

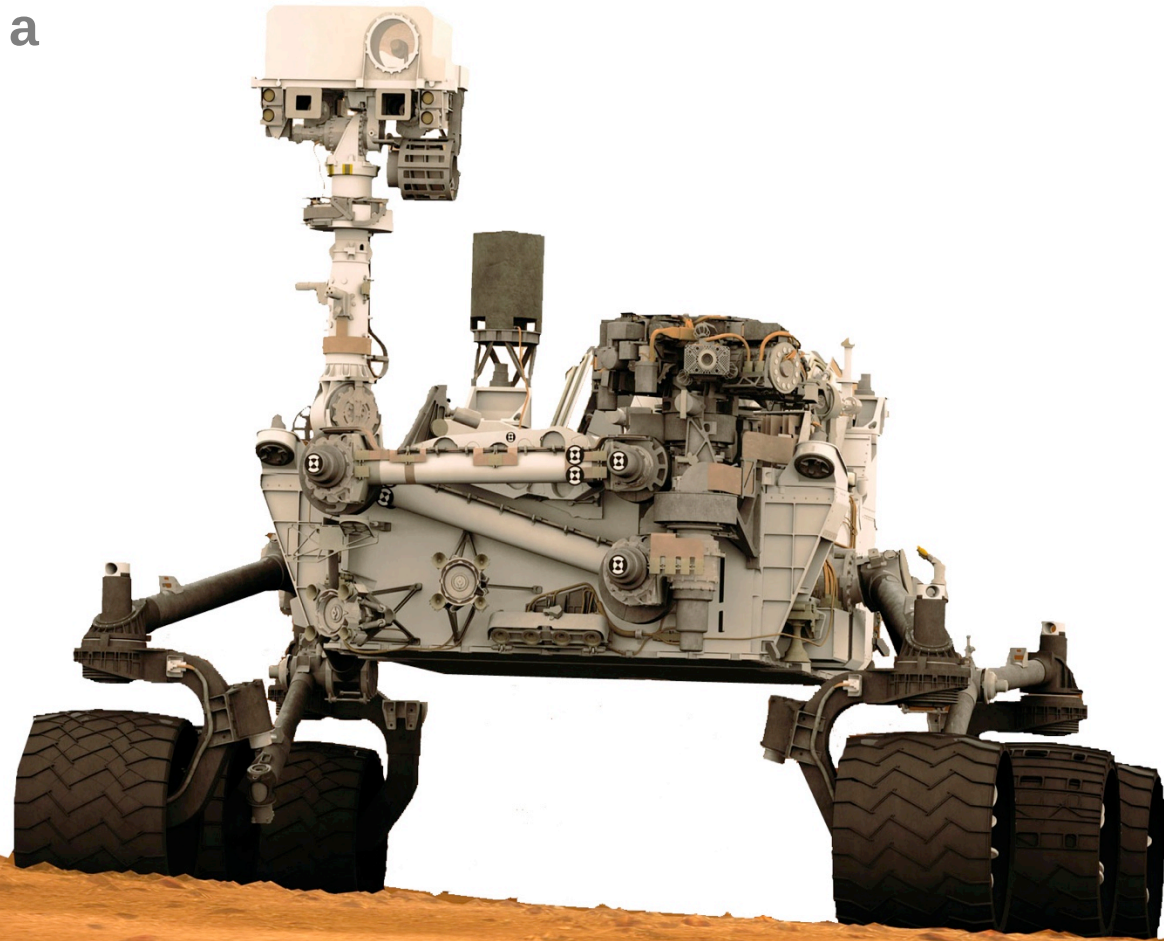
The Challenges of Landing a Car-Sized Rover on Mars

a presentation for the

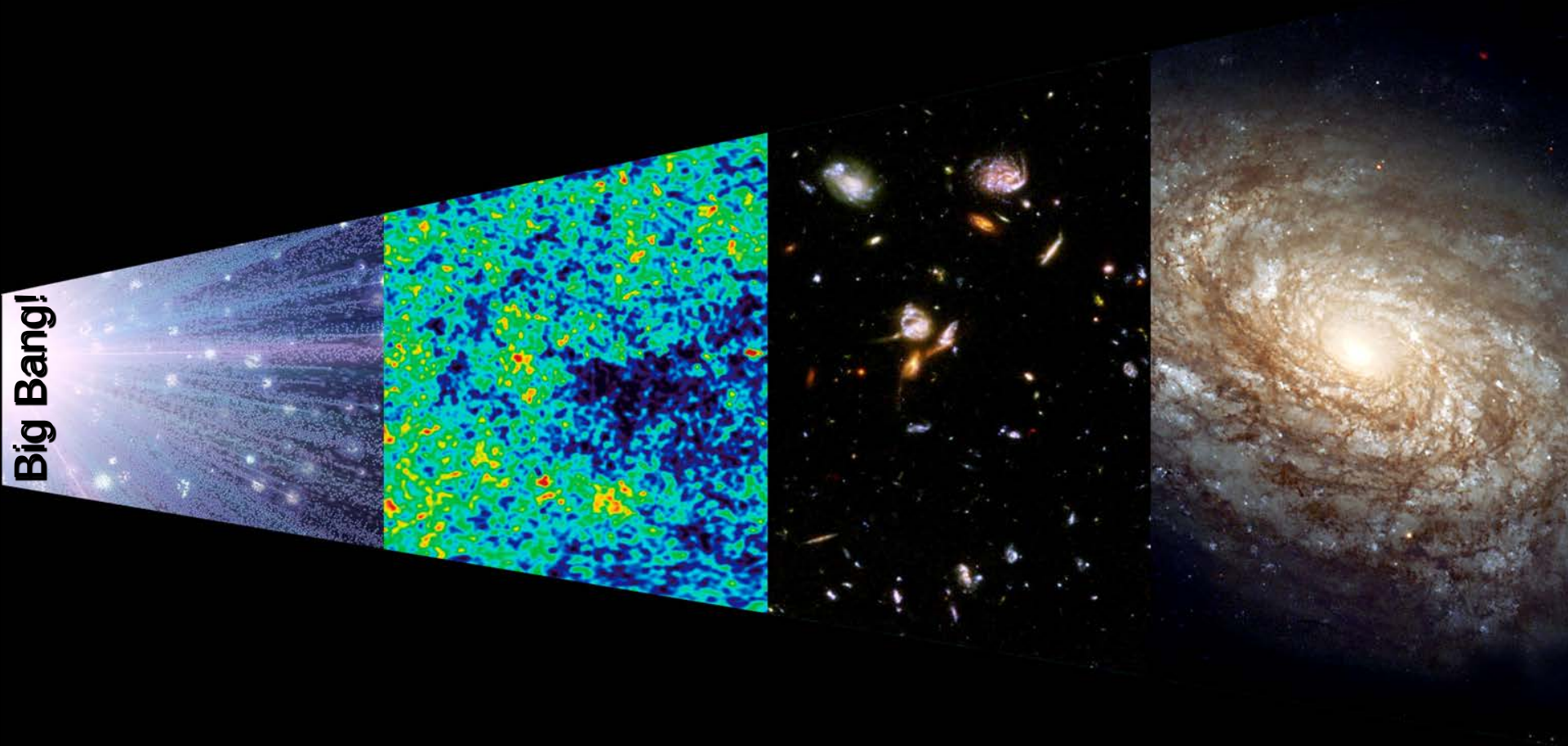
ICALEPCS

9 October 2013

Charles Elachi, Director
NASA Jet Propulsion Laboratory
California Institute of Technology



Big Bang!



History of the Universe



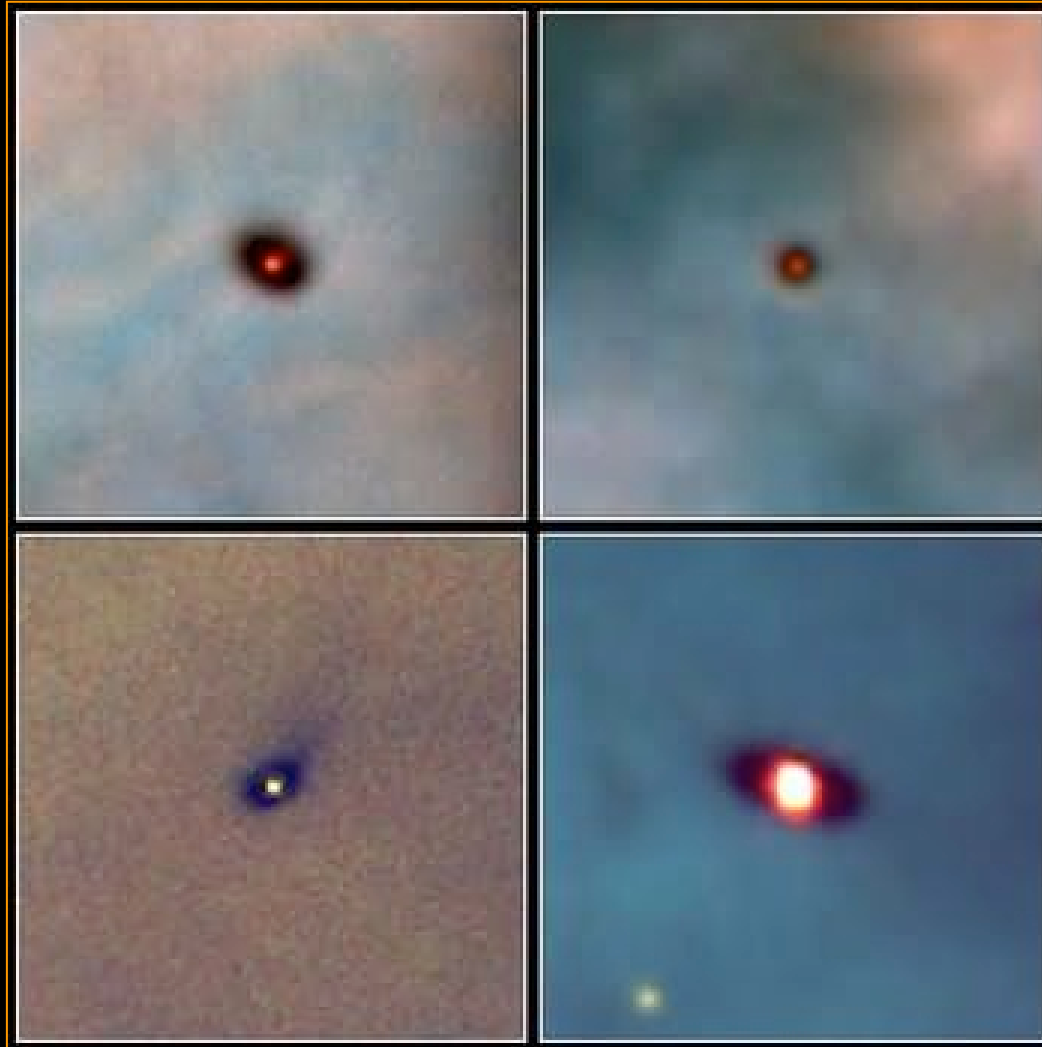
Five Interacting Galaxies

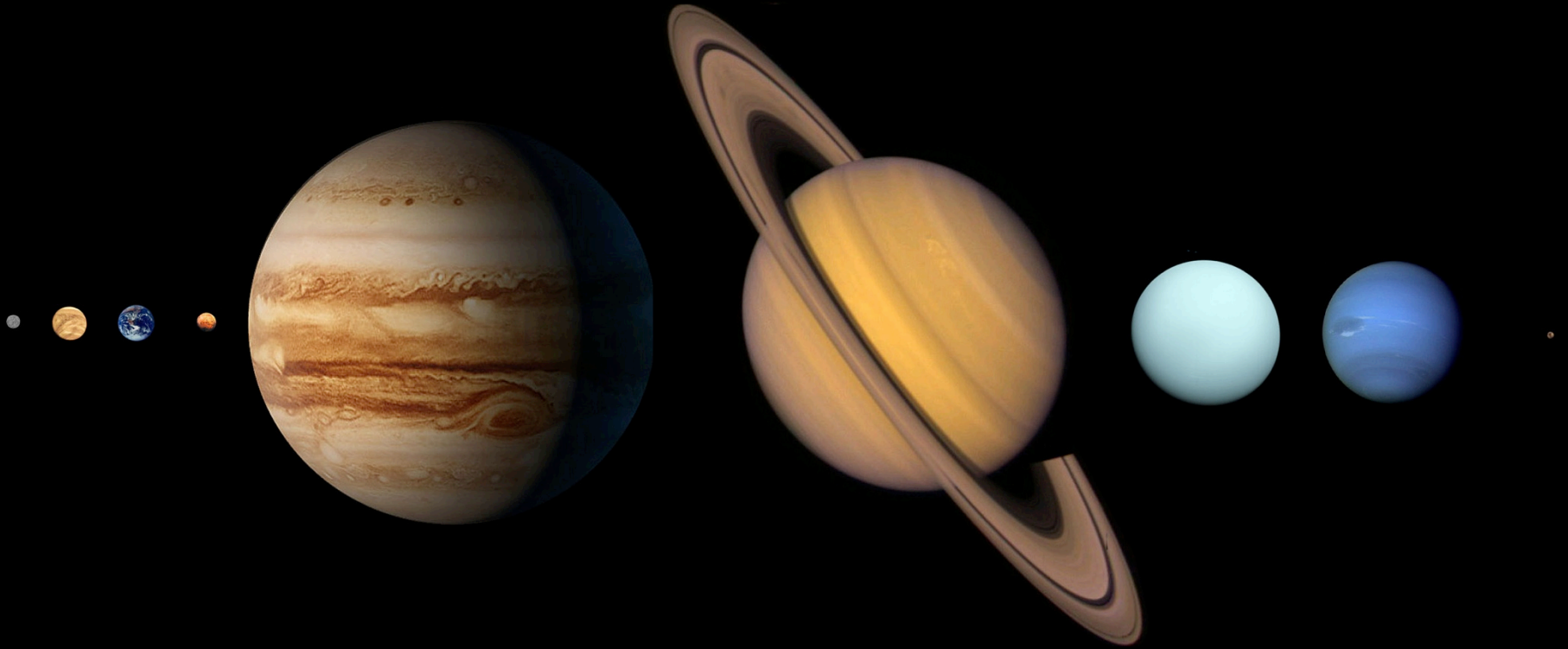


Spiral Galaxy
Composite: Spitzer, Hubble, Chandra

Formation of Extra-Solar Disks

Hubble Space Telescope

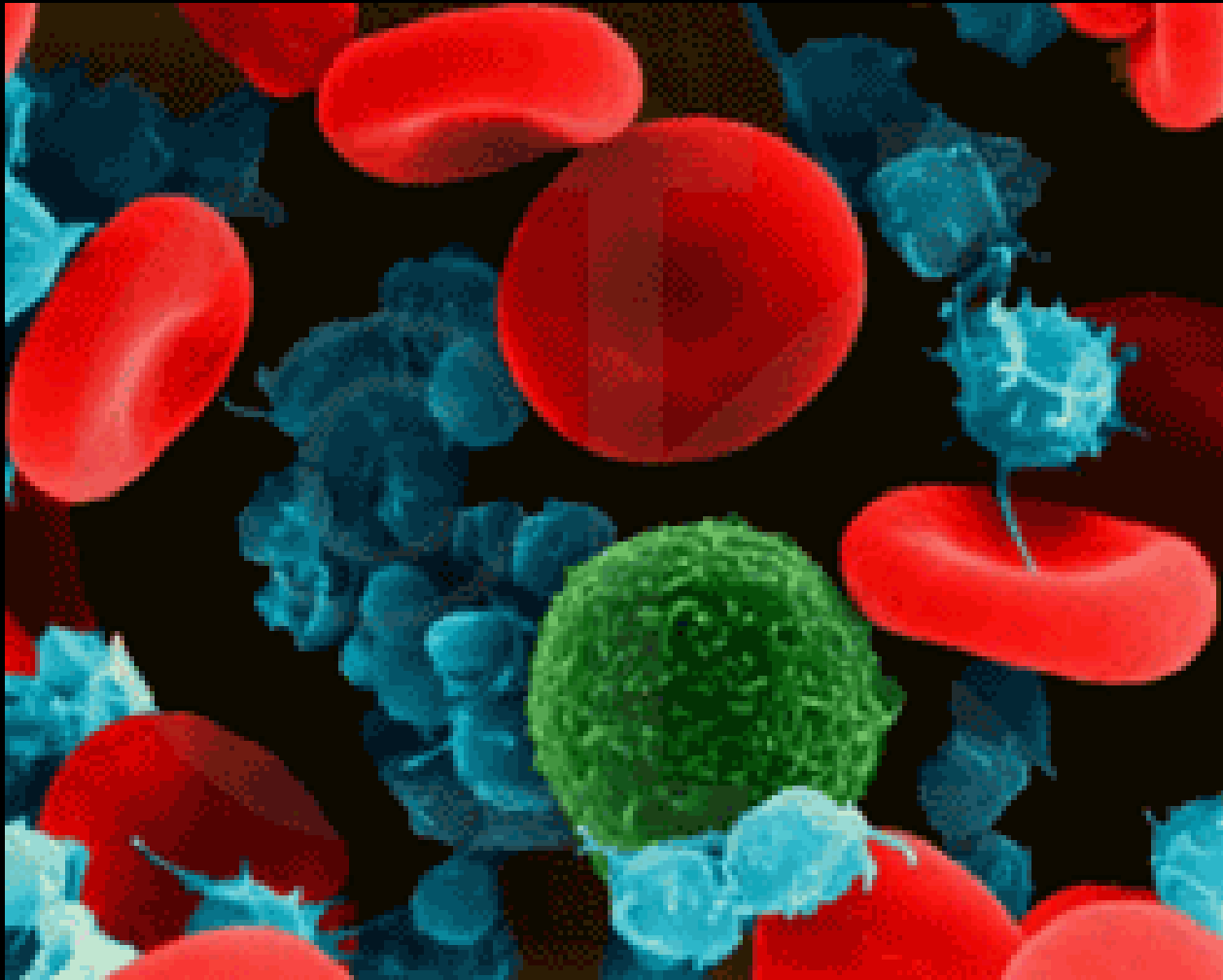




Our Solar System



A Planet Friendly to Life



Self-replicating Molecules Lead to Cells and Life



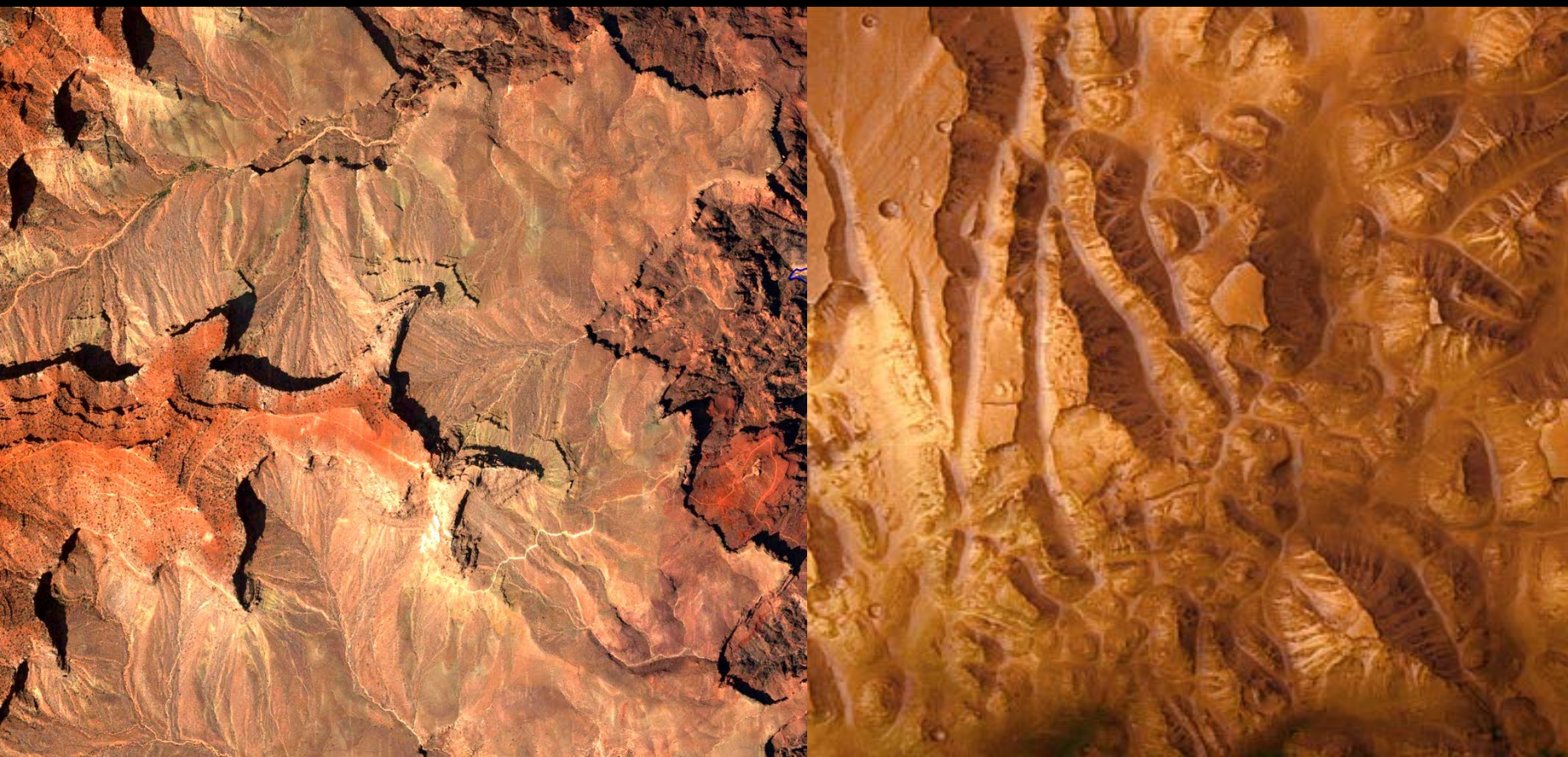
3.8 Billion Years of Evolution Produced....



...the Lawrence Livermore National Laboratory!



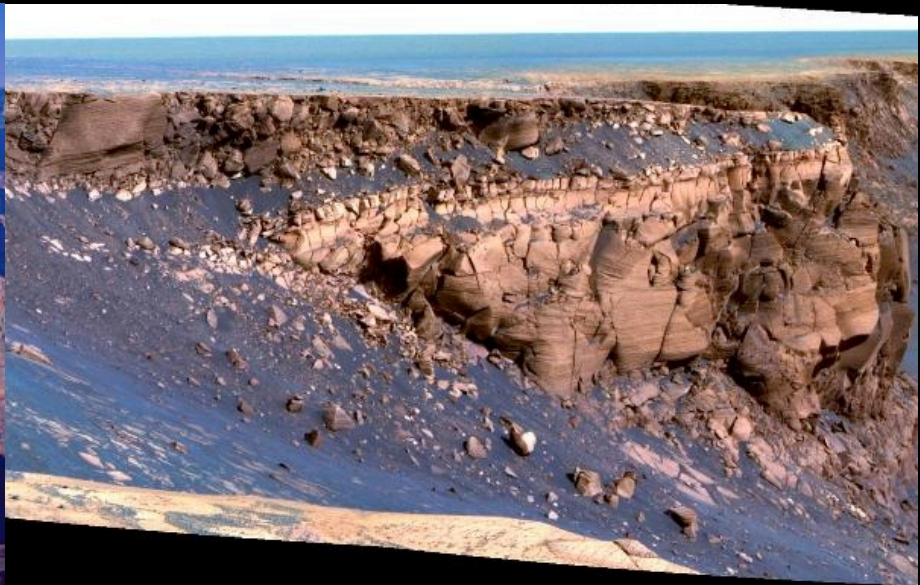
Earth and Mars share several features



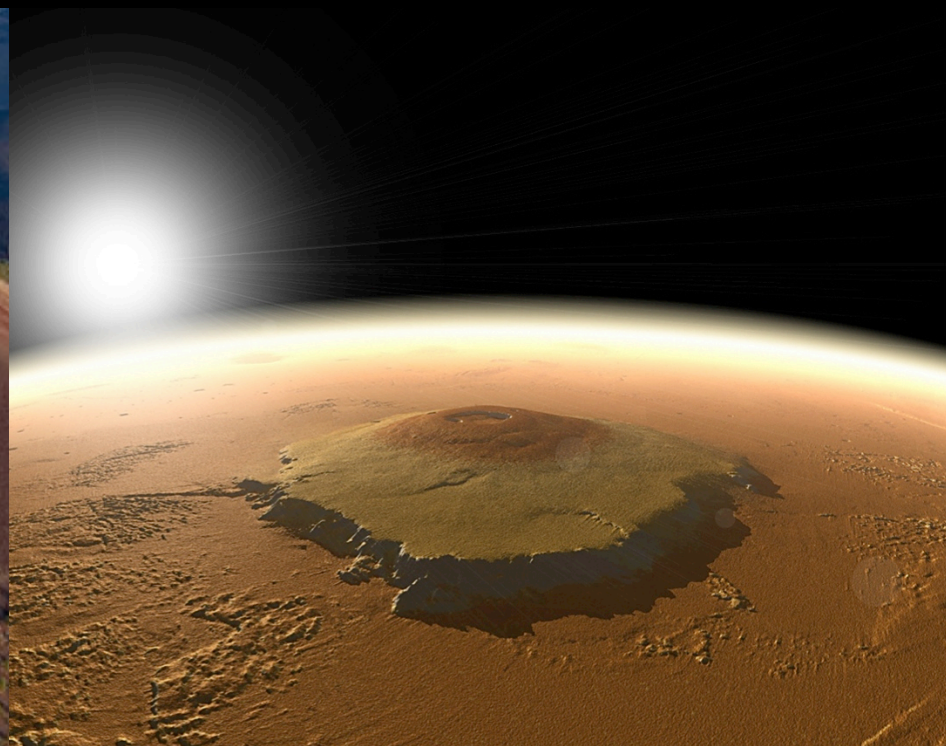
Grand Canyons



Arizona's Grand Canyon



Mars' Victoria Crater from *Opportunity*



Great Volcanoes



Geology

Traveling 100 Million Miles to Mars



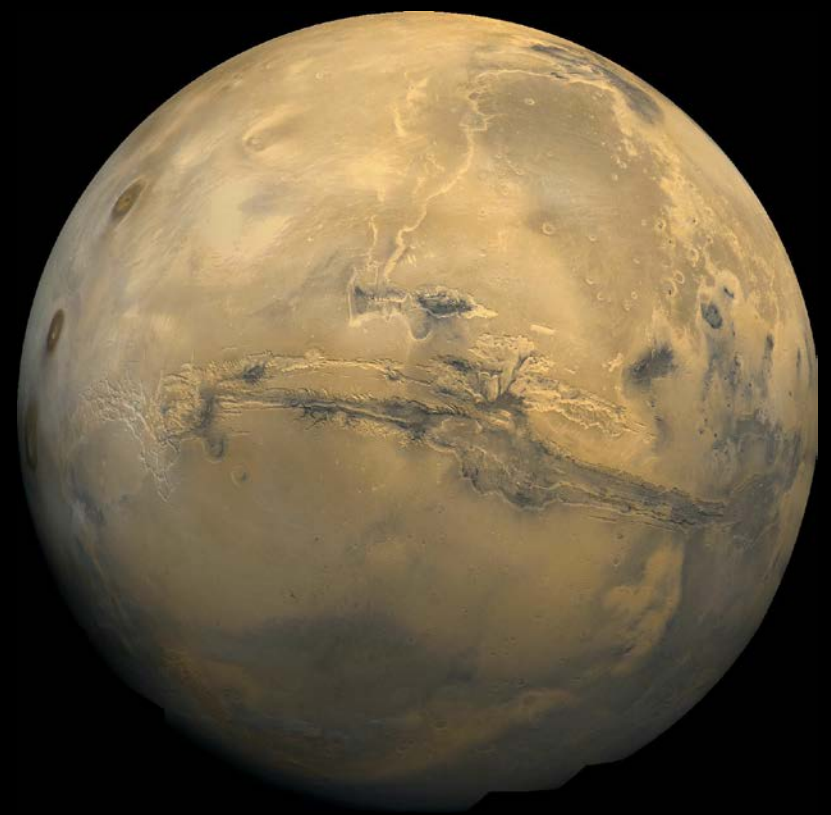
Lewis & Clark
40,000 YEARS



Columbus
10,000 YEARS

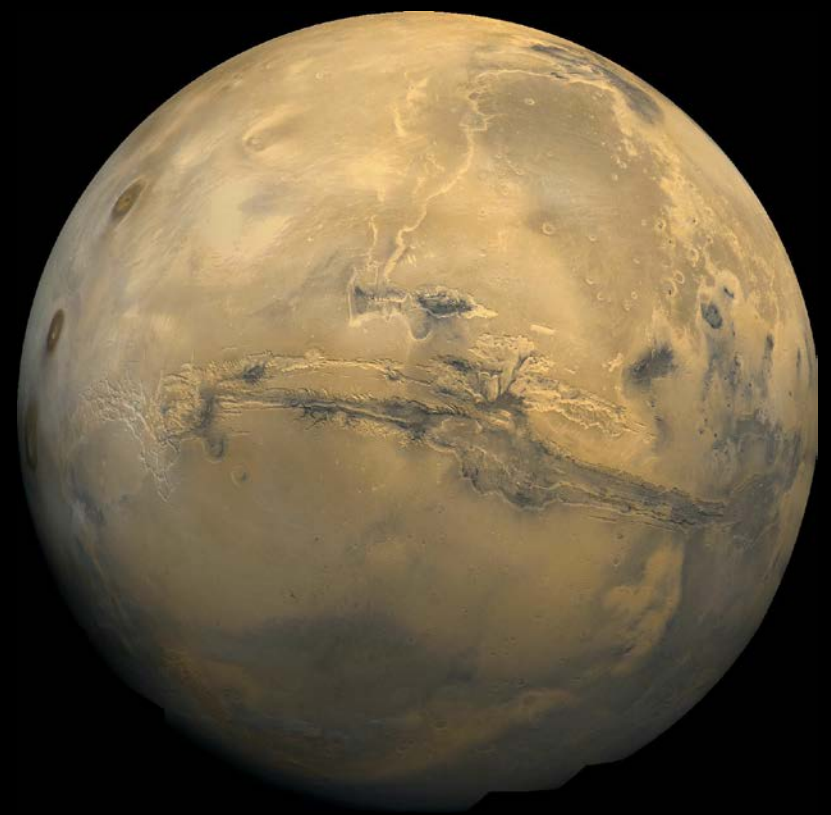
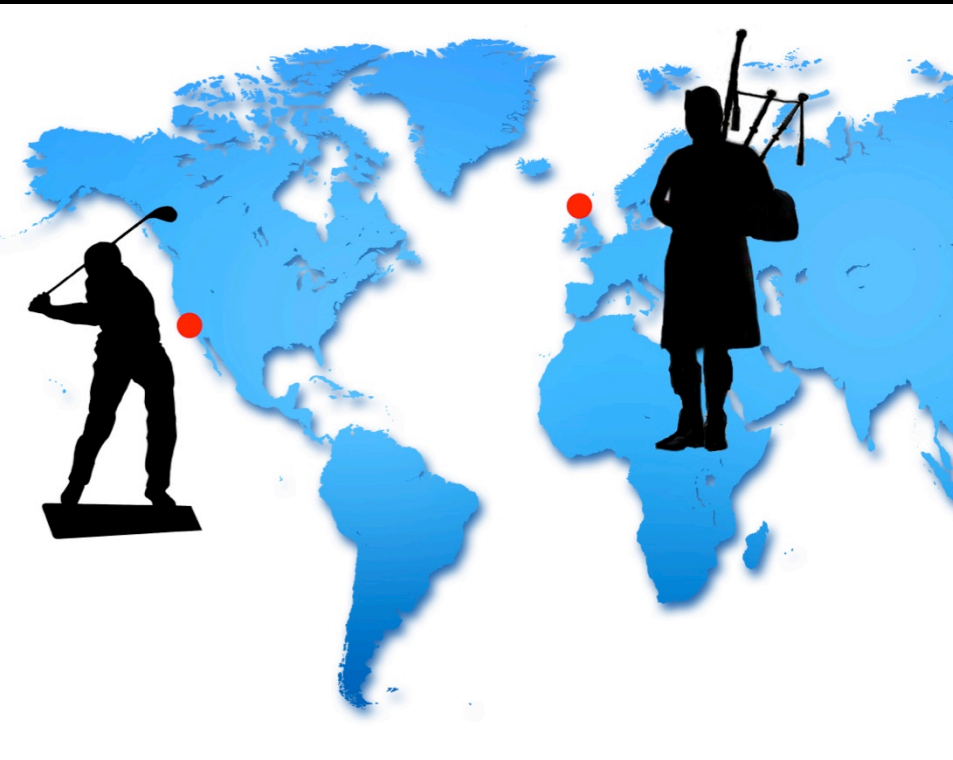


JPL Director's Z
175 YEARS



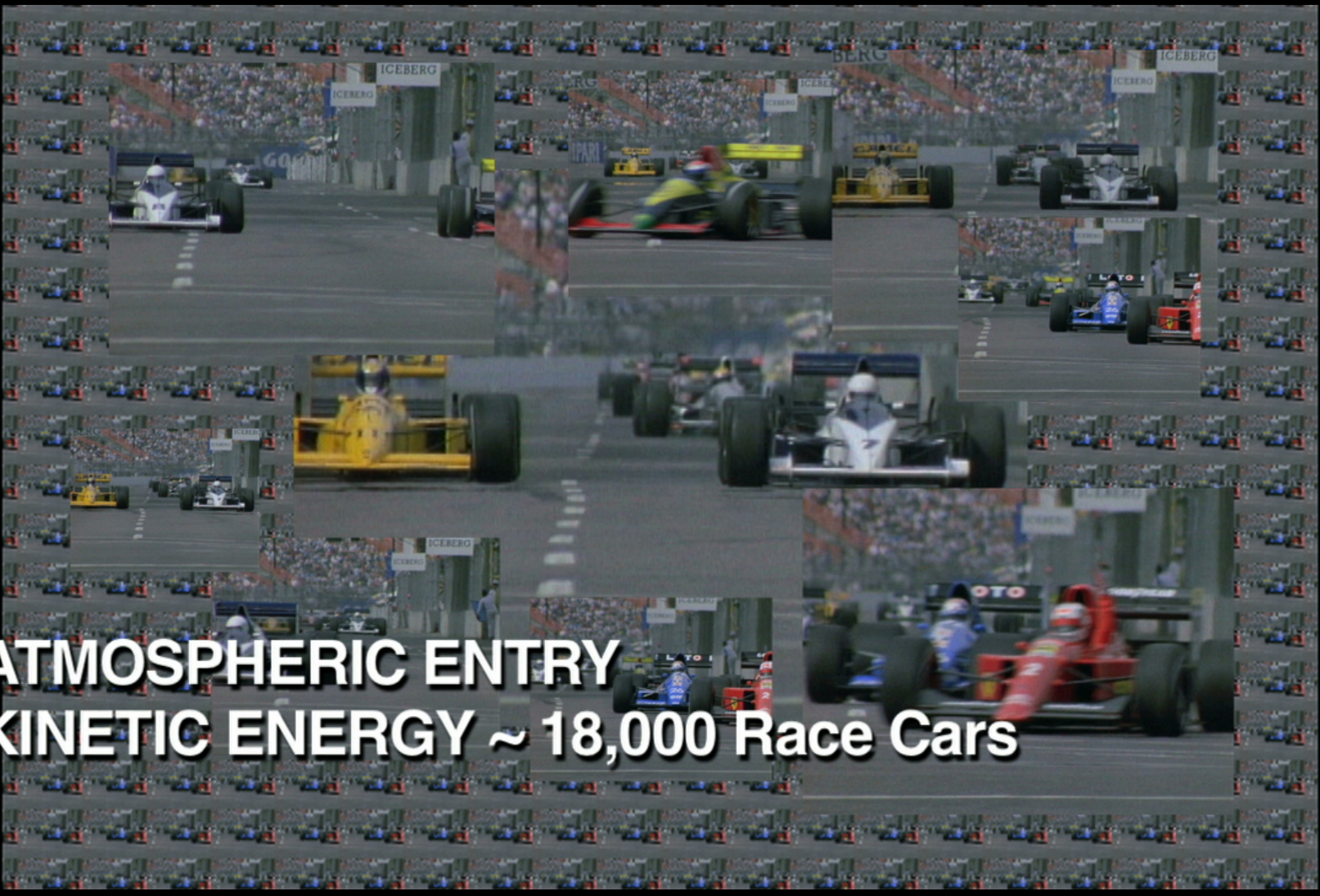
Navigation

After traveling 450 million kilometers, the rover *Curiosity* arrived at Mars within 2 kilometers of its intended landing site...



Navigation

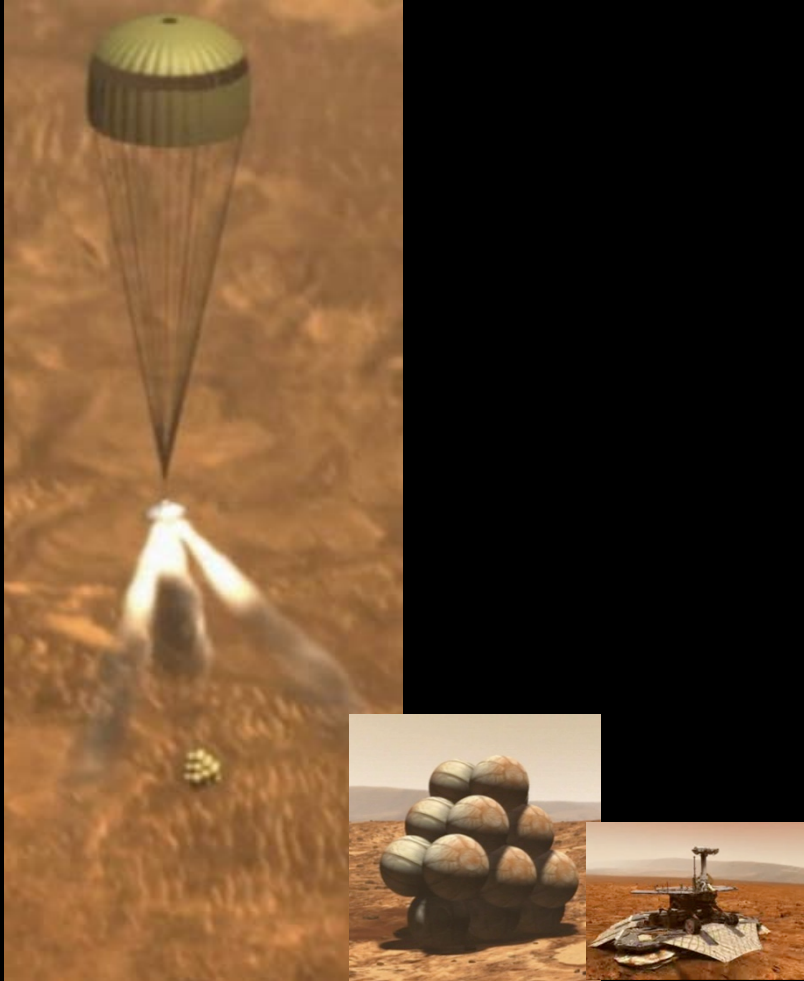
...the equivalent of teeing off in Los Angeles and sinking a hole in one in St Andrews Scotland. And the hole on Mars was moving at 60,000 mph!



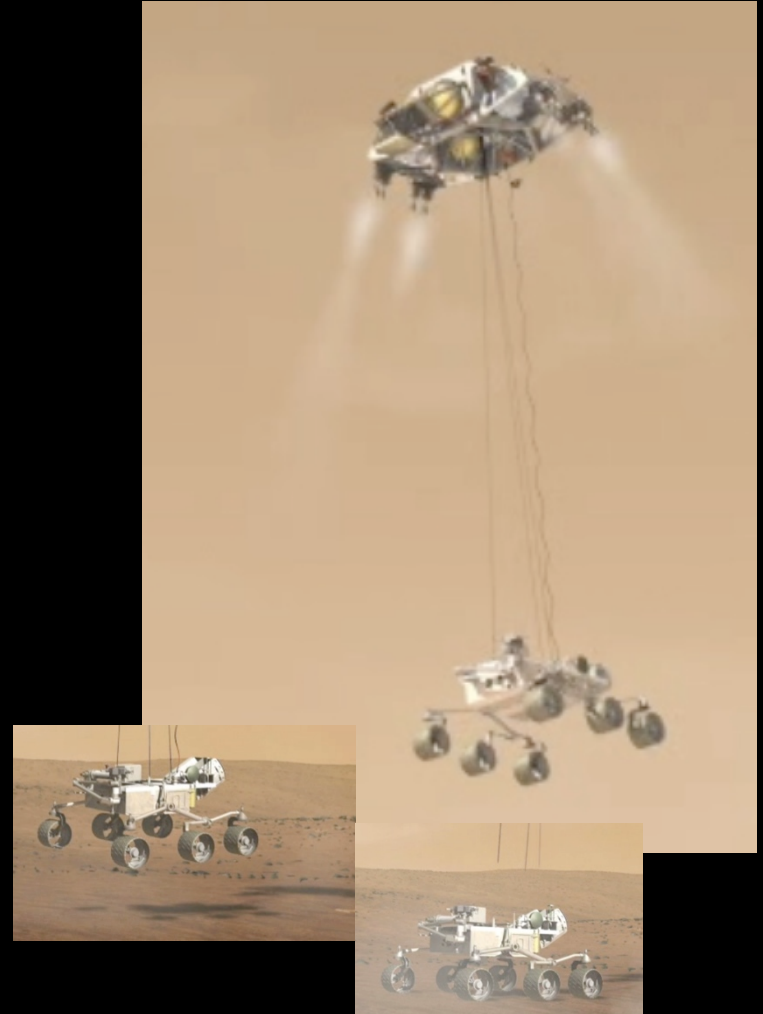
ATMOSPHERIC ENTRY
KINETIC ENERGY ~ 18,000 Race Cars

Entry, Descent, and Landing

Spirit & Opportunity

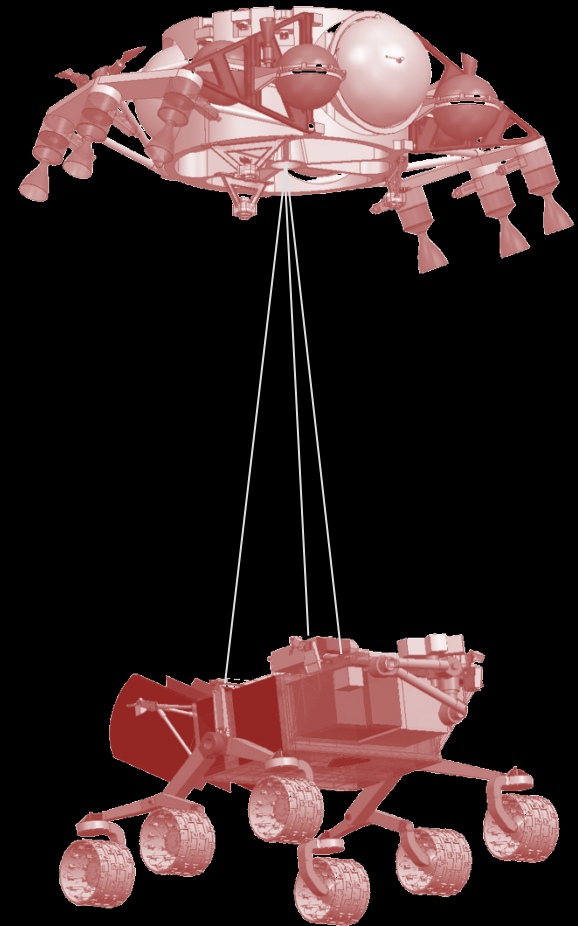


Curiosity





2003: The Skycrane maneuver is born



ChemCam

(Chemistry)

Mastcam

(Imaging)

REMS

(Weather)

DAN

(Hydrogen)

RAD

(Radiation)

MAHLI

(Imaging)

APXS

(Chemistry)

SAM

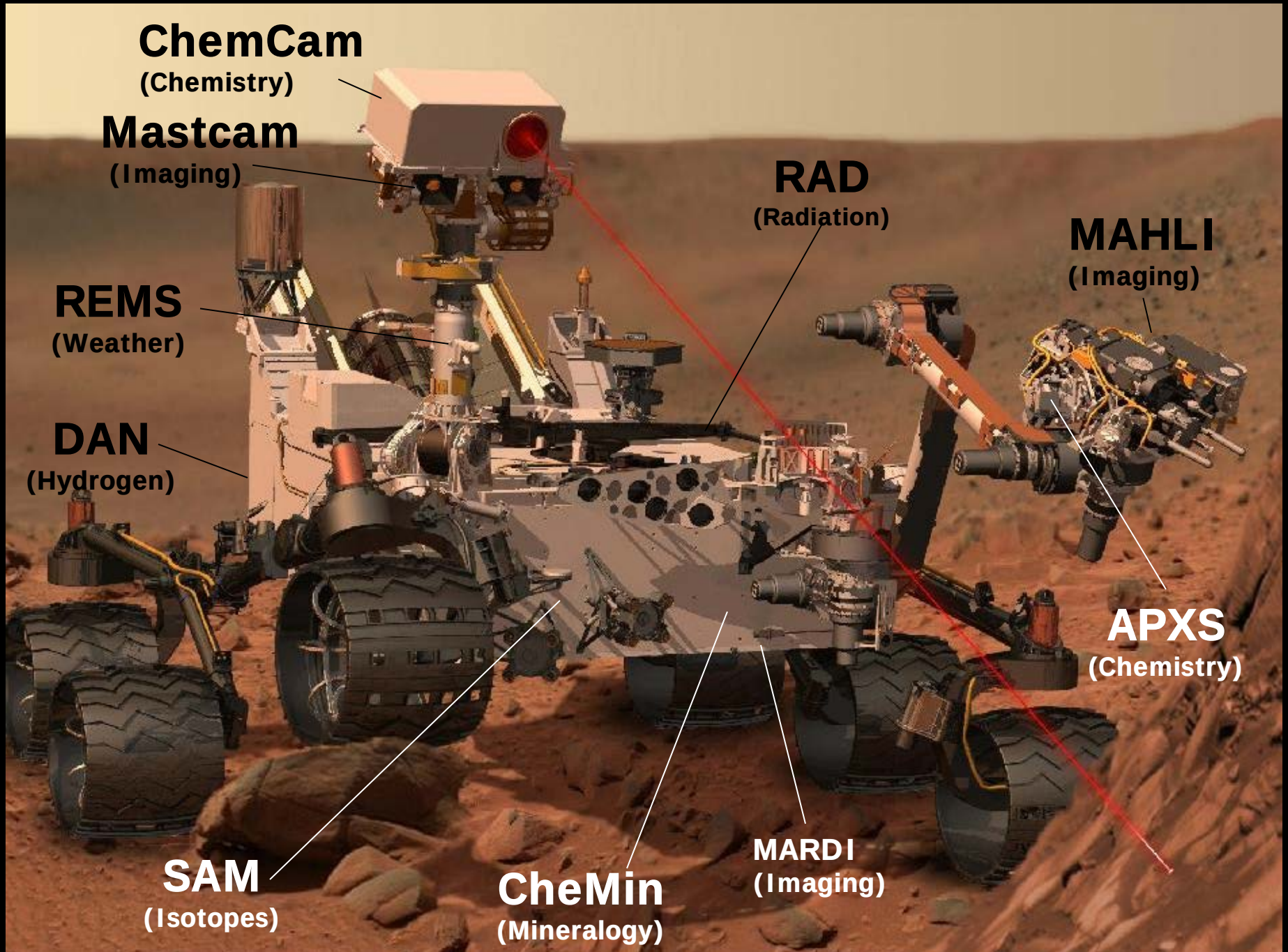
(Isotopes)

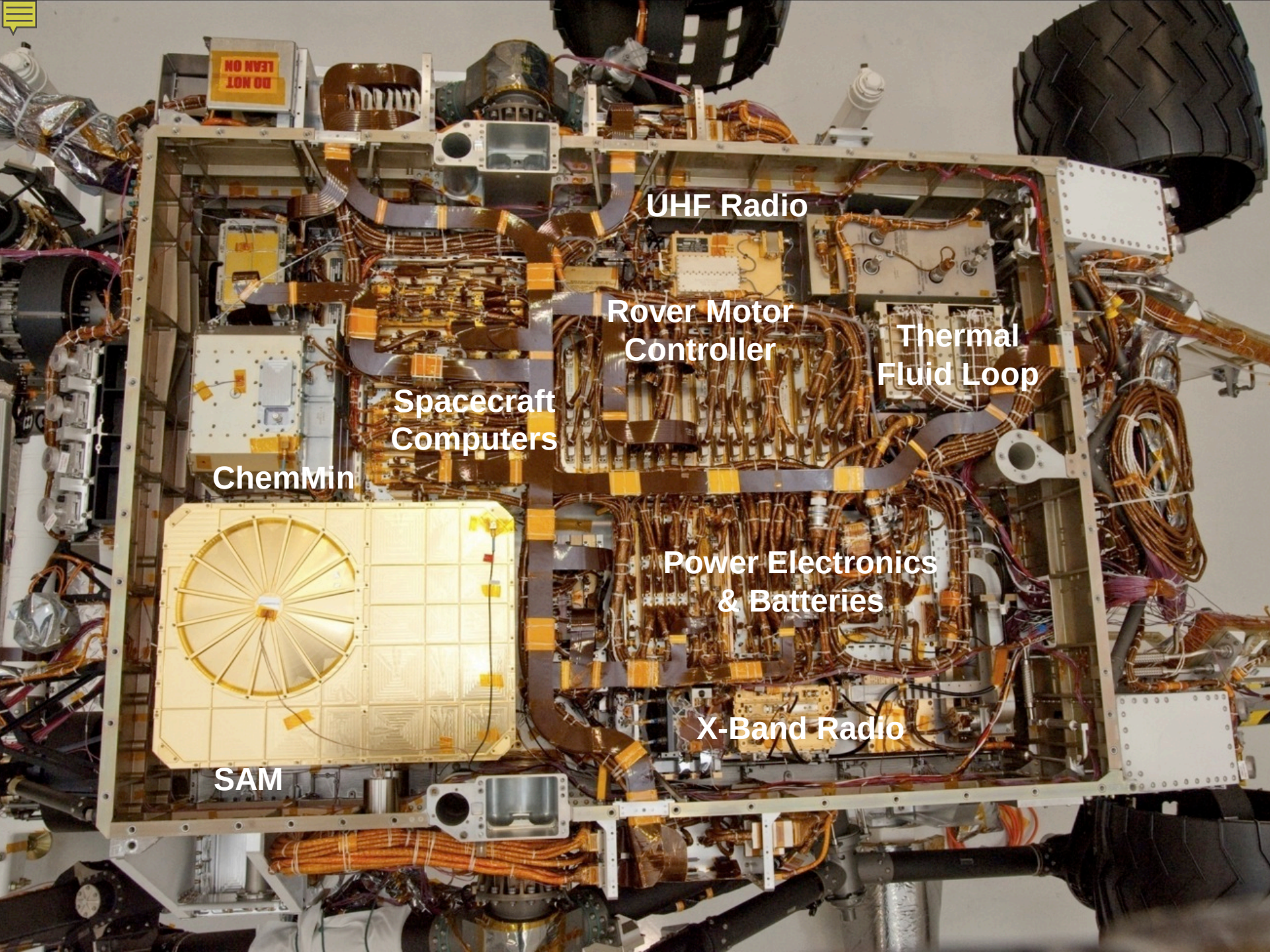
CheMin

(Mineralogy)

MARDI

(Imaging)





DO NOT
LEAN ON

UHF Radio

Rover Motor
Controller

Thermal
Fluid Loop

Spacecraft
Computers

ChemMin

Power Electronics
& Batteries

X-Band Radio

SAM

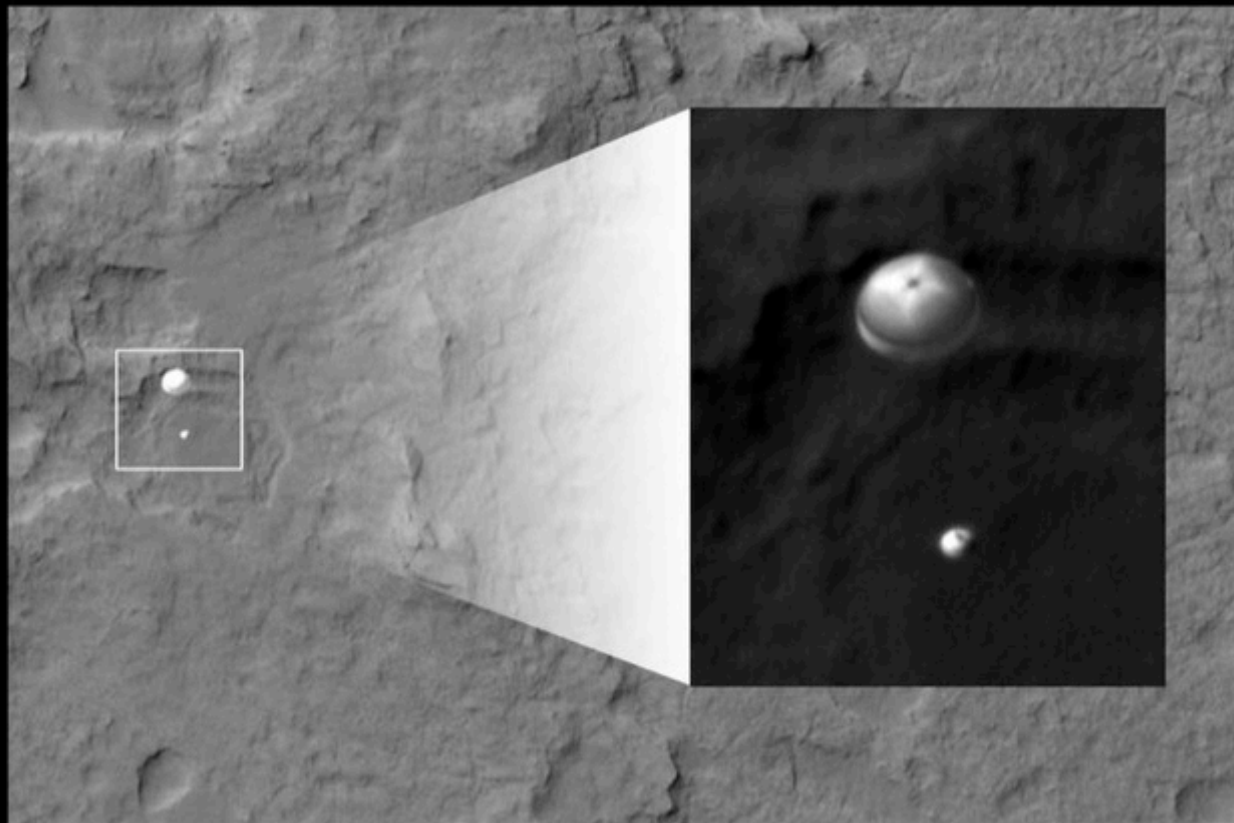
Where were you?

Where were you?

Where were you?

Where were you?

Where were you?



Parachute Deployed
MRO HiRISE camera

Designing the World's Largest Parachute



Parachute Test

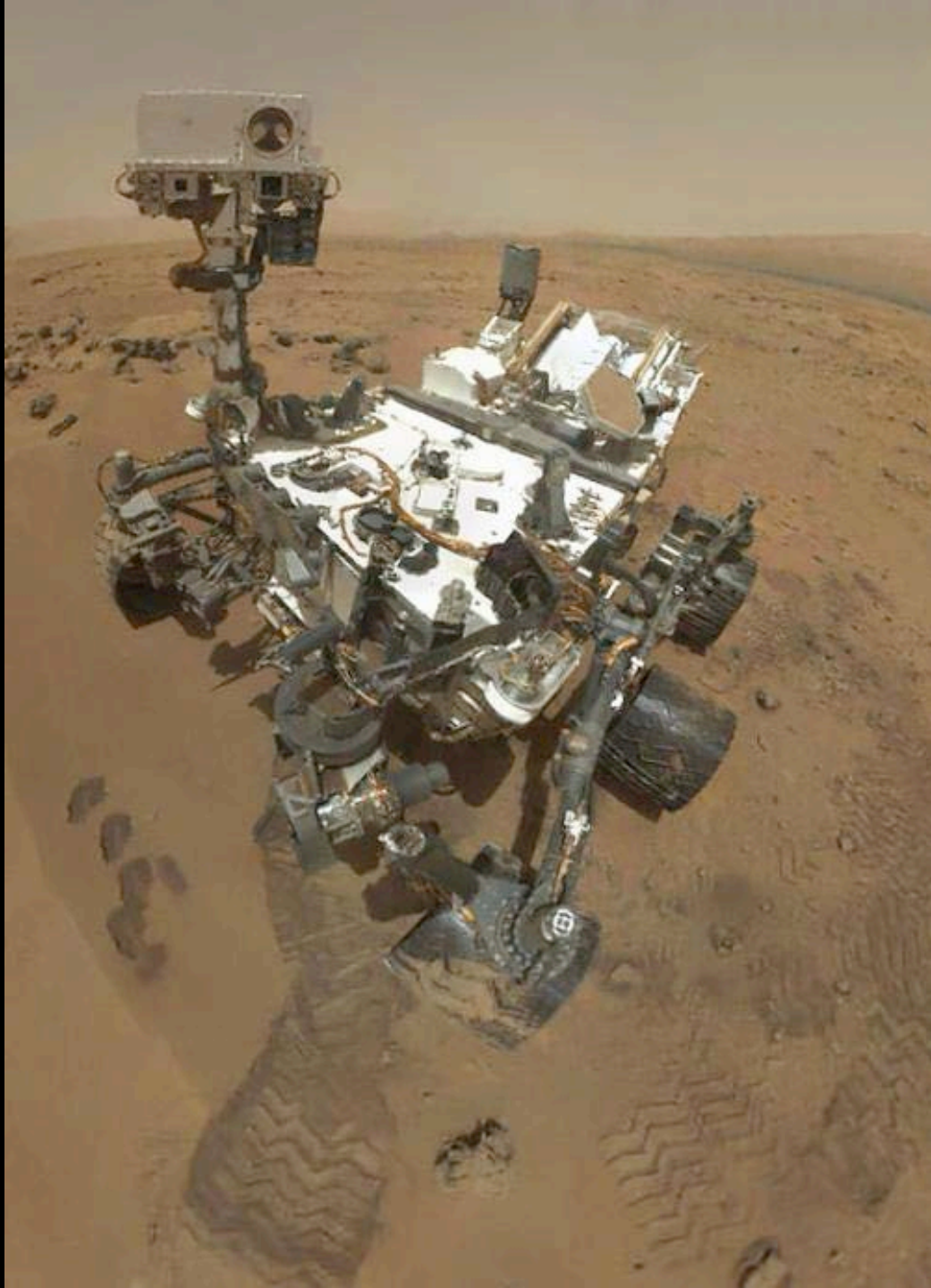
Parachute Test

Parachute Test

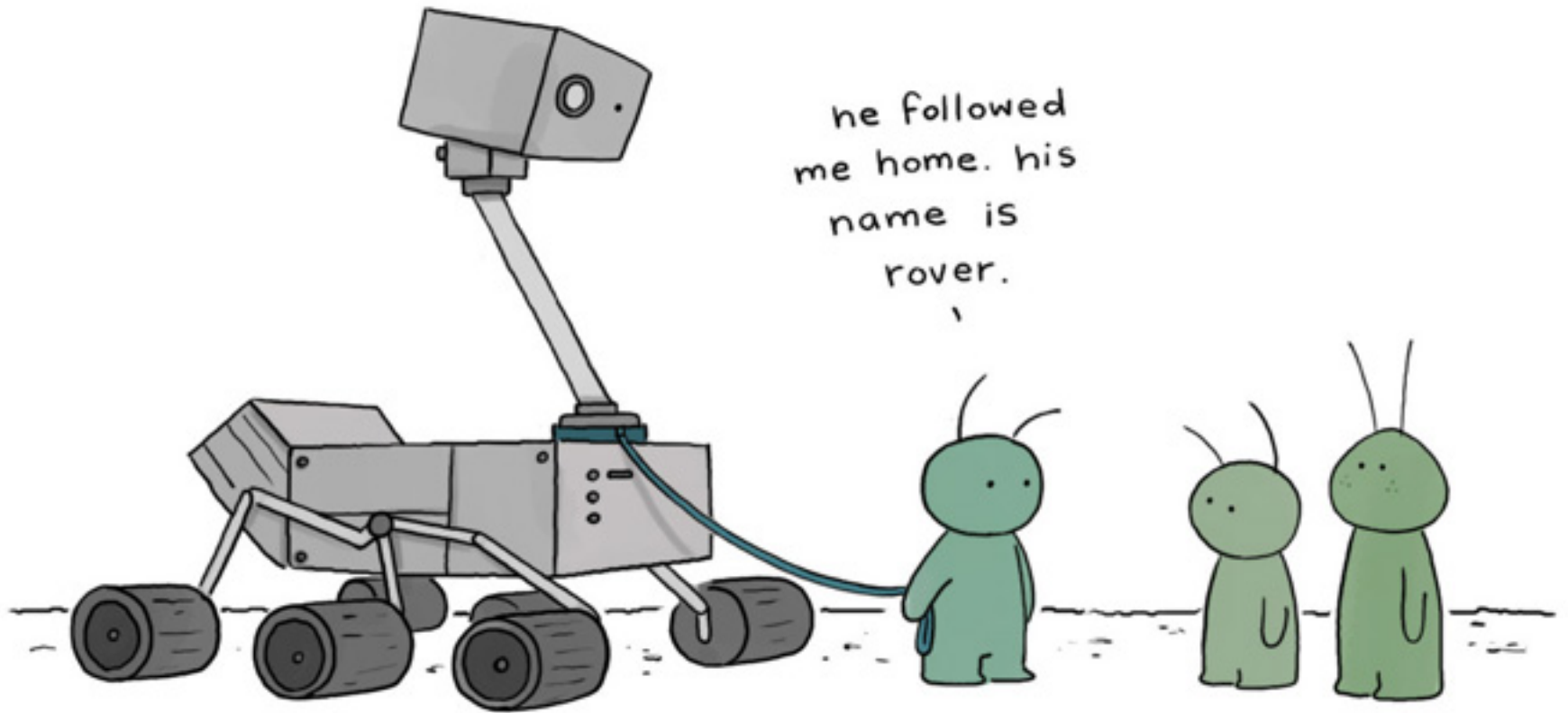
Parachute Test



Parachute Test



he followed
me home. his
name is
rover.





NASA/JPL-Caltech/MSSS

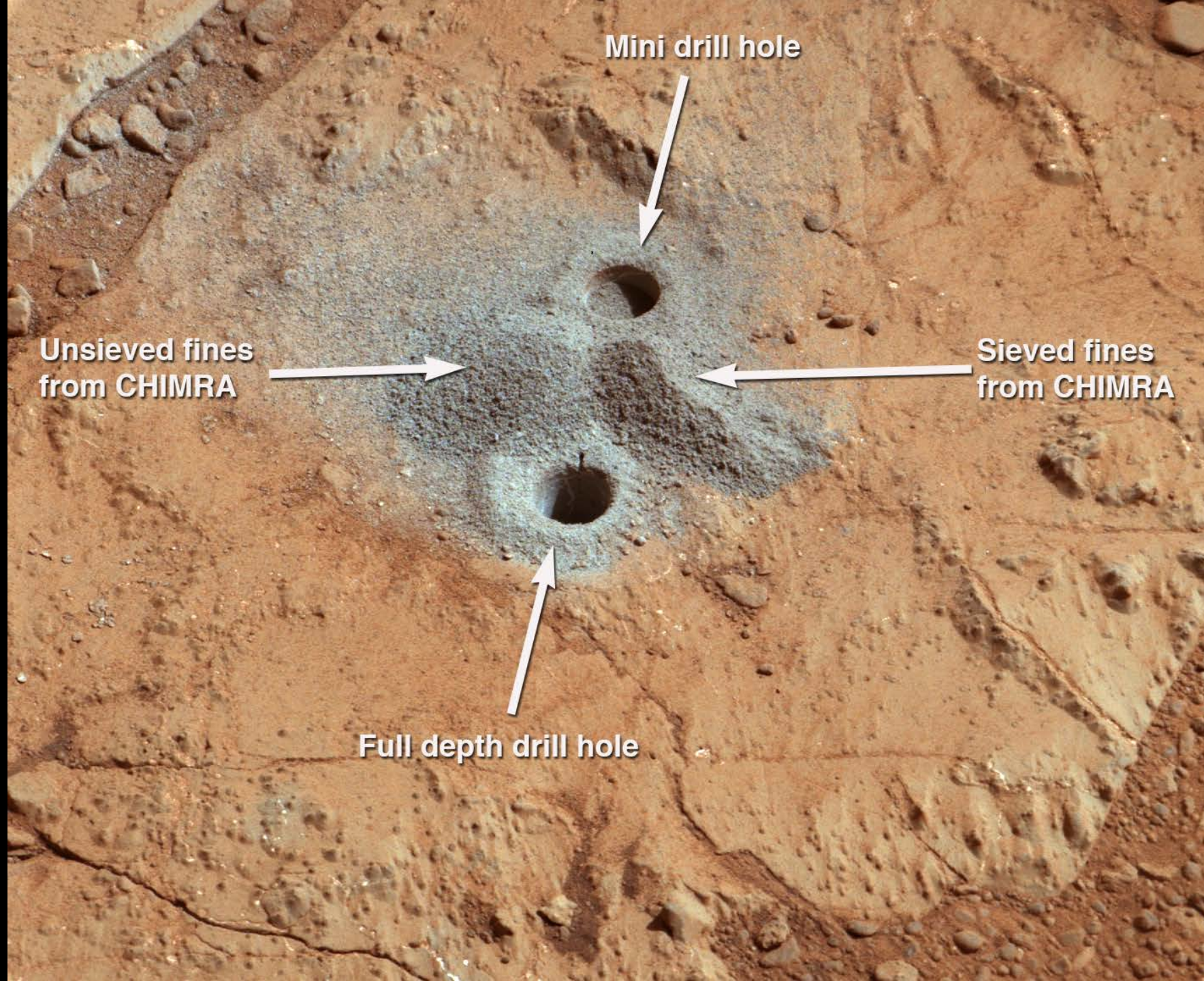








Cumberland Drill Hole

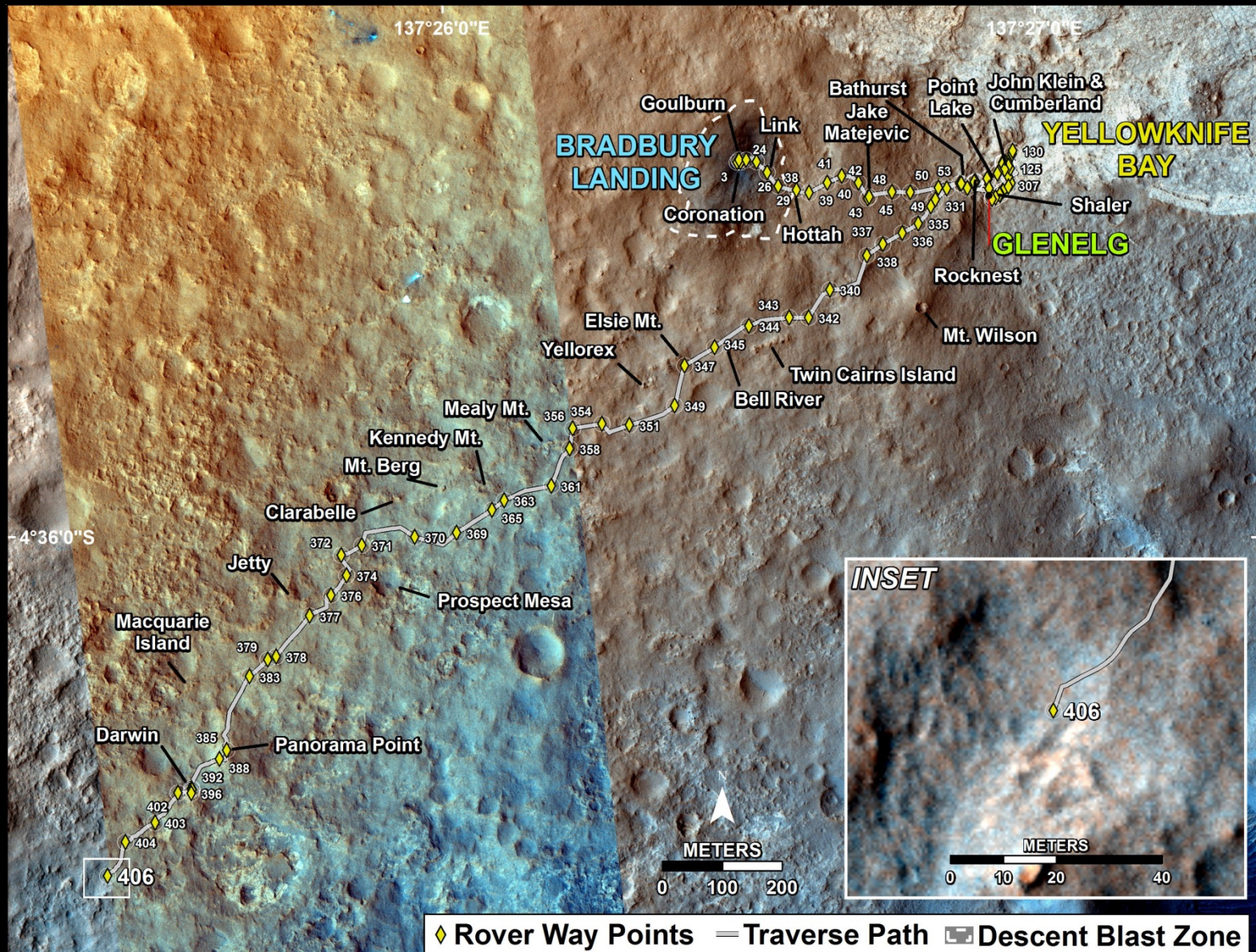
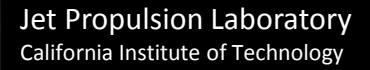


Mini drill hole

Unsieved fines
from CHIMRA

Sieved fines
from CHIMRA

Full depth drill hole





Vista With 'Twin Cairns' on Route to Mount Sharp

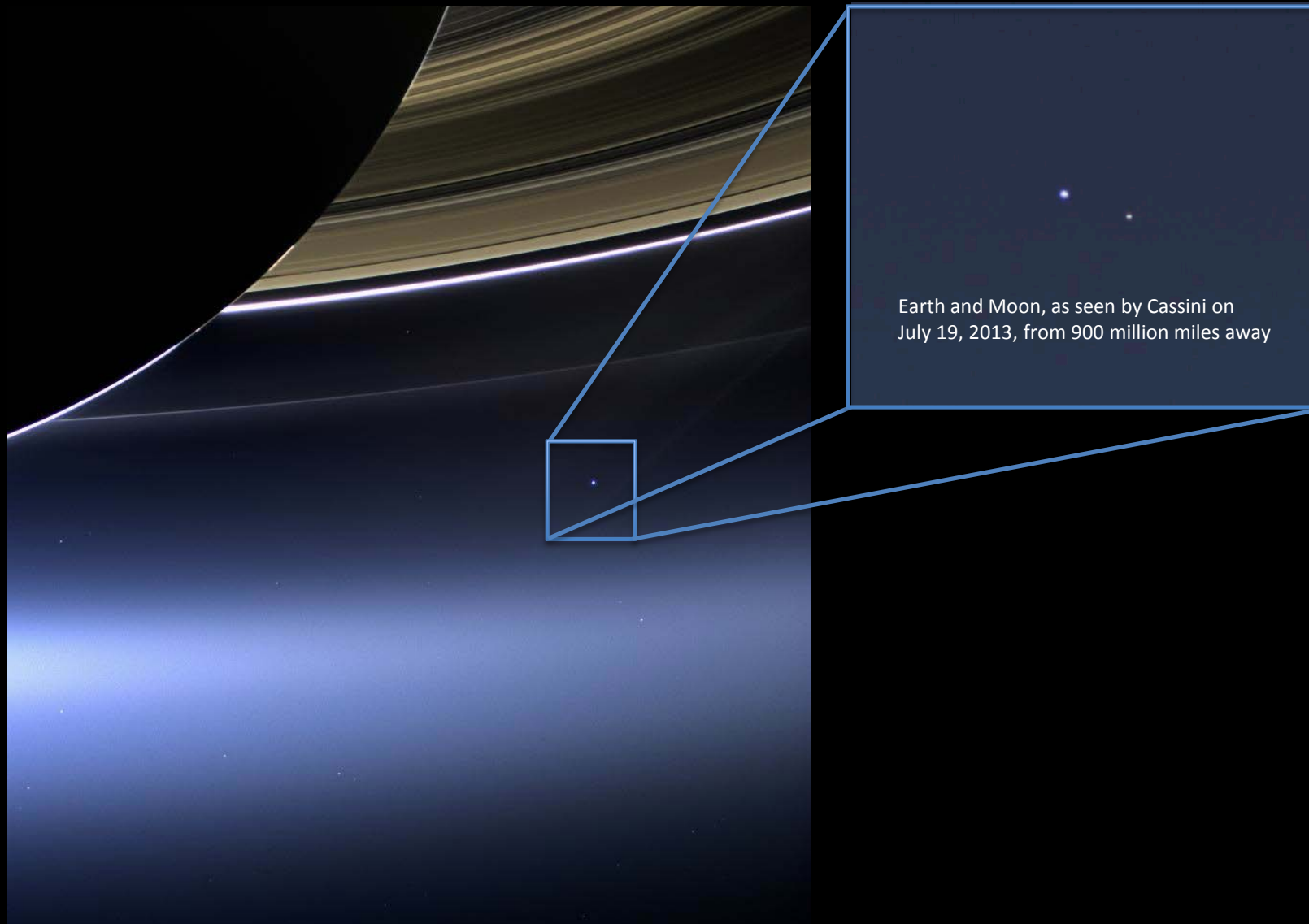


Destination: Mount Sharp



Image of Earth taken by Cassini

July 19, 2013



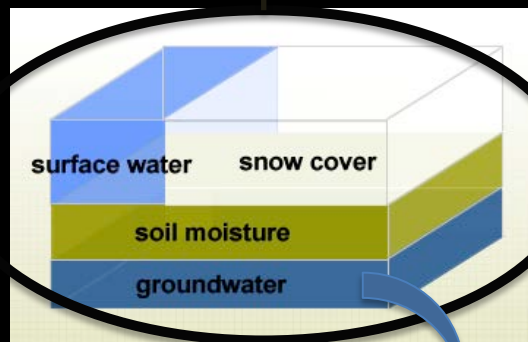
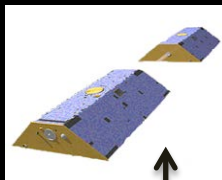
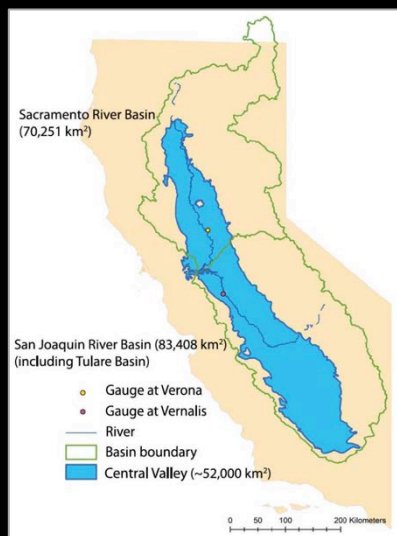


Black Holes shine for NuSTAR

California's Central Valley 2003 - 2012: Groundwater changes from GRACE

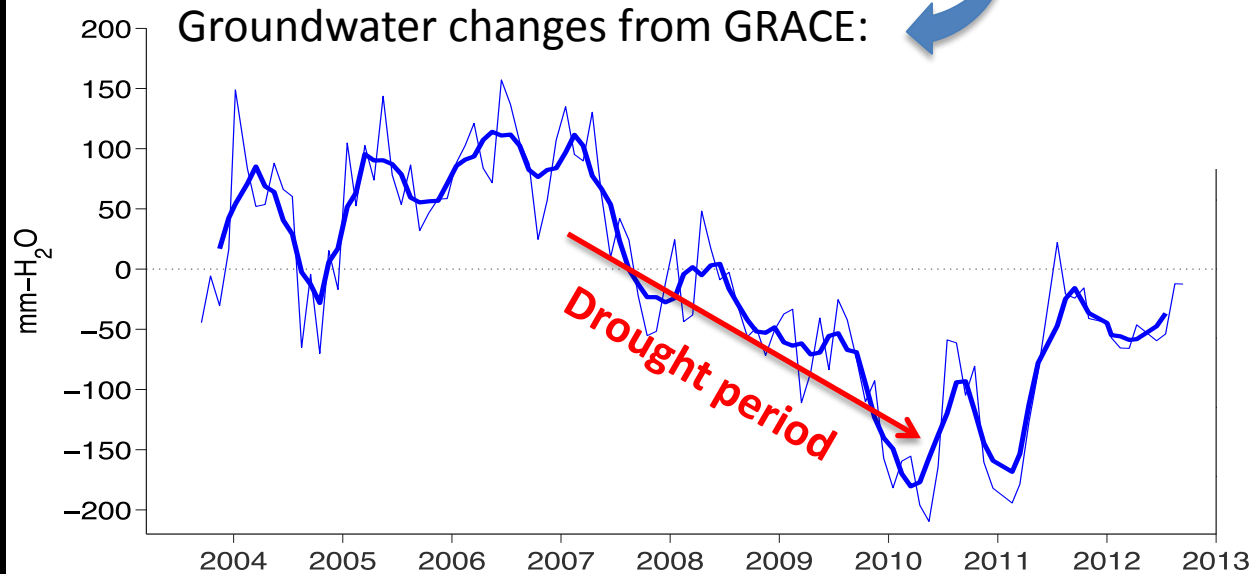


Jet Propulsion Laboratory
California Institute of Technology



- GRACE measures all the water storage changes on land
- To estimate groundwater, the snow, surface water and soil moisture changes must be subtracted
- **Result:** even after official drought ended in 2010, GRACE detects that Central Valley groundwater still remains *below* pre-drought levels

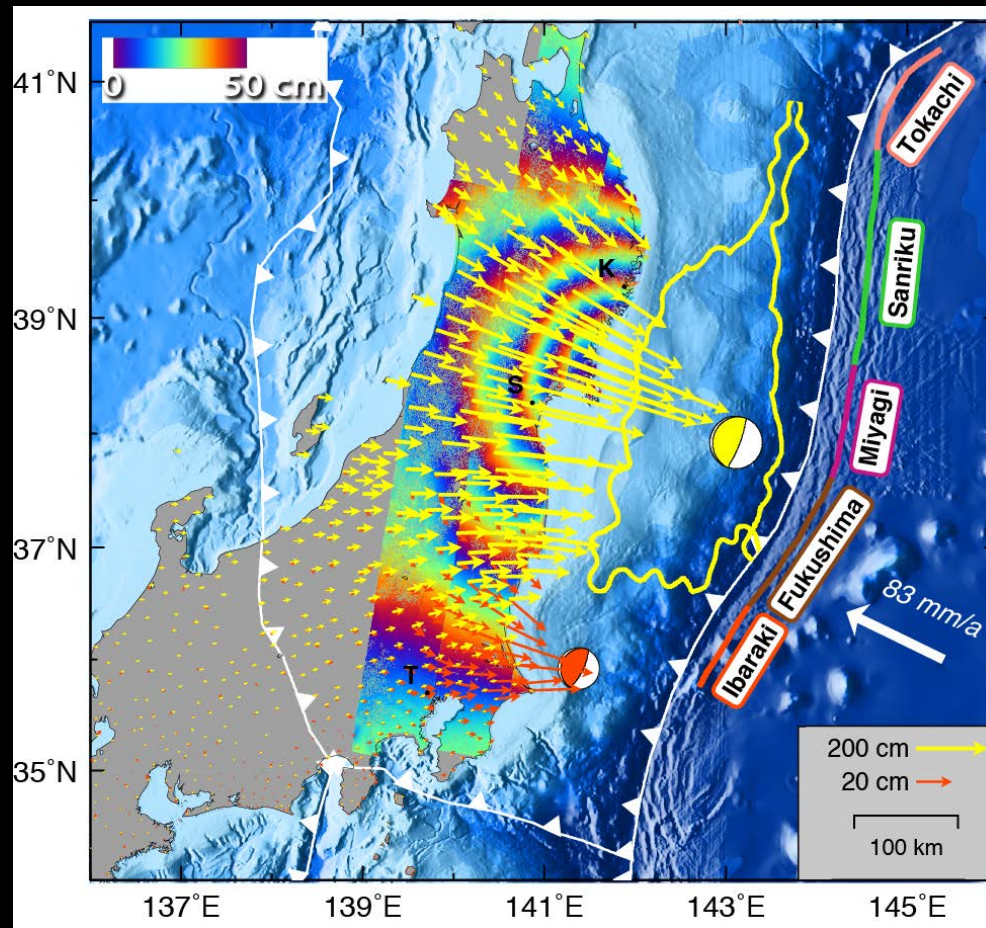
Groundwater changes from GRACE:



Science and the Environment: Natural Hazards



Jet Propulsion Laboratory
California Institute of Technology



Coseismic interferogram (Envisat), coseismic GPS offsets (mainshock in yellow, aftershock in orange), and 8 m contour of mainshock fault slip model from 2011 Magnitude 9.0 Tohoku-Oki Earthquake (Simons et al, Science, 2011)

Apollo 11 & Curiosity Rover



"Do not go where the path may lead. Go instead where there is no path and leave a trail."

- Ralph Waldo Emerson

