National Aeronautics and Space Administration

NASA

JPL Strategic Implementation Plan

2018

STRATEGIC HIGHLIGHTS

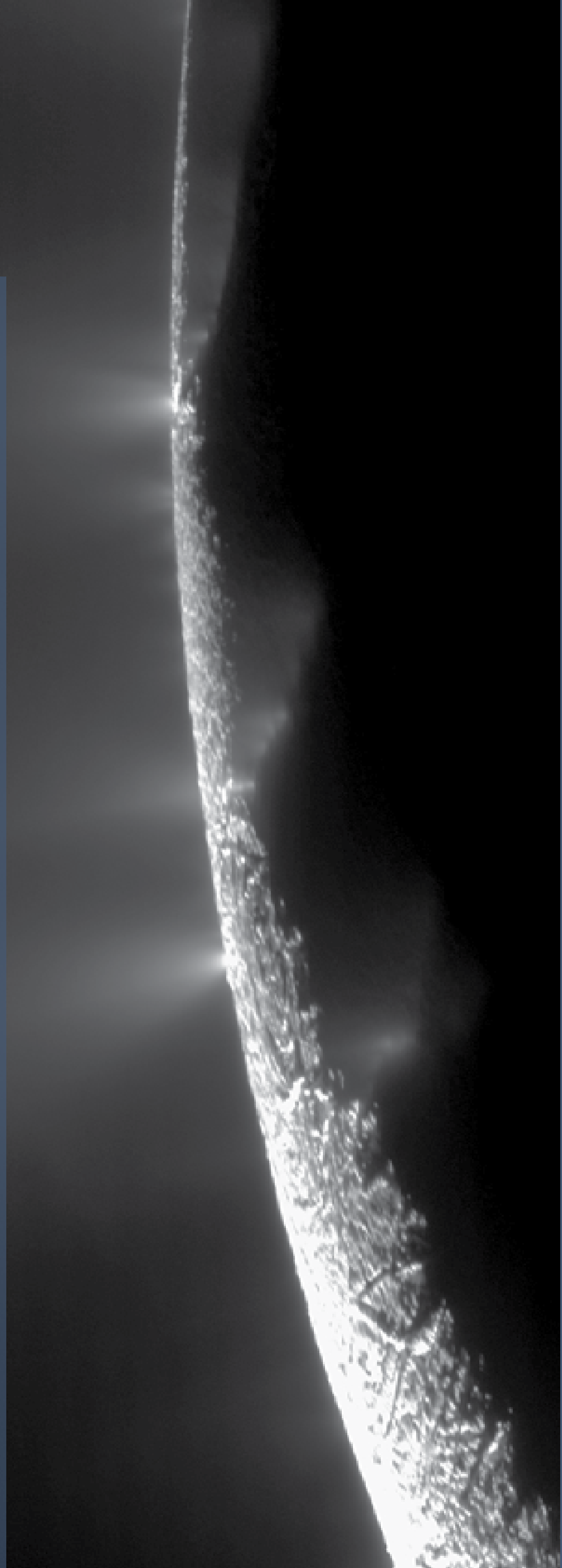
To "explore space in pursuit of scientific discoveries that benefit humanity," we will:

1. Pursue a diverse and bold portfolio of science missions

2. Create the Laboratory of the future, defined by a talented and inclusive workforce, rapid information sharing, and a culture of innovation

3. Strengthen our end-to-end capability while accelerating technology infusion into our missions

The cover illustration taken from the ***Cassini Grand Finale*** movie illustrates Cassini's fly-through of the Enceladus plume in October 2015. The image on this page shows dramatic plumes, both large and small, spray water ice and vapor from many locations along the famed "tiger stripes" near the south pole of Enceladus.



Michael Watkins
Director
Jet Propulsion Laboratory

MESSAGE FROM THE JPL DIRECTOR

To pursue our vision to "explore space in pursuit of scientific discoveries that benefit humanity," the JPL 2018 Strategic Implementation Plan responds to the NASA 2018 Strategic Plan and to the exciting new developments in the worlds of science, technology, and commercial space.

We will pursue our long-term scientific quests with a diverse and bold portfolio of missions as we push the limits of space exploration technology by developing and fielding ever more capable autonomous robotic systems. We will strengthen our core expertise while developing and maintaining strategic partnerships with other NASA centers, U.S. national laboratories, academia, industry, and our international partners.

We will build a robust Laboratory of the future that fosters a culture of innovation, openness, and inclusiveness, and we will transform our systems to promote easier collaboration and information sharing. How we conduct our business is as important to JPL, and to our ultimate success, as what we do. We also will continue to inspire the world through our stories and our journey into space.

We will strengthen our end-to-end mission capabilities and accelerate the infusion of new technologies and capabilities into our future missions. We will support American leadership in space and as we ***Dare Ever Mightier Things***.

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EXECUTIVE SUMMARY

This document outlines a strategic direction for the next decade that will strengthen JPL's ability to achieve mission success and open a new path for leading autonomous robotic space exploration for the nation and for the world. The following strategies summarize the core body of this plan:

1. **Pursue a diverse and bold portfolio of science missions**

   JPL Quests define the key scientific questions and pursuits that the Laboratory strives to answer; these Quests are aligned with NASA's strategic goals and consistent with the National Academy of Sciences Decadal Surveys.

   - JPL will maintain a diverse portfolio of science missions focused on these scientific Quests.
   - JPL will invest in advance technical capabilities from early concept development to technology maturation and technology infusion into our science missions.
   - JPL will strategically partner with other national laboratories, academia, and international space agencies that have synergistic core competencies with JPL to achieve our mission goals. JPL will enter into innovative public-private partnership agreements with the growing commercial space industry to improve the Laboratory's agility and robustness and to leverage new ideas and opportunities for collaboration.

2. **Create the Laboratory of the future, defined by a talented and inclusive workforce, rapid information sharing, and a culture of innovation**

   JPL Thrusts and related key initiatives collectively lay the groundwork for the Laboratory of the future.

   - JPL will continue to invest in our workforce, workplace, and work practices to keep pace with rapidly changing expectations, environments, and transformative ways of doing our work.
   - JPL will invest in and foster a culture of innovation not only in what we do but also in how we conduct our business.
   - JPL will inspire the world through our stories.
   - JPL will embark on a digital transformation strategy that includes enhanced information sharing, accelerated connectivity, and advanced technologies for analytics and deep learning.
   - JPL will develop innovative engineering methods, processes, and tools to improve mission success and reduce technical risk.

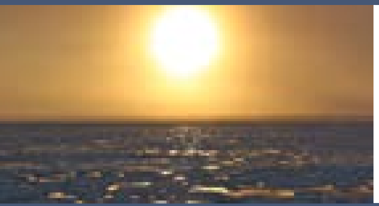
3. **Strengthen our end-to-end capability while accelerating technology infusion into our missions**

   JPL will strengthen its end-to-end capability while stepping up the development of new mission capabilities and the infusion of advanced technologies.

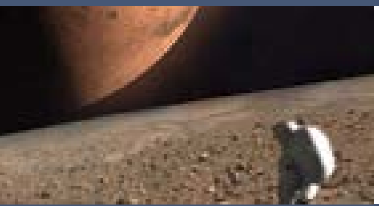
   - JPL will invest in a diverse portfolio of early stage to mid-stage technologies and innovative new capabilities.
   - JPL will invest in advanced testbeds, facilities, simulation environments, and in-space test platforms to improve and streamline the rapid design, prototyping, and testing of flight and mission systems.

JPL QUESTS

Long-term endeavor in support of the JPL Vision to "explore space in pursuit of scientific discoveries that benefit humanity"

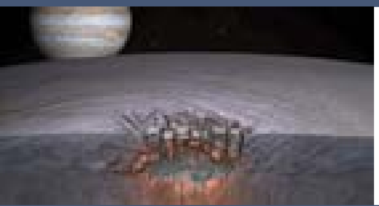


Understand how Earth works as a system and how it is changing



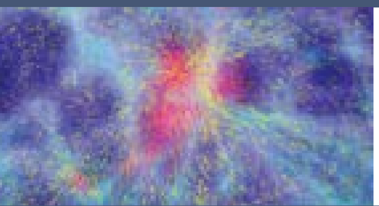
Help pave the way for human exploration of space

Understand how our Solar System formed and how it is evolving



Understand how life emerged on Earth and possibly elsewhere in our Solar System

Understand the diversity of planetary systems in our Galaxy

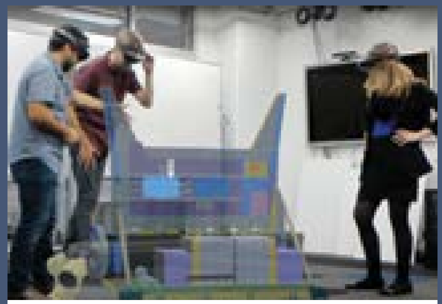


Understand how the Universe began and how it is evolving

Use our unique expertise to benefit the nation and planet Earth

JPL THRUSTS

Cross-cutting initiatives designed to support our culture of innovation and the pursuit of our Quests



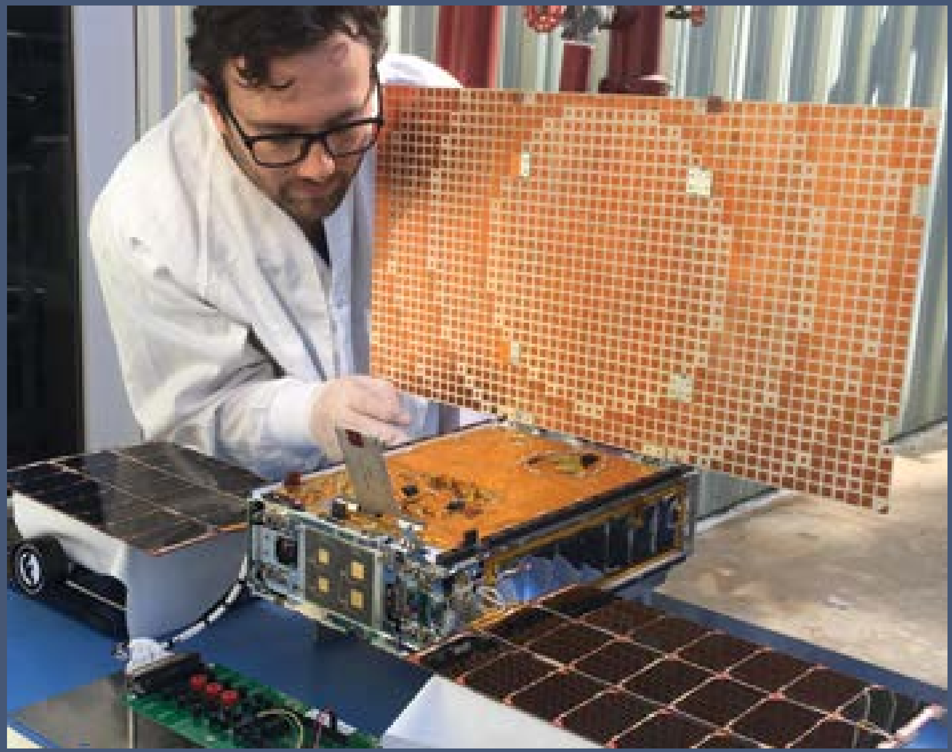
Creating the Laboratory of the future

Innovating what we do and how we do it

Inspiring the world through our stories

FUTURE CAPABILITIES

Development and infusion of advanced technical capabilities into our future missions in pursuit of our Quests and in support of creating the Laboratory of the future



JPL engineer tests one of the two Mars Cube One (***MarCO***) small satellite spacecrafts launched together with the ***InSight*** mission to Mars in May 2018. The twin spacecrafts are the first ever deep-space small satellites, which will fly by Mars in November 2018 and provide additional telecommunications coverage for the ***InSight*** landing on Mars, scheduled for November 26, 2018.

QUESTS

EARTH SCIENCE & APPLICATIONS

MARS EXPLORATION

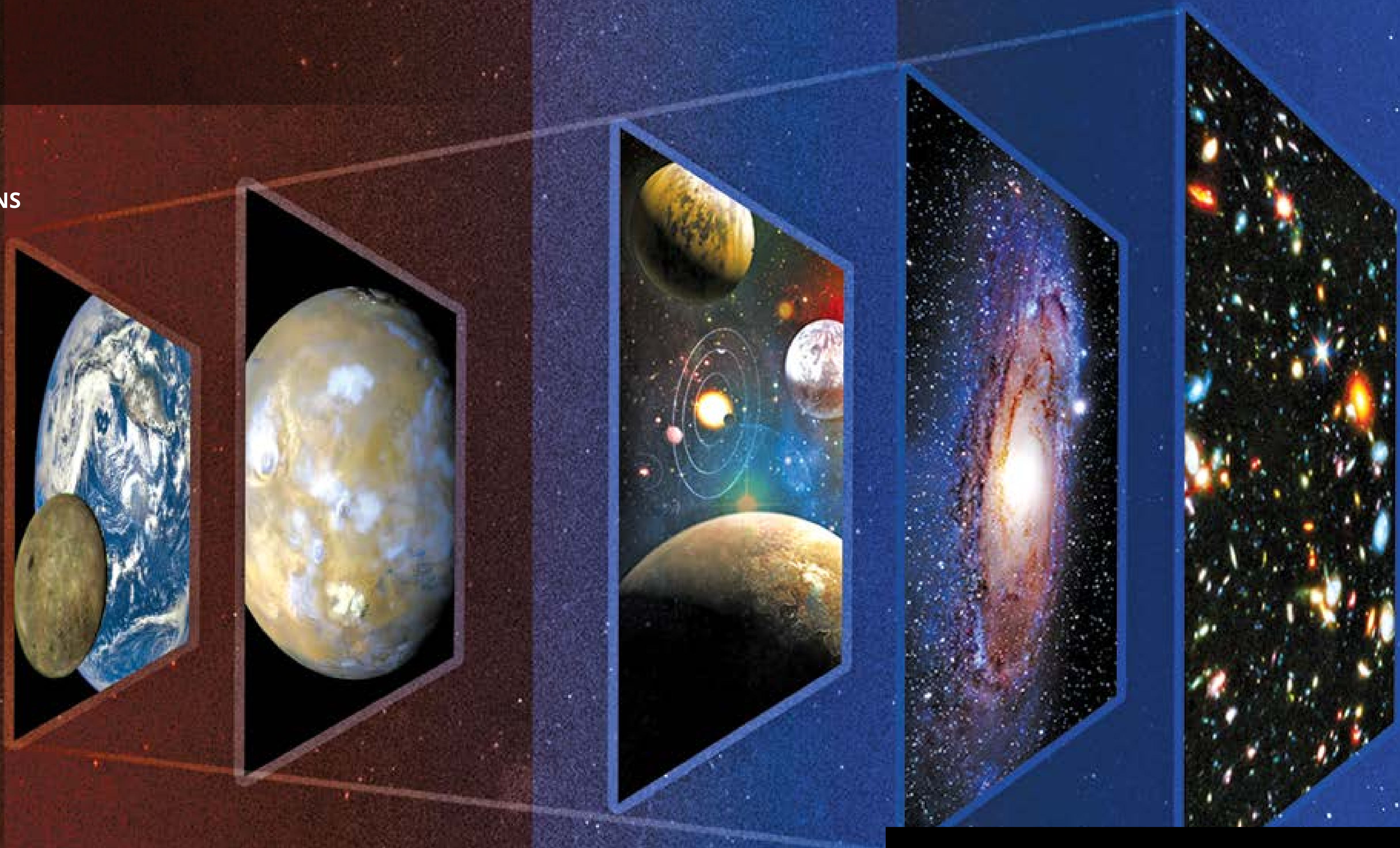
SOLAR SYSTEM EXPLORATION

ASTRONOMY & PHYSICS

INTERPLANETARY NETWORK

ADDRESSING NATIONAL CHALLENGES & CATALYZING ECONOMIC GROWTH

BENEFITS TO NATIONAL SECURITY



QUESTS:* *Pursue a diverse and bold set of science missions

Consistent with NASA's goal to "expand human knowledge through new scientific discoveries," JPL will work closely with the NASA Science Mission Directorate to understand the Sun, Earth, our Solar System, and the Universe.

EARTH SCIENCE & APPLICATIONS

The Earth Science and Applications Directorate studies components of the Earth system and their coupling to better understand how the Earth responds to natural and human-induced changes; how these complex dynamic systems interact to influence our environment and Earth's climate; and how to use this improved knowledge to better predict and respond to natural hazards and other extreme conditions involving weather, water, and climate.

JPL QUESTS

Directly aligned with NASA's objectives, the Earth Science and Applications Directorate's key Quests are to:

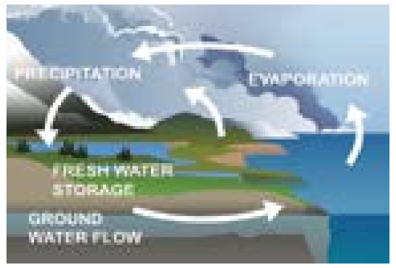
- **Understand how Earth works as a system and how it is changing**
- **Use our unique expertise to benefit the nation and planet Earth**

STRATEGIC THEMES

The Earth Science and Applications Directorate has identified the following strategic themes to address the JPL Quests, and in turn, aid NASA in its overall goals to ***discover***, ***explore***, ***develop***, and ***enable***.

Understanding Our Water Cycle and Monitoring Freshwater Availability

Fresh water is vital to human communities, agriculture, and the health of ecosystems throughout the planet. Its availability poses an increasingly significant management challenge. To predict changes in availability, we must monitor and understand many interrelated and dynamic phenomena. Learning how Earth's water is distributed and exchanged and how these quantities change over time informs our ability to make sound management decisions. JPL is bringing significant satellite instrument and mission capabilities to meet this challenge, as well as developing the methods to combine observations and models to examine and quantify the role and impacts of water across the Earth system.



JPL is making a number of contributions to NASA's goal of measuring and understanding the global water cycle and providing information for better water management.

STRATEGIC GOALS

- **Develop advanced and complementary measurements of clouds and precipitation**
- **Develop feasible capabilities to measure the amount of water in mountain snowpack**
- **Continue measurements of the movement of water mass around the planet**

Measuring Sea Level Rise and Quantifying Contributing Processes

One of the more profound illustrations of Earth's changing climate is the increase in global sea level. With societal impacts already evident, it is critical to understand the causes in order to sharpen future projections. JPL is leading the way in advancing this understanding by developing and operating two crucial satellite measurement systems—altimetry and gravity measurements. In addition, JPL provides scientific expertise and advanced modeling capabilities that help determine and quantify the various contributions to sea level rise, including from ice sheets, glaciers, ocean warming, as well as the influences from the solid earth and water cycle variations.

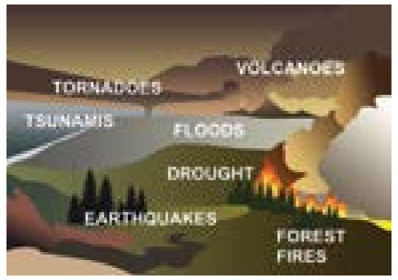
A number of factors influence the rate of sea level rise and its regional variations. JPL provides the altimetry measurements central to monitoring sea level rise and contributes measurement technology and scientific expertise that help determine and quantify the various contributions to sea level rise.

STRATEGIC GOALS

- **Continue advancing the fidelity of our measurements of global sea level variations**
- **Enhance our capabilities to measure and distinguish ocean warming versus mass contributions to sea level rise**
- **Improve our measurements and understanding of ice sheets, a key contributor to sea level rise**

Monitoring the Solid Earth to Understand and Respond to Natural Hazards

Government agencies charged with anticipating, mitigating, assessing, and responding to hazards rely on JPL's spaceborne and airborne instruments and scientific data processing capabilities for a fleet of international synthetic aperture radar (SAR) satellites. These data are changing how the nation and the world monitor infrastructure and prepare for and react to both natural and human-caused hazards. JPL is providing leadership in the use of SAR data for natural hazards response but also combining it with ground observations, other satellite assets, and models to advance our understanding of the solid earth and its interactions with the hydrological cycle, cryosphere, and atmosphere.



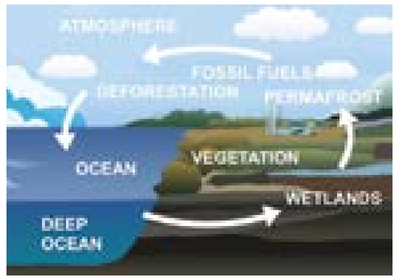
There is a need for near-constant monitoring of the Earth's surface to optimally prepare and respond to the variety of natural hazards affecting our planet and livelihood.

STRATEGIC GOALS

- **Provide more frequent and detailed observations of surface movements associated with earthquakes, volcanoes, landslides, subsidence, etc.**
- **Improve our ability to monitor and understand the influence of water and its movements on the evolution of the Earth's surface**

Understanding Our Carbon Cycle and Changing Ecosystems

Carbon is vital to life, with a complex set of reservoirs and exchanges that are dominated by natural processes and modified by human activity leading to increases in greenhouse gases that in turn influence the Earth's temperature and climate. Understanding the carbon cycle is critical to managing the carbon inventory and its impact on society. JPL is making many contributions to space missions to meet this objective, including developing methods to use and combine observations across many platforms (spaceborne, airborne, and ground based) with state-of-the-art models to quantify the exchanges of carbon between land, ocean, and atmosphere, and to disentangle natural changes from those caused by humans.



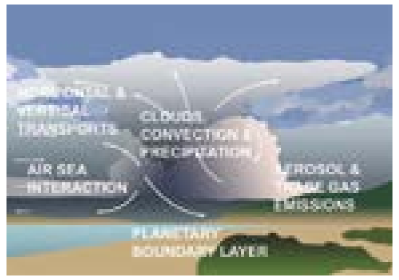
JPL is helping to lead NASA's effort to design a system of satellites and ground sensors to measure the most critical components of the global carbon cycle.

STRATEGIC GOALS

- **Provide more frequent and more detailed surface biology and geology observations**
- **Design feasible and more comprehensive observing systems of the global carbon cycle**
- **Develop capabilities to better monitor our coastal and inland water systems**

Enabling Improvements In Weather and Air Quality Forecasts

Our day-to-day lives and ability to thrive are influenced strongly by variations in weather and air quality. More accurate and timely predictions of extreme weather events and air quality events, as well as knowing when to expect quiescent conditions, are essential for sound decision making—whether for individual daily concerns or for larger civil, commercial, and military planning. JPL is at the forefront of technology and science advances, to increase our understanding of weather and air quality and enable better monitoring and prediction capabilities. This includes improving our understanding of the multi-scale and coupled interactions across the Earth system that result in extreme weather and air quality events and in the complex interplay between weather and atmospheric chemistry that leads to impacts on human and ecosystem health.

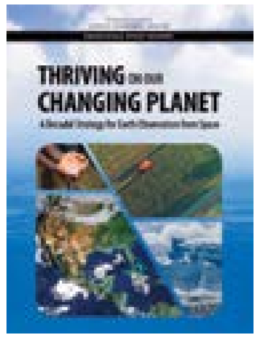


Challenges in the coming decade associated with improving weather and air quality forecasts include better observations on clouds and precipitation, atmospheric winds and ocean currents, and the characterization of air quality near the surface.

STRATEGIC GOALS

- **Improve our ability to measure and predict extreme precipitation**
- **Contribute novel approaches for measuring atmospheric winds and ocean currents**
- **Develop advanced technologies and remote sensing approaches to provide better weather and air quality information closer to the Earth's surface**

Strategic Alignment with Decadal Survey



The National Academies 2017–2027 Decadal Survey for Earth Science and Applications from Space recommends a rich and complex set of Earth science and application measurements to be developed in the coming decade that address the challenges and opportunities associated with the five strategic themes highlighted above.

JPL is well positioned to contribute to many of these Decadal Survey priorities. These contributions are enabled through advancing sensor technologies; formulating nimble and capable constellations of satellites; miniaturizing components to facilitate the use of small satellites; developing commercial and international partnerships; meeting big data challenges presented by these satellite missions; developing and applying sophisticated Earth system component and coupled models to guide formulation; optimizing the use and value of models and observations via data assimilation; and quantitatively accounting for uncertainties that arise in the end-to-end measurement, modeling, and processing chains that lead to science and applications products.

MARS EXPLORATION

The Mars Exploration Directorate manages the activities and projects that are assigned to JPL by NASA's Mars Exploration Program. The Program applies a successive and integrated mission approach to undertake detailed scientific explorations of Mars using orbital remote sensing and robotic landers. It has had a continuous presence of both landers/rovers and orbiters since the early 2000s.

JPL QUESTS

Directly aligned with NASA's objectives, the Mars Exploration Directorate's key Quests are to:

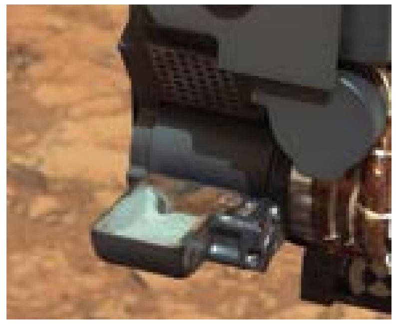
- **Understand how life emerged on Earth and possibly elsewhere in our Solar System**
- **Understand how our Solar System formed and how it is evolving**
- **Help pave the way for human exploration of space**

STRATEGIC THEMES

The Mars Exploration Directorate has identified the following strategic themes to address the JPL Quests, and in turn, aid NASA in its overall goals to ***discover***, ***explore***, ***develop***, and ***enable***.

Life on Mars

Does life exist elsewhere in the Universe? What better and more accessible place to search than our neighbor Mars? Investigations by JPL in support of NASA's Mars Exploration Program have steadily increased our knowledge of the environments on Mars, revealing evidence of diverse habitable conditions in its ancient past. Mars orbiters and rovers have mapped geomorphic and geochemical evidence of past rivers, lakes, and large bodies of long-standing water with diverse chemistry—requisites for life. JPL, other NASA centers, and industry are developing capabilities for sample return from Mars to Earth, which would enable detailed analyses of potential signatures of ancient microbial life.



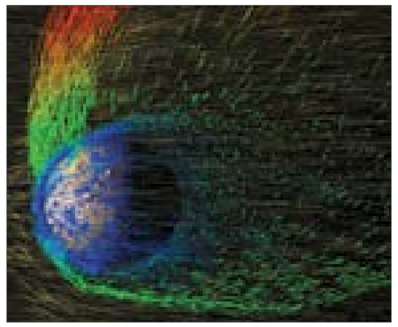
Curiosity finds sulfur, nitrogen, oxygen, phosphorus, and organic carbon—key ingredients necessary for life—in the powder sample drilled from the "*Sheepbed*" mudstone in Gale Crater on Mars. The sample also reveals clay minerals and not too much salt, which suggests fresh water once flowed there.

STRATEGIC GOALS

- **Help determine if life existed on Mars by enabling detailed analysis of samples through:**
  - **Mars sample return**
  - **In-situ life-related investigations**
- **Enable access to Mars environments, such as potential subsurface liquid water aquifers or possible surface brine flows that may serve as natural abodes for extant Martian life**

Mars Climate Processes and History

Understanding the processes and history of climate on Mars has been a major objective of Mars exploration. Past missions have provided a better understanding of Mars's atmosphere and its constituents. JPL is continuing to explore the history of climate processes that have shaped Mars through time, especially as Mars shifted from an early climate with potentially large bodies of liquid water to the very arid environment today. These studies not only shed light on our understanding of how the environment has changed this ancient Earth-like planet but will also assist in the safe implementation of future robotic and human missions to Mars.



Visualizing atmospheric loss on Mars. Mars today is a cold, barren desert, but scientists think it was once a warmer and wet planet. The change may have been caused by the loss of an early atmosphere driven into space by the Sun's solar wind. *Credit: NASA Goddard Space Flight Center*

STRATEGIC GOALS

- **Conduct long-term continuous weather monitoring**
- **Develop new capabilities to make 3D global wind measurements**
- **Improve our understanding of Martian polar processes, and how these seasonally move water and carbon dioxide, globally influencing the Martian atmospheric and geological systems**

Origin and Evolution of Mars as a Geological System

Studying the composition, structure, and history of Mars contributes toward our understanding of the Earth's history and processes. Mars is similar enough to Earth that our models should apply but different enough to challenge the physical understanding on which those models are based. Comparative planetary studies also help answer many key Solar System science questions. The global data sets acquired by Mars missions have enabled an updated understanding of the geological history of the surface of Mars—the Solar System's most Earth-like planet and the only other planet in our Sun's "habitable zone," the range of orbits where liquid water could exist on the surface of a terrestrial planet. In addition, these data enable long-range site selection for upcoming landed science investigations and potential future human space exploration programs.

This view from NASA's ***Curiosity rover***, which was led by JPL, includes four geological layers to be examined by the mission, and higher reaches of Mount Sharp beyond the planned study area.

STRATEGIC GOALS

- Improve our understanding of the composition and structure of Mars through multiple orbiters and landers delivered to diverse sites
- Develop capabilities to explore multiple diverse geologic regions with extreme-terrain robots and helicopters
- Enable exploration of the Martian subsurface via new remote sensing and deep drilling technologies

Human Exploration of Mars

Mars is the only planet in the Solar System that is realistically accessible for human exploration. NASA Mars orbiters are currently imaging potential human landing sites and assessing key characteristics, such as the presence of near-surface water ice or hydrated minerals, necessary resources for human presence. The suite of landers/rovers along with the orbiters at Mars are evaluating environmental and geological characteristics that would affect humans on the surface. The orbiters currently implement an international telecommunications relay network for surface assets, pioneering the way for the communication network needed for human exploration of Mars.

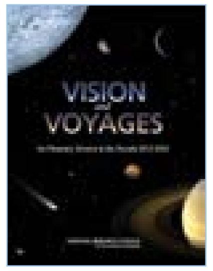
Getting astronauts to the Martian surface and returning them safely to Earth is an extremely difficult engineering challenge. A thorough understanding of the Martian environment is critical to the safe operation of equipment, access to in situ resources, and human health.

Image Credit: NASA/JSC/Pat Rawlings, SAIC

STRATEGIC GOALS

- Discover and determine potential human landing sites through high-resolution site reconnaissance
- Identify in-situ resources with the potential to support human presence
- Provide an initial demonstration of in-situ resource utilization with the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) experiment on Mars 2020, which aims to produce oxygen from the Martian carbon-dioxide atmosphere
- Evaluate environmental and geological characteristics like wind and atmospheric dust and how that affects humans on the surface

Strategic Alignment with Decadal Survey

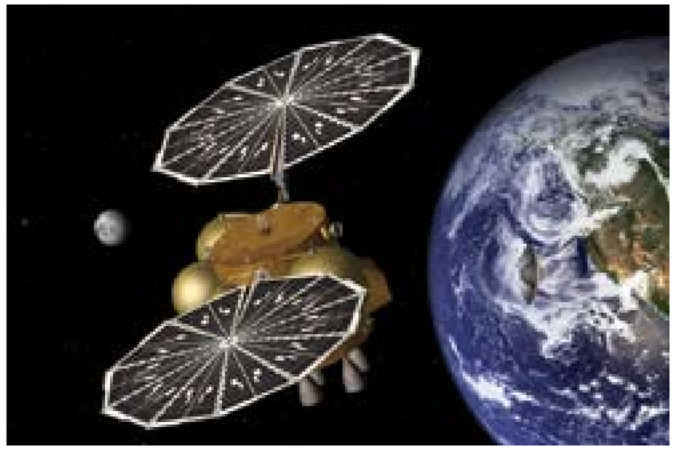


Mars sample return is a high priority identified in the 2013–2022 Planetary Science Decadal Survey. The sample-caching rover, now Mars 2020, was advocated as the highest priority flagship mission in that time frame. The survey also advocated that NASA embark on the key technologies necessary to complete the campaign, including a Mars Ascent Vehicle and highly robust sample containment systems, which JPL and partners have been advancing during the past few years. In exploring a potential Mars sample return campaign, JPL will team with other NASA centers across the Agency and seek opportunities for international and commercial partnerships.

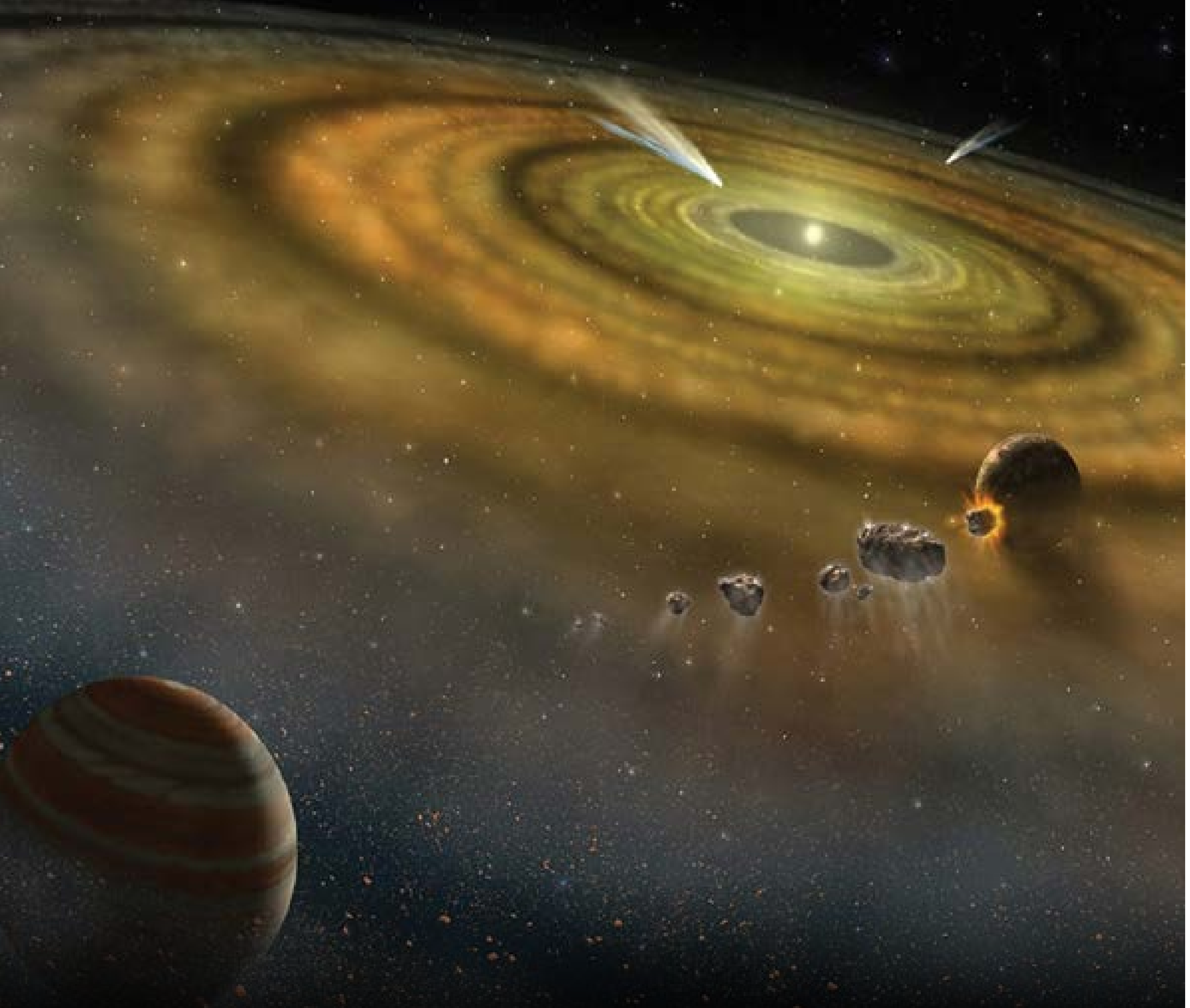
Mars Sample Return Campaign—The Mars Exploration Program Future Focus

The ***Mars 2020*** rover mission, currently in development and led by JPL, will cache a variety of rock and soil samples as the first step of a potential sample return, while conducting in-situ exploration. The ***Mars 2020*** mission takes the next step in the search for life by not only seeking signs of habitable conditions on Mars in the ancient past but also searching for past biosignatures preserved in surface rocks and soil.

The execution of a potential ***Mars sample return*** campaign requires an additional lander that would collect the sealed sample tubes left by the ***Mars 2020*** rover and place them in an ***Orbiting Sample*** container that would be launched into orbit around Mars by a ***Mars Ascent Vehicle***. The retrieval lander would use many of the capabilities developed for ***Mars 2020*** to land in the same site as ***Mars 2020***.



The final mission of a potential ***Mars sample return*** campaign is an orbiter that would capture the orbiting sample and operate as an ***Earth Return Orbiter***, carrying an ***Earth Entry Vehicle*** that would land with the samples. Assured containment of any Mars material and protection of the pristine samples are challenges being addressed.



SOLAR SYSTEM EXPLORATION

The Solar System Exploration Directorate studies the Solar System by investigating the formation and evolution of Solar System bodies, searching for evidence of life on the ocean moons of Saturn and Jupiter, and undertaking detailed analyses of Solar System environments in preparation for possible future human spaceflight missions.

JPL QUESTS

Directly aligned with NASA's objectives, the Solar System Exploration Directorate's key Quests are to:

- **Understand how life emerged on Earth and possibly elsewhere in our Solar System**
- **Understand how our Solar System formed and how it is evolving**
- **Help pave the way for human exploration of space**

STRATEGIC THEMES

The Solar System Exploration Directorate has defined the following strategic themes to address the JPL Quests, and in turn, aid NASA in its overall goals to ***discover***, ***explore***, ***develop***, and ***enable***.

Life in Ocean Worlds

Does life exist only on Earth or does it arise where water, energy, and essential chemicals come together? JPL is helping NASA define a systematic roadmap for exploring ocean worlds, such as Europa, Enceladus, and Titan, by getting to them quickly, gaining access to the best discovery sites, delivering and operating new generations of space flight instrumentation to seek out life, and eventually searching in every promising niche to study whatever biology we may find. Technologies and missions coming over the horizon now are finally spiriting us into the age in which humankind can determine whether we are alone.

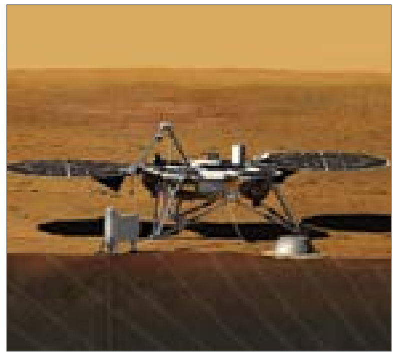
The three most important ocean worlds—***Europa***, ***Enceladus*** (pictured left), and ***Titan***—require ***New Frontiers*** and ***Flagship-class*** missions even to answer the basics. ***Cassini*** has determined that ***Enceladus*** is habitable; it has a global, long-lived ocean containing organic molecules.

STRATEGIC GOALS

- Europa Clipper: Assess the habitability of Europa and scout for landing sites
- A potential Europa Lander: Search for biosignatures on the surface of Europa
- Determine whether life emerged in the oceans of Europa and Enceladus
- Explore the oceans of Europa and Enceladus
- Explore Titan, an organic world of two oceans

Formation and Evolution of Solar System Objects

At a time when thousands of exoplanets are being discovered, the need to understand how Earth became habitable leads us to better understand the first tens of millions of years of the Solar System and to characterize other terrestrial planets to determine how sister planets like Earth and Venus have had such a divergent evolution. Where in the nebula did the building blocks form? How close to the Sun did Jupiter migrate? How heterogeneous was the solar nebula, and when and where did the ice giants form? To answer these questions, JPL is designing mission concepts and instruments to help characterize the composition and interior structure and dynamics of the diverse objects orbiting our Sun.



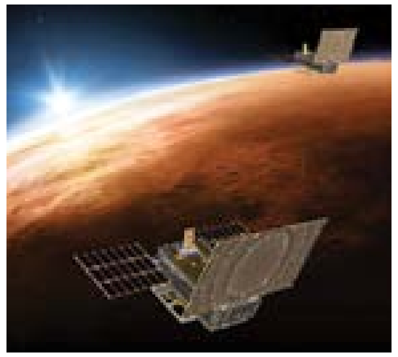
InSight is a JPL-led terrestrial planet explorer that will address one of the most fundamental issues of planetary and Solar System science—understanding the processes that shaped the rocky planets of the inner Solar System (including Earth).

STRATEGIC GOALS

- Determine how Venus and Earth have geologically evolved on such different pathways
- Use the Moon to understand early Earth's environment
- Lead the development of a mission to an ice giant
- Compete for Discovery-class and New Frontiers–class missions for Solar System exploration
- Partner with NASA centers, industry, and international agencies

Small Spacecraft

JPL is designing missions with small spacecraft that can make unique science measurements to directly address planetary science Decadal Survey goals for NASA at a much lower cost. Missions using small spacecraft with miniaturized electronics and instruments now make it possible to deploy multiple small probes to make distributed measurements, or to go to new places such as the surface of an ocean world. While some technology exists today, higher performance communication and propulsion and high-efficiency power generation, conversion, and storage technologies are needed to extend our reach farther into the Solar System. JPL will develop these key technologies in partnership with industry and academia.



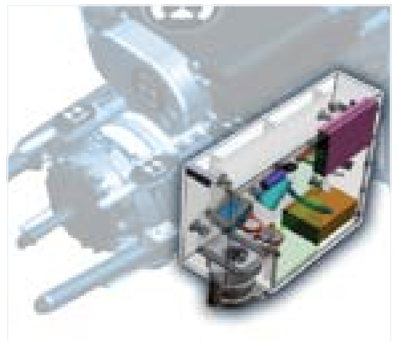
MarCO CubeSats at Mars. These 6U CubeSats have been launched with the ***InSight*** mission and have successfully completed communication and navigation technology demonstrations on their trip toward Mars. These pair of CubeSats might also act as real-time data relays for the ***InSight*** Mars lander during its entry, descent, and landing (EDL) in late November 2018.

STRATEGIC GOALS

- **Develop and mature small planetary science mission concepts with a launch mass of less than 180 kg and a cost of less than $55M**
- **Develop key and enabling technologies in partnership with industry and academia**
- **Utilize, where possible, commercial small satellite spacecraft buses**
- **Perform technology demonstrations and partner with international agencies**

Planetary Science Instruments

The Solar System Exploration Directorate develops planetary science instruments and matures them for future planetary mission opportunities, which are pursued through the Discovery and New Frontiers programs (medium and large missions); Flagship opportunities such as the Europa Lander mission concept; and emerging opportunities such as CubeSat, SmallSat, and technology demonstration platforms.



The ***Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals*** **(SHERLOC)** technology uses spectrometers, a laser, and a camera to search for organics and minerals that have been altered by watery environments and may be signs of past microbial life.

STRATEGIC GOALS

- **Develop science instruments for life detection in ocean worlds**
- **Develop advanced planetary science instruments for solar system exploration, such as seismometers, ultraviolet–infrared spectrometers, etc.**
- **Develop miniaturized planetary science instruments for CubeSat and SmallSat applications without loss of performance**

SOLAR SYSTEM EXPLORATION STRATEGY

Human Spaceflight

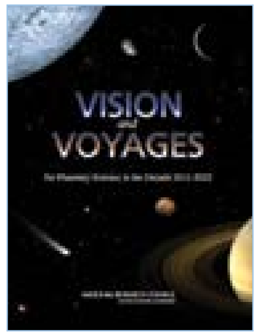
JPL supports NASA's goal to extend human presence deeper into space. Just as was done during the early days of NASA with Surveyor, precursor robotic missions and instruments are being developed to understand the challenges and opportunities for future human deep space missions. JPL is collaborating with Johnson Space Center (JSC) on robots that assist and supplement humans in space and on planetary surfaces.

NASA is preparing for human exploration of Mars. The ***Mars Oxygen In-Situ Resource Utilization Experiment*** **(MOXIE)** will demonstrate a way that future explorers might produce oxygen from the Martian atmosphere for propellant and for breathing.

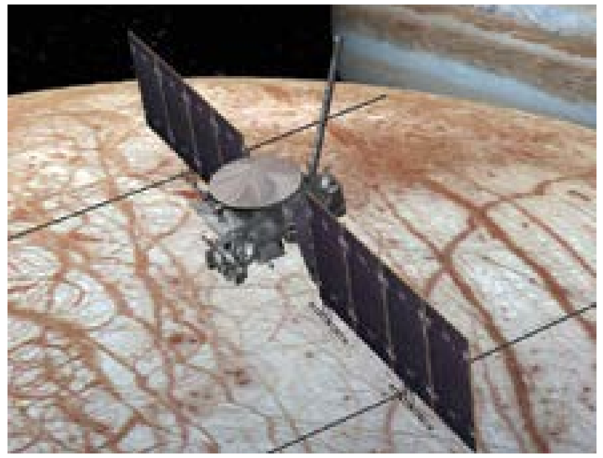
STRATEGIC GOALS

- **Develop payloads for commercial Lunar landers, the International Space Station, and the Deep Space Gateway**
- **Partner with commercial Lunar lander developers in areas of JPL's unique expertise including EDL, communication, and navigation**
- **Develop Lunar surface operation capability in partnership with JSC**

Strategic Alignment with Decadal Survey



JPL's Solar System Exploration strategic plan is fully aligned and supportive of the National Academies' 2013–2022 Planetary Science Decadal Survey. Central to this strategy are three Flagship missions (Mars Sample Return, Europa, and Uranus), as well as a regular series of competed missions in the New Frontiers and Discovery cost-capped planetary science programs. As such, JPL, in collaboration with our strategic partners, is actively supporting the formulations of the Europa Clipper and Mars Sample Return missions, and is also working with both internal and external principal investigators on multiple New Frontiers and Discovery mission concepts. By investing and developing cutting-edge instruments for Solar System exploration, JPL also participates and supports mission concepts proposed by other NASA centers and institutions. With the first deep space CubeSats successfully on their way to Mars, JPL plans to continue to pioneer innovative small satellite mission concepts for planetary science.



2016 artist rendering of NASA's ***Europa Clipper*** spacecraft, which is being developed for a launch in the 2020s (the design could change as the spacecraft is developed). The mission will conduct detailed reconnaissance of Jupiter's moon Europa to see whether the icy moon could harbor conditions suitable for life. The mission will carry a highly capable, radiation-tolerant spacecraft that will perform repeated close flybys of the icy moon from a long, looping orbit around Jupiter.

ASTRONOMY & PHYSICS

The Astronomy and Physics Directorate studies the Universe and our place in it by investigating the formation and evolution of stars, galaxies, and the Universe, and studying the diversity of planets outside of our Solar System (exoplanets) with the ultimate goal of finding an exoplanet with evidence of life.

JPL QUESTS

Directly aligned with NASA's objectives, the Astronomy and Physics Directorate's key Quests are to:

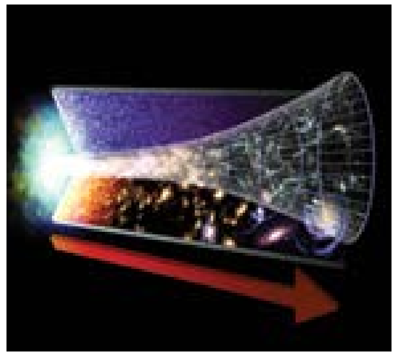
- **Understand how our Solar System formed and how it is evolving**
- **Understand the diversity of planetary systems in our Galaxy**
- **Understand how the Universe began and how it is evolving**
- **Use our unique expertise to benefit the nation and planet Earth**

STRATEGIC THEMES

The Astronomy and Physics Directorate has identified the following strategic themes to address the JPL Quests, and in turn, aid NASA in its overall goals to ***discover***, ***explore***, ***develop***, and ***enable***.

Cosmology

There are two components of the Universe that dwarf the normal matter that we see around us and observe in the Universe—dark matter and dark energy. Despite making up ~95% of the mass-energy of the Universe, we still know very little about these mysterious components. Using different probes, cosmologists are able to investigate the evolution of different epochs of the Universe to better understand the nature of dark matter and dark energy. JPL is currently leading scientific efforts on future missions designed to investigate the interplay between the gravitational pull of dark matter, the repulsive push of dark energy, and their effect on the evolution of the Universe over the past 10 billion years. JPL is also developing mission concepts to investigate the very early Universe and its evolution over its first billion years.



This artist's illustration shows the evolution of the Universe over time, starting with the Big Bang.

STRATEGIC GOALS

- Understand the physics of inflation, the mechanism that caused the very early Universe to expand exponentially
- Understand the nature of dark matter and dark energy

Astrophysics

All parts of the electromagnetic spectrum, from radio waves to gamma rays, provide important information about the amazingly rich variety of phenomena and objects in the Universe, from the near-vacuum between galaxies to black holes with a mass of billions of Suns. Star-forming regions, cool objects, distant highly red-shifted objects, and anything shrouded in dust can be explored through infrared and radio waves. JPL is currently developing infrared mission concepts designed to study the formation and evolution of stars and galaxies, the origins of interstellar ices, and to detect and characterize most of the potentially dangerous asteroids near the Earth as part of a planetary defense project. JPL is also continuing engagement in short wavelength missions and technologies ranging from x-ray to ultraviolet, where scientific study areas include Galactic and extra-Galactic black hole growth, and the life cycle of normal matter in the Universe.

STRATEGIC GOALS

- Understand galaxy formation and evolution
- Understand star and planetary system formation and evolution
- Trace the formation of elements and the path of water

ASTRONOMY & PHYSICS STRATEGY

Exoplanets

Is there life elsewhere in the Universe? This question has fascinated humanity for generations. JPL's ability to detect and spectrally characterize exoplanets has increased dramatically in recent years. JPL is continuing to develop capabilities to detect exoplanets both indirectly, by identifying characteristic signatures in observations of the host star, and directly, by blocking the light from the host star to reveal the exoplanets that are in orbit around the star. Future direct imaging experiments are also being designed to explore the diversity of Earth-sized and larger exoplanets and to investigate the compositions of their atmospheres, with the ultimate goal of identifying the molecular species that are indicative of life.

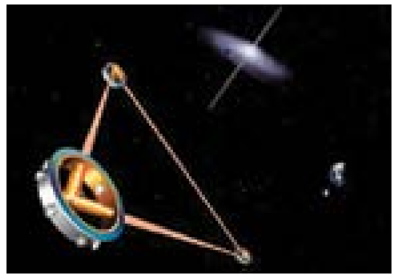
The ***Starshade*** is a large sunflower-shaped structure that blocks light from a star before it enters the telescope. The ***Starshade*** would deploy to its full size in space, blocking the light of distant stars so that a space-based telescope can image exoplanets orbiting the stars.

STRATEGIC GOALS

- Find and characterize exoplanets
- Understand planet formation
- Find habitable exo-Earths
- Find life elsewhere

Gravitational Waves

Gravitational waves are ripples in the fabric of space-time emanating from the locations of intense gravitational interactions. They provide a new way of investigating the Universe, enabling observations of events and epochs that are not possible to observe with the electromagnetic spectrum. JPL is currently preparing for future ground- and space-based gravitational wave experiments both scientifically and technologically. These future experiments should be able to detect impending supermassive black hole mergers long before the final merger, providing ample time to prepare for direct observation of the event when it happens. Gravitational waves may even make it possible to open a window into the mysterious era of the very early Universe, before light was able to propagate, giving entirely new insight into the processes occurring in this as yet unseen epoch.



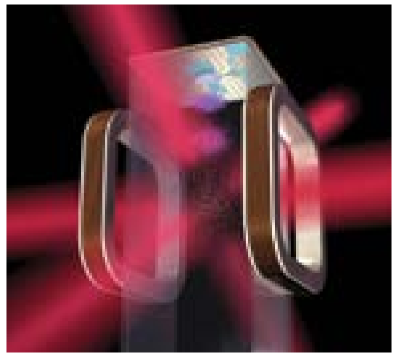
The ***Laser Interferometer Space Antenna* (LISA)** is a European Space Agency (ESA) mission designed to detect and accurately measure gravitational waves—tiny ripples in the fabric of space-time—from astronomical sources.

STRATEGIC GOALS

- Detect and understand the most cataclysmic events in the Universe
- Measure the growth of black holes
- Test the behavior of matter and energy in the strong-field limit of gravity

Fundamental Physics

Fundamental physics is the study of the principles that govern how matter and energy behave in the Universe. For example, time is a fundamental property of the Universe, and precise time measurements are key to both science and industry. Bosons are fundamental particles that can occupy the same quantum state, and Bose-Einstein condensates, bosons with their temperature reduced to almost absolute zero, exhibit observable macroscopic quantum behavior. JPL is continuing to develop missions, instruments, and scientific concepts to provide a deeper understanding of fundamental physics and how this might benefit the world and its people.

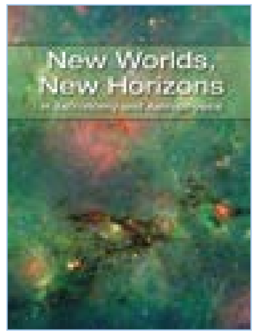


The ***Cold Atom Laboratory* (CAL)** is an ISS payload to study ultra-cold gases in a microgravity environment. It addresses fundamental questions about the quantum behavior of matter, and demonstrates Bose-Einstein condensates in a space environment. In addition, it will advance the development of extremely sensitive quantum detectors.

STRATEGIC GOALS

- Discover new physics beyond today's knowledge of fundamental laws governing matter, space, and time
- Understand organizing principles of nature from which structure and complexity emerge

Strategic Alignment with Decadal Survey



The National Academies 2010–2020 Decadal Survey for Astronomy and Astrophysics recommended the Wide Field Infrared Survey Telescope (WFIRST) as the top-priority large space mission, as well as partnership with the ESA on LISA as another priority. JPL continues to actively engage both scientifically and technologically on these missions. The top-priority medium-scale activity was a technology development program in preparation for an exoplanet imaging mission that would launch beyond 2020. JPL is continuing to develop exoplanet direct imaging technologies, including taking the lead on the Coronagraph technology demonstration instrument on WFIRST.

JPL is also preparing for the upcoming National Academies 2020 Decadal Survey for Astronomy and Astrophysics by leading and engaging in both Flagship- and Probe-class mission studies. NASA will submit the reports from these studies to the 2020 Decadal Survey panels for consideration as they prepare the prioritizations for the next decade

INTERPLANETARY NETWORK

The Interplanetary Network Directorate (IND) is JPL's programmatic focal point for deep space communications, navigation, and mission operations, and performs world-class Solar System science and astrophysics. The IND is responsible for the design, development, operation, and services for three of NASA's key mission-enabling systems: the Deep Space Network (DSN), the Advanced Multi-Mission Operations System (AMMOS), and the Planetary Data System (PDS) support nodes.

JPL QUESTS

Directly aligned with NASA's objectives, the IND's key Quests are to:

- **Help pave the way for human exploration of space**
- **Understand how our Solar System formed and how it is evolving**
- **Understand how life emerged on Earth and possibly elsewhere in our Solar System**
- **Understand the diversity of planetary systems in our Galaxy**
- **Understand how the Universe began and how it is evolving**
- **Use our unique expertise to benefit the nation and planet Earth**

STRATEGIC THEMES

To answer the JPL Quests and aid NASA in their goals, the IND recognizes the need for capabilities to handle larger data sets generated by more capable science instruments, new mission possibilities through interplanetary small spacecraft, human spaceflight beyond low Earth orbit, and higher definition videos for public engagement.

Seamless, Higher Rate, Larger Volume Data and Information Delivery

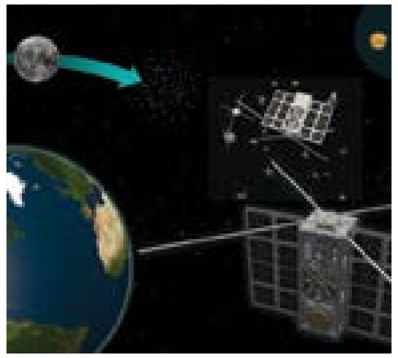
With each step in exploring and understanding the Solar System, the questions asked have become more complex, requiring that larger and richer data sets be transmitted from our orbiters and in-situ platforms to scientists here on Earth. JPL is leading the way in enabling richer science and exploration through higher data rate communications and more efficient delivery of larger volumes of information to end users. Higher frequency radios and software-defined radios with digital processing, deployable antennas, and efficient power amplifiers provide more bandwidth. In addition, the integrated AMMOS and PDS will allow mission operators, users, and the public to query and process data from NASA and its international partners. In the long run, large-aperture optical communication telescopes integrated with the radio network will provide a seamless data and information transfer between radio and optical frequencies.

STRATEGIC GOALS

- **Ensure each deep space communications complex has at least four 34-meter beam waveguides (BWGs), with the goal of six 34-meter BWGs**
- **Demonstrate Deep Space Optical Communications (DSOC) technology on the Psyche Discovery mission**
- **Develop an integrated platform for archiving and accessing telecommunications and tracking data and information, both uplink and downlink**

An Increasing Number of Deep Space Spacecraft

Human spaceflight and small spacecraft will likely lead to many more deep space missions. JPL is developing and deploying new technologies to support the increase in the number and diversity of these missions, including multiple spacecraft per aperture and multiple uplinks per aperture implemented with enhanced software-defined signal processing, enabling a single antenna to provide science teams and mission operators simultaneous connections to multiple spacecraft. These capabilities will allow better science investigations and joint human-robotic reconnaissance.



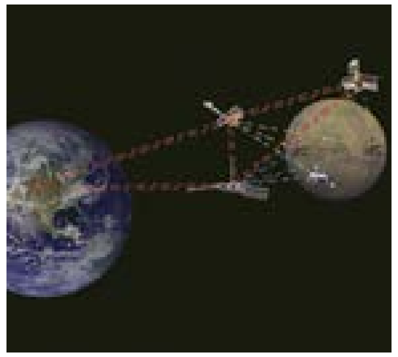
Scientists are developing ambitious mission concepts involving multiple spacecraft exploring planetary bodies and observing the Universe, demanding novel approaches and technology improvements.

STRATEGIC GOALS

- **Implement user-initiated services (demand access) in the DSN**
- **Develop the ability to handle multiple uplinks and downlinks with a single antenna or array**
- **Develop DSN-compatible stations, e.g., commercial or academic, for managing periods of high demand**

Networked and Autonomous Operations

Historically, robotic spacecraft have required substantial interaction with human operators on Earth and operated independently of each other. Now, over the past decade of presence on the surface of Mars, the beginnings of an Interplanetary Internet and autonomous operations have been established. Technologies such as disruption-tolerant networking (DTN) have been developed, based on terrestrial Internet concepts, to enable an Interplanetary Internet that provides autonomous, error-free data delivery.



Both robotic and human exploration will increasingly rely on networks, which will in turn demand new levels of automation for mission operations. This Interplanetary Internet will be similar to the terrestrial Internet, but with unique challenges for deep space.

STRATEGIC GOALS

- **Demonstrate a fully autonomous Principal Investigator (PI) request for an instrument to capture data and have that data returned to the PI, over a network that includes the terrestrial Internet, Multimission Ground Systems and Services (MGSS), the DSN, and at least one deep space planetary relay with no human intervention**
- **Implement DTN on all new NASA deep space flight assets and new and existing ground assets**
- **Demonstrate a multi-asset DTN network**
- **Establish an Interplanetary Internet Operations office**

Scientific and National Benefit

The Goldstone Solar System Radar (GSSR) on the 70-meter DSN antenna at the Goldstone Deep Space Communications Complex in Goldstone, California, is one of only two planetary radar transmitters in the world. A major focus of the GSSR efforts is tracking and characterizing near-Earth asteroids. In support of national needs, the GSSR contributes to NASA's tracking of debris orbiting the Earth, and DSN antennas have been used to prove new space situational awareness techniques. DSN antennas have been used for noninterference-based astronomical observations, such as studying supermassive black holes using very-long-baseline interferometry (VLBI) techniques, and for understanding the Solar System through radio science techniques that show oceans underneath the icy shells of the moons of Jupiter and Saturn.

STRATEGIC GOALS

- **Establish full-sky (4π) planetary radar coverage**
- **Establish DSN antennas as complements to NASA's far-infrared and sub-millimeter missions and to leading radio astronomy facilities, notably the Atacama Large Millimeter/sub-millimeter Array (ALMA)**
- **Collaborate with JPL's Earth Science and Applications Directorate to ensure appropriate utilization of IND facilities and capabilities for national needs**

International and Commercial Partnerships

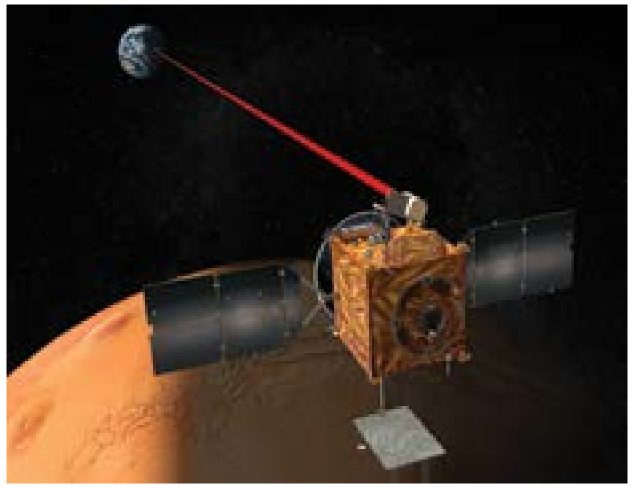
NASA often partners with international space agencies—notably the ESA, the Japan Aerospace Exploration Agency (JAXA), and the Indian Space Research Organisation (ISRO)—for the telecommunications, tracking, and command for missions to deep space. In addition, a number of emerging space agencies are considering deep space missions for which such partnerships might be developed. Working through the Consultative Committee for Space Data Systems (CCSDS), the IND aims to ensure that the flight and ground systems for NASA and the international space agencies are interoperable, which improves efficiencies and enables greater science return. International space agencies are deploying ground systems modeled after the DSN's 34-meter-diameter antennas, and the data model developed in the context of the PDS has served as a portion of the basis for international planetary data standards.

STRATEGIC GOALS

- **Establish cross-support agreements using the ESA agreement as the model**
- **Lead the Planetary Science Data Archive Community in establishing the International Data Archive Architecture and Standards**

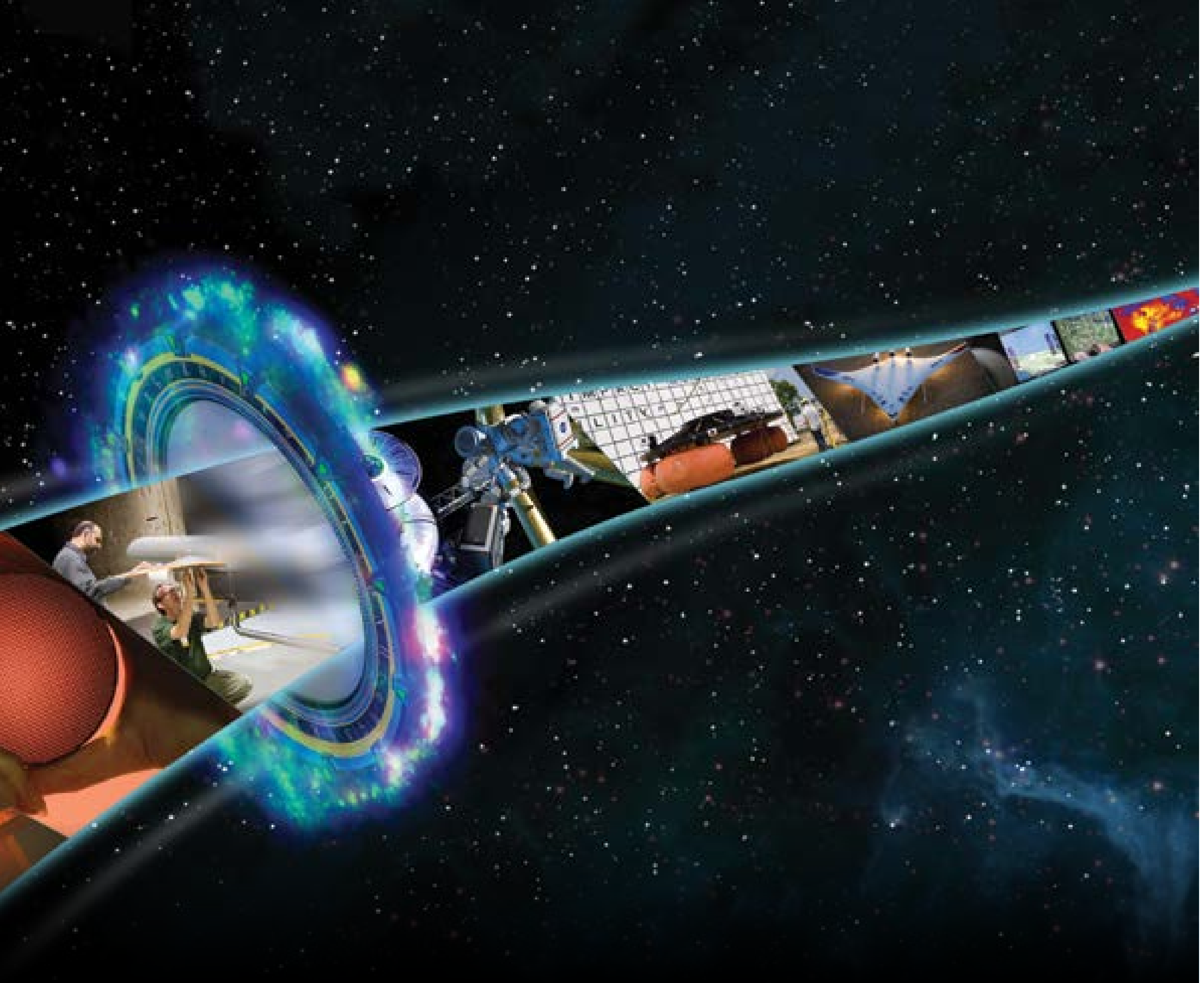
Strategic Alignment with NASA

The IND works closely with both the NASA Science Mission Directorate (SMD) and the NASA Human Exploration and Operations Mission Directorate (HEOMD) to ensure alignment between NASA goals and the near-term and long-range planning for the DSN, AMMOS, and PDS. Mission models are developed to understand the potential future needs of both robotic and crewed missions for communications, navigation, and operations. The IND participates in road-mapping activities led by both SMD and HEOMD. The IND coordinates closely with the other NASA communication networks and with the NASA Office of International and Interagency Relations (OIIR), to protect the portions of the radio spectrum required to communicate with distant spacecraft so as to be able to detect their faint signals.



Developing and implementing unprecedented optical communications technologies, ***Deep Space Optical Communications* (DSOC)** will deliver a flight-ready, deep space optical transceiver and ground data system. Communications between the flight and ground will employ novel, advanced lasers in the near-infrared region of the electromagnetic spectrum. These systems will be capable of delivering information at rates at least 10 times faster than conventional systems that use comparable mass and power.

The ***Lunar Orbiting Platform/Gateway* (LOP/G)** is a crew-tended cis-lunar space station planned by NASA and Roscosmos for construction in the 2020s. The LOP/G could be a focal point for a cis-lunar communications network, as it is also being considered by international partners for use as a staging ground for robotic and crewed lunar surface missions.



ADDRESSING NATIONAL CHALLENGES & CATALYZING ECONOMIC GROWTH

JPL has a robust set of collaborations with government agency and private-sector sponsors to address national challenges and catalyze economic growth. The goals of these sponsored collaborations align with NASA's Strategic Plan and ensure a positive impact on NASA projects.

JPL QUEST

Directly aligned with NASA's objectives, the key Quest is to:

- **Use our unique expertise to benefit the nation and planet Earth**

STRATEGIC THEMES

Sponsors fund JPL's cutting-edge concepts (***Innovate***), increase the technology readiness level (TRL) of basic research (***Incubate***), and demonstrate mature systems in flight or prototype operational environments (***Infuse***). Consistent with NASA's Strategic Plan, JPL also supports an active technology transfer effort that ensures national economic benefit from the technology investments made by NASA and other sponsors at JPL (***Technology Transfer***).

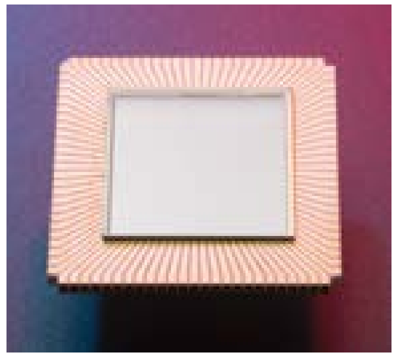
Innovate

JPL innovates new technologies in sensors, robotics, autonomy, data science, and other areas that both advance NASA's capabilities and address problems of national significance. A recent example is the technique to determine position and orientation using magneto quasi-static fields (MQS) funded by the Department of Homeland Security (DHS). This capability can provide position and orientation information for subsurface planetary rovers, and the same capability can be used on Earth for accurate positioning of first responders and robots in GPS-denied environments.

STRATEGIC GOALS

- **Innovate and mature new NASA-relevant technologies with Defense Advanced Research Projects Agency (DARPA), National Science Foundation (NSF), DHS, and other organizations**
- **Establish early coordination with NASA's Planetary, Mars, Earth Science, Astrophysics, and Deep Space Network programs to ensure successful infusion into NASA programs**

Incubate (Technology Maturation)



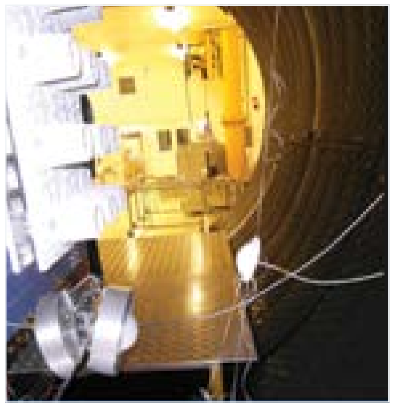
NASA, other federal agencies, and the private sector are an important part of the campaign to mature and infuse technologies into future missions.

The medium-wavelength infrared (MWIR) and long-wave infrared (LWIR) focal plane arrays based on the high operating temperature barrier infrared detectors (HOT BIRD) technology is a good example. Sustained collaborations with federal and commercial organizations since 2010 have matured this technology to the point where cost-effective sensors are being produced and available to future NASA missions.

STRATEGIC GOALS

- **Align non-NASA-sponsored technology maturation with priority NASA technology needs, including optics, robotics, instruments, electronics, artificial intelligence, big data, and metrology**

Infusing Technologies with Public and Private Entities



JPL works with federal agencies and commercial-sector sponsors to demonstrate and infuse NASA technologies and systems to advance their operational capabilities. NASA also benefits from these infusion successes because proven technologies can have a positive impact on its missions as well.

JPL successfully infused a NASA-funded advanced TriG GNSS radio-occultation system (TGRS) into the COSMIC 2A program, which is a constellation of six satellites that is scheduled to launch in 2018 and led by the National Oceanic and Atmospheric Administration (NOAA) and the National Space Organization of Taiwan. These satellites provide cost-effective and highly accurate atmospheric measurements, including three-dimensional profiles of temperature, humidity, and pressure for improved weather forecasting. NASA is planning to use this same system on future satellites.

STRATEGIC GOALS

- **Demonstrate advanced technologies that support NASA future needs on in-situ, airborne, and spaceborne platforms in collaboration with federal and commercial organizations**
- **Transfer JPL technologies and systems to operational agencies, state entities, and the commercial sector, which creates societal benefits and provides low-cost commercial providers for future NASA needs**
- **Demonstrate the utility of NASA observational data to improve decision support systems for federal, state, and local agencies**

Technology Transfer

JPL has an active technology transfer program with Caltech to pursue the transfer of technologies to the commercial sector so that the public can directly benefit from federal investments. These benefits include new commercial products that improve quality of life, create new jobs, and even generate new suppliers for NASA missions.

To ensure technology transfer success, JPL utilizes an integrated process that includes inventor disclosures, patent and copyright protection, public engagement, licensing, open-source software release, and commercial-sector support through Space Act Agreements.

STRATEGIC GOALS

- **Transfer technologies to industry to create new commercial products, services, and jobs**
- **Support U.S. industry to develop innovative, high-performance, low-cost systems for future NASA missions**

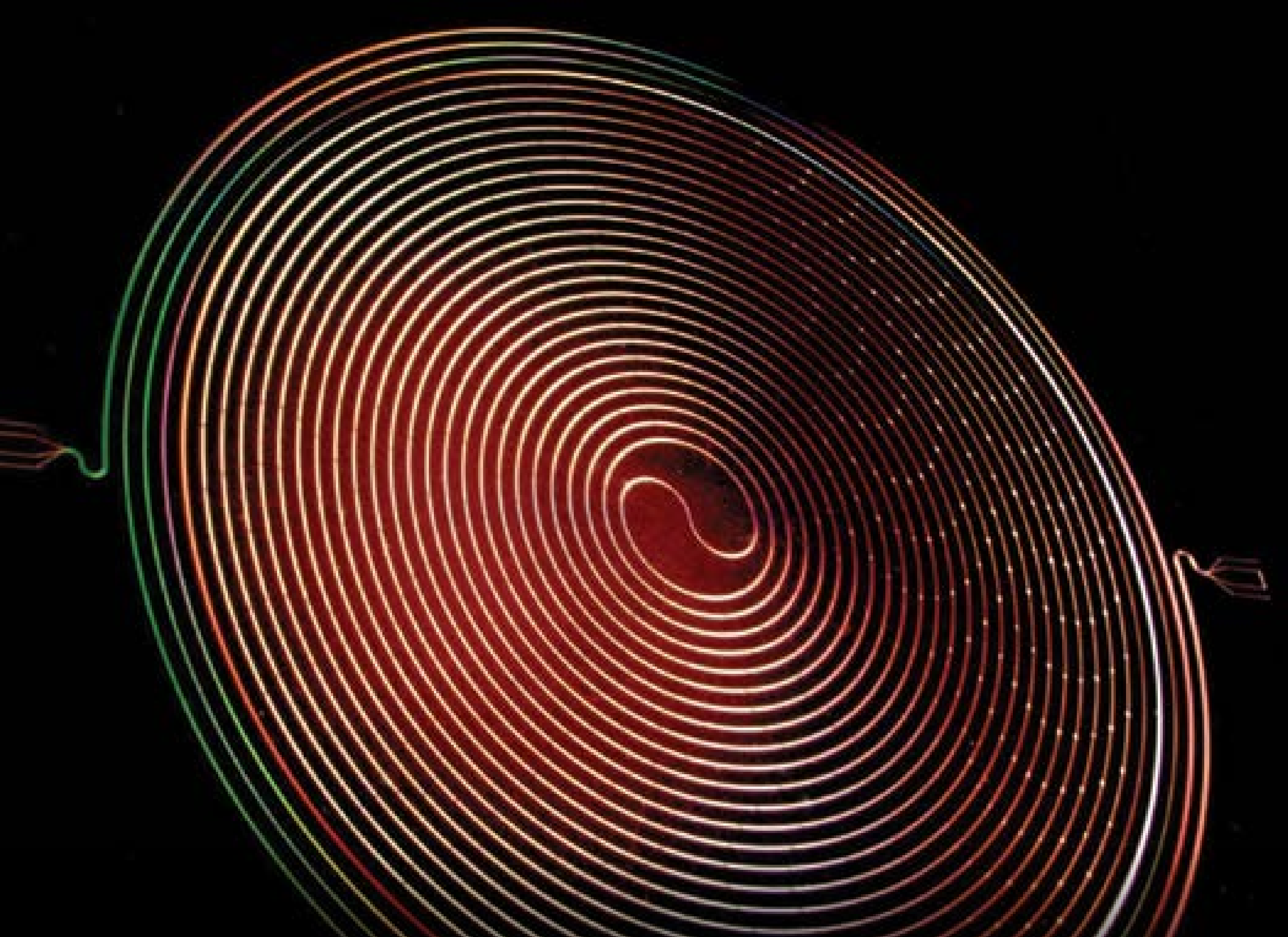
Strategic Alignment with NASA

In support of NASA's objectives for the transfer of revolutionary technologies, JPL-developed technologies are routinely licensed to the commercial space industry to enable new observation, communication, and analytical capabilities. These licenses have been made to both large, established firms and young startups. Technical areas of specific interest to industry include remote-sensing technologies such as GPS radio-occultation, satellite positioning, optical communications, and data analytics. U.S. industry has also licensed JPL innovations for a variety of applications beyond the space program, including healthcare, energy, information technology, and consumer products. As innovation becomes increasingly vital to success in the commercial sector, JPL will continue to maintain an active technology transfer program to support these important Agency objectives.

The ***Finding Individuals for Disaster and Emergency Response* (FINDER)** portable radar pictured has been used to save lives using advanced radar technology to "hear" a heartbeat in a rubble caused by a collapsing building after an earthquake. Over the past 5 years, Caltech has granted more than 80 licenses to companies to support commercialization of NASA-developed technologies, with 14 licenses to startups.

Stratuscent Inc. is a JPL startup that is building a chemical-sensing platform, based on JPL-developed E-Nose technology, for applications such as monitoring indoor air quality, tracking daily fat burn rates, medical diagnostics (detecting diabetes, cancer, asthma), and monitoring food safety.

SeekOps Inc. offers miniature gas sensors and leak detection services to the energy industry. SeekOps uses proprietary gas sensors on unmanned aircraft systems to detect methane, the primary component of natural gas. SeekOps is commercializing a tunable laser spectroscopy technology that was originally developed at JPL for space applications but quickly gained the interest of the energy sector.



Quantum-limited wideband parametric amplifier enabling a multiplexed readout of superconducting qubits in a quantum processor. The recently demonstrated amplifier performs almost ideally, delivering quantum limited sensitivity over a band from 5 to 10 GHz.

BENEFITS TO NATIONAL SECURITY

JPL realizes that many of its technologies and capabilities that are critical to exploring space can also be made available to solve challenging problems on Earth, thus providing a benefit to our nation and society at large. One of those areas is national security. JPL's goal is to remain a trusted partner for the U.S. national security community. The National Security Program Office (NSPO) at JPL is the programmatic focal point for applying JPL's capabilities in space exploration, space utilization, and space communications to areas of national interest for all classified work that requires clearance access, and has a classified deliverable for an intelligence community agency sponsor.

JPL QUEST

Directly aligned with NASA's objectives, the key Quest is to:

- **Use our unique expertise to benefit the nation and planet Earth**

STRATEGIC THEMES

The NSPO has identified the following strategic themes to address its JPL Quest, and in turn, aid NASA in their overall goals to ***discover***, ***explore***, ***develop,*** and ***enable***.

JPL's classified work is a synergistic portfolio of multi-sponsor, multi-classification work that positions JPL for future NASA missions, advances technologies useful to NASA missions, and keeps core competencies at JPL. The NSPO accomplishes this via funding from non-NASA sponsors. NSPO has a strong governing principle and sets a high bar for work selection, governance, and performance of JPL's classified work. Work must meet JPL's "Four Pillars" of national security work:

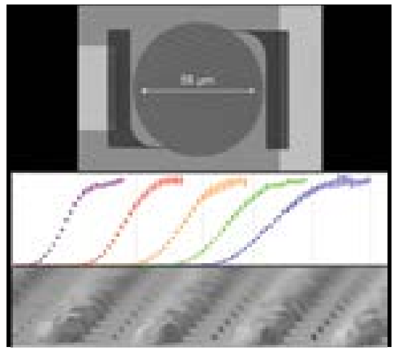
1. JPL capabilities can be applied in areas of critical national interest.
2. The work is synergistic with the science and technology that forms the basis for our NASA work by helping to develop capabilities that can be applied in NASA's scientific missions.
3. The work is consistent with the guidelines established by the Caltech Board of Trustees with respect to transparency, maintaining JPL culture, and defensibility.
4. The work is compatible with our ability to carry out our responsibilities defined in the NASA Contract with respect to uniqueness and use of resources.

Technologies advanced under the NSPO cross the breadth of directorates and address technologies such as optics, robotics, instruments, electronics artificial intelligence, big data, metrology, and communications.

National security work is strategically valuable to JPL because it matures cross-cutting technologies that fulfill NASA needs and satisfy critical national security priorities. NSPO bridges non-NASA national security work and JPL's NASA work to drive technology advancements and infusion, technology transfer to industry, and transformational demonstrations.

Technology Advancements and Infusion

NSPO leverages non-NASA funding to advance and mainstream national security technologies for greater usefulness to JPL and for continual demonstration of benefit to NASA.



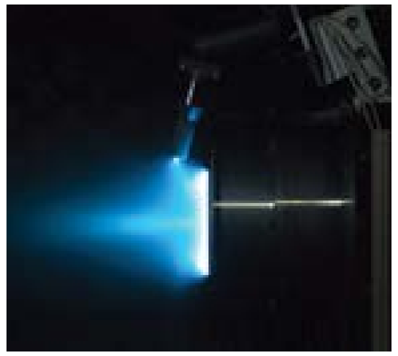
Enabling Yb-171 qubit state readout fidelity and speed through cavity quantum electrodynamics.

STRATEGIC GOALS

- **Infuse technologies matured in classified technology demonstrations into NASA mission concepts**
- **Leverage synergistic technologies developed under the classified programs to the NASA space science missions, as permitted.**

Transformational Demonstrations

NSPO engages in one-of-a-kind / first-of-a-kind technology demonstrations of sufficient significance so that both NASA and non-NASA sponsors can use it as evidence for the next level of funding toward a mission capability.



Supporting research into ion thrusters for diagnostics, plume dynamics, and thruster interactions. Advancements are being made in the area of low power and small thrusters.

STRATEGIC GOALS

- **Advance the current technology capability by securing the next technology demonstration activity**

Technology Transfer to Industry

NSPO employs a layered transition strategy from the outset of each new effort. Inherent in our FFRDC role is supporting NASA's robust commitment to commercialization. Where appropriate, NSPO strives to partner with industry to license technology, possibly enhancing it in the process for manufacturing, and to transition proven technologies for follow-on government benefit.

Autonomous precision landing of sUAS (small unmanned aerial systems) is enabled by identifying safe landing zones in unknown environments. These areas are mapped out in 3D using 2D images in real time on the aircraft and state estimation algorithms that determine position and orientation.

STRATEGIC GOALS

- **Transition technological capabilities and support the U.S. industrial base, while retaining the unique capability to modify**

Strategic Alignment with NASA

Strategic alignment with the needs of future NASA scientific missions is a cornerstone of JPL's work in support of the national security community. In addition, JPL's work in this area directly supports NASA's objectives for the research, development, and transfer of revolutionary technologies, and furthers the Agency's efforts to address national challenges.

X-37B

X-37B Orbital Test Vehicle

The U.S. Air Force's X-37B Orbital Test Vehicle mission 4 (**OTV-4**) spent a record 718 days in space, touching down May 7, 2018 at the Shuttle Landing Facility (SLF) at NASA's Kennedy Space Center in Florida—the first landing at the SLF since the final space shuttle mission came back to Earth in July 2011.

THRUSTS

Create the Laboratory of the Future

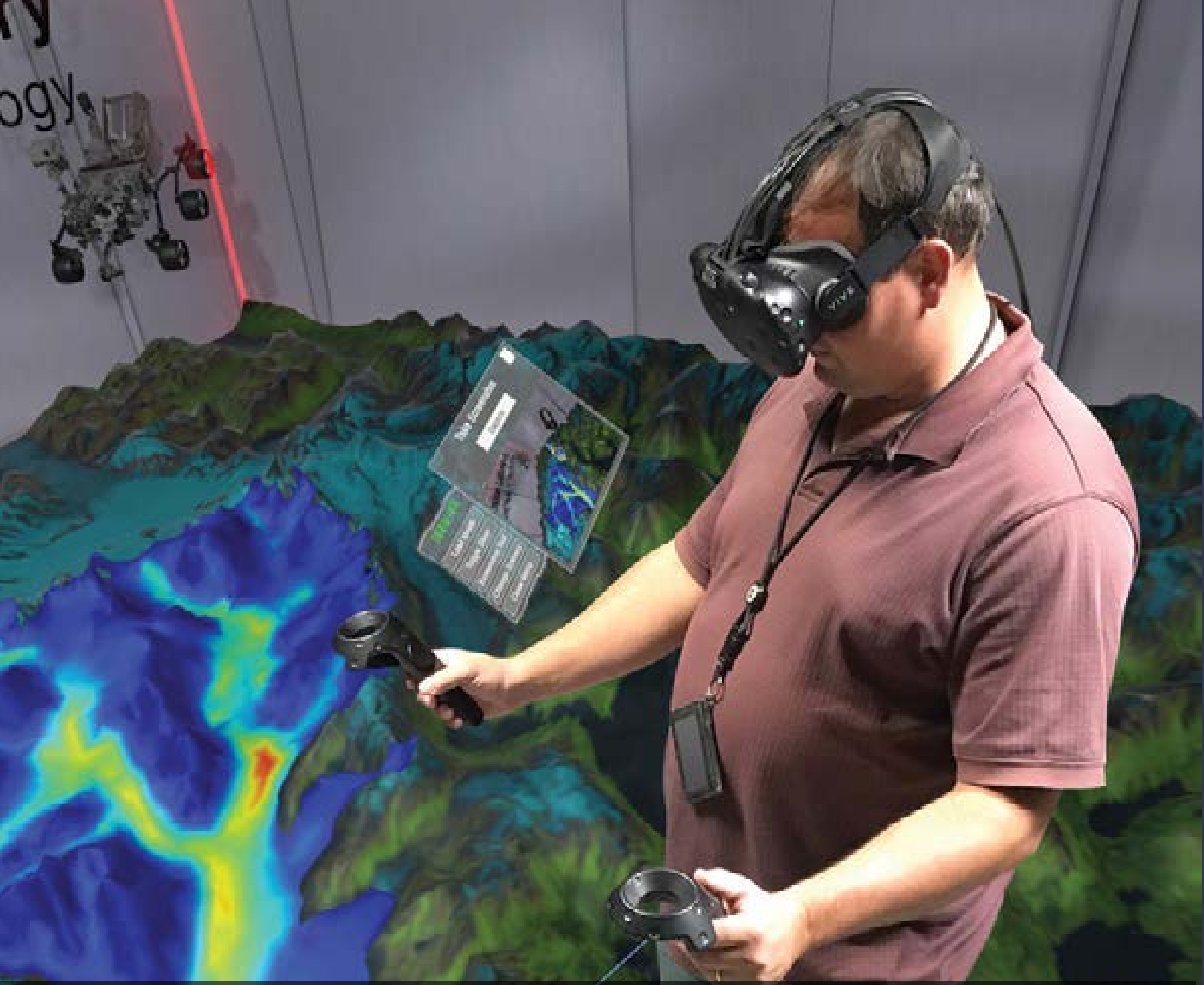
CREATE THE LABORATORY OF THE FUTURE

- **CREATING THE LABORATORY OF THE FUTURE**
- **INNOVATING WHAT WE DO AND HOW WE DO IT**
- **INSPIRING THE WORLD THROUGH OUR STORIES**

DIGITAL TRANSFORMATION STRATEGY

ENABLING MISSION SUCCESS

Currently on exhibit at The Huntington in San Marino, California, NASA's ***Orbit Pavilion*** is an innovative "soundscape" representing the movement of the ***International Space Station*** and 19 Earth Science satellites.



JPL scientist Eric Larour investigates the interior of Alaska's Columbia Glacier from the comfort of his office at JPL using the Virtual Earth System Laboratory (**VESL**) virtual reality system.

CREATE THE LABORATORY OF THE FUTURE

JPL's strategic priority is to create the Laboratory of the future, defined by a talented and inclusive workforce, rapid information sharing, and a culture of innovation. We frame and organize this pursuit according to three JPL strategic Thrusts. These represent our emphasis on nurturing the Lab's culture to complement and support JPL's seven scientific Quests. JPL will invest in a culture of innovation that spans not only the "what" of our business but the "how." We will invest in the future needs of our people, our workplace, and our work practices; and we will strengthen our ability to share our stories and inspire new generations across the world.

JPL STRATEGIC THRUSTS

Creating the Laboratory of the Future

We seek to attract the world's best talent to shape an innovative and inclusive culture where passion, opportunity, and expertise combine to launch historical endeavors. We will invest in the future of our workplace and work practices to keep pace with the rapidly changing expectations and environments in which talent wants to work.

STRATEGIC GOALS

- Nourish an inclusive and innovative environment by recruiting, promoting, and embracing diversity in its broadest representation
- Reinvent the way employees learn in order to strengthen leadership capabilities and accelerate the development of technical talent
- Invest in tools that will push the boundaries of remote and virtual work and collaboration

Innovating What We Do and How We Do It

We will elevate the importance of how we conduct our business to the same level of significance as the work we do. We will develop and invest in improved methods and streamlined practices, while also anticipating, adopting, and advancing on innovations and technologies from the commercial sector. We will establish an environment that delivers innovative and agile solutions to how we conduct our business.

STRATEGIC GOALS

- Modernize our engineering and business practices
- Create Maker Labs that include designing, modeling, visualizing, prototyping, and 3D printing new materials, concepts, and robots
- Partner with leading industry innovators on game-changing, emerging technologies and capabilities

Inspiring the World through Our Stories

The Space Act charges NASA and JPL to "provide for the widest practicable and appropriate dissemination of information" about space exploration, and to enhance public understanding of, and participation in, the nation's space program in accordance with the NASA Strategic Plan.

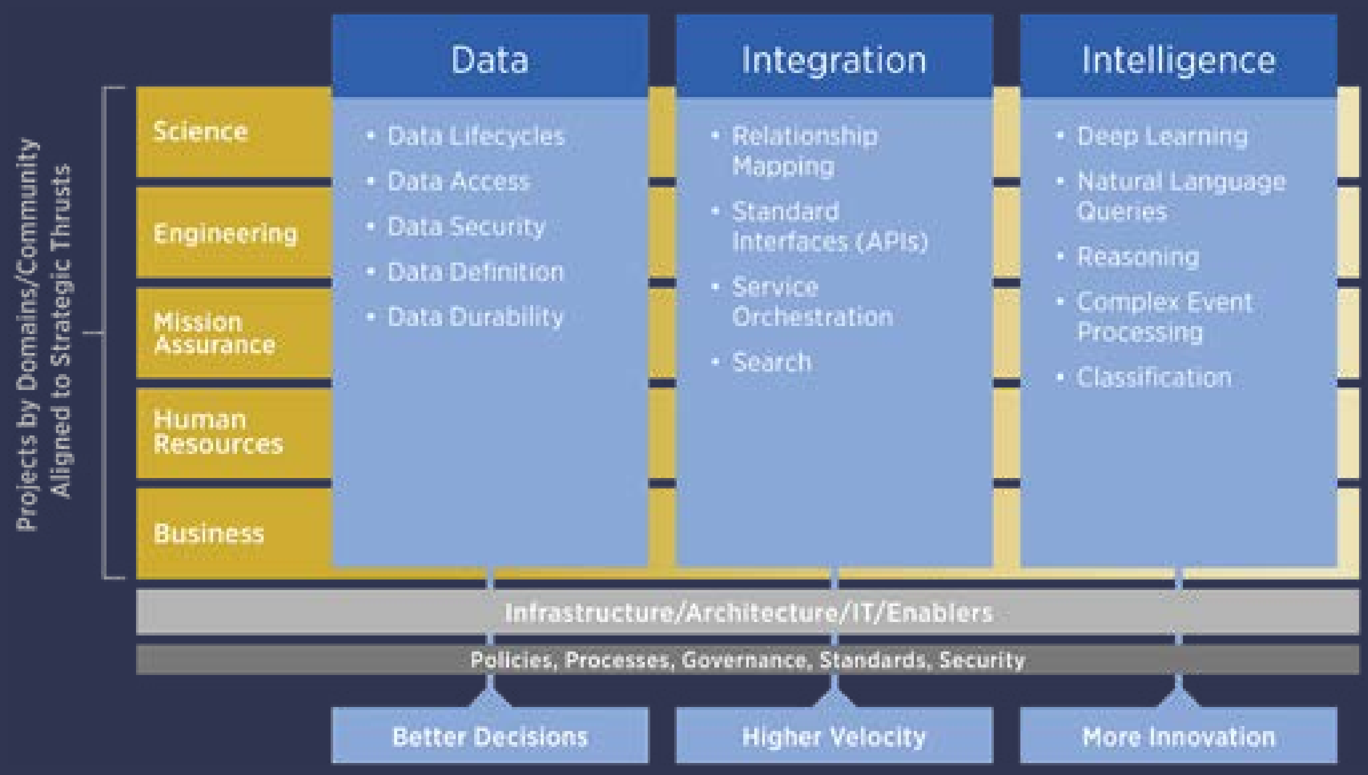
STRATEGIC GOALS

- Enhance broadcast, digital, and storytelling capabilities to expand our external audiences
- Strengthen the engagement of the JPL workforce
- Leverage the success of student and education programs to align with JPL's workforce needs

DIGITAL TRANSFORMATION STRATEGY

In support of the JPL Thrusts, JPL's strategy is to digitally transform the Laboratory from legacy processes and systems to modern, integrated, and information-driven ways of doing business, including automation of routine processes and data-related tasks, integration of data and systems, advanced search and analytics, and improved information sharing and collaboration. In pursuing the Laboratory's Digital Transformation, JPL will coordinate closely with the NASA Office of the Chief Technologist (OCT) and the NASA Office of the Chief Information Officer (OCIO) on Agency-wide Digital Transformation efforts to create a more agile and efficient NASA operating model.

By leveraging the evolving landscape of digital technologies across the Lab's activities, processes, competencies, capabilities, and products, this Digital Transformation will benefit all domains of JPL work (Science, Engineering, Mission Assurance, Human Resources, and Business) through increased efficiency, flexibility, and performance, as well as better-informed decision making. Strategic themes include Data Maturation and Sharing, Connectivity (Acceleration), and Innovation and Analytics.



STRATEGIC THEMES

Data Maturation and Sharing

Enrich and evolve data throughout its lifecycle along the technology continuum from being free of silos to securely accessible to readily searchable to robustly predictive, resulting in better data-driven decisions.

Connectivity

Invent, refine, and improve tools such as relationship mapping, standard interfaces (APIs), and ontologies to increase the velocity of obtaining, and benefiting from, integrated information and insight.

Innovation and Analytics

Implement advanced technologies for deep learning, such as natural language queries and complex event processing, to derive maximum intelligence from JPL's rich data stores and ignite the imagination to greater innovation.

ENABLING MISSION SUCCESS

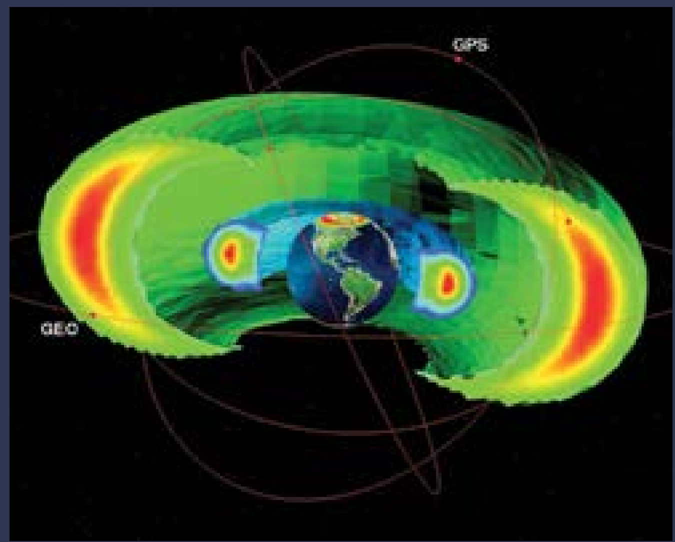
Assuring the safety of our people and facilities and the reliability of our missions are essential to the success of our current and future missions. This is made possible by continually enhancing the safety of our workplace, and embracing new processes and mission assurance techniques that can facilitate the insertion of new technologies and enable future missions.

Enhancing our technical capabilities, processes, and tools is essential to maintaining our ability to field and operate reliable space systems. Assessments of advanced technologies for insertion into space systems are based on having a detailed understanding of the technologies and their operational and reliability characteristics in the relevant environment.

OFFICE OF SAFETY & MISSION SUCCESS STRATEGIC PROGRAMS

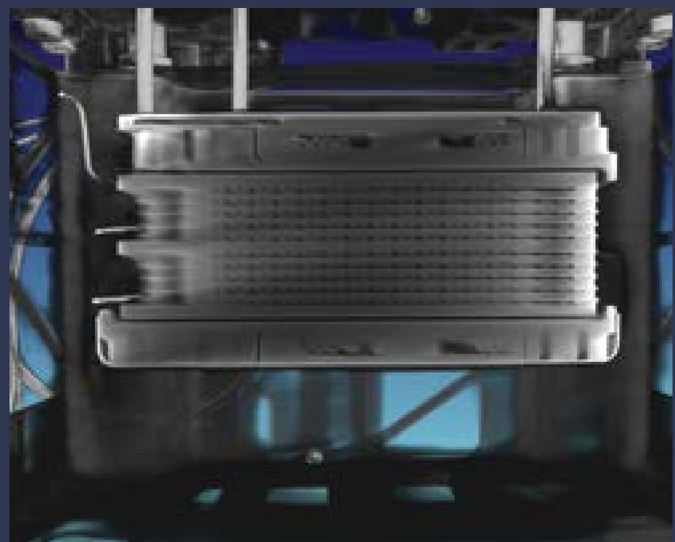
Technology Infusion

Infusing commercial technologies and design practices into JPL designs and utilizing modeling tools and techniques to augment inspection or testing can greatly enhance our understanding of the design and reduce associated cost and schedule. In addition, developing methodologies for autonomy assurance can be enabling for future autonomous mission operations.



Process Improvements

Transforming and automating data collection, accessibility, and analysis to track the flow of work and engineering data across a project's lifecycle can be of great benefit across the spectrum of JPL activities. This coupled with the infusion of system reliability practices and integration of mission assurance practices, processes, and tools into the model-based engineering practices can result in increased system reliability with a streamlined process for data assessment and analysis.



Enhancing Technical Infrastructure

Developing and maintaining technical skills and capabilities for the assessment of advanced technologies such as optical technologies, compound semiconductors, and software assurance require continual improvements to the technical infrastructure. These improvements include enhancements to JPL radiation modeling, test and analysis capabilities and tools, and development of technology failure investigation and analysis techniques to facilitate technology insertion and enable future missions.

FUTURE CAPABILITIES

Accelerating Technology Infusion into Future Missions

JPL's strategy is to 'Strengthen our end-to-end capability while accelerating technology infusion into our missions.' Developing and infusing advanced technologies is key to transforming our vision into a set of bold but achievable space science missions. This section presents a snapshot of some of the key future capabilities that the Laboratory is investing in as part of our long-term strategy.

LIFE DETECTION, ASTROBIOLOGY

AUTONOMOUS SYSTEMS & ARTIFICIAL INTELLIGENCE

SMALLSATS

ADDITIVE MANUFACTURING

IN-SPACE ROBOTIC ASSEMBLY

CONSTELLATIONS, SWARM SYSTEMS

IN-SITU SCIENCE

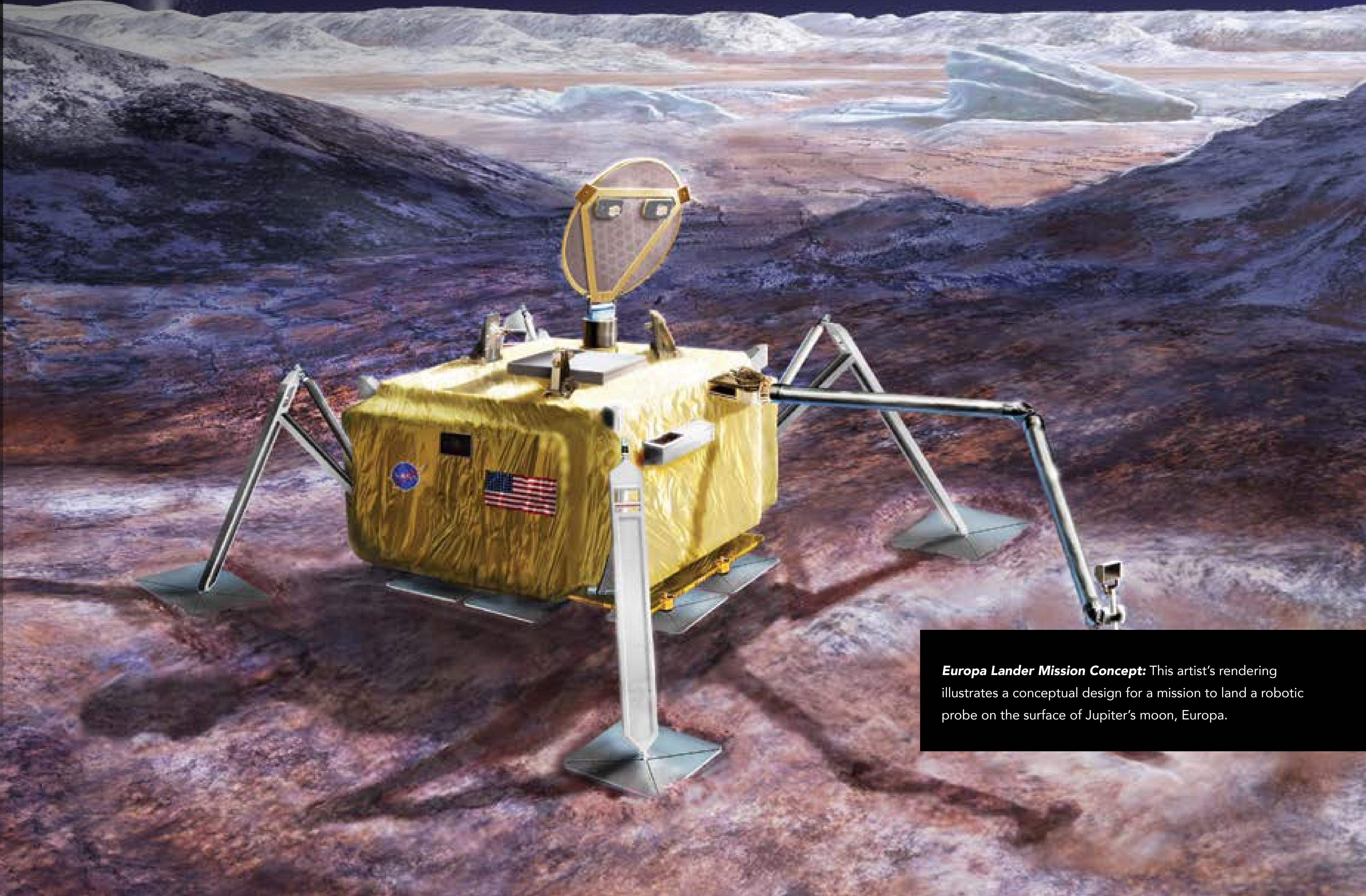
HIGH-PERFORMANCE SPACE COMPUTING

ADVANCED DETECTORS

QUANTUM SENSING & COMMUNICATIONS

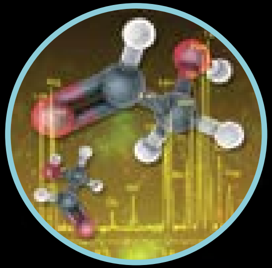
AUGMENTED REALITY/ VIRTUAL REALITY

BIG DATA, DATA ANALYTICS



Europa Lander Mission Concept: This artist's rendering illustrates a conceptual design for a mission to land a robotic probe on the surface of Jupiter's moon, Europa.

FUTURE CAPABILITIES



Life Detection, Astrobiology

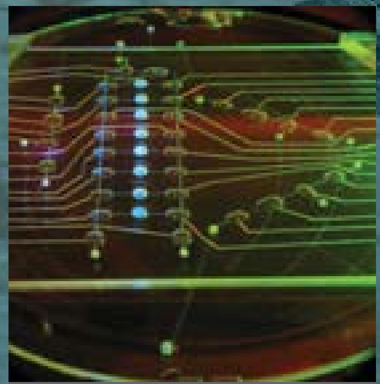
Detecting life in deep space environments (Europa, Mars, Enceladus, Titan, and Ceres) requires innovation in the next level of instruments. The Organic Capillary Electrophoresis Analysis System (OCEANS) and the Digital Holographic Microscope (DHM) are two instruments being developed at JPL to detect and characterize organic compounds and to study the composition, structure, and particles preserved in ice, snow, and subsurface water, respectively.

Europa Clipper

NASA's Europa Clipper mission will conduct detailed reconnaissance of Jupiter's moon, Europa, to investigate whether the icy moon could harbor conditions suitable for life.

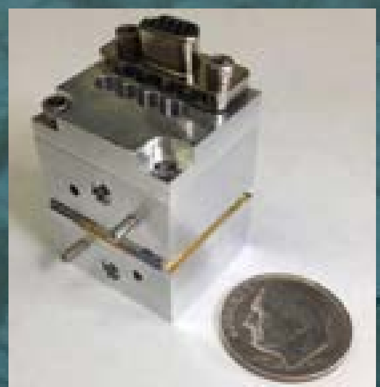
Microfluidic Capillary Electrophoresis Instrument

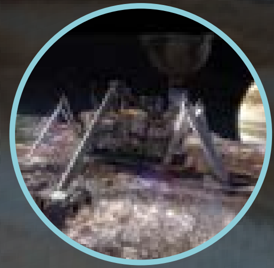
This instrument is designed to search for signs of life on other planetary bodies. It determines the relative abundances and chirality ratios of amino acids using laser-induced fluorescence detection. It can also inject species into a mass spectrometer through electrospray ionization, enabling a broad survey of complex organic compounds.



Miniature Submillimeter Radiometer-Spectrometer

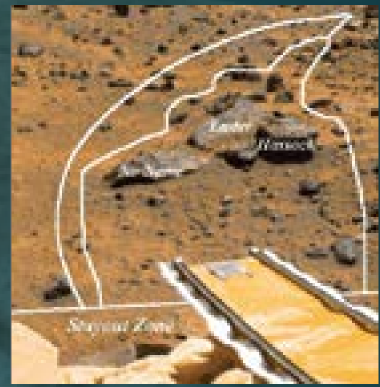
The miniature submillimeter radiometer-spectrometer is ideal for remotely characterizing plume activity and plume chemistry at Enceladus and Europa. It provides nearly five times greater sensitivity and wider spectral tuning than the current state of the art, but with significantly reduced mass, volume, and power consumption.





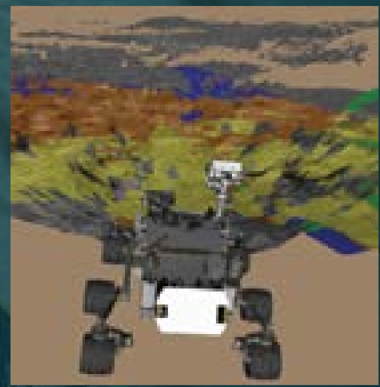
Autonomous Systems & Artificial Intelligence

Space exploration involves spacecraft operating in harsh and unforgiving environments. JPL is pioneering resilient, self-aware, and autonomous systems able to weigh risk and make decisions on the spot to ensure that tomorrow's missions are a success.



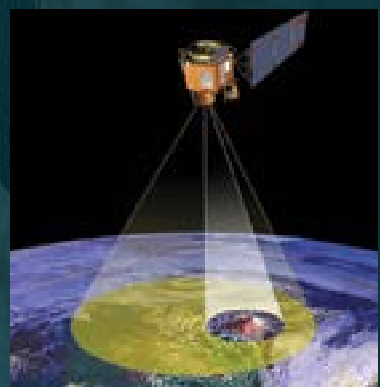
System-Level Autonomy

Technologies such as perception prediction, system-health assessment, and risk-awareness enable on-board decisions and choosing actions with consideration of uncertainty in knowledge of self and the environment. Using probabilistic reasoning across subsystems, the system can arrive at decisions that meet user-specified safety criteria.



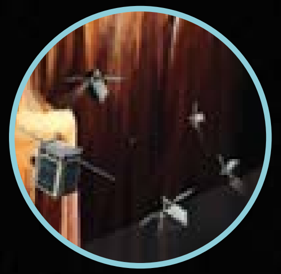
Autonomous Robots

Autonomous navigation and manipulation technologies enable efficient and reliable access to targets of scientific interests on planetary surfaces. Using advances in sensing, perception, estimation, learning, reasoning, mobility, and manipulation, robots are able to perceive and classify terrains, assess hazards, plan safe trajectories, reach targets of interest, and improve performance by learning from past experiences.



Autonomous Sciencecraft

Autonomy software technologies enable operations analysis to optimize spacecraft and mission design (trajectory, coverage, spacecraft design, particularly for constellations/swarms), as well as enable onboard data analysis and response (scheduling and execution) for novel science and in-situ exploration of unknown, unpredictable environments.

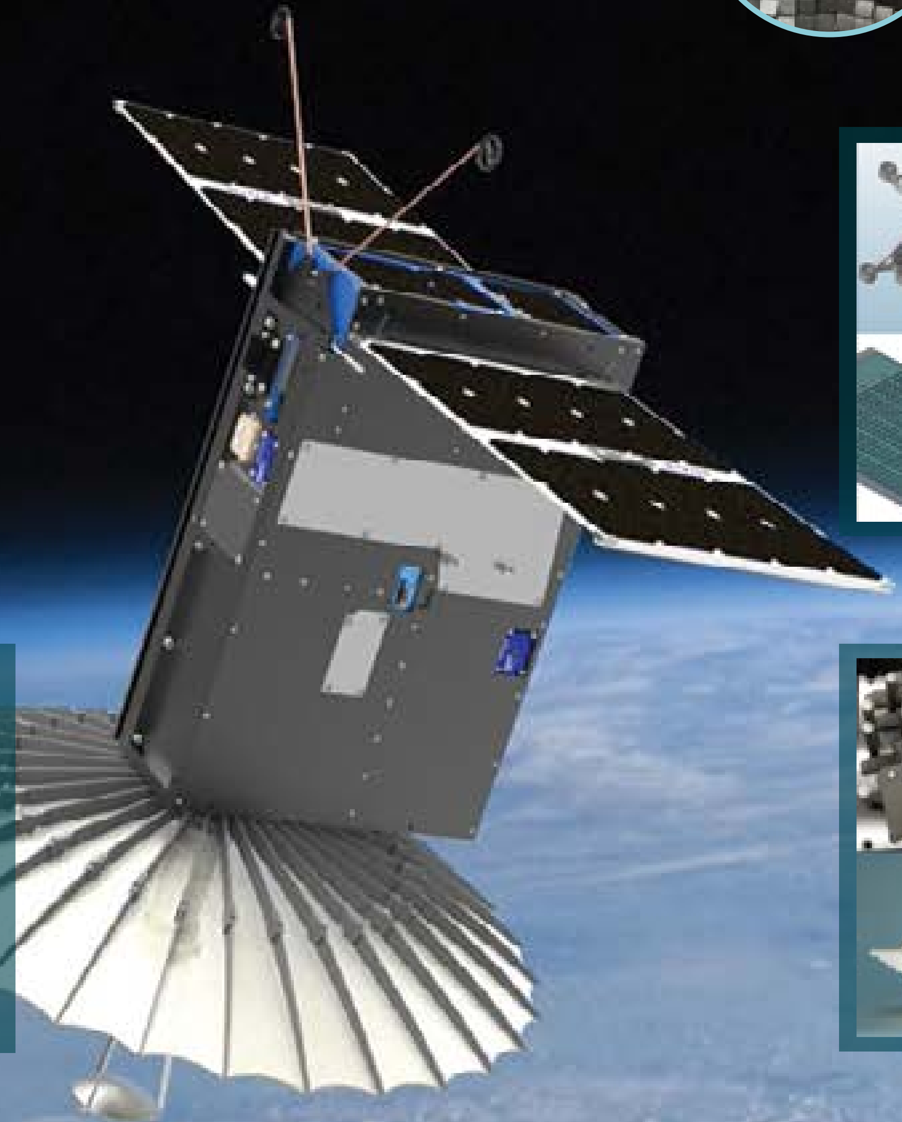


SmallSats

Big ideas, small satellites: The SmallSat revolution is upon us, and JPL is at the forefront of helping redefine the way we do science in space. Small, modular, and inexpensive to build and launch, SmallSats offer a new world of possibilities in research and technology development for everyone—students, universities, technology pioneers, and crowd-sourced initiatives.

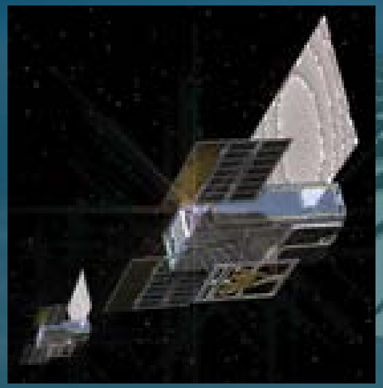
RainCube

RainCube—a radar in a CubeSat—is just that: a miniaturized precipitation-studying radar instrument that weighs just over 26 pounds. RainCube is smaller, has fewer components, and uses less power than traditional radar instruments.



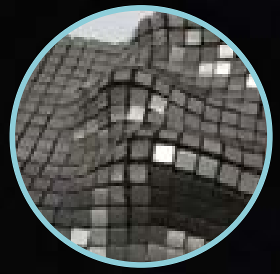
MarCO

Launched on May 5, 2018, the twin Mars Cube One CubeSats are the first deep space use of miniature, modular CubeSat spacecraft design. Flying along behind NASA's InSight lander, they are the first CubeSats to go to another planet.



ASTERIA

This space telescope mission earned the 2018 Small Satellite Mission of the Year award for being the first CubeSat to measure the transit of an exoplanet. This demonstrates that SmallSats can make sensitive detections to study astrophysical phenomena. ASTERIA, a collaboration with MIT, is funded by JPL's Phaeton Program for training early career employees.

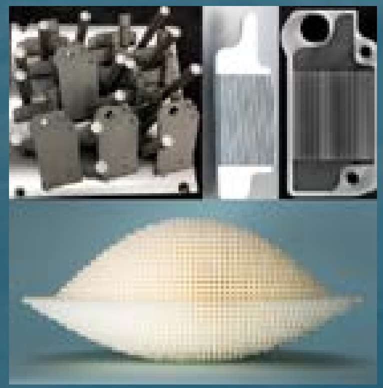


Additive Manufacturing

Additive manufacturing represents a new frontier in the development of optimized, unique geometries and multifunctional structures, and in prototyping new ideas at reduced schedule and cost. In partnership with other NASA centers, industry, and academia, JPL is paving the way in additive manufacturing within design and build processes and applications to enable new opportunities for future missions and to increase science return.

Planetary Robotics and Landers

JPL is using additive manufacturing to enable future robotic landers. This includes structural applications (such as the topologically engineered and printed prototype Mars helicopter motor mount), as well as modeled and printed parts (such as two-phase heat exchangers for thermal management). Additive manufacturing may also enable robotic mobility through printed wheels, gears, and actuators.



Multifunctional Spacecraft

JPL is using additive manufacturing in innovative multifunctional spacecraft applications. It allows structural components to be combined with function (such as the heat exchanger printed for MOXIE or a printed Luneburg lens spacecraft antenna). Future applications will allow more advanced functions, such as shape morphing and printed metal fabrics.

New Materials for Extreme Environments

JPL is a leader in the development of new metal alloys and composites for use in space. A new additive manufacturing technology, directed energy deposition, allows JPL to create functionally graded metals with more than one alloy composition in the final part. These advanced metals have the ability to change properties throughout a printed part, including magnetism, wear resistance, and strength.

In-Space Robotic Assembly

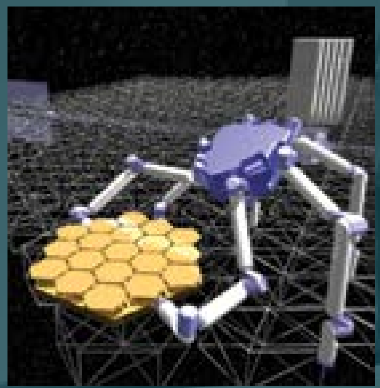
In-space robotic assembly, servicing, and manufacturing are bold new ways of thinking about implementing future science missions. It holds the potential to enable new missions that cannot be launched today, enhance missions with the ability to repair and upgrade components, and dramatically alter the risk and cost postures of space missions. JPL is formulating new architectures, developing technologies, and forging collaborations toward the next generation of science missions that leverage this new paradigm.

Science Station

In collaboration with industry, JPL is developing robotic technologies for a robotically assembled and serviced persistent platform for hosting Earth observation payloads.

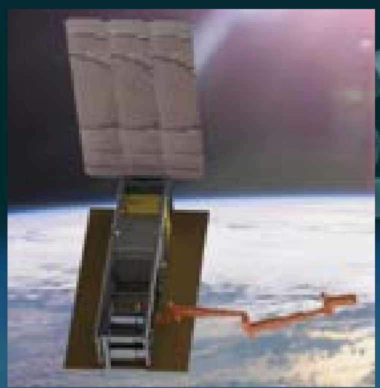
In-Space Assembled Telescope

JPL is developing concepts and technologies, along with ground demonstrations, for in-space, robotically assembled optical telescopes, starshades, interferometers, radars, and communication payloads.



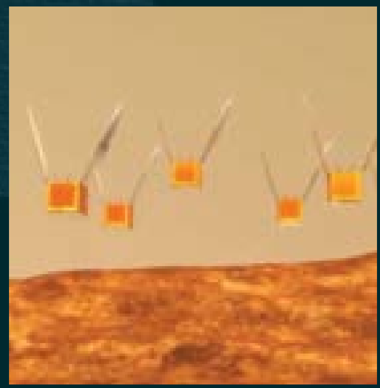
Aggregates of SmallSats and CubeSats

Can a large asset be redesigned to be made of smaller CubeSat or SmallSat components that can be assembled together in space using robotic manipulators for berthing and adjustability? JPL is developing robotic solutions for this.



Constellations, Swarm Systems

JPL is developing key technologies to make swarms of spacecraft a reality on future missions. From forming reconfigurable deep space antennas to expanding the reach of our planetary rovers into extreme terrains, these systems will provide a substantial leap in NASA's capability to explore the universe.



Marsbees

NASA is funding a preliminary study to develop Marsbees as a concept for exploring the Martian environment. The bumblebee-sized robots would make brief flights to sample the Martian atmosphere before returning to their Mars rover home base to recharge.

Distributed Swarm Antenna Arrays

JPL is investigating the feasibility of constructing a deep space, reconfigurable, high-bandwidth communication system using swarms of interconnected or free-flying satellites. The idea is to develop an efficient antenna array of CubeSat-like transmit-antennas to enable autonomous, distributed, on-demand, high-data-rate communication systems.

Guidance of Swarms Deployed from the Back Shell

JPL has developed a guidance algorithm for a swarm of assets deployed from the back shell of the Mars spacecraft for distributed science. The guidance algorithm computes the release time of the assets during the entry, descent, and landing sequence, such that the swarm achieves the desired configuration upon landing, despite individual assets being subject to significant environmental disturbances.

In-situ Science

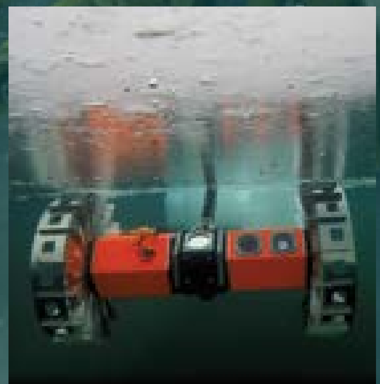
Many of our scientific investigations will require close encounter and the sampling of extra-terrestrial material in potentially habitable worlds and in extreme environments where life could have originated or may exist today. These may include sampling deep ocean thermal vents under the icy crust of Europa, sampling the methane oceans of Titan or plumes of Enceladus, drilling deep under the surface of Mars, or sampling the hot surface of Venus and other exciting and challenging destinations.

Underwater Gripper

Hydrothermal vents on the ocean floor, rich with nutrients and energy, are potential locations where life might have emerged. This gripper, designed for a deep-water robotic vehicle, can sample the minerals and microbial communities found in these extreme environments.

Buoyant Under-Ice Rover

This ocean-going robot is buoyant, allowing it to drive on the underside of ice sheets. This interface between liquid and solid water is a key place to look for life on other worlds. On Earth, the rover has been deployed to locate methane seeps on the bottoms of frozen lakes in Alaska, and under sea ice several meters thick.



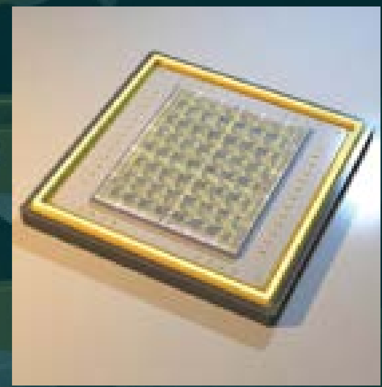
Quadrupole Ion Trap Mass Spectrometer

This is a new, multipurpose planetary exploration tool that provides exceptional accuracy and sensitivity for measuring noble gases and trace species in planetary atmospheres. It is also capable of conducting geochronology experiments, as well as studying planetary habitability and searching for signs of life.

FUTURE CAPABILITIES

High-Performance Space Computing

JPL is exploring semiconductor technologies to enable dramatic (orders of magnitude) increases in processing capabilities to meet a wide spectrum of NASA needs and requirements. This includes autonomous operation, machine learning and artificial intelligence, high-speed wireless infrastructure, robotics, and multiple sensor input and fusion. Areas of research are focused on a wide array of technologies that can be used across all of NASA's space environmental conditions and mission classes.

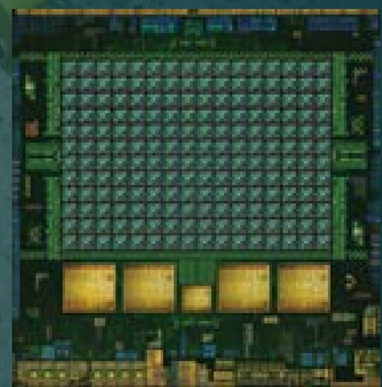


Radiation-Hardened Computing Hardware

This focus develops high-performance, low-power computing capabilities for use in extreme environments, where reliability requirements are paramount and power is at a premium. Initial developments have provided greater than two orders-of-magnitude increases in processor throughput, memory bandwidth, and input/output bandwidth compared to the current state of the practice in radiation-hardened space electronics, at similar power levels, with an order-of-magnitude improvement in radiation and fault tolerance.

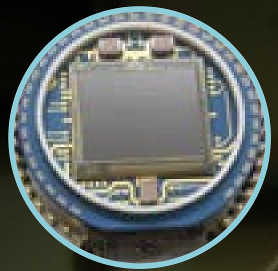
Advanced Software Technologies

Current software technology does not allow the generation and validation of the tens of millions of lines of complex parallel codes required for the autonomous systems envisioned for next generation space systems. New approaches are being developed that will enable the rapid, low-cost generation of the verifiably correct codes required for these future systems.



Advanced Commercial Chipsets and Platforms

Mobile phone and next generation automotive system on a chip (SoC) platforms, based on highly scaled (less than 16 nm) commercial complementary metal-oxide semiconductor (CMOS) technologies, provide multiple giga-ops of processing power, often with less than 1 Watt of total power consumed. These platforms are based on heterogenous computing architectures (CPUs, GPUs, and DSPs all integrated on one piece of silicon). JPL is partnering with these chipset providers to adapt and leverage existing solutions to meet next generation mission and project opportunities.



Advanced Detectors

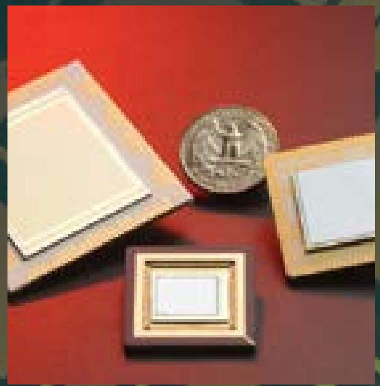
New science and new missions are enabled by access to new observables. Advanced detector technologies being developed at the JPL Microdevices Laboratory (MDL) measure electromagnetic radiation over a wide range, from soft x-rays to millimeter wavelengths. Advances are being made in spectral range, sensitivity, dimension, speed, manufacturability, etc. These new detectors enable new science opportunities across NASA. For more information, including the latest MDL Annual Report, visit https://microdevices.jpl.nasa.gov/.

Superlattice-Doped Ultraviolet Detectors

Using a fundamentally new superlattice-doping approach, MDL has developed silicon-based, deep- and far-ultraviolet detectors with vastly improved stability and quantum efficiency.

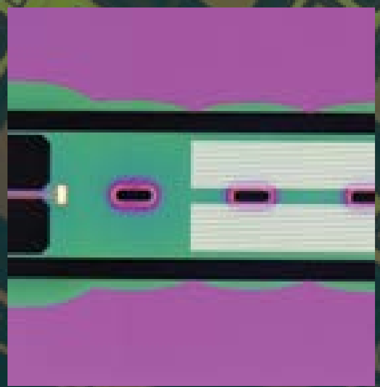
High-Temperature Infrared Detectors

Using III-V semiconductor material in conjunction with novel type-II bandgap engineering, MDL is developing new classes of infrared detectors that operate at higher temperatures and have improved manufacturability over the state of the art.



Superconducting Millimeter Detectors

A new class of thermal kinetic inductance detectors are being developed for millimeter wave astronomy in the 200–300 GHz spectral range and for other objectives. These detectors have the potential to achieve excellent time and energy resolution and, most importantly, can be scaled up to megapixel arrays.

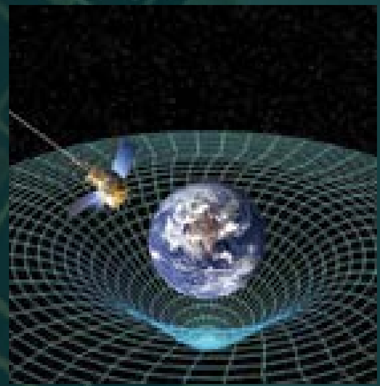


Quantum Sensing and Communications

Quantum sensors and communications form a wide class of instruments and technologies whose performance is not limited by the boundaries of classical physics. Such instruments are capable of ultrasensitive measurements, while quantum communications provide for unparalleled security, data rates, and efficiency. Implementing these technologies allows for testing of fundamental physics with unprecedented precision and provides for new capabilities in space communications, navigation, in-situ measurements, and astrophysics observations.

Quantum Communications

Optical communication links are indispensable to future space missions. The quantum mechanical nature of light waves can be explored to achieve ultimate capacity. Quantum key distribution can provide unconditionally secure cryptographic communication channels. This technology employs dedicated communication satellites to establish space-space, ground-ground, or space-ground crypto channels to ensure the safety and reliability of spacecraft command and control.

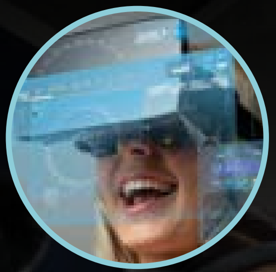


Quantum Measurements and Remote Sensing

Light wave–based interferometric measurement, imaging, and sensing capabilities can be greatly enhanced by novel measurement techniques that take into account the quantum nature of electromagnetic radiation. Quantum schemes of squeezed lights, entangled photon sources, and weak value principles can help achieve measurement precisions not obtainable with classical methods. Long-distance quantum links can also explore fundamental quantum effects under gravity.

Atomic Quantum Sensors

Sensors are based on atomic clocks and atom-wave interferometry with trapping and laser-manipulation of atoms. The intrinsic atomic properties and quantum interference measurements provide new high-precision measurement capabilities for space position, navigation, and timing (PNT), as well as for gravity science and direct detections of dark matter, dark energy, and gravitational waves.

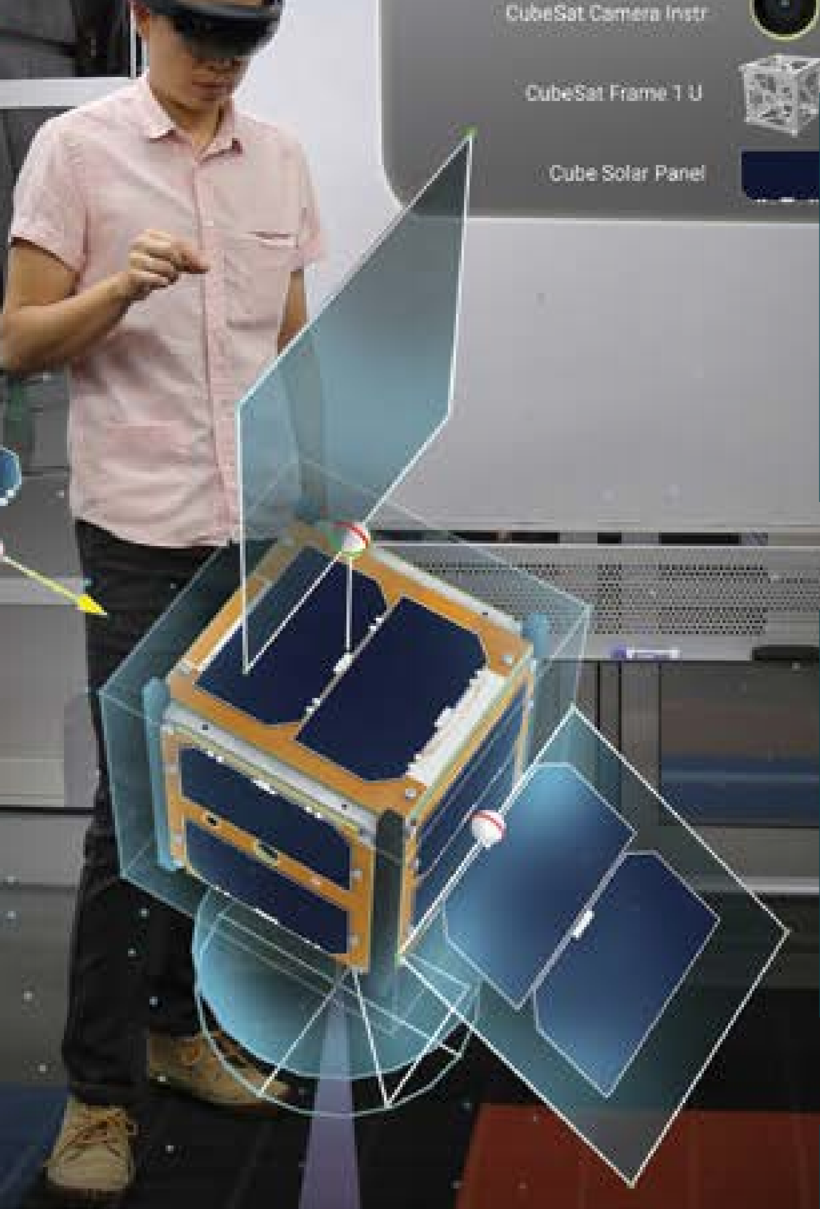


Augmented Reality / Virtual Reality

Immersive visualization offers a powerful tool to view, manipulate, and understand complex data and systems. Several JPL projects are already taking advantage of this capability, including the Mars Science Laboratory, Europa Clipper, and the Innovation Foundry. These tools, in the context of mission formulation, design, and operations have revealed several areas that offer strong potential for multi-mission solutions.

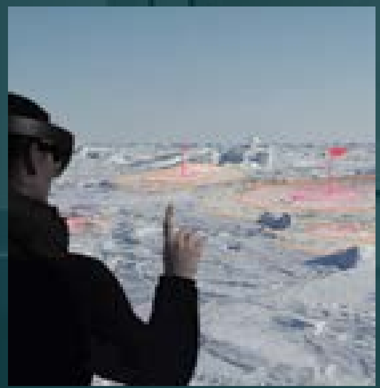
Formulation & Design

Rapid evaluation of the concept of operations (ConOps) is a key establishing step for all formulation projects. Being able to share the ConOps with all designers in a session is critical for syncing the context for the mission design. We will enable the ability to pull in preconfigured assets (spacecraft, planetary bodies, etc.) from a toolbox and quickly develop and share a mission plan.



Direct Robotics Operations

Users can visualize a remote environment to control robots with data overlays that inform scientific discovery. The ability to see what the robot is thinking (telemetry, state, path planning), overlaid on the reconstructed environment, allows for greatly enhanced situational awareness.

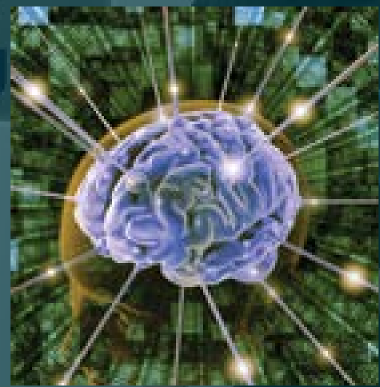


User Guidance & Training

The use of new tracking and object recognition technologies for storage and inventory of cleanrooms and the space station can be employed to improve human navigation in unfamiliar spaces. Route planning for robotic vehicles could implement virtual simulations with an accompanying front-end visualization. Human operators can be trained prior to and during execution of various procedures.

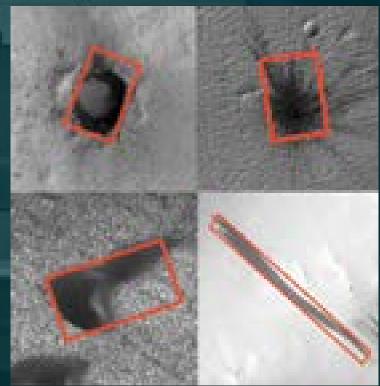
Big Data, Data Analytics

JPL is at the cutting edge of research and development in big data, algorithms, software, and its applications to planetary and space science. Novel pattern recognition algorithms and effective data visualization provides a bridge between the quantitative content of the data and human intuition, leading to scientific discoveries like black hole mergers.



Scalable Data Architectures

JPL's ability to handle massive, complex, and distributed data sets requires systematic approaches to capturing, generating, organizing, managing, distributing, and analyzing data at scale. The diversity of data from remote sensing instruments requires sophisticated information models of the application domain and approaches for helping to understand and automate the handling of big data.



Data-Driven Computational Methods

Different computationally intensive methods from machine learning to statistical inference are critical to enabling data-driven approaches to analyzing massive data sets. JPL needs a range of data-driven methods to help automate the analysis and inference from big data.

Interactive Data Analytics Environments

The analysis of massive data and the intercomparison between data and models require the ability to bring together diverse data sets and enable on-demand computation, analysis, and visualization as an agile and effective paradigm for data exploitation, both exploration and discovery, and deep-dive analytics.

APPENDIX

Strategic Implementation

ALIGNMENT WITH NASA STRATEGIC PLAN

STRATEGIC TRACEABILITY

JPL STRATEGIC PLANNING & GOVERNANCE PROCESS

STRATEGIC FRAMEWORK

MISSION STRATEGY

TECHNOLOGY STRATEGY

PARTNERSHIP STRATEGY

Jovian Tempest: This color-enhanced image of a massive, raging storm in Jupiter's northern hemisphere was captured by NASA's Juno spacecraft during its ninth close flyby of the gas giant planet.

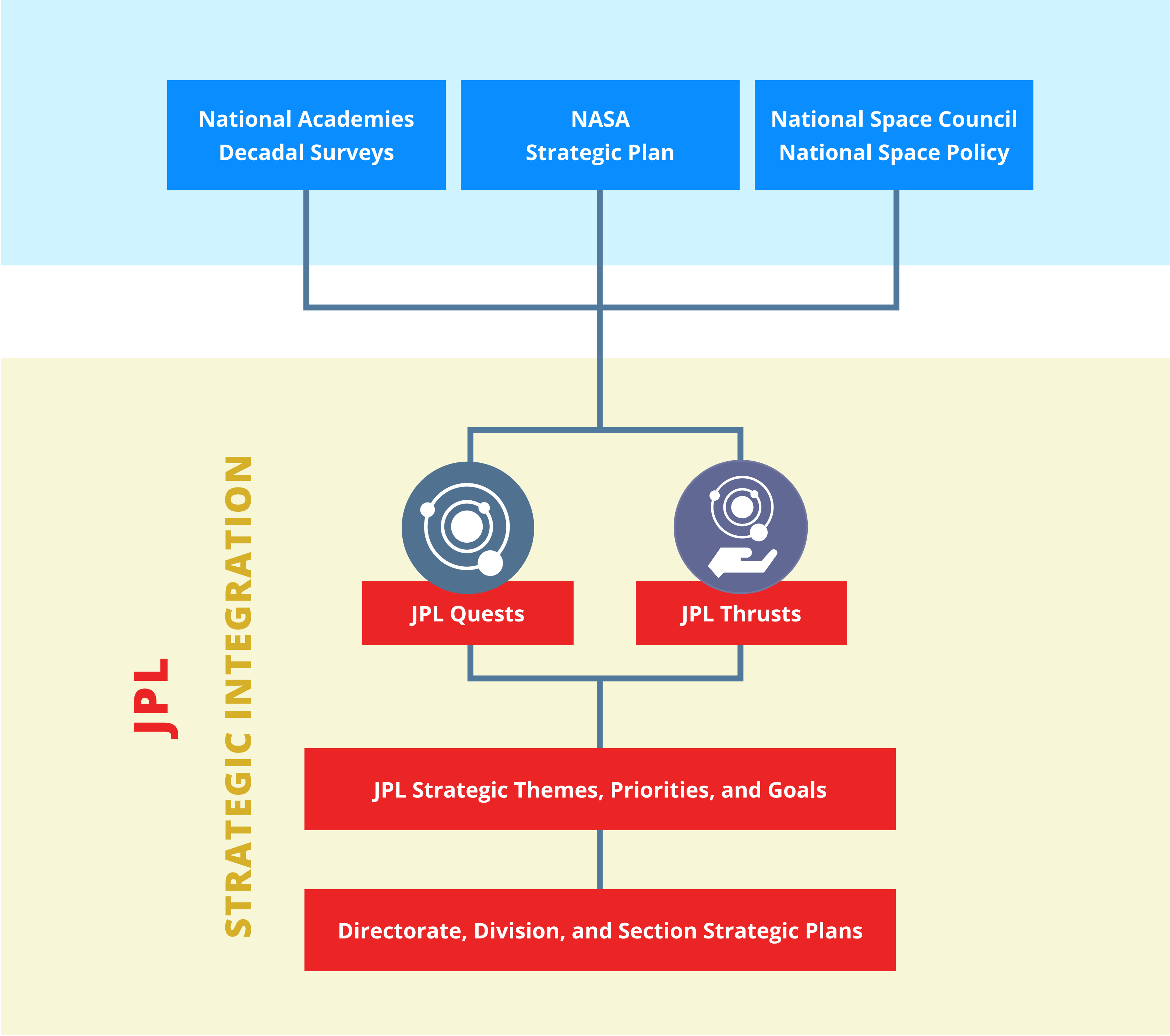
ALIGNMENT WITH NASA STRATEGIC PLAN

NASA's 2018 Strategic Plan is a federally mandated plan outlining NASA's vision for 2018–2021. The plan emphasizes space exploration, while affirming NASA's commitment to the advancement of science and aeronautics. As outlined in the table below, the JPL Strategic Implementation Plan is closely aligned with the NASA Strategic Plan and its strategic goals and objectives (https://www.nasa.gov/news/budget/index.html).

NASA Goals		NASA Objectives	JPL Alignment
DISCOVER Expand human knowledge through new scientific discoveries	1.1	**Understand the Sun, Earth, Solar System, and Universe**	Pages 6, 10, 14, 18, 22
	1.2	**Understand Responses of Physical and Biological Systems to Spaceflight**	Pages 10, 14
EXPLORE Extend continuous human presence deeper into space and to the moon for sustainable long-term exploration and utilization	2.1	**Lay the Foundation for America to Maintain a Constant Human Presence in Low Earth Orbit Enabled by a Commercial Market**	Pages 26–29, 48
	2.2	**Conduct Human Exploration in Deep Space, including to the Surface of the Moon**	Pages 10, 22
DEVELOP Address national challenges and catalyze economic growth	3.1	**Develop and Transfer Revolutionary Space Technologies to Enable Exploration Capabilities for NASA and the Nation**	Pages 6, 18, 22, 26, 30
	3.2	**Transform Aviation through Revolutionary Technology Research, Development, and Transfer**	Pages 26, 30
	3.3	**Inspire and Engage the Public in Aeronautics, Space, and Science**	Page 37
ENABLE Optimize capabilities and operations	4.1	**Engage in Partnership Strategies**	Pages 6,10,14,18,22,26,30
	4.2	**Enable Space Access and Services**	Pages 14, 22
	4.3	**Assure Safety and Mission Success**	Pages 40, 41
	4.4	**Manage Human Capital**	Page 37
	4.5	**Ensure Enterprise Protection**	Pages 37–39
	4.6	**Sustain Infrastructure Capabilities and Operations**	Pages 6, 10, 14, 18, 22

STRATEGIC TRACEABILITY

JPL's integrated strategic planning process ensures alignment and traceability with NASA's goals and objectives, the national space policy as established by the National Space Council, and key scientific questions as determined by the National Academies Decadal Surveys. As a result, the JPL Strategic Implementation Plan is structured in the form of long-term scientific Quests and cross-cutting institutional Thrusts. These are then refined into JPL Strategic Themes and Goals, followed by organizational (directorate and division) strategic implementation plans.



JPL STRATEGIC PLANNING & GOVERNANCE PROCESS

STRATEGIC INVESTING

HORIZONTAL VIEW
Focusing on the key strategic issues, involving the right people, and making collaborative decisions across the Laboratory allow us to align our investment planning process.

DATA-DRIVEN
By leveraging the transformative power of data, visualization, and analytics, we harness a new generation of data-driven capabilities to facilitate making the right strategic choices for our exciting future.

FAIL-FAST AGILITY
Experimentation and exploration is our culture. By empowering our organizations to adjust and respond to their dynamic environment, and embracing the opportunity to fail, learn, and pivot, increases the strategic agility of our organization.

STRATEGIC PLANNING CYCLE

GOVERNANCE
The Executive Council and Laboratory Management Council meet on a regular basis to monitor and manage the performance of Lab-wide implementation plans and investment and operations budget

Strategic Planning Management Council Managed by Associate Director for Strategic Integration	Project & Engineering Management Council Managed by Associate Director for Flight Projects and Mission Success	Laboratory Management Council Managed by Chief Financial Officer

Strategy & Business Development
• Advance capabilities to land new business
• Lead the management of JPL's Strategic Implementation Plan
• Research and Technology
• Advanced Concepts
• Bid and Proposal
• Strategic investments
  • Blue Sky Program
  • JPL Next Program
	Engineering Excellence
	• Enhance engineering capabilities
	• Improve and maintain technical facilities
	• Technical Equipment & Facilities Infrastructure Management (TEFIM)
	• Engineering Tools
		Operations Effectiveness
		• Reduce future operational cost
		• Increase institutional efficiency
		• Institutional infrastructure
		• Institutional information technology
		• Cyber security
		• Facilities maintenance
		• Sustaining business systems

STRATEGIC FRAMEWORK

QUESTS: JPL's Quests are aligned with NASA's Strategic Goals and are consistent with the National Academies of Sciences Decadal Surveys in Planetary Sciences, Solar and Space Physics, Earth Science and Applications from Space, and Astronomy and Astrophysics.

MISSIONS: JPL pursues our Quests through robotic missions and projects. These include Earth, Mars, planetary, and astrophysics missions; instruments delivered to missions implemented by other organizations; and research and development projects.

TECHNOLOGIES: JPL's missions are enabled by the development and infusion of advanced technologies. JPL invests in early-stage technology development, midrange and near-term technologies, as well as technology demonstration projects. Technology is the lifeline that enables future missions.

PARTNERSHIPS: JPL actively engages other NASA centers, national laboratories, industry, and academia, as well as international partners to enable missions, develop technology, and achieve our scientific quests.

THRUSTS: The JPL Thrusts represent the emphasis that the Laboratory places on nurturing our culture while pursuing our scientific quests in a strategic, sustained, and focused manner. Through our Thrusts, JPL invests in our culture of innovation—not only in what business we do but also in how we conduct our business; the future needs of our people, our workplace, and work practices; and our ability to share our stories and inspire new generations across the world to join our pursuit of knowledge and discovery for the benefit of humankind.

MISSION STRATEGY

JPL's mission development strategy is to continuously pursue a diverse and bold portfolio of advanced mission concepts that can feed into the project formulation pipeline to directly support the JPL Quests. At any one time, JPL is working on missions in early concept development (pre-Phase A and Phase A), preliminary design (Phase B), implementation (Phases C and D), and mission operations (Phase E). Below are examples of ongoing missions in various stages of the mission development and operations pipeline.

MISSION DEVELOPMENT PIPELINE

Advanced Mission Concepts

Ocean Worlds

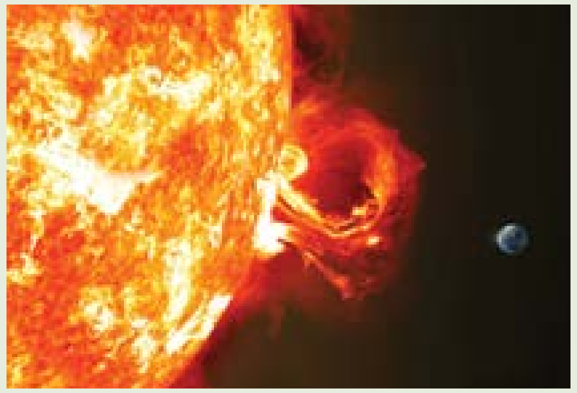
The story of oceans is the story of life. Finding microbial life outside of Earth in our Solar System will have scientific, philosophical, economic, agricultural, and medical impacts. Steps to discover and understand life elsewhere include finding liquid water, quantifying habitability, detecting biosignatures, confirming life is present, and understanding its biochemistry. JPL is currently formulating ways to explore the ocean worlds of Europa, Enceladus, and Titan.

PRE-PHASE A

Strategy

JPL's approach is to invest in a diverse set of mission concepts focused on our scientific Quests and NASA-sponsored Decadal Surveys. As these concepts mature, they may be proposed to competitive solicitations released by NASA's science mission programs, or realized as assigned (directed) missions. Technology development and infusion needs are often defined at this stage of mission development.

Mission Formulation



Sun Radio Interferometer Space Experiment (SunRISE)

Our Sun is the most important source of energy for life on Earth but also has the potential to be the most destructive force we face. The SunRISE concept for the first space-based low-radio-frequency array made up of six CubeSats would investigate one of these threats—coronal mass ejections (CMEs), explosions in the Sun's corona that spew out solar particles. A CME hitting Earth head on would majorly disrupt modern society's way of life. Data from SunRISE would help us understand these important stellar phenomena and protect our planet.

PHASES A–B

Strategy

JPL's approach is to invest in risk reduction and technology maturation of the mission preliminary design. Key to this study is the use of advanced tools for rapid trade space analysis, modeling and design, model-based systems engineering (MBSE), risk management, and more.

Mission Implementation

Mars 2020

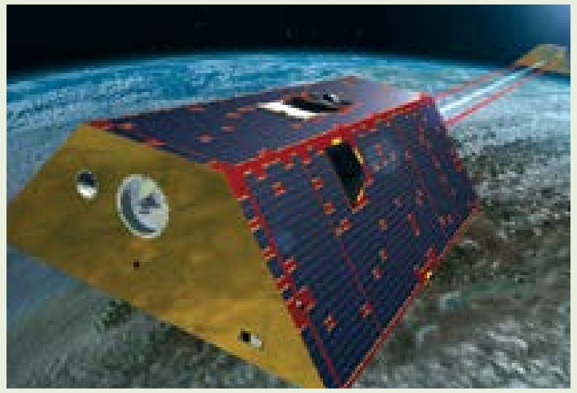
The Mars 2020 rover will study parts of Mars where the ancient environment may have been favorable for microbial life. The mission includes a subsystem, with a coring drill on its arm and a rack of sample tubes, to collect and prepare Martian rock and soil samples. These samples could be returned to Earth on a future mission. Back on Earth, these specimens could be analyzed for evidence of past life on Mars and possible health hazards for future human missions.

PHASES C–D

Strategy

JPL's approach is to develop innovative engineering methods, processes, and tools to strengthen technical robustness and streamline the design, fabrication, assembly, and test of flight hardware, the development of software, and the integration of systems.

Mission Operations



Gravity Recovery and Climate Experiment Follow-On (GRACE-FO)

GRACE Follow-On is continuing GRACE's legacy of tracking Earth's water movement across the planet. Monitoring changes in ice sheets and glaciers, underground water storage, the amount of water in large lakes and rivers, and changes in sea level provides a unique view of Earth's climate and has far-reaching benefits for its people.

PHASE E

Strategy

JPL's approach is to continuously develop and improve tools and processes for streamlined and safe mission operations, including science operations, data visualization, and augmented and virtual reality (AR/VR). Extended missions can provide an opportunity to gain in-flight experience for new technologies. Lessons learned and new discoveries in operations feed into new ideas for advanced mission concepts.

TECHNOLOGY STRATEGY

JPL will invest in the technology development pipeline in support of our missions and in pursuit of our Quests. This includes investments that span the technology readiness levels (TRLs): ideation (TRL 0–1), maturation (TRL 2–3), development (TRL 4–6), and infusion or validation (TRL 7–9). Advanced technology development is key to transforming our vision into reality. JPL strives to mature, further develop, and infuse NASA, non-NASA, and commercially developed technologies into our future missions. JPL will invest in our people, a culture of innovation, advanced laboratories and equipment, and collaborative methods and tools. JPL will also take advantage of the emerging technologies in the fast-moving commercial sectors to enable our own missions.

TECHNOLOGY DEVELOPMENT PIPELINE

Ideation

Our People

The source of innovation at JPL is our talent pool, our culture of innovation, and the tradition of Daring Mighty Things. JPL's investment portfolio includes a healthy investment in low-TRL, high-risk, high-payoff technologies that can change the way we do our business and the nature of space science and exploration. Innovative new missions, projects, instruments, and subsystems are constantly being investigated by scientists and research staff.

TRL 0–1

Strategy

The JPL R&TD Program invests in early-stage technology ideation and innovation. JPL encourages innovation and ideation at all stages of the project development life cycle and across all disciplines and sectors of the scientific and engineering staff. JPL often collaborates with other government agencies and universities at this early stage of technology development.

Maturation

Gecko Gripper

Geckos are nature's most amazing climbers. The animals use micro- and nano-scopic hairs on their feet to stick to surfaces using van der Waals forces. JPL is developing robotic versions of gecko feet that can apply this novel sticking technology to space applications like assembly of large telescopes, inspection and repair of spacecraft, and grappling orbital debris. The LEMUR robot, shown above, has been equipped with four Gecko Grippers, each capable of supporting over 100 N of force on a variety of spacecraft surfaces.

TRL 2–3

Strategy

Technology maturation requires investment in advanced testbeds, tools, equipment, and facilities that can demonstrate system functional performance, including rapid design, prototyping, and testing. Examples are Atelier, Advanced Manufacturing Center, and Robodome.

Development

Axel Rover

The Axel Rover has been under development at JPL for over 10 years and is now in the final stages of technology development. This is a unique, two-wheel rover that is designed to reach very steep and inaccessible terrains. Target applications include the exploration of deep craters, lava tubes on the Moon, caves on Mars, and other hard to reach locations on planetary bodies. The system is also designed to carry small payloads for sensing and sampling the terrain.

TRL 4–6

Strategy

Technology maturation requires investment in advanced testbeds, tools, equipment, and facilities that simulate operations in a relevant space environment and can demonstrate form-fit-functional system performance. Examples are Mars Yard, NASA's parabolic aircraft, etc. JPL technologists also keep a close eye on maturing technologies external to the Lab that are ripe for infusion.

Validation

Mars Helicopter

The Mars Helicopter is commissioned to be launched as part of the Mars 2020 lander as a standalone technology demonstration. This will be the first ever technology demonstration of aerial mobility on a planetary body. The small (1.8 kg) helicopter will be deployed, fly and image the rover surroundings, and scout the region for the rover to explore.

TRL 7–9

Strategy

JPL's strategy is to increase the pace and likelihood of technology infusion into our future missions; for example, the Mars Helicopter demonstration, and Deep Space Optical Communications on Psyche. The JPL NEXT program is designed to accelerate the infusion of advanced technologies into our future missions.

PARTNERSHIP STRATEGY

Consistent with the NASA Strategic Plan and in coordination with the NASA's Office of International and Interagency Relations (OIIR), the JPL strategy is to actively engage other NASA centers, national laboratories, industry, and academia, as well as international partners to achieve its vision and pursue its scientific quests for the benefit of humankind.

NASA CENTERS

JPL, part of the NASA family of field centers, is managed by Caltech and is the only NASA Federally Funded Research and Development Center (FFRDC). The JPL strategy is to actively engage other NASA centers in a strategic partnership relationship, and favor teaming over competing wherever possible. The JPL strategy is also to offer support to other NASA centers as they pursue their own strategic goals.

JPL will foster and support a culture of One NASA.

ACADEMIA

The JPL strategy is to invest in collaborations with universities across the country and the rest of the world to bring the best science, science teams, and Principal Investigators (PI) to NASA missions. JPL maintains a Strategic University Research Partnership (SURP) program that supports research at universities where JPL has a critical mass of ongoing work. JPL supports an active postdoctoral program, faculty exchanges, and distinguished visiting scientists.

INTERNATIONAL

NASA and JPL realize that many of our science and exploration goals cannot be achieved alone. International partnerships are not only important but are in many cases enabling. In coordination with NASA's OIIR, the JPL strategy is to actively engage in the formulation of new mission opportunities with our international partners, such as the European Space Agency (ESA), the French Space Agency (CNES), the German Space Agency (DLR), the Italian Space Agency (ASI), the Indian Space Research Organisation (ISRO), the Japanese Aerospace Exploration Agency (JAXA), and others. This includes the opportunity to perform joint technology demonstration missions in space.

NATIONAL LABORATORIES

The JPL strategy is to partner with national laboratories and other FFRDCs that have synergistic and complementary core competencies, such as the Johns Hopkins University Applied Physics Laboratory, Sandia National Laboratories, MIT Lincoln Laboratory, and Southwest Research Institute, among others.

COMMERCIAL

The JPL strategy is to actively consider the use of public-private partnerships on an equal opportunity basis in pursuit of our scientific goals wherever possible. This includes collaborating with U.S. industry to bring cost-effective solutions to NASA mission, co-developing dual-use technology that benefits both NASA and the public, commercializing technology to create federal and private-sector benefits, and leveraging new capabilities created by the fast-growing new space industry.

CLOSING STATEMENT

The main purpose of the JPL Strategic Implementation Plan is to inform all of JPL about the vision and strategy for the future of the Laboratory.

The 2018 JPL Strategic Implementation Plan builds on the excellent work led by previous JPL Associate Directors Jakob Van Zyl and Firouz Naderi. This work resulted in the JPL Vision 2025 framework, composed of the JPL Quests and Thrusts. The 2018 JPL Strategic Implementation Plan further refines this framework into constituent Strategic Themes and Goals, and expands the Quests into strategic missions, technologies, and partnerships.

In summary, JPL will pursue a diverse and bold portfolio of science missions in pursuit of our scientific Quests; we will pioneer the concept of the Laboratory of the future, defined by a talented and inclusive workforce, rapid information sharing, and a culture of innovation; we will strengthen our end-to-end capabilities while accelerating the infusion of new technologies into our future missions.

The intended audience for this Strategic Implementation Plan is internal to JPL, even though this document has been cleared for external release, and will be shared with selected visitors and partners. The time horizon of this plan is the next decade.

We anticipate great ideas in pursuit of our strategy will come from sources within and outside of JPL. In sharing this plan, we will harness the bold ideas of our creative thinkers, problem solvers, and diverse population. As these plans and ideas are implemented, we will create a Laboratory of the future that is open, inclusive, and ***Dares Mighty Things*** in pursuit of space exploration and science for the benefit of humankind.

Office of Strategic Planning
Associate Director for Strategic Integration
Jet Propulsion Laboratory
California Institute of Technology
Questions or suggestions: SIP@jpl.nasa.gov

Mars Helicopter

Mars Helicopter to Fly on NASA's Mars 2020 Rover Mission

Mars Helicopter is a technology demonstration that will travel to the Red Planet with the Mars 2020 Rover. The design is a fusion of technologies developed both internally at JPL and externally. It will attempt a controlled flight in the thin atmosphere of Mars.

If successful, helicopters may have a real future as low-flying scouts and aerial mobility systems on Mars, Venus, and Titan, to access locations not reachable by surface mobility systems.

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