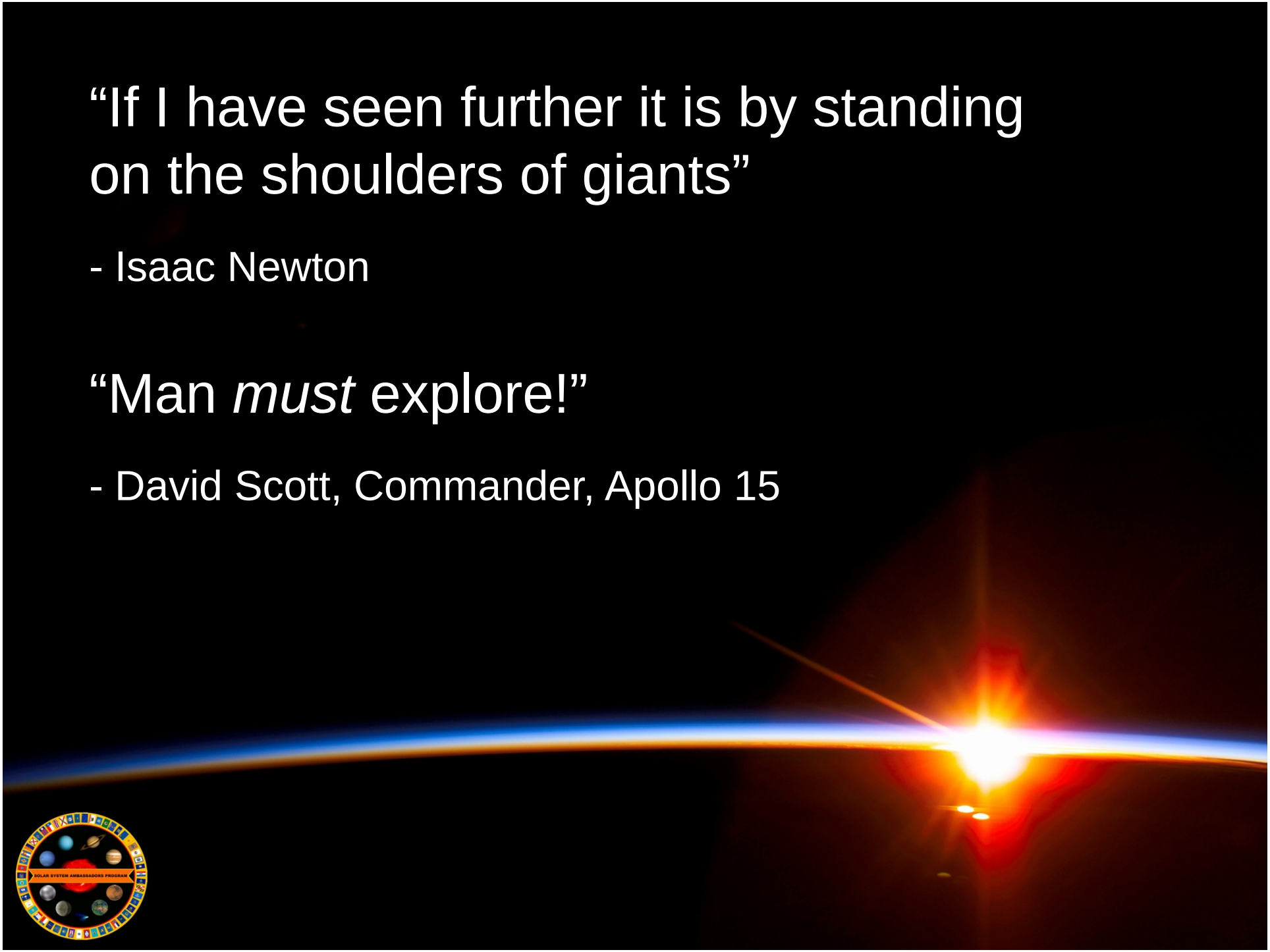
Roving on Mars:

The Journey of Curiosity


“If I have seen further it is by standing on the shoulders of giants”
- Isaac Newton
“Man *must* explore!”
- David Scott, Commander, Apollo 15

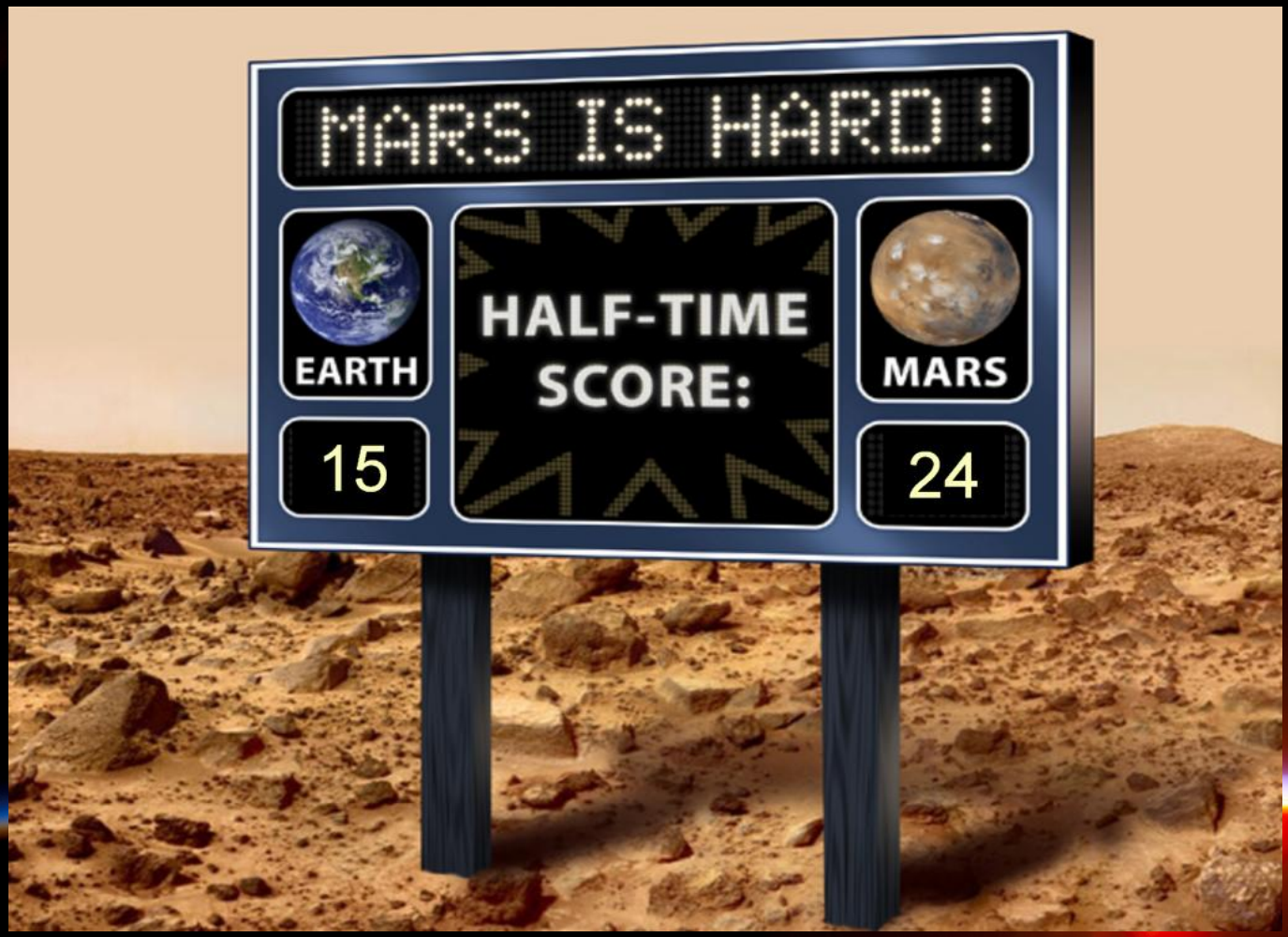
Telescopes gave a limited view

This was the best we could do in 1962

A Martian Invasion ?

Well, maybe not like that one….

But this is really hard to do…

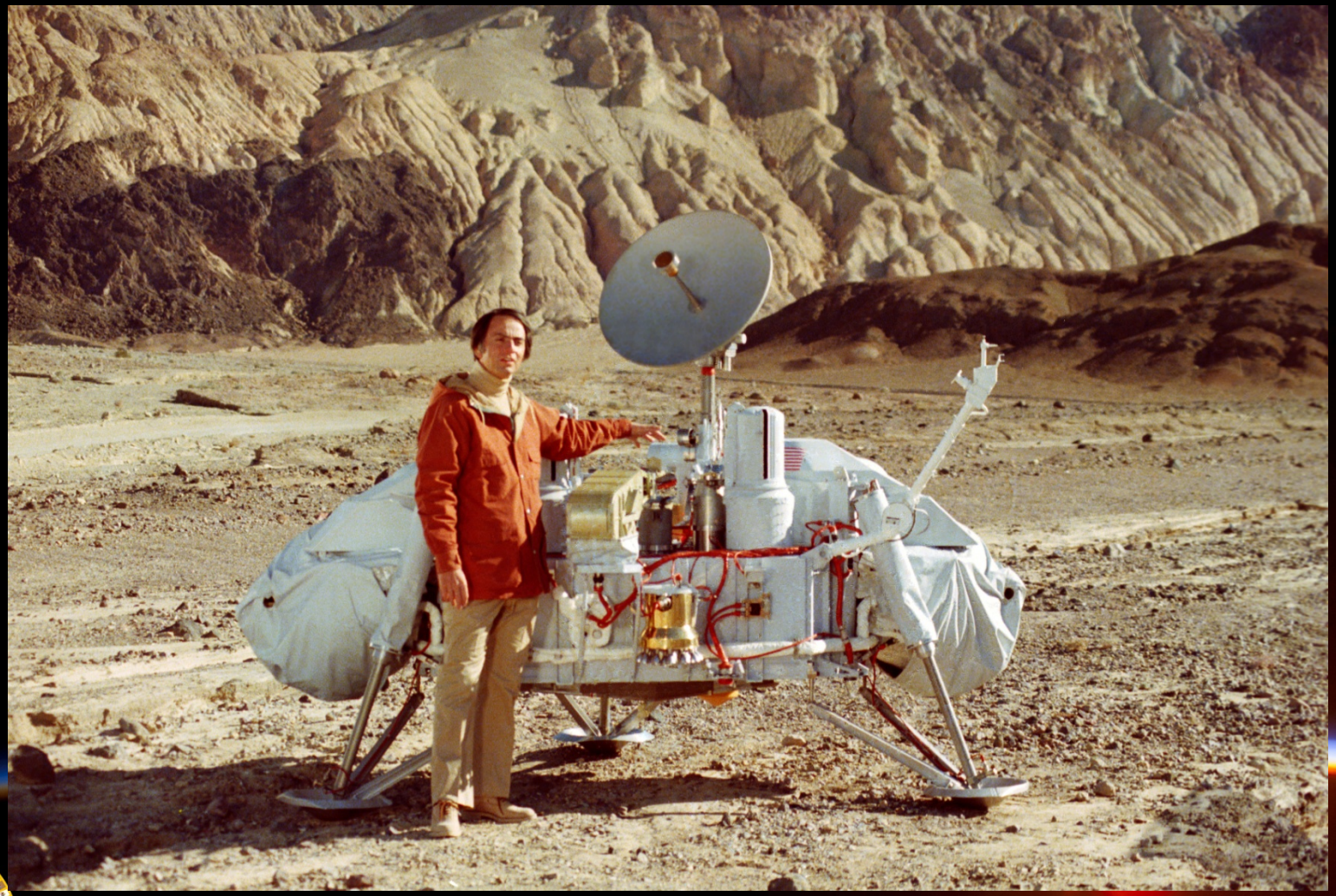


Sometimes we were very lucky… or very good

Mariner IV – First glimpse of Mars!

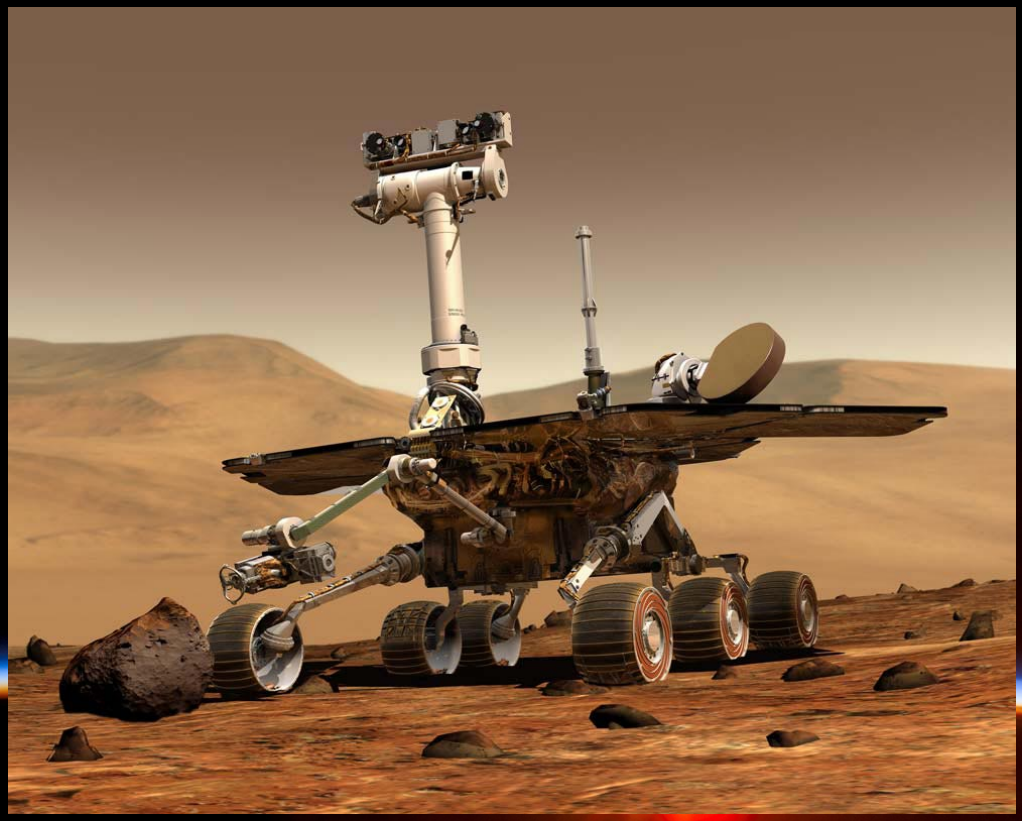
A bit of a bummer…..

A bold step – Viking 1 and 2



OMG! Postcards from Mars !

Rovers followed...



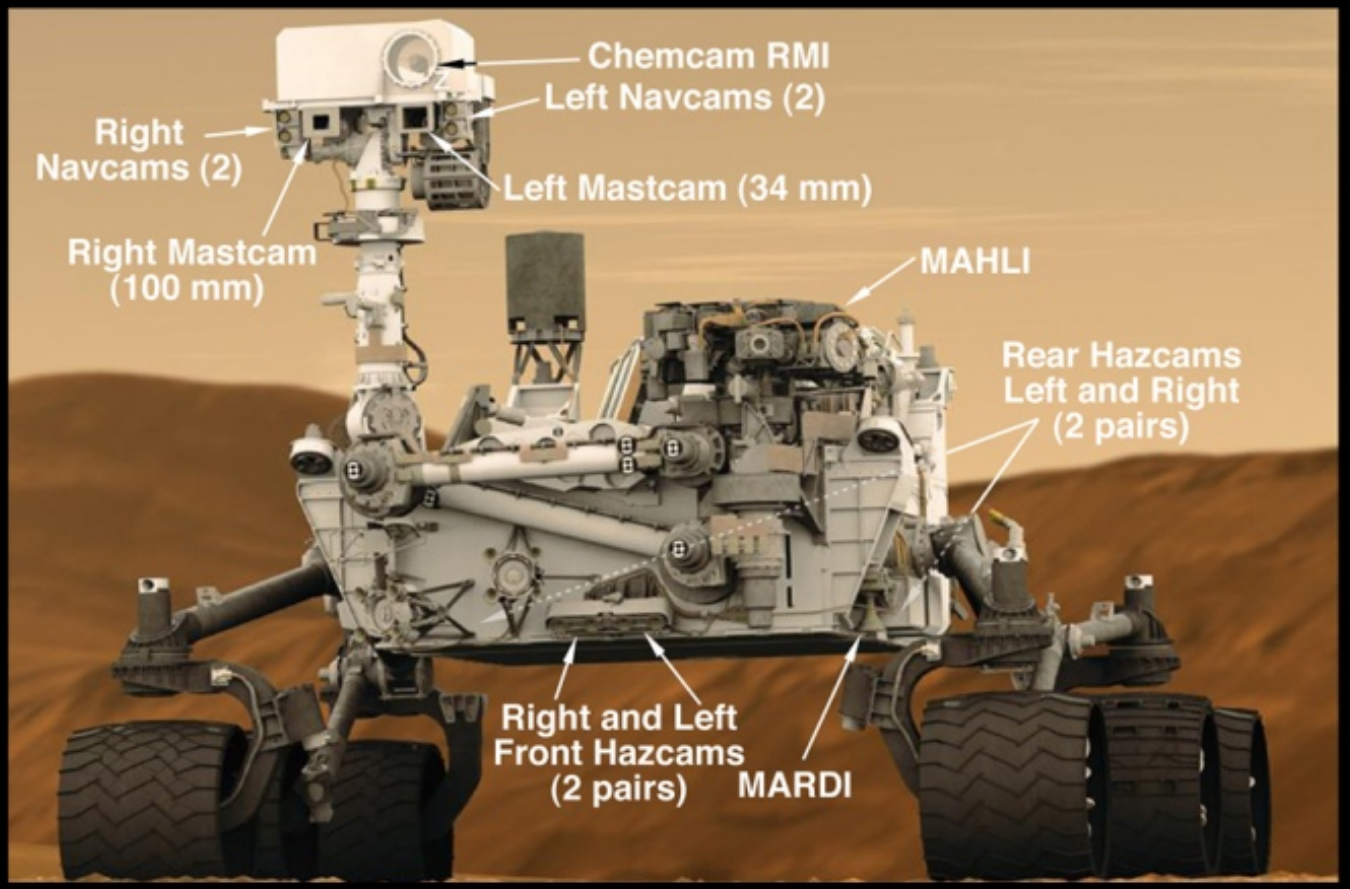
From the shoulders of these giants…

- Small rovers = small science
- MER: 5 experiments, 11 pounds
- Mars Science Laboratory (Curiosity) selected as NASA “flagship” mission
- 10 experiments, 165 pounds
- Most sophisticated analytical laboratory sent to another world

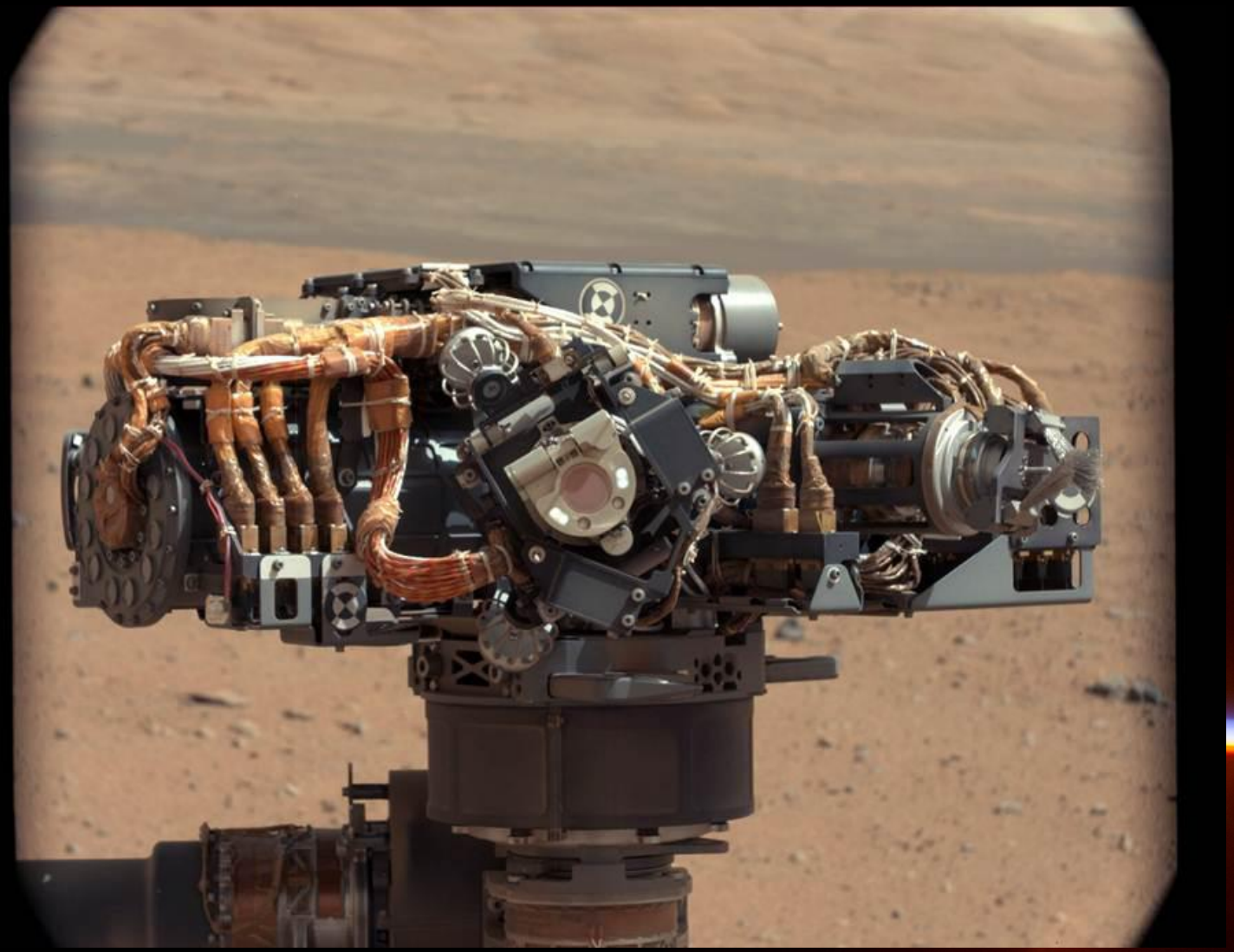
Who said this would be easy?

- 4X the mass of Spirit and Opportunity
  - Airbags simply not an option
- Interesting sites are hard to get to
  - Need a precision, *guided* entry
- A big rover needs lots of power
  - Uses nuclear battery – solar panels too heavy

17 Cameras !

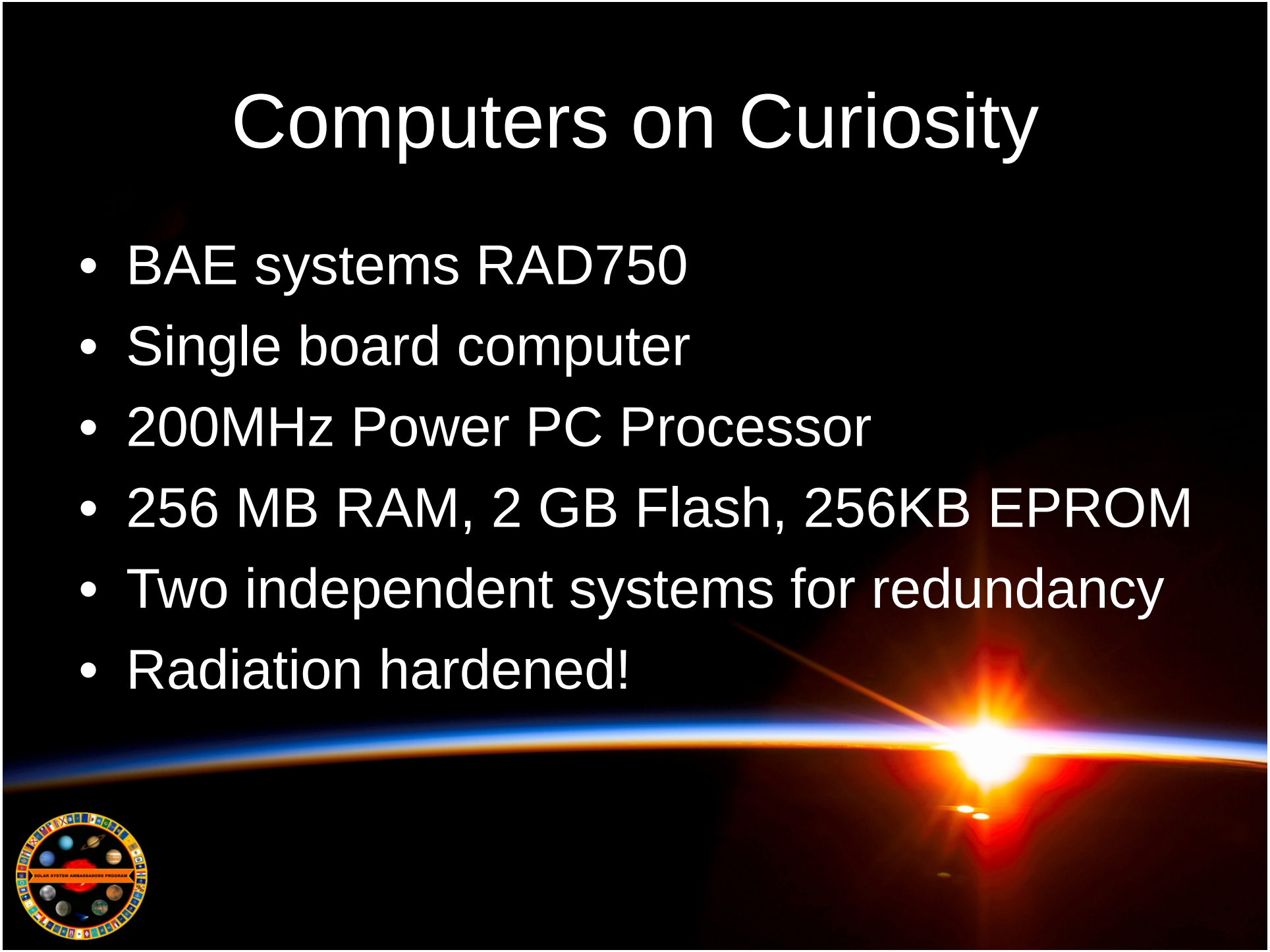

Chemcam RMI
Left Navcams (2)
Right
Navcams (2)
Left Mastcam (34 mm)
Right Mastcam
(100 mm)
MAHLI
Rear Hazcams
Left and Right
(2 pairs)
Right and Left
Front Hazcams
(2 pairs)
MARDI

Experiments on Turret



Computers on Curiosity

- BAE systems RAD750
- Single board computer
- 200MHz Power PC Processor
- 256 MB RAM, 2 GB Flash, 256KB EPROM
- Two independent systems for redundancy
- Radiation hardened!



Operating System Software

- VxWorks, from Wind River Systems
- Commercial and proprietary
- Used in many avionics applications
- Optimized for embedded, real-time processing
- Very reliable, robust

Driving and Steering

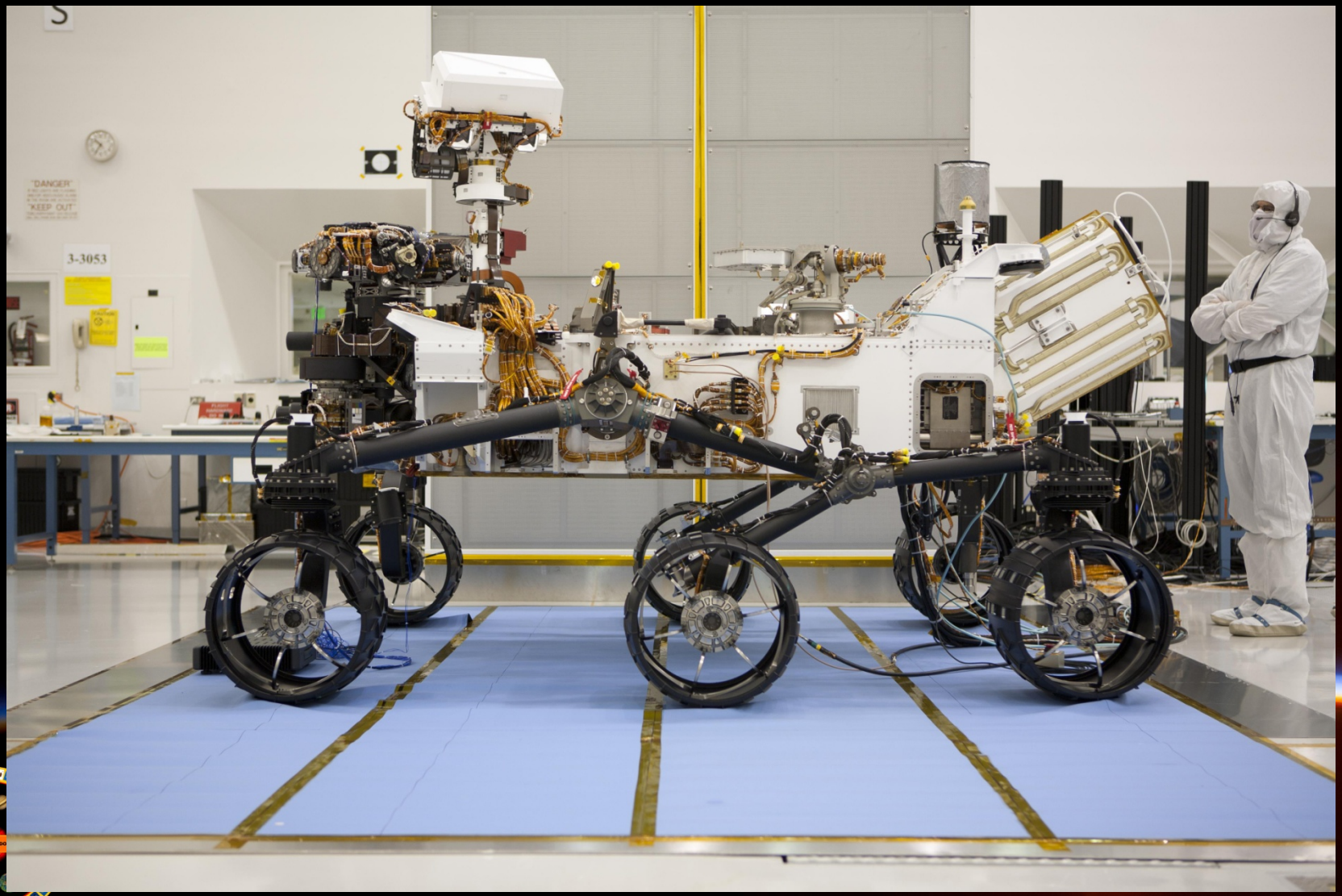
- 6 independently powered wheels
- Front, back wheels are steerable
- 20 inch titanium wheels
- 2 cm/sec average speed (4 cm/sec max)

Driving and Steering

Rocker-Bogie Suspension

- Completely passive suspension
- No shocks, springs, torsion bars
- Ensures all six wheels are on the surface
- Maintains constant weight on all wheels
- One attachment point to rover chassis
- Both sets connected via differential to limit chassis tilt

Rocker-Bogie Suspension



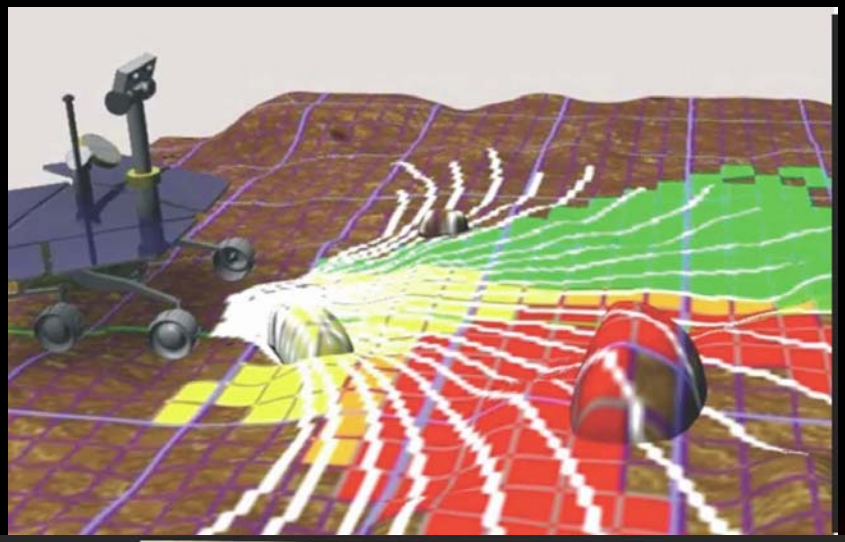
Driving the Rover

- Not really what you call “driving”….
- Rover is slow: 2 – 4 cm/sec
- Up to 40 minute round trip delay
- Planning a drive can take days
- Routes are uplinked to rover
- Autonomous navigation does the rest

Autonomous Navigation

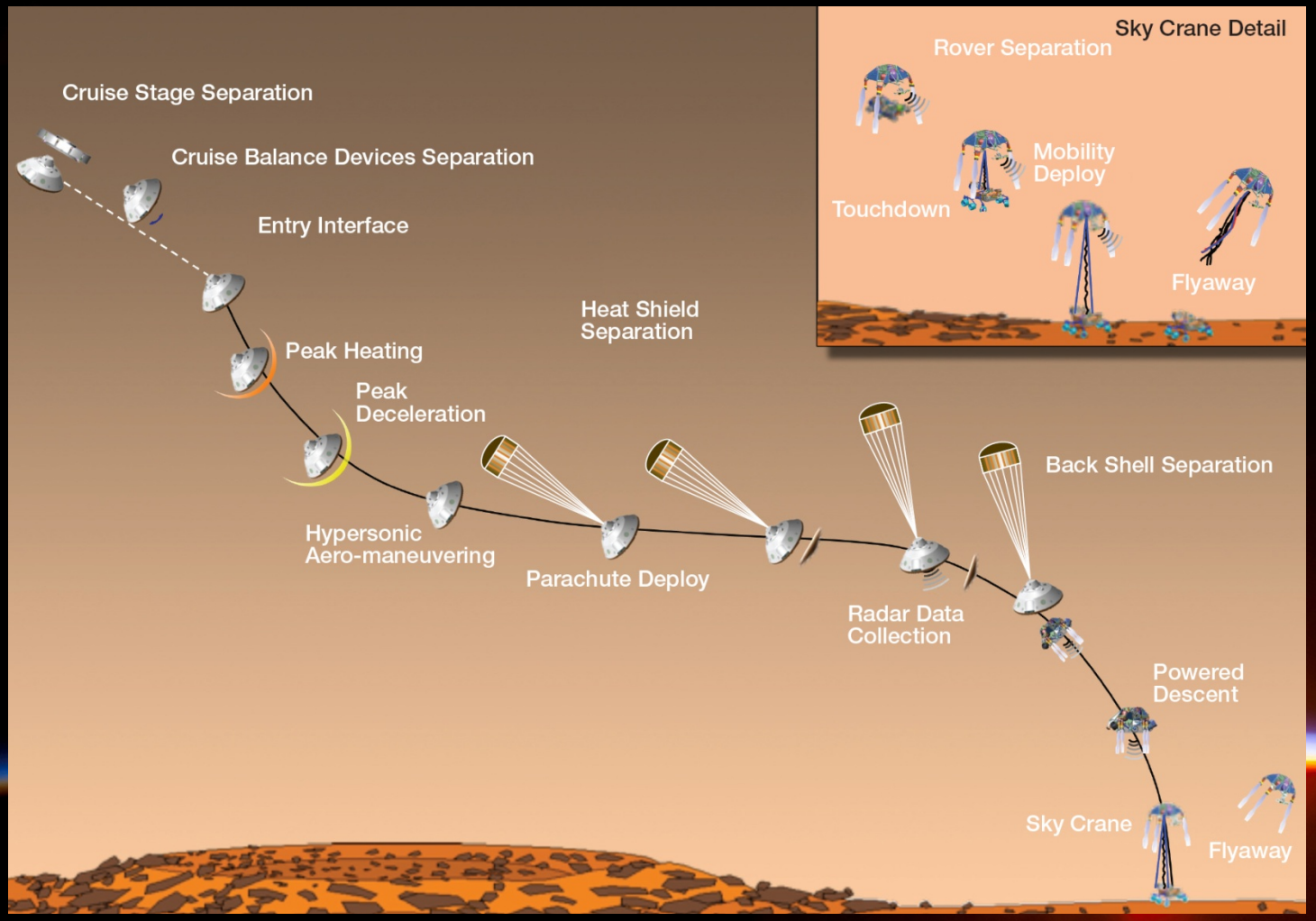
- Nav cameras on mast take stereo pictures
- Computer constructs 3D image of surface
- Rocks, fissures, and other obstacles characterized
- Safest path identified to drive to goal
- Path recalculated every meter or so
- Not all driving is autonomous

Autonomous Navigation



Leaving for Mars!

MSL Entry



But this is a kinda boring graphic….

Mount Sharp, Gale Crater

MSL Science Objectives

- NOT “Looking for Life”
  - At best, looking for evidence that past life *could* have existed!
- Assess the biological potential of the site, searching for organics and evidence of biologically relevant processes
- Observe the geology and atmosphere to understand how features were created
- Study radiation environment

Chemistry Scientific Instruments

- ChemCam: Laser to vaporize samples
- ChemMin: Minerology
  - X-ray diffraction and X-ray fluorescence
- SAM: Sample Analysis at Mars
  - Ovens, mass spectrometer, tunable laser spectrometer and gas chromatograph
- APXS: Alpha Particle X-Ray Spectrometer
  - On turret

Evidence of flowing water

More outcrops

Scooping samples for SAM

Drilling into rocks – grey ?!?

What have we learned so far?

- Flowing water was key in creating geologic formations and minerals
- Some organics found in soil (maybe)
- Perchlorates
  - Reactive oxygen-chlorine compound
- Water and sulfur containing compounds
- Half volcanic, half non-crystalline (glass)
- Radiation environment is manageable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But what if life *does* exist?

- Back-contamination now a *political* problem!

- Is the life different enough that cross-species transfer is unlikely?
- Is a two year isolation enough to satisfy quarantine issues?

- Can you allow the crew to return to Earth?

A busy schedule for years to come!

- MAVEN (Nov 2013)
- Mangalyaan (Nov 2013)
- InSight (March 2016)
- ExoMars Trace Gas Orbiter (Oct 2016)
- ExoMars Rover (May 2018)
- Curiosity follow-on (July-Sept 2020)
- Sample return (mid - 2020’s?)

Questions ?

Spontaneous applause goes here… !