



Landing On Mars

by Rob Manning
NASA/Caltech/JPL
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Introduction

- Who does this stuff?
- What's so hard about it?
- How do we know it will work?
- What's ahead?

Who does this stuff?

- In the US, only a handful of people and places:
 - ◆ NASA: JPL, Johnson Space Center, Langley, Ames, etc
 - ◆ Lockheed Martin, etc
- It's a small world

Bill, Dick, Dara, Sam, Bobby, Michele, Wayne, Prasun, Bob, Dave, John, Claude, Mary Kay, ...

Who's tried landing before?

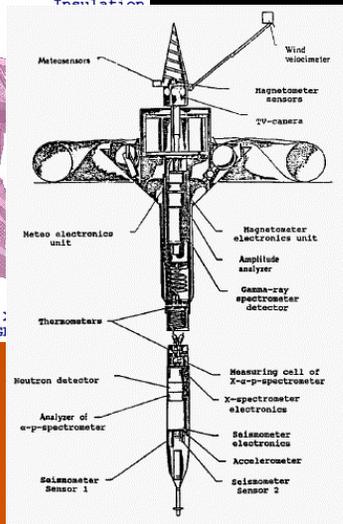
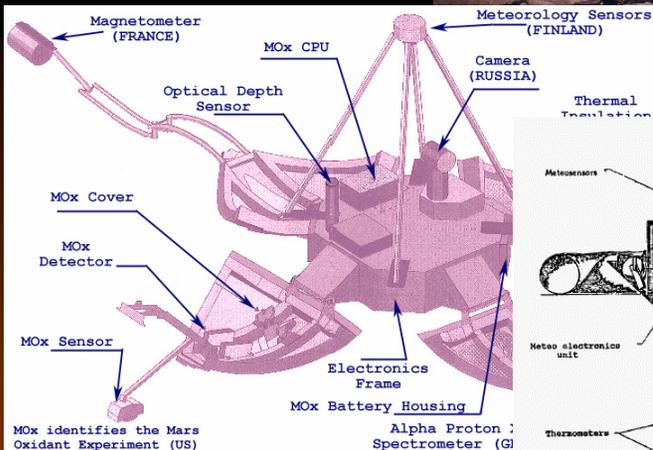
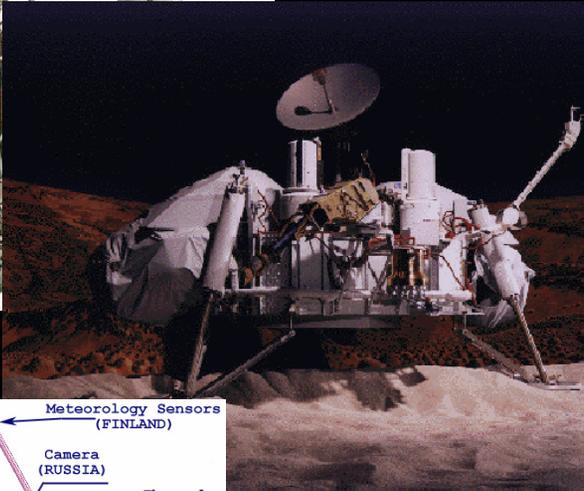
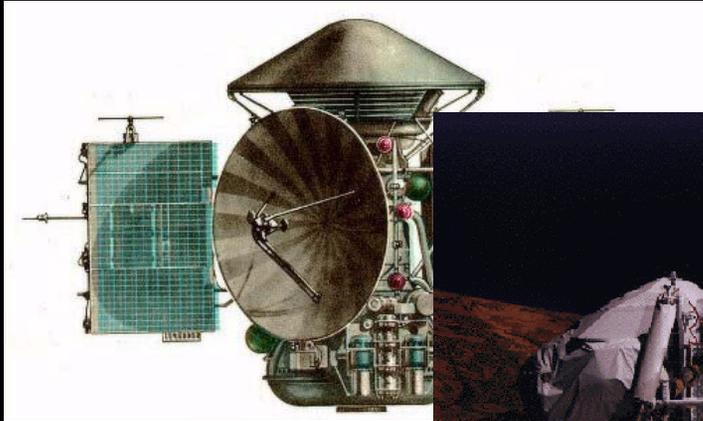
- US:

- ◆ Viking 1 & 2 1976
- ◆ Mars Pathfinder 1997
- ◆ Mars Polar Lander 1999 (crashed)
- ◆ DS-2 Microprobes 1999 (crashed)

- Russia/USSR:

- ◆ MARS 2 1971 (crashed)
- ◆ MARS 3 1971 (20 sec)
- ◆ MARS 6 1974 (touched?)
- ◆ MARS 7 1974 (missed)
- ◆ Mars96: Small Station 1996 (failed)

Landers of the Past



Why is this so hard?

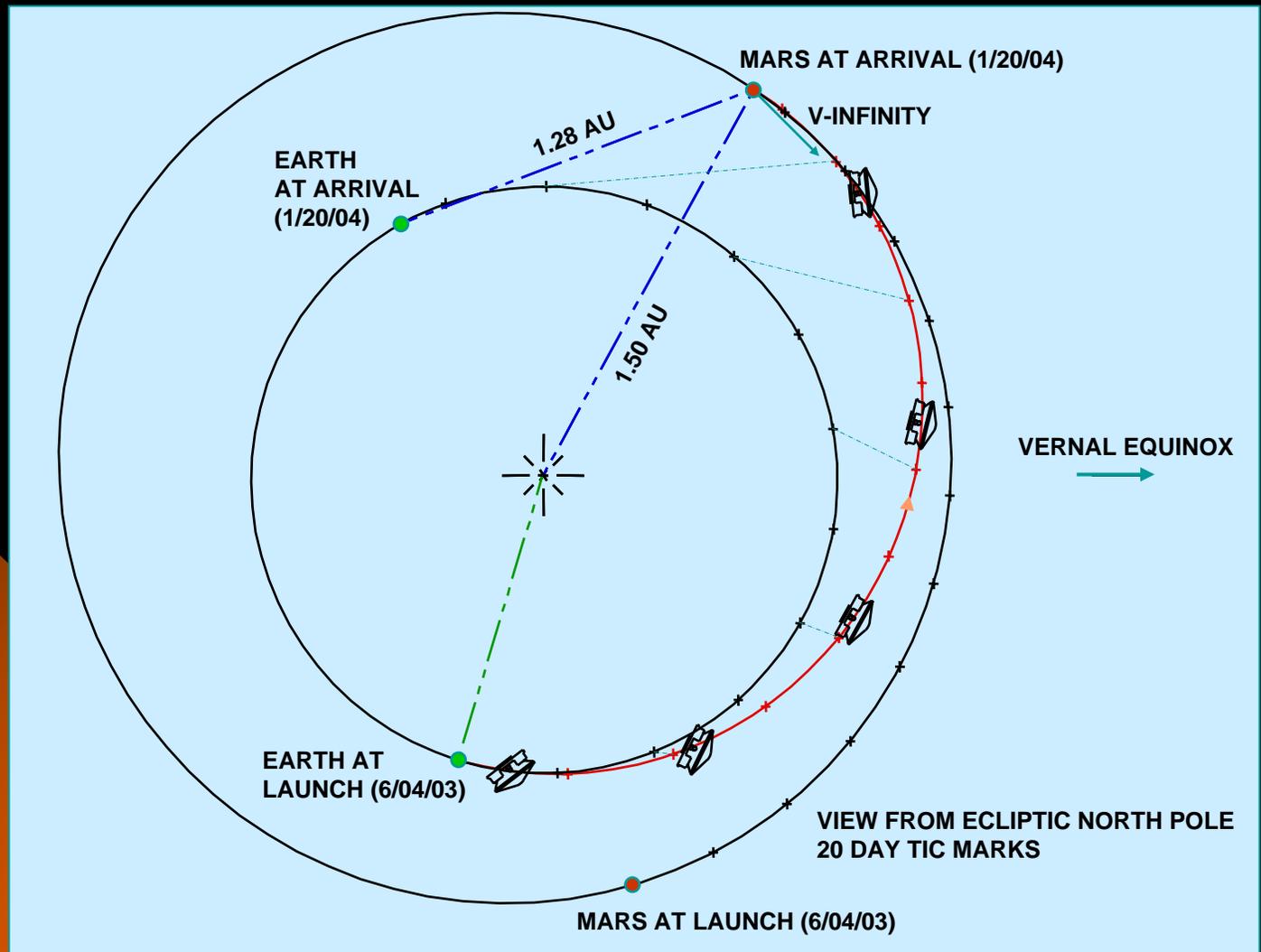
- Harder than programming a VCR?
 - ◆ Ready, set, aim ! (and aim again)
 - ◆ How do you slow down before hitting the ground?
 - ◆ Can your lander handle an extra-terrestrial terrain?
 - ◆ How do you know it'll work ?

Ready, Set, Aim, and ...

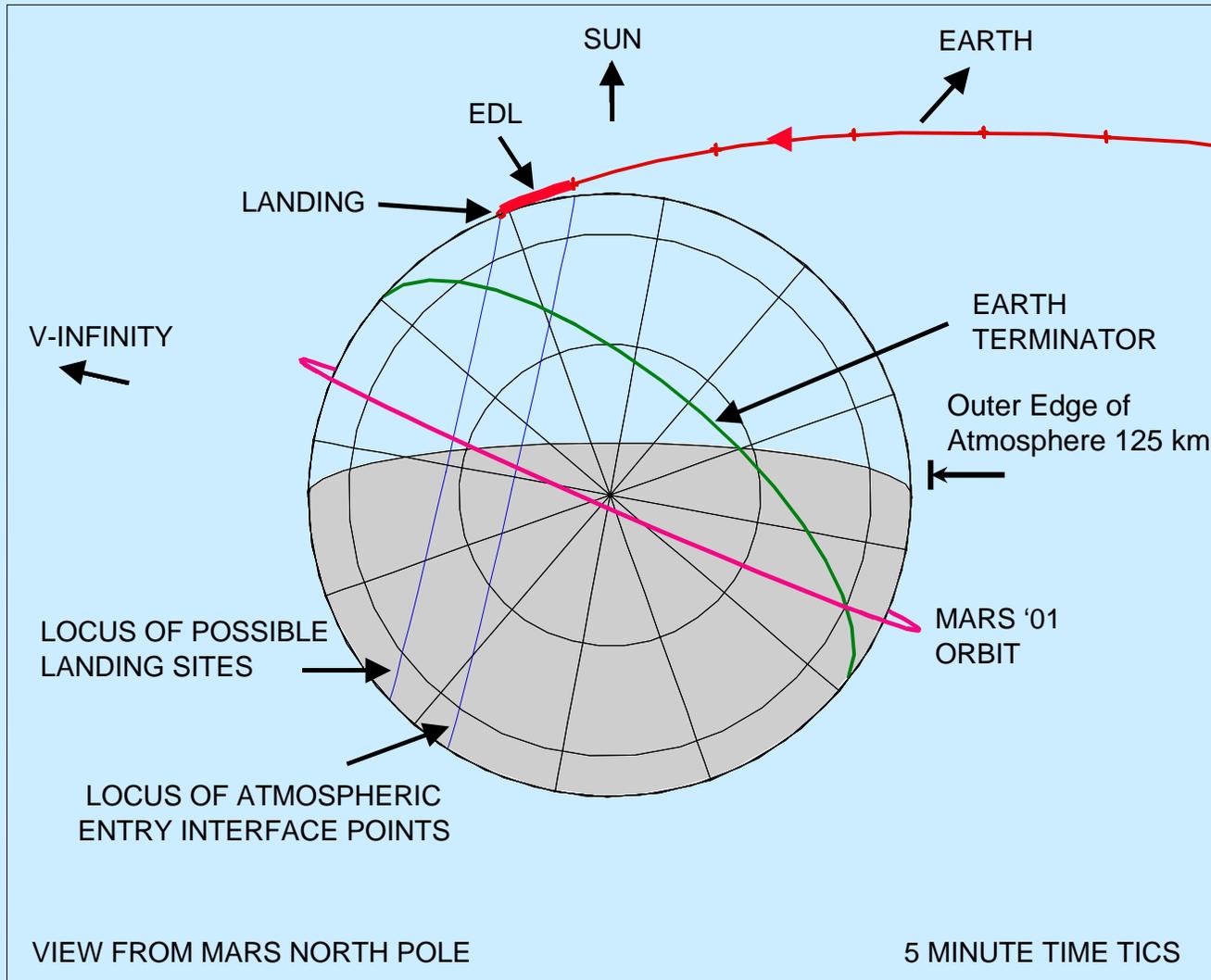
- Here's the deal ...
 - ◆ Aim for a spot in space 6 miles across
 - ◆ Do it 7 months in advance
 - ◆ Do it from 100 million miles away
 - ◆ Don't miss.
(don't worry you have 5 attempts)
- How is this done?

Radio Navigation

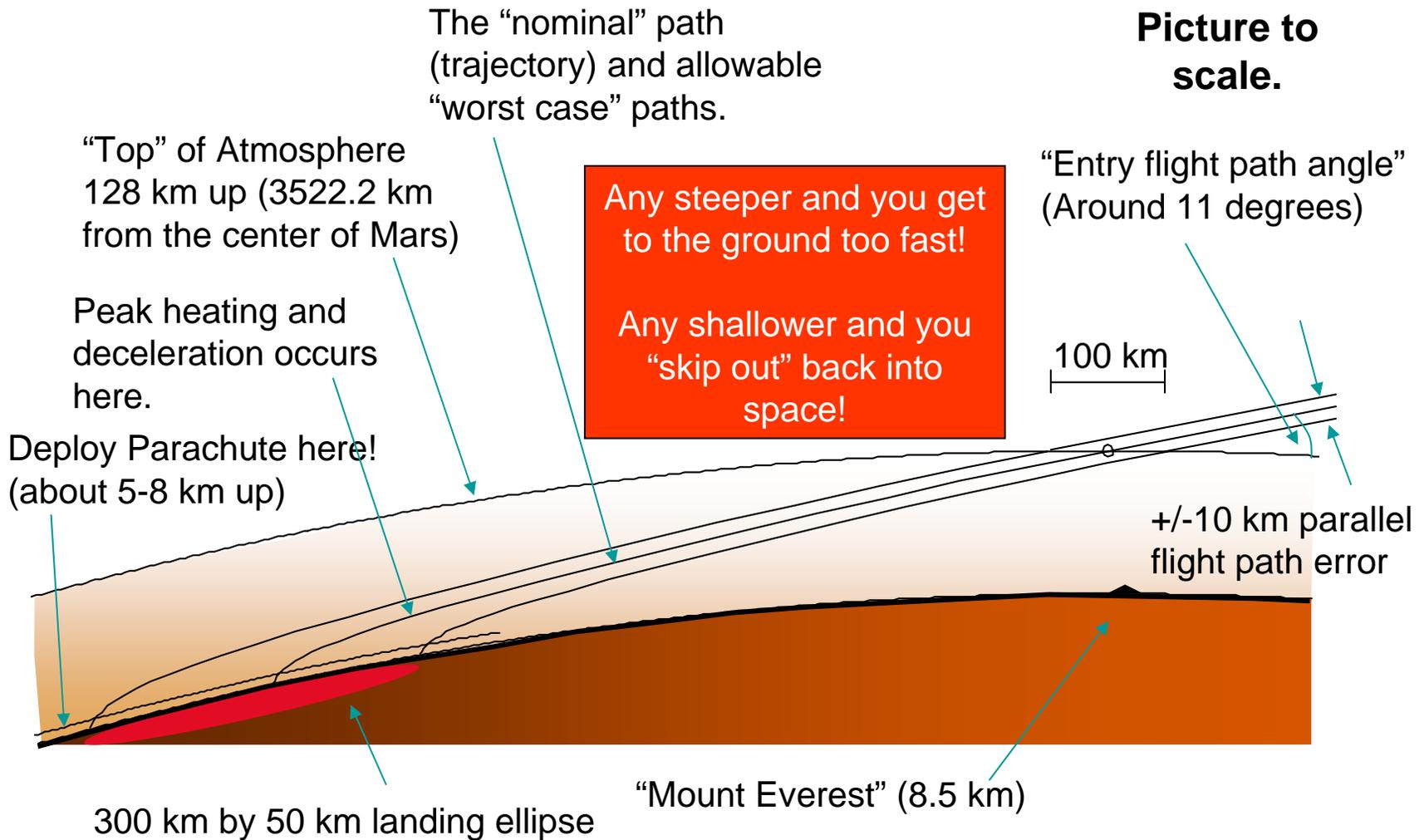
- Getting distance & radial speed using the radio



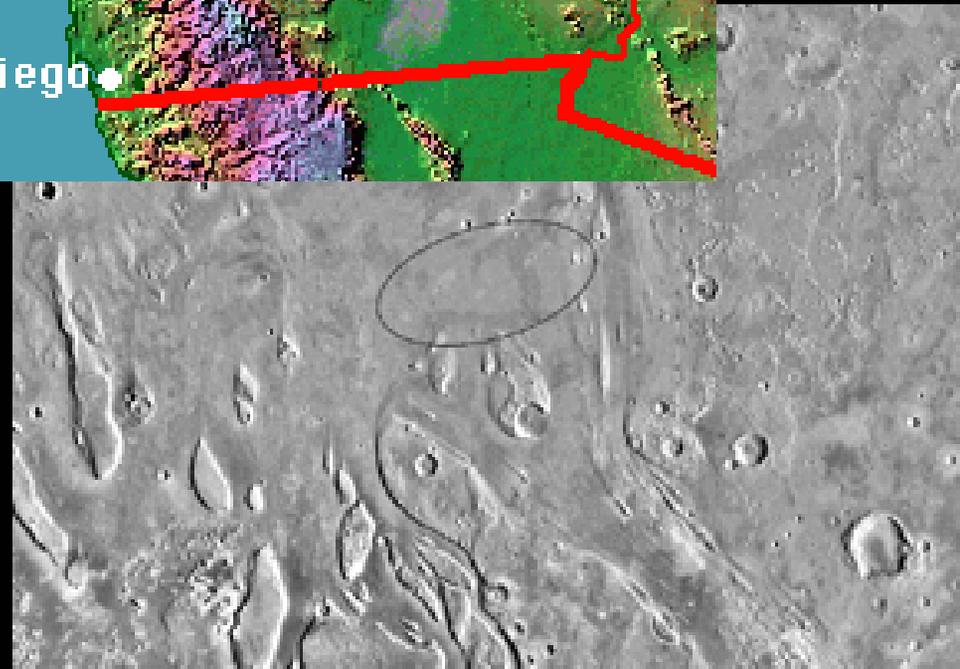
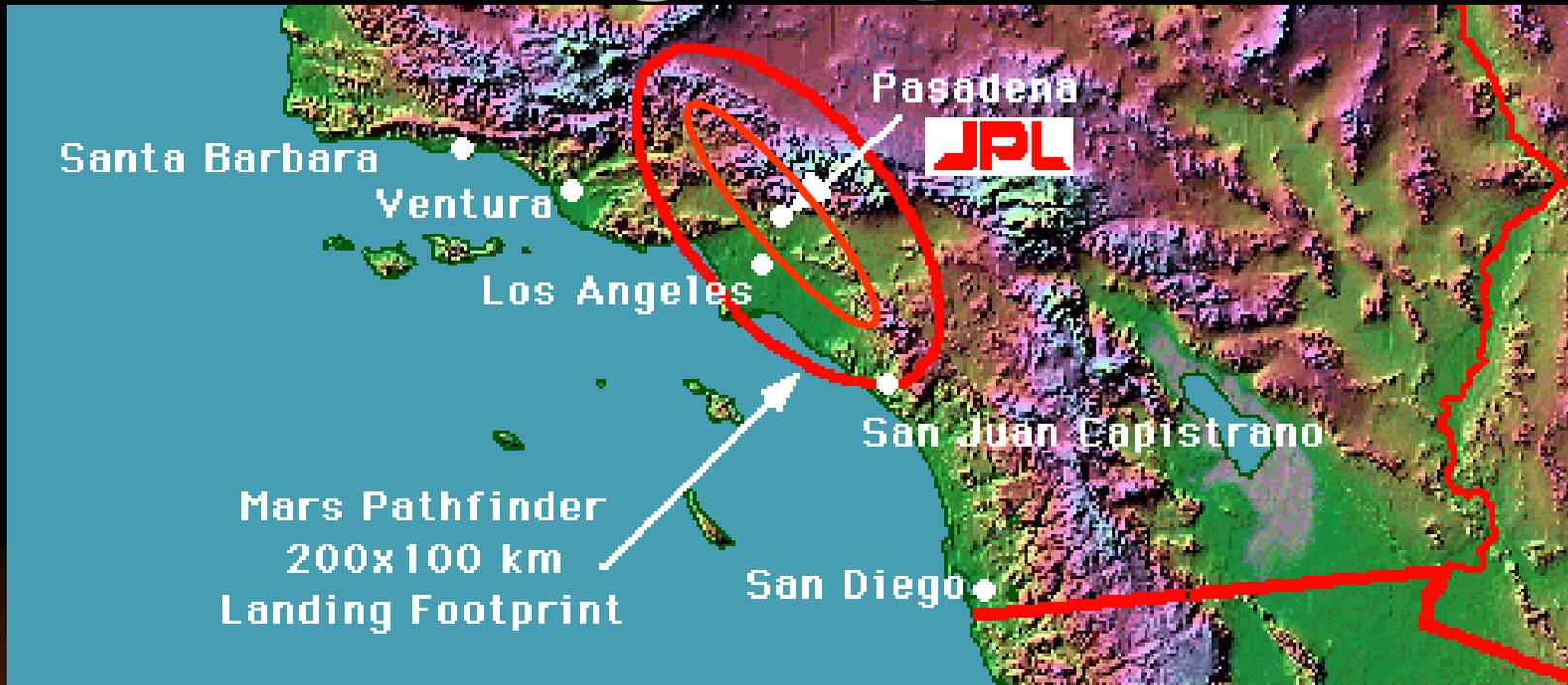
Now don't miss !



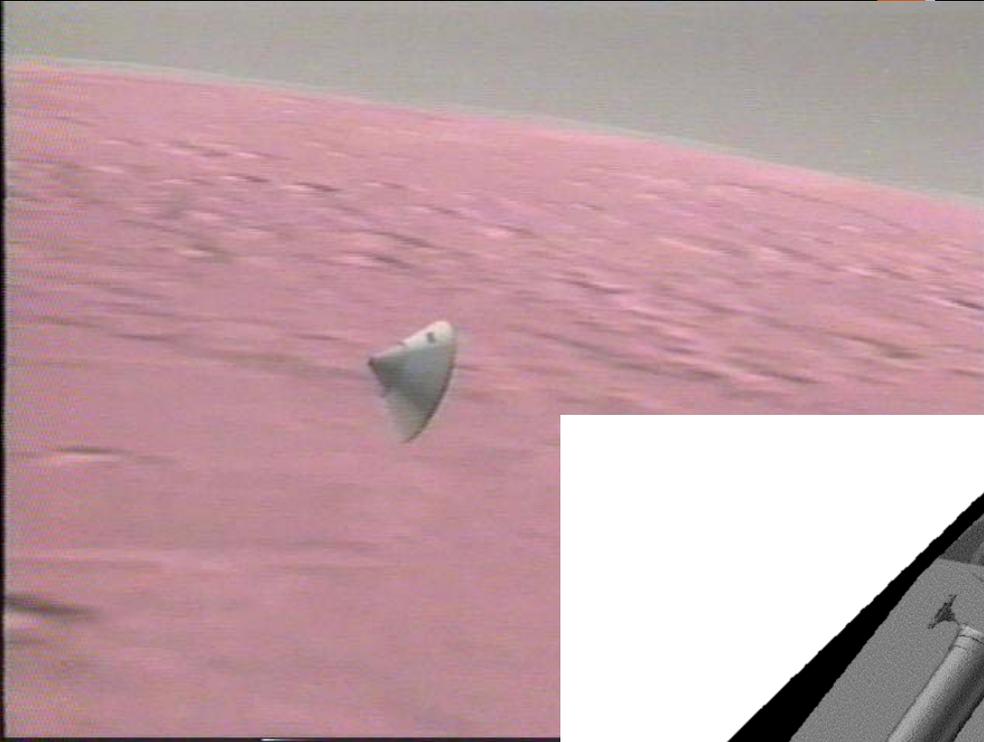
Using the Atmosphere



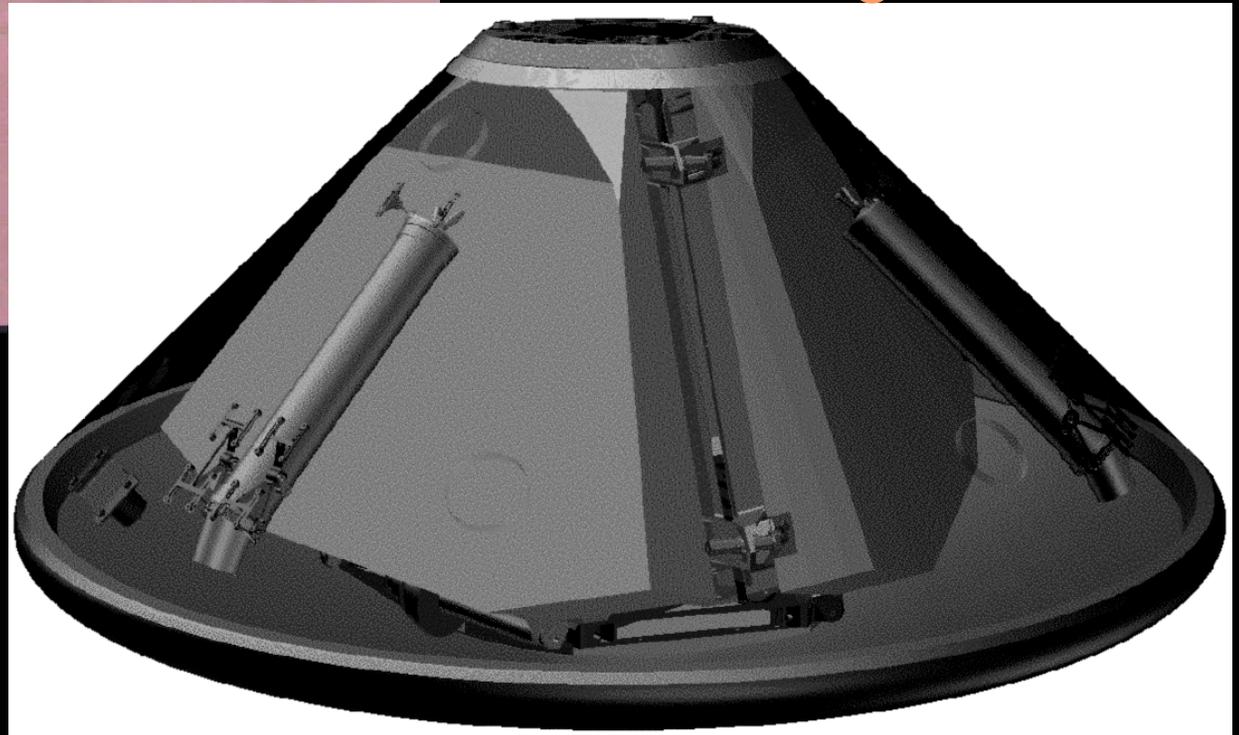
Landing Ellipse Size



Aerobraking

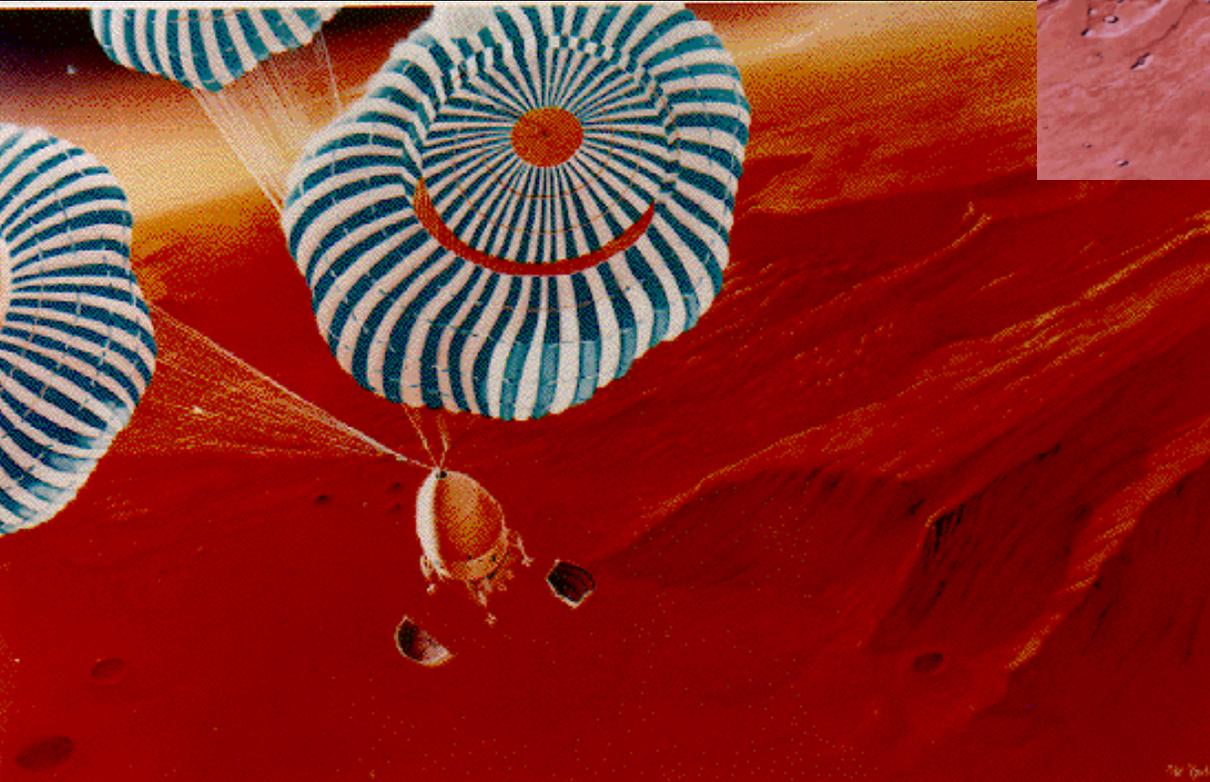
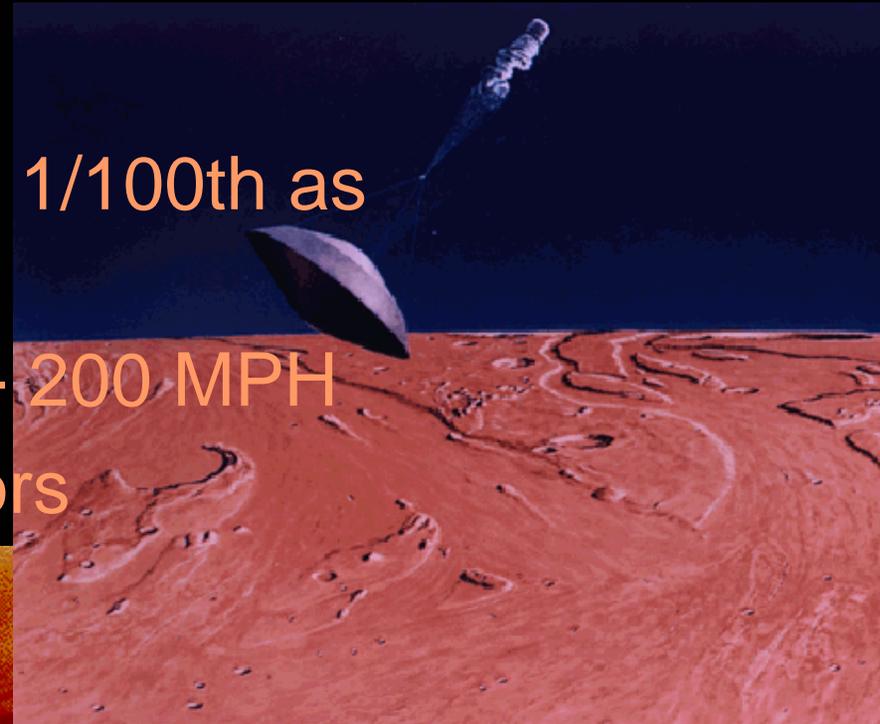


- 12,000 MPH to 500 MPH in 60 seconds!
- 10-20 G's
- 100 Megawatts



Parachutes

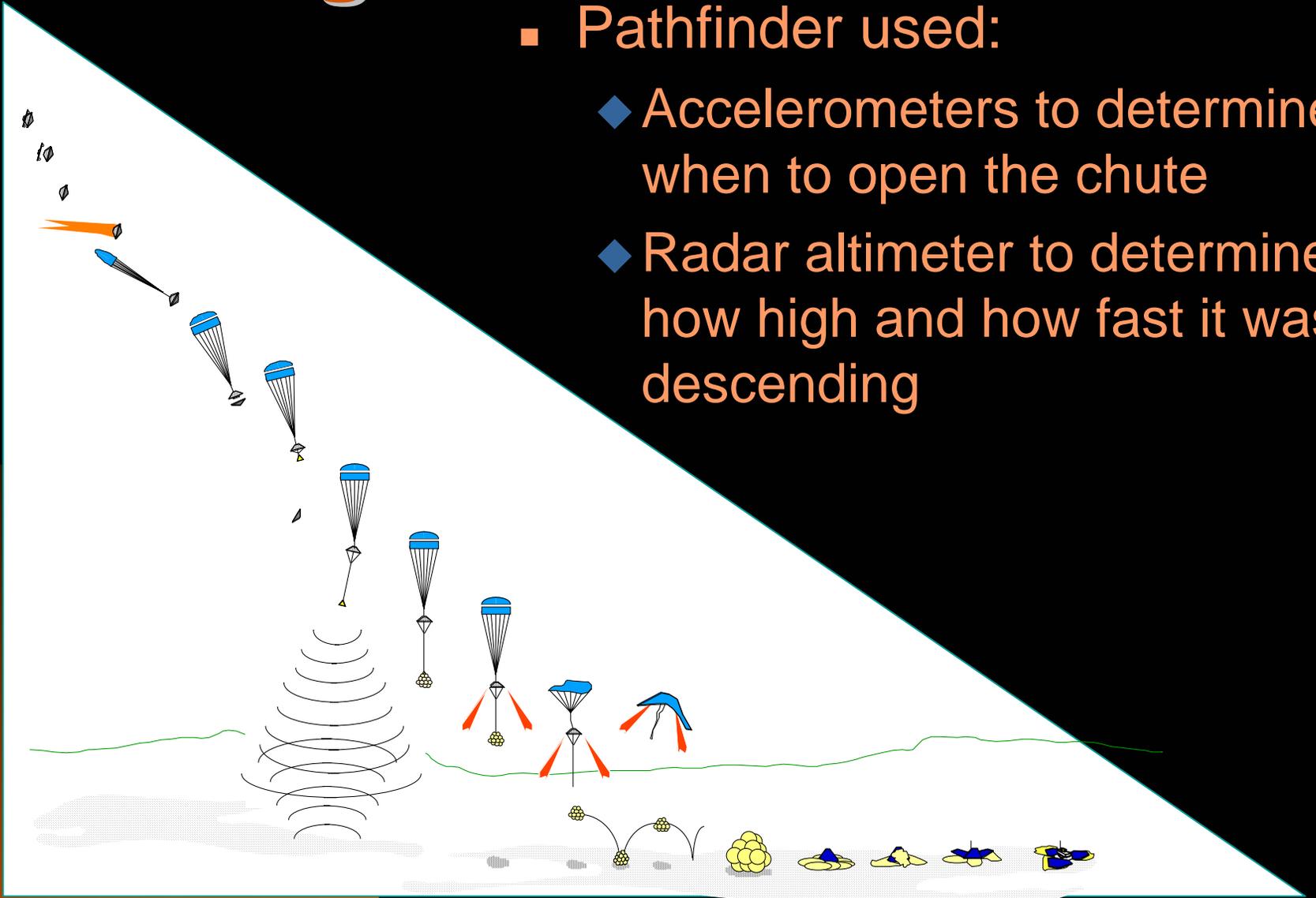
- Mars Atmosphere is only 1/100th as dense as Earth's
- Slows down to *only* 100 - 200 MPH
- Not needed for penetrators



Landing Control: Pathfinder

- Pathfinder used:

- ◆ Accelerometers to determine when to open the chute
- ◆ Radar altimeter to determine how high and how fast it was descending

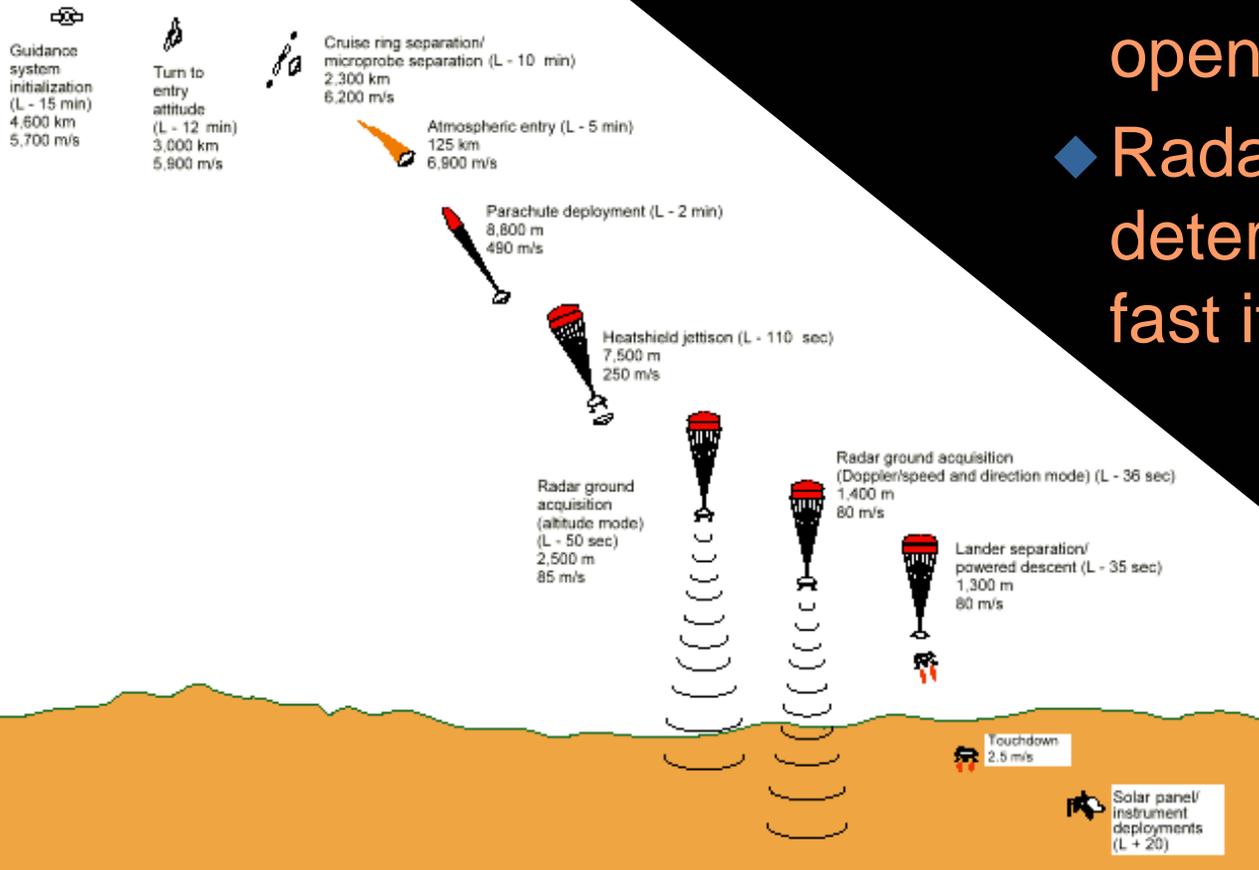


Descent Thrusting: Pathfinder

- Three solid rockets
- From 140 MPH to 0 MPF in 2.5 seconds
- Dead stop with lander about 20 m (65 feet!) above the ground.
- Airbags protect the lander during fall.

Landing Control: Viking/MPL

- Viking & MPL used:
 - ◆ Inertial sensors to determine when to open the chute
 - ◆ Radar altimeter to determine how high and fast it was descending



Entry, descent and landing

Descent Thrusting: Viking & Mars Polar Lander



- Liquid hydrazine engines (pulsed or throttled)
- Start firing about 1 km up
- Slows down to 8 feet per second
- Engines stop when the legs touch

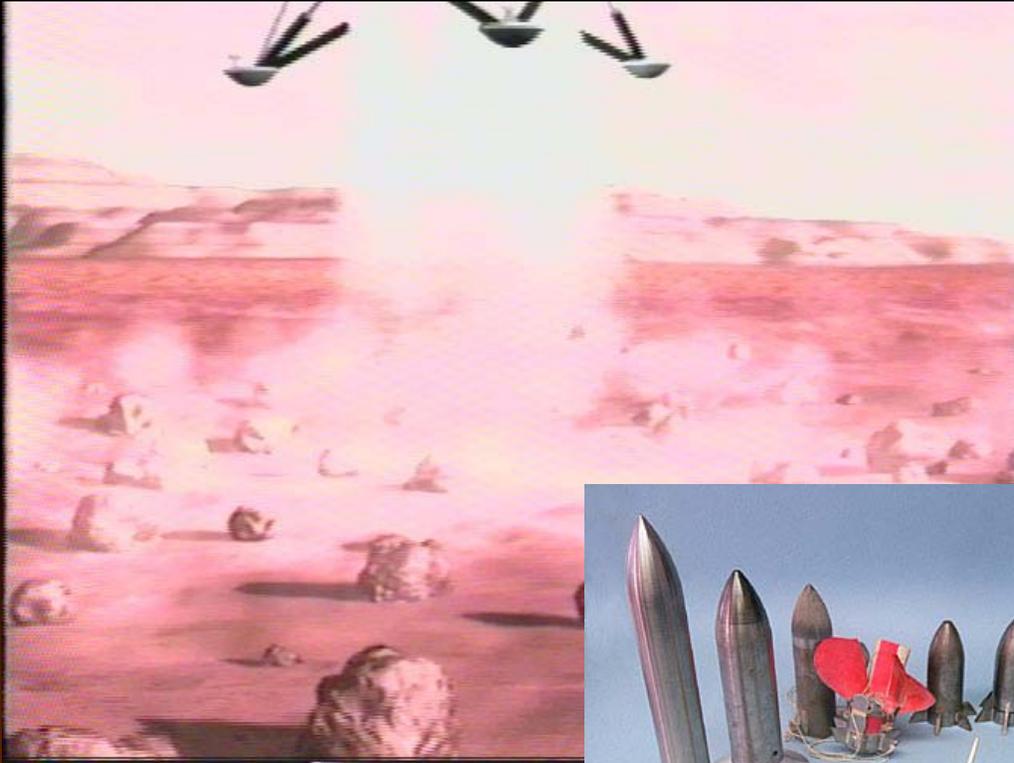


Landing

(that “sudden stop at the end”)

- Pick your favorite ...
 - ◆ Penetrators
 - ☞ Russia’s Mars96 penetrators
 - ☞ DS-2 Microprobes
 - ◆ Hard landers (“bouncers”)
 - ☞ Russia’s Mars96 Small Stations
 - ☞ Pathfinder
 - ☞ Beagle II (future)
 - ◆ Soft (propulsive) landers
 - ☞ Russia’s Mars 3-7
 - ☞ Viking 1 & 2
 - ☞ Mars Polar Lander

The Touchdown



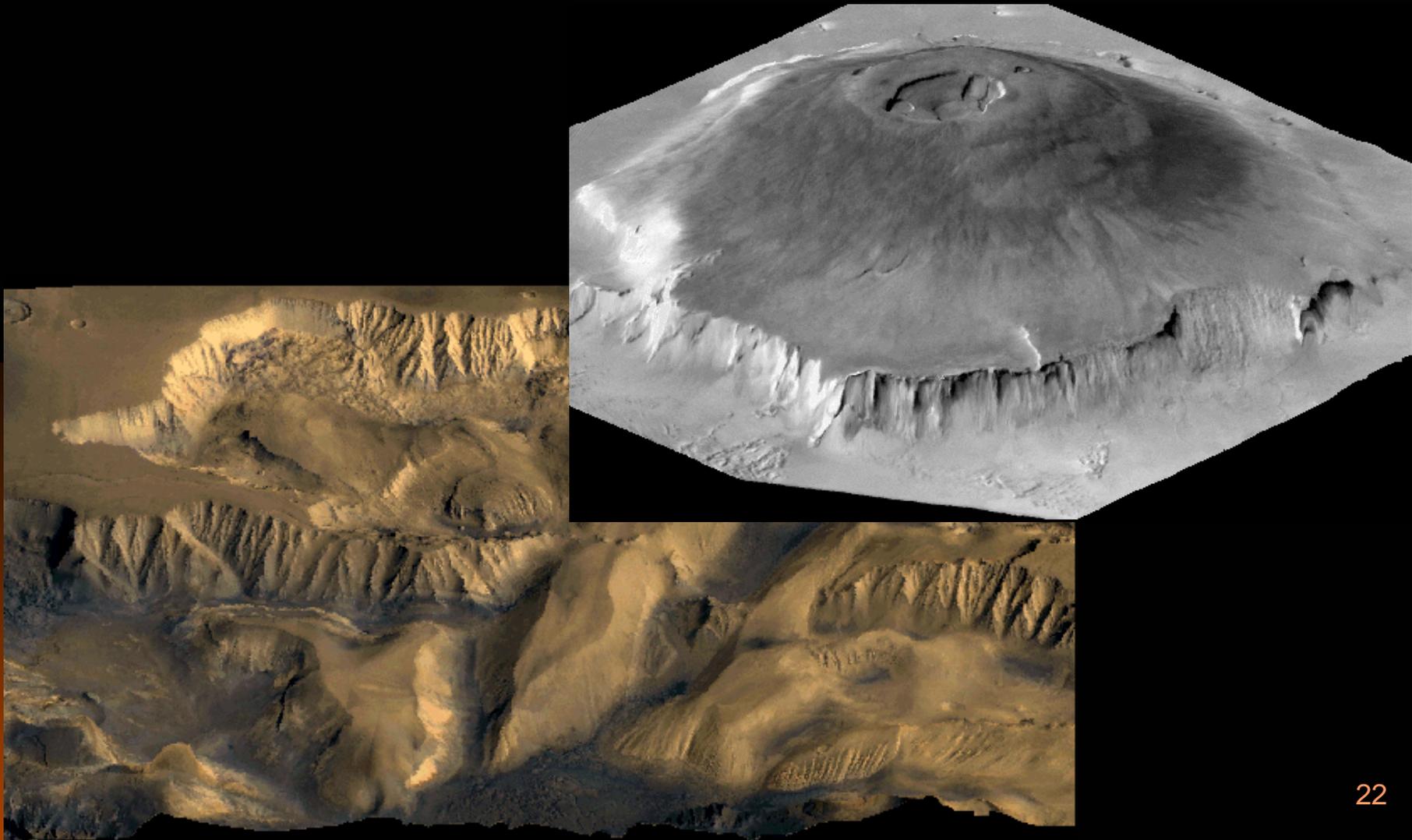
How do we know it will work?

- Testing on Earth is a big challenge
 - ◆ Mars' gravity is $3/8$ Earth's
 - ◆ Mars' atmosphere is $1/100$ ths Earth's
 - ◆ Mars' temperature is -40 to -90 deg F
- Virtual Landings on Computers!
 - ◆ Create a virtual lander (rockets, chute ...)
 - ◆ Create a virtual Mars (wind, gravity ...)
 - ◆ Verify the computer model's ability to predict outcomes of Earth-based tests.
- Test, Test, Test !!!!!!!

The Future ...

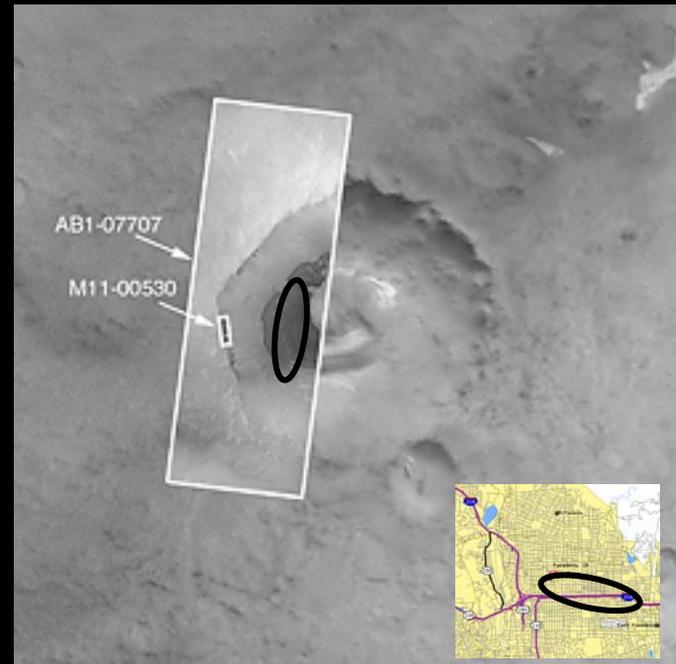
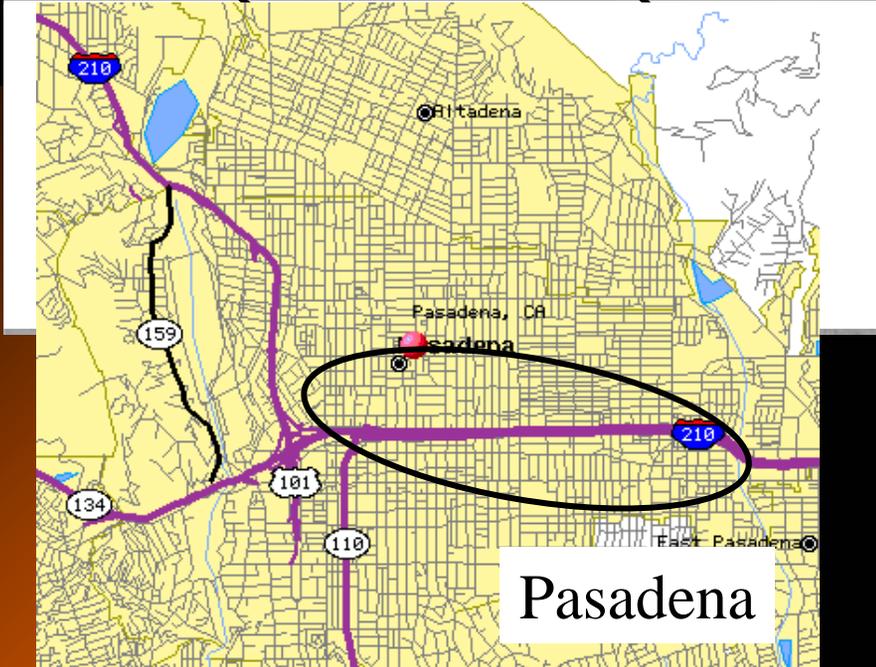
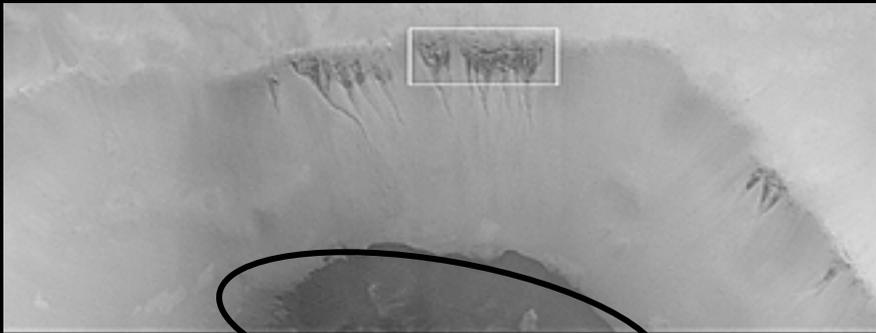
- What are we doing to make landing better?
 - ◆ Can we improve our ability to aim?
 - ◆ Can we improve our ability to land safely?
 - ◆ What will humans lander look like?

**We want to go *someplace*,
not *anyplace***



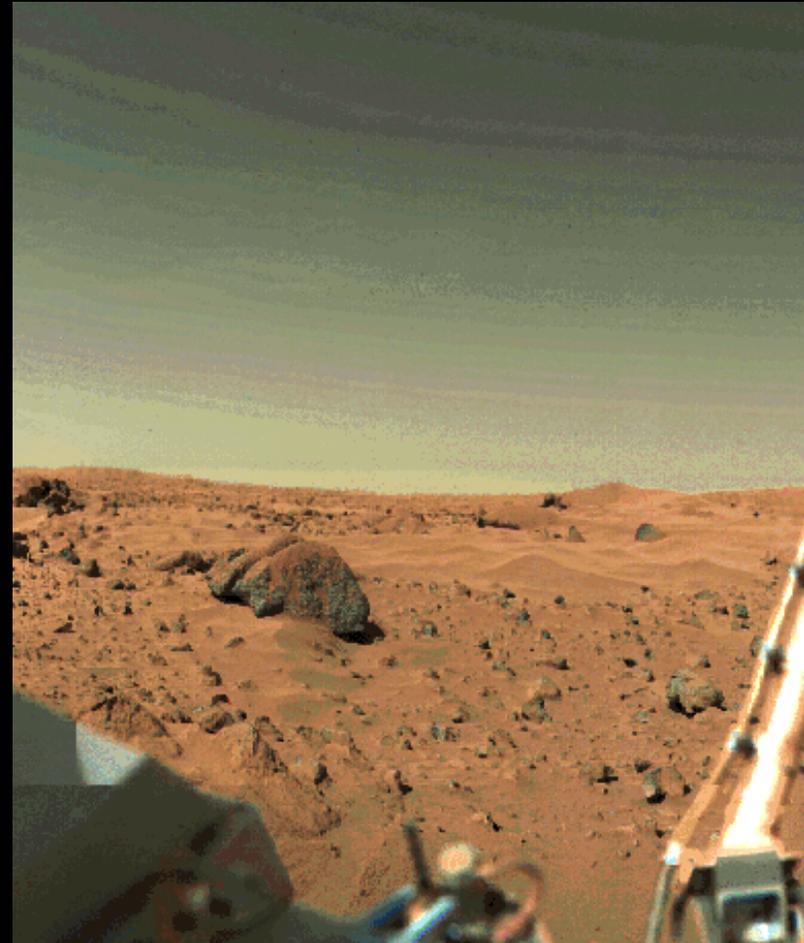
Improving our Landing Ellipse

- So far no lander has been able to correct its course automatically in order to land near something interesting.
- Aeromaneuvering (“steering the aircraft”) during entry can reduce our landing ellipse from 200 km (size of So. Calif.) down to 10 km (size of Pasadena!)



Landing Hazards

- Rocks
 - ◆ Hard landers don't mind rocks
 - ◆ Rocks larger than 30-50 cm are hard on legged landers
- Slopes
 - ◆ Legged landers won't roll down a hill after landing
 - ◆ But they can tip over

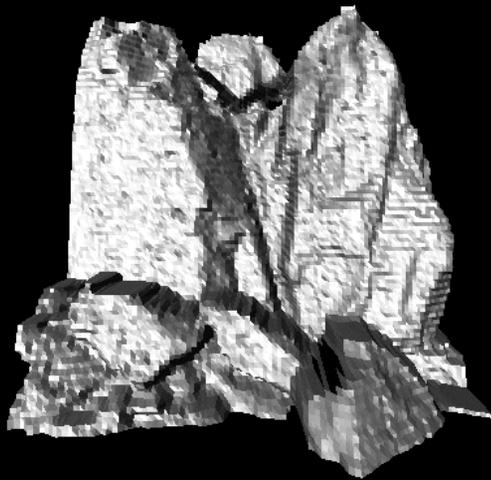


Landing Hazard Avoidance

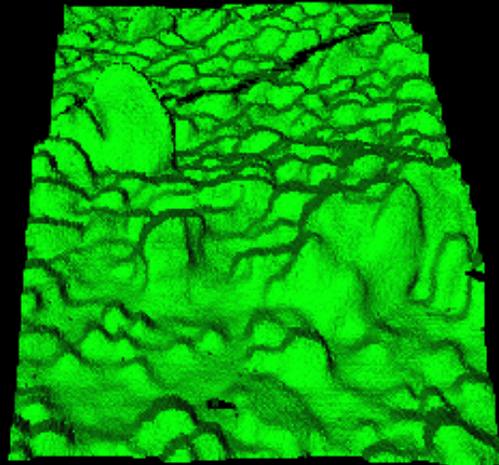
- Improved landing precision will allow us to improve our ability to pick sites that look safe from the orbiter images
- So far no lander has been able to automatically find and avoid hazards.
 - ◆ Viking and MPL “rolled the dice”
 - ◆ Pathfinder bounced and rolled over them
- What does it take to automatically avoid hitting a rock or slope?

Future Hazard Sensing?

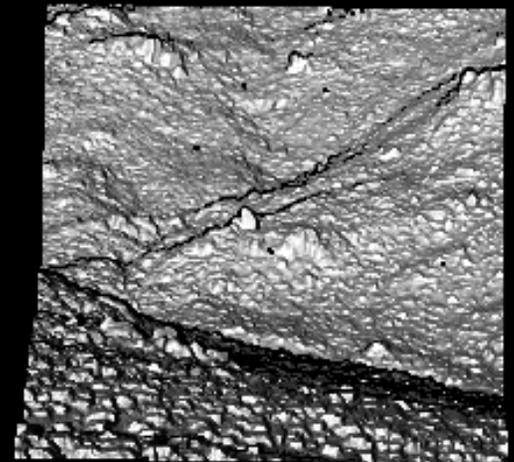
- If we did, could our lander see the surface ?
 - ◆ Need 3-D glasses!
 - ☞ Or something like an imaging laser-radar (LIDAR)
 - ◆ Remember we're moving >100 MPH downward!
 - ☞ So think fast !! (sorry Neil Armstrong)



Cliffs



Rocks

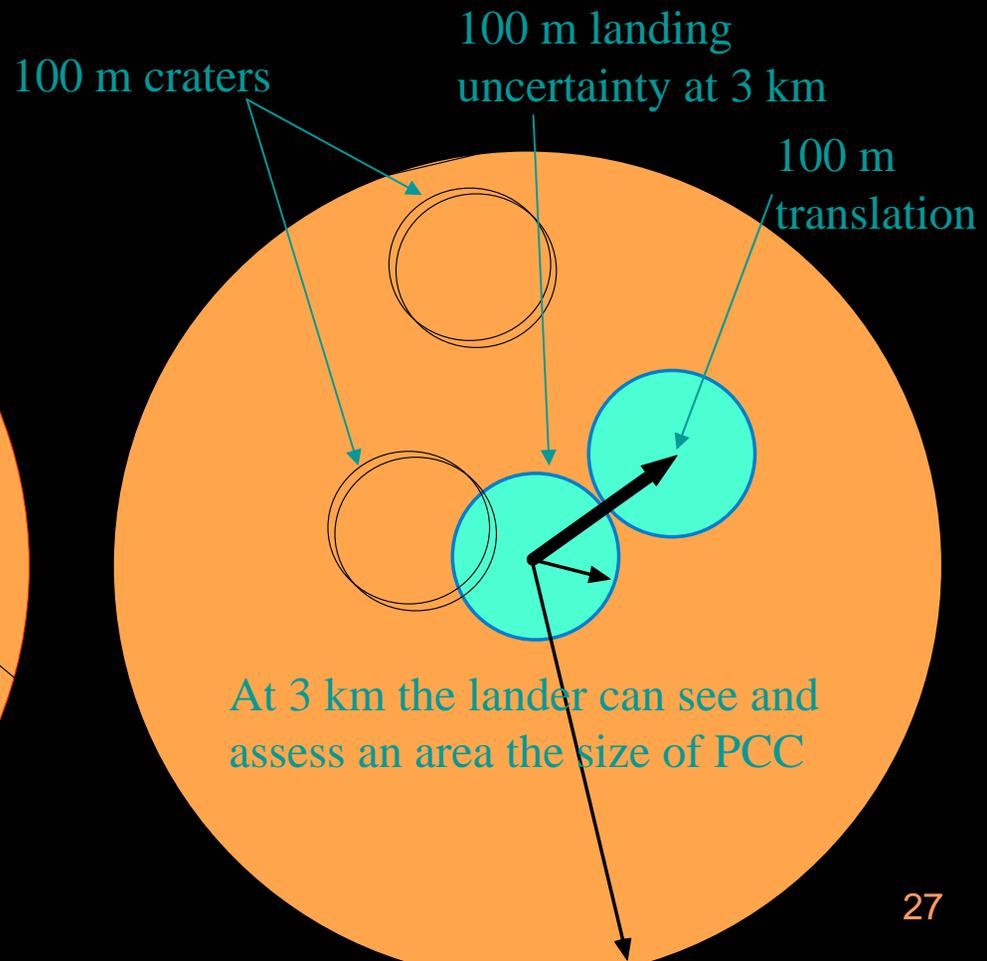


Slopes

Quick! Move!

- How far can our (future) lander laterally move?
 - ◆ Only about 100-200 meters over 25 seconds

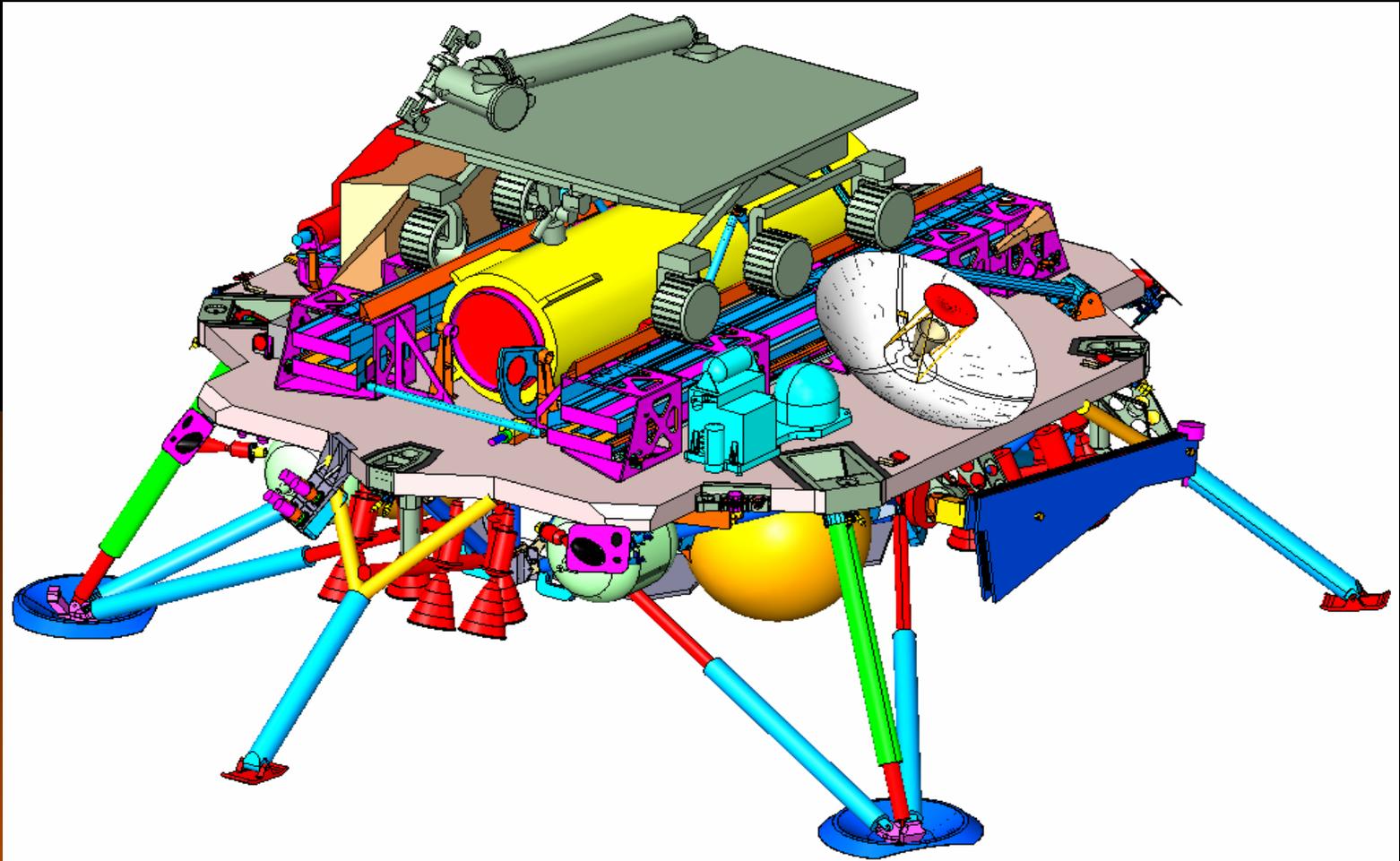
Lander can “see” about this much area 3 km up (520 m dia)



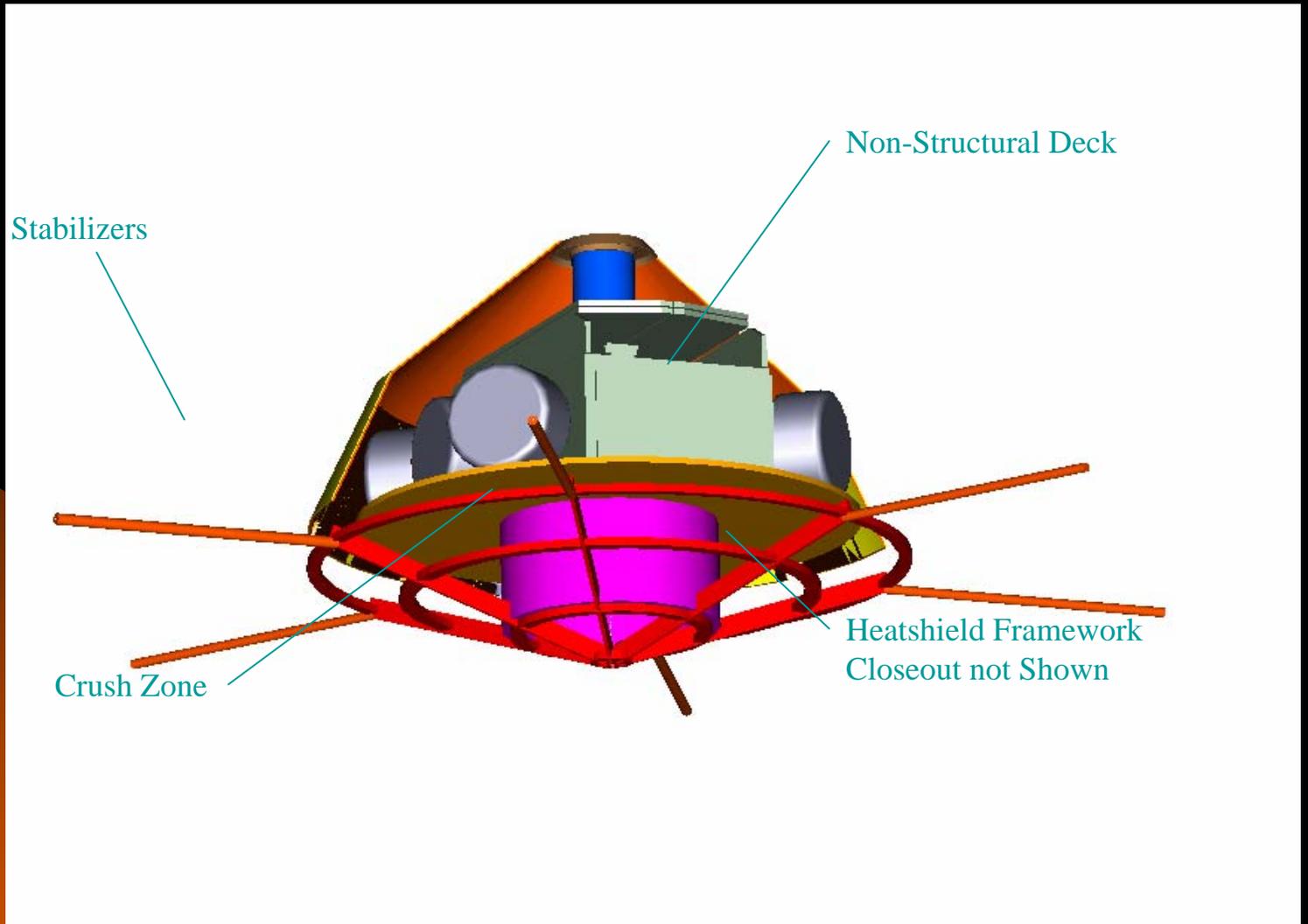
Future Robotic Landers

- What might they look like?
 - ◆ Legs and Outriggers?
 - ◆ Airbags?
 - ◆ Mega-Rovers in Bags?

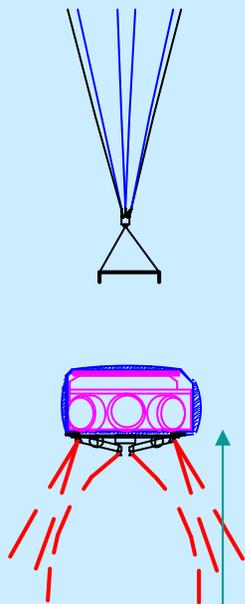
Legs with Outriggers



Pallet

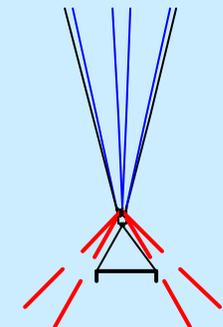


Airbags



Lander separation from parachute. Vernier system activated and used to set up pre-RAD firing vertical attitude.

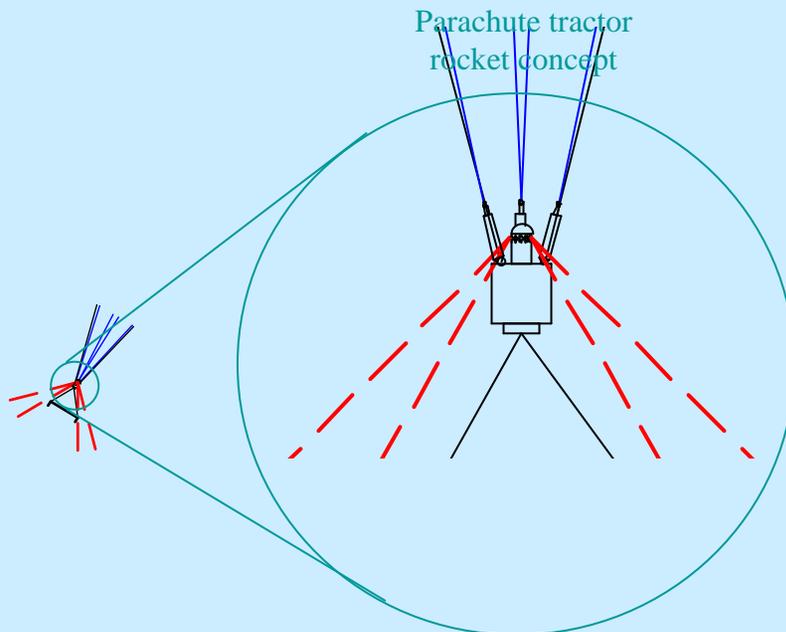
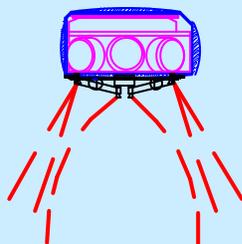
~80 m



RAD rocket firing. Vernier rocket attitude maintenance.

Rockets are staged to enable **thrust termination** by pyrotechnically severing 2 rocket nozzles.

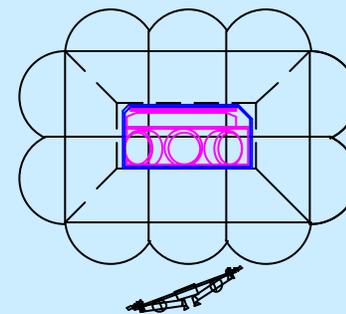
~5 m



Parachute tractor rocket concept

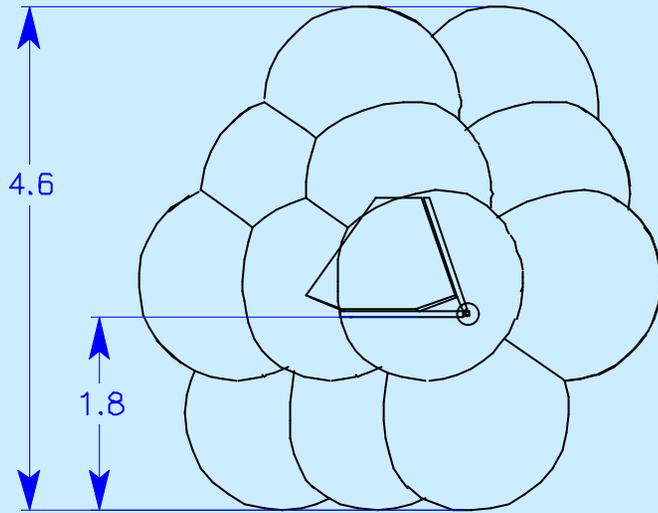


RAD rocket thrust termination, vernier system attitude maintenance.

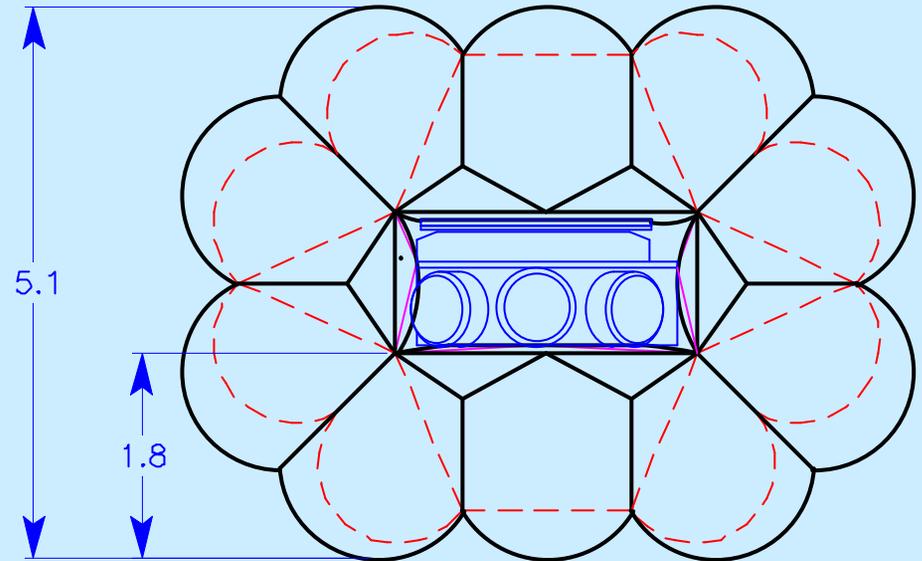


Propulsion sub-pallate is jettisoned and "thrown" clear during airbag inflation, <1 sec.

Large Payloads using Airbags

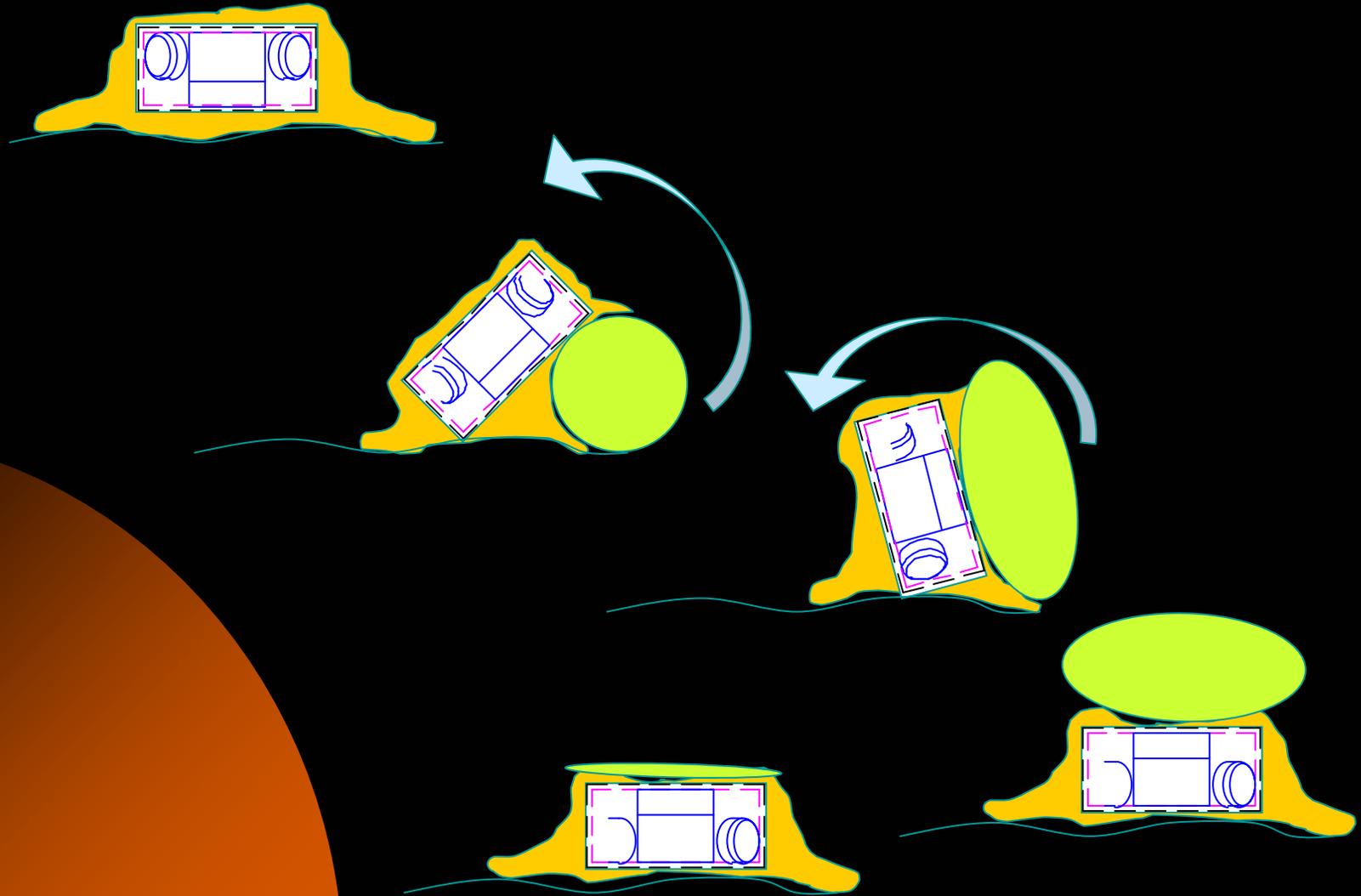


Mars Pathfinder Airbag Configuration

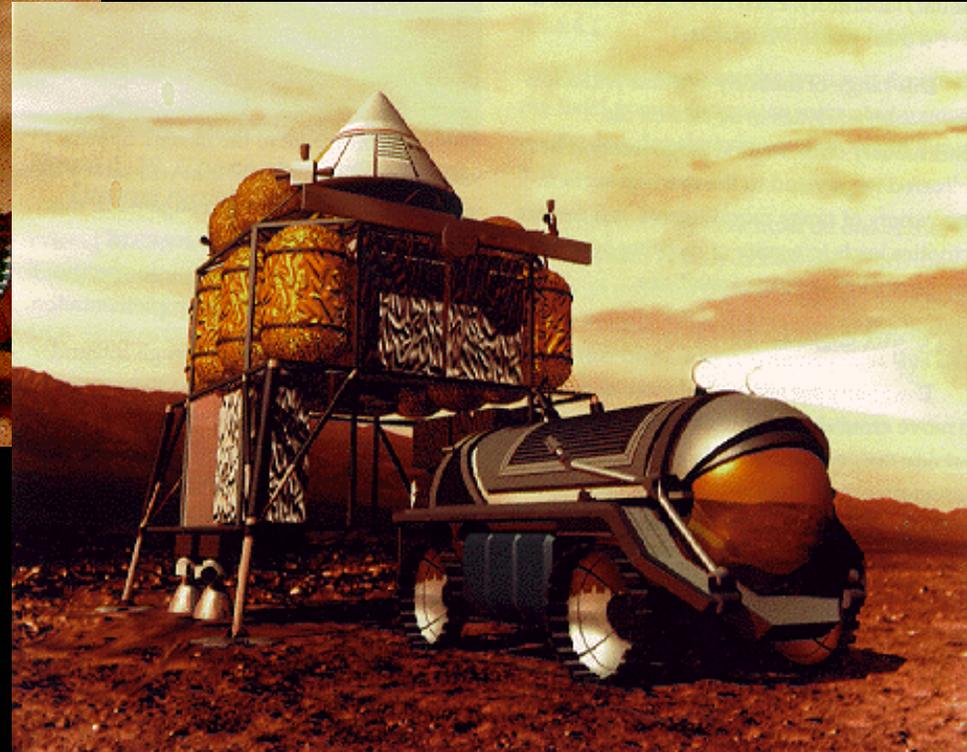
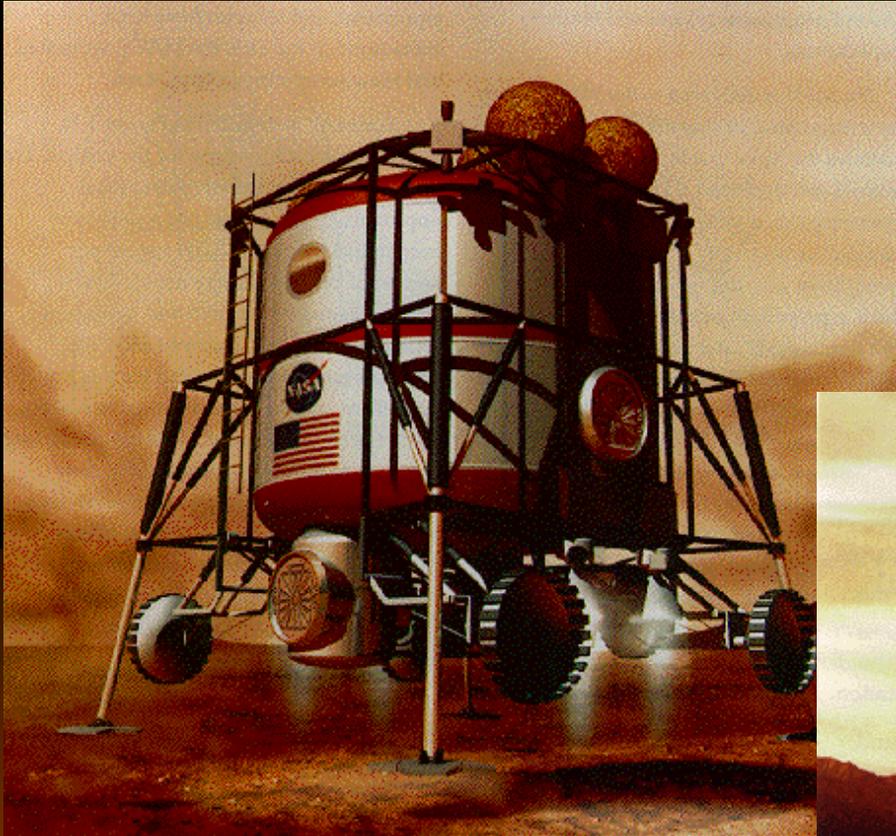


Mega Rover Airbag Configuration

Righting Large Airbags



Next Step: Humans



What it's all about ..

