Presentation at the KISS Workshop on

Engineering Resilient Space Systems: Leveraging Novel System Engineering Techniques and Software Architectures

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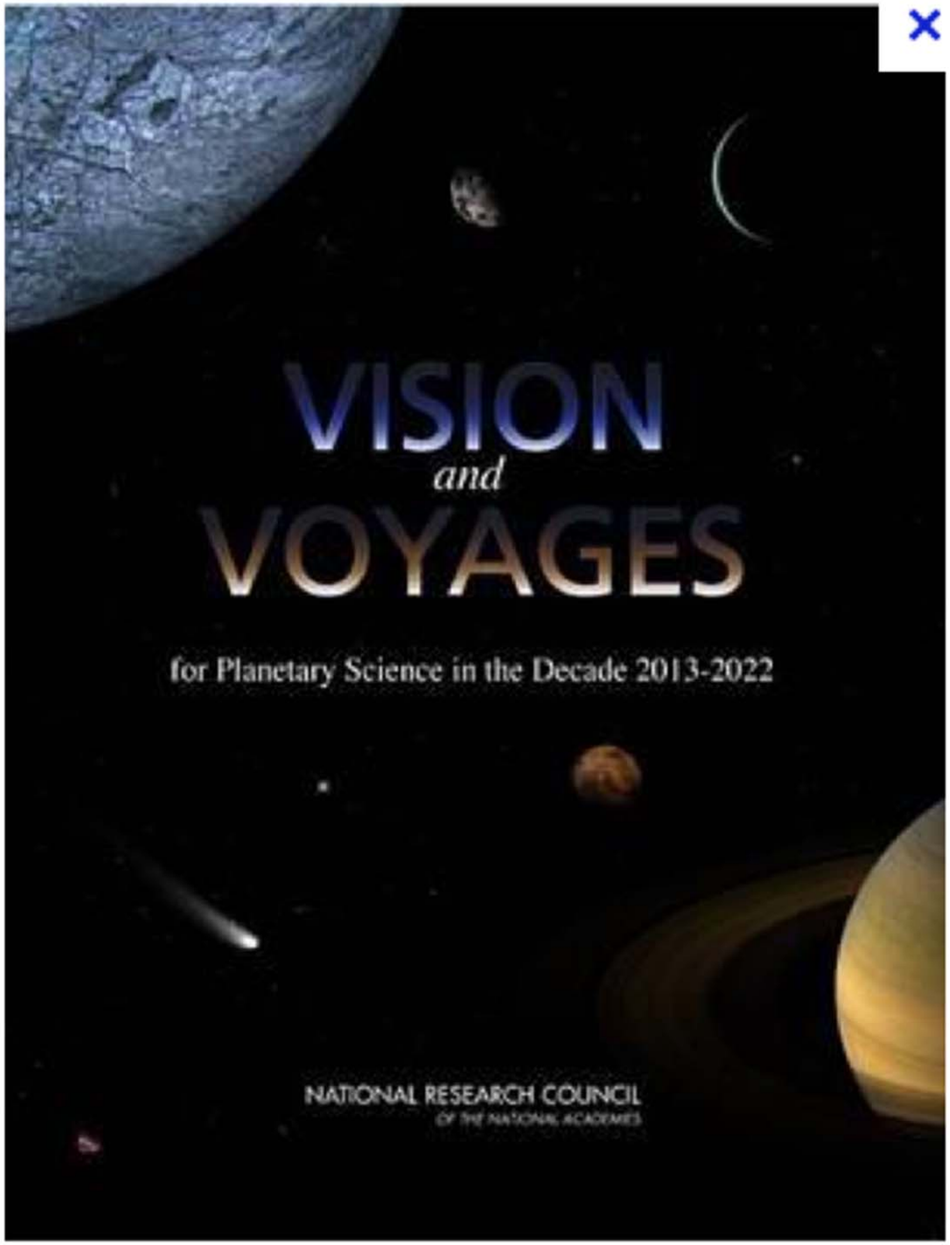

Vision and Voyages for Planetary Science in the Decade 2013-2022

Committee on the Planetary Science Decadal Survey
Space Studies Board
Division on Engineering and Physical Sciences
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

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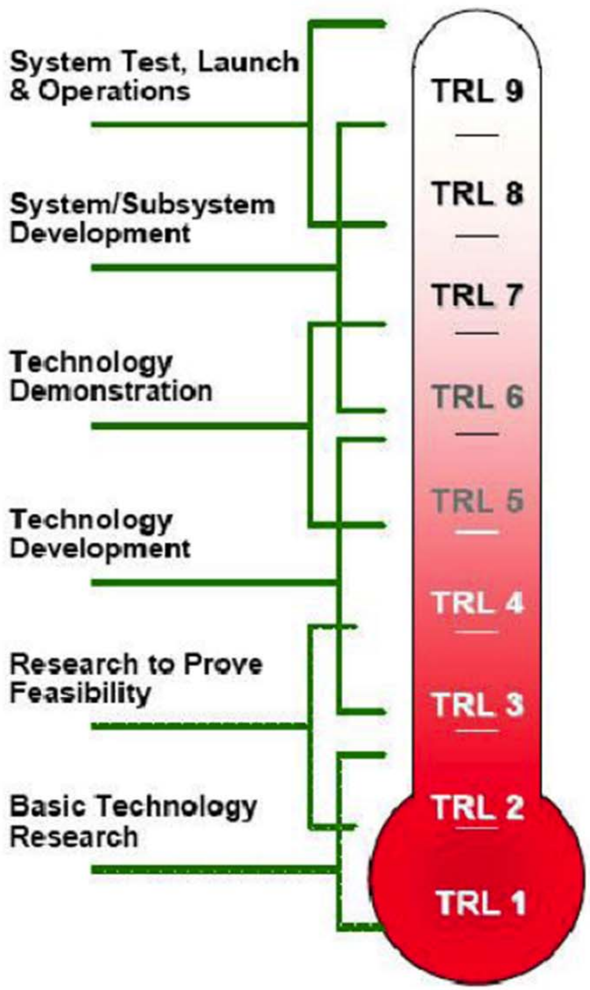
The Mid-TRL Crisis (TRL 4-6), the Valley of Death



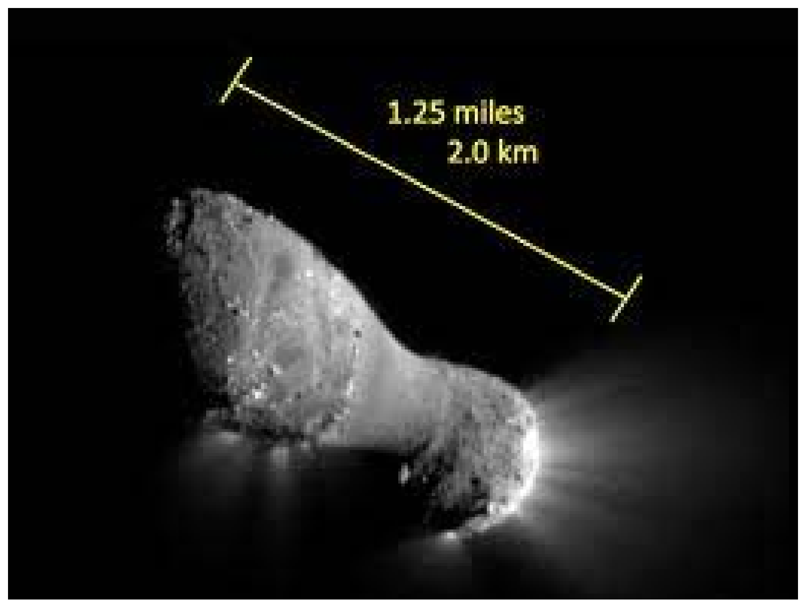
A primary deficiency in past NASA planetary exploration technology programs has been overemphasis on TRLs 1-3 at the expense of the more costly but vital mid-level efforts necessary to bring the technology to flight readiness.

To properly complement the flight mission program, therefore, the committee recommends that the Planetary Science Division's technology program should accept the responsibility, and assign the required funds, to continue the development of the most important technology items through TRL 6.

FIGURE 11.1 Technology Readiness Levels for space missions. SOURCE: NASA.

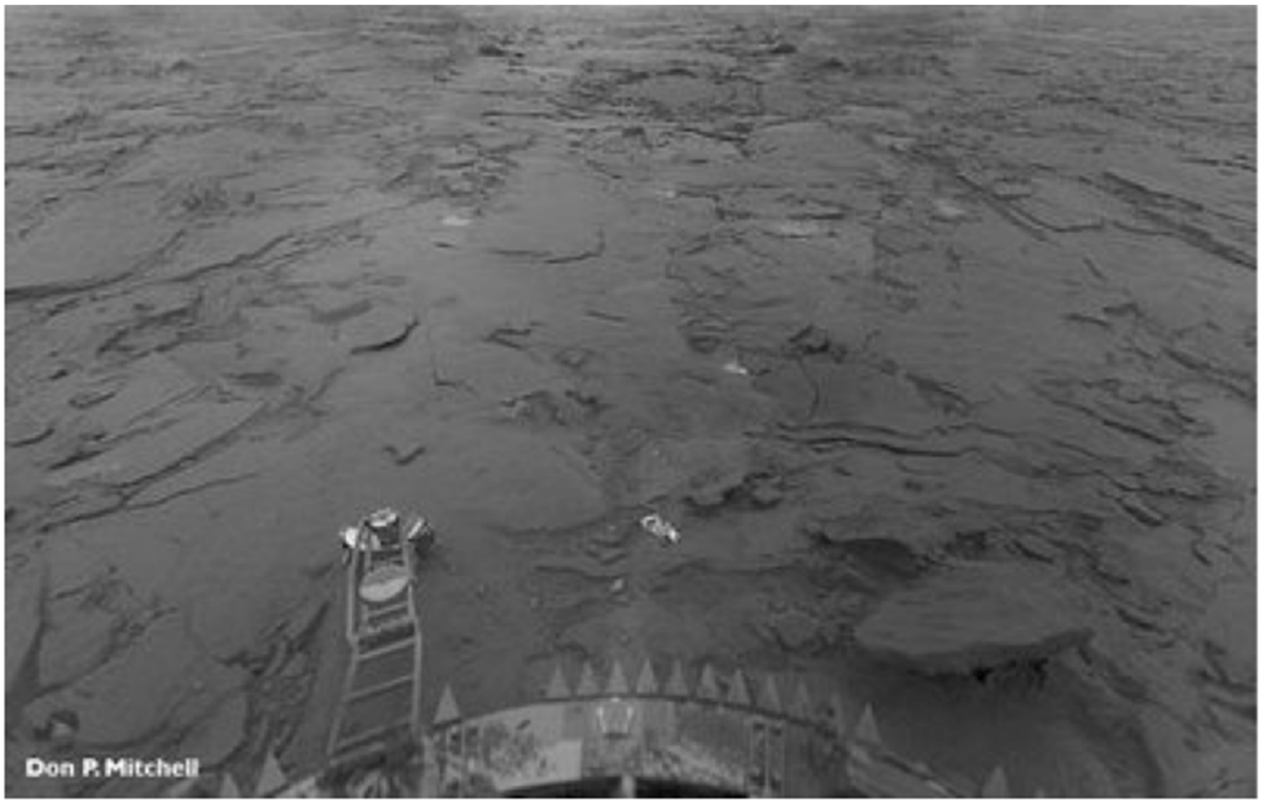
Key Technology Findings and Recommendations. Chapter 4 The Primitive Bodies

Continue technology developments in several areas including ASRG (Advanced Stirling Radioisotope Generator) and thruster packaging and lifetime, thermal protection systems, remote sampling and coring devices, methods of determining that a sample contains ices and organic matter and preserving it at low temperatures, and electric thrusters mated to advanced power systems. Develop a program to bridge the TRL 4-6 development gap for flight instruments.



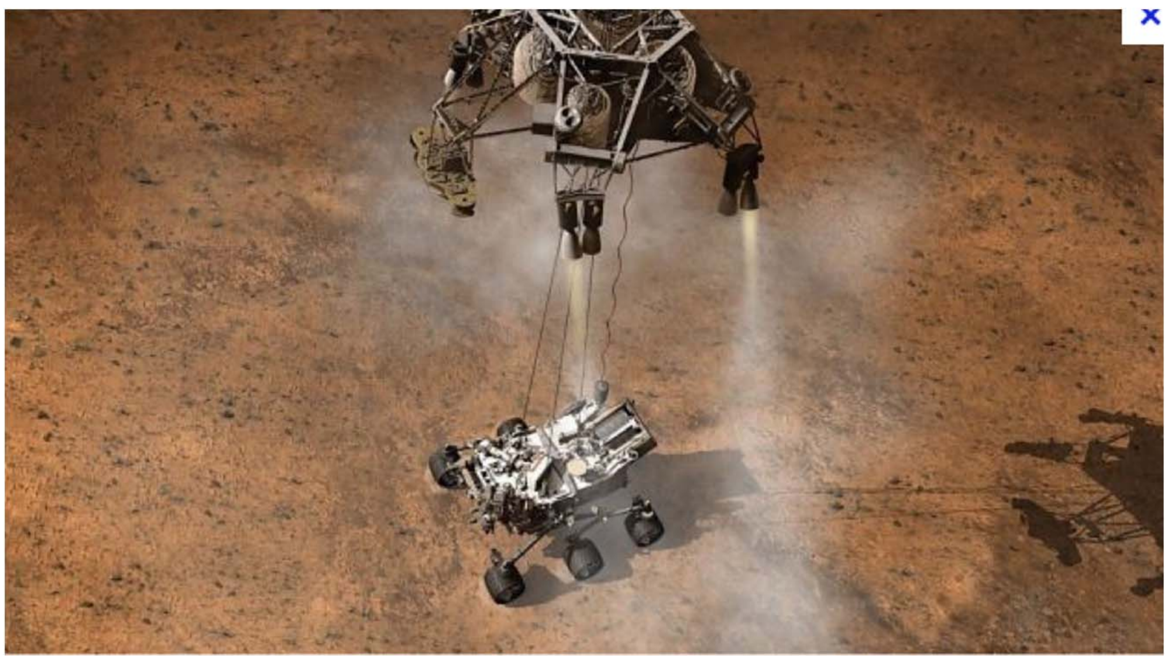
Key Technology Findings and Recommendations. Chapter 5 The Inner Planets

Continue current initiatives. Possibly expand to include capabilities for surface access and survivability for Venus's surface and frigid polar craters on the Moon.



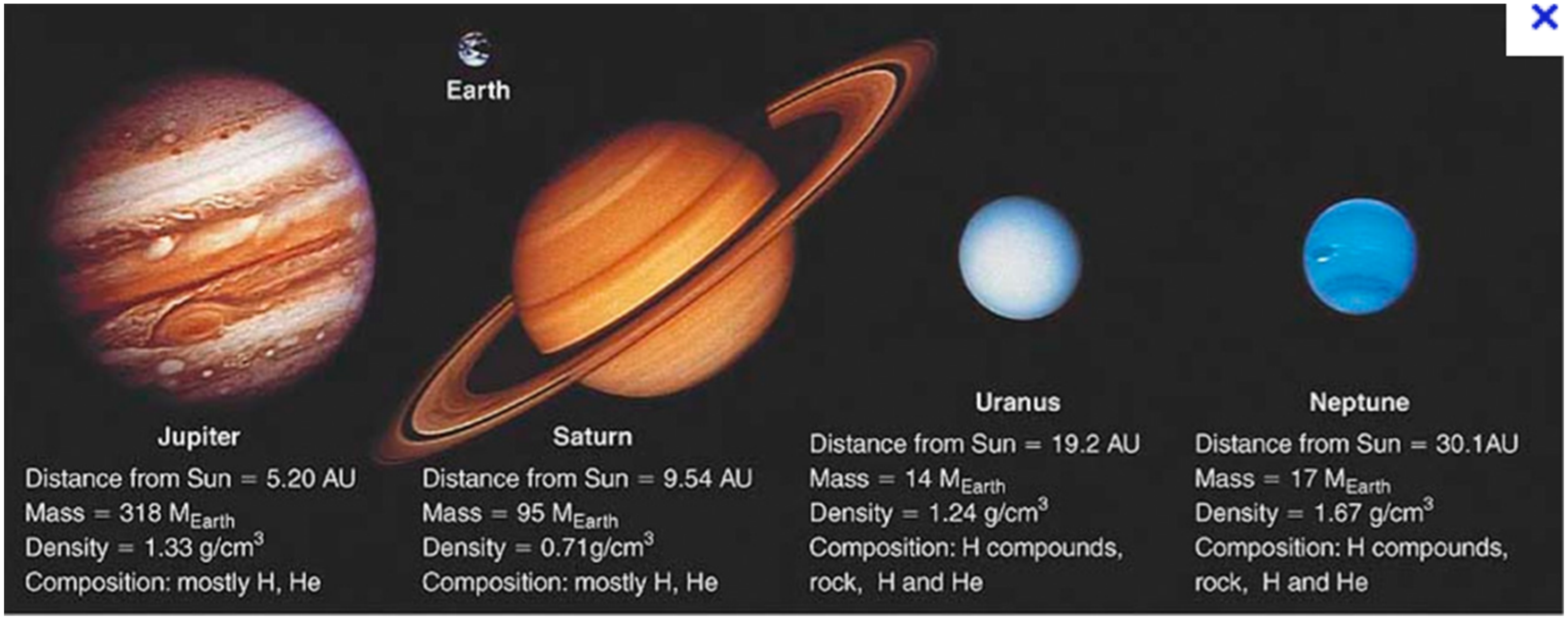
Key Technology Findings and Recommendations.
Chapter 6 Mars

Key technologies necessary to accomplish Mars Sample Return are: Mars ascent vehicle, rendezvous and capture of orbiting sample return container, and planetary protection technologies.



Key Technology Findings and Recommendations. Chapter 7 The Giant Planets

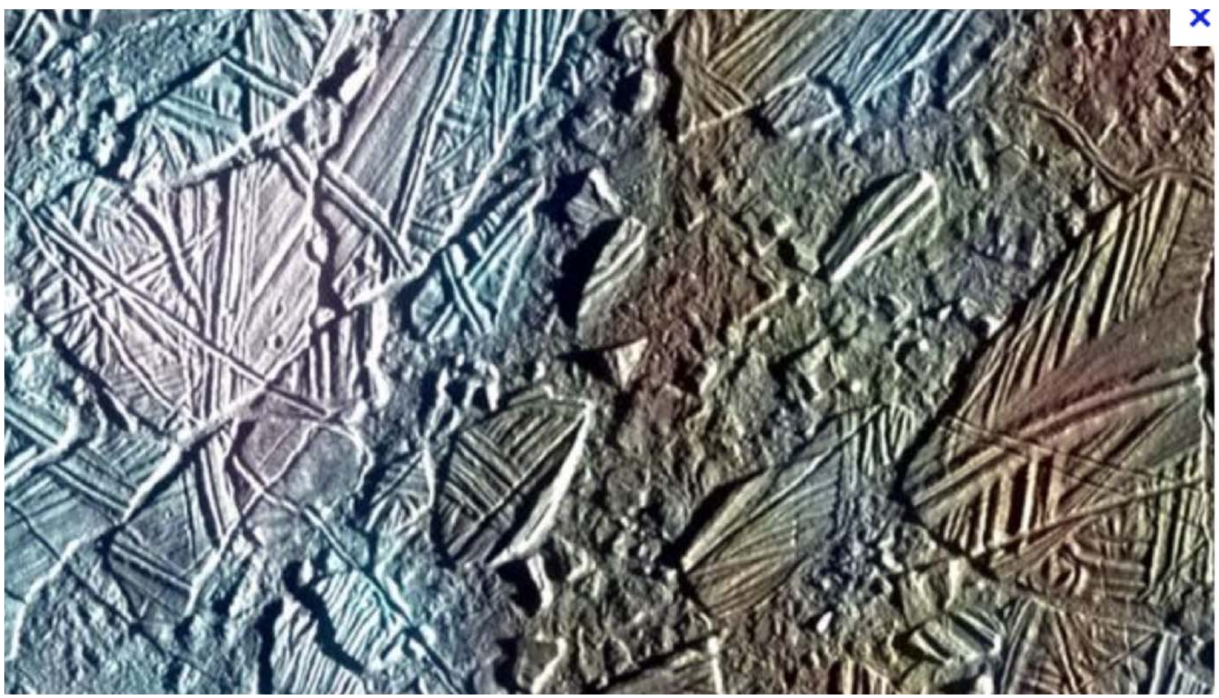
Continue developments in: ASRGs, thermal protection for atmospheric probes, aerocapture and/or nuclear electric propulsion, and robust deep-space communications capabilities.



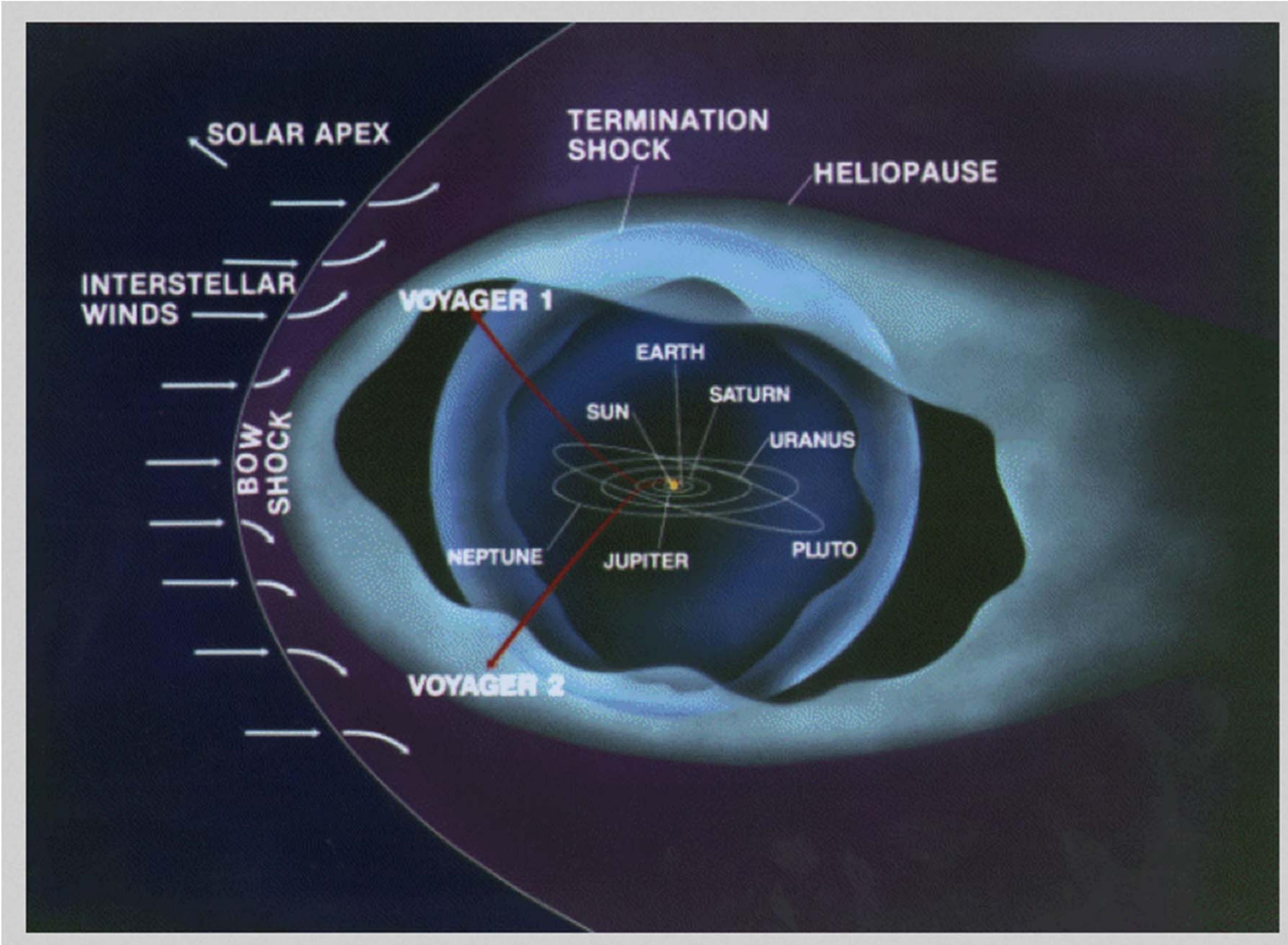
Key Technology Findings and Recommendations.
Chapter 8 Satellites

Develop technology necessary to enable Jupiter Europa Orbiter. Address technical readiness of orbital and in situ elements of Titan Saturn System Mission including balloon system, low mass/power instruments, and cryogenic surface sampling systems.

Europa



Titan



Voyager Interstellar Mission
http://voyager.jpl.nasa.gov/mission/interstellar.html

Prioritize observations in a limited amount of time – which instruments, what to look at, which data to transmit

- Venus – limited amount of time on the surface
- Trojan asteroids – objects appear suddenly and pass out of range quickly
- Comet or satellite – plume eruption during a fast flyby requires on board decision-making
- Ring observer – hovering above the ring plane consumes fuel; is a target worth investigating?

Hazard avoidance – all timescales

- Mars rovers – decision-making at Earth is slow, and it would be better to let the rover choose the route
- Ballooning on Titan, Venus, Mars – Updrafts, downdrafts, and topography pose a hazard
- A smart balloon can adjust its altitude and search for favorable winds
- Comet nucleus obscured by dust – onboard processing during a fast flyby, observe new plumes
- Aerocapture, high-speed entry, landing on an irregular surface, rendezvous in orbit all require autonomy

Failure of a spacecraft component

- Downlink failure – are the data worth saving? Decide whether to re-transmit or overwrite?
- Avoid safing – diagnose the problem, isolate the component, switch to backup system
- Provide margin – propellant, electrical power, computational power, data storage, communication bandwidth
- Modular design – spares, plug-ins

TABLE 11.1 Summary of Types of Missions That May Be Flown in the Years 2023-2033 and Their Potential Technology Requirements

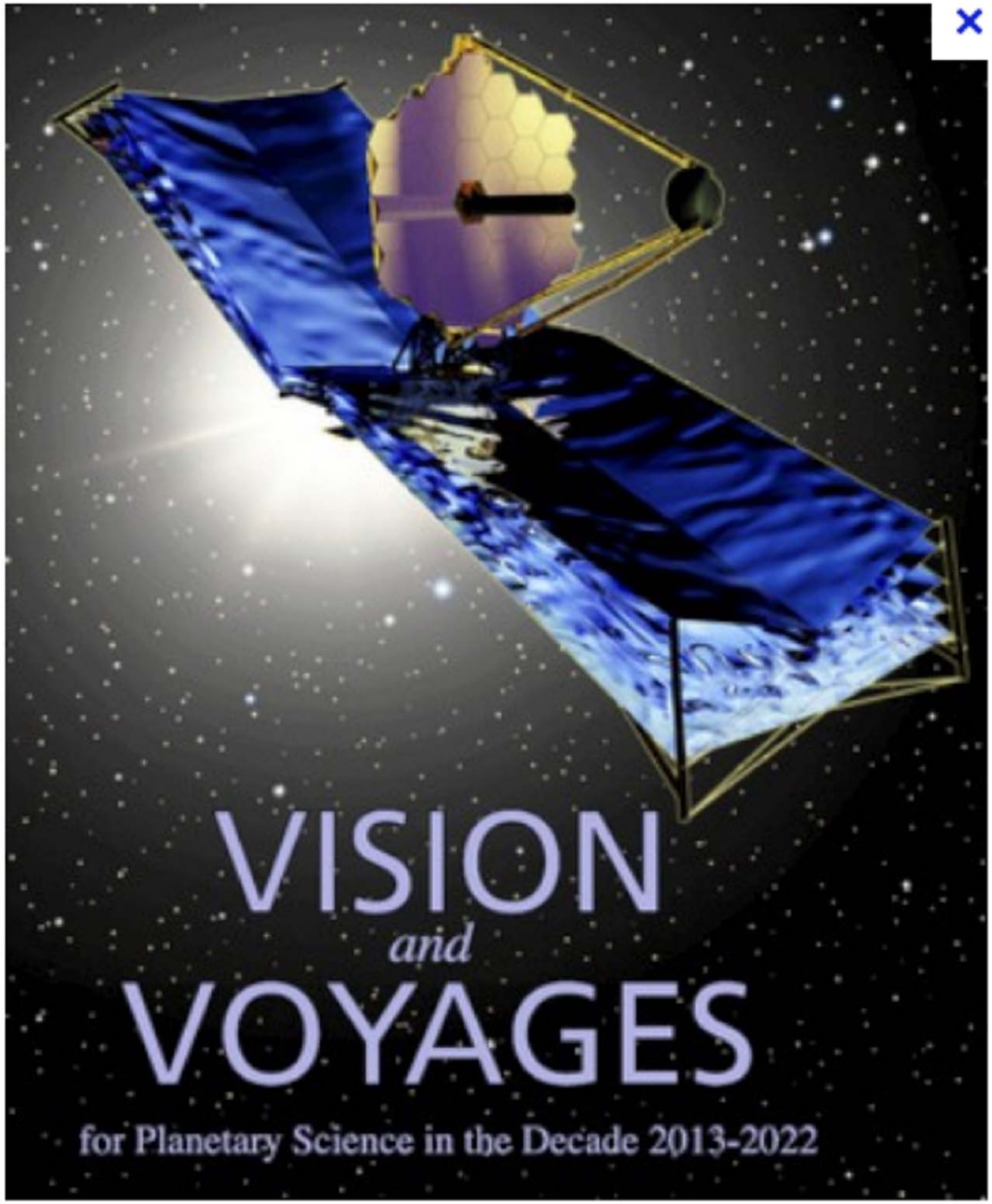
Objective: 2023-2032	Mission Architecture	Key Capabilities
Inner Planets		
Venus climate history	• Atmospheric platform • Sample return	• High-temperature survival • Atmospheric mobility • Advanced chemical propulsion • Sample handling
Venus/Mercury interior	Seismic networks	• Advanced chemical propulsion • Long duration high-temperature subsystems
Lunar volatile inventory	Dark crater rover	• Autonomy and mobility • Cryogenic sampling and instruments
Mars		
Habitability, geochemistry, and geologic evolution	Sample return	• Ascent propulsion • Autonomy, precision landing • In situ instruments • Planetary protection

Giant Planets and their Satellites		
Titan chemistry and evolution	Coordinated platforms: orbiter, surface and/or lake landers, balloon	• Atmospheric mobility • Remote sensing instruments • In situ instruments-cryogenic • Aerocapture
Uranus and Neptune/Triton	Orbiter, Probe	• Aerocapture • Advanced power/propulsion • High-performance telecom • Thermal protection/entry
Primitive Bodies		
Trojan and KBO composition	Rendezvous	Advanced power/propulsion
Comet/asteroid origin and evolution	• Sample return • Cryogenic sample return	• Advanced thermal protection • Sampling systems • Verification of sample—ices, organics • Cryogenic sample preservation • Thermal Control during entry, descent, and landing

TABLE 11.2 An Example of a Possible Technology Investment Profile That Would Be Appropriately Balanced for the Future Requirements for Solar System Exploration

Technology Element	Percentage Allocation	Key Capabilities
Science instruments	35	Environmental adaptation Radiation tolerance In situ sample analysis and age dating Planetary protection
Extreme environments	15	High temperature and pressure Radiation tolerance (subsystems) Cryogenic survival and mobility
In situ exploration	25	Sample acquisition and handling Descent and ascent propulsion systems Thermal protection for entry and descent Impactor and penetrator systems Precision landing Mobility on surfaces and in atmospheres Planetary protection
Solar system access and core technologies	25	Reduced spacecraft mass and power Improved interplanetary propulsion Low-power, high-rate communications Enhanced autonomy and computing Aerocapture Improved power sources Innovative mission and trajectory design

The End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