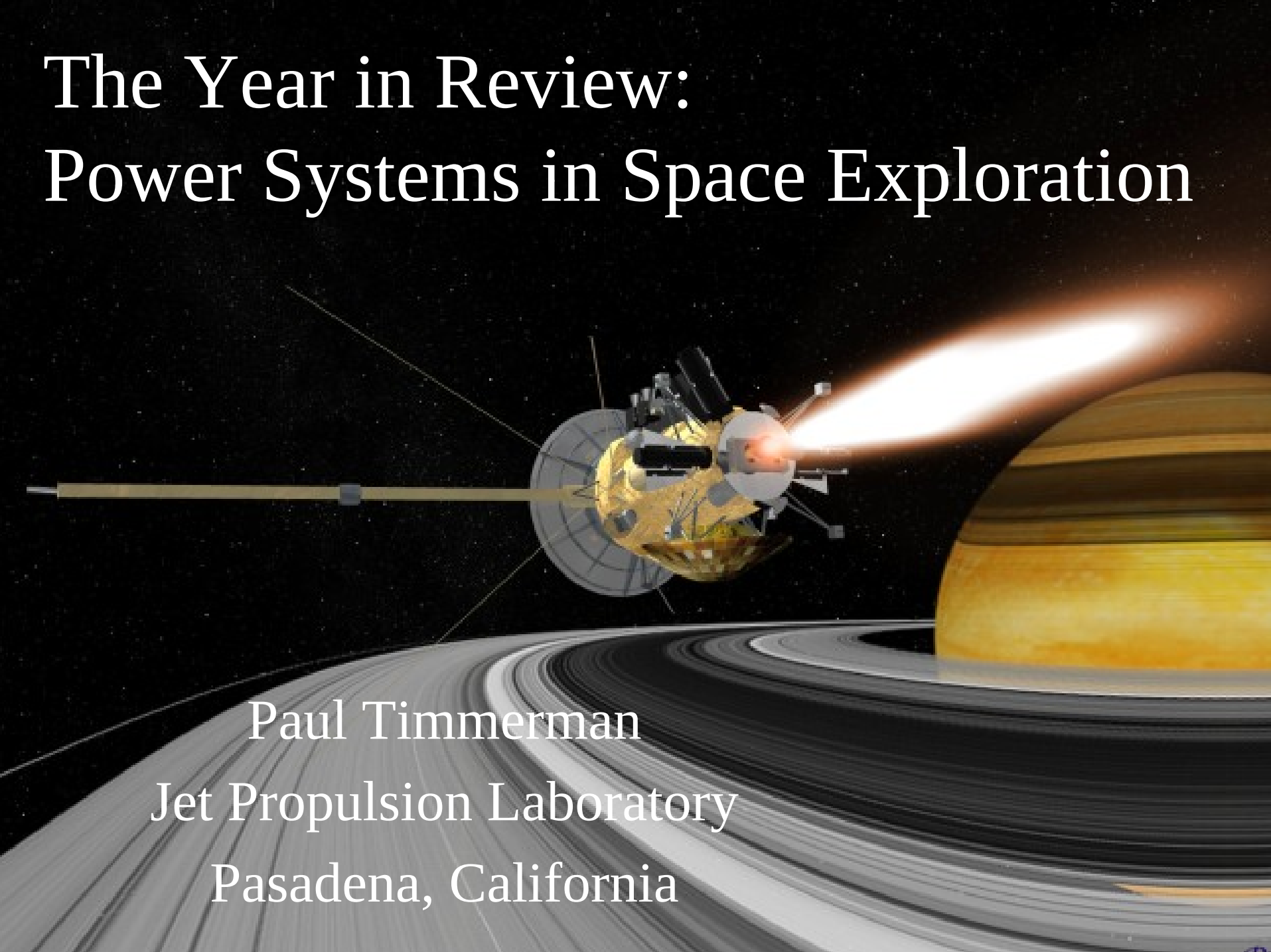
The Year in Review: Power Systems in Space Exploration



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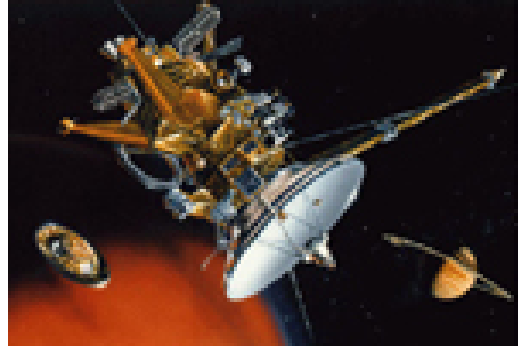
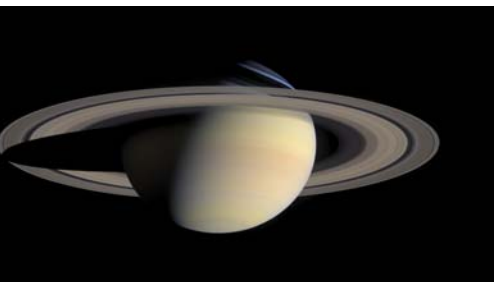
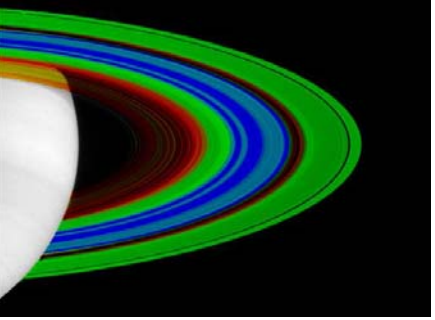
Introduction

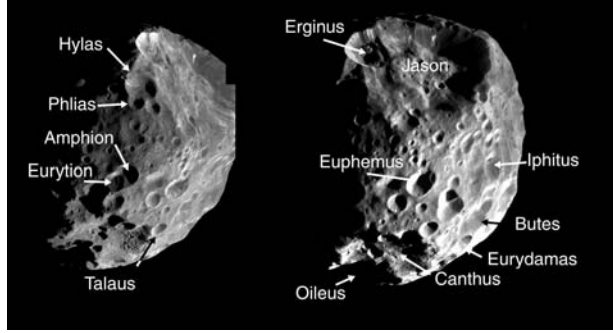


- 2004 was a banner year for space exploration
- The Cassini Spacecraft arrived at Saturn
- Huygens Probe visited largest moon, Titan
- Twin Mars Exploration Rovers Landed
- Spirit and Opportunity both roving the surface
- Several more missions are being prepared





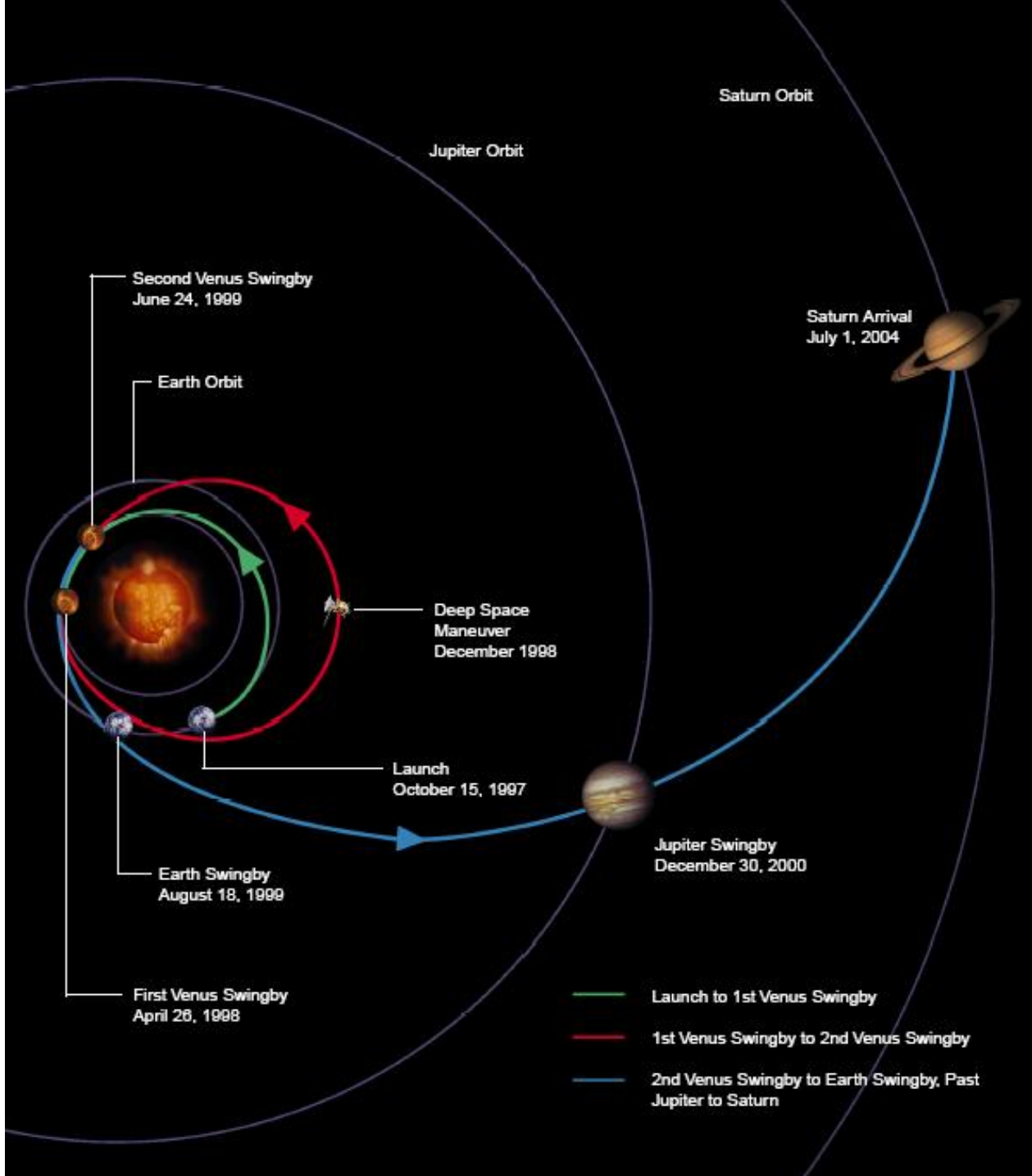
Cassini-Huygens Mission to Saturn



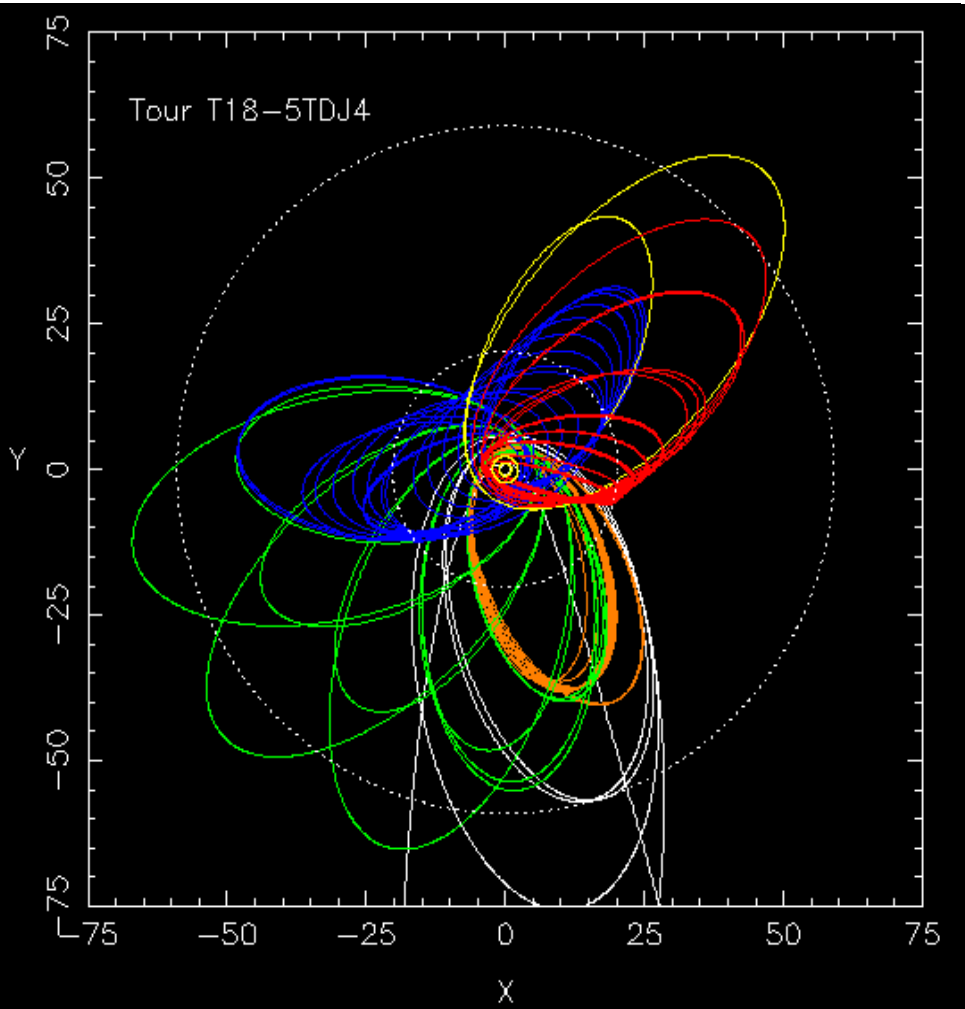
- *Mission Summary*
  - Large orbiter (>5700 Kg) , Titan probe
    - JPL designed and build orbiter
    - ESA designed and built probe
  - Dozens of individual experiments onboard
  - Flagship Mission - Class A reliability
  - Orbiter is nuclear powered, using RTG’s
  - Probe is powered by primary batteries

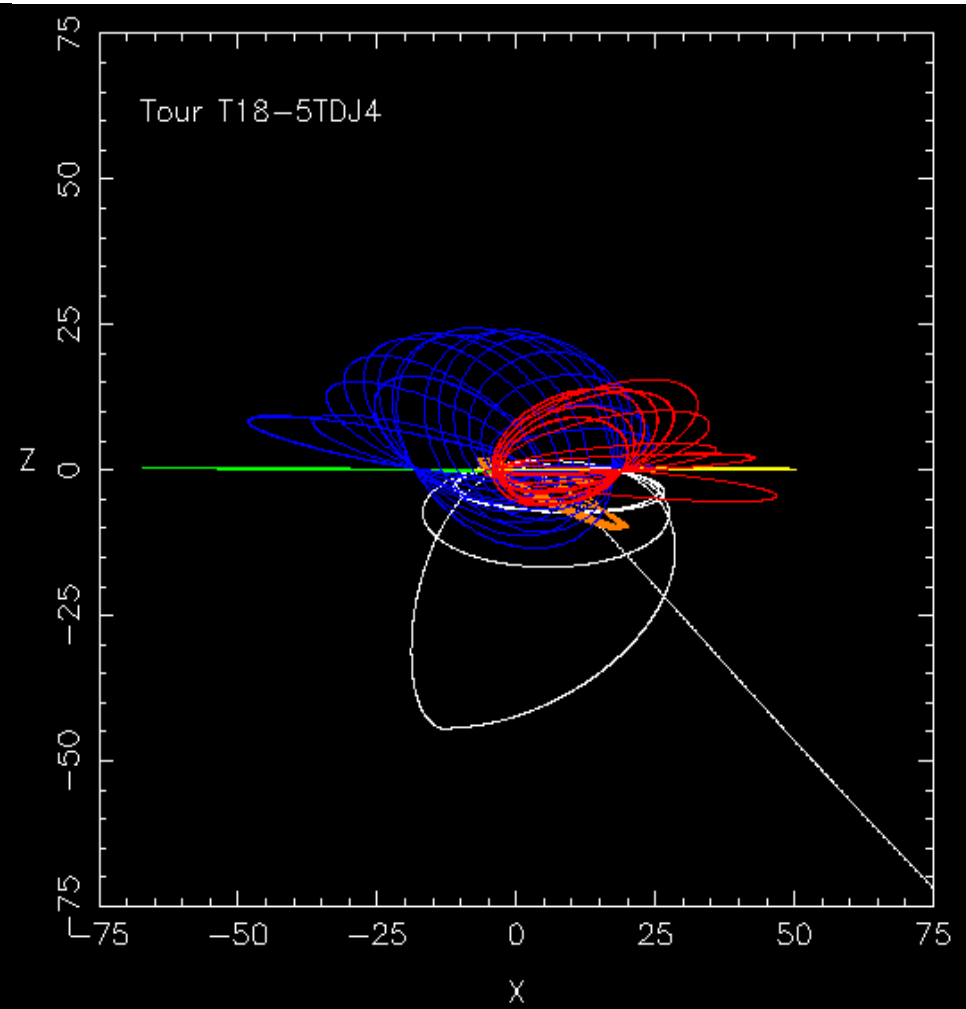
The Journey

- Oct. 1997 Launch
- April 1998 Venus
- Aug. 1999 Earth
- June 1999 Venus
- Dec. 2000 Jupiter
- July 2004 Saturn

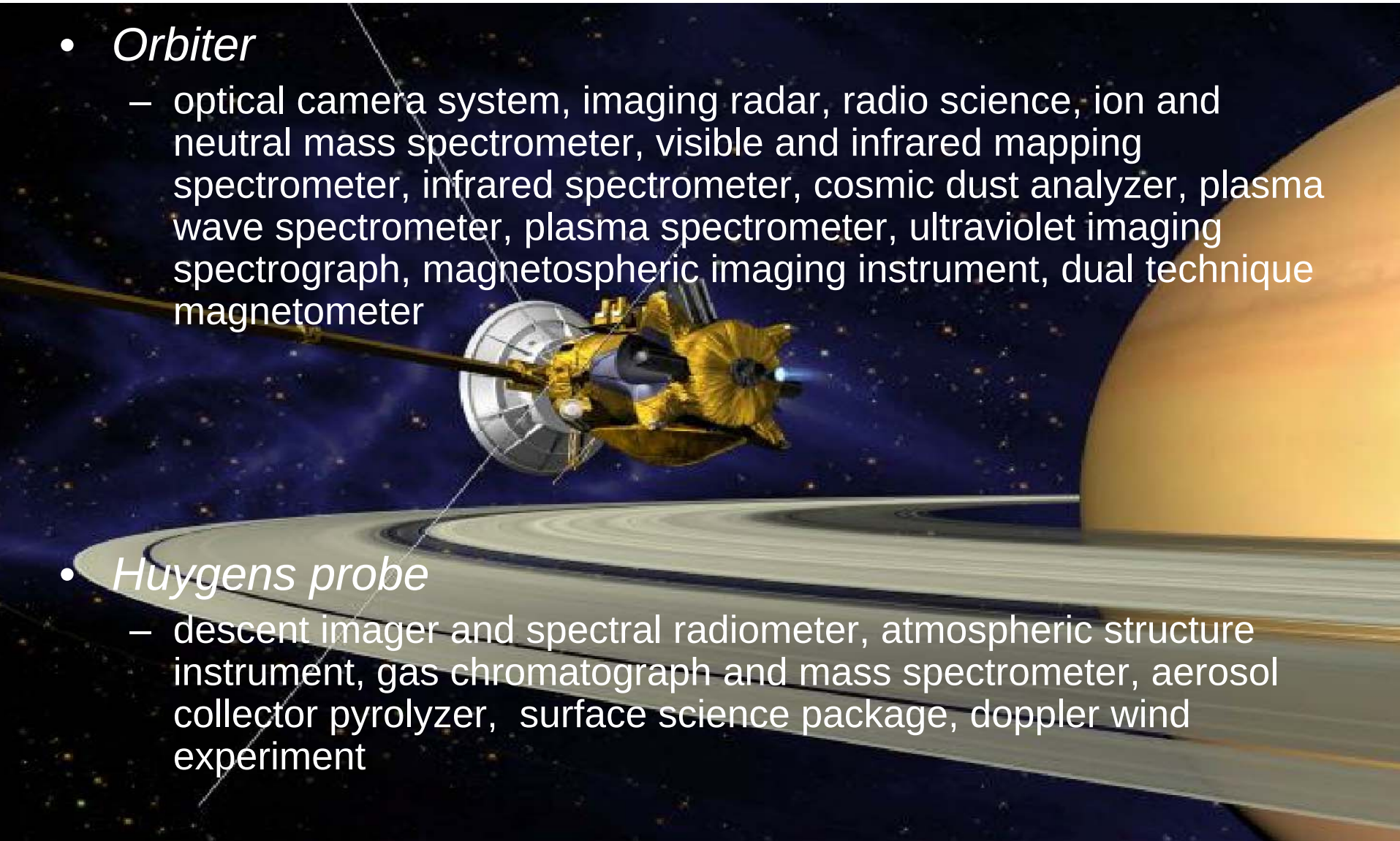


Saturn System Tour after Arrival



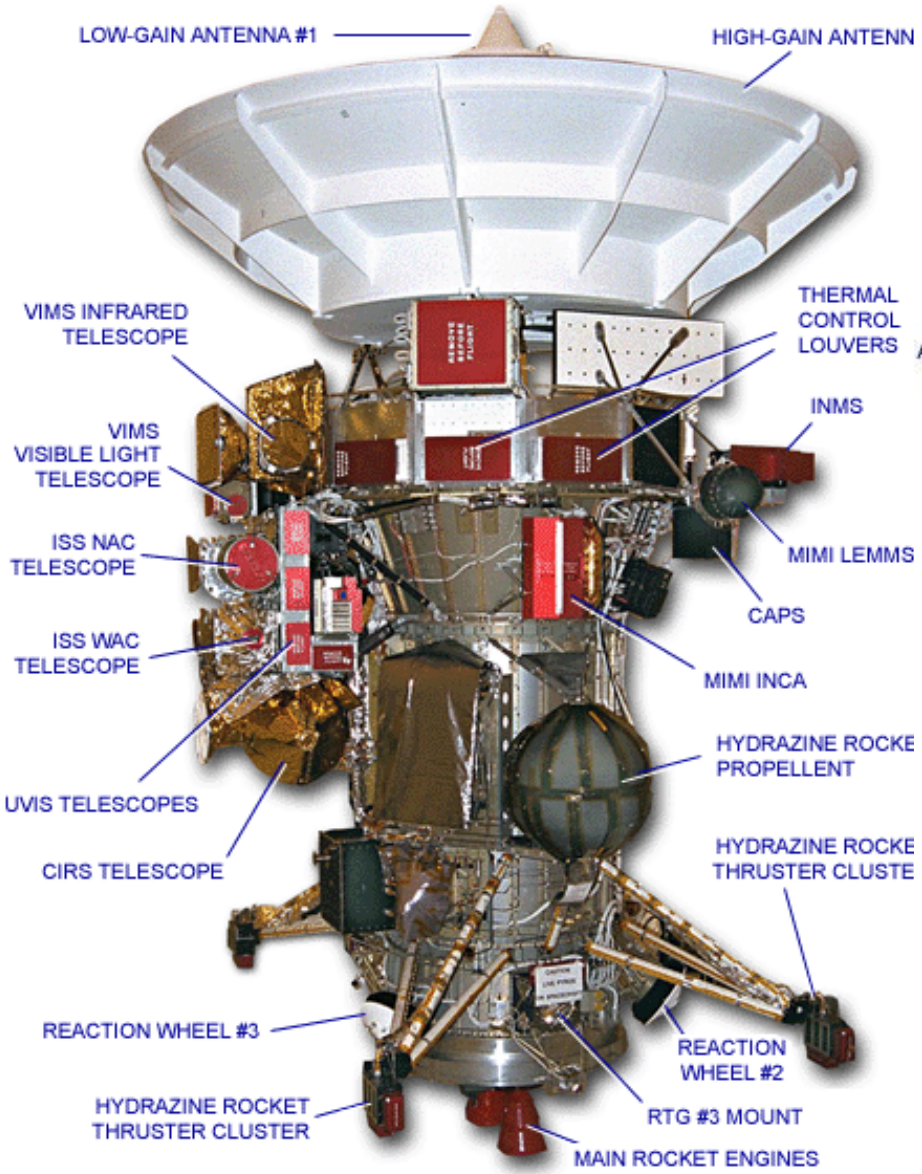


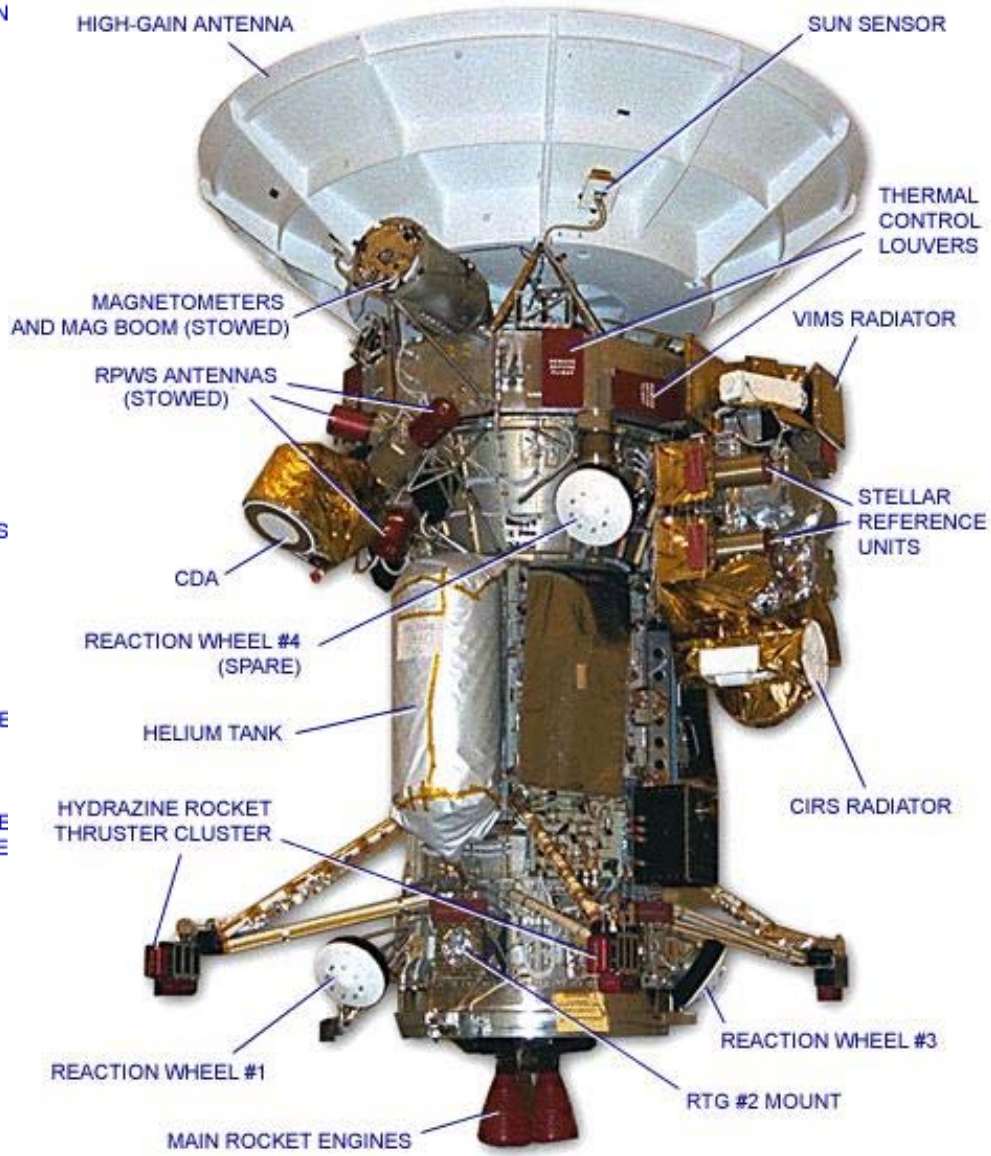
Science instruments

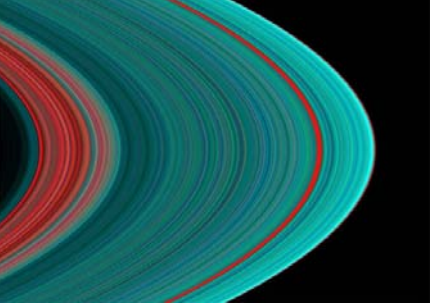


- *Orbiter*
  - optical camera system, imaging radar, radio science, ion and neutral mass spectrometer, visible and infrared mapping spectrometer, infrared spectrometer, cosmic dust analyzer, plasma wave spectrometer, plasma spectrometer, ultraviolet imaging spectrograph, magnetospheric imaging instrument, dual technique magnetometer
- *Huygens probe*
  - descent imager and spectral radiometer, atmospheric structure instrument, gas chromatograph and mass spectrometer, aerosol collector pyrolyzer, surface science package, doppler wind experiment

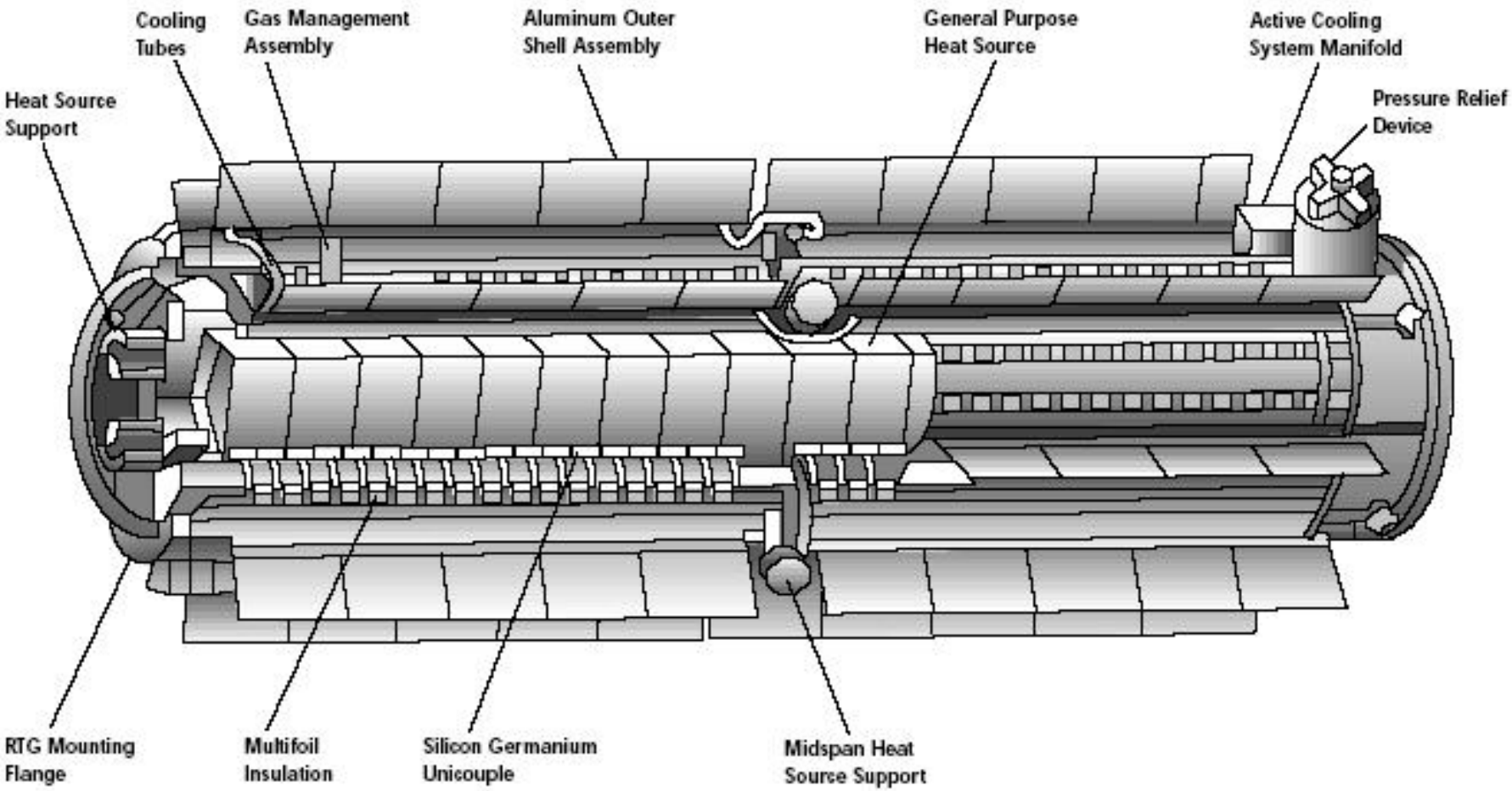
Cassini Spacecraft Configuration

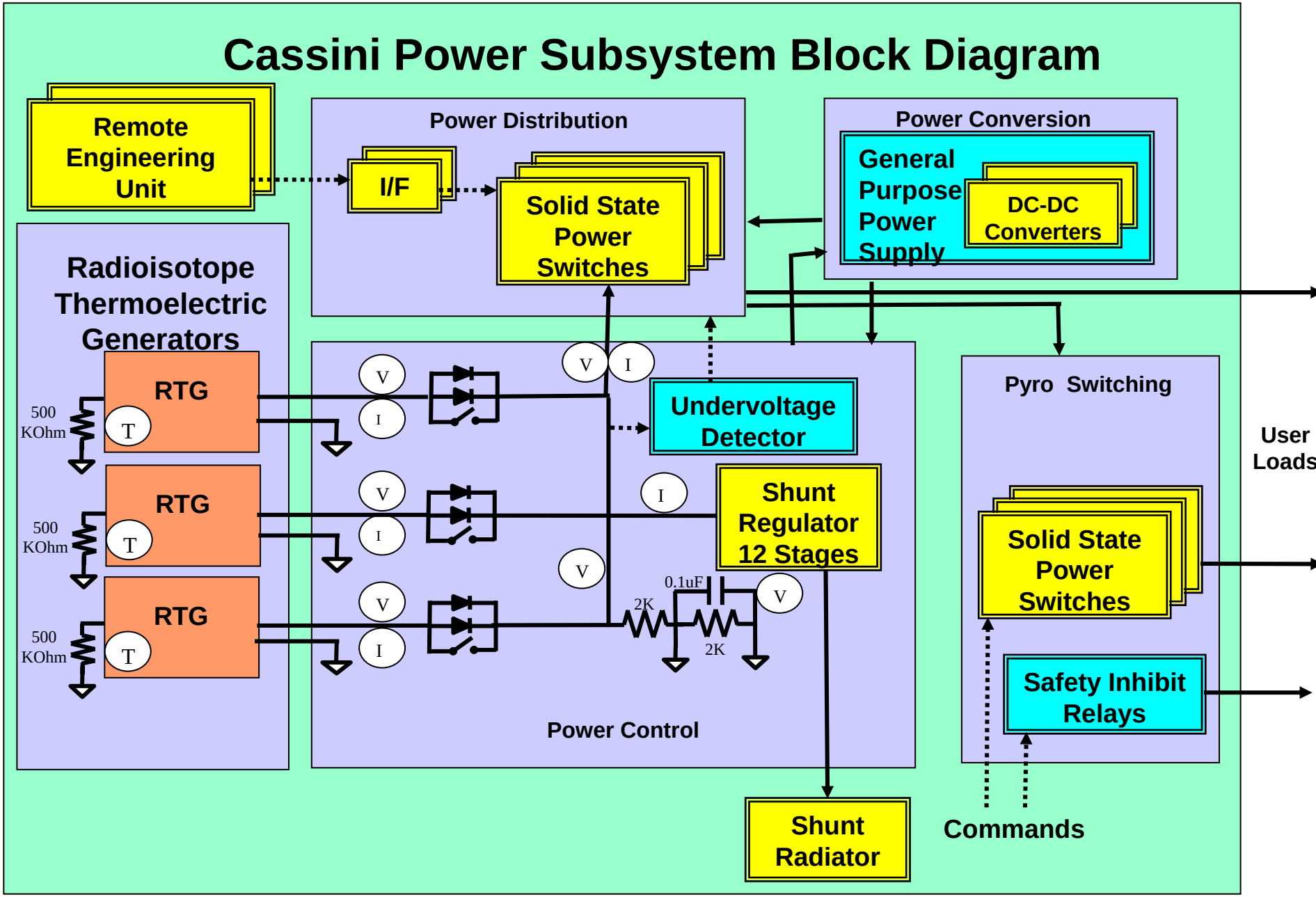




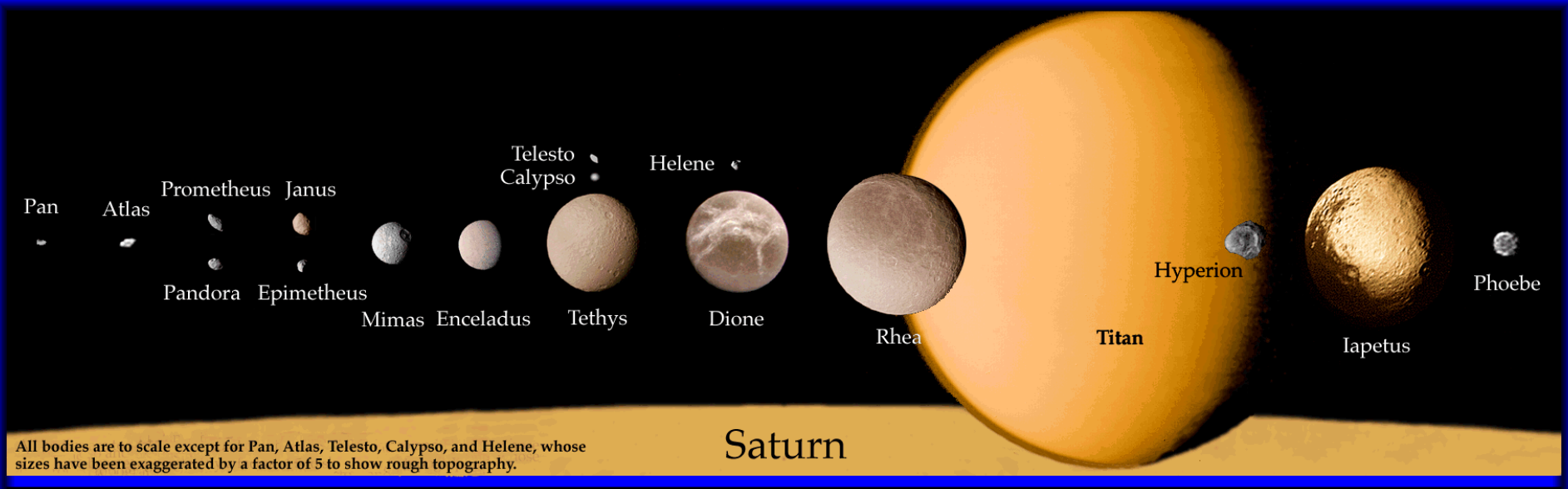


Radioisotope Thermoelectric Generator

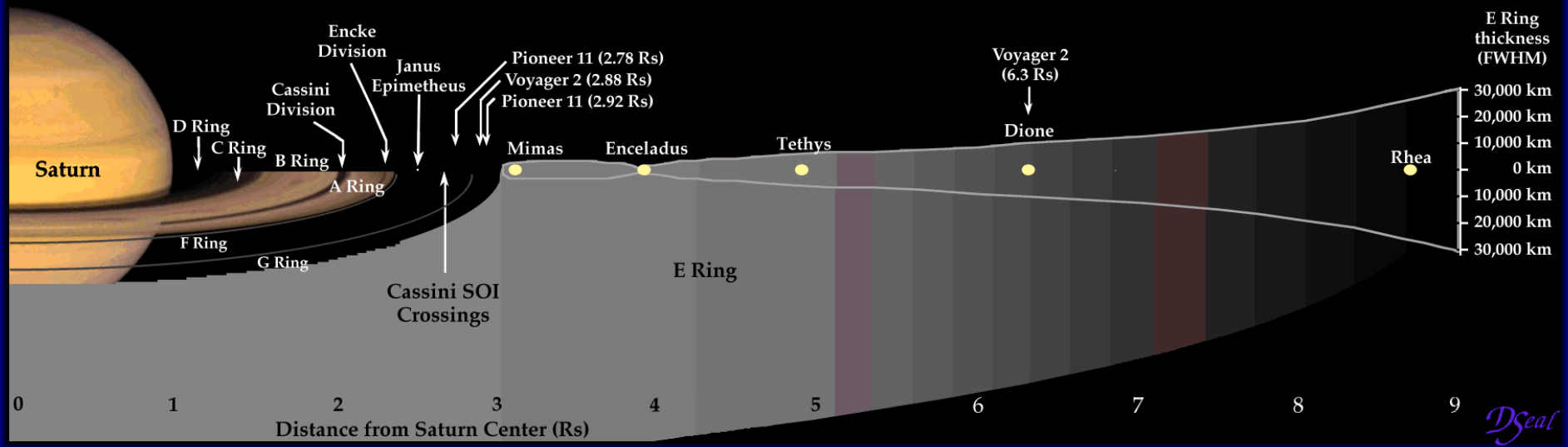



Cassini Power Subsystem Block Diagram
Remote Engineering Unit
Power Distribution
I/F
Solid State Power Switches
Power Conversion
General Purpose Power Supply
DC-DC Converters
Radioisotope Thermoelectric Generators
RTG
RTG
RTG
500 KOhm
500 KOhm
500 KOhm
T
T
T
V
I
V
I
V
I
V
I
Undervoltage Detector
Shunt Regulator 12 Stages
0.1uF
2K
2K
V
V
Power Control
Pyro Switching
Solid State Power Switches
Safety Inhibit Relays
User Loads
Shunt Radiator
Commands

Saturn's Satellites and Ring Structure



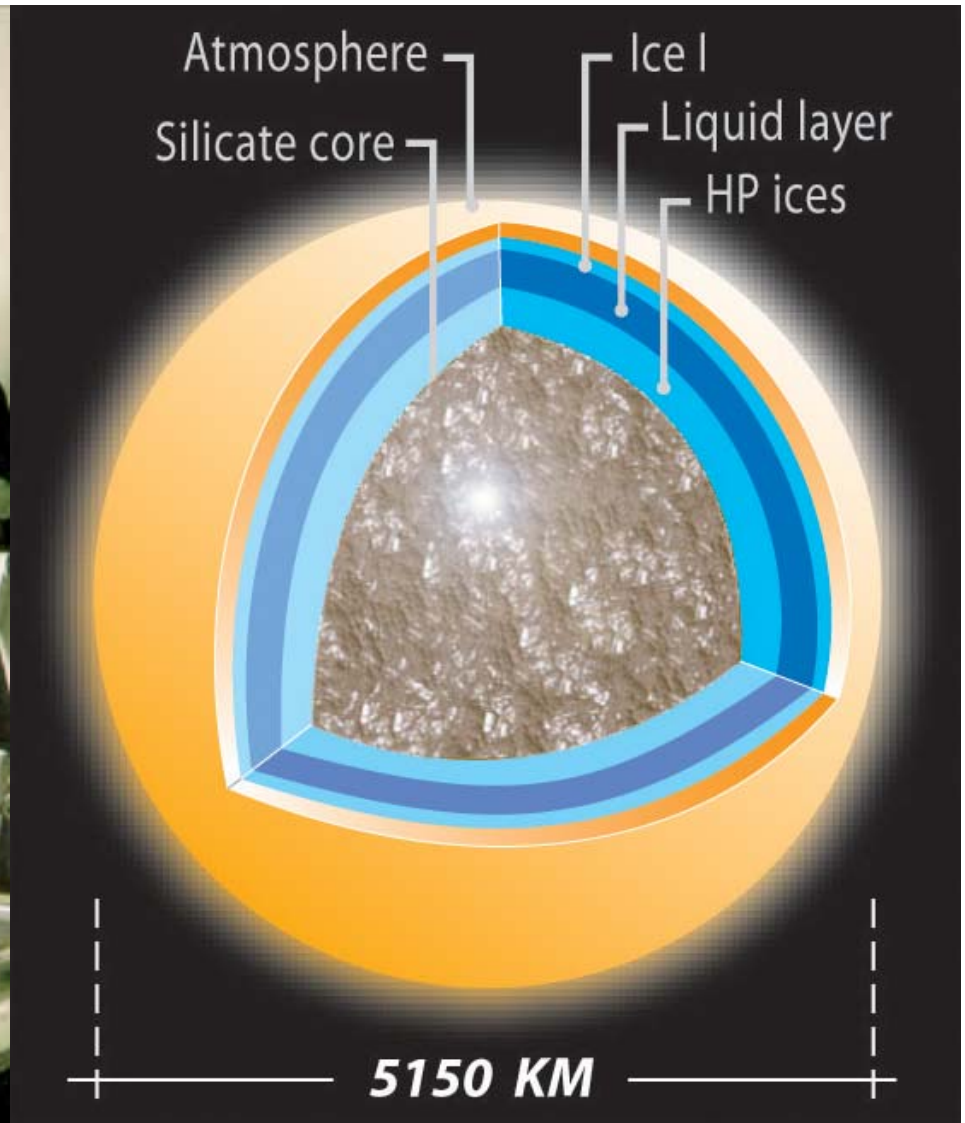
Not shown:				
Pan	2.22 Rs	Titan	20.3 Rs
Atlas	2.28 Rs	Hyperion	24.6 Rs
Prometheus	2.31 Rs	Iapetus	59.1 Rs
Pandora	2.35 Rs	Phoebe	214.9 Rs

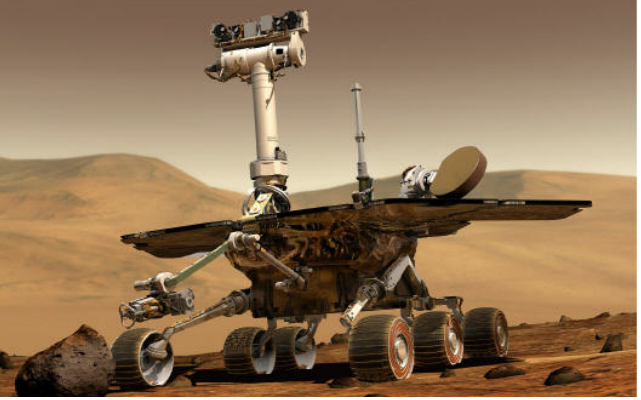


This graphic is available in color if required.

Huygens Probe Injection and Descent

ESA Built Huygens Probe

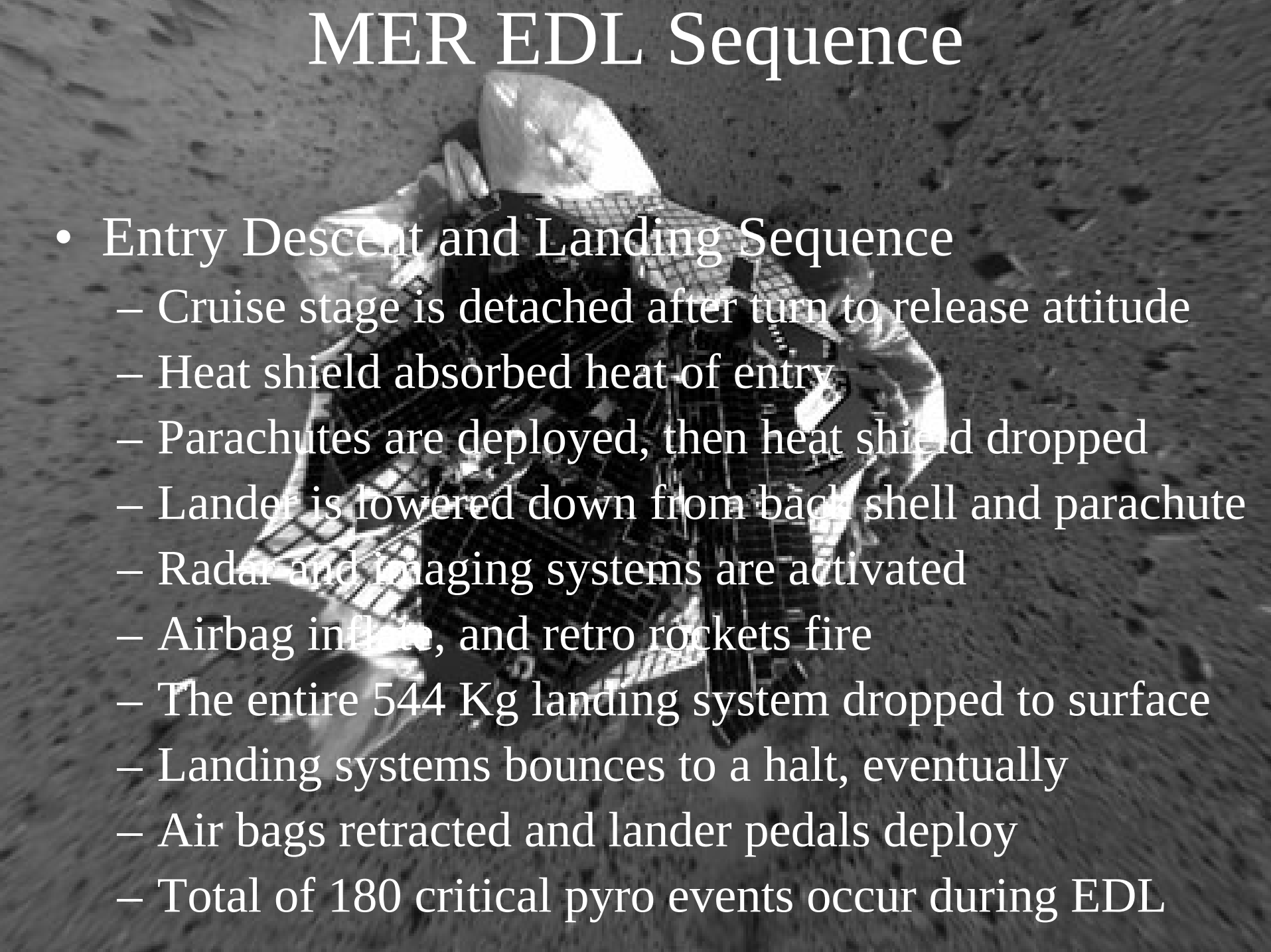




Mars Exploration Rovers

- Two launch occurred in June / July of 2003
- Both Landed successfully in July / August 2004
- Two rovers, working on opposite sides of Mars
- Planned surface mission of 90 days completed
- Both rovers are now in extended missions
- All lifetime expectations have been exceeded
- Limited Solar Power is being worked around
- Drive Motor problems also being worked around

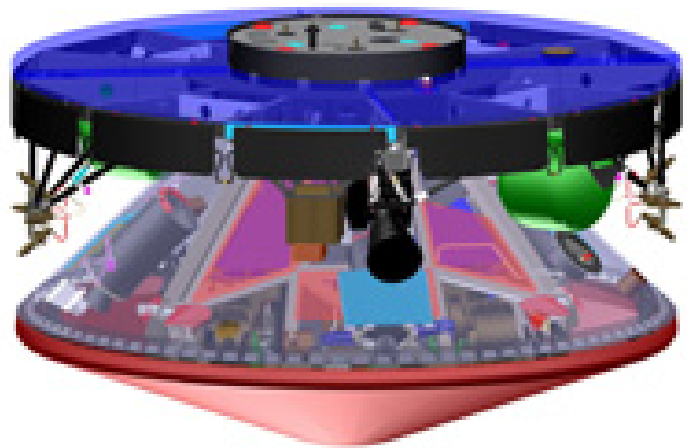
MER EDL Sequence



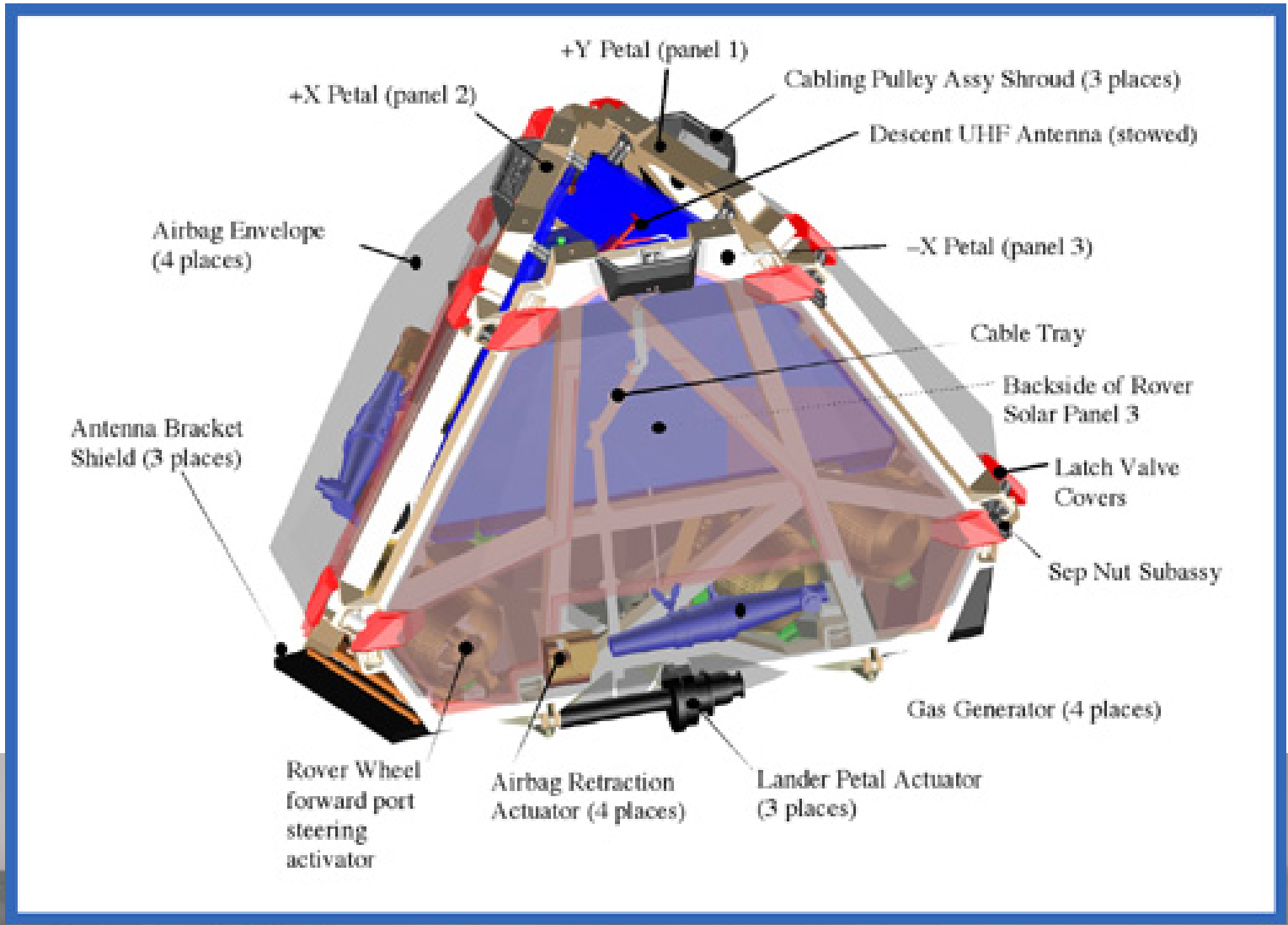
- Entry Descent and Landing Sequence
  - Cruise stage is detached after turn to release attitude
  - Heat shield absorbed heat of entry
  - Parachutes are deployed, then heat shield dropped
  - Lander is lowered down from back shell and parachute
  - Radar and imaging systems are activated
  - Airbag inflate, and retro rockets fire
  - The entire 544 Kg landing system dropped to surface
  - Landing systems bounces to a halt, eventually
  - Air bags retracted and lander pedals deploy
  - Total of 180 critical pyro events occur during EDL

MER Hardware Summary

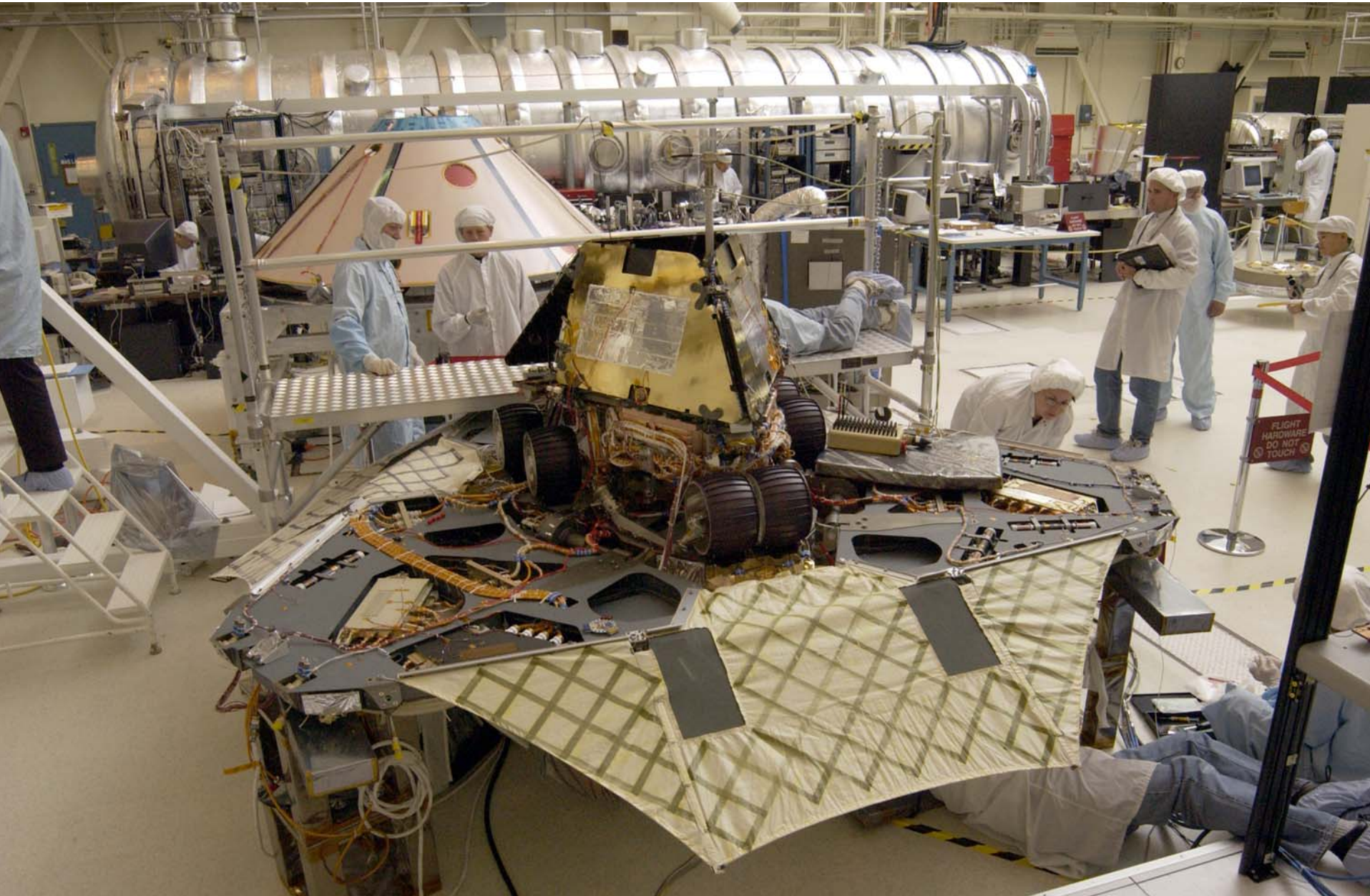
Spacecraft Element	Mass	Power Hardware
Rover	185 kg	TJ Solar Array Lithium Ion Batteries Power Electronics, Pyro
Lander	348 kg	LiSO2 Batteries
Backshell / Parachute	209 kg	Thermal Battery, Pyro
Heat Shield	78 kg	None
Cruise Stage	193 kg	TJ Cruise Array, Shunts
Propellant	50 kg	
Total System Mass	1063 kg	



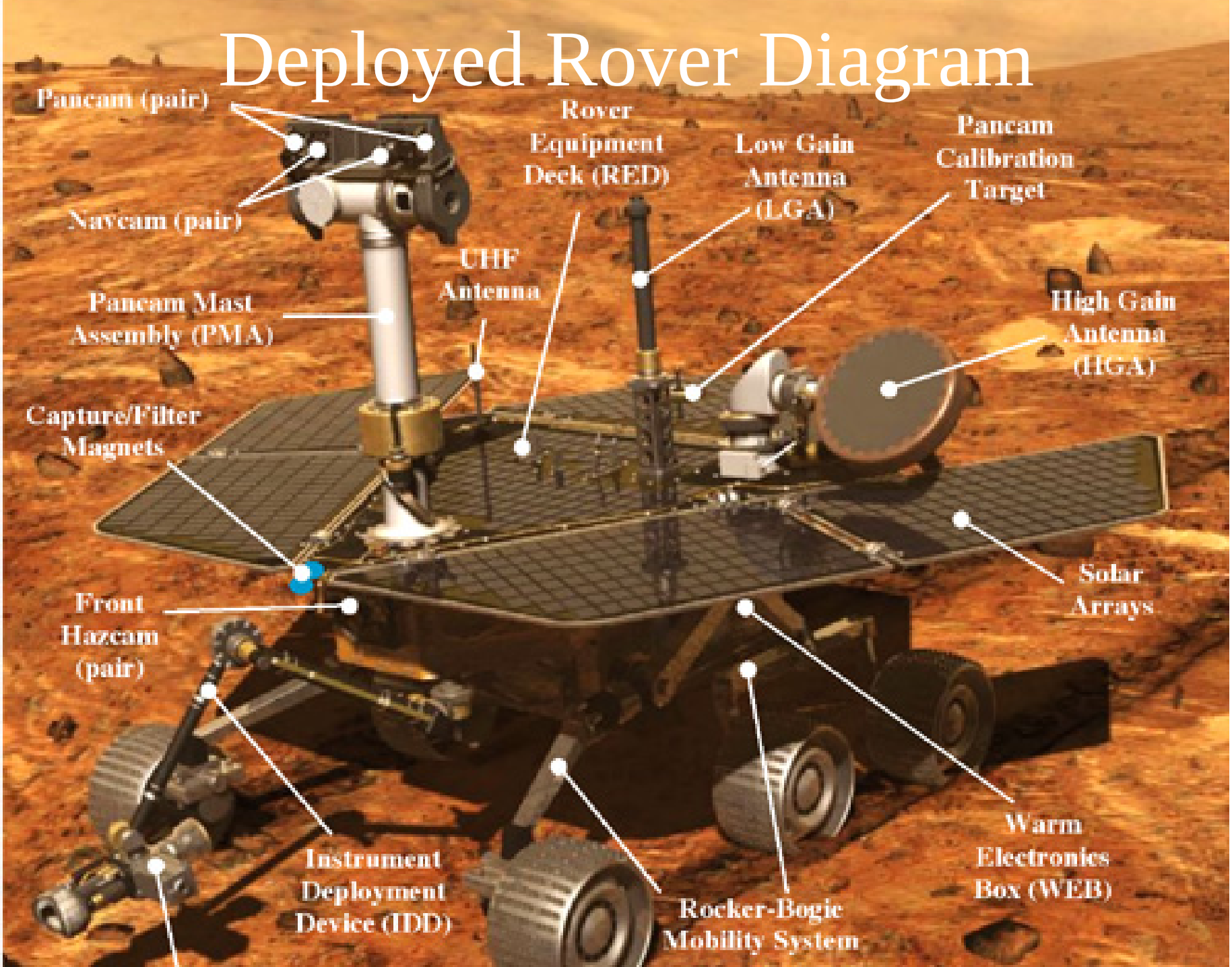
Landing System Diagram



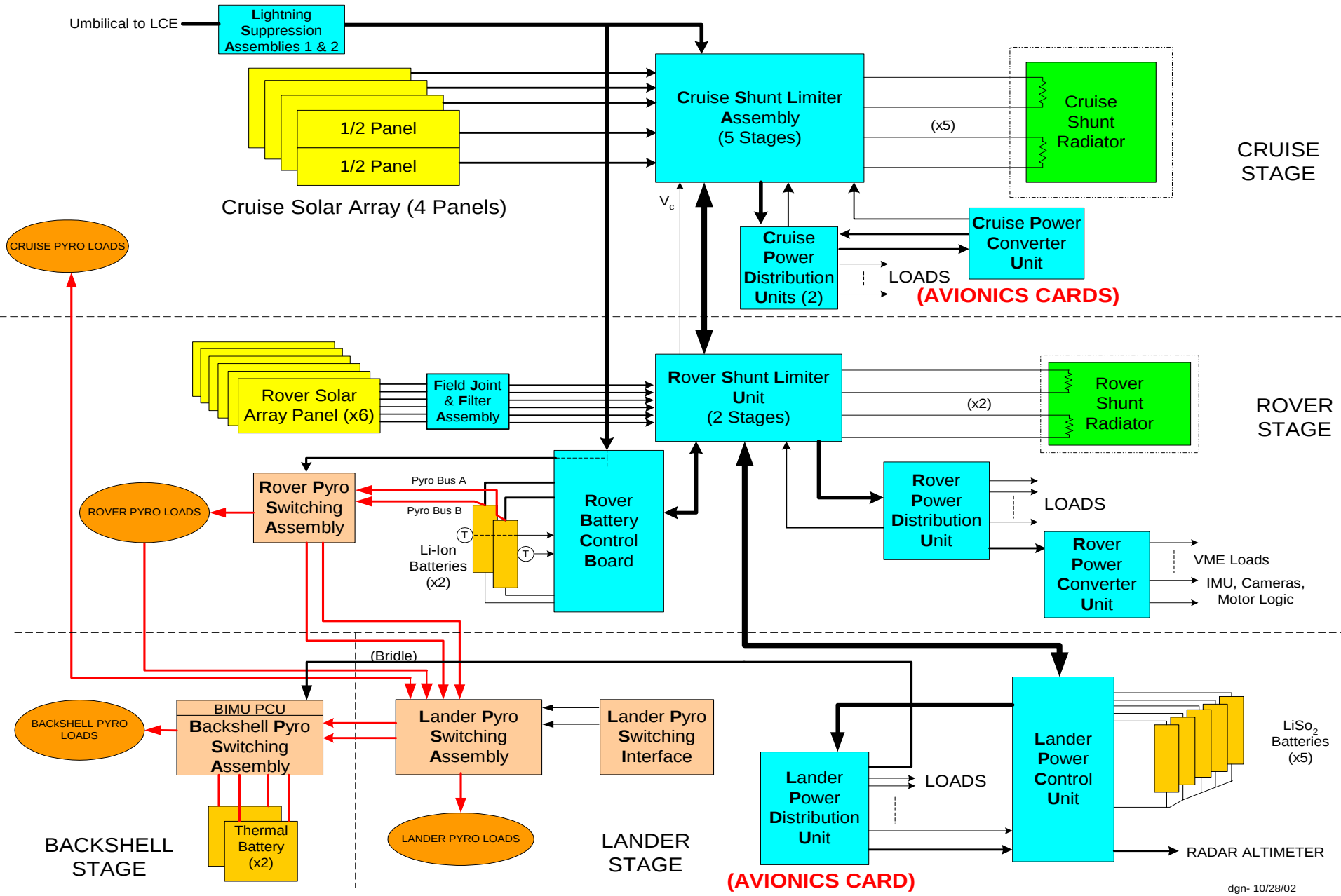
Undeployed Rover on Open Lander



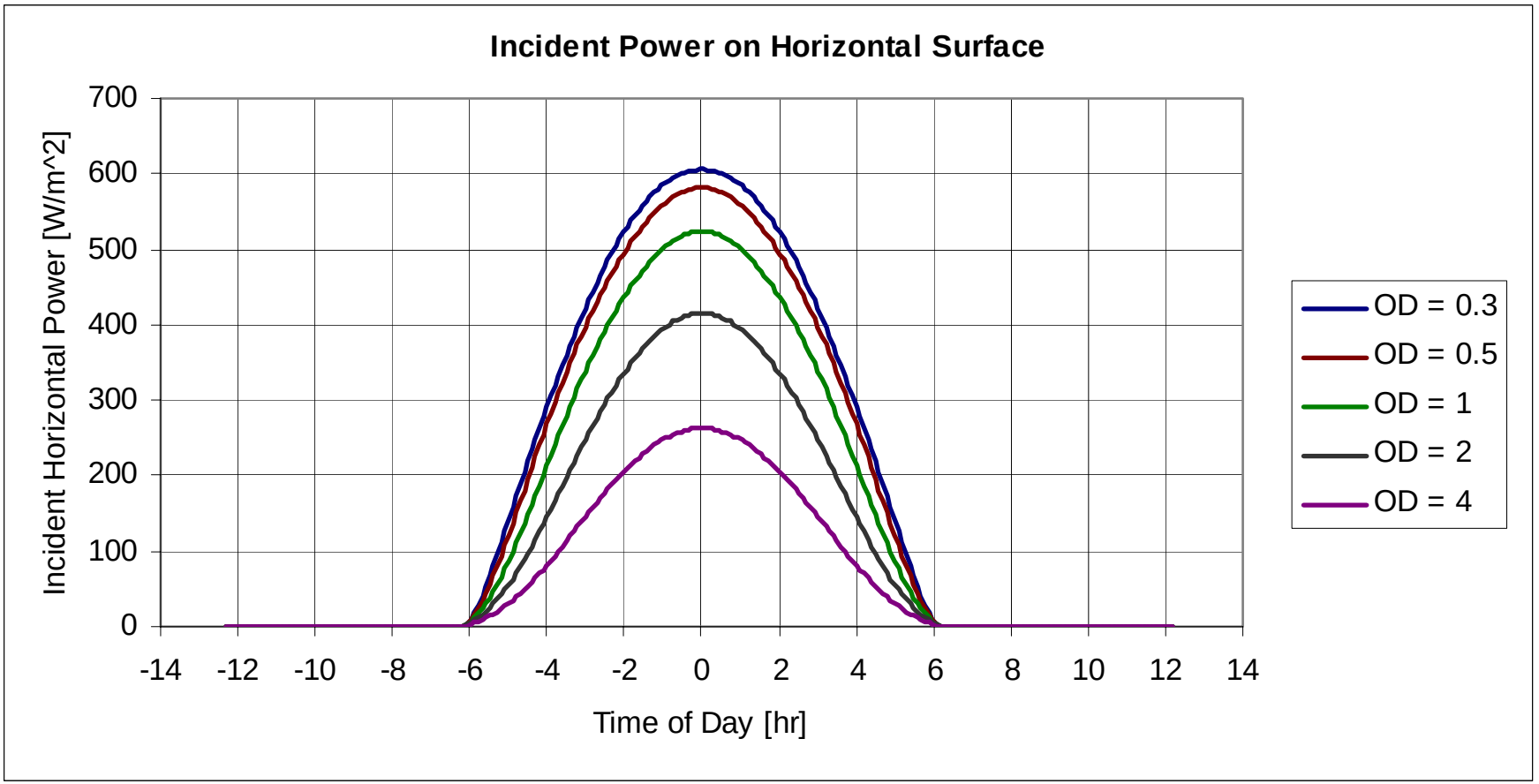
Deployed Rover Diagram



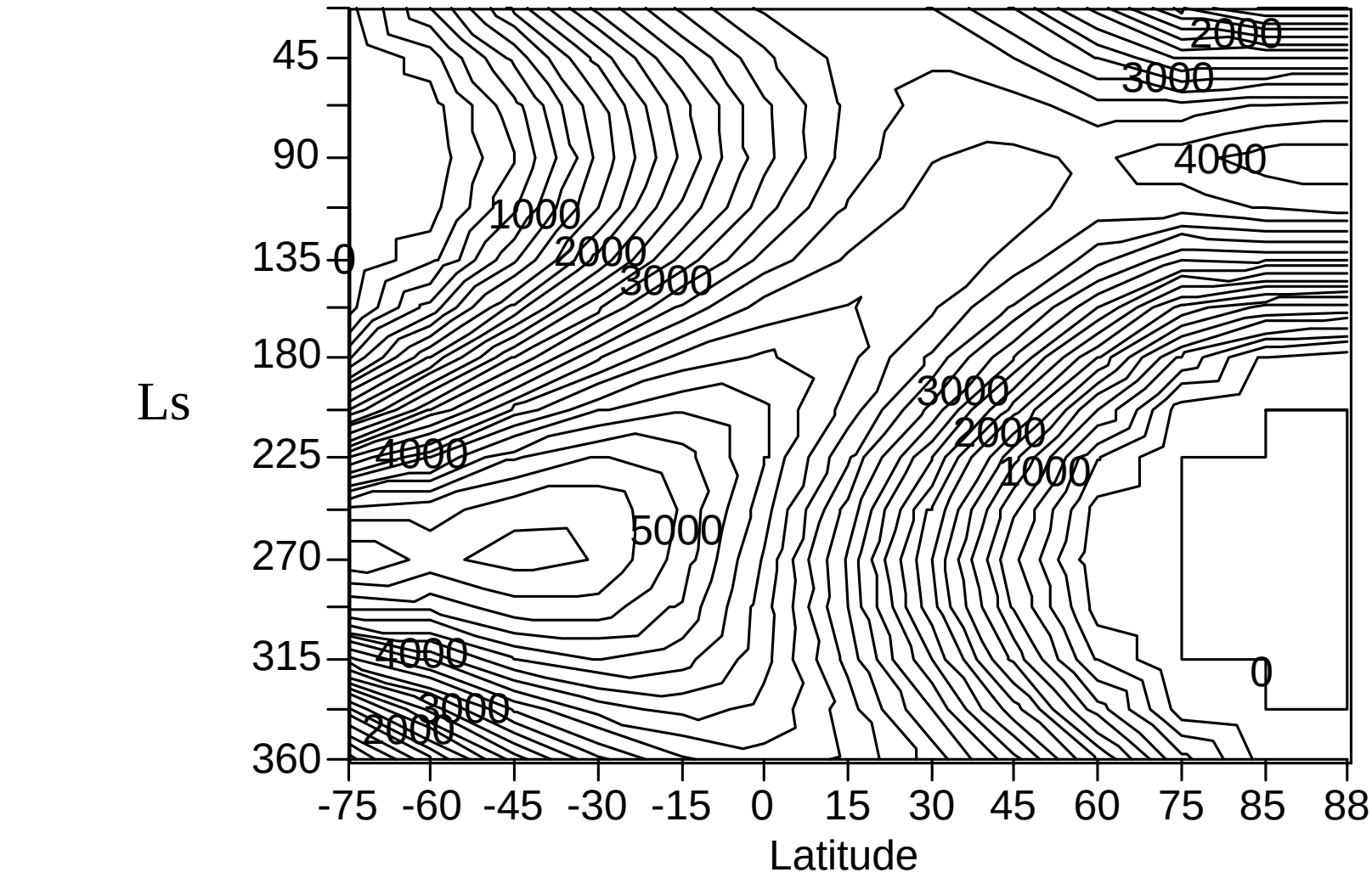
Functional Block Diagram

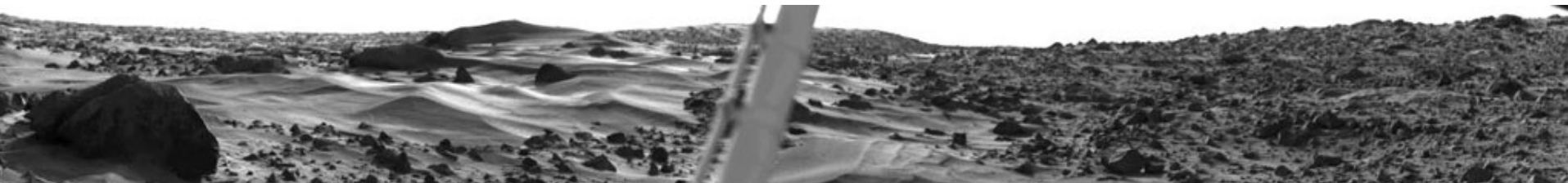


Mars Atmospheric Dust Effects



Seasonal Solar Availability (WH/M^2/sol)





Your Mileage May Vary