Future of Exploration and Discovery

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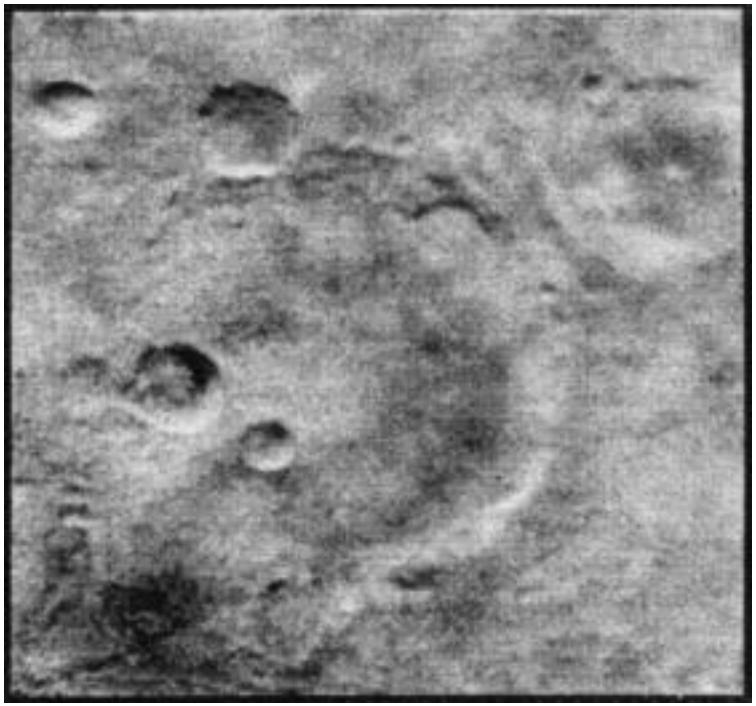
Robotic Exploration: How far we have come



Mariner 4, Mars, 1965

Curiosity Rover, Mars, 2015

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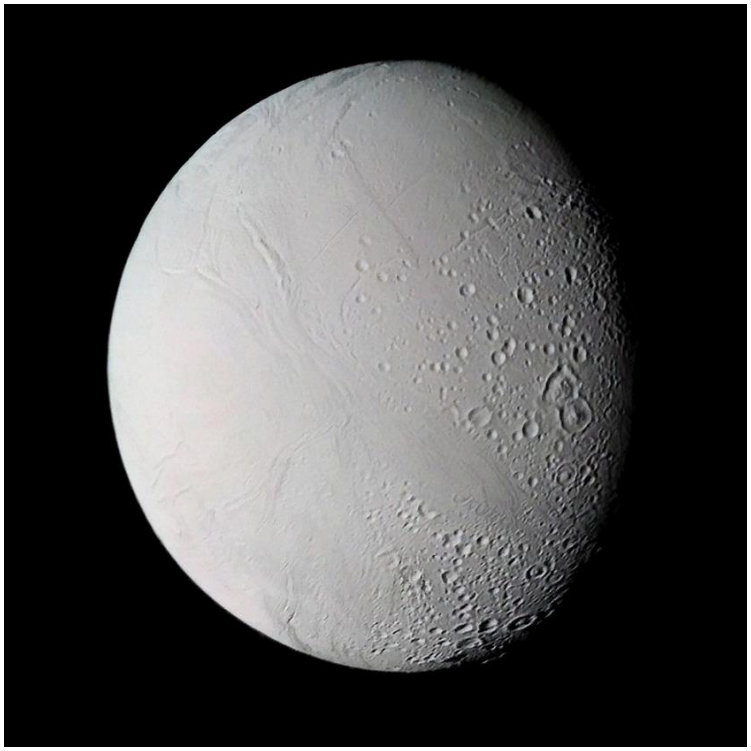
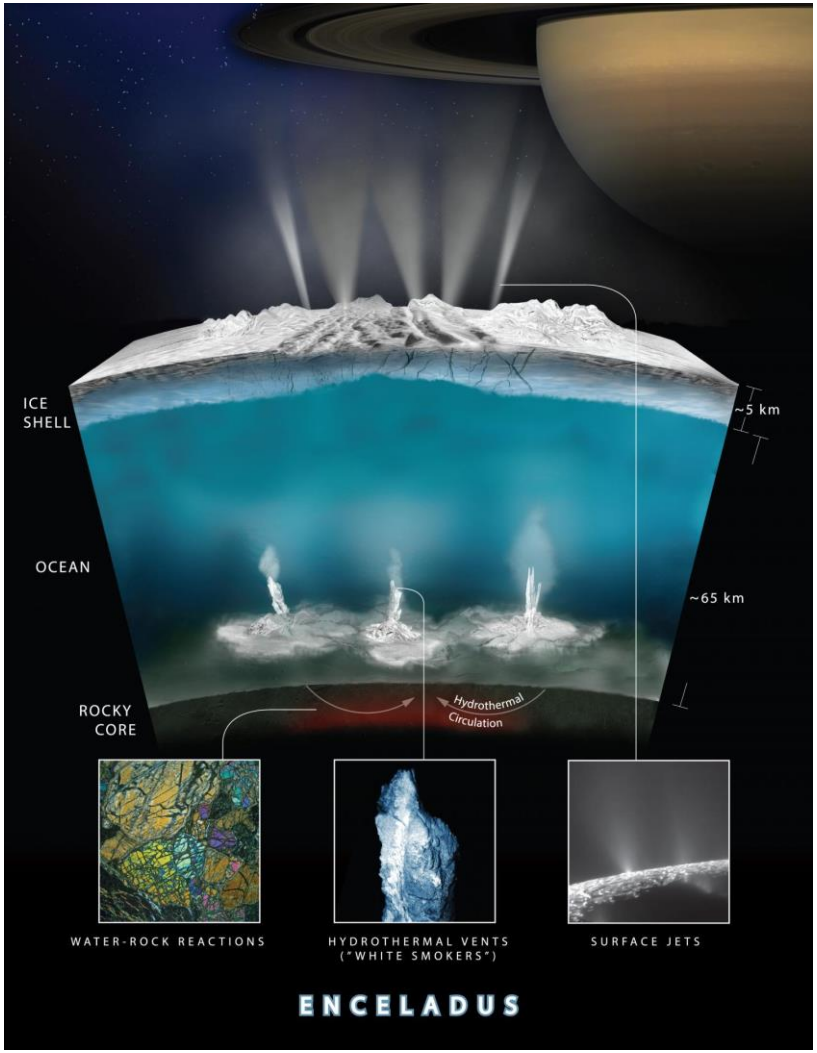


Voyager 2, Enceladus, 1981



Cassini, Enceladus, 2015

But with each giant leap the follow-up becomes either more focused or more expensive:

Pioneer 11, Saturn 1979 flyby:

- F-ring
- Magnetic field
- Titan cold and hazy
- Excess heat from Saturn

Voyager 1 and 2, 1980, 81 flyby:

- Dense N_2 atmosphere on Titan
- Enceladus bright and smooth
- Complex geology on Saturn's moons
- Intricate ring structure
- Shepherd moons

Cassini-Huygens, 2004-2017, orbiter and lander

- Methane hydrologic cycle on Titan with rivers, lakes, seas, dunes, subsurface water ocean
- Enceladus plume evidencing habitable/hydrothermal salty ocean
- Complex ring-moon interactions; vertical ring structure
- Saturn convective atmosphere, hurricanes, hexagon
- Slippage in Saturn magnetospheric rotation
- Ambiguous helium depletion; Z-element enrichm.

Titan lander/boat?

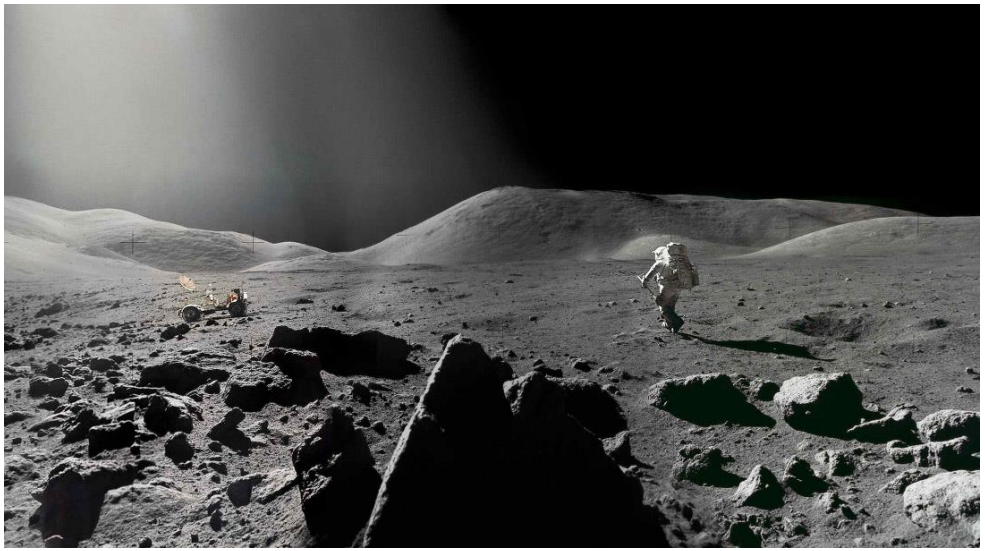
Enceladus life search?

Saturn atmospheric probe?

Saturn ring probe?

Meanwhile, in human spaceflight……

LEO 1961-1969



Lunar and LEO 1968-1972

LEO only 1973-present:
There is a general sense that we're "stuck".

What are the new paradigms that will get humans *out of* low Earth orbit, and allow for ever-more-daring exploration of the solar system?

- Lower LV costs?
- Faster trip times?
- Novel human/robotic synergies?
- Novel approaches to the science?
- Novel commercial arrangements?
- Greater acceptance of risk?

Amundsen at the South pole, 19