

A Vision for Future Software

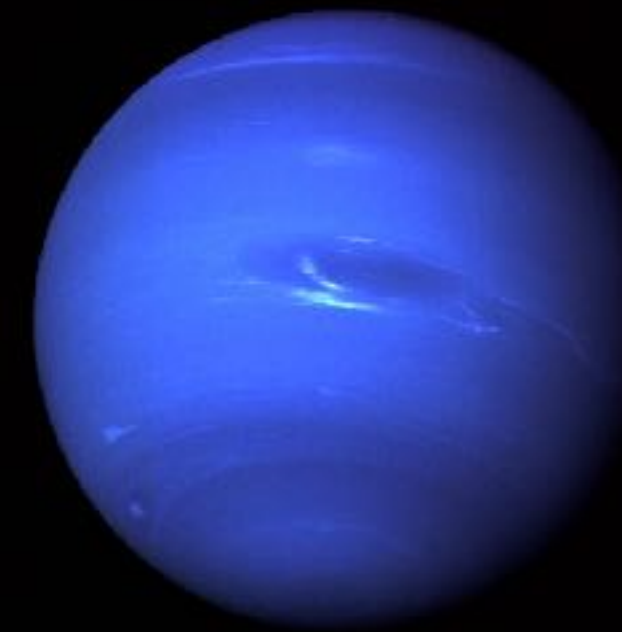
Open Source and Design Thinking at NASA

Jay Trimble
NASA Ames Research Center

Frontiers 2017



Personal Milestones



1960's

1981

1989

1994

Now

NASA JSC Intern

Science Ops
Voyager Neptune

Lead Ops Director
Space Radar Lab 1

Lunar Rover MOM

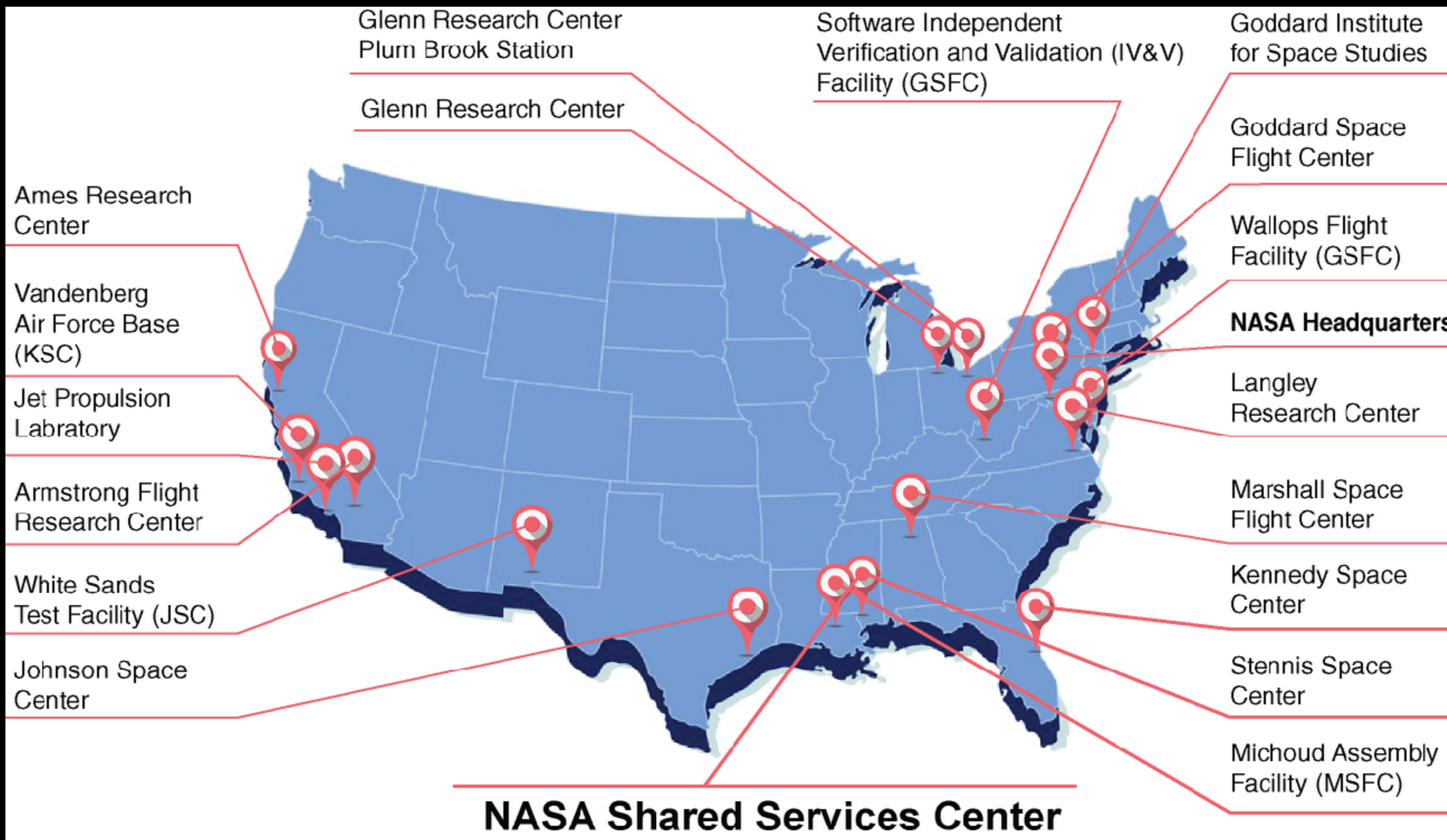
NASA Johnson Space Center

NASA Jet Propulsion Laboratory

NASA Ames Research Center



NASA Centers





Mission Control: The Icon



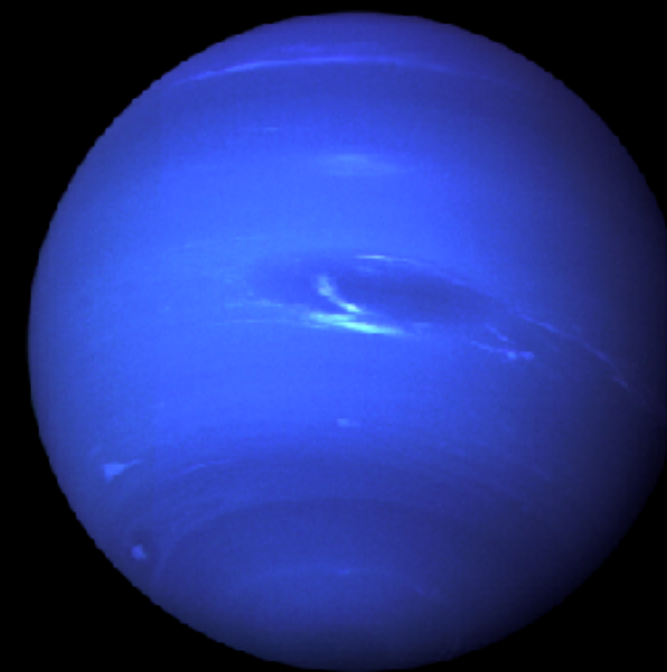
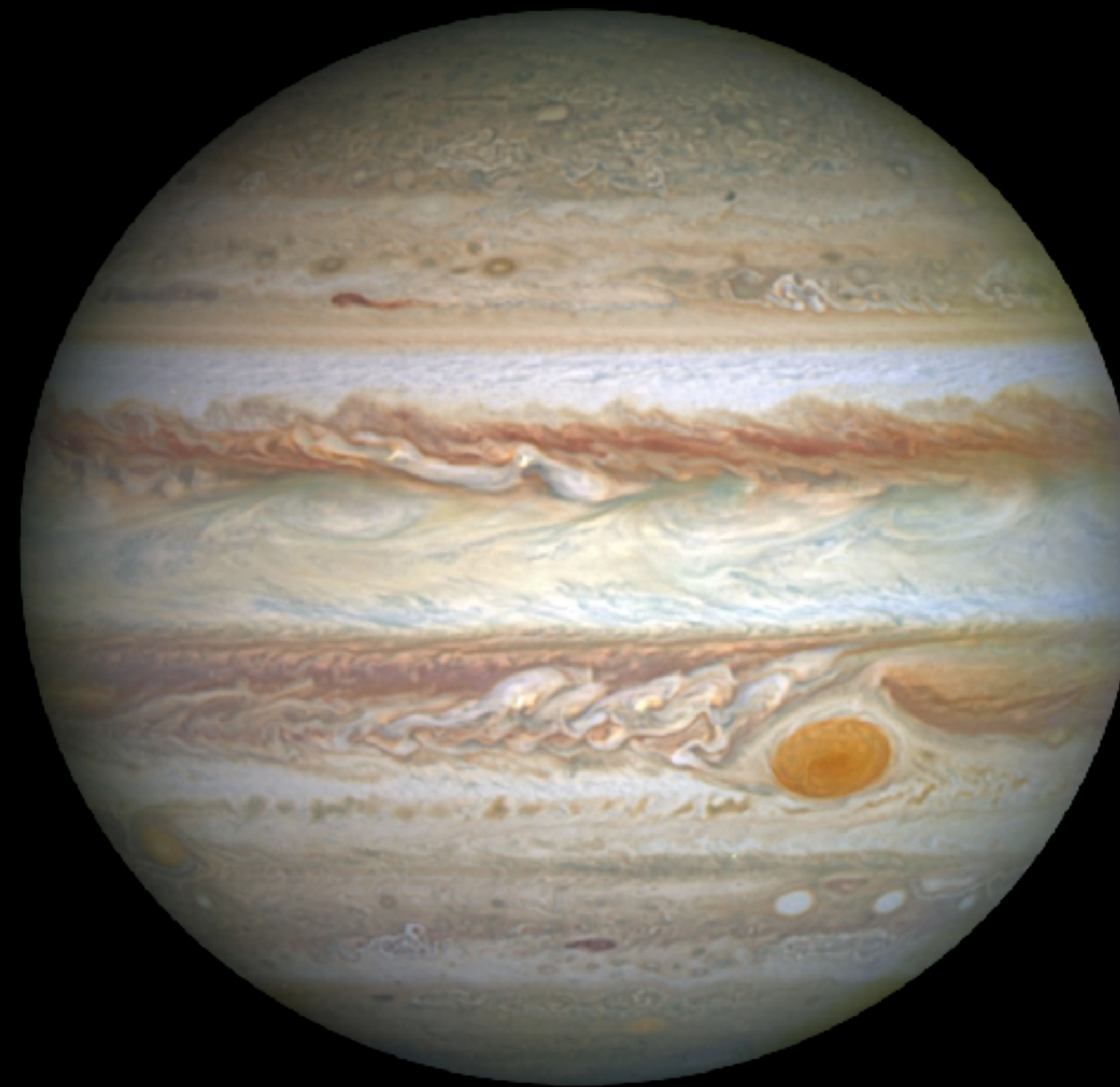
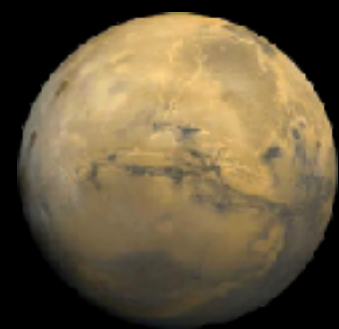


Mission Control for Mars Rovers





The Light Speed Constraint



Earth-Moon

~6 - 25s

Mars

~14 - 40 Min

Jupiter

~80 Min

Neptune

~8 hours



Mission Control v. Star Trek

- NASA

- Flight Director
- Systems
- Trajectory
- Payloads/POCC
- INCO



- Star Trek

- Captain (Kirk, Janeway, Picard, Cisco,...)
- Engineering (Mr. Scott)
- Navigation (Chekov)
- Science Officer (Spock)
- Communications (Uhura)





Mission Control Famous Calls





Mission Control Famous Calls





Mission Control Famous Calls





Houston Mid-1980's

The Mission

Repair a malfunctioning satellite

In orbit capture and repair has not been done

It's made possible by the Space Shuttle





The First Epiphany

0 DAY 0 4 6

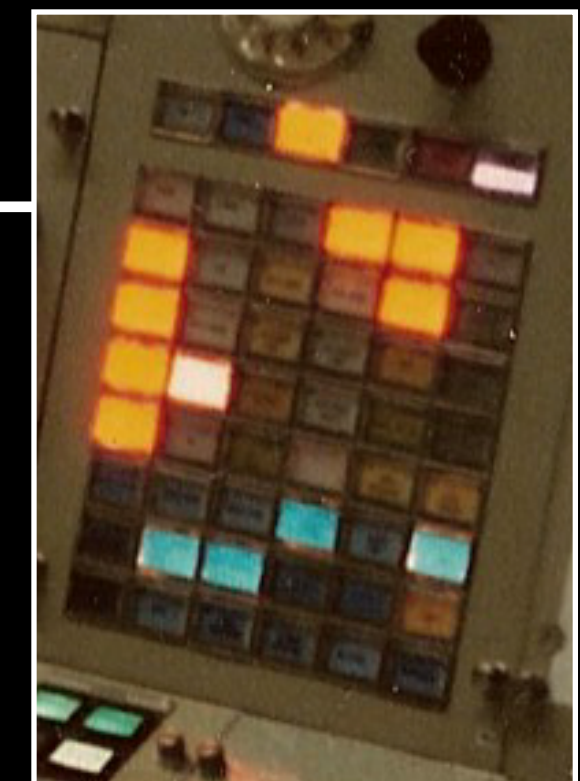
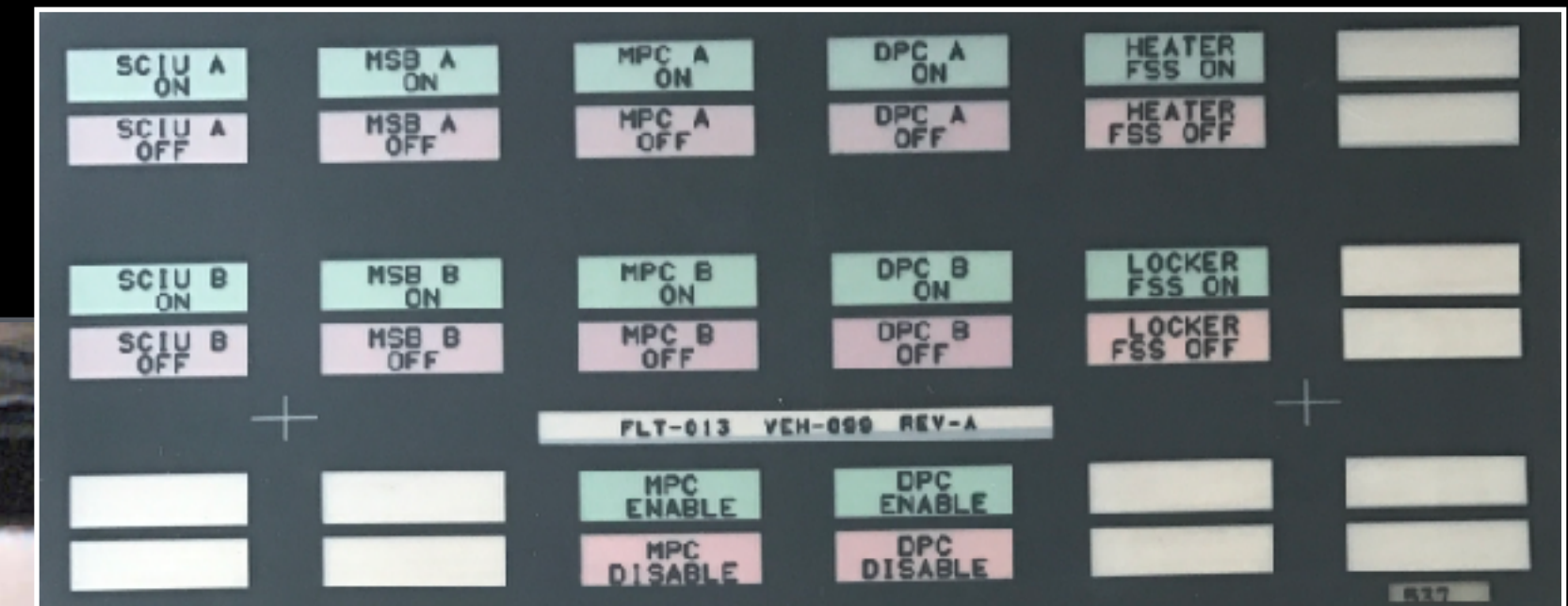
F/V 13/009 FSS CONTROL RR3408A CH020

CGMT 46:19:11:11 DMET 0:00:00:00 SITE MIL OI 188 GN 0
RGMT 46:19:11:11 U/D RATE 1 SM 64 BF 0

MECHANISM SELECTION	CONFIGURATION	TELEMETRY
BERTH LAT 1 1	ON A B OFF A B	AMPS TEMP
2 2	SCIU 16 * 17 * *	SCIU 0.56 22
3 3	MSB 18 * 19 * *	MSB 0.06 23
UMB MAIN 4	MPC 20 * 21 * *	MPC 3.6
HEATER 5	DPC 22 * 23 * *	DPC 0.1
RET LAT KEEL 6	LCKR 24 * 25 * *	FSS LCKR 1 84
PORT 7		2 83
STBD 8		
ROTATOR 9	HEATERS (SSP)	
PIVOTER 10	ENA AMPS	FCU 26
TRANSLATOR 11	FSS 0.1	PDSU 22
PLAT LOCK 12	SMM 0.1	
DESELECT 13	MACS 0.1	
		FMDM 0.90
OVERRIDE		FMDM BOX A 34
ENABLE 14		B -954
DISABLE 15		

DEU 1 DISP MF
2 2200 SM
3 1 SM
4 5 05 5
5 5 05 5

YB4 001 9 0001 1 SEC 1





Evolution





Pasadena Early 1990's

The Mission

Earth Observations Using
Synthetic Aperture Radar

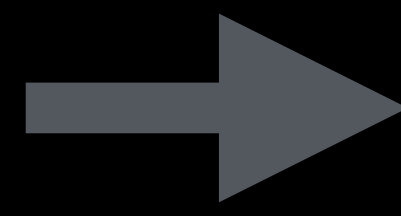
Two missions on Space
Shuttle Endeavor



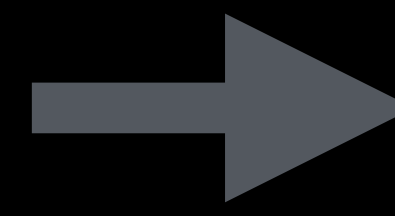


The Second Epiphany

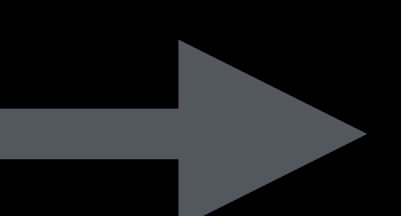
Write software requirements



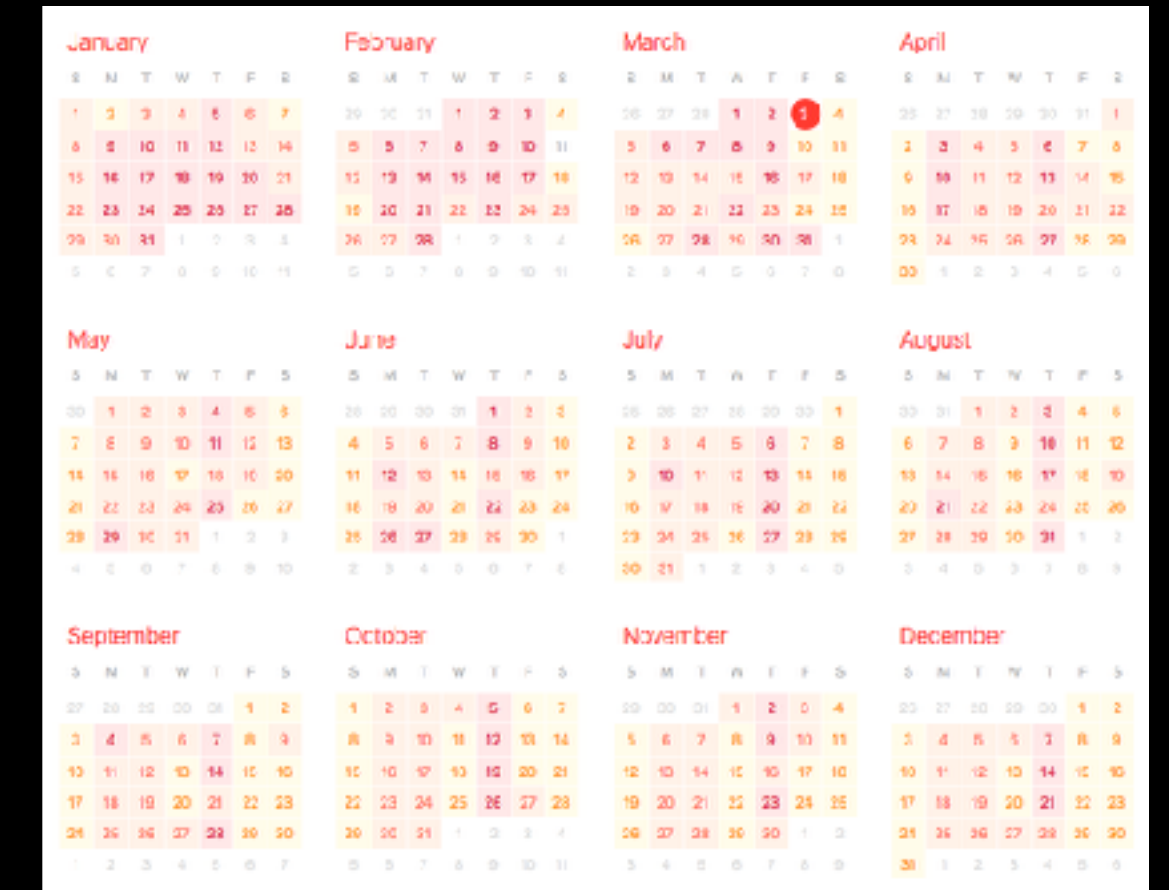
Customer signs requirements



Expectations and mental models diverge



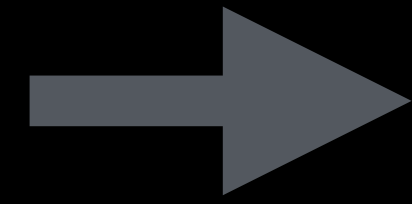
MOS shall track the orientation of the solar panels with respect to Sun (+/- TBR arcmin)



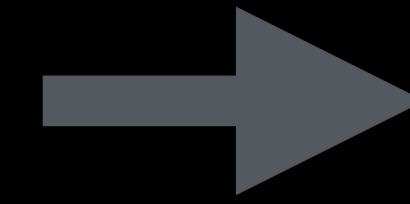


Expectations Meet Reality

About to get a look



Users see the software



Why this reaction?





There must be a better way

Follow the (as yet undefined for us) road to user centered agile or, take a long vacation



Early 2000's Mars Rover Ops

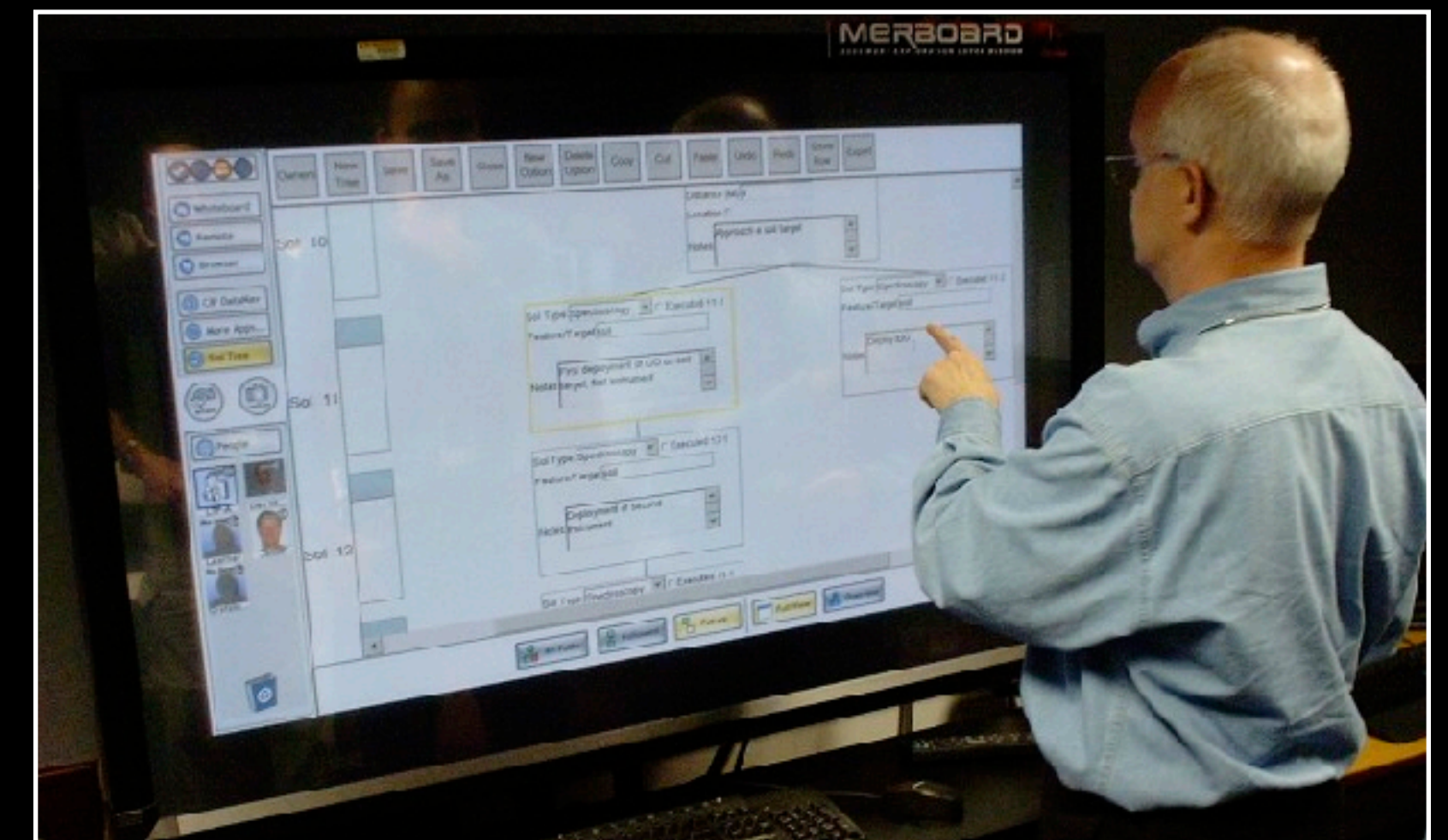
The Mission

Mars Exploration Rovers (JPL)

Human Centered Computing (ARC)

We proposed methods, not specific solutions or tools

We called it Human Centered Computing, inspired by Don Norman, The Invisible Computer



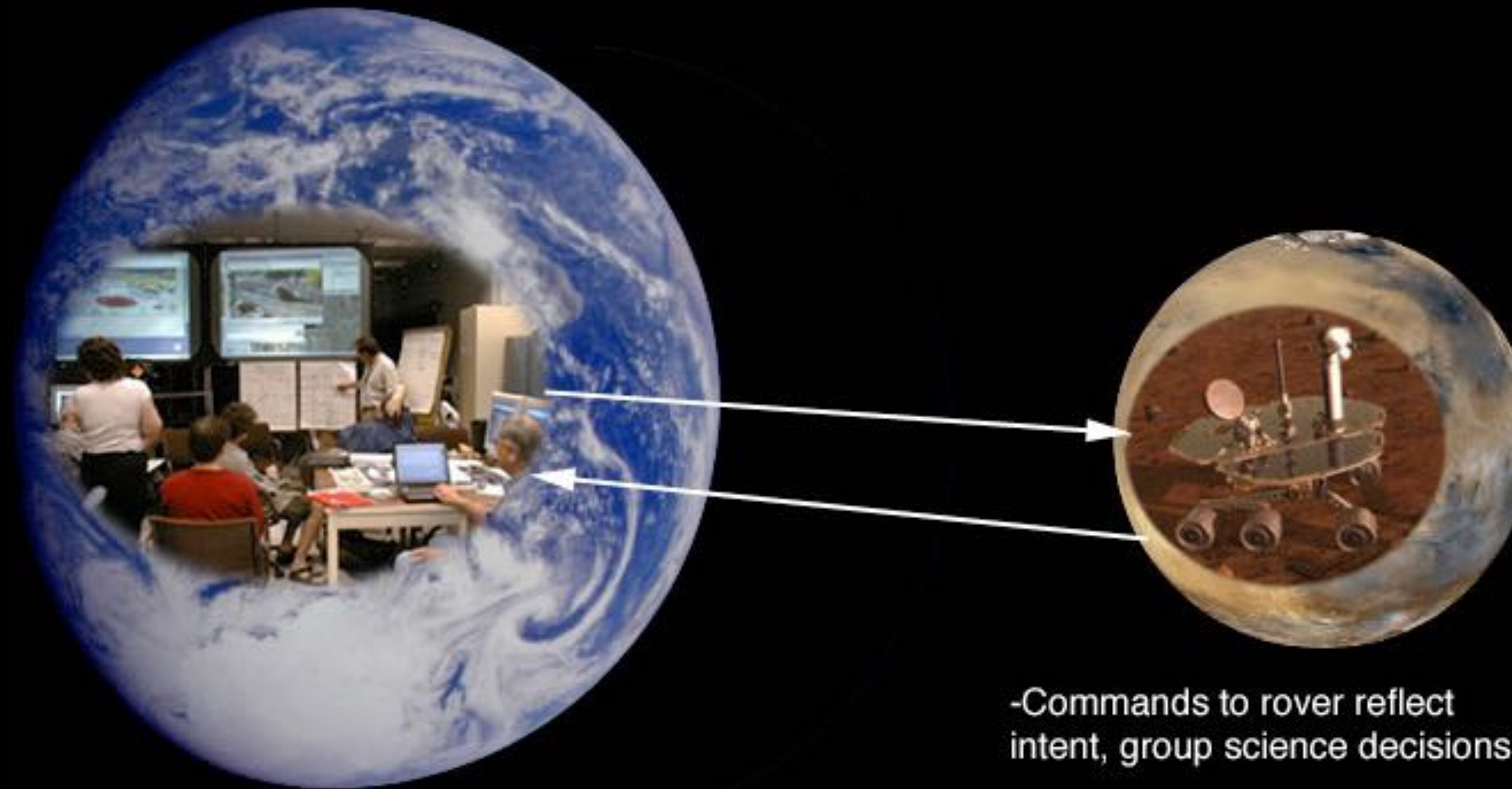


Mars Exploration Rover Scenario

Users on Earth

Rover on Mars

Max round trip light
time ~40 min



-Human Science Team with
Computer tools
-Intent, Qualitative Assessment, Judgement,
-Science Priorities, Resource
Management

-Commands to rover reflect
intent, group science decisions



Acceptance

To fund MER HCC, we had to “sell” the ideas to our funders at NASA Ames, to the Mars Exploration Rover Project at JPL and to the users

We focused on outcomes and touched on the methods using analogies

Easier to market an artifact or a result than an idea

Mental model example - Ethnography = User observations - what people say and what they do are often different. How often do you exercise?

Goals - Mission productivity, communications, safety

Note no mention of design thinking, this is 2000



Key Lessons so far

This is a small community and most people know each other

Each mission is its own community, somewhat like the cast in a performance

Speak the stakeholders language

Be careful with generalizations like “the invisible computer” or software that adapts to users rather than the other way around

Most of the stakeholders care only about what your product or method does for their mission

Most of users don't care about design, but they may care about the results

Users who are used to a way of doing things, even an inefficient way, will resist change. Don't give them change unless it adds significant value.

Don't go against established conventions, no change for changes sake, use established, mental models

Do not try to take away existing tools. Give them new tools in shadow mode.

Be careful about getting too excited about your cool new technology



Next

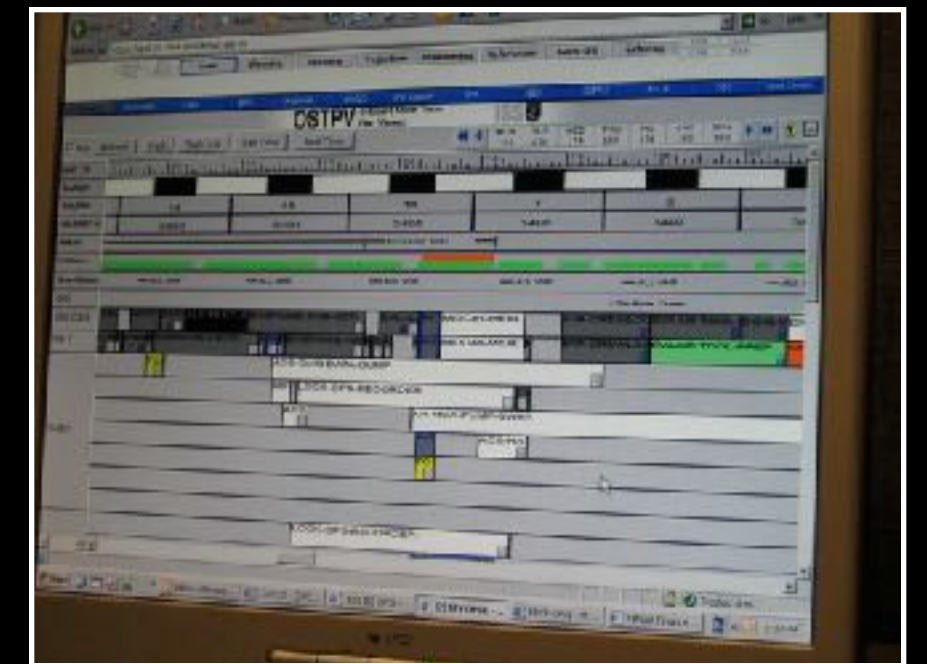
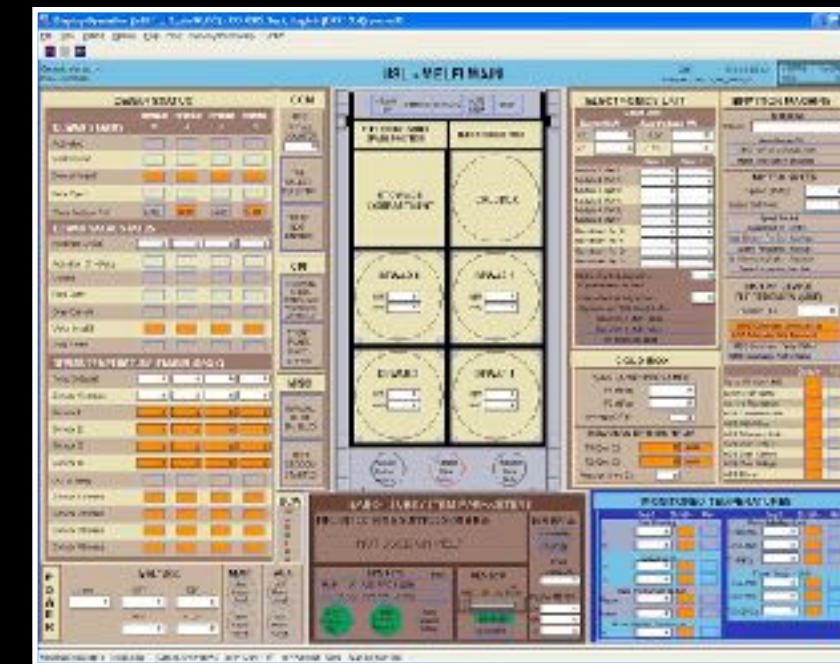
We now believe we need new technology, not just methods and process

So we embark on a new course and instead of proposing methods we propose tools...



We are trying to “fix”

Multiple heterogeneous applications create walls, turning users into integrators





The Selling Points

Decrease Cost

Save on maintenance by retiring existing applications, make the users productive

Empower the users

Compose your own displays without programming, all your stuff in one place

Top Down v. Bottom Up

The top provides the funding

The Bottom provides the advocacy (remember this is a small community)

The problem that we could not see yet

The management funded the project based on the retirement of existing applications

Users are open to new technology but less so when they are told that they are going to lose the current capability on which they depend



Participatory Design

Designers facilitate design process, users are domain experts

We used The Bridge Method

Built a shared language

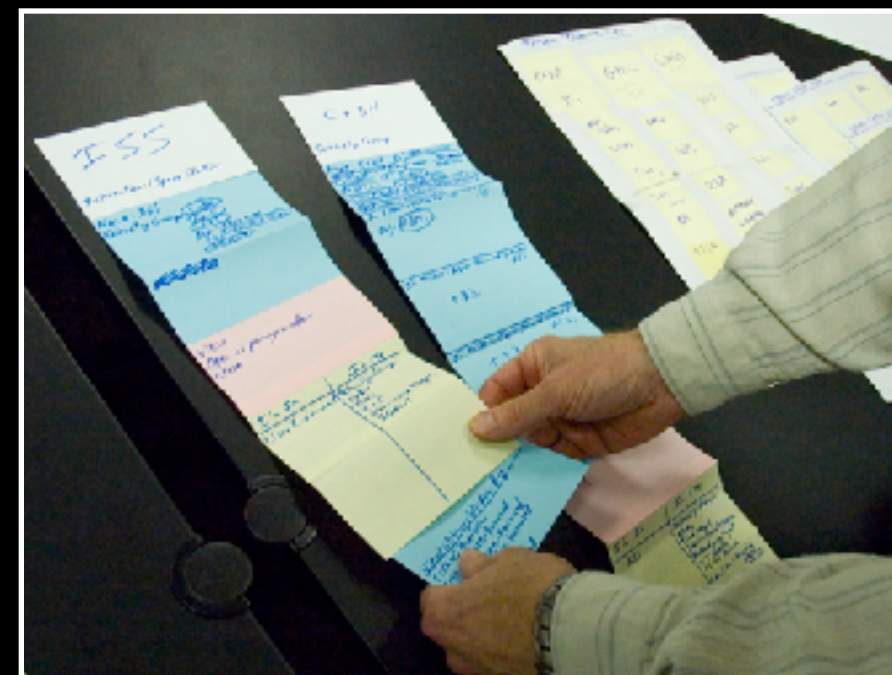
Built shared mental models

Enabled us to design solutions with users

Created a tight bond between the design team and participatory users

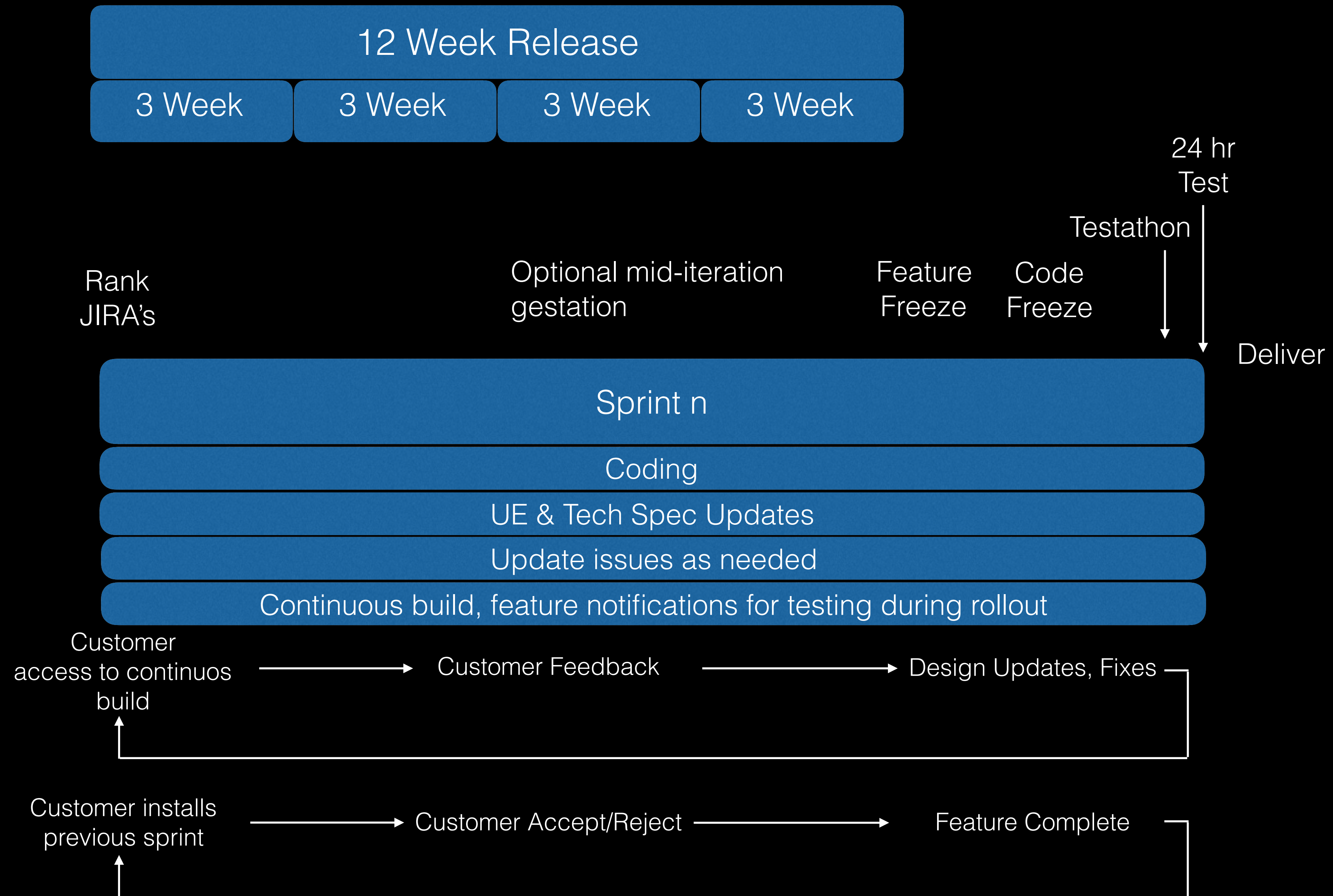
Shared ownership

Created an us v. them between the participatory team and the larger user community





Agile User Centered Design

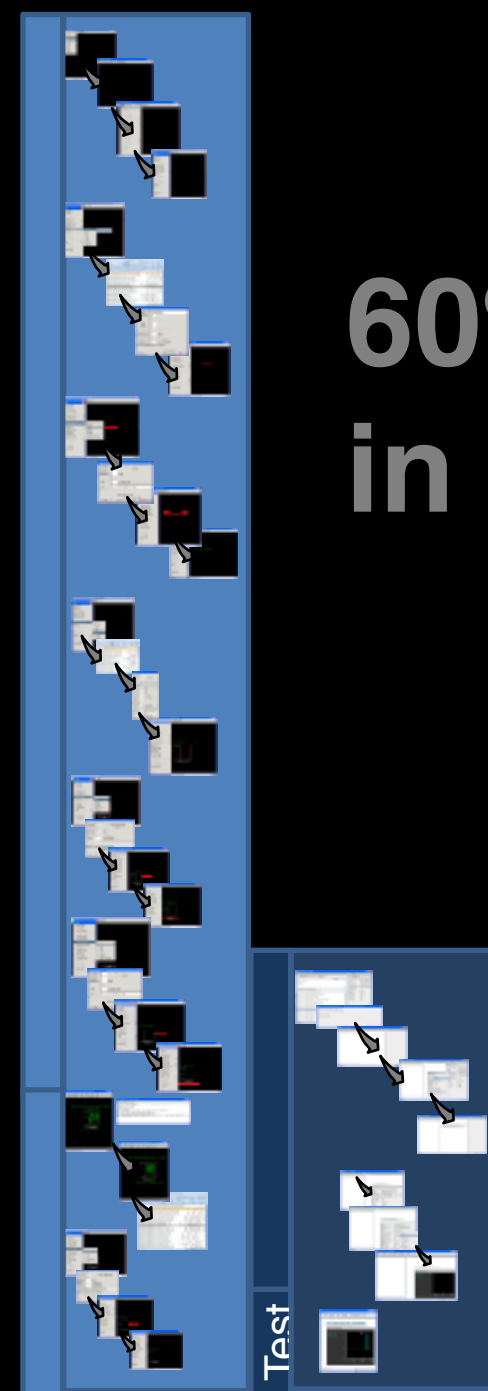




Did we help the users?

Process steps

What actions does it take to build and test a display?



60% reduction in steps

80% reduction in manual entry

Manual data entry is the primary source of errors / risk

	Legacy	MCT
Steps	20	8
Manual data entries	5	1
External tools used	1	0

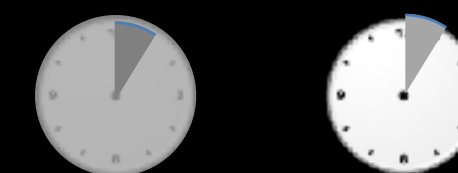
Process time

How long does it take to accomplish those steps?



90% reduction in time

	Legacy	MCT
Minutes to complete	65	6





Key Lessons

Design is not enough

End user composition alone is not enough, it must be mixed with the specific job enabling features that users want. The combination is powerful.

The term end user composition is nerdy and does not grab people, the popular lexicon on this shifts... "mashups," "dashboards" and can confuse the message

Unknown cultural differences can have a big impact - our first user test, though we stated it as such, was thought by users to be the final software because this is the only mental model they had

New capabilities take a long time to catch up to "old" capabilities, benefits must outweigh the inconvenience

Don't take away "old" capabilities, let new co-exist with old in shadow mode, for a period of time

Customers will map what you say into their own expectations, creating a mental model that varies across groups and that may be unknown to the design team

Show constant progress, make it visible and accessible

If it's not easy, people won't even try it

Customers want and expect new capabilities, they also want all of their legacy capabilities

Openness increases with time and use

A new mental model, even a better one, at first will be confusing to users



It's all so simple

Succeed

Know who your stakeholders are, focus

Fail

Try to solve too many problems for an undefined stakeholder base

We did better creating generalizations from instances than creating instances from generalizations - start by solving real problems not generalizations



Rebuilding

The desktop version is ultimately cancelled

We rebuild, our funders are now in California



New Stakeholders

Jet Propulsion Lab

Multi-Mission Ground Systems

Multiple missions use the software over time, at many NASA centers

Jet Propulsion Lab

Many Flight Projects

Each one concerned about success of their mission

NASA Ames Research Center

Resource Prospector

Successful Mission

Open Source Community

NASA, Commercial, Other

The success of their project



Stakeholder Language

User Test

Our users mental model in the early 2000's was that software is delivered and that's what you get (remember those inflexible displays). We conducted a user test on early software with unforeseen consequences

Prototype

A designer thinks of a prototype as a question rendered as an artifact, the expectation is that there will be many

A system engineer thinks of a prototype as a risk reduction exercise to buy down risk associated with system requirements, expectation is that there will be few because they tend to be expensive

Demo, Test

Popular mental models, such as dashboards and mashups affect user perception

Say it then sim it



Mental Model Map Example

System Engineering

Requirements (tendency
fewer ideas)

Prototypes for Risk Reduction,
typically few

Review

Build

Train, Fly

Design Thinking

Observations
Ideation
Synthesis (more ideas)

Prototypes - questions rendered
as artifacts, typically many

Try/Use ("Say it then sim it")

Iterate

Train, Fly



Open MCT

Open Mission Control Technologies

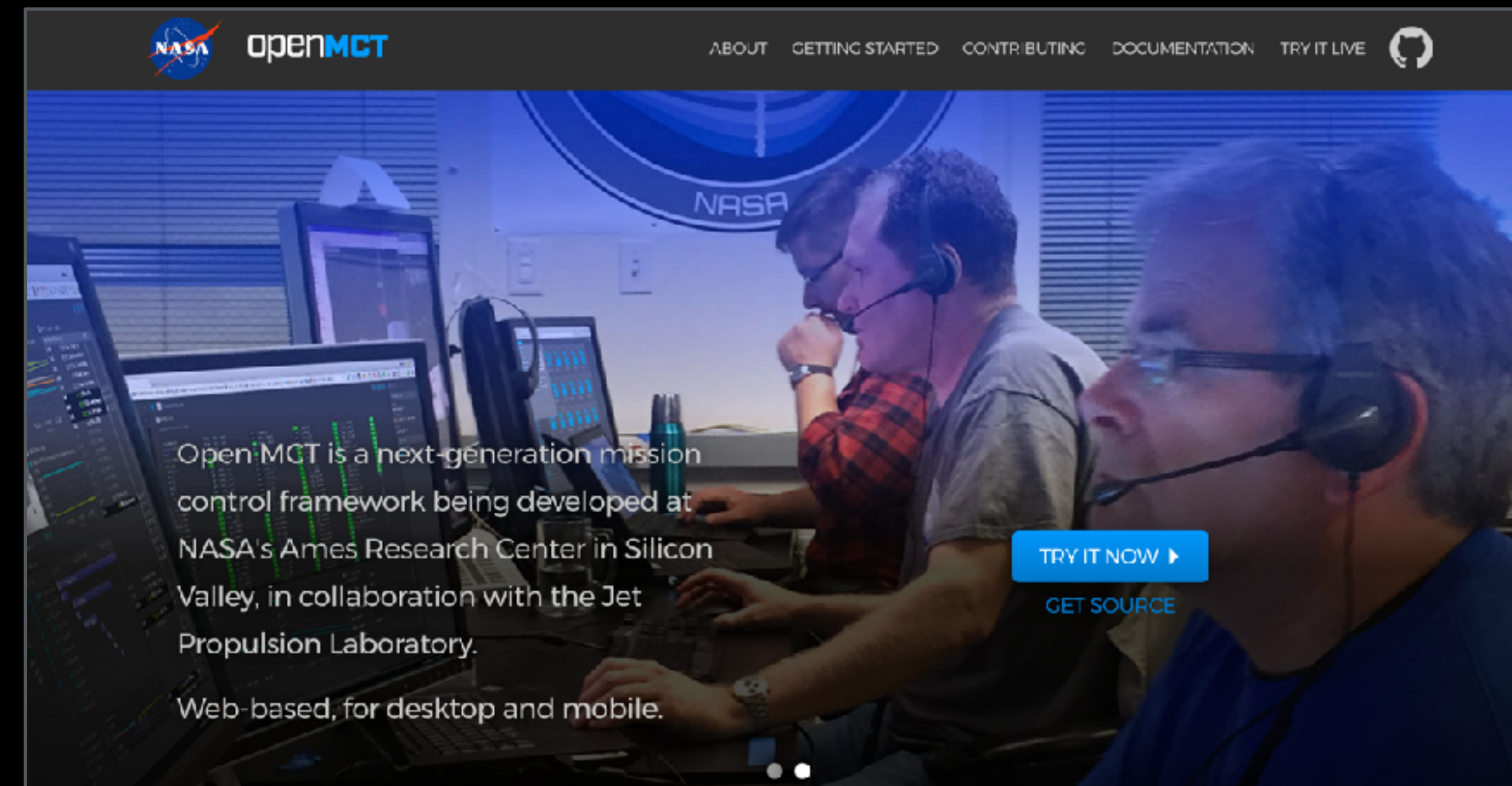
Goals

Provide users with an all your data in one place solution

Empower users to compose their own displays

Create new opportunities for collaboration and community involvement using open source

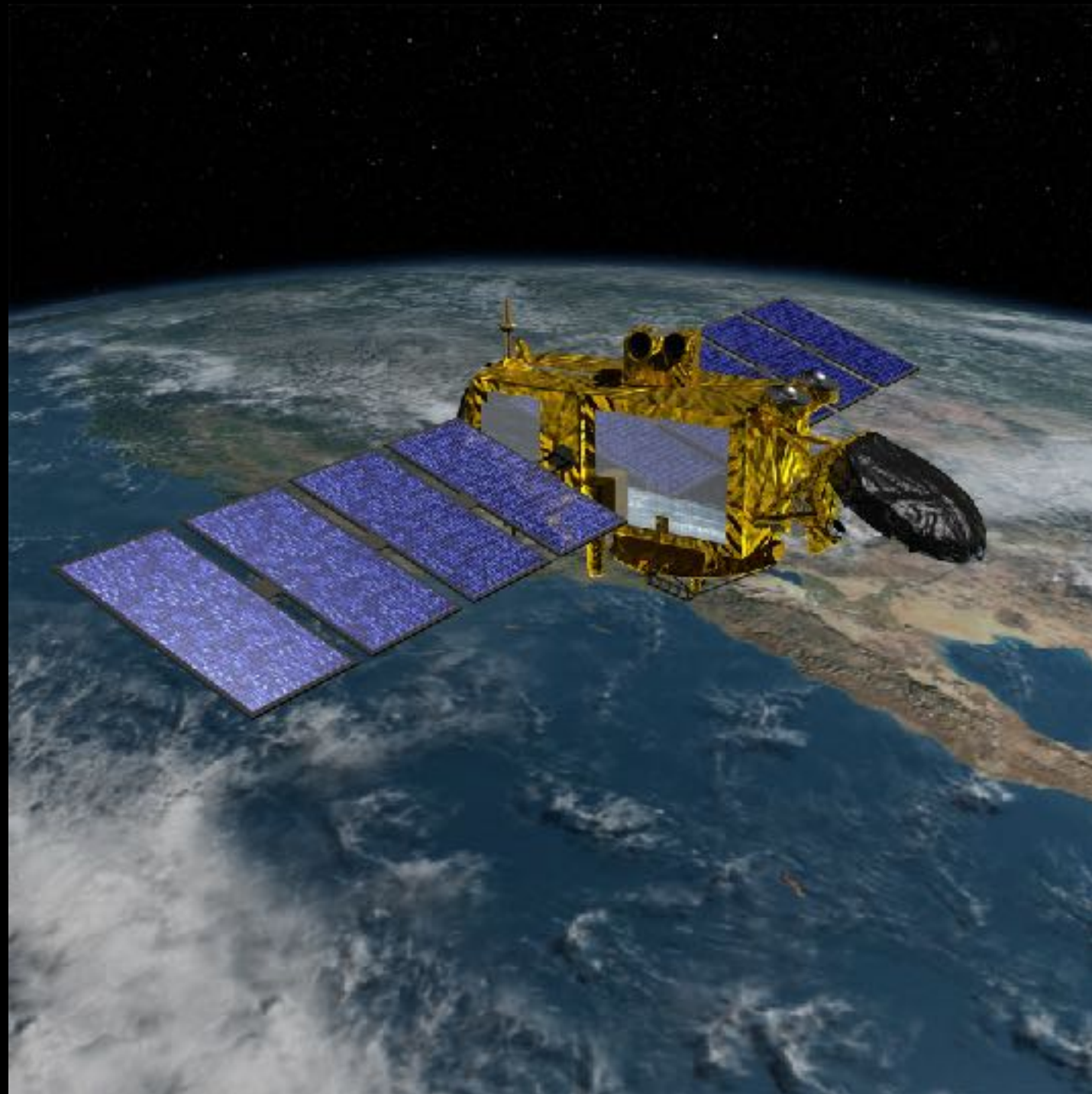
Take what has been a closed and hence mysterious world and open it up



<https://nasa.github.io/openmct/>



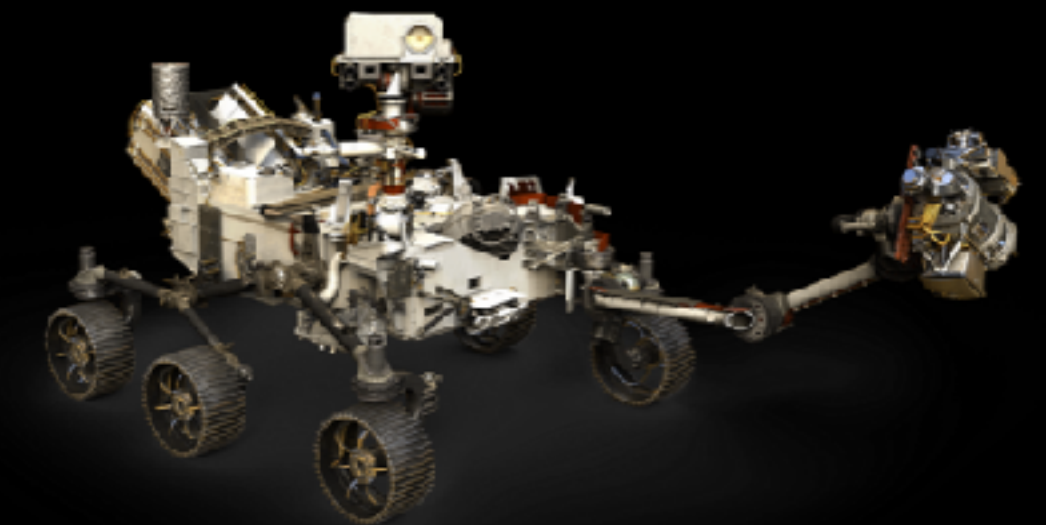
Initial Mission Users



Jason-3



Resource Prospector



Mars 2020
(expected testbed)



All Your Data in One Place

A layout is a composition of data objects

Search your Data Objects

Browse your Data Objects

Inspect your Data Objects

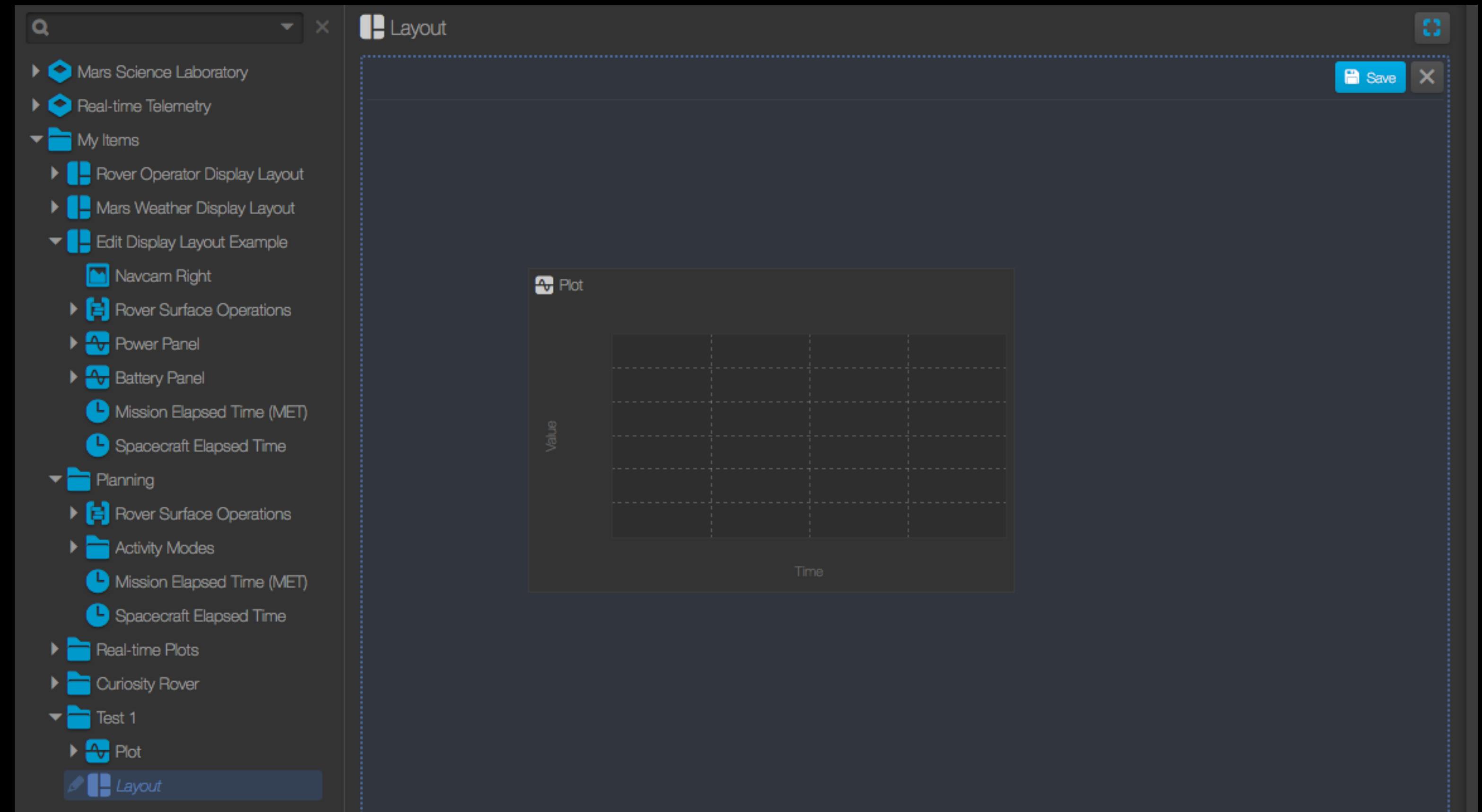
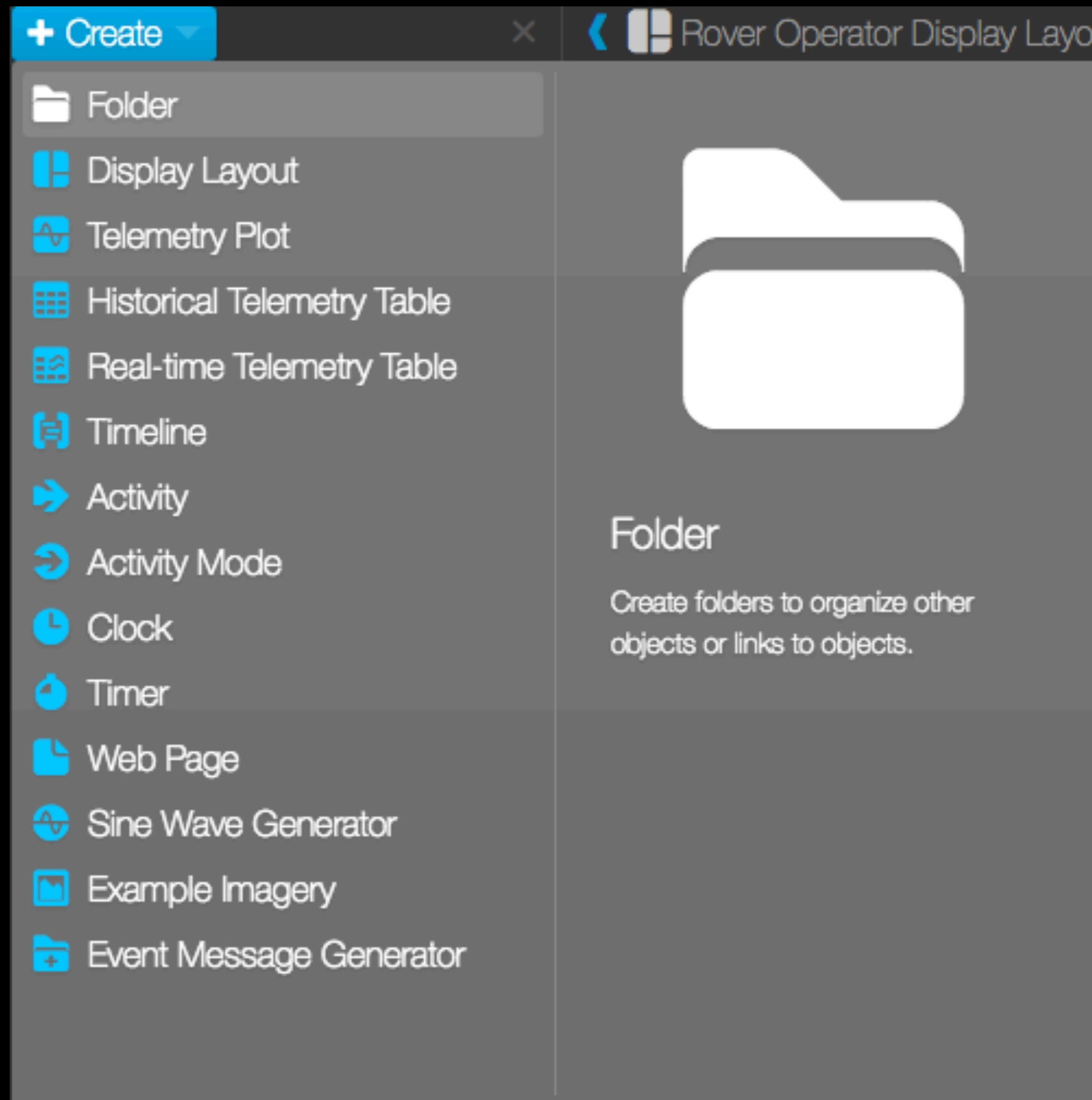
The screenshot displays the OpenMCT interface for a NASA mission. The main area contains several data plots and a table of data objects. The plots show various parameters over time, such as 'EHA_RT_PROD_CNT' and 'DMD_SAR_READ_MEM_LOC_1'. The table lists data objects with columns for ID, Title, Value, and SCET. The interface includes a search bar, a navigation pane on the left, and a properties panel on the right.

ID	Title	Value	SCET
P-0219	PWR_RDE_SENSED	1	2016-21
R-0005	RAD_OP_STATE	1	2016-21
R-0047	RAD_UT_INDEX	744	2016-21
R-0024	RAD_DATA_RATE	0	2016-21
D-2199	DMD_UNSENT_RAD_DATA	14448	2016-21
R-0034	RAD_STM_WORD2_WORDS	505672470	2016-21
R-0236	RAD_RFE_PDU_16V_NEG_CURRENT	-0.08712095022201538	2016-21
R-0224	RAD_PDU_RDE_5_I_P	1.7924302816390991	2016-21
R-0249	RAD_DPU_3_3V_DIG_VOLTAGE	3.3047077665792236	2016-21
R-0238	RAD_RBE_PDU_13_5V_CURRENT	0.6470895734024048	2016-21
Universal			
R-0019	RAD_SEQUENCE_AND_MASTER_FLAGS	33224	2016-21
R-0027	RAD_RPM_COUNTER	17511	2016-21
Temps			
R-0175	RAD_HPOL_MIXER_TEMP	13.13481330671582	2016-21
A-0039	ICE_RFE_TEMP_5	23.01236854264856	2016-21
R-0134	RAD_RFE_CTRL_BRD_TEMP	25.429784466604492	2016-21
R-0140	RAD_RFE_1_MID_RANGE_TEMP	20.239271205731335	2016-21
R-0143	RAD_RFE_2_MID_RANGE_TEMP	20.118951848773155	2016-21
R-0146	RAD_RFE_3_MID_RANGE_TEMP	19.990138252678272	2016-21
A-0033	ICE_RBE_RDE_TEMP_1	15.33680941141956	2016-21
A-0043	ICE_RBE_RDE_TEMP_2	14.811549724013275	2016-21
RBA			
A-0013	ICF_RBA_ROOM_MOT_PHASE		

<https://nasa.github.io/openmct/>



Create & Compose



Example of user object types

Layout is the users canvas



User-Built Compositions

This screenshot shows a web-based status overview interface. The main content area displays a message log with columns for Name, Time, and Message. Below the log, there are two video feeds: one showing a 3D model of a rover on a white surface, and another showing a live camera feed of the rover on the lunar surface. The interface includes a sidebar with navigation options and a top navigation bar.

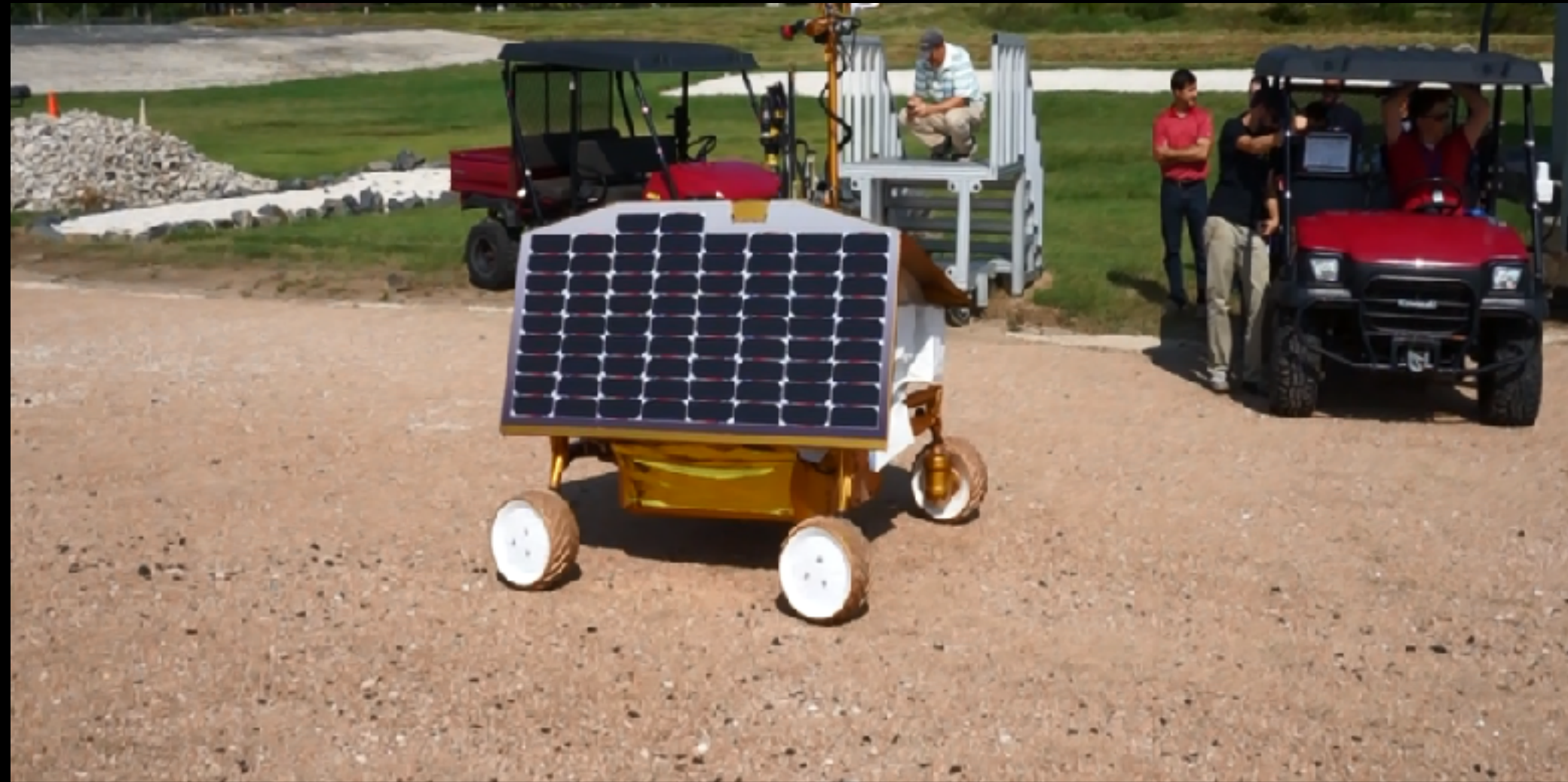
This screenshot displays a power layout interface. It features a tree view on the left side with categories like 'RP15 Tim Panels', 'Location Layout', 'Mobility Layout', and 'Power Layout'. The main area shows a detailed view of the 'EP8K0_BIT' component, listing various sub-components and their status (ON/OFF). The interface also includes a sidebar with navigation options and a top navigation bar.

This screenshot shows an SFORAM Error interface. It features a table with columns for ID, Name, Status, and Date. Below the table, there are several charts and graphs displaying error data over time. The interface includes a sidebar with navigation options and a top navigation bar.

This screenshot displays an RP15 Layout interface. It features a tree view on the left side with categories like 'RP15 Tim Panels', 'Location Layout', 'Mobility Layout', and 'Power Layout'. The main area shows a detailed view of the 'RP15 Tim Panels' component, listing various sub-components and their status (ON/OFF). The interface also includes a sidebar with navigation options and a top navigation bar.



User Testing



2015/08/21 10:05 AM 66%

<https://192.168.1.107:10080/static/index.html#/browse/mir>

Display Layout Battery

Rover Mode		Battery SOC		BMSIO_DATA_DAT	
imm_mode	SAFE	STATE_OF_CHARGE	1593.000	No updates	
mob_state	STOP	MIN_CELL_VOLTAGE	2.000	applicationId	
kin_drive_state	OFF	MAX_CELL_VOLTAGE	3.000	sequenceCount	
kin_susp_state	OFF	AVG_CELL_VOLTAGE	4.000	length	
Estop	0.000			timestamp	
Pitch	-0.039			COM_FIRL_EN	
Roll	0.023			ARM_FIRL_DEEBUS	
Ride Ht	0.346			MANUAL_BALANCING_EN	
Tim Filter	to_highrate tbl(*)			ARM_FIRL_BALANCING	
Data Rate	BAU_900000.000				

BMSIO_DETAIL_DAT					
2015 238 16:05:14.7972					
applicationId	951	CELL_VOLT_S1_C2	598	CELL_TEMP_S1_C05	364
sequenceCount	1090	CELL_VOLT_S1_C3	598	CELL_TEMP_S1_C06	359
length	229	CELL_VOLT_S1_C4	598	CELL_TEMP_S1_C07	359

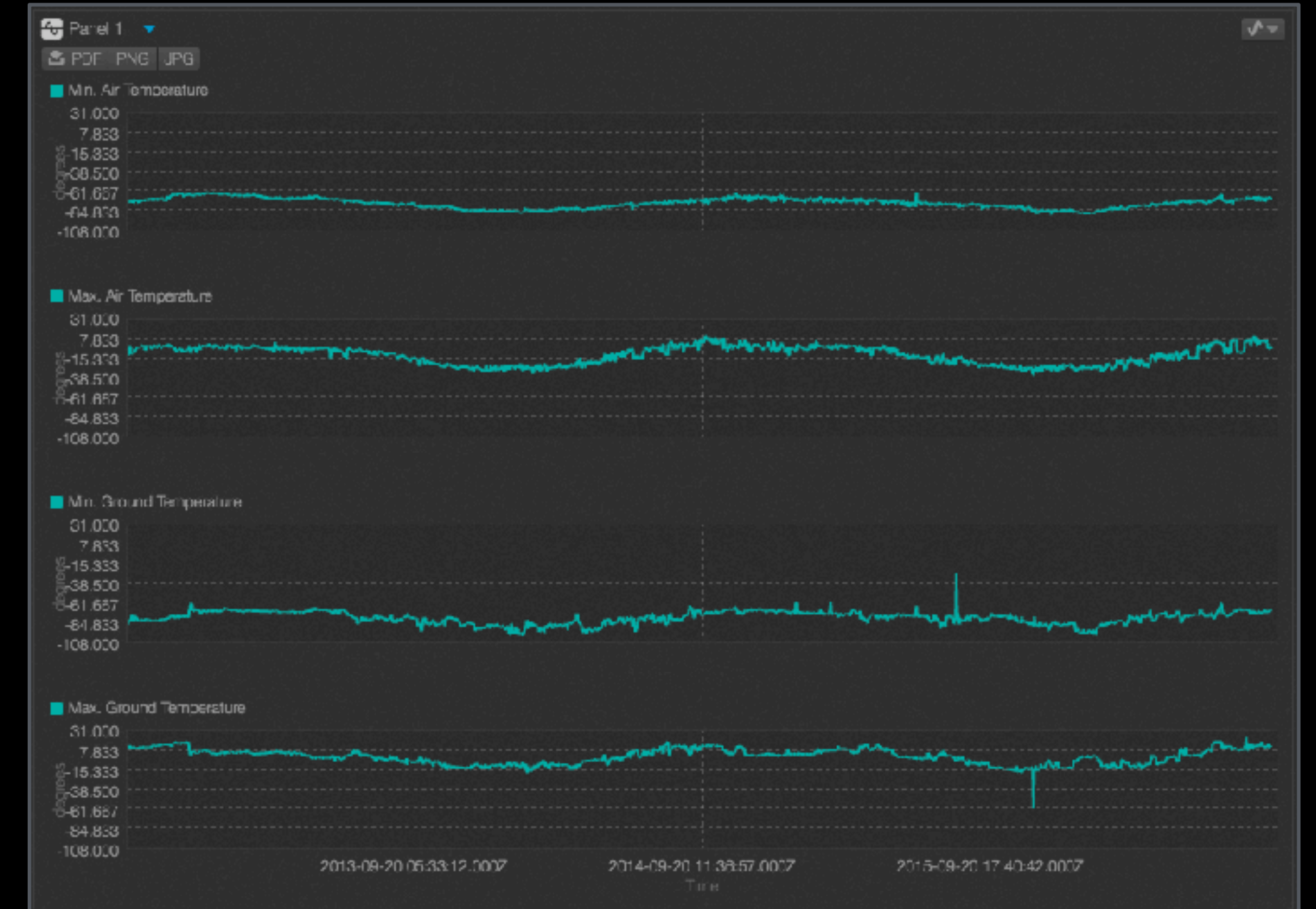
2015/08/21 15:05:14 UTC CONNECTED CONNECTED STREAMING WARP



For Fun



2001: A Space Odyssey



Open MCT



Sprint

GV Style Design Sprint



MEASUREMENT GOALS			ENG GOALS		STATS	
Zone	NSA	VA	Zone	NSA	Stat	Value
PSR		0/1	100m	Done	Drive Distance	431 m
Deep	2/2	1/1	Enter PSR	Not done	Battery SOC	63%
Shallow	1/2	1/1		Not done	Downlink Rate	100 kbps
Dry	0/2	0/1		Not done	Rover Mode	Drive

GOALS AND ACTIVITIES

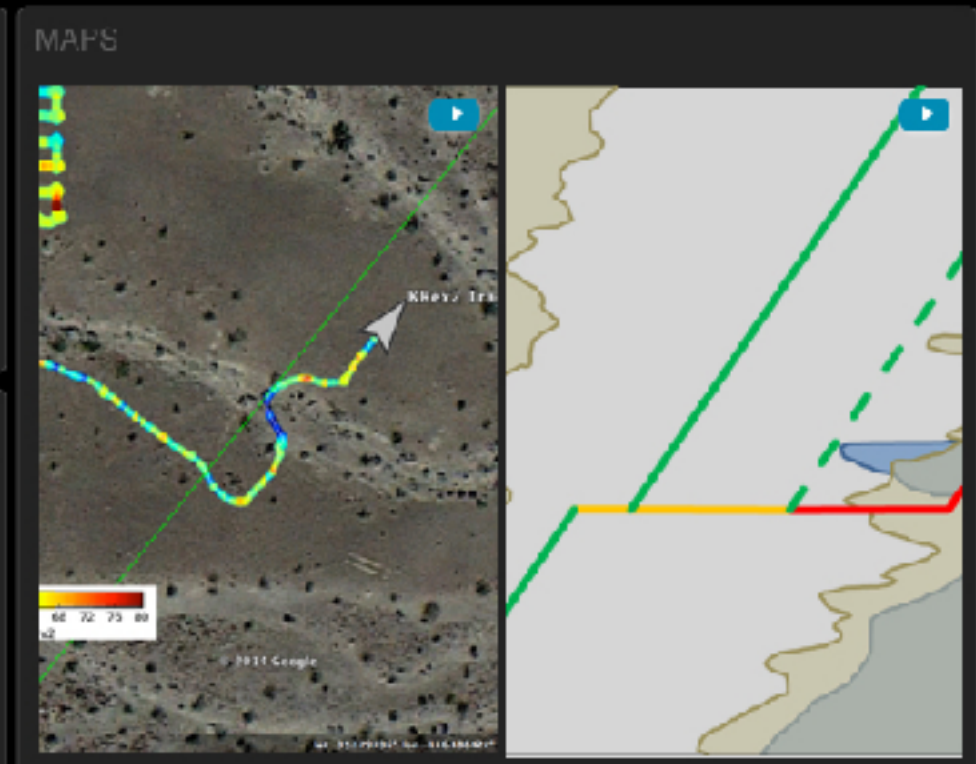
- Subsurface Assay
- Traverse PSR
- Collect Sample In PSR

Activity	Start	End	Coordinates
P3 Preheat	30' 05:42:00	30' 08:12:00	301.3, -57.9
P4 Sample Collection and Transfer	30' 08:12:00	30' 08:42:00	301.3, -57.9
P5 Volatile Analysis	30' 08:42:00	30' 07:42:00	301.3, -57.9
P6 Sample Dump	30' 07:42:00	30' 08:07:00	301.3, 57.9

Drive to Kobayashi PSR

Activity	Start	End	Coordinates
D2 Payload Prospecting Prep	30' 10:42:00	30' 11:12:00	301.3, -57.9
C4 Update Heater Setpoint	30' 11:12:00	30' 11:17:00	351.3, -44.1
P3 Preheat	30' 10:42:00	30' 11:12:00	411.3, -50

LIMIT VIOL	TOP ISSUES	FSW MSGS
0	1. Image scan line dropouts higher than expected (GDS change in review)	2016-200-23:11:15 INFO CF CFDP file download complete
5	2. Wheel 4 temperatures low (thermal team proposal due 2016-201-10:00:00 UTC)	2016-200-23:11:03 WARN ITOS Command Retry 'CL_NOOP
	3. Cruise phase Safe mode root cause analysis (ongoing)	2016-200-23:09:45 ERR CI Uplink error correction failure, ignored



ACTIVITIES

CURRENT

Sample Collection and Transfer

DRILL OPERATOR 10:47 MINUTES LEFT

NEXT

Volatile Analysis

LAVA OPERATOR 14:03 MINUTES UNTIL



The Community

<https://nasa.github.io/openmct/>

60 Visitors per week then..

User Reddit Post

20k visitors in two days

Outside contributors

Collaborations inside and outside of NASA that were not possible or practical before open source





The Role of Failure

“Failure is not an option” - Gene Kranz

Referring to human space flight operations



Design Thinking

...is now an accepted part of our organization, though it is only practiced by a small number of teams.

My team is moving design thinking from software, where we first established it, to the design and development of the mission system for a lunar prospecting rover.

“Say it then sim it”