

# CURIOSITY



NASA/JPL-Caltech/MSSS



## Mars Science Laboratory

David Oh  
JPL/Caltech  
Lead Flight Director  
Macworld: 31 January 2013

# CURIOSITY

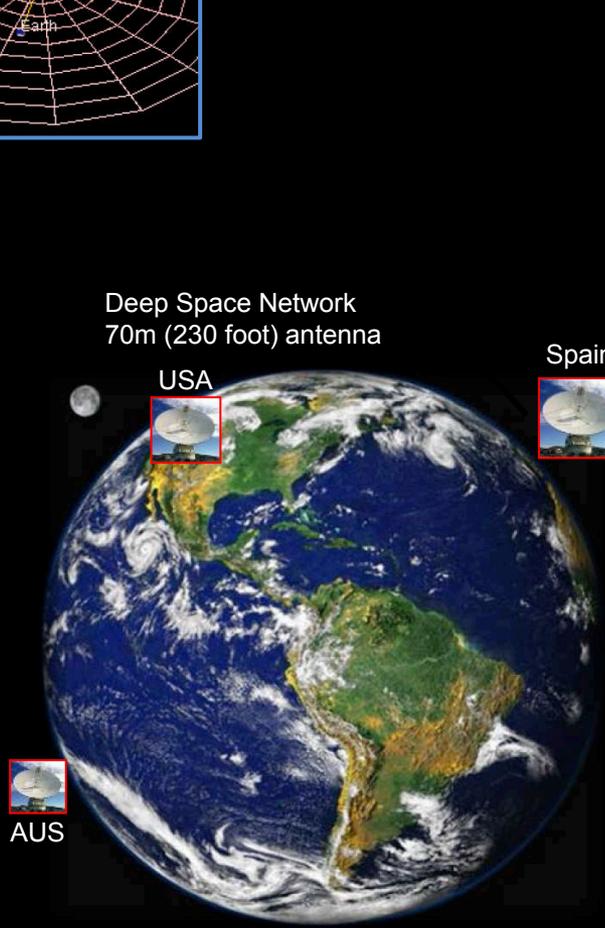
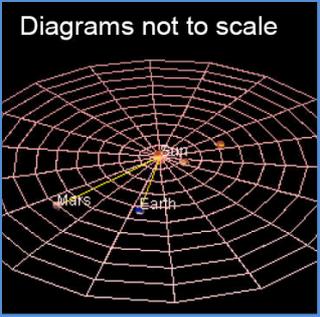


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## MSL Ops & Uplink Software

Dr. James Kurien,  
JPL/Caltech  
Lead, Activity Planning &  
Sequencing Software



Deep Space Network  
70m (230 foot) antenna

USA



AUS

Earth's Rotation: 24 hour day



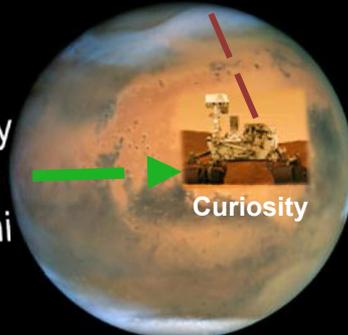
Spain

Up to 24 minute delay

Up to 249,000,000 mi



MRO, Mars Odyssey, MEX

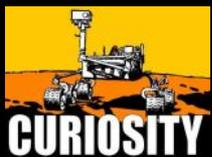
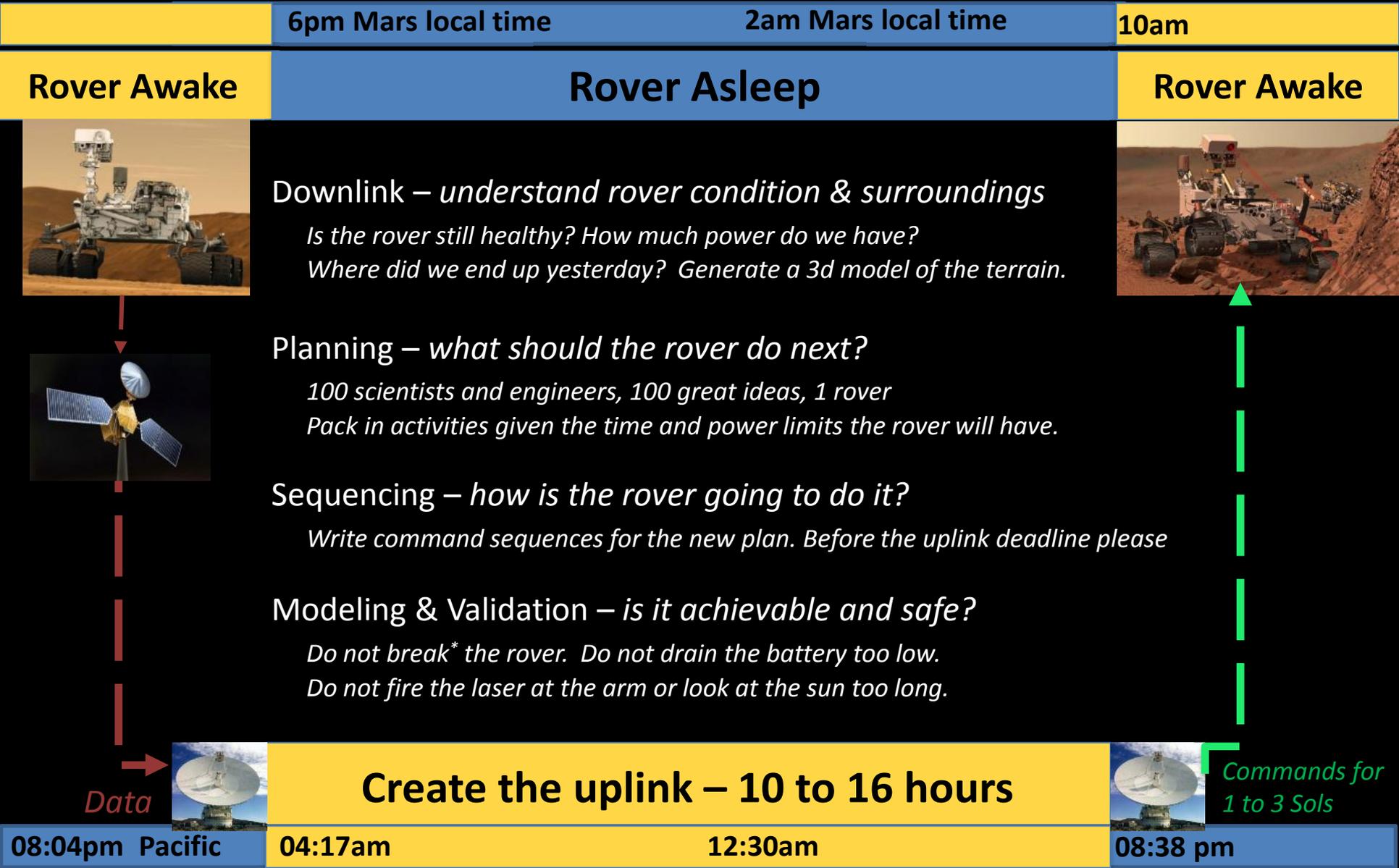


Curiosity

Mars' Rotation: 24.65 hour Sol

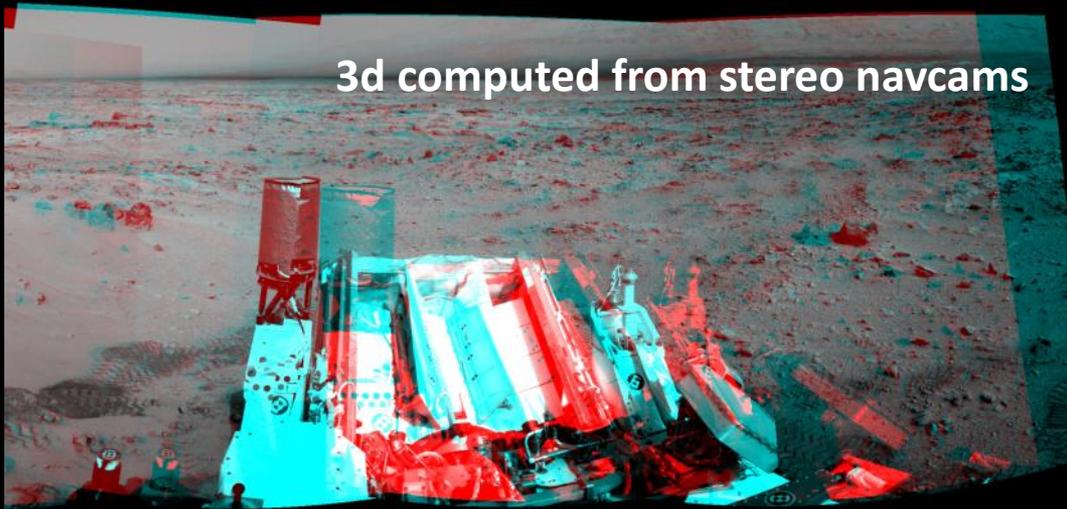


# How we communicate with Mars surface craft



What the heck takes so long?

3d computed from stereo navcams



Quick animation from hazcams



Commercial Cloud Storage



*Users worldwide*



**JPL  
Services**

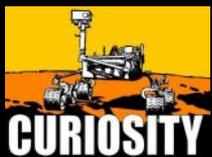


**Downlink processing software**

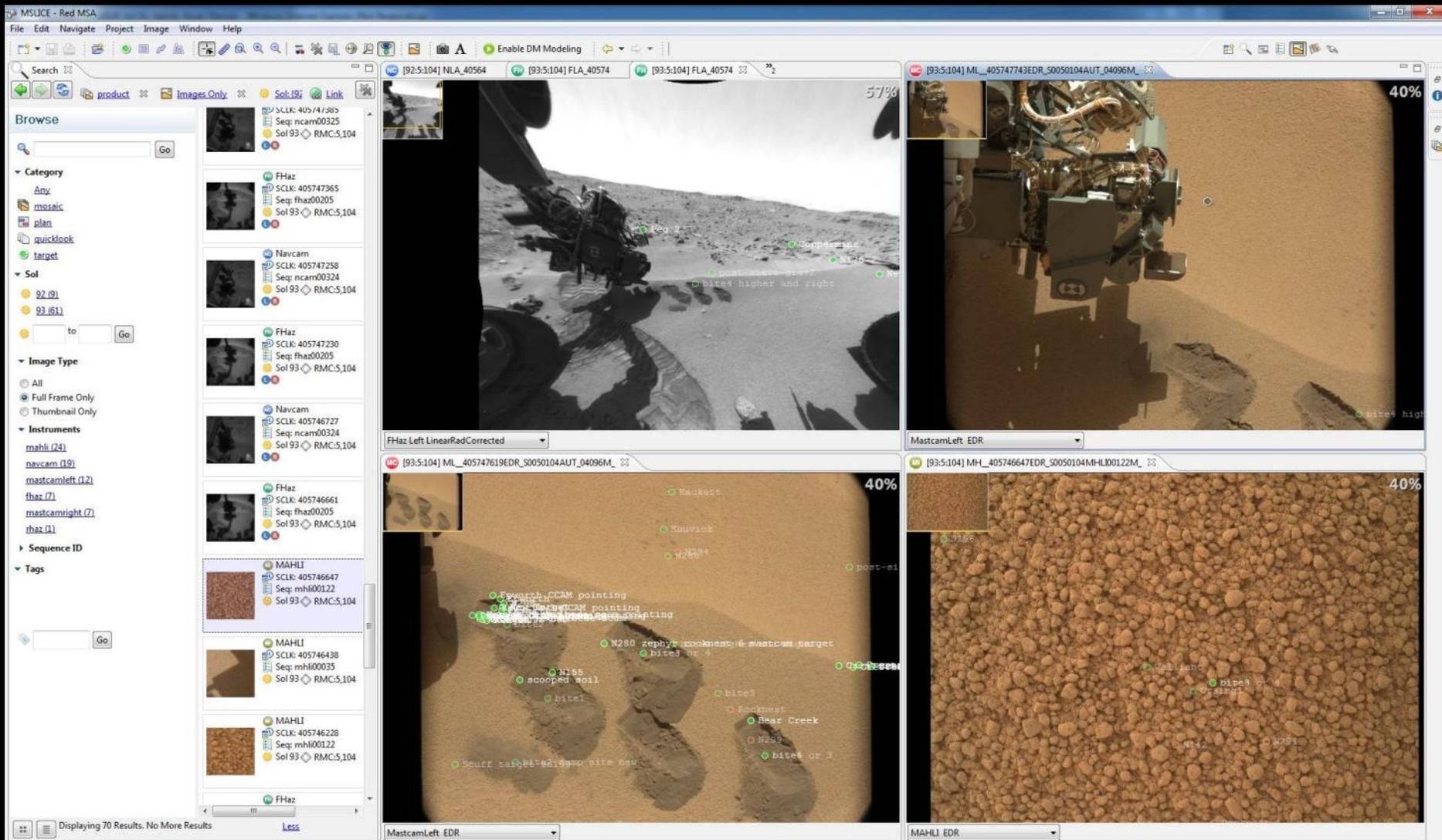
- Reassembles data from the rover
- Tracks what data was received
- Indexes and distributes it
- Produces derived data
  - Telemetry analysis/trending
  - Engineering products
  - 3d models
  - Image mosaics



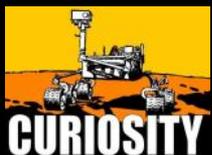
**Downlink Processing**



# Engineering Downlink Analysis



Scientists world wide use MSLICE to browse images and share targets to mark areas of interest



Science image browsing and targeting

The screenshot displays the MSLICE software interface for mission planning. The main window shows a Gantt chart for Sol 71, with activities scheduled across three days (11, 12, 13). The Plan Hierarchy on the left lists various activities, including Mastcam and ChemCam tasks. The right-hand pane provides detailed information for the selected activity, Mastcam\_1x1\_N267\_R0, such as its name, color, notes, originator, and schedule. The bottom pane shows a Plan Advisor with a list of violations, including 'CPU is required to be On' during 'Mastcam\_1x1\_R0'.

Science groups create activities to meet Sol's science goals – image a target, fire LIBS laser, ...  
 Engineering activities not considered yet – CPU on/off, communication, ..  
 Complex activities worked in advance – where to drive next, sample scoop/deliver/SAM process



# Creating science activities



Rapid analysis tools allow scientists and engineers to negotiate options for the Sol's activities. Activities from different science groups and engineering teams are merged together. Activities are adjusted to meet constraints on power, data downlink, safety, image shadows....



# Bringing the activity plan together

MSLICE - Red MSA - Activity Dictionary: MSL Surface AD v.2012-09-18

File Edit Navigate Project SeqDB Plan Window Help

Role Observer (Read Only)

sol00016M13:36:53

Enable DM Modeling

Detail

MRO\_MSL\_2012\_235\_02

Name MRO\_MSL\_2012\_235\_02

Color

Notes

Originator

Uplink\_Priority 0

Command\_Notes

Seq Id eng\_00051

Invocation Method

Request Id Unassigned

Schedule

Start Time Sol-00016M14:51:08

Duration 00:25:10

Override\_Duration 00:00:00

End Time Sol-00016M15:15:38

Scheduled

PEF Modeled Times

Start Time

End Time

Resource Usage

ActivityEnergy 17.20 Wh

Arm\_claimed

Data\_Low < 1 Mbit

Data\_Low\_87 < 1 Mbit

Data\_Medium 1.13 Mbit

Data\_Medium\_68 1.13 Mbit

Front\_HazCam\_claimed

HGA\_claimed

MAHLI\_claimed

Mastcam\_claimed

Resources Plan repository Remote Compiler

LST

Sol-16 09 10 11 12 13 14 15 16 17

PostDrive PreCleanup MARGIN

CleanUp

PostDrive Imaging

MARGIN

CleanUp

MARGIN - 2 min

MRO\_MSL\_2012\_235\_02

ODY\_MSL\_2012\_235\_03

MARGIN - 5 min

REMS\_ST Engineering Transition Obse

MRO\_MSL\_2012\_236\_01

ODY\_MSL\_2012\_236\_01

REMS ST Run Extended

Margin

Sol\_17\_AM\_HGA\_DFE

RPFA\_Survival\_Heating

REMS (bkngnd)

Unscheduled/Descoped

Survival\_Heating

RSDST On

RAD Background

CPU

REMS ST Run Extended

RPFA\_Survival\_Heating

REMS (bkngnd)

Survival\_Heating

RSDST On

RAD Background

CPU

Resource Graph

Data\_Critical 1430 Mbit

150.00 Mbit

0.00 Mbit

Timeline Table

Activity Dictionary Templates Profiles

Version: <http://msl.nasa.gov/> MSL Surface AD v.2012-09-18

THRM

- HGA\_Maintenance\_Heating
- HGA\_Preheat

XBAND

- XBAND\_HGA\_DFE\_Window
- XBAND\_HGA\_DFE\_Window\_Inngested

activity type hga

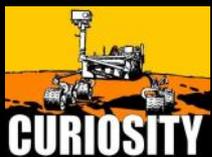
Plan Advisor

Plan Rules Constraints Console

1 waived, 29 fixed

Violations	Description	Participants	Observation	Time
Activity Require:				
Transmitting	Transmitting is required ...	HGA Beep	S...	Sol-00
Transmitting	Transmitting is required ...	HGA Beep	S...	Sol-00
Transmitting	Transmitting is required ...	HGA Beep	S...	Sol-00

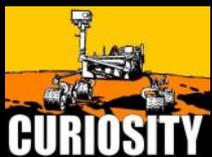
We end with an integrated plan that's used to check power use, data downlink, basic safety rules  
 To do this MSLICE communicates with engineering analysis software, plan storage system, ...

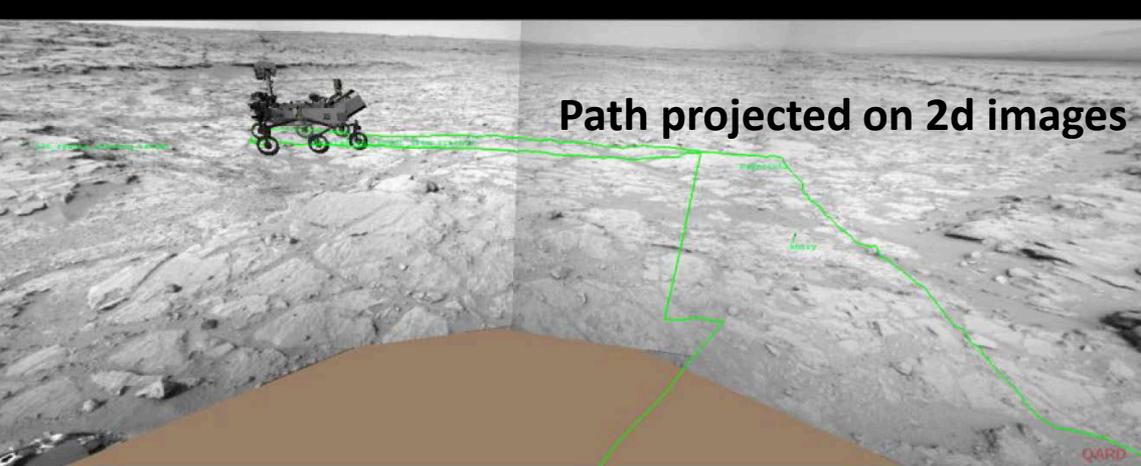


# Modeling the integrated activity plan

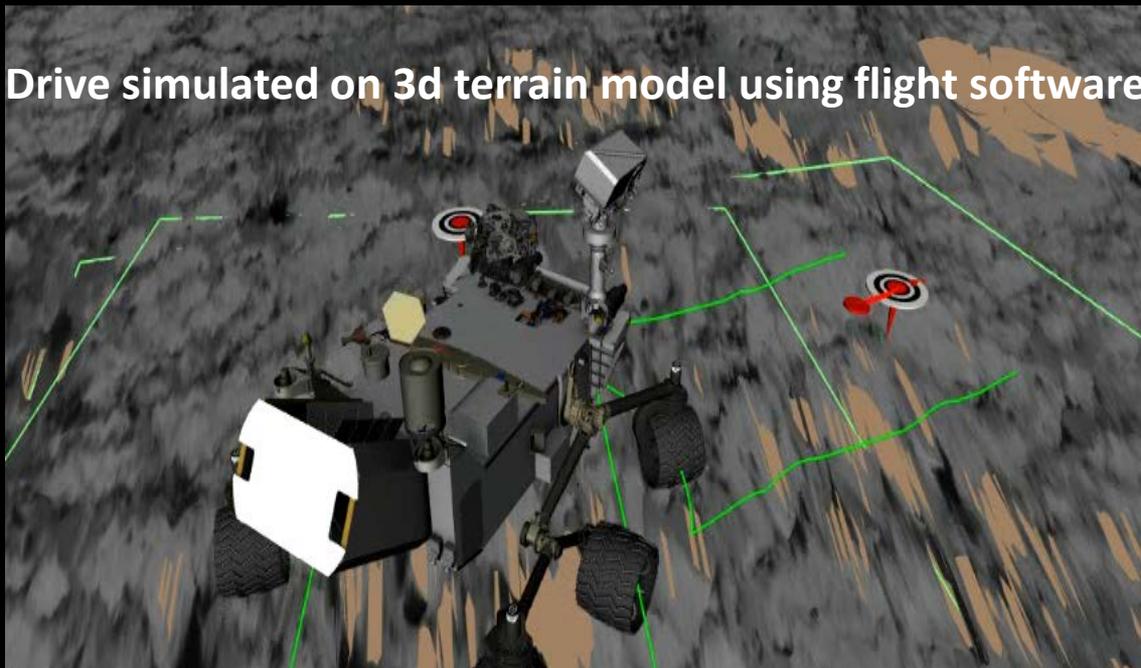
Activities specify what the rover should do, but we need commands to make the rover do it  
 Some command sequences are written by hand, others are generated from the activity  
 Rover motion and arm sequences are created with specialized 3d visualization tools

# Sequencing - from activity to rover commands





Path projected on orbital image



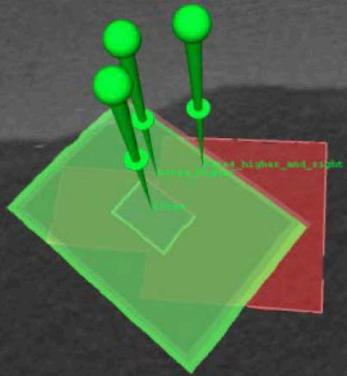
RSVP program used to

- Specify desired rover motion
- Explore different ways to get there
- Write commands to safely achieve it
- Simulate execution at current locale
- Check safety rules and limits
  - E.g. pitch, sun angle to camera



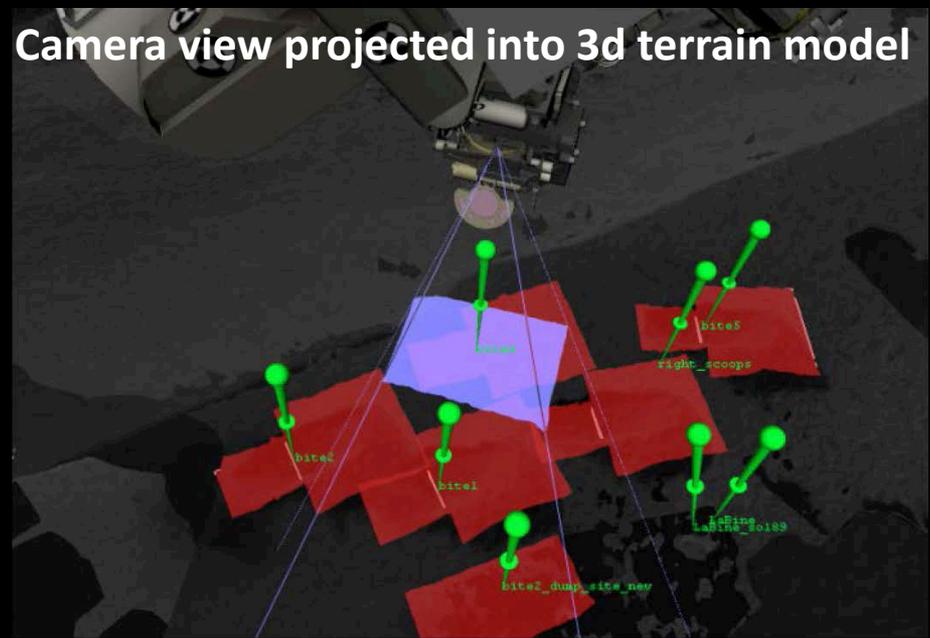
Sequencing and validating rover motion

Targets projected onto 3d terrain model



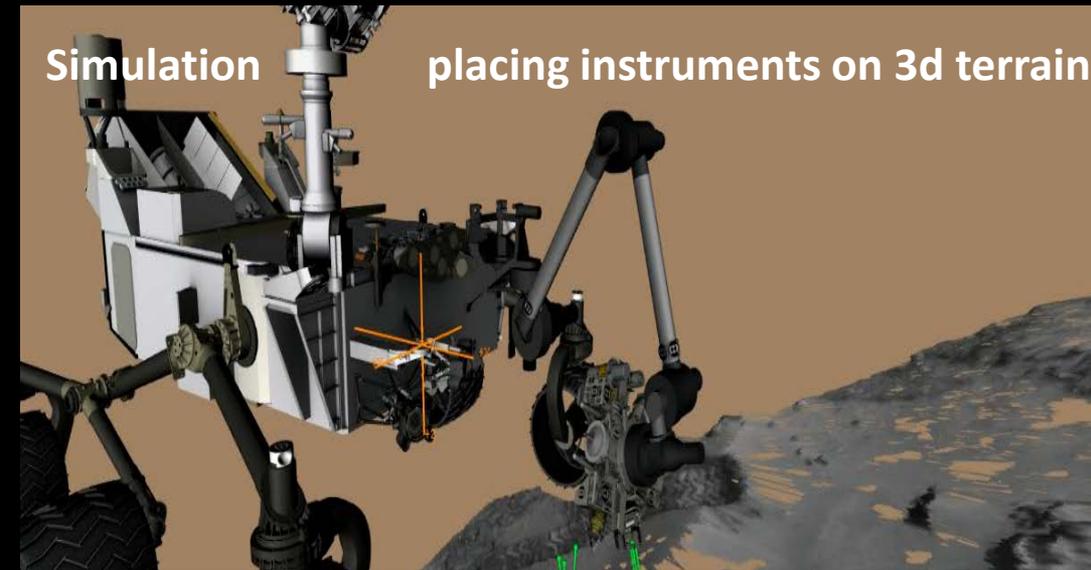
RSVP HyperDrive

Camera view projected into 3d terrain model



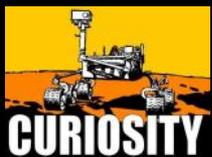
Simulation

placing instruments on 3d terrain



RSVP is used to

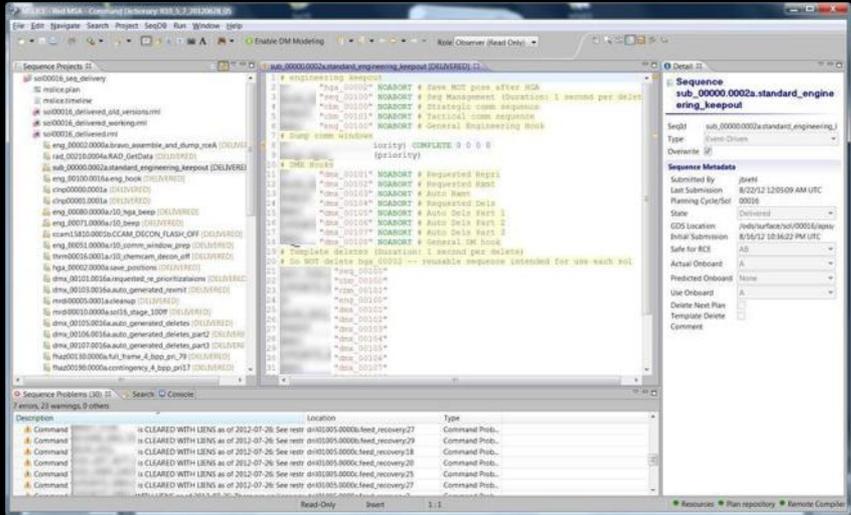
- Specify instrument targets in detail
- Explore different placements
- Write commands to safely achieve it
- Simulate interaction with the surface
- Check safety rules and limits
  - E.g. clearance, drill pressure



Sequencing and validating arm motion

All sequences integrated into a single package

One of many sequence validation reports



**SYS-0113 Warnings (11)**

Note: warnings in grey are from onboard sequences

No.	SCET [LMST]	Message	Command	Sequence	SEQEN Cmd #
1	2012-308T10:32:26.272 [ 87M11:00:12 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			12
2	2012-308T10:32:26.272 [ 87M11:00:12 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			13
3	2012-308T10:34:24.272 [ 87M11:02:06 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			6
4	2012-308T11:03:18.288 [ 87M11:50:14 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			7
5	2012-308T12:38:19.314 [ 87M12:41:18 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			2
6	2012-309T01:45:21.779 [ 88M01:48:42 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			8
7	2012-309T07:46:39.966 [ 88M07:46:29 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			2
8	2012-309T08:27:12.003 [ 88M08:19:47 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			2
9	2012-309T08:28:16.003 [ 88M08:20:49 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			7
10	2012-309T09:55:55.048 [ 88M09:45:48 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			8
11	2012-309T10:55:24.086 [ 88M10:44:01 ]	[FR-SYS-0113, CRIT-A] Do not issue unverified cmds. Verification status WITH LIENS.			6

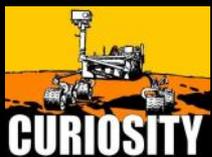
**SYS-0040 Warnings (4)**



Deep Space Network control room

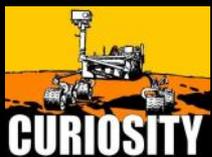
Once all sequences are ready we

- Integrate them together
- Create a 'master' sequence to run them all
- Run the final sequence safety checks
- Fully review the sequences and reports
- Sign it over to DSN for uplink to Mars
- Wait for the uplink window to begin



Preparing the sequences for uplink to Mars

Note: This image is ridiculous and completely imaginary, though awesome.



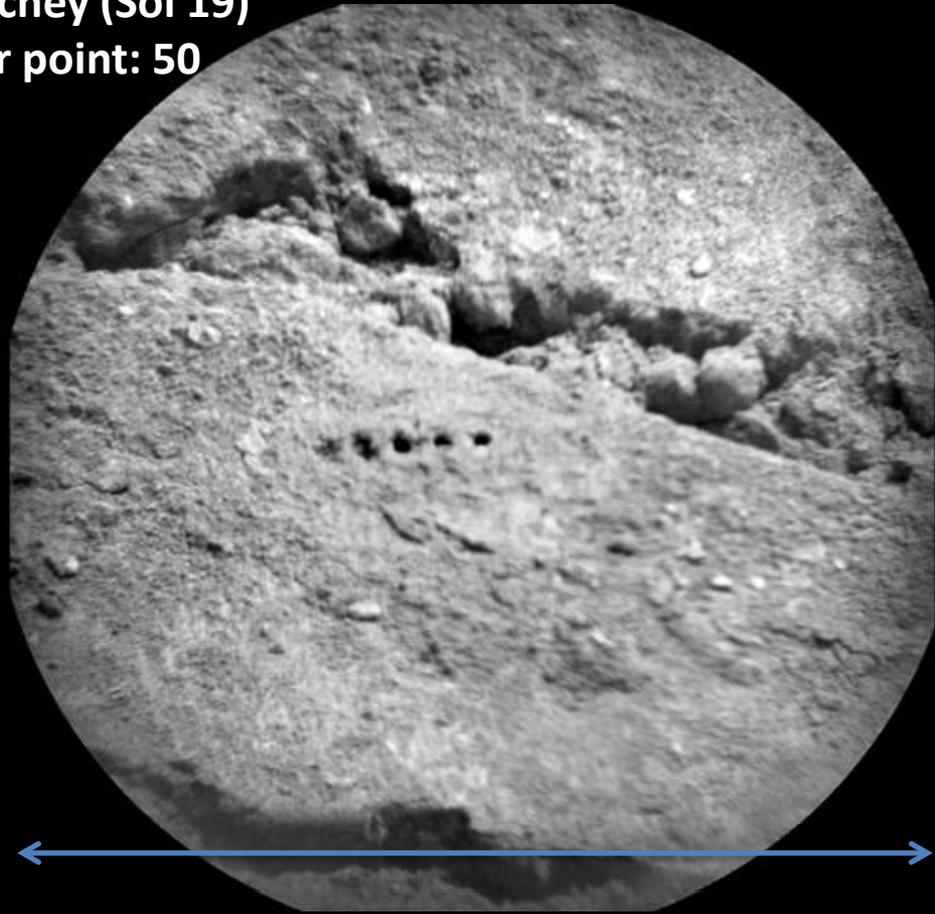
Result – rover safely executes our plan on Mars

Target: Beechey (Sol 19)  
Shots per point: 50



**Before**

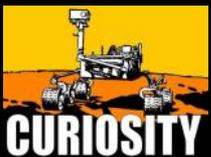
NASA/JPL-Caltech/LANL/CNES/IRAP/LPGN/CNRS

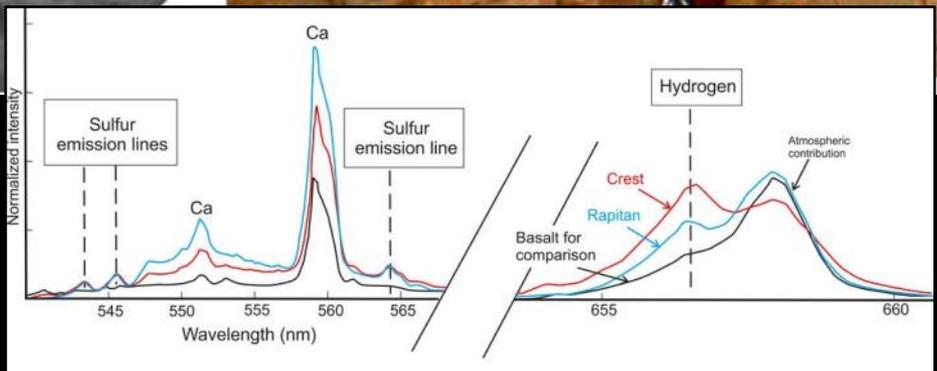
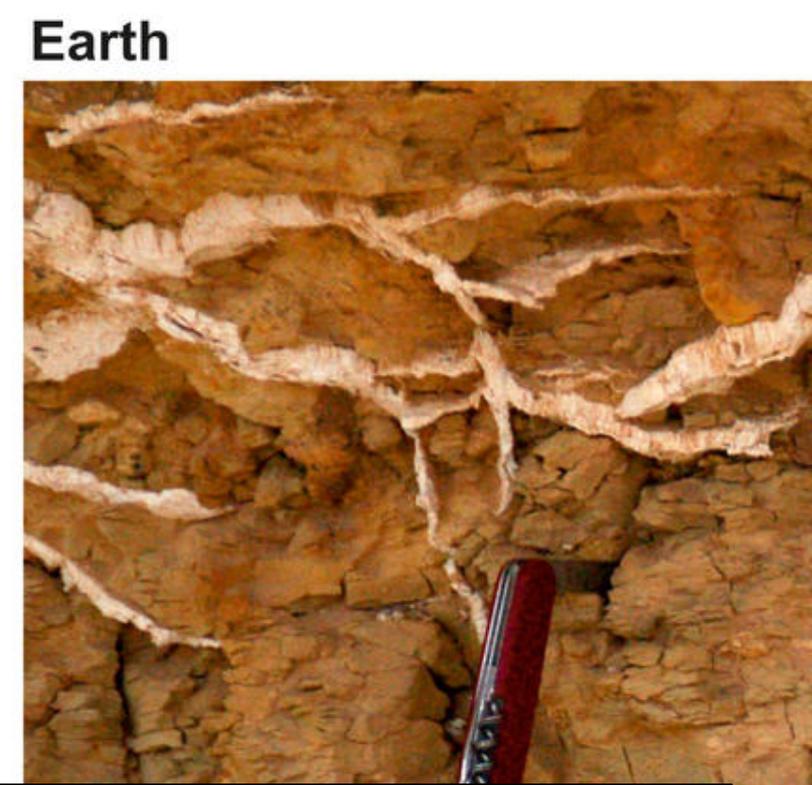
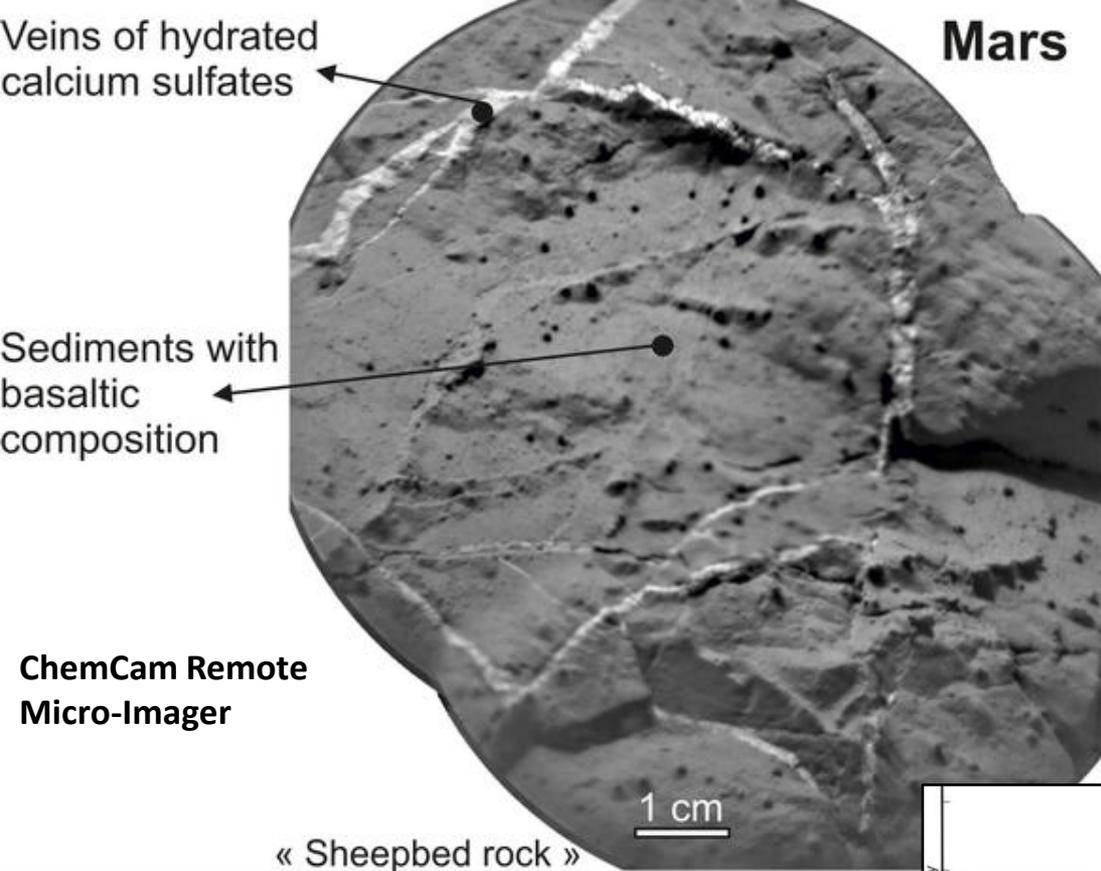


**After**

8 cm (3")

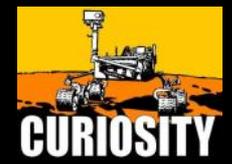
Result – rover safely executes our plan, adding to the story of Mars' past or future habitability



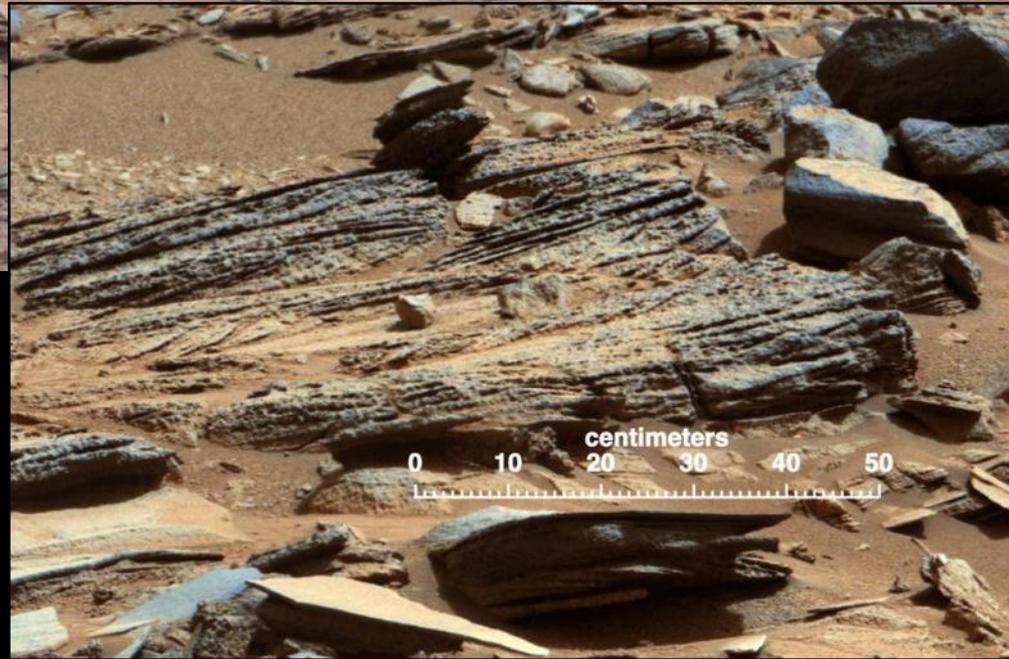


ChemCam spectra from sol 125  
"Crest" and 135 "Rapitan"

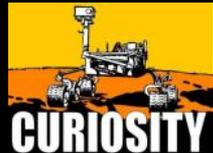
**"Sheepbed" rocks contain 1 to 5-mm fractures filled with calcium sulfate minerals that precipitated from fluids at low to moderate temperatures**



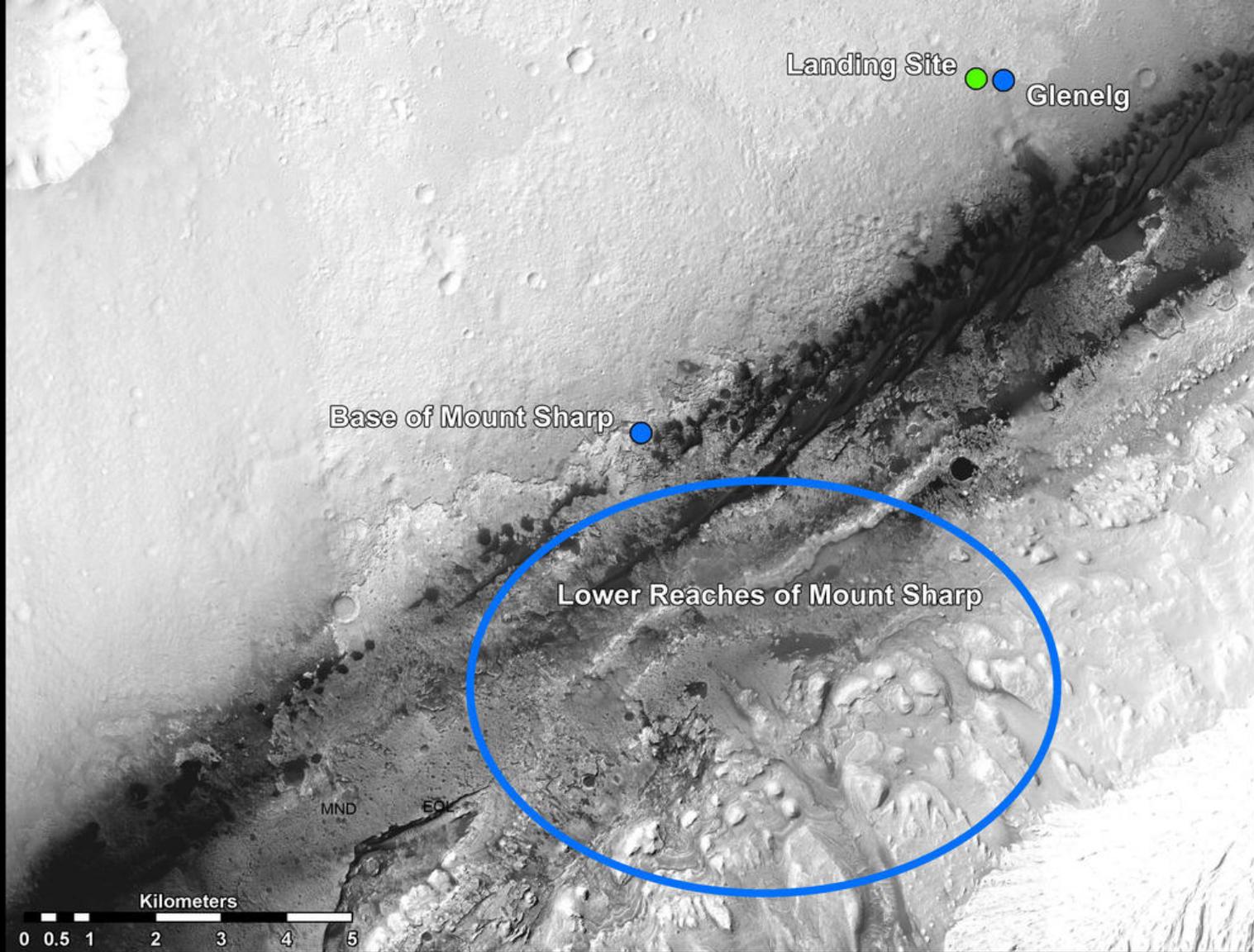
NASA/JPL-  
Caltech/LANL/CNES/IRAP/LPGNantes/C  
NRS/LGLyon/Planet-Terre



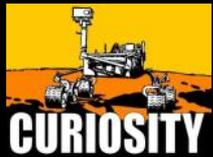
NASA/JPL-Caltech/MSSS



**“Shaler” rocks just outside Yellowknife Bay show inclined, fine layers that indicate sediment transport**



NASA/JPL-Caltech/Univ. of Arizona



**Curiosity's ultimate goal is to explore the lower reaches of the 5-km high Mount Sharp**

