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# Antenna Technology at NASA/JPL From Mars Rovers to CubeSats to Microfabricated Devices

IWAT 2013, Karlsruhe, Germany

Dr. Tom Cwik, Manager Space Technology  
Jet Propulsion Laboratory  
California Institute of Technology  
March 4, 2013



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# Curiosity

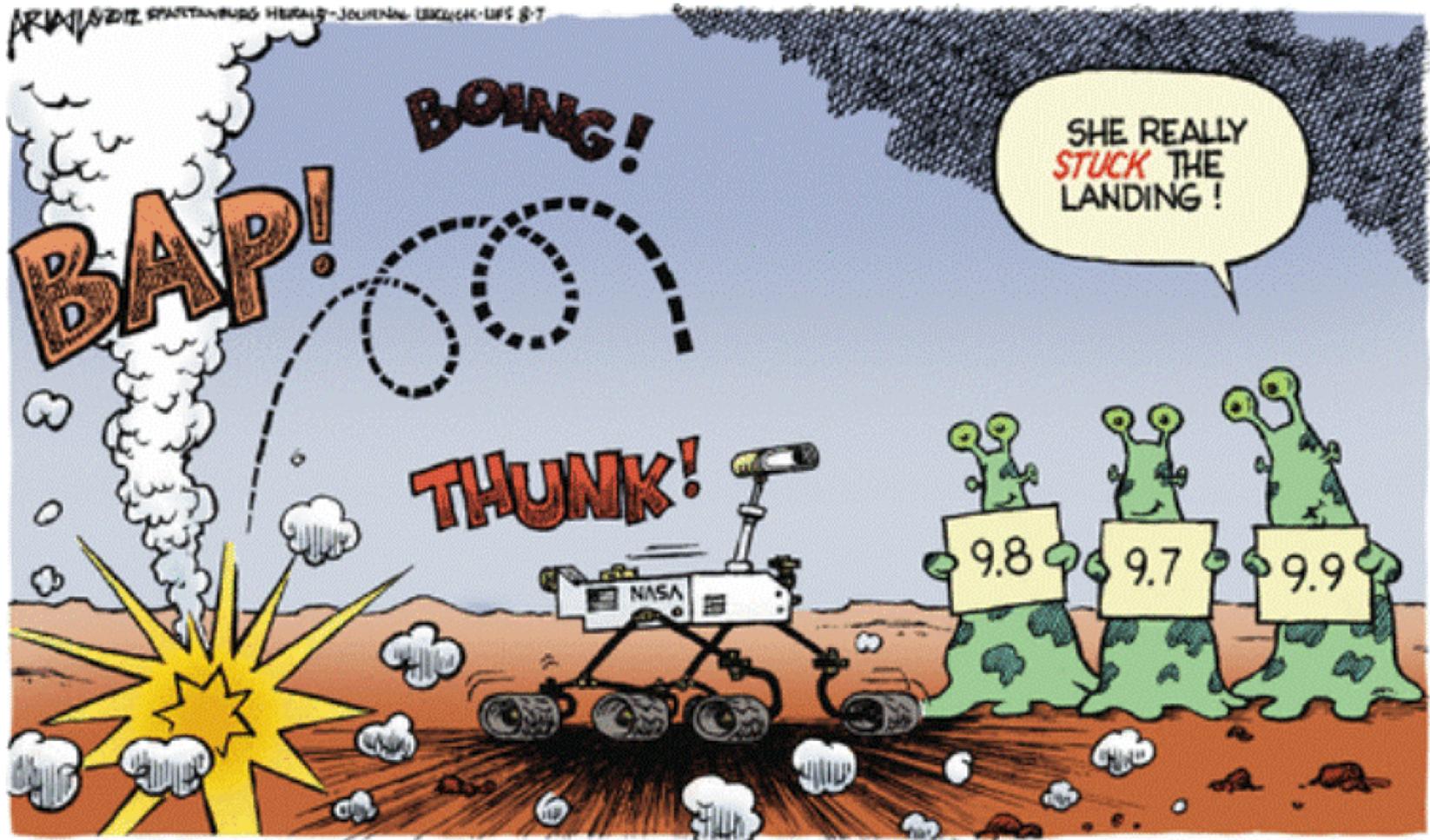




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# Curiosity everywhere ...

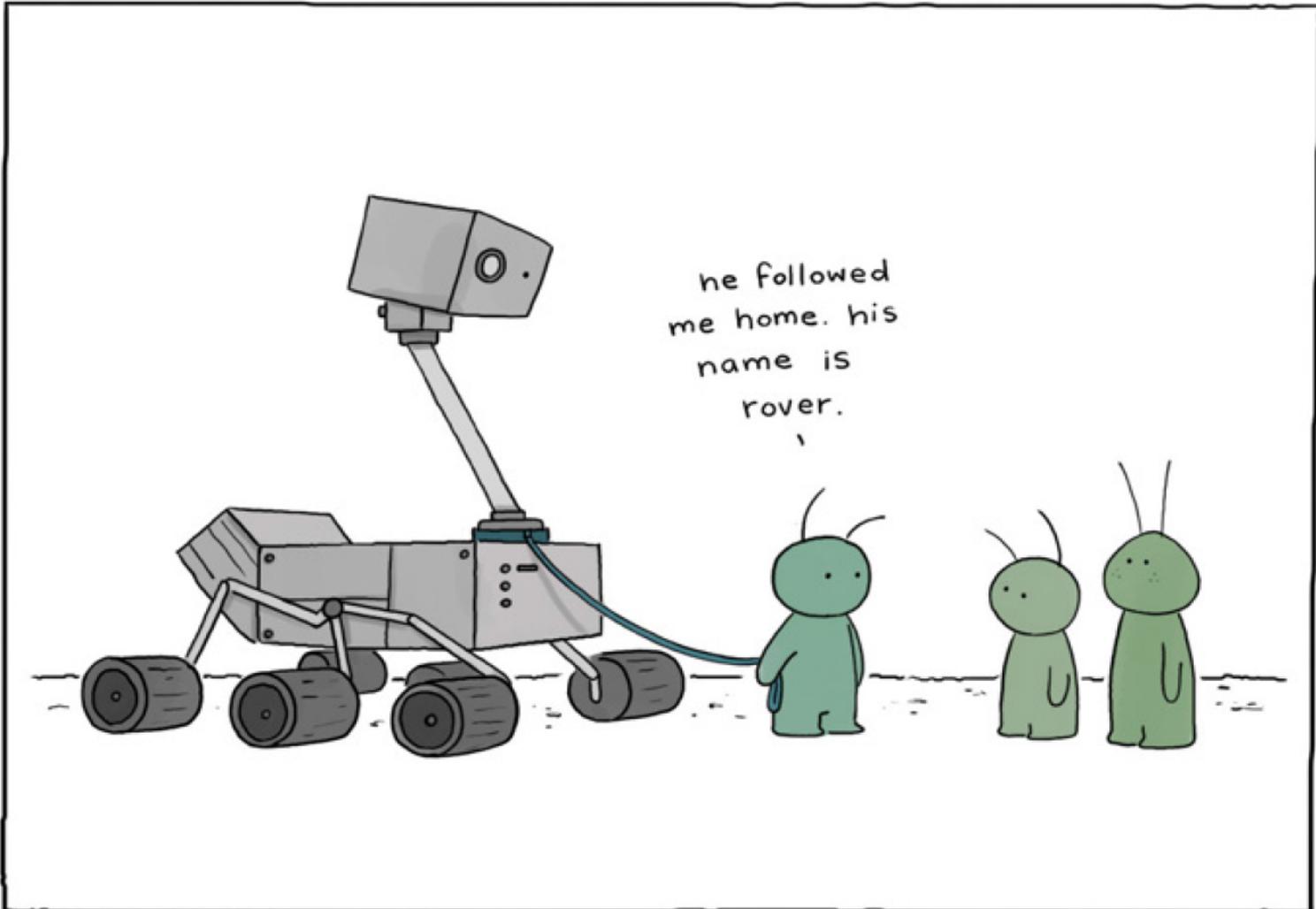




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# And here ...





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# And here ...



<http://www.uni-kiel.de/aktuell/pm/2012/2012-225-marslandung-erfolgreich.shtml>

***„Radiation Assessment Detector (RAD)“ wurde gemeinsam vom Institut für Angewandte und Experimentelle Physik der CAU in Kiel und dem Institut für Luft- und Raumfahrtmedizin des DLR in Köln***



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# CURIOSITY COMMUNICATIONS



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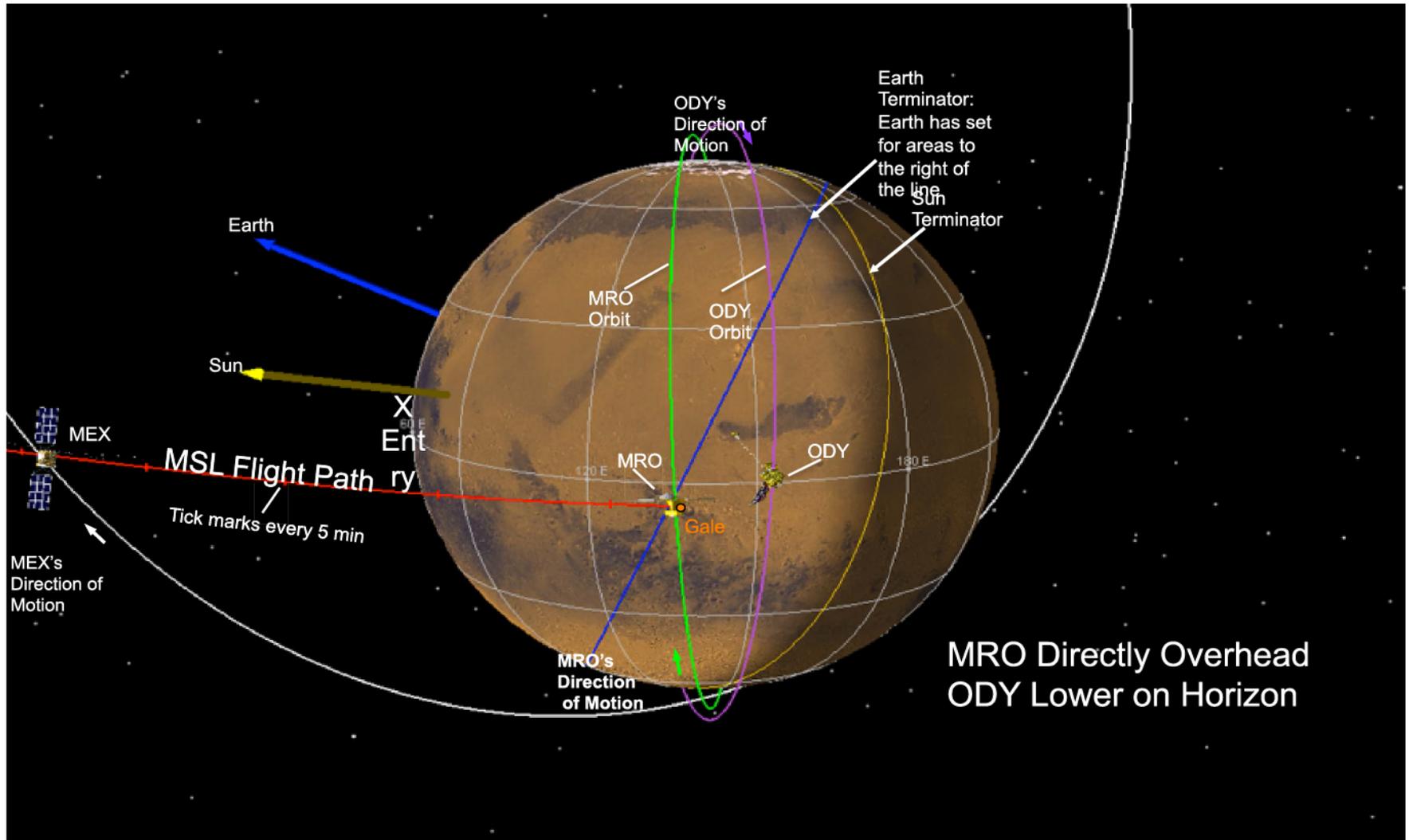
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# EDL Geometry at Landing – Aug 5, 2012

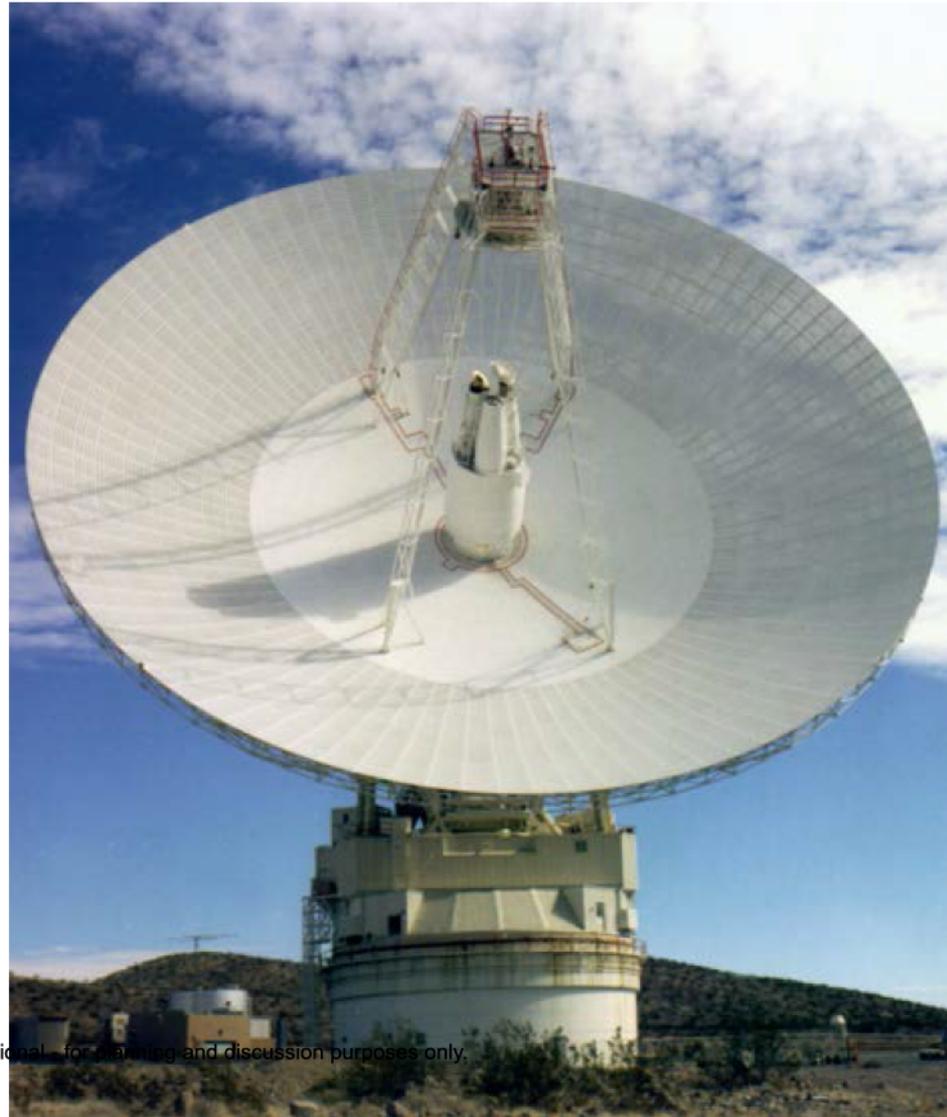




# On Earth



- During EDL, the 70 meter antenna in Canberra provided communications coverage.
- Signal travel time from Mars to Earth was 14 minutes.

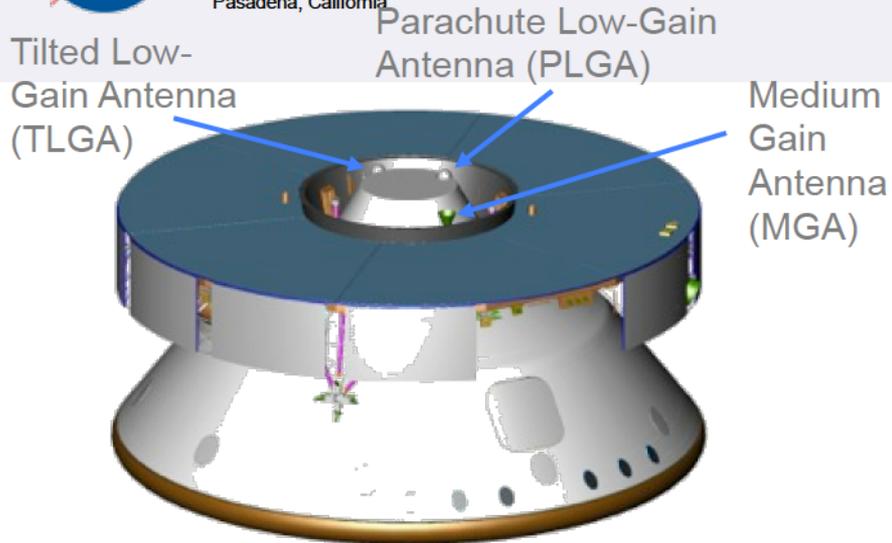




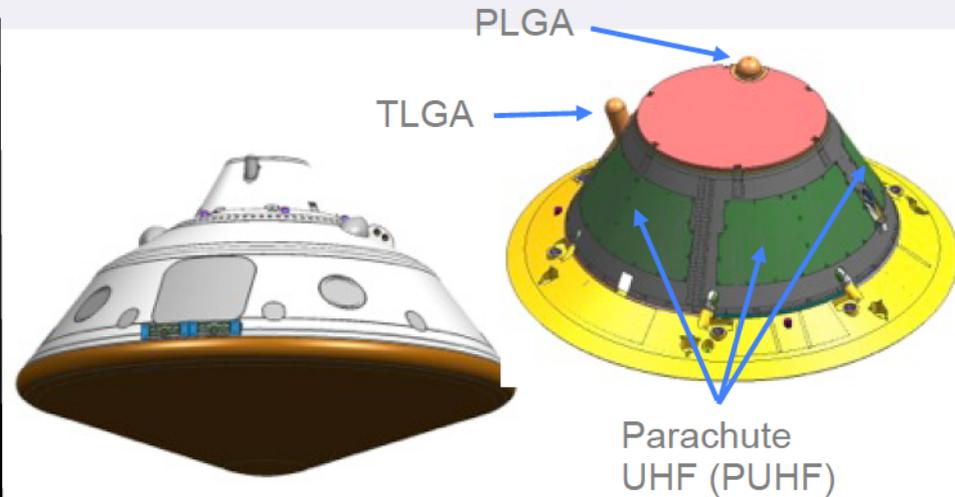
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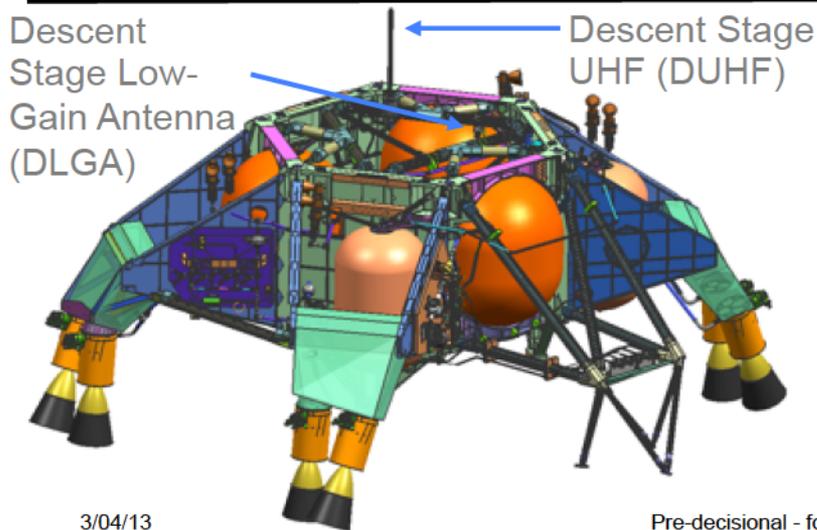
# X-band and UHF Antenna Locations



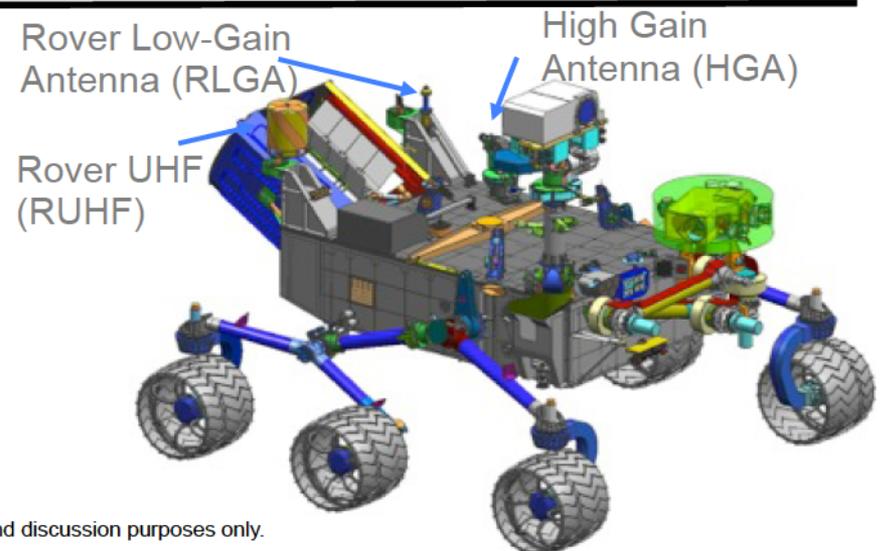
**Cruise**



**Entry**



**Power Descent**



**Surface**

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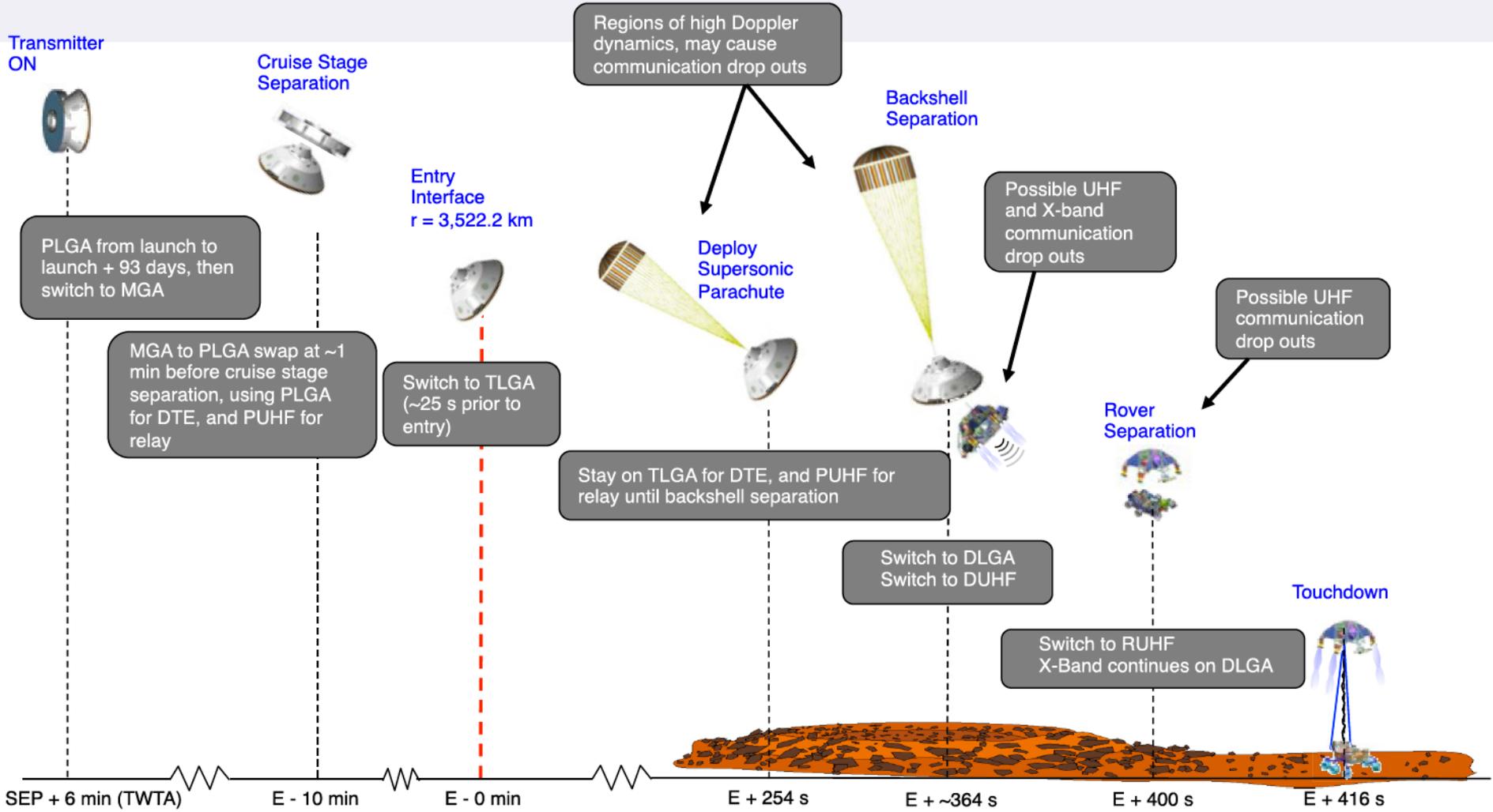
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# Antenna Usage During Touchdown



X-Band 2 kbps → Tones  
 UHF: 8 kbps

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# Antennas on Curiosity

- Curiosity uses its UHF antenna to communicate with orbital assets overhead for relaying science and engineering data back to Earth.

- There is direct to Earth X-band capability through X-band low and high gain antennas. This, however, is mostly used for receiving uplinked commands.

Rover UHF Antenna

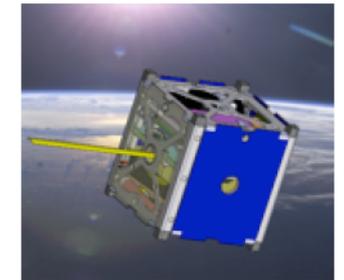
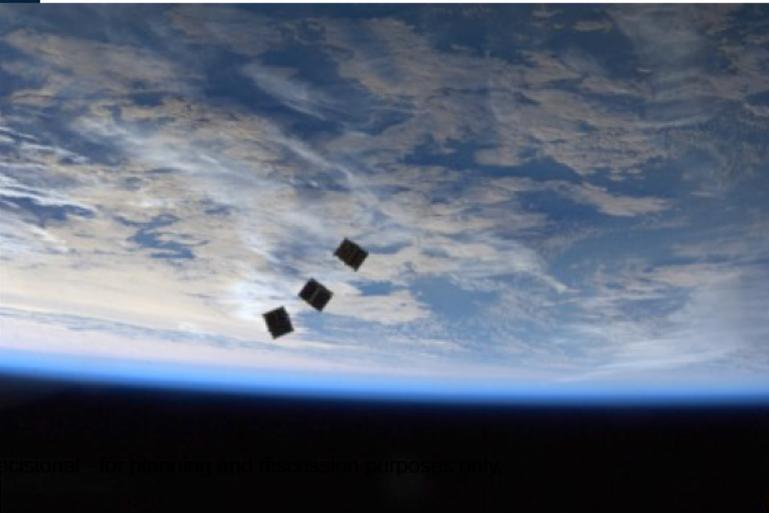
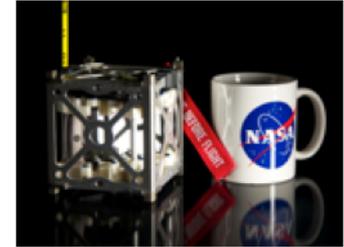
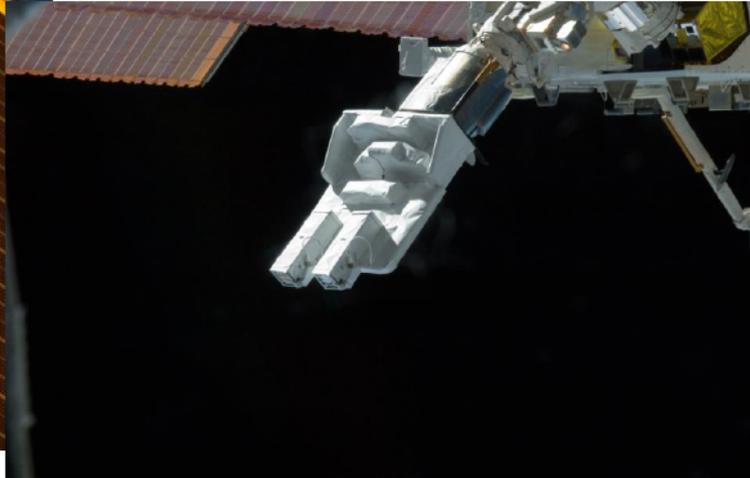
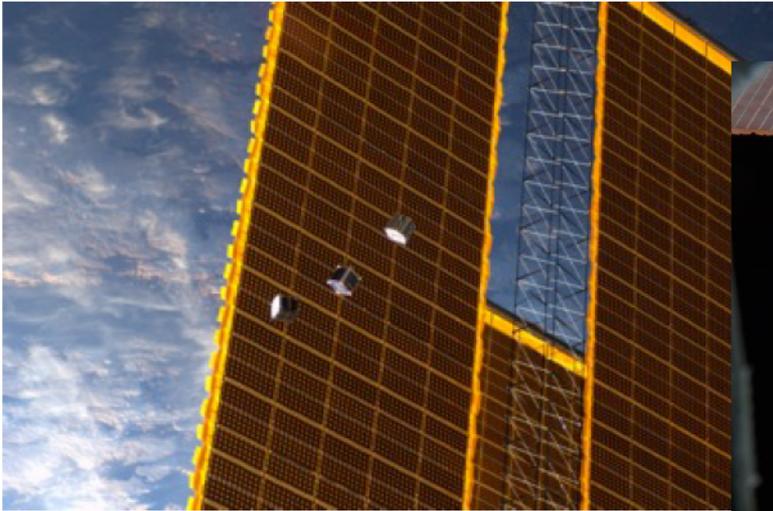
X-band Low Gain Antenna (LGA)

X-band High Gain Antenna (HGA)



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# THE CUBESAT WORLD



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Pre-d

TechEdSat Deployment from ISS

[http://www.nasa.gov/offices/oct/stp/small\\_satellite\\_subsystem\\_tech/index.html](http://www.nasa.gov/offices/oct/stp/small_satellite_subsystem_tech/index.html)



# ISARA CubeSat - Rich Hodges PI

## Integrated Solar Array & Reflectarray



### Reflectarray Characteristics

- Reflector type antenna
- Flat and thin form factor.
- Capable of pencil beam, shaped beam, etc.
- Relatively good efficiency (>50% demonstrated)

### Solar Panel Mounting

- Use “Turkey Tail” solar panel configuration
- Reflectarray panels mounted on back side of solar array panels
- Fits within the available space for solar panel
- Flatness is sufficient for antenna
- Hinges may need better positioning tolerance

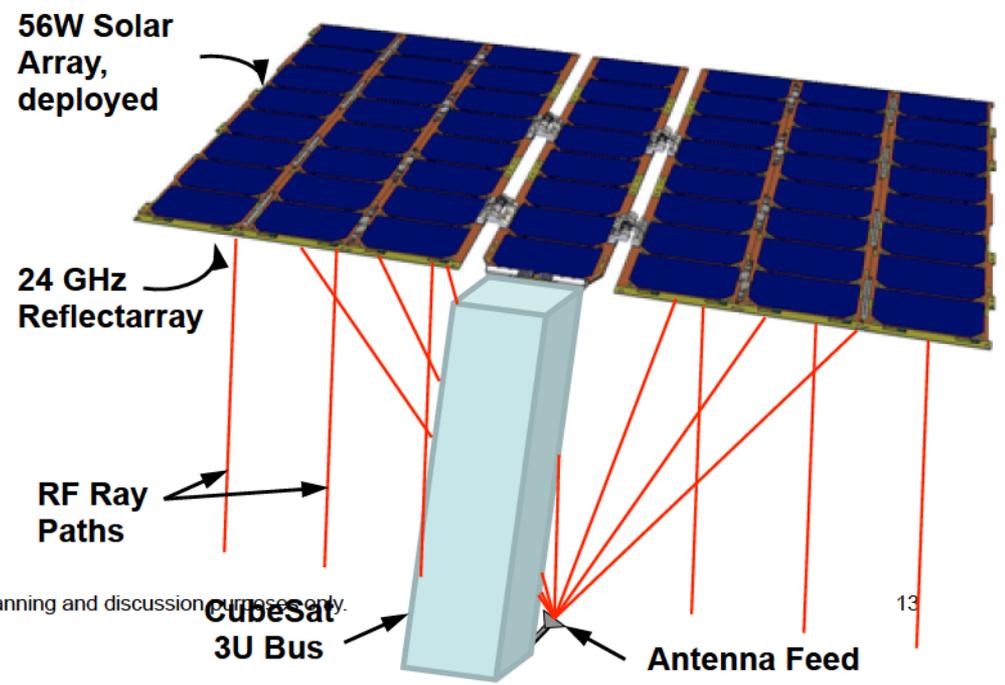
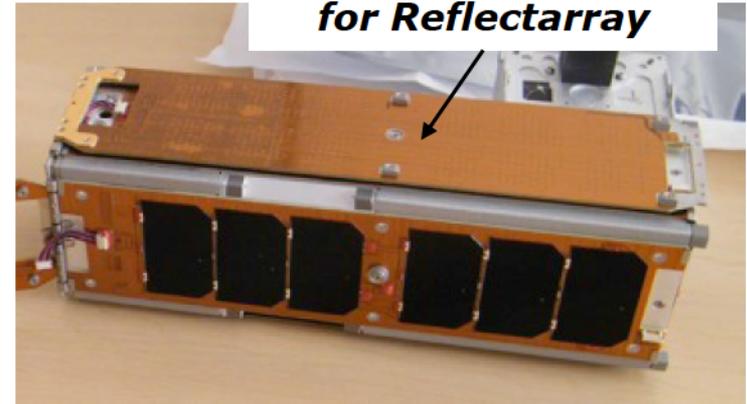
### Feed

- Mounted on S/C bus (can “flip out” if necessary)

### Key S/C Requirements

- Pointing accuracy – use reaction wheels
- Solar panel deployment accuracy – hinges

**Smooth, flat surface for Reflectarray**





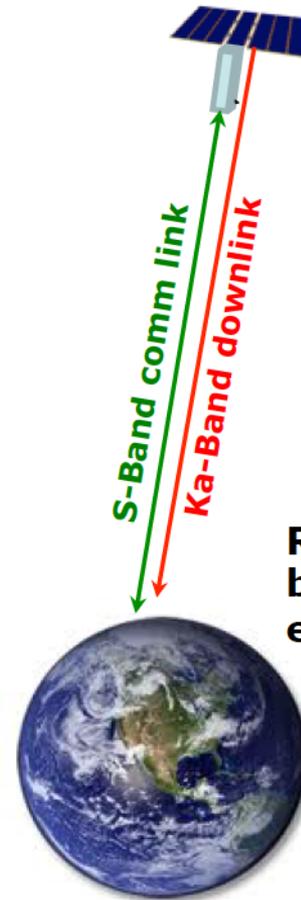
## Orbit (TBD)

- Geosynchronous orbit preferred.
  - ❑ No previous cubesat launched to Geo
  - ❑ Need to address issues with radiation hardness of COTS components
  - ❑ GTO launch more difficult
- LEO orbit
  - ❑ Could work but timing is more difficult

## Antenna Test

- Measure HGA gain relative to onboard standard gain antenna
- Measure patterns by rotating s/c on orbit
- Antenna performance metrics confirm deployment accuracy – prove TRL 7.
- Test could be repeated at 6 month intervals to verify there would be no performance degradation

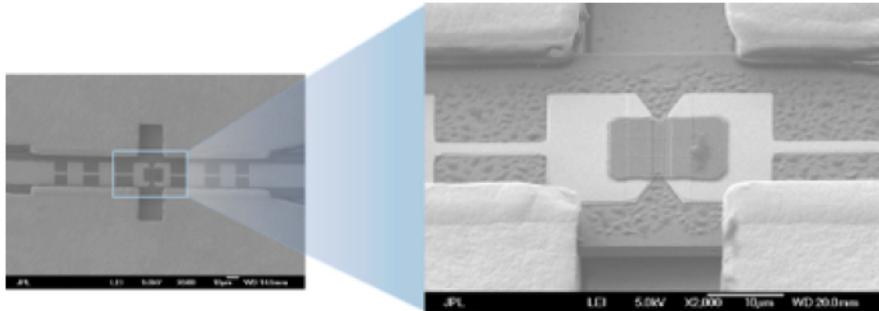
**Rotate S/C. Monitor received power to measure antenna pattern**



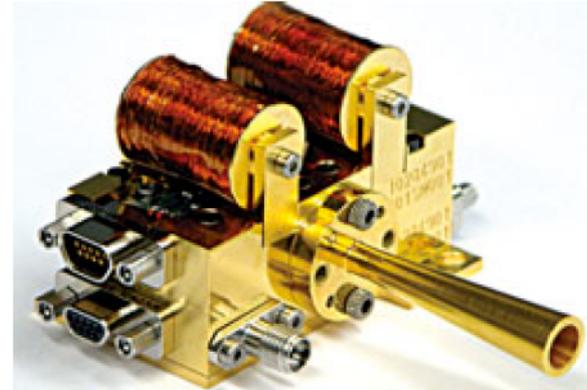
**Receiver site would be Goldstone 34-m experimental antenna**



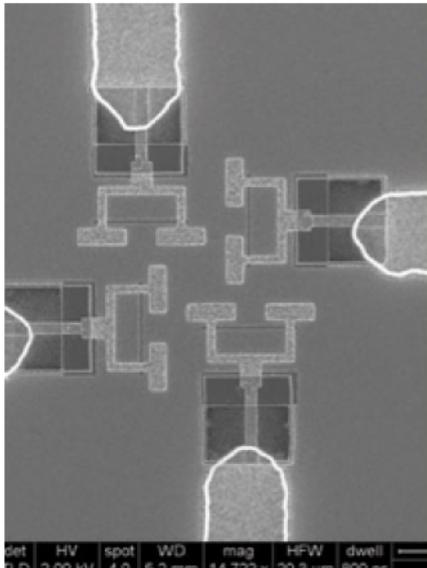
# Microfabricated Systems



Hot electron bolometer (HEB)-based mixers



SIS Receivers for Studying Global Atmospheric Chemistry



Antenna-coupled NTJ IR detectors for Hyperspectral Polarimetric FPA



Compact Submillimeter Spectrometers for Outer Planet Missions

A 500–600 GHz receiver front-end combines the local oscillator and mixer chips in a single block. It can be used to detect water molecules in the ppb range.

# CURIOSITY SCIENCE





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# Heat Shield Separation





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# Kicking Up Dust Prior to Landing





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# 'Hottah'



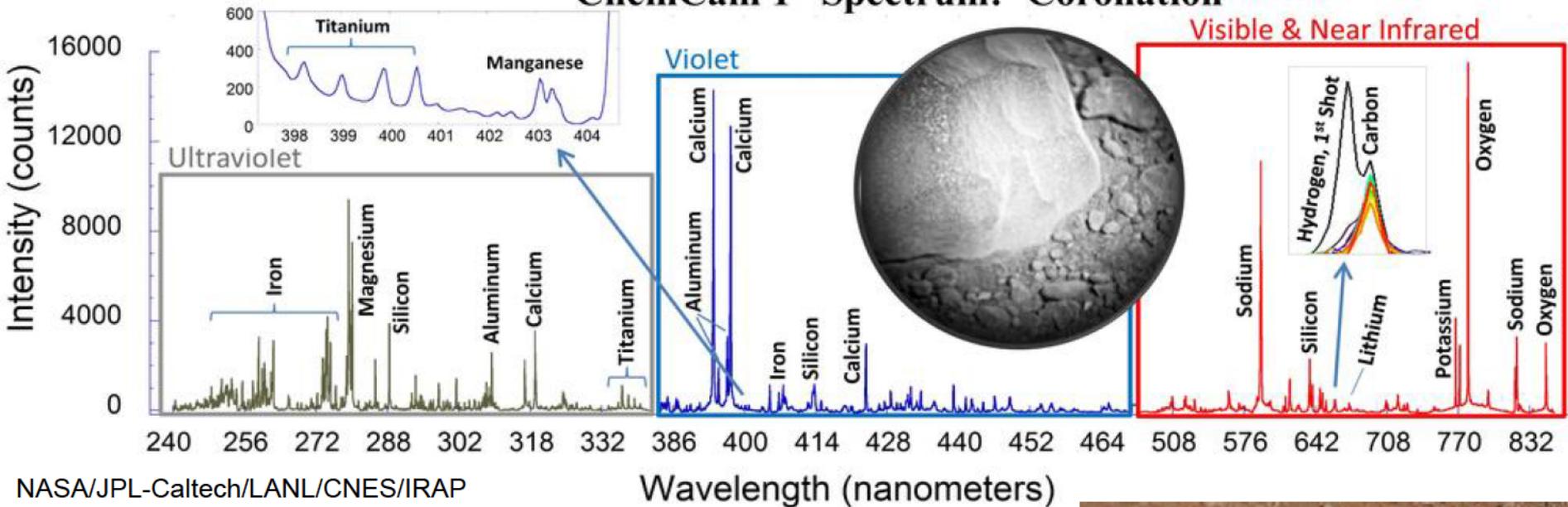
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## ChemCam 1<sup>st</sup> Spectrum: 'Coronation'



NASA/JPL-Caltech/LANL/CNES/IRAP

Wavelength (nanometers)

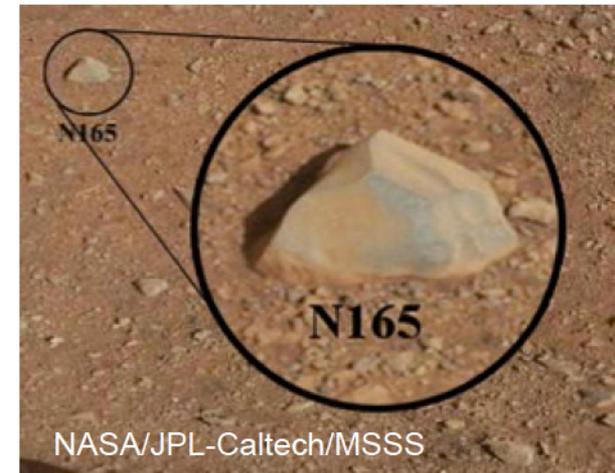
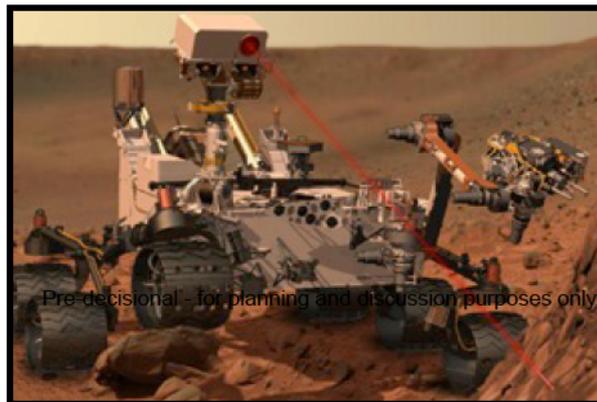
## ChemCam spectra of Coronation

Target: Coronation (N165)

Sol 13

Shots: 30

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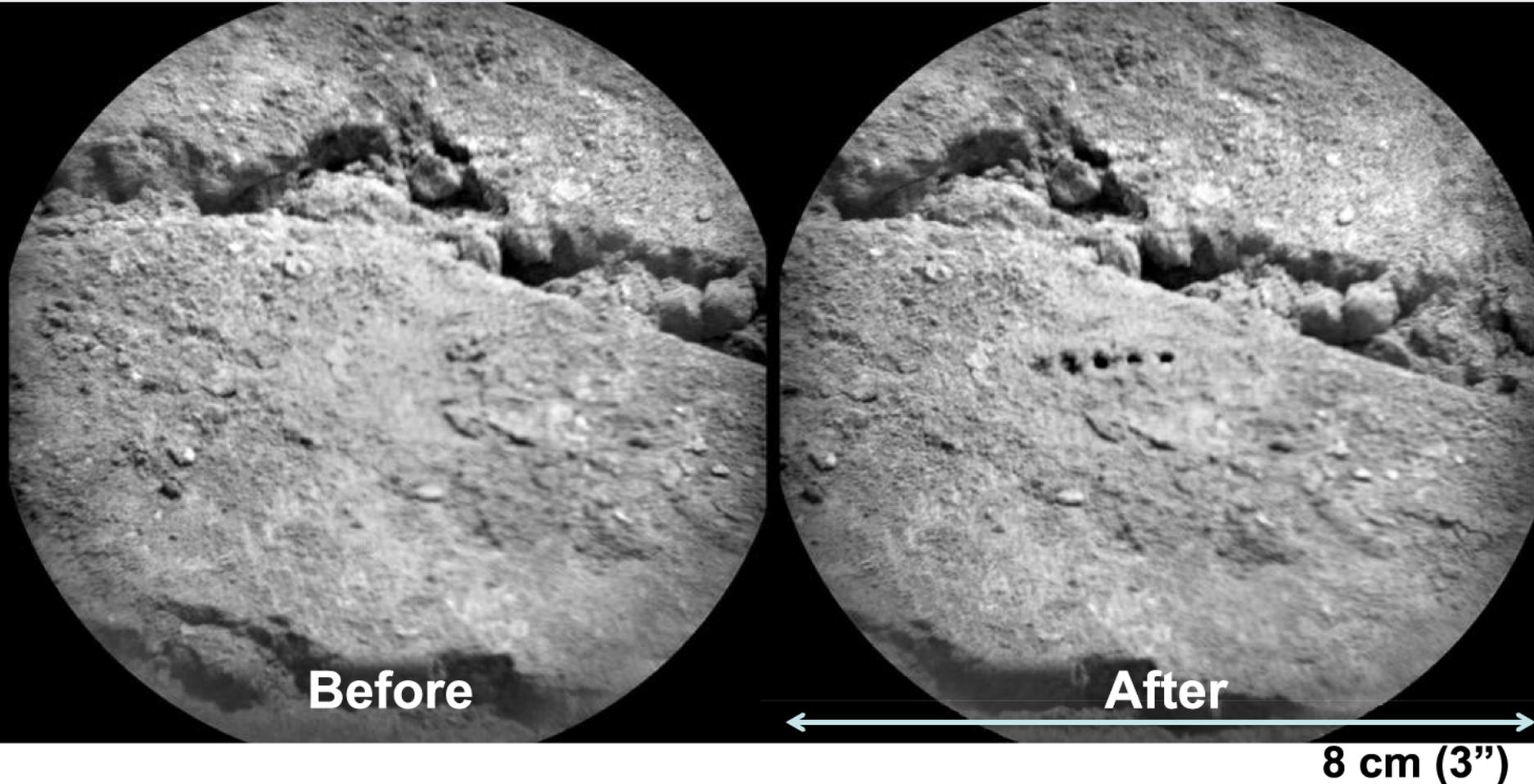
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## Target: Beechey (Sol 19) Shots per point: 50



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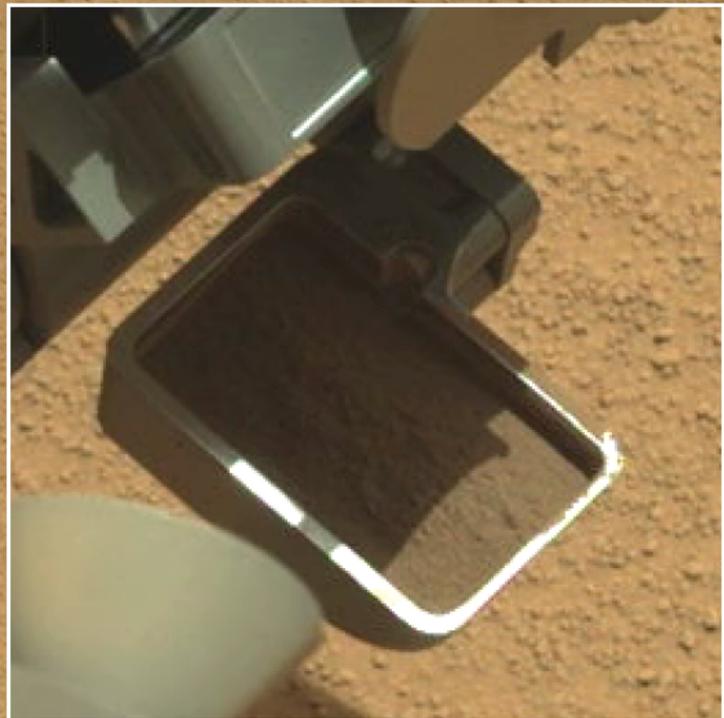
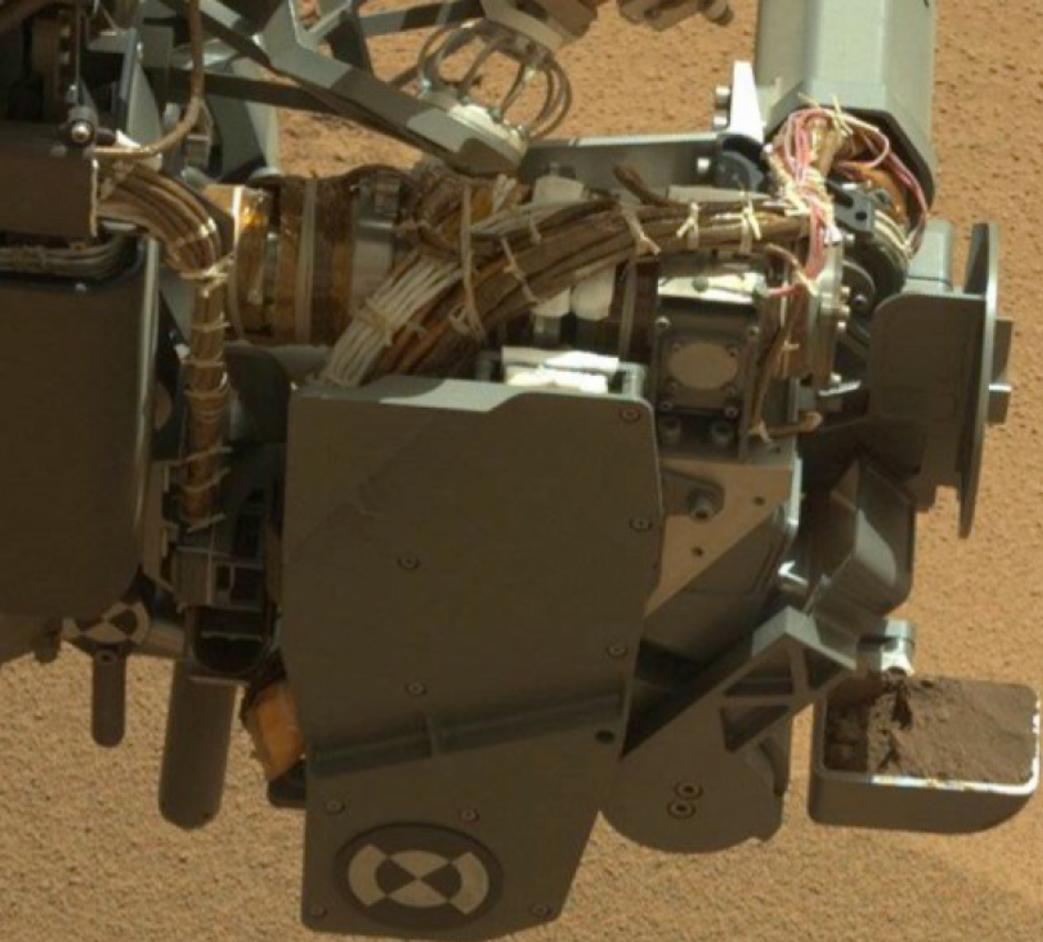
**ChemCam's laser induced breakdown  
spectrometer acquires a 5-point raster in soil**



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# Cartoon ChemCam





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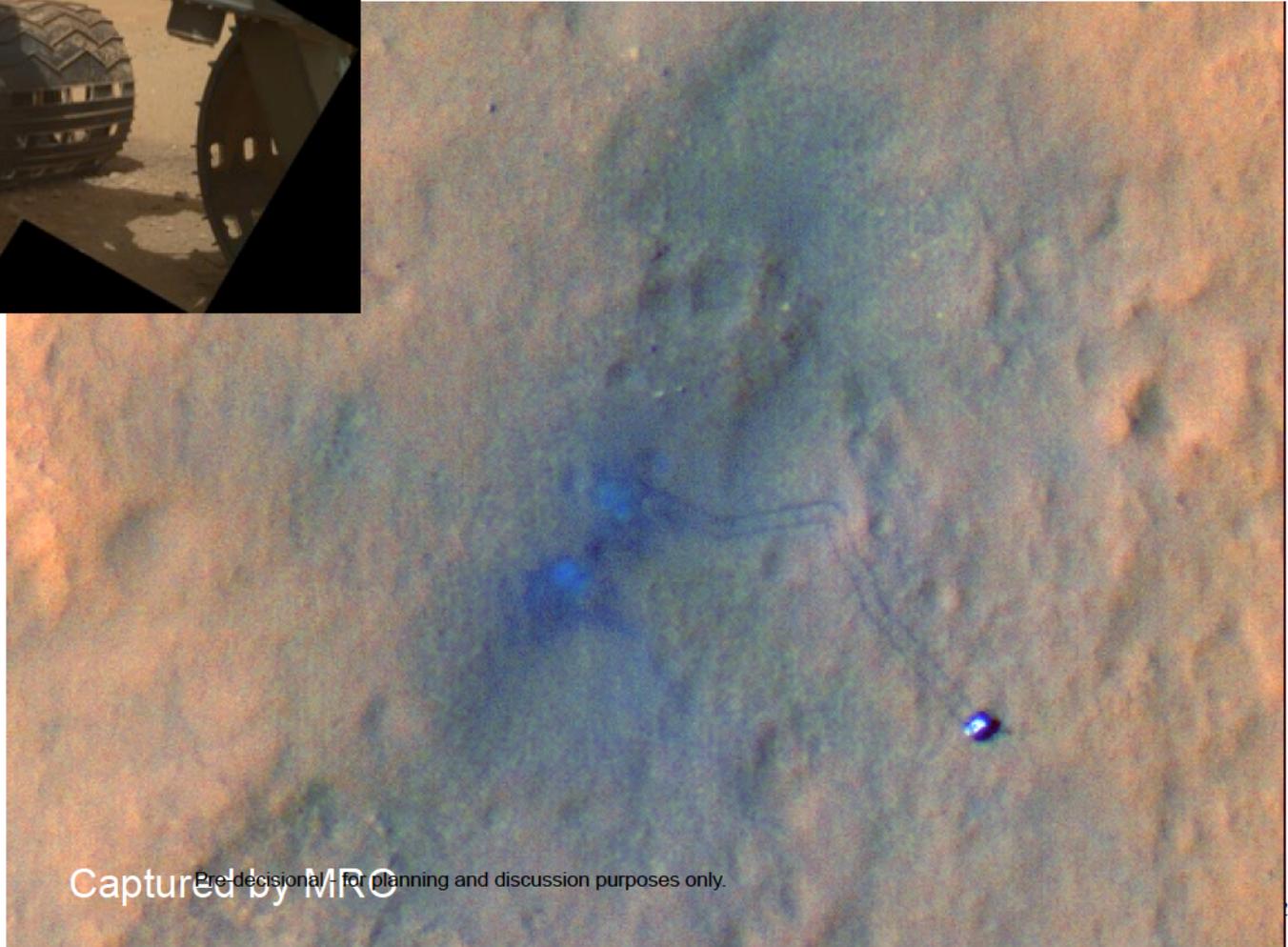


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# Roving ....



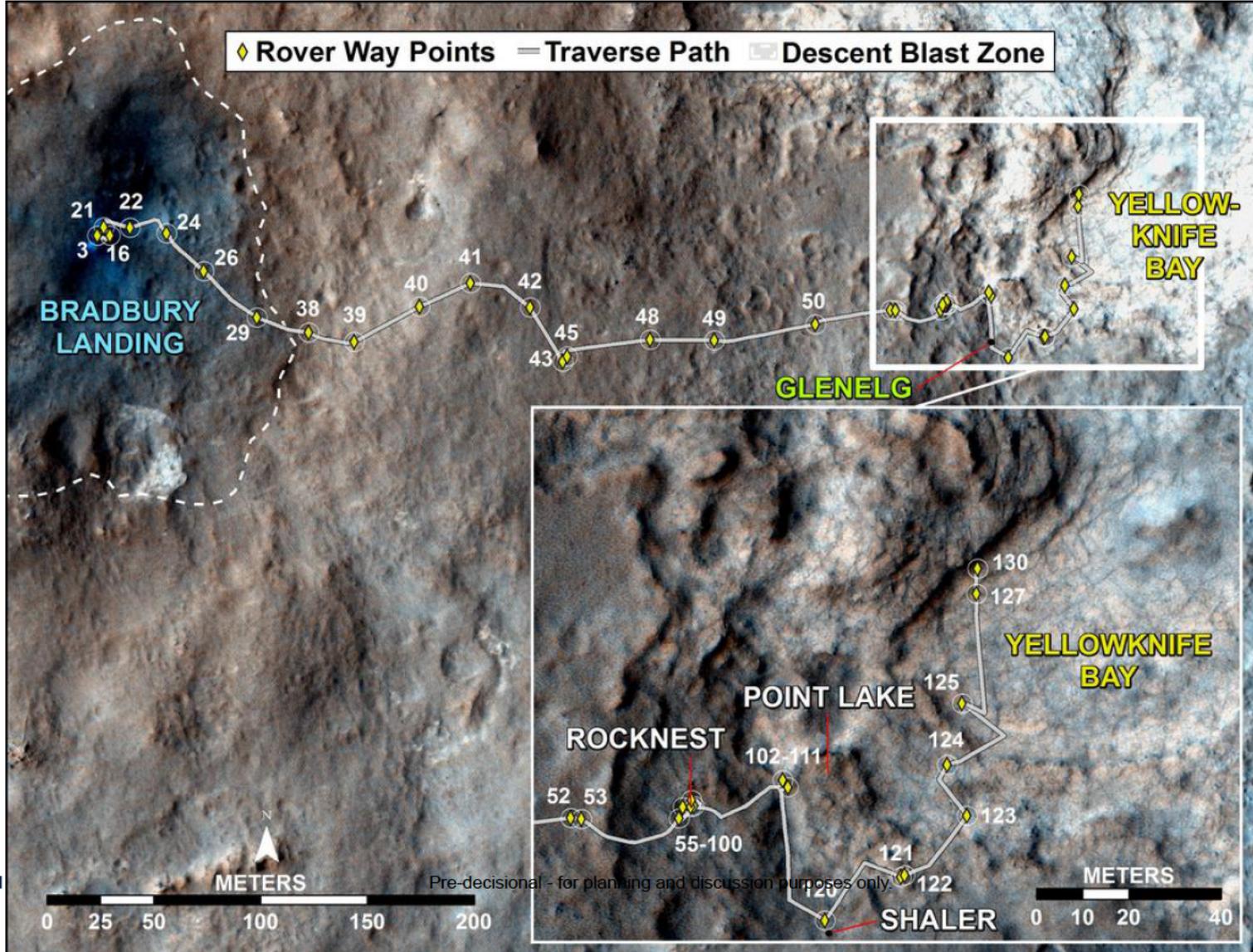
*Three Left Wheels*  
MSL MAHLI camera



Captured by MRO Pre-decisional - for planning and discussion purposes only.



# Traverse Aug – Nov 2012





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# Where to Go ...



**This boulder is the  
size of Curiosity**

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# Looking Back ...





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# Apollo 11 and Curiosity Rover



3/04/1

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