



Space Exploration: The Role of Knowledge Management in a High Risk Environment

Federal Knowledge Management Community

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NASA Jet Propulsion Laboratory (JPL)

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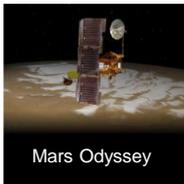
- JPL is the lead NASA Center for the robotic exploration of the solar system... and beyond
- JPL has visited every planet, e.g., 4 rovers on Mars
- NASA assigns to JPL high risk exploration missions that have never before been attempted

JPL invents products where we may make only a single unit— which may cost a billion dollars— that is designed to go somewhere previously unreachable.

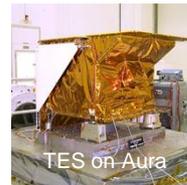
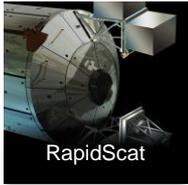
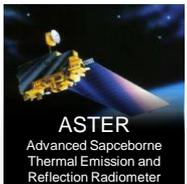


Current JPL Spaceflight Projects

Deep Space Missions



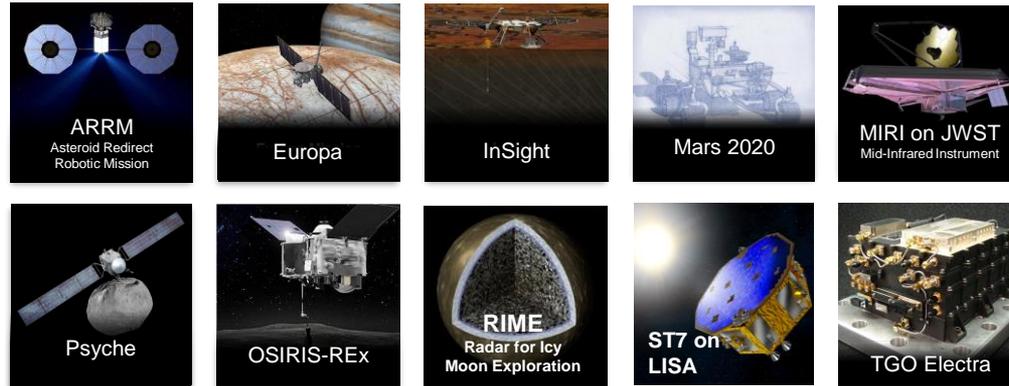
Earth Orbiting Missions



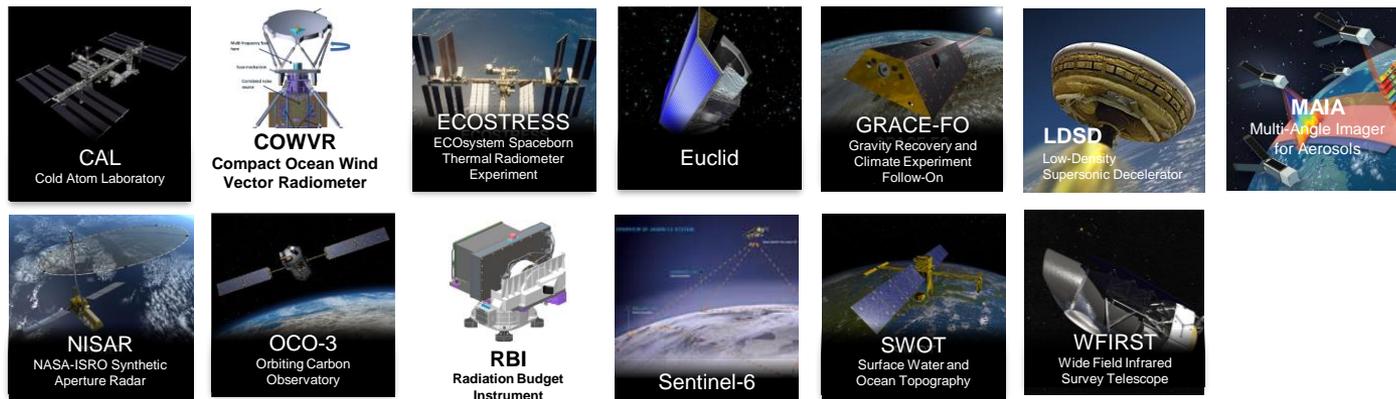


JPL Spaceflight Projects in Development

Deep Space Missions



Earth Orbiting Missions





Extreme Risk → Extreme Engineering

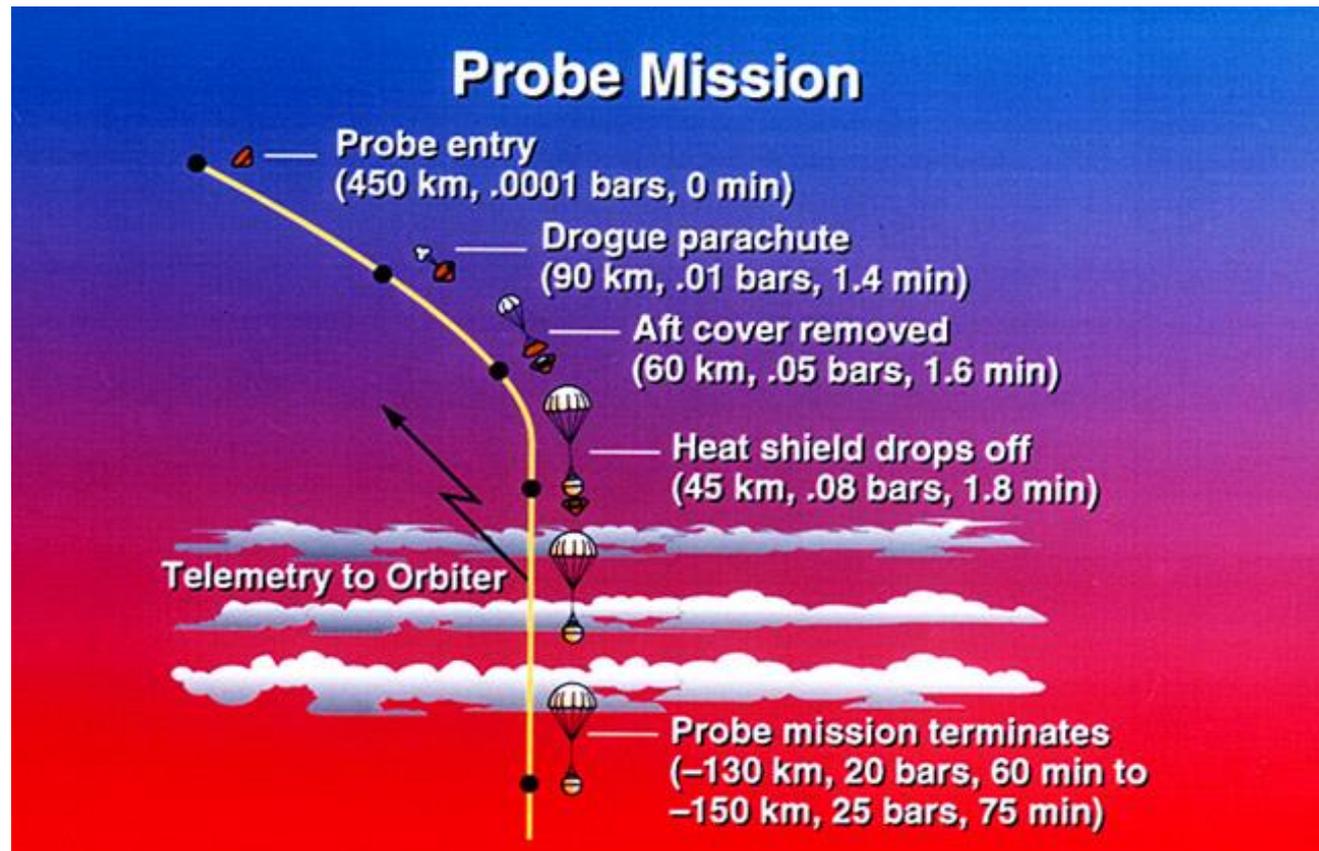
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- **JPL systems:** often one-of-a-kind, high unit value, that must operate with precision in an extremely hostile environment
 - **Deep Impact** (2005): An optically navigated flying copper “bullet” ran head-on into a comet while being tracked on the mother ship, all autonomously



Another Extreme Engineering Example

- Galileo Jupiter Probe

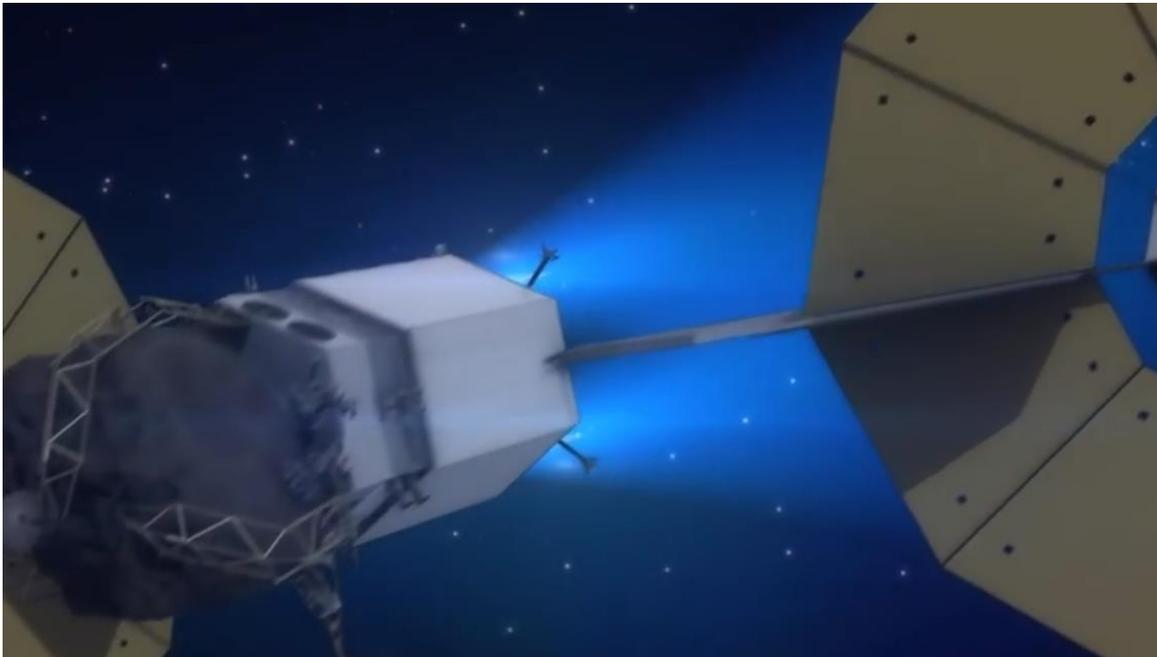




Another Extreme Engineering Example

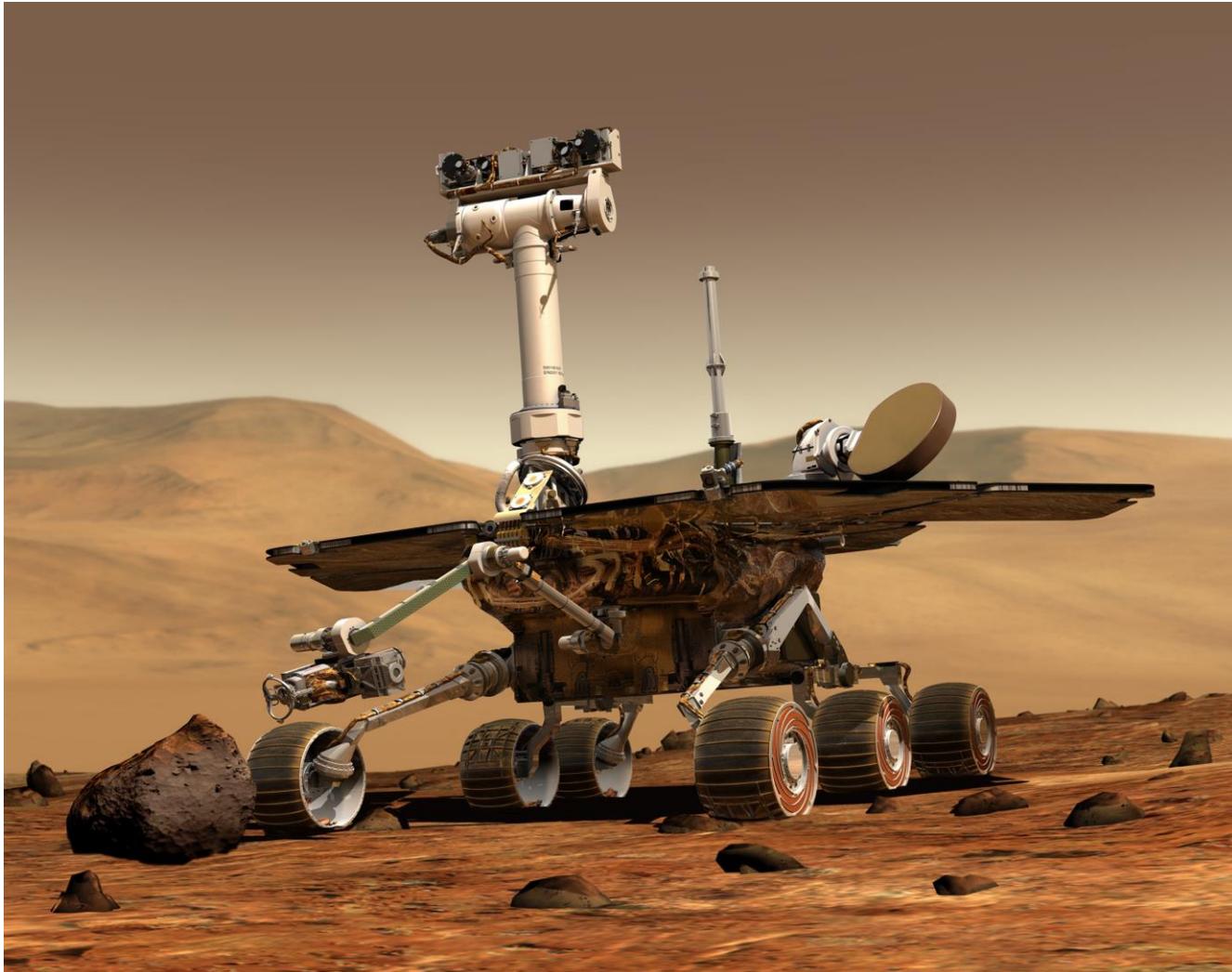
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- **Asteroid Redirect Mission** would demonstrate the electric propulsion technology that may also be needed to deliver heavy cargo (i.e., supplies) to Mars, pre-positioning them for a crewed Mars mission, and maybe even bringing the crew.



Design Challenge from Highly Unique Missions

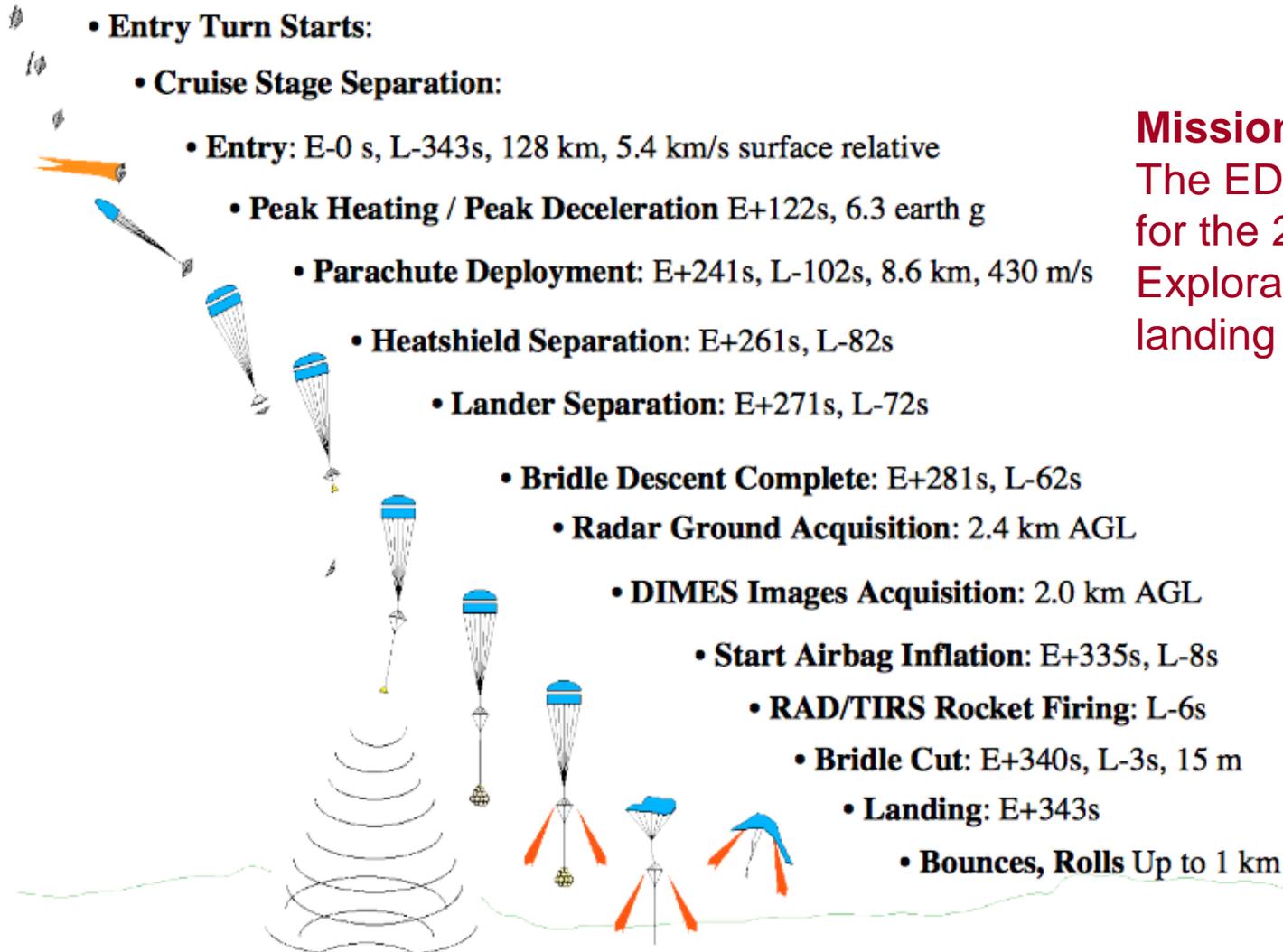
- Mars Exploration Rovers: “Spirit” & “Opportunity”





Mars Entry, Descent, and Landing (EDL)

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Mission Complexity:
The EDL sequence for the 2004 Mars Exploration Rover landing

The “7 Minutes of Terror”



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76



PYROTECHNIC
DEVICES



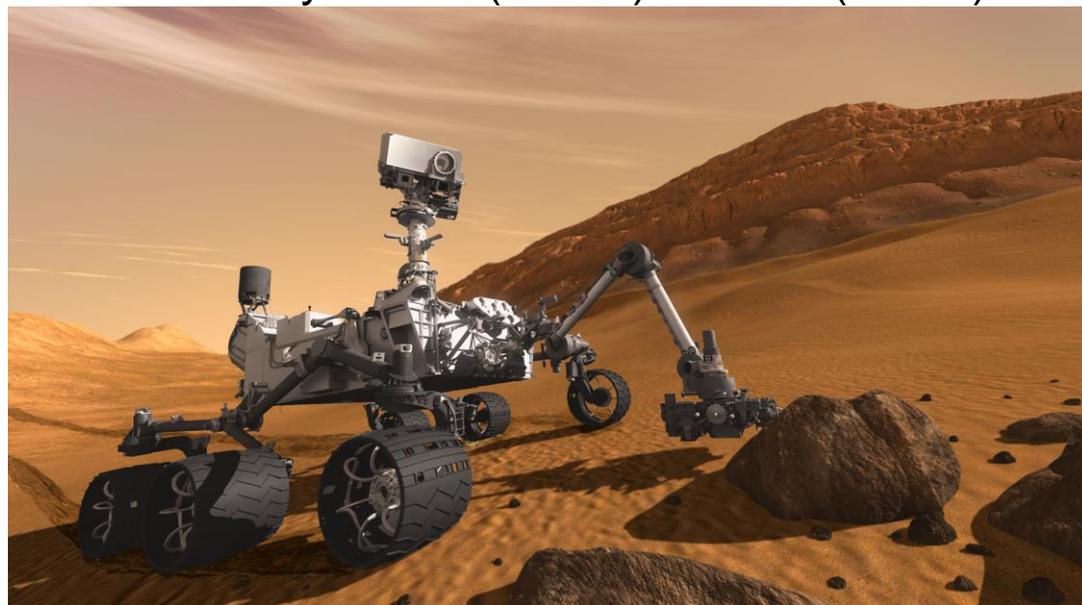
Risk Necessitates Extreme Innovation

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- Curiosity rover was too massive to land on airbags, hence “sky crane” design solution
- Best design solution for desired year-around, 30 degree N/S latitude operation was radioisotope power



Curiosity lander (above) & rover (below)





So How Do We Mitigate Risk?

- “Preventions”
 - Robust design (e.g., margins), redundancy, fault tolerance, fault detection & recovery, thermal control, design rules
- Analyses
 - Structural stress, reliability (FTA, FMEA, PSA, WCA, SCA), software safety/reuse, peer reviews, modeling (thermal, radiation, micrometeoroid, 3D), pyroshock, IESD, RVA
 - Active risk assessment/mgmt throughout the project lifecycle
- Controls
 - Quality assurance, vendor inspection, materials/parts selection, verification & validation, engineering standards
- Test, Test, Test!
 - Technology qualification, assembly testing, system-level testing, life testing, mission simulation (testbed)

Knowledge Management



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- Corporate knowledge is often treated as if it has little value
- Key corporate knowledge may be lost unless leadership supports active measures to capture and retain it



The ancient Romans used pozzolan concrete to build large structures
--until the technology was lost for 1000 years

Lost Knowledge: Throttleable Thrusters



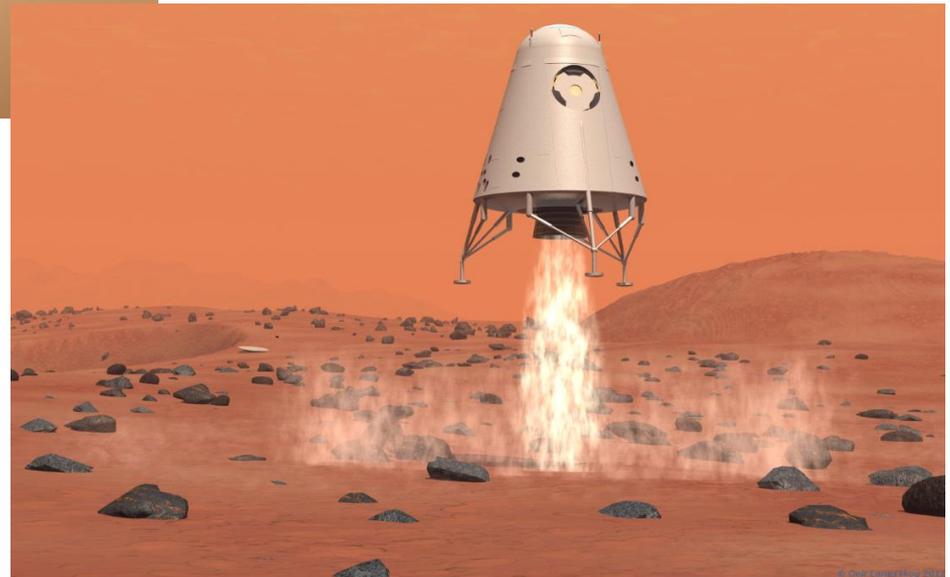
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Mars Science Laboratory:
launched in 2011

Hovering “sky crane” ↑ required the recovery of “lost” knowledge that had been used 36 years earlier on →

Mars Viking:
launched in 1975



Effective Knowledge Management Practices



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- Obtain your leadership's commitment to knowledge husbandry
- Prepare a knowledge management strategic plan
 - Identify (1) what knowledge is critical, (2) gaps in capturing/retaining/sharing it, and (3) activities needed to address the gaps
 - But don't neglect ad hoc opportunities and "quick wins"
- Adopt industry-wide knowledge management "best practices"
 - Institute a formal **lessons learned** process
 - Encourage your subject matter experts to **mentor** junior staff
 - Investigate tools (e.g., case studies, video capture, Pause & Learn)
 - Collect metrics to show continuous improvement
- Serve as a knowledge champion by advocating knowledge husbandry and reuse within your organization
- And lastly...



***Make good use of what
your agency knows***



Dare Mighty Things



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“Far better is it to **dare mighty things**, to win glorious triumphs, even though checked by failure...than to rank with those poor spirits who neither enjoy much nor suffer much, because they live in a gray twilight that knows not victory nor defeat.”

- Theodore Roosevelt, 26th
President of the United States