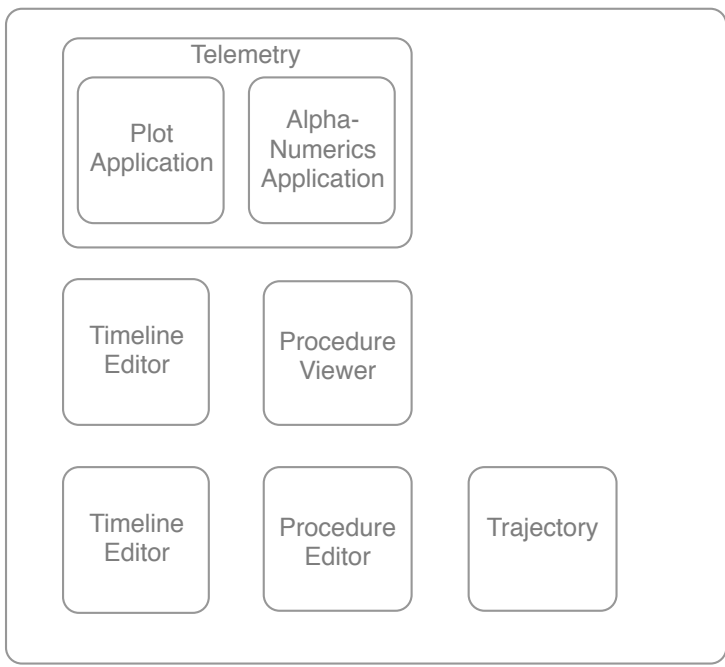
- How do we view and interact with information
 - Applications, apps, widgets, directly with our data
 - Increasing tendency towards sandboxes
- Where is my stuff
 - It could be in Google Drive, iCloud, Drobbox, Box, or even (heaven forbid) my local file system

Mental Models - Displays, Applications, Objects

from Gemini to Shuttle

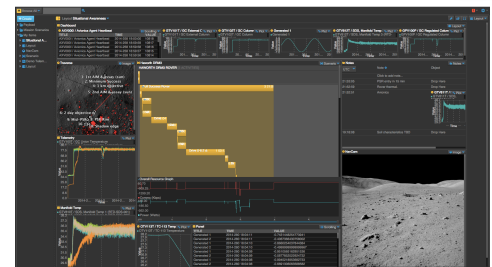
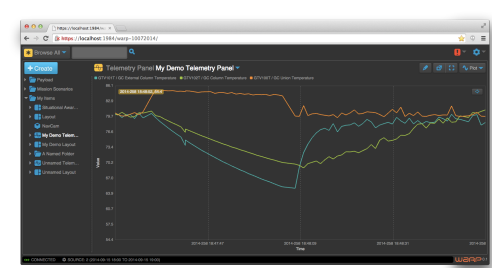
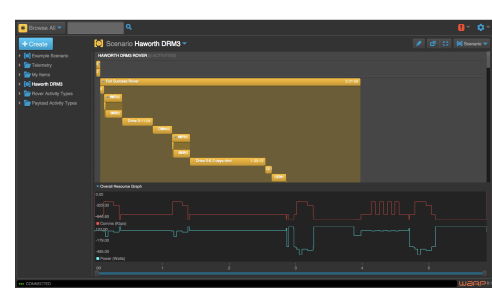
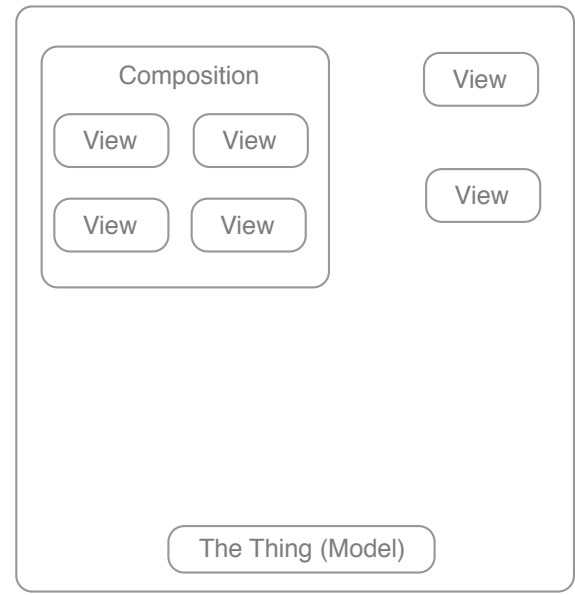


Shuttle to ISS, Robotic Missions

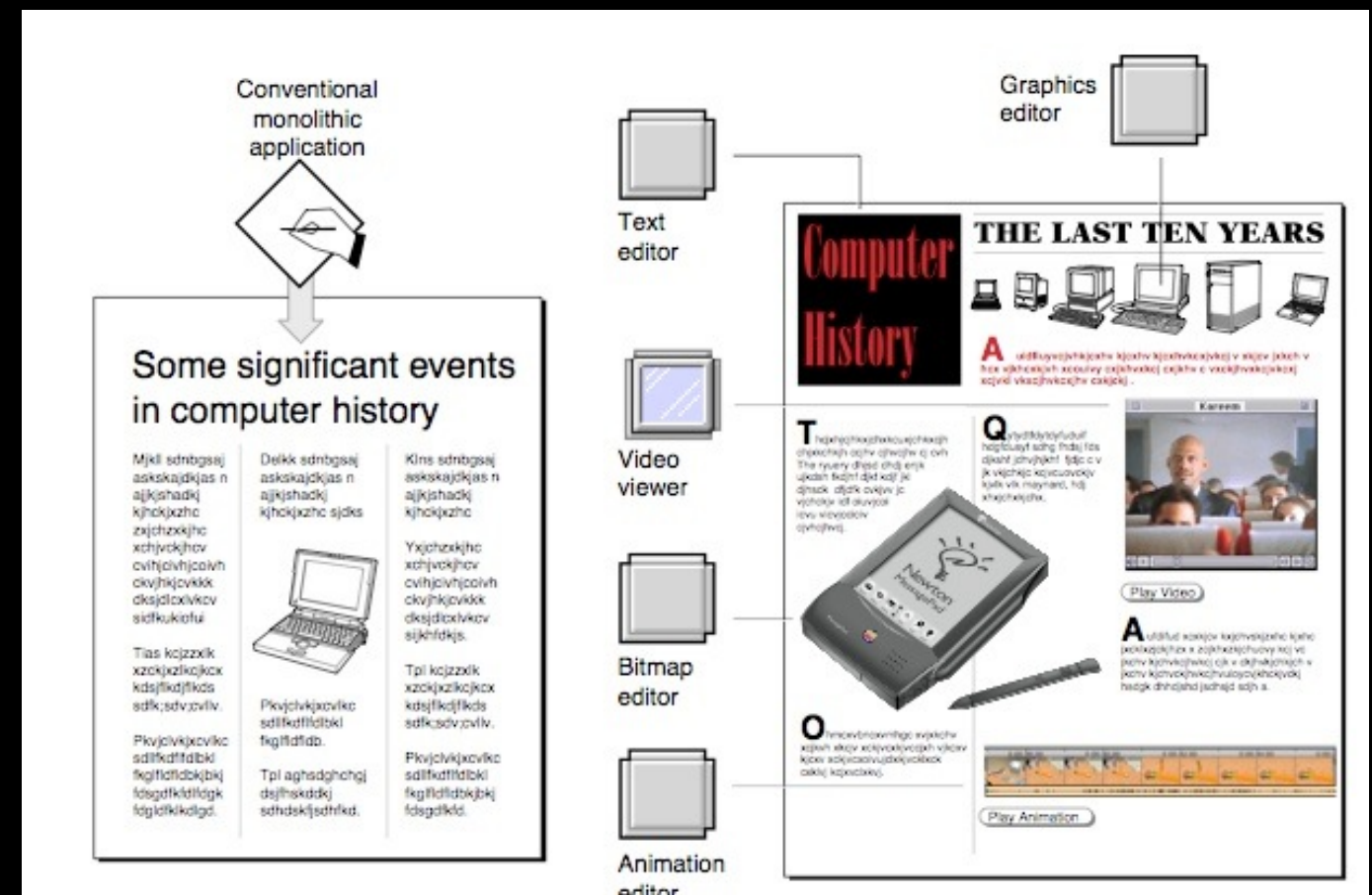
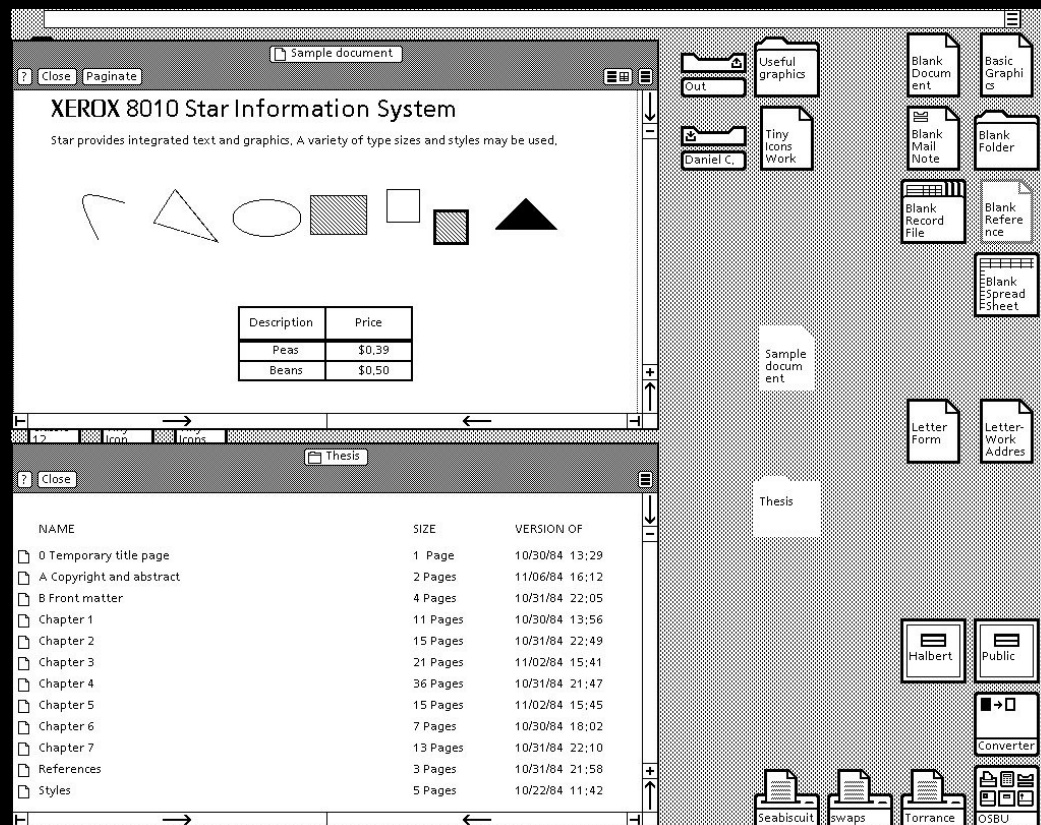


MCT to WARP

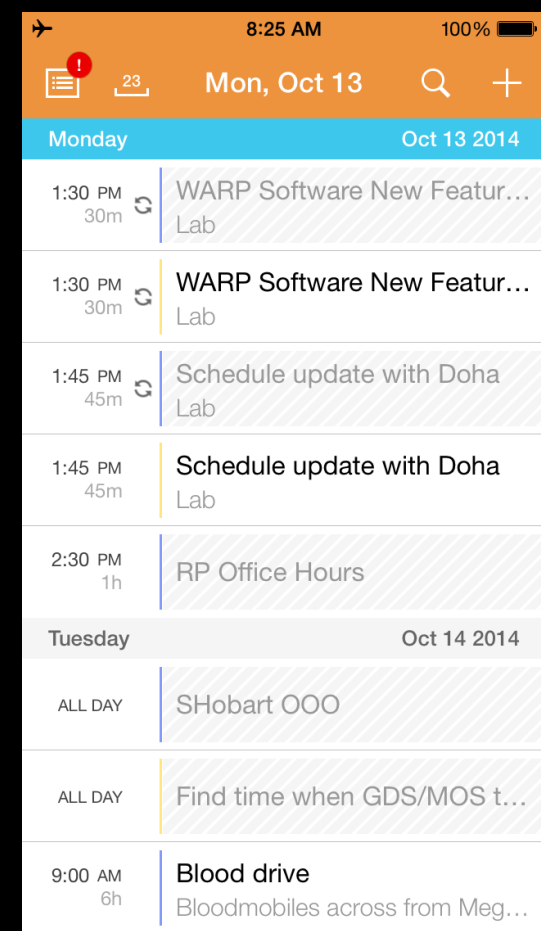
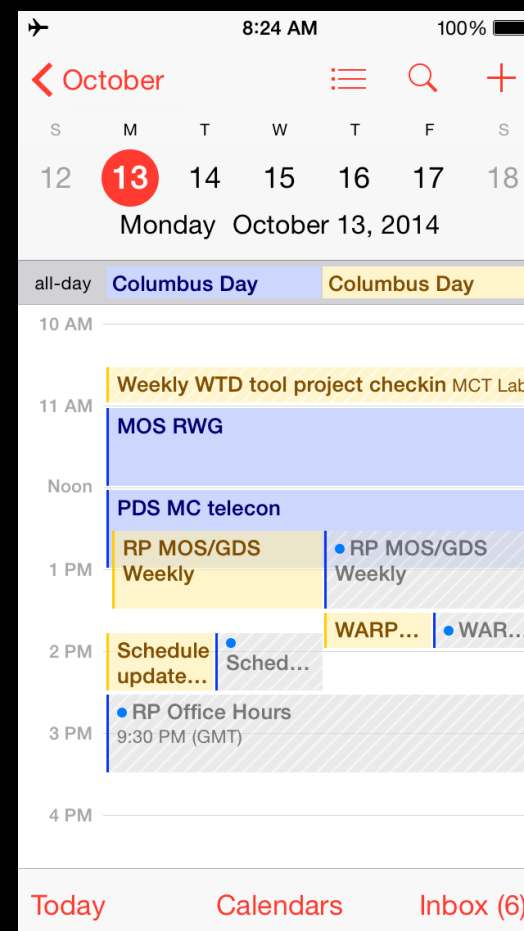
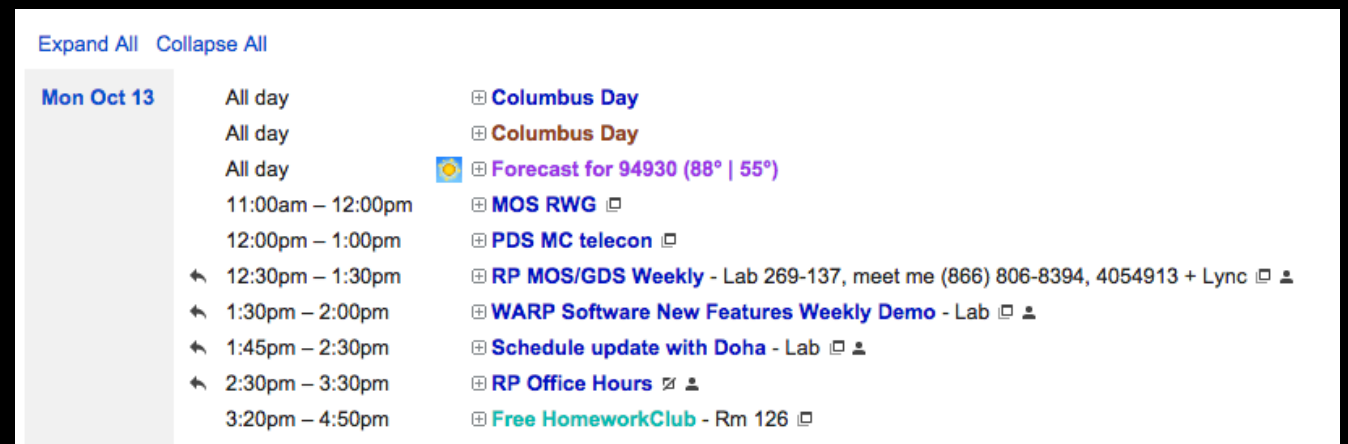
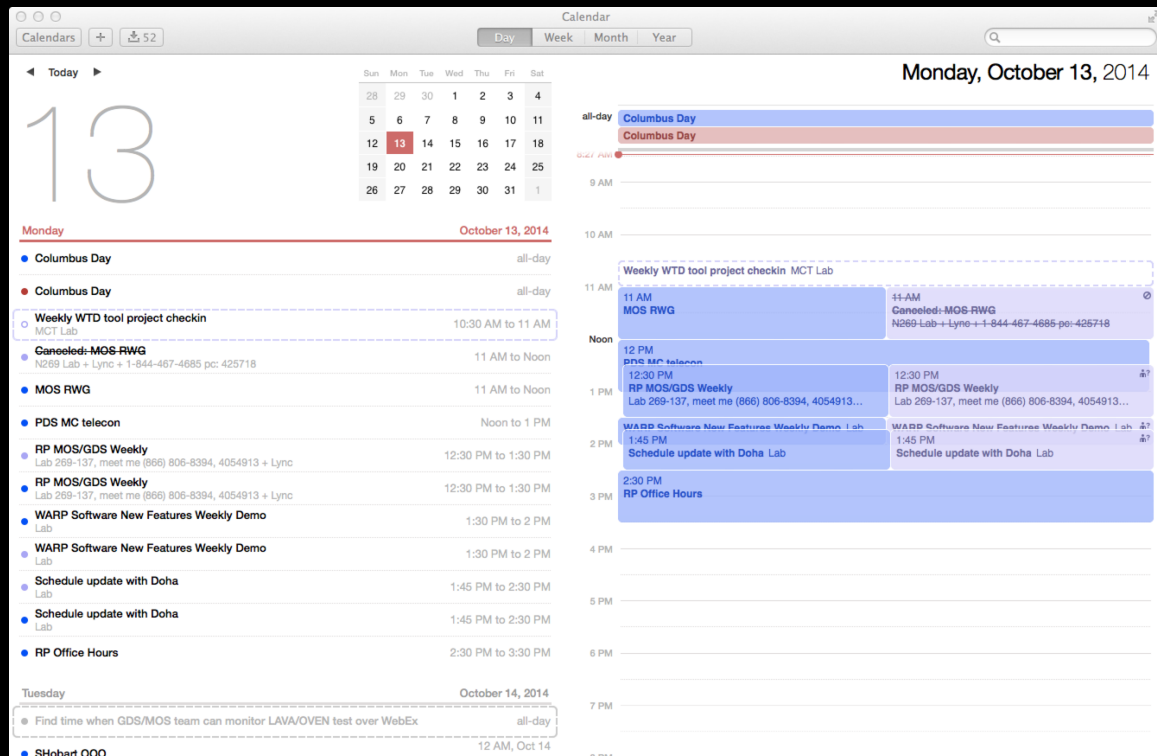
Objects, Models, Views



History

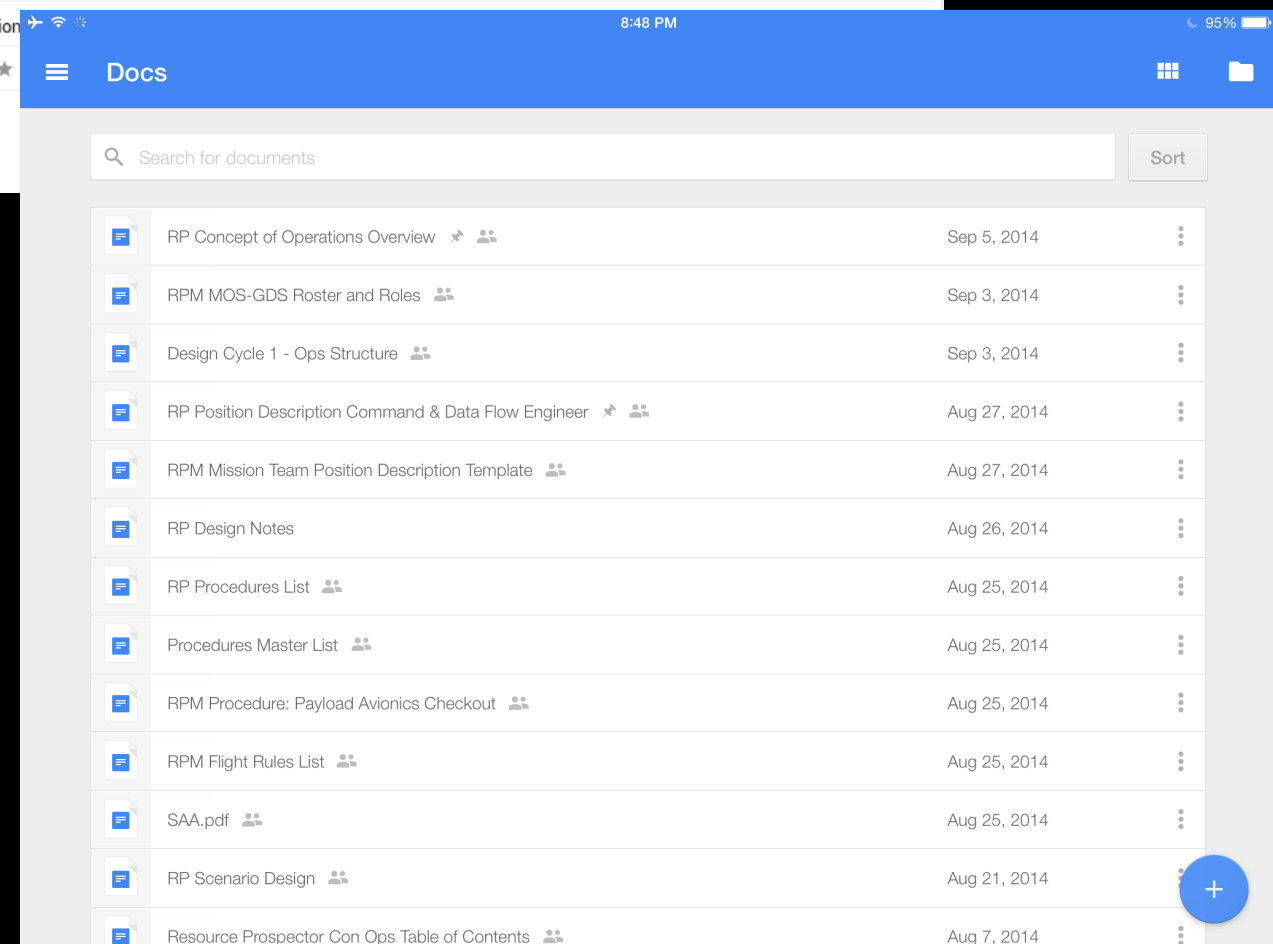
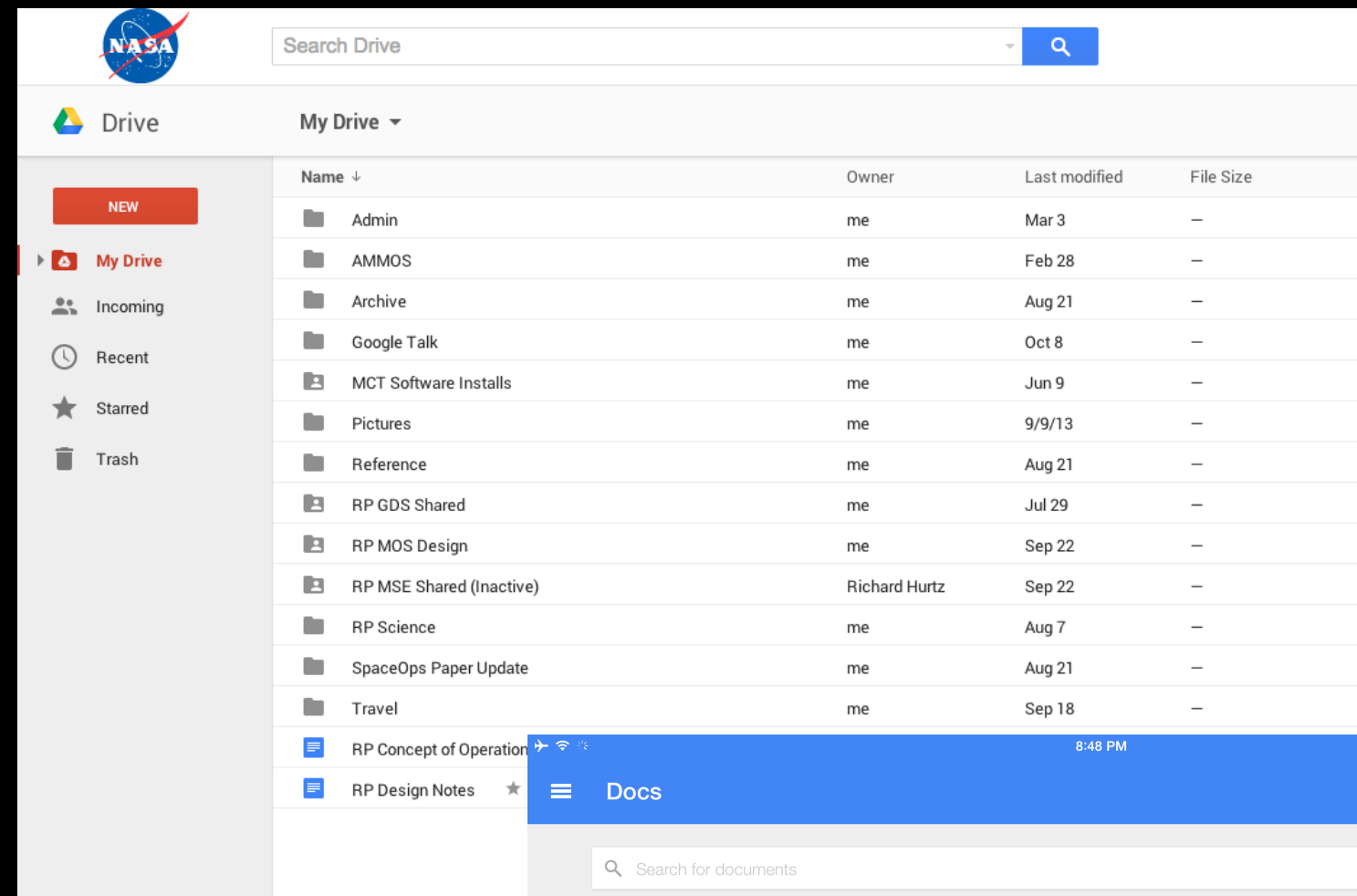


The same thing looks different



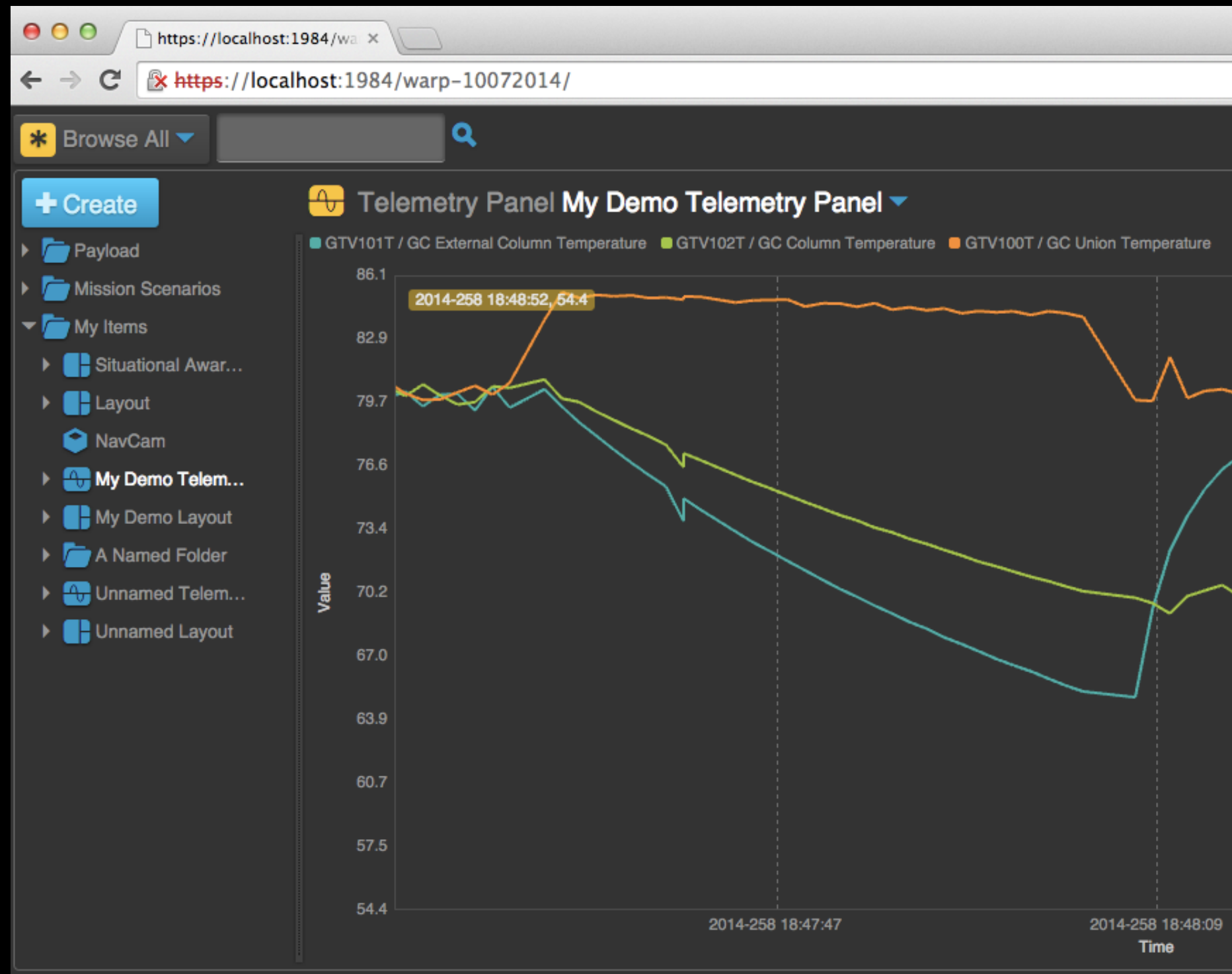
The same thing, diff. views

- How do I interact with information?
- Data centric views, I interact with my stuff
- Application centric, I interact with applications then use my data?



Our Approach - Integrated User Environment, Objects

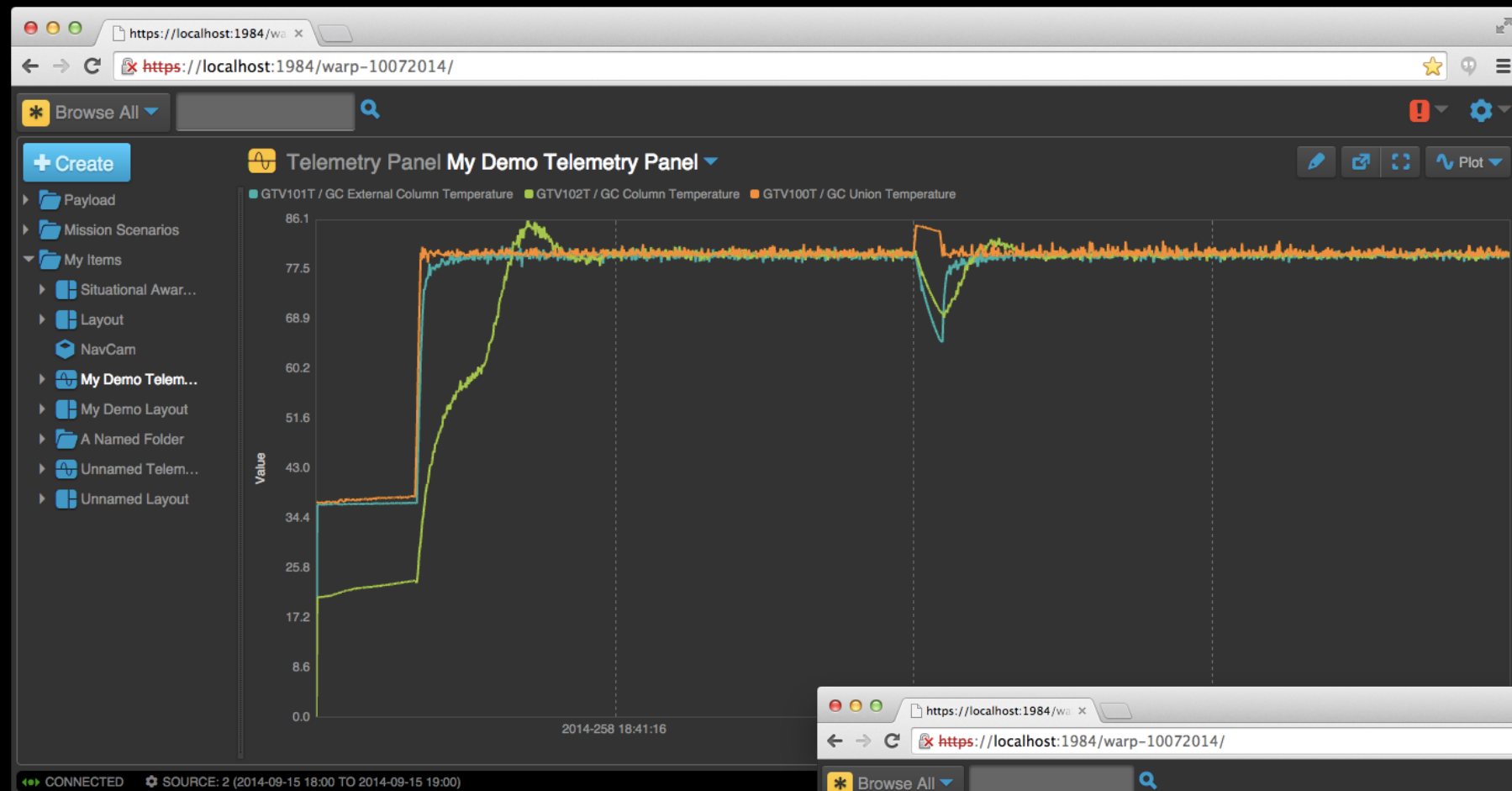
- Interact directly with data
- View that data in different ways
- No concept of separate applications



Core Tenets

- Objects and Compositions instead of applications
- The same thing in many places
- The same thing, different views

The same thing, different views



The screenshot shows the WARP interface with a browser window at <https://localhost:1984/warp-10072014/>. The left sidebar is identical to the first screenshot. The main area displays a 'Telemetry Panel My Demo Telemetry Panel' with a table view. The table has three columns: TITLE, TIME, and VALUE. The table contains 15 rows of data, showing temperature readings for GTV101T, GTV102T, and GTV100T at various times.

TITLE	TIME	VALUE
GTV101T / GC External Column Temperature	2014-258 19:00:00	80.6065368652344
GTV102T / GC Column Temperature	2014-258 19:00:00	79.7803192138672
GTV100T / GC Union Temperature	2014-258 19:00:00	79.773193359375
GTV101T / GC External Column Temperature	2014-258 18:59:59	79.8243103027344
GTV102T / GC Column Temperature	2014-258 18:59:59	80.0666961669922
GTV100T / GC Union Temperature	2014-258 18:59:59	79.8633117675781
GTV101T / GC External Column Temperature	2014-258 18:59:58	80.0264892578125
GTV102T / GC Column Temperature	2014-258 18:59:58	79.9845886230469
GTV100T / GC Union Temperature	2014-258 18:59:58	79.6528015136719
GTV101T / GC External Column Temperature	2014-258 18:59:57	80.3740539550781
GTV102T / GC Column Temperature	2014-258 18:59:57	80.4899291992188
GTV100T / GC Union Temperature	2014-258 18:59:57	80.6515808105469
GTV101T / GC External Column Temperature	2014-258 18:59:56	80.3558959960938
GTV102T / GC Column Temperature	2014-258 18:59:56	80.7545776367188
GTV100T / GC Union Temperature	2014-258 18:59:56	79.6505432128906

Mission Example



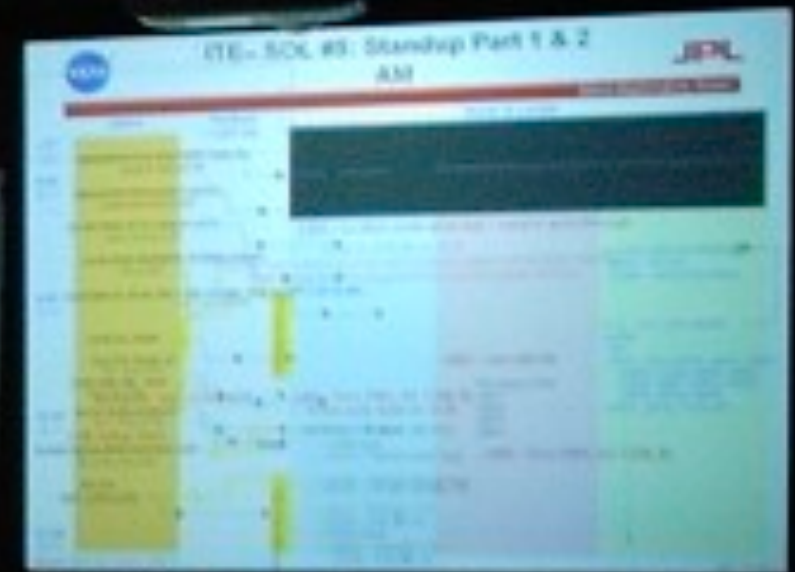
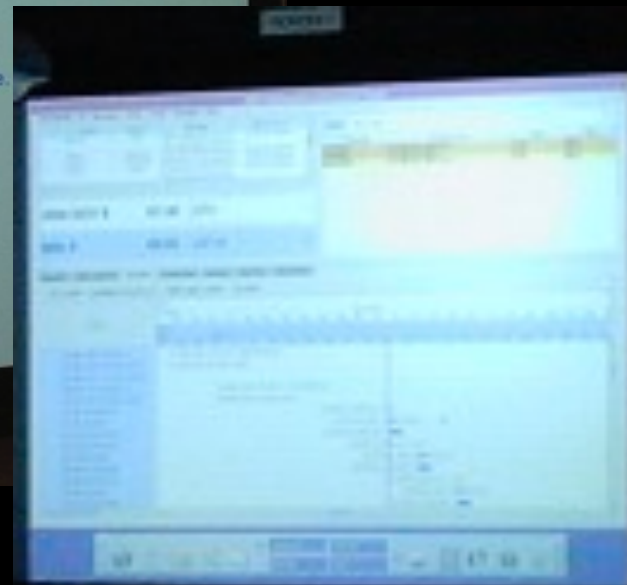
Sol 72 Activity Summary (continued)

JPL

Mars Exploration Rover

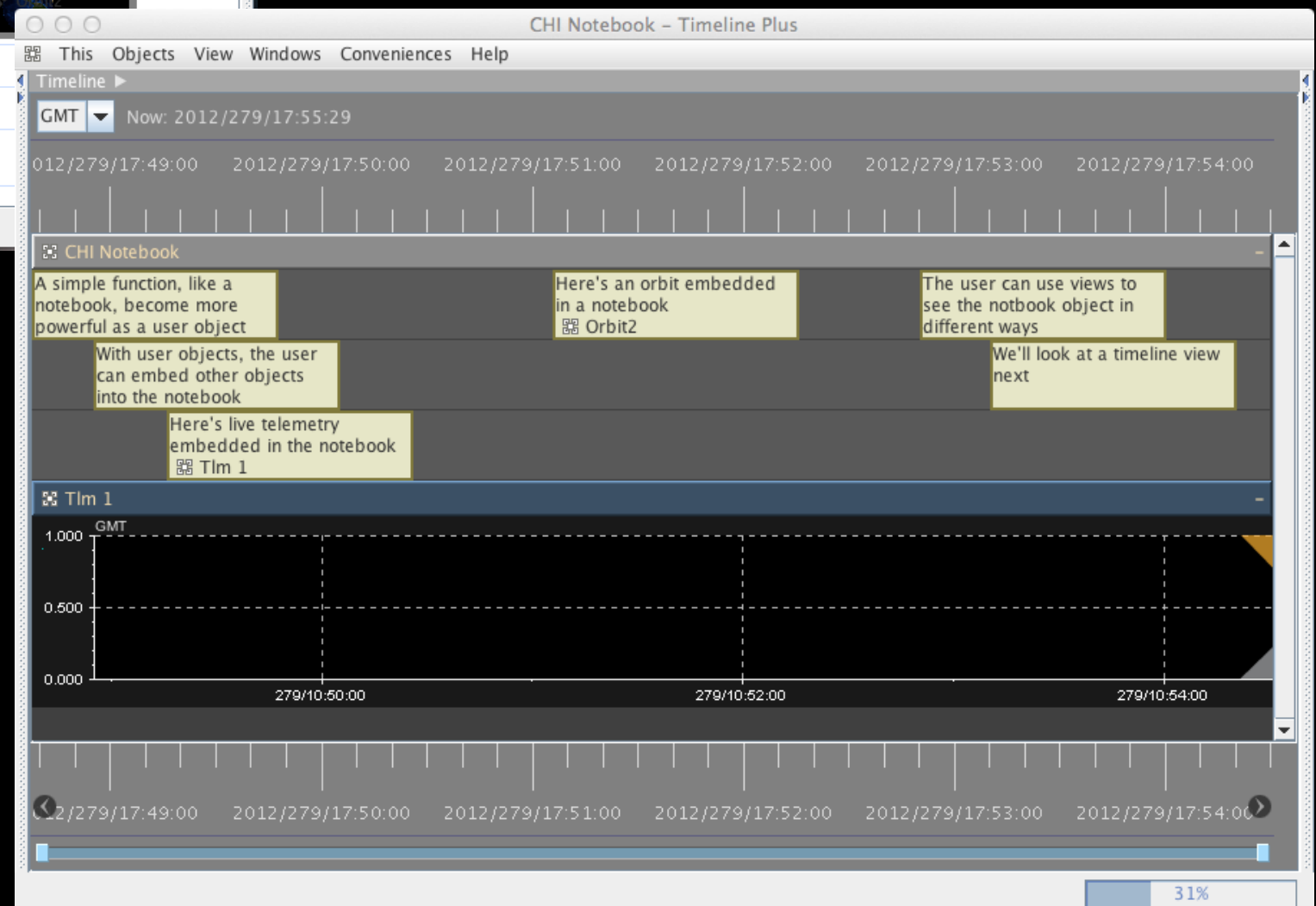
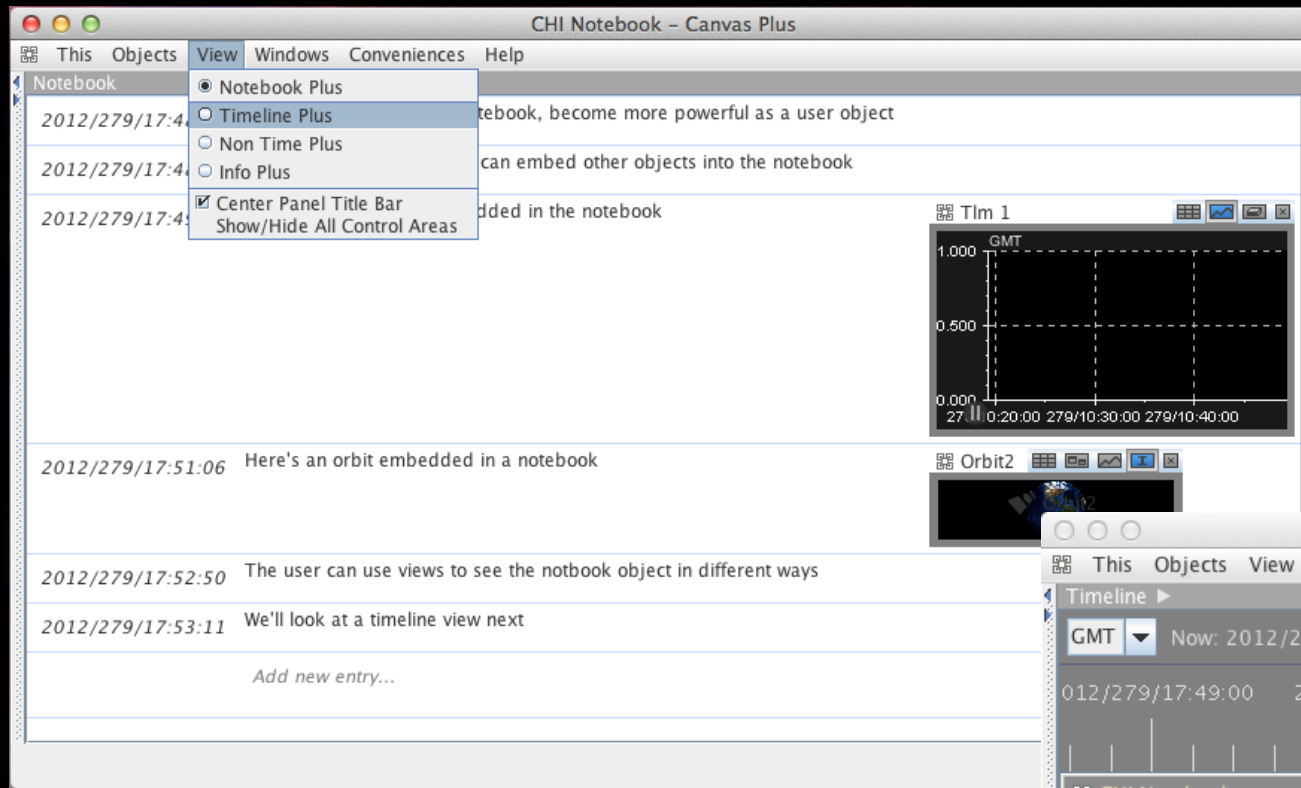
- Avoid radiating 2004-076T22:28:28 - 22:33:28 so not to step on the non-beep.
- Non-Beep at 10:00 LST if old master is still active - 2004-076T22:58:26 ERT (10:14:35 LSTA); otherwise, no beep (Confirmation of new master activate will be via EVRs.)
- 9:45 – 10:00 Engineering housekeeping keep-out
- 10:00 – 10:48 Siesta. DSS-14 drive off at 2004-076T22:30.
- Standard uplink sweep @ 2004-076T23:21 (10:36:33 LSTA) to hit at ~10:51 LSTA.
- 10:48 – 11:06 Pre-drive science
 - Pancam tau
 - Pancam observations on Serpent dune
- 11:06 – 11:20 MTES observation of Serpent Dune
- 11:20 – 13:50 Drive/Scuffing activity (All blind drives this sol). MTOD set to 14:00.
 - Turn to 90°.
 - Drive forward 1 meter.
 - Turn to 45° face Serpent Dune. Drive straight forward onto Serpent Dune
 - Perform a series of five turn-in-place and backup 10 cm sets to scuff up the dune.
 - Turn to 90° and backup 75 cm, then turn to 45°.
 - Front and rear hazcam
 - Drive backward to antepenultimate position (-0.85 meters)
 - Front hazcam
 - Pancam and mtes observations of disturbed Serpent dune
 - Drive forward onto Serpent dune (0.85 meters)
 - Post drive penultimate and ultimate hazcam imaging

Version 4

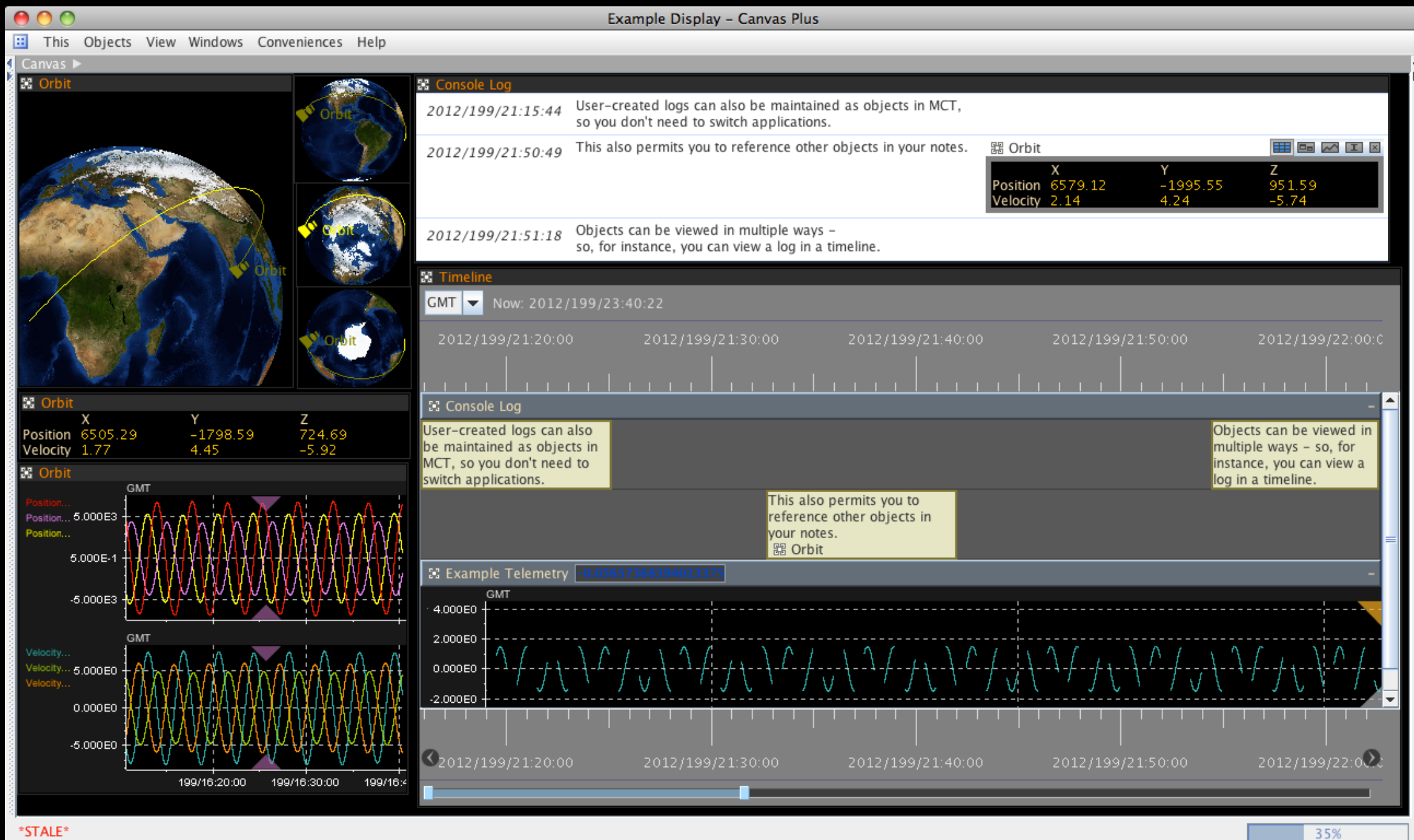


Mars Exploration Rover Timeline Views

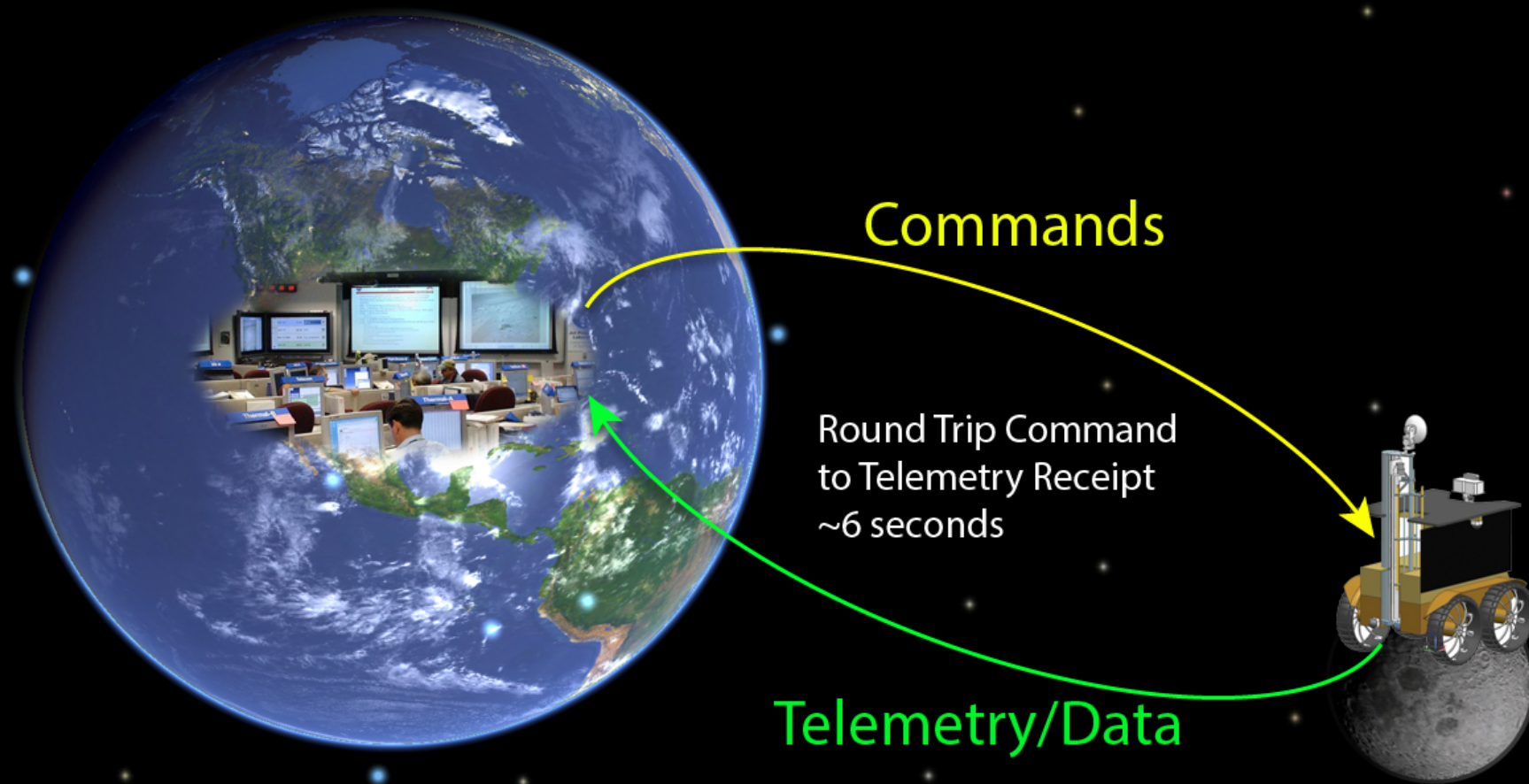
Composition/Views

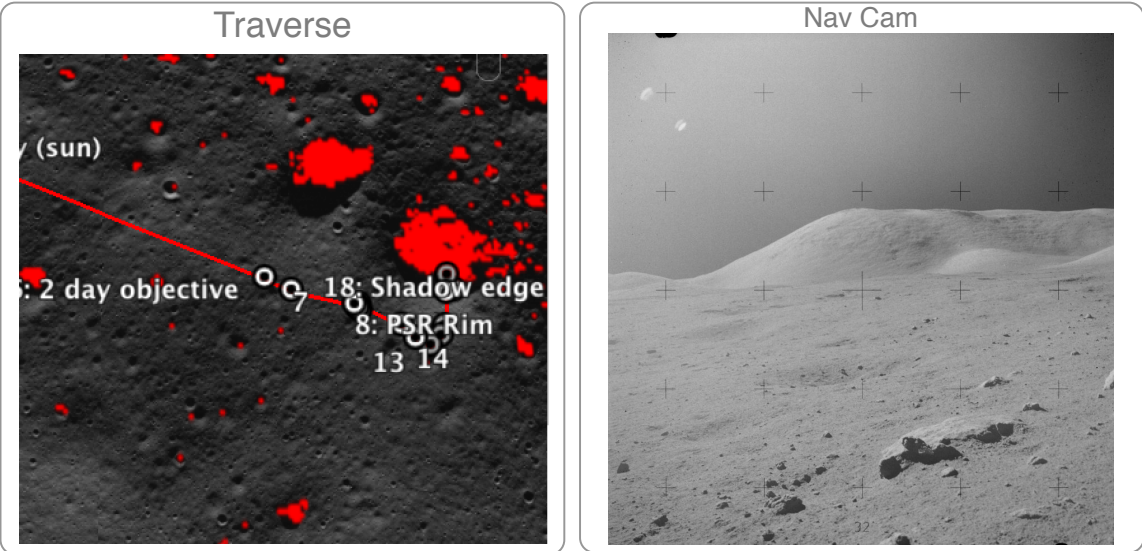


Combining more data types



Resource Prospector





Notifications		
dd:hh:mm:ss	PSR Pre-Entry	
dd:hh:mm:ss	PSR Approach	
dd:hh:mm:ss	Drill Secure	

Alerts		
dd:hh:mm:ss	Rover Thermal	More
dd:hh:mm:ss		More
		More

Timeline

PSR Pre-Entry Checklist

Drive to Entry Point 1

Rover Thermal Check

Path Verify

Nav Cam Verify

Haz Cam Verify

Go/No-Go

Go/No-Go

Current Procedures

PSR Entry Procedure

Regolith Characteristics

Verify Path

Drive to Entry Point

PSR Entry

Verify Rover Thermal

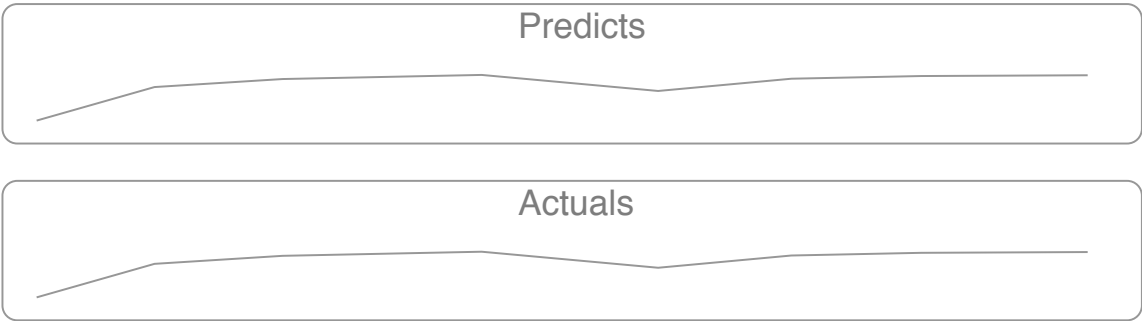
Temp 1 xx.x

Temp 1 xx.x

Temp 1 xx.x

Temp 1 xx.x

Add Note



Telemetry

	Volts	Amps
Ch 1 Serial	41.07	41.83
Ch 2 Serial	41.25	41.12
Ch 3 Serial	40.85	41.52
Ch 4 Serial	40.60	41.67

Flight Director

Console Log

<User Name>

UTC

ddd:hh:mm:ss

Waiting for thermal call from Rover Ops

xx.x deg C

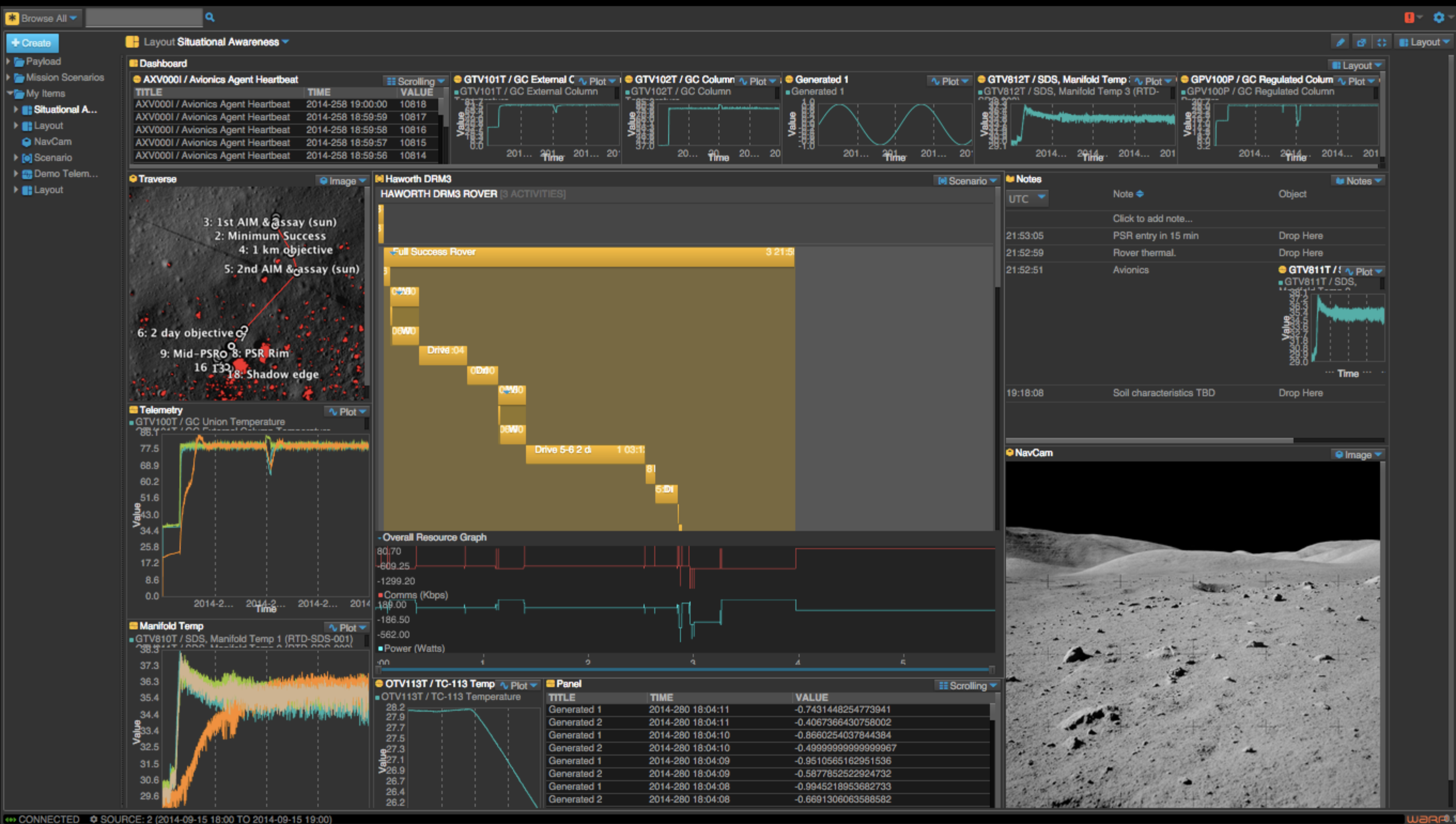
ddd:hh:mm:ss

Science discussing soil properties

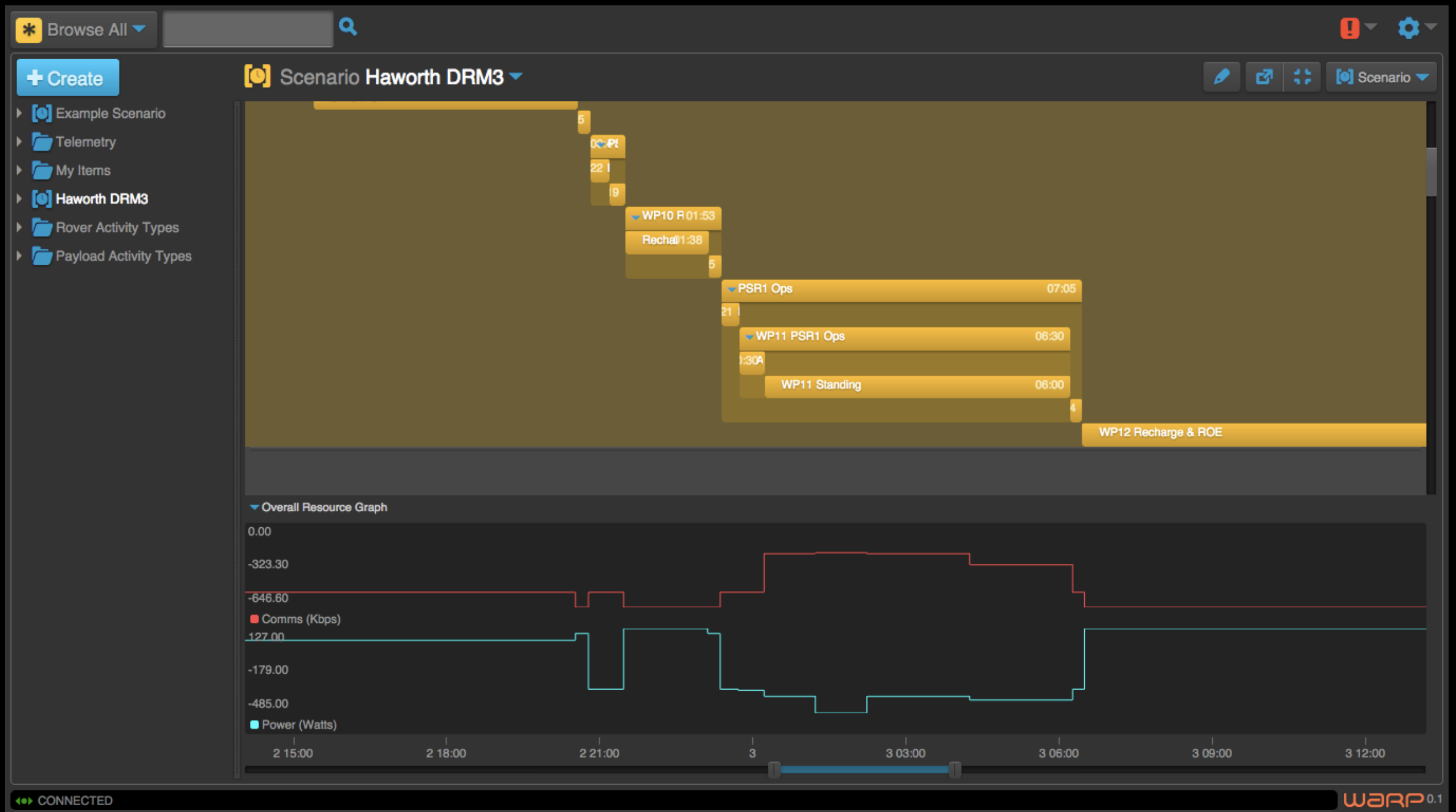
ddd:hh:mm:ss

Rover drive eval nav cam images

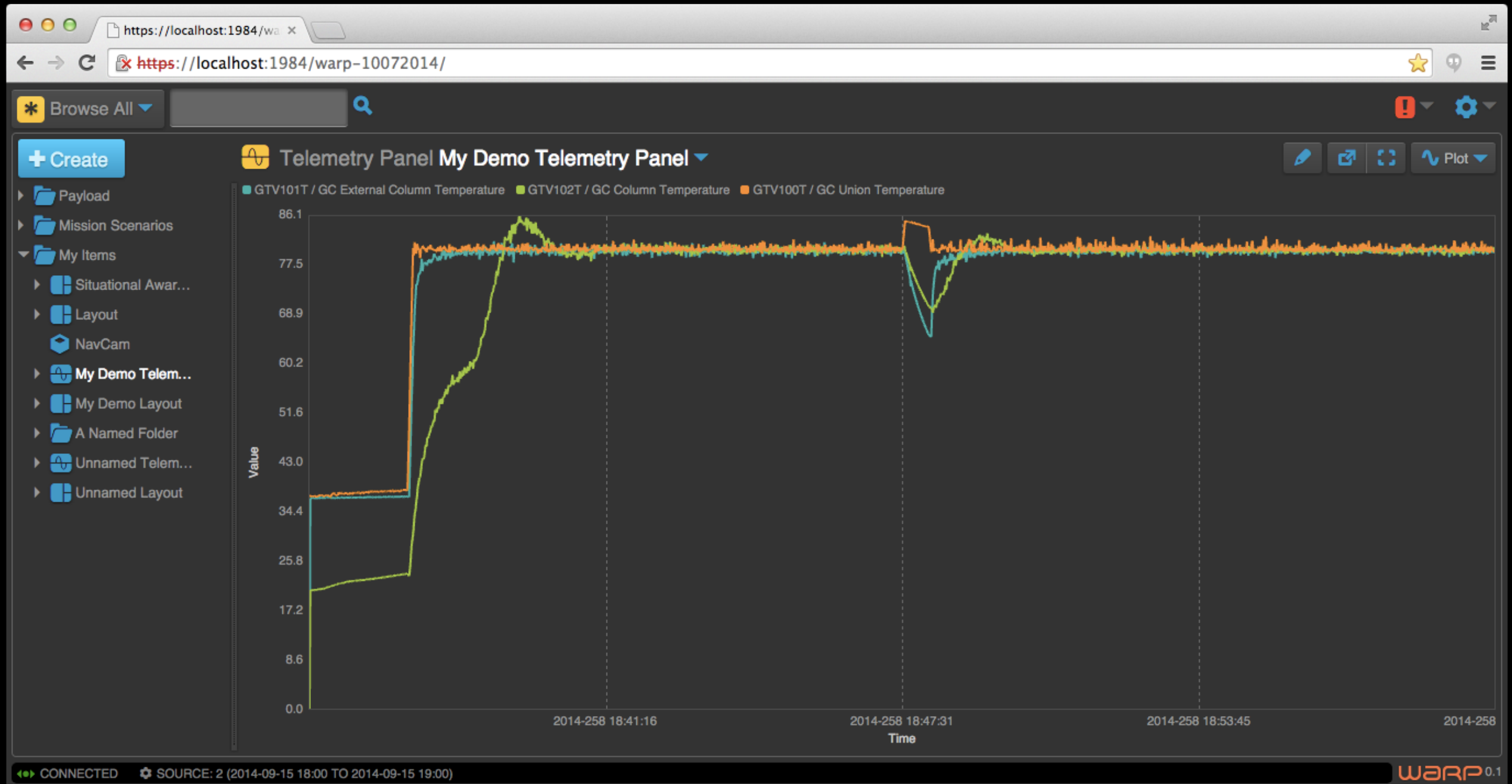
Situational Awareness for Resource Prospector



Timelines



Telemetry - Plots

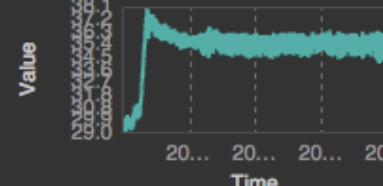


Notebook with embedded objects

The screenshot displays the WARP 0.1 interface, which is a software tool for managing and visualizing data. The interface is divided into several sections:

- Top Bar:** Includes a "Browse All" button, a search bar, and a "Notes" dropdown menu.
- Left Sidebar:** Contains a "Create" button and a list of items under "My Items". The items include:
 - Payload
 - Mission Scenarios
 - Situational Awareness
 - Notes
 - Dashboard
 - Telemetry
 - OTV113T / TC-113 Temp...
 - Panel
 - Manifold Temp
 - NavCam
 - Traverse
 - Haworth DRM3
 - Layout
 - NavCam
 - My Demo Telemetry Panel
 - My Demo Layout
 - A Named Folder
 - Unnamed Telemetry Panel
 - Unnamed Layout

- Main Notebook Area:** Titled "Notebook Notes", it features a table with columns for "UTC", "Note", and "Object".

UTC	Note	Object
	Click to add note...	
21:53:05	PSR entry in 15 min	Drop Here
21:52:59	Rover thermal.	Drop Here
21:52:51	Avionics	
		● GTV811T / SDS, Manifold Plot ■ GTV811T / SDS, Manifold Temp 2 (RTD-SDS-002) 

Open Source Mission Control Applications

- We started with Java on the desktop
 - Open Mission Control Technologies (MCT)
 - On Github
 - <https://github.com/nasa/mct>

WARP Open Source

- Coming Soon, check
 - <http://ti.arc.nasa.gov/OpenMCT/>
 - <https://github.com/nasa/mct>