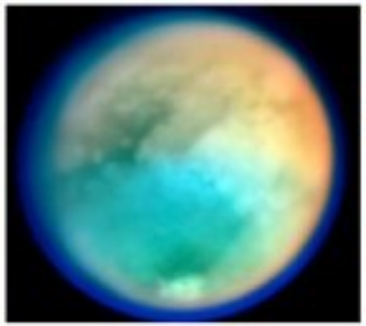
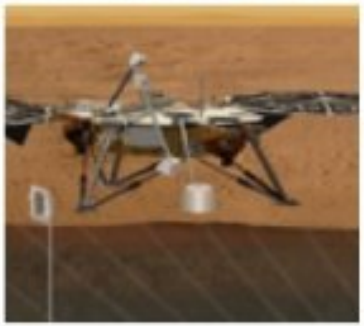




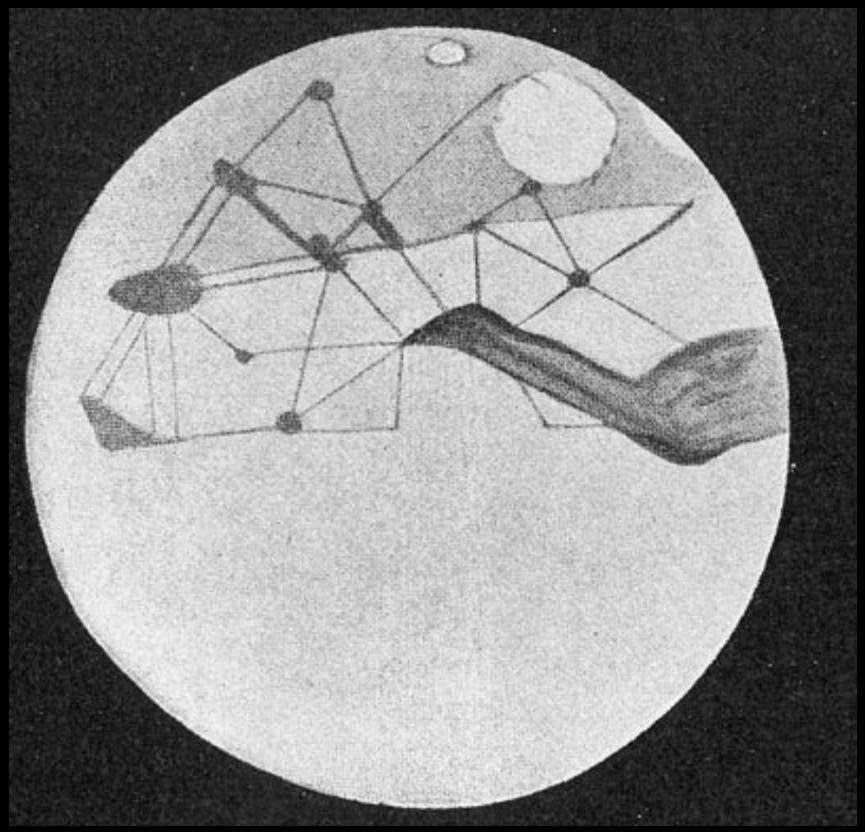
The Next 50 Years of Planetary Exploration with Probes

James A. Cutts

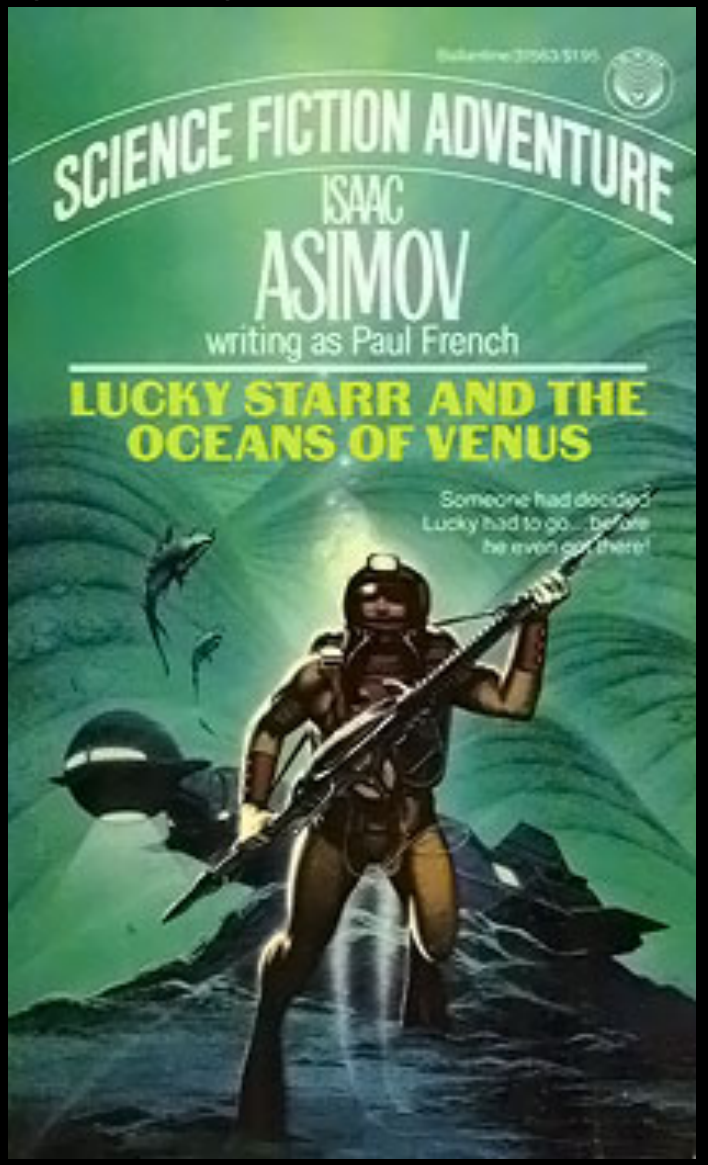
Jet Propulsion Laboratory

California Institute of Technology

Mars and Venus in the pre spacecraft era

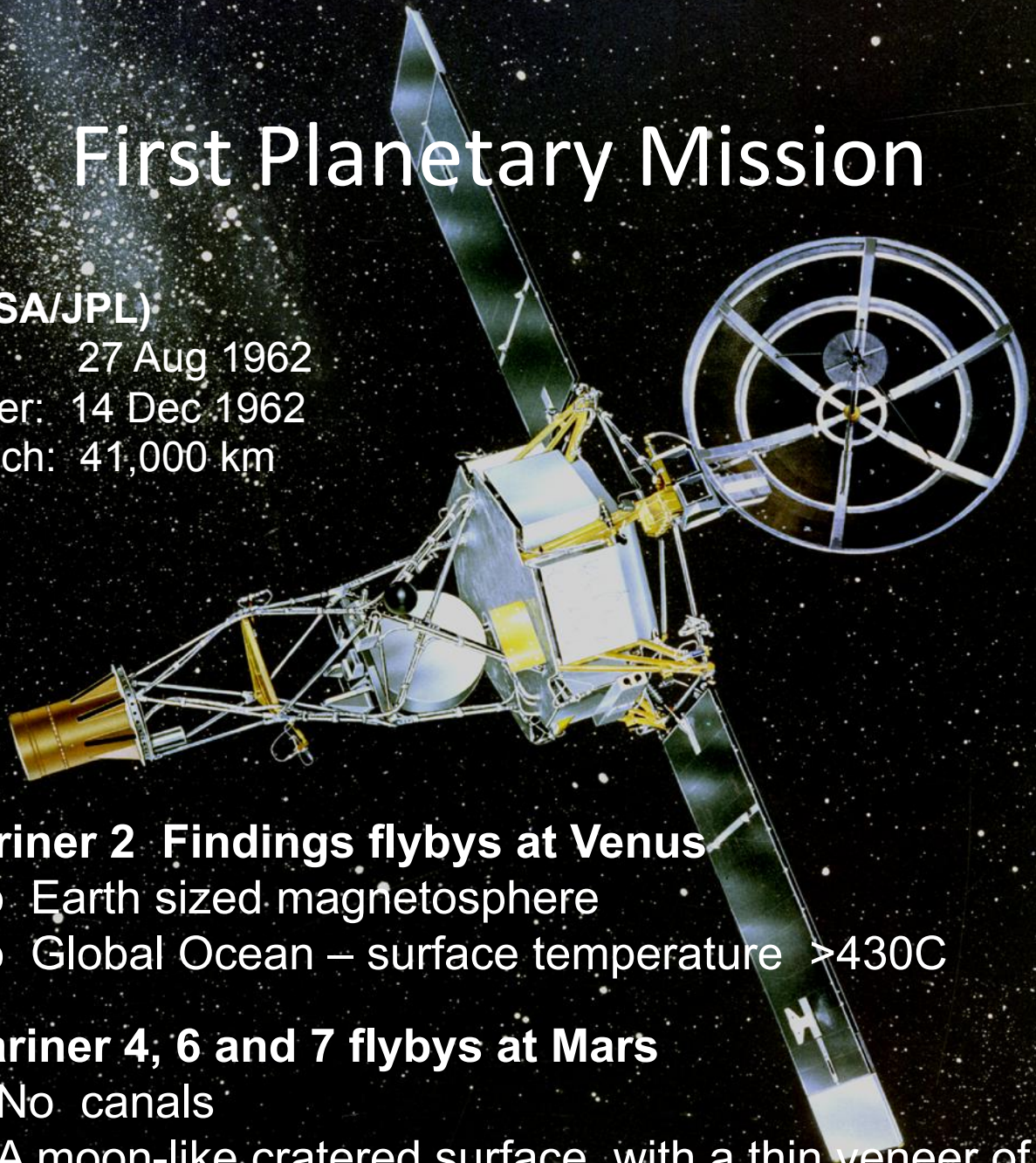


Martian canals as perceived
by Percival Lowell



First Planetary Mission

Mariner 2 (NASA/JPL)
Launch: 27 Aug 1962
Venus encounter: 14 Dec 1962
Closest approach: 41,000 km

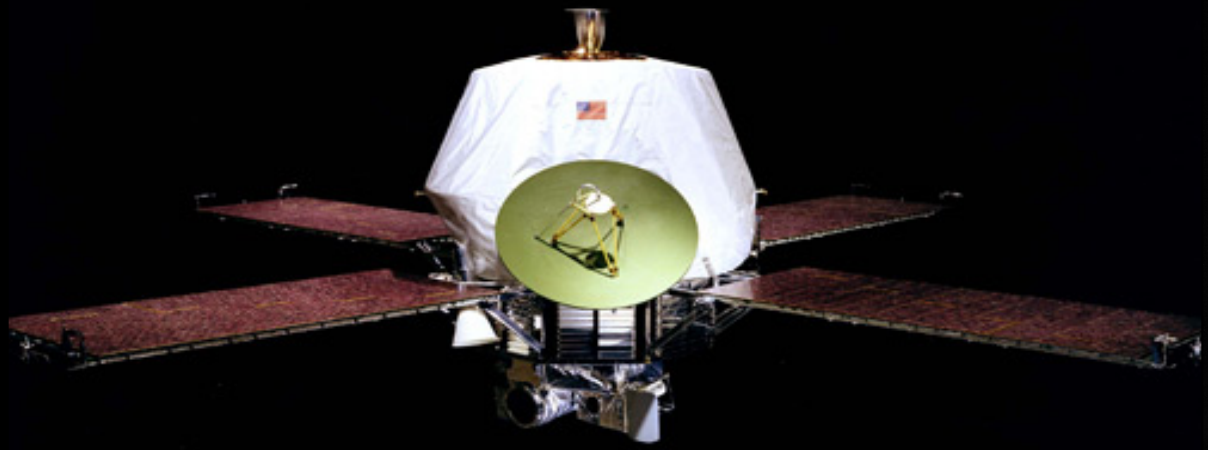


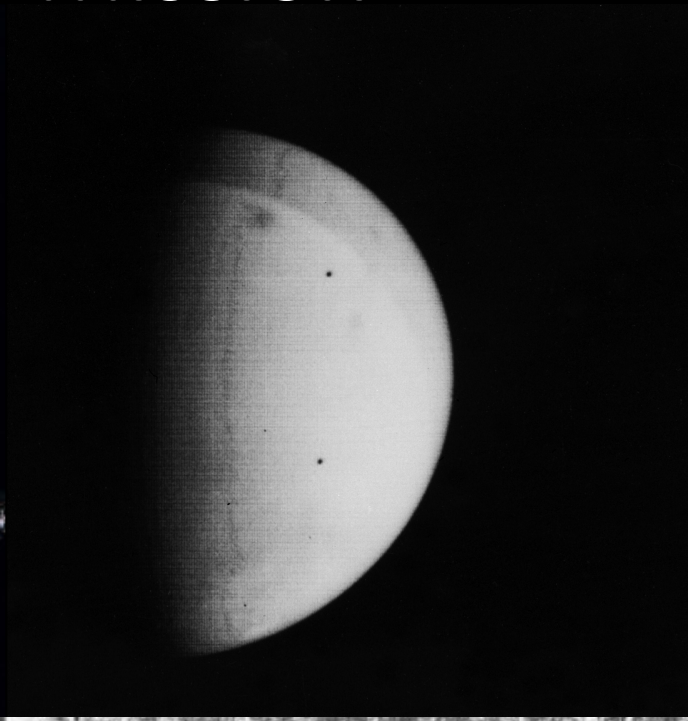
Mariner 2 Findings flybys at Venus
- No Earth sized magnetosphere
- No Global Ocean – surface temperature >430C

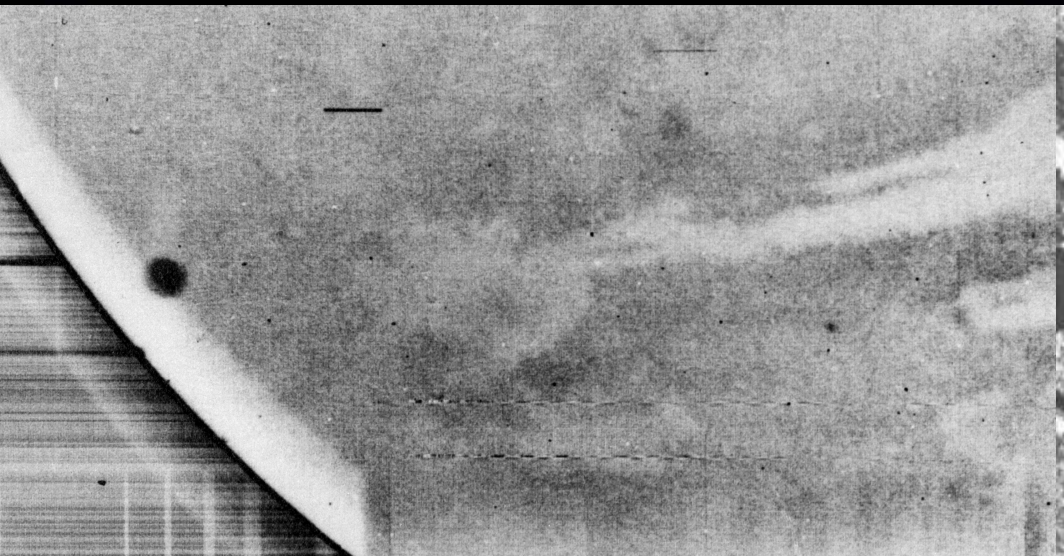
Mariner 4, 6 and 7 flybys at Mars
- No canals
- A moon-like cratered surface with a thin veneer of windblown dust

First Planetary Orbiter Mission

Mariner 9 (NASA/JPL)
Entered Mars Orbit on 13 Nov 1971



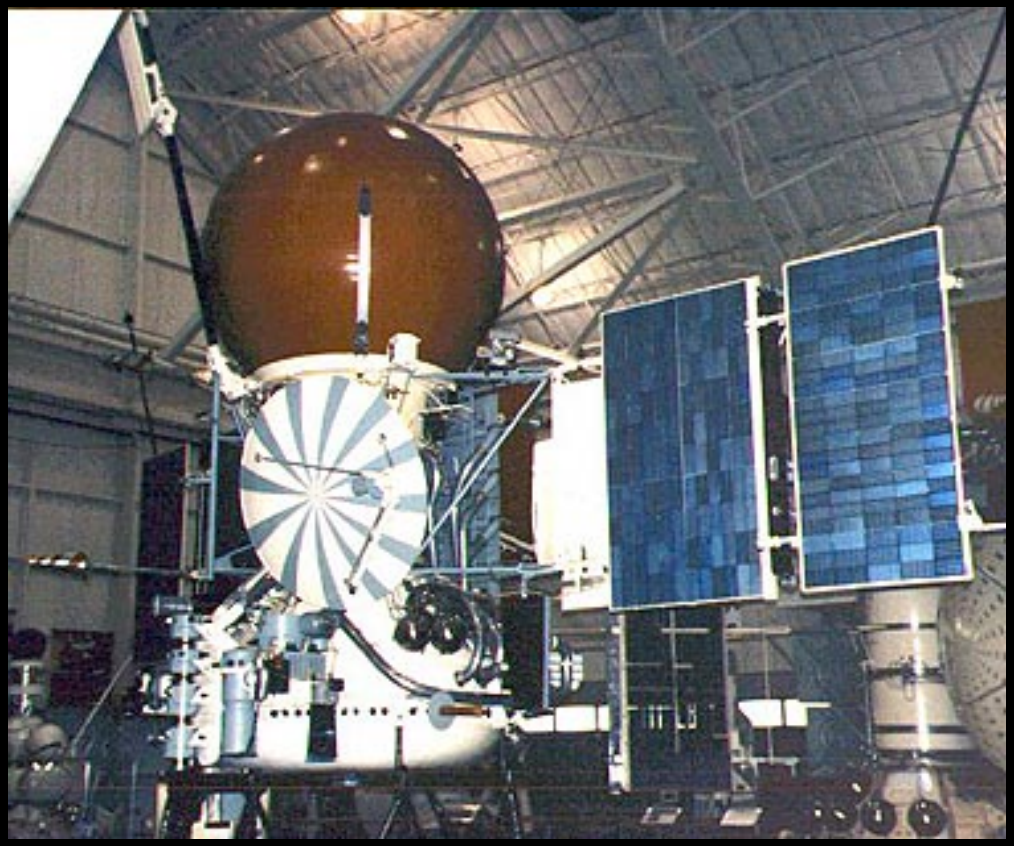




Venus Exploration by USSR

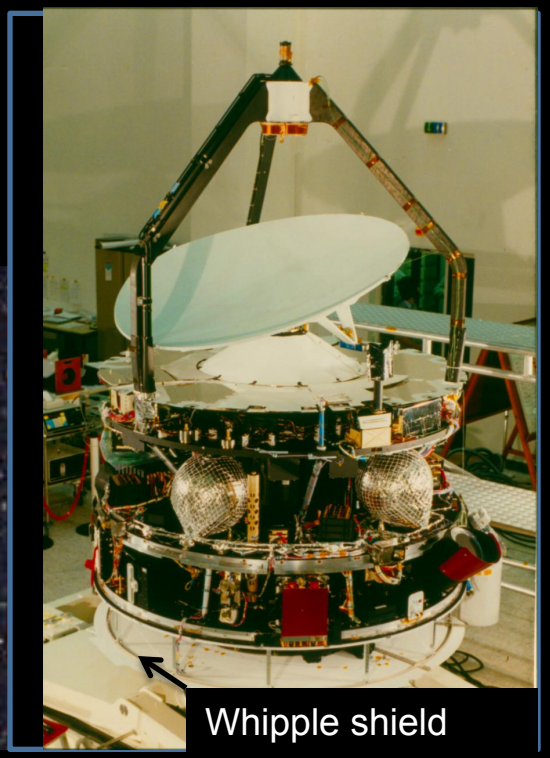
- 15 successful missions between 1967 and 1984

- Included flybys, orbiters, atmospheric probes, balloons and landers.



Giotto – Mission to Halley's Comet (ESA)

Giotto (ESA)
Launch: 2 July 1985
Flyby March 6 1986



Whipple shield

Halley Armada
Giotto (ESA)
Vega 1 (USSR)
Vega 2 (USSR)
Sakigake (Japan)
Suisei (Japan

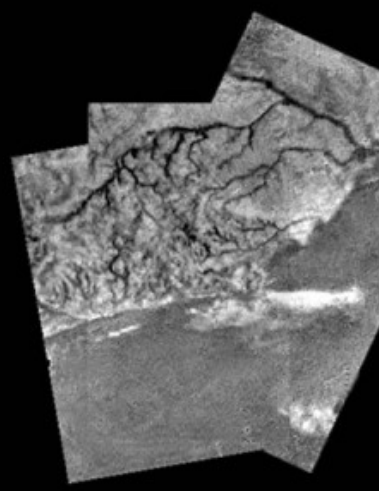
Giotto
Fly by distance
590 km

Approach speed
68 km/sec

Outer Planet Exploration

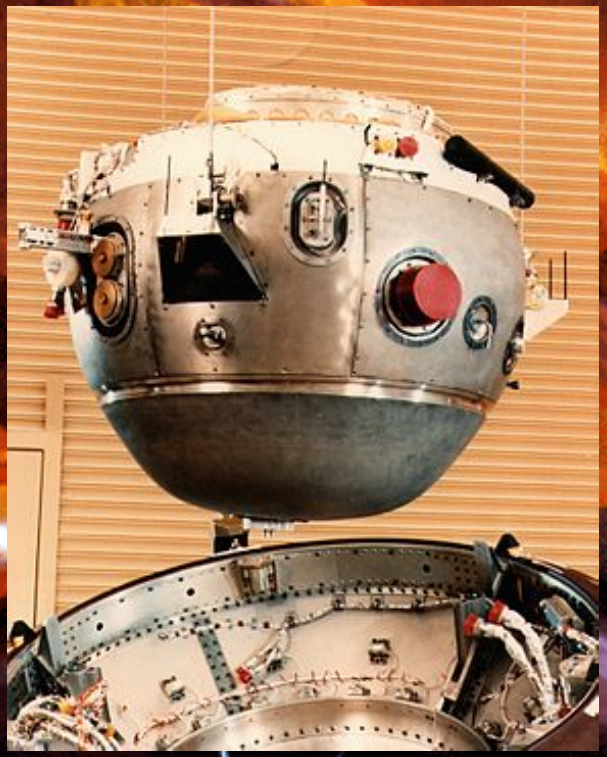
Fly By Missions
Pioneer 10
Pioneer 11
Voyager 1
Voyager 2
New Horizons

Orbiter Missions
Galileo
Cassini /Huygens
Juno



Galileo – First probe into a gas giant's atmosphere

Key Entry Parameters
Entry speed: 47.8 km/sec
Peak Deceleration: 230g



Heat Shield Performance
Probe Mass: 339 kg
Heat Shield Mass: 152 kg
Ablated Mass: 80 kg

Scientific Results

- Measured temperature profile during entry/descent
- Determined noble gas abundances and isotope ratios
- Measured winds and turbulence during descent
- Determined cloud properties in situ

Mobile Exploration of Mars

Mars Exploration Rovers

Event	Spirit	Opportunity
Launch	Jun 10 '03	Jul 7 '03
Landing	Jan 3 '04	Jan 24 '04
Site	Gusev	Meridiani
Distance (km)	7.73	34.47+

Iron rich spherule in layered rock,Meridiani, Mars

"Homestake" gypsum vein Endeavor crater, Mars,

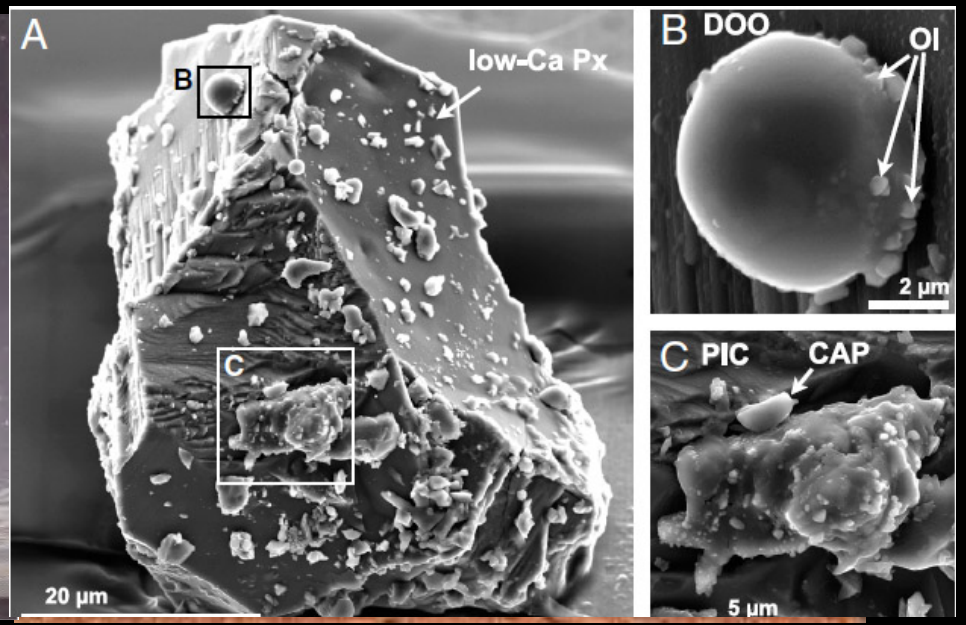
First sample return from an asteroid

Hayabusa Spacecraft at Asteroid Itakawa

Hayabusa's Seven Year Odyssey

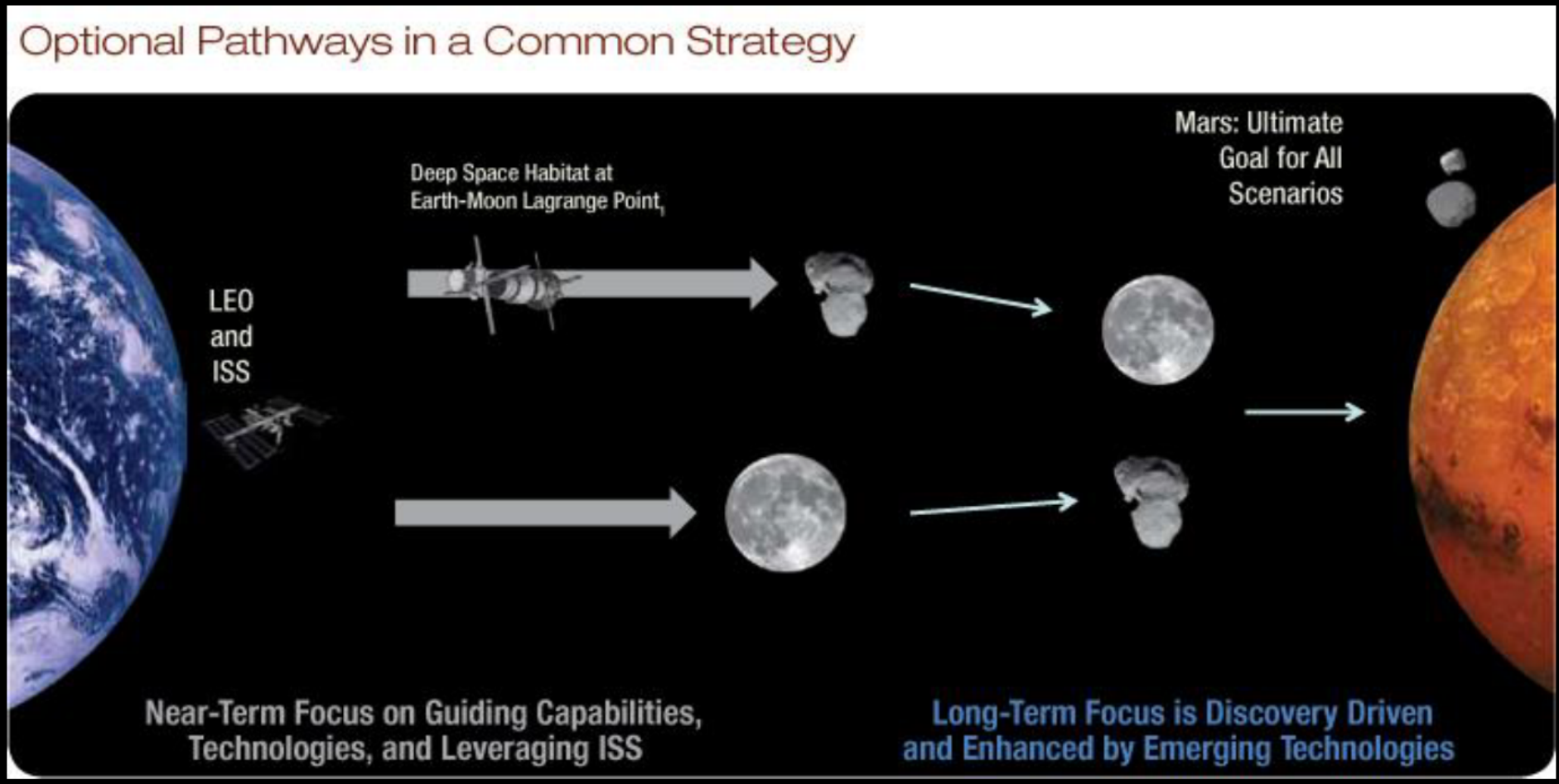
- **May 2003 Launch from Kagoshima, Japan**
- Nov 2003 Spacecraft damaged by solar flare
- July 2005 Reaction wheel damaged
- Nov 2005 Second touchdown on Hayabusa - Hydrazine leak
- Dec 2005 Loss of attitude control and communications
- Nov 2009 Ion thruster failure and recovery
- **June 2010 Safe landing in Australia**

Hayabusa Reentry Fireball, June 13 2010



The Next Fifty Years

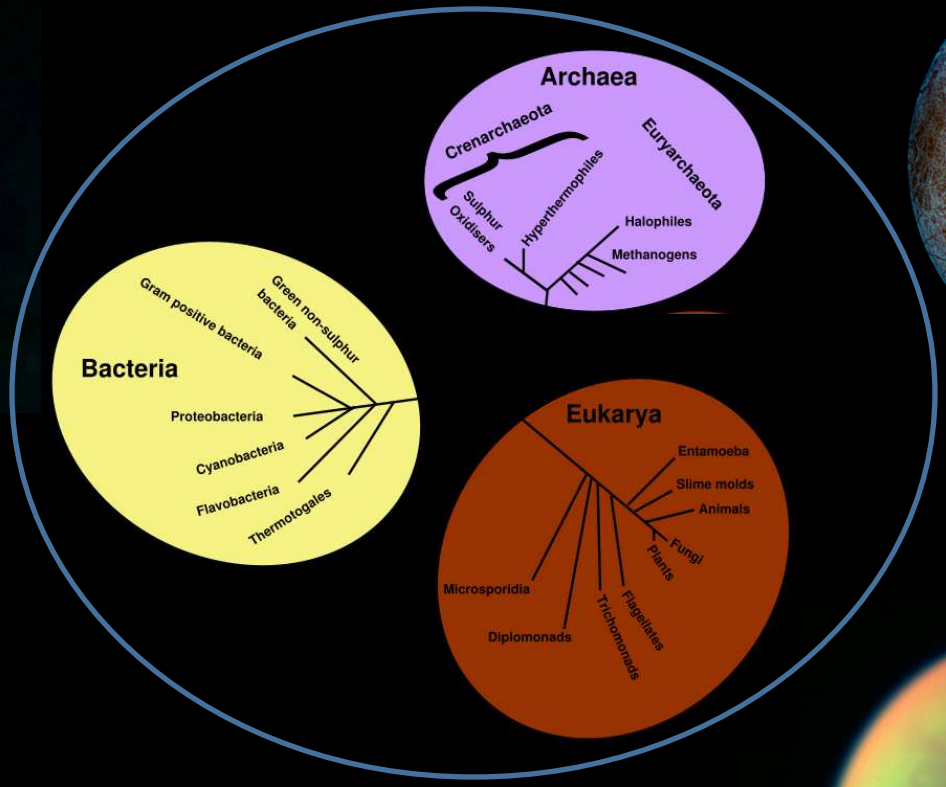
Human Exploration Strategy



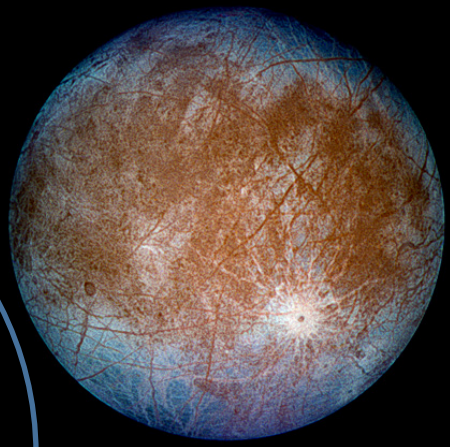
From presentation by Clive Neal at the Global Space Exploration Conference 2012

Robotic Exploration Strategy
The Search for Life

Mars

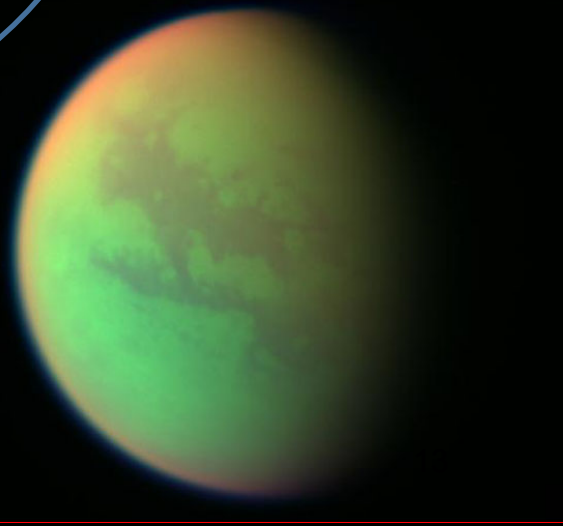


The Tree of Life



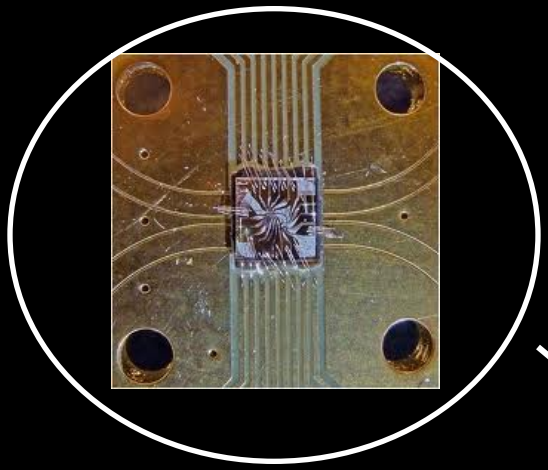
Europa

Enceladus



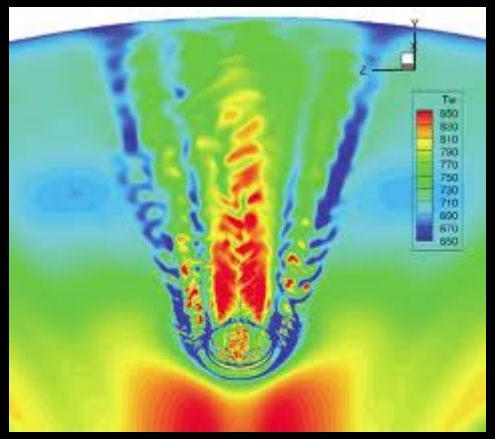
Titan

Riding the Information Technology Wave

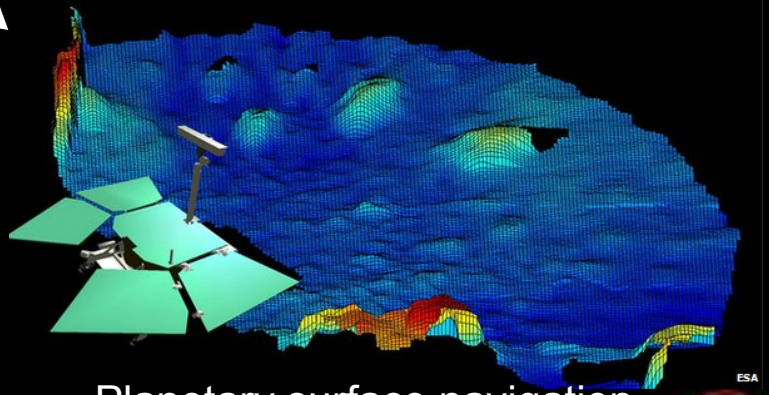


Key technical drivers

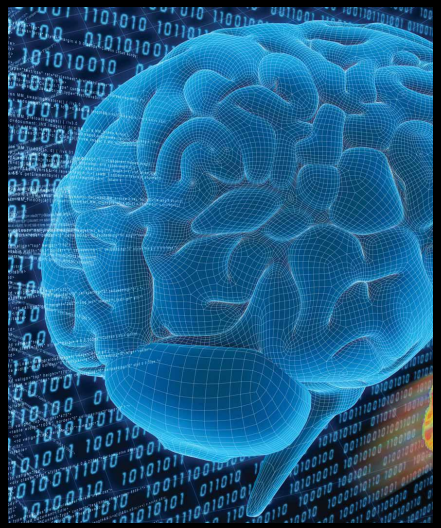
- Miniaturization
- New Devices
- Software
- Ground Systems
- Space Systems



Modeling and simulation



Planetary surface navigation



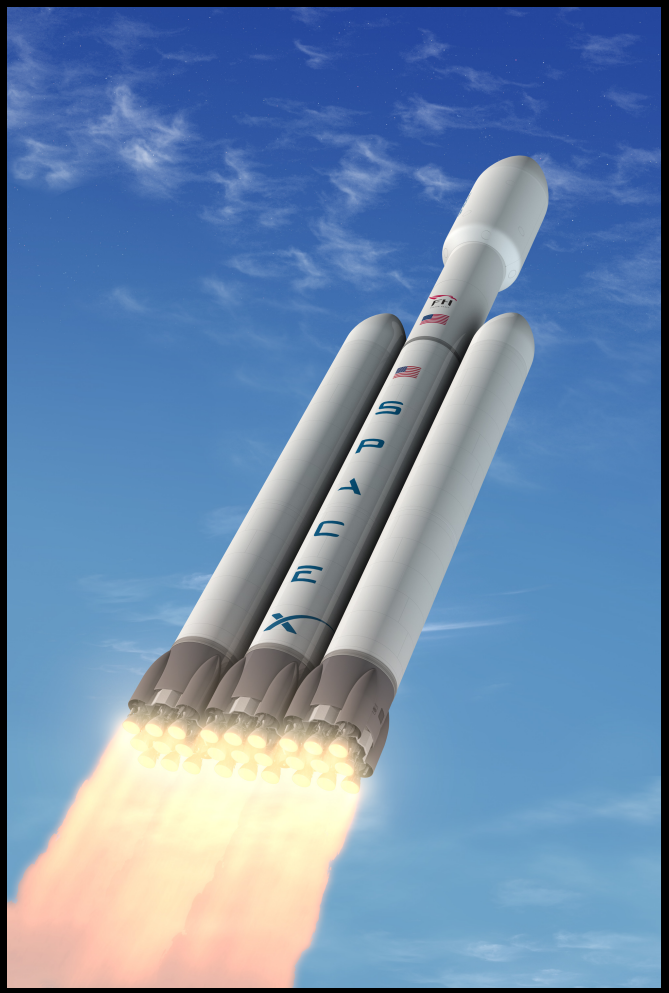
Autonomous surface science

Science Data analysis

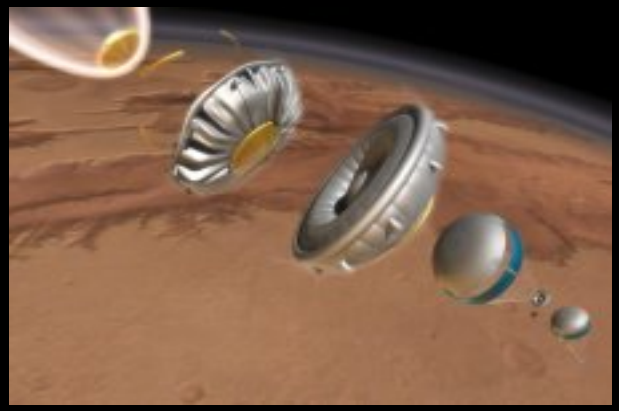
Planetary mission navigation

Emerging Capabilities at NASA

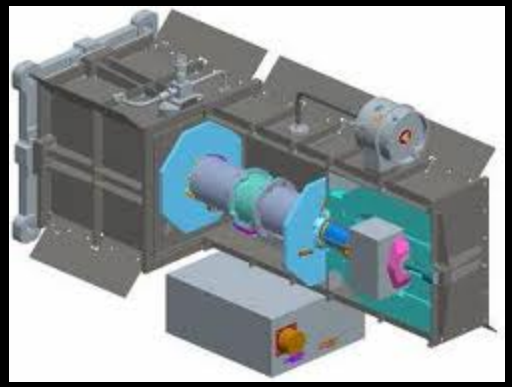
Sunjammer Solar Sail



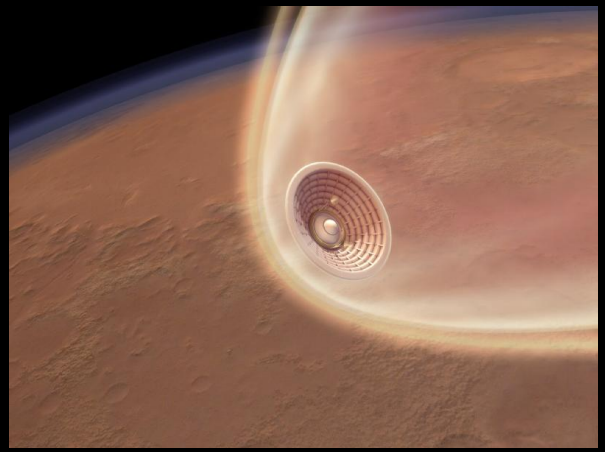
Falcon Heavy –biggest LV since Saturn V



Low Density Supersonic Decelerator (LDSD)

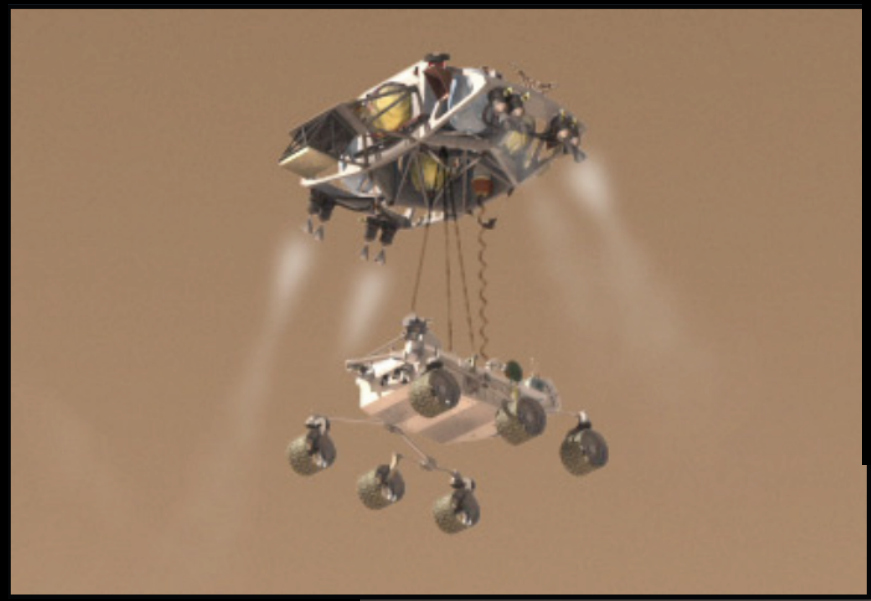


Advanced Stirling Radioisotopic Generator (ASRG)



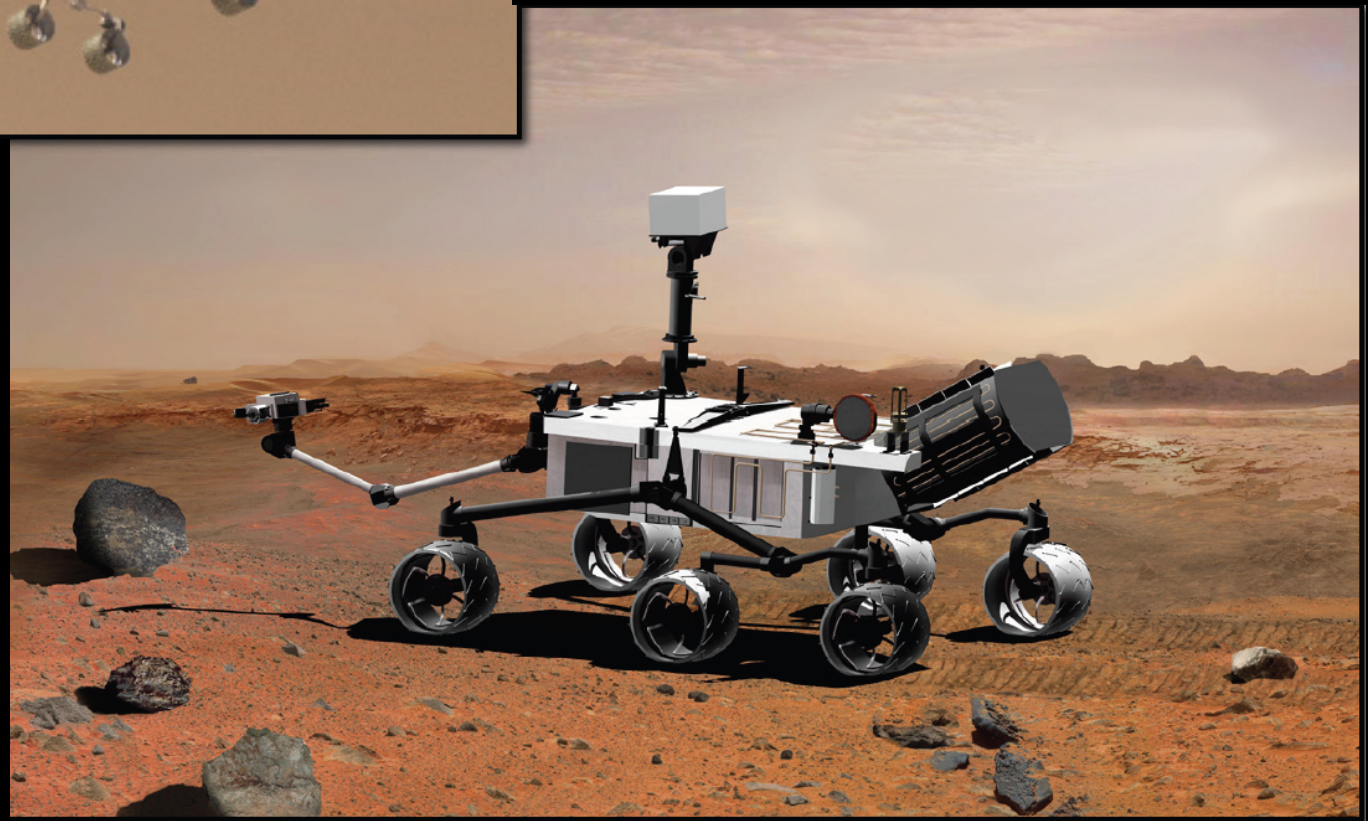
Hypersonic Inflatable Aerodynamic Decelerator (HIAD)

Planetary Exploration – the Next 50 days



Mars Science Laboratory
"Sky crane" landing system

Curiosity Rover



New International Players

Chang'e 1

Chandrayaan 1

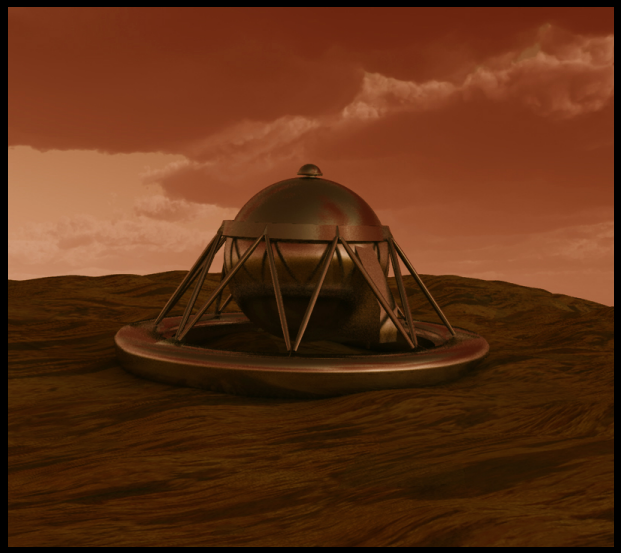
Yinghuo-1

Chandrayaan 2

CHINA

INDIA

International Venus Exploration



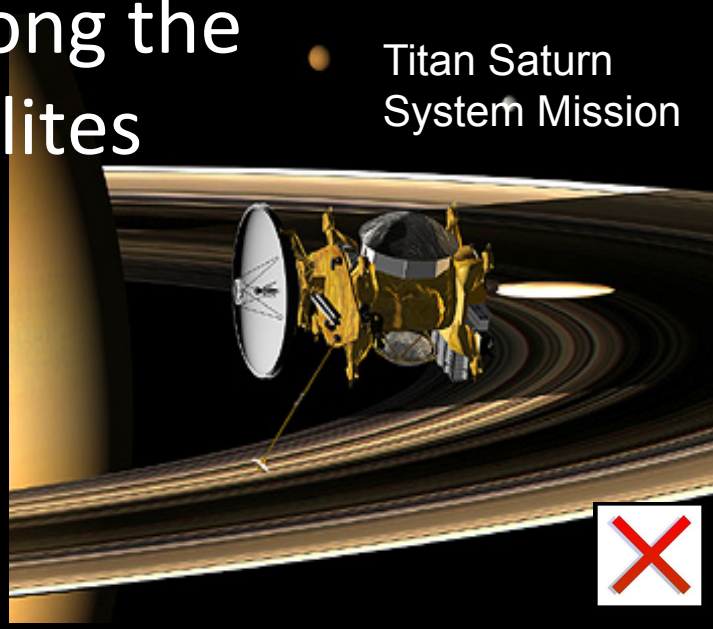
Why Venus?

- Proximity to earth
- Relevance to climate change
- Multiple mission modes needed
- Missions can be loosely coupled

Searching for life among the outer planet satellites

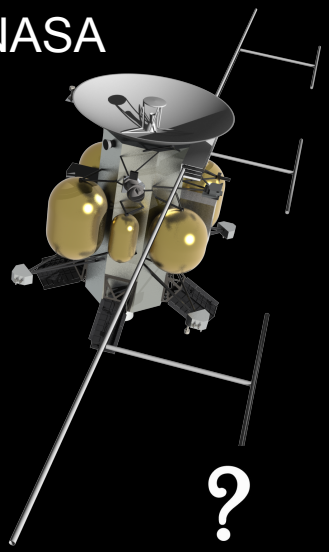
Europa Jupiter System Mission

Titan Saturn System Mission



ESA

NASA



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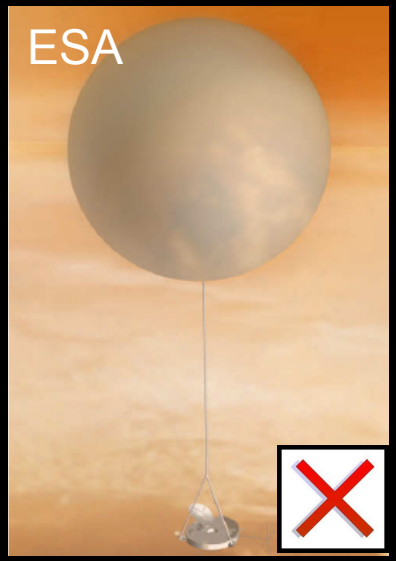
ESA



NASA

?

Prognosis

- Technology investments at NASA have emerged at just the right time to revitalize planetary exploration
- Human and robotic exploration have become intertwined for future Mars initiatives
- Involvement of China and India in human exploration is positive for Mars exploration
- Immediate future will be dominated by smaller largely competitive missions in Europe and USA
- This is not sustainable for the longer term and larger strategic missions are going to be ultimately needed

Acknowledgements

- Mark Adler
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