LASP

Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**

Planetary Science

Space Physics

Solar Science

Atmospheric Science

Engineering

Mission Operations & Data Systems

A message from the director

The Laboratory for Atmospheric and Space Physics (LASP) brings together science, technology, and the education of the next generation of space professionals.

LASP has emerged as one of a small set of academic space centers able to meet the increasingly stringent requirements of space exploration in the new millennium. The ability to blend space science with hardware design, development, and implementation, as well as mission operations and data management is increasingly rare among university-based space centers. With up to a dozen space science flight programs in development at any given time, the capability to build multiple space instruments simultaneously in state-of-the-art facilities, and the demonstrated experience to operate more than 100 space instruments concurrently, LASP is a leader in space exploration.

LASP is the world's only space research institute to have sent instruments to all eight planets in our solar system and Pluto. This is only one of many LASP accomplishments, but it's the kind of success that comes from a commitment to asking and answering the most exciting questions in planetary science, space physics, solar science, and atmospheric science.

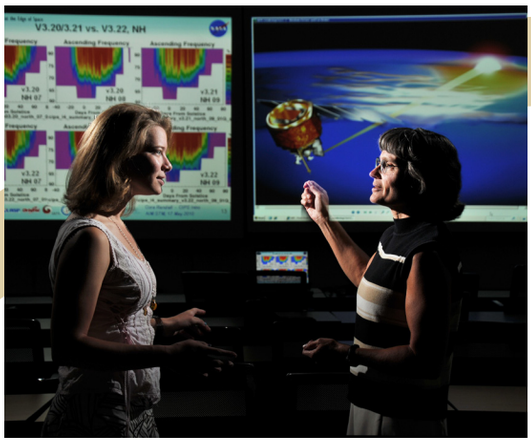
With a deep and abiding integration of undergraduate and graduate students into the organization, LASP embraces the enthusiasm of our nation's future scientists and engineers, while training them for life after graduation.

Dr. Daniel N. Baker
Director

LASP has been a part of the University of Colorado Boulder (CU) since its inception as the Upper Air Laboratory in 1948 when CU contracted with the Air Force to conduct sub-orbital solar rocket studies. LASP still flies sounding rockets to calibrate flight instruments and test new technologies. (An Aerobee 150 hangs in the LASP Space Technology Building, one of LASP's four facilities on CU Boulder's East Campus).

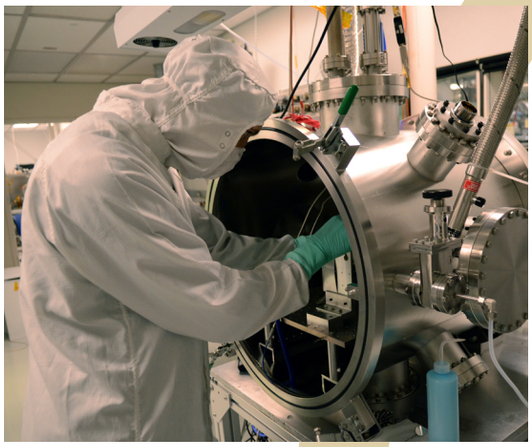
Bringing space science and exploration full circle

The Laboratory for Atmospheric and Space Physics (LASP) is a full-cycle space institute, combining all aspects of space exploration through expertise in science, engineering, mission operations, data analysis, and education.



Science drives exploration

LASP scientists develop areas of focus for space and aircraft missions and define the technology required to collect data and answer scientific questions.

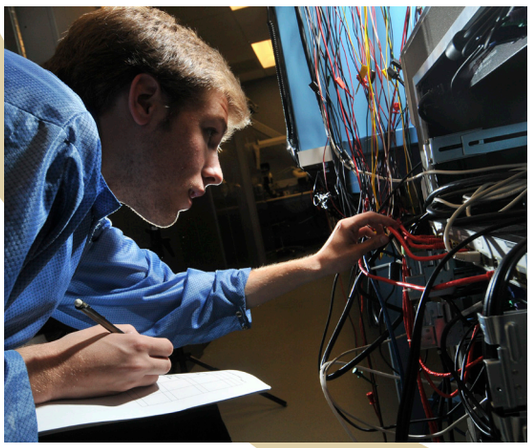


Engineering supports scientific endeavors

LASP has the on-site engineering capabilities and facilities to support the design and manufacture of space-based and suborbital instruments, as well as entire spacecraft.

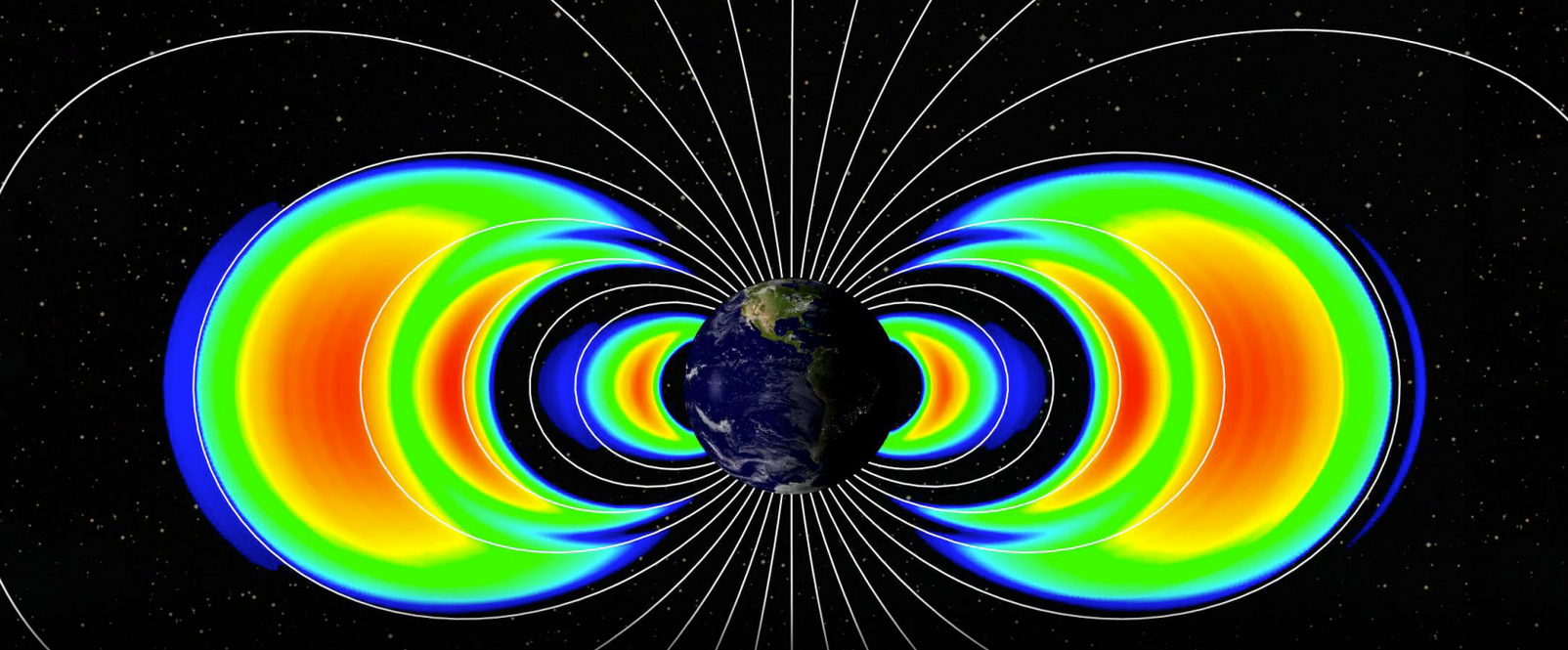
In-house mission operations secures science data return

After launch, LASP manages day-to-day mission and science operations for spacecraft and instruments. In addition, LASP data analysts are responsible for the delivery of scientific data to scientists and the public, continuing the cycle of space exploration.



Students are involved at all levels

Throughout this process, undergraduate and graduate students are integrated into working teams at LASP. Students take this unique experience with them into government, industry, or academia. They are the next generation of space scientists, engineers, and mission operators—the future experts of space exploration.



Data from the LASP-built Relativistic Electron-Proton Telescope (REPT) on NASA's twin Van Allen Probes were used to create this image. It shows the emergence of a new third transient radiation belt, which is shown as the middle orange and red arc of the three seen on each side of the Earth. (Courtesy APL/NASA)

Understanding plasmas and space weather

Scientists in the Space Physics Group at LASP seek to understand the fundamental processes of the fourth and least understood state of matter: plasma. Plasmas—partially ionized gases that fill much of the known cosmos—impact technology in space (e.g. GPS) and on Earth (e.g. electric power grids). Plasma interactions guide the behavior of matter within the solar-terrestrial system; improving the understanding of plasma helps scientists explore the underlying physics occurring in various situations on Earth.

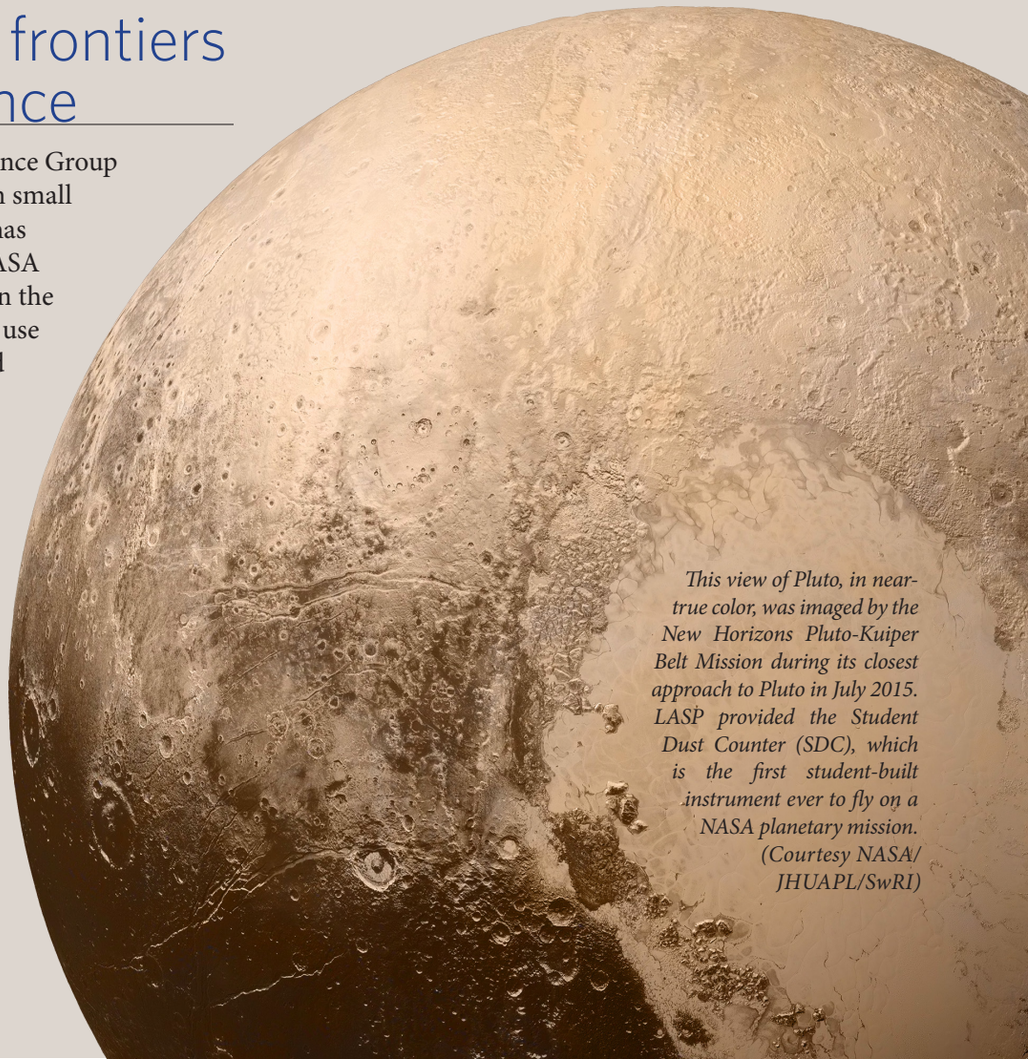
The researchers in the Space Physics Group investigate several areas:

- Space plasmas
- Earth's magnetosphere
- Earth's electrical fields, waves, and currents
- Aurora
- Space weather
- Planetary space physics

Discovering new frontiers in planetary science

Researchers in the LASP Planetary Science Group study space objects ranging in size from small meteoroids to gas giant planets; LASP has provided instruments for numerous NASA missions and has studied every planet in the solar system and Pluto. LASP scientists use telescopes and data from spacecraft and space-based instruments to study the characteristics, dynamics, formation, interrelations, and history of planetary objects. The LASP Planetary Science Group studies the following areas:

- Planetary surfaces and their evolution
- Atmospheres and exospheres
- Magnetospheres
- Planetary rings
- Dusty plasmas
- Comets, asteroids, and meteoroids
- Astrobiology and the search for life in the universe



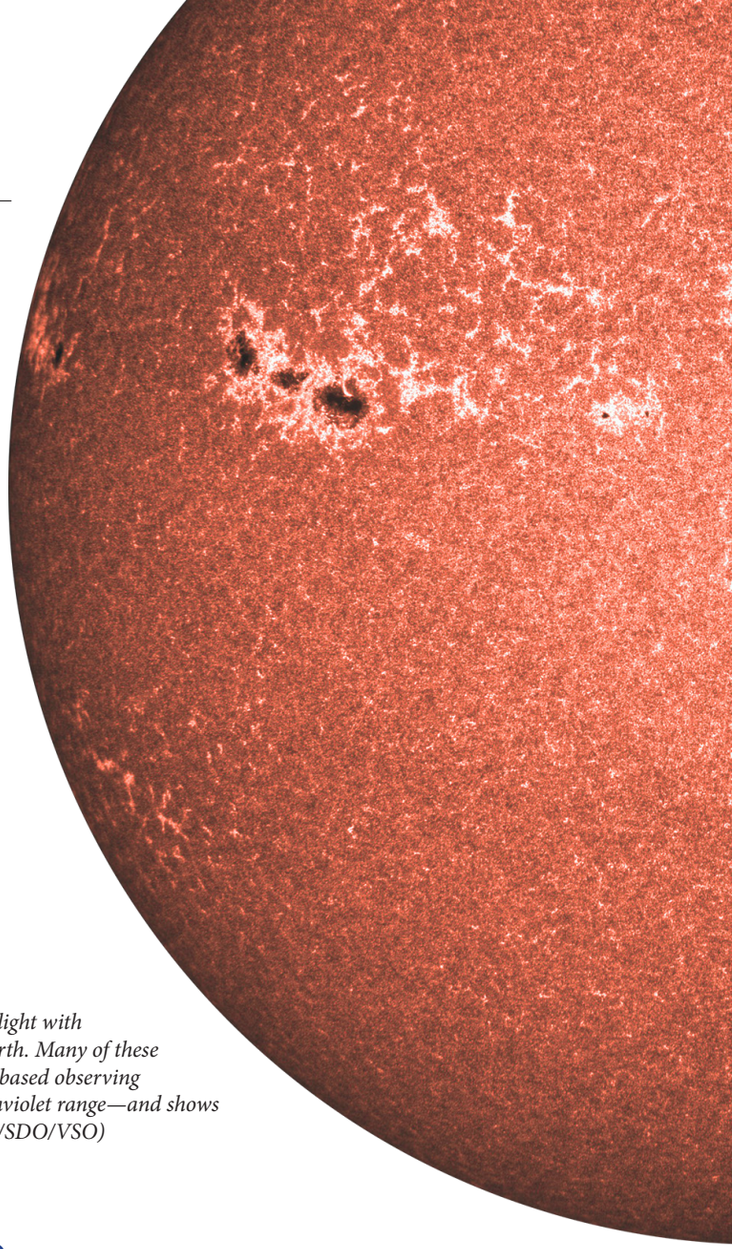
This view of Pluto, in near-true color, was imaged by the New Horizons Pluto-Kuiper Belt Mission during its closest approach to Pluto in July 2015. LASP provided the Student Dust Counter (SDC), which is the first student-built instrument ever to fly on a NASA planetary mission. (Courtesy NASA/JHUAPL/SwRI)

Studying the Sun

The LASP Solar Science Group studies solar irradiance variations, convection in the solar atmosphere, the solar dynamo that generates and transports magnetic fields, and magnetic reconnection processes that produce flares and coronal mass ejections. Through this research, LASP continues to contribute to a long-term space-based solar irradiance record going back to the 1980s.

Solar irradiance is the primary energy input into Earth's atmosphere, and understanding the Sun's effects on our atmosphere and climate system is critical. This research increases our knowledge of solar variability and its influence on the terrestrial environment and climate, as well as the impact of solar storms for a variety of space weather applications. The Solar Science Group has developed technology to improve the accuracy of irradiance measurements, advancing our understanding of solar variations throughout the spectrum and on time scales ranging from minutes to years.

The group has expanded significantly in recent years through a partnership with the National Solar Observatory (NSO), resulting in NSO's move to Boulder and LASP's addition of several solar physics professors to the CU faculty.



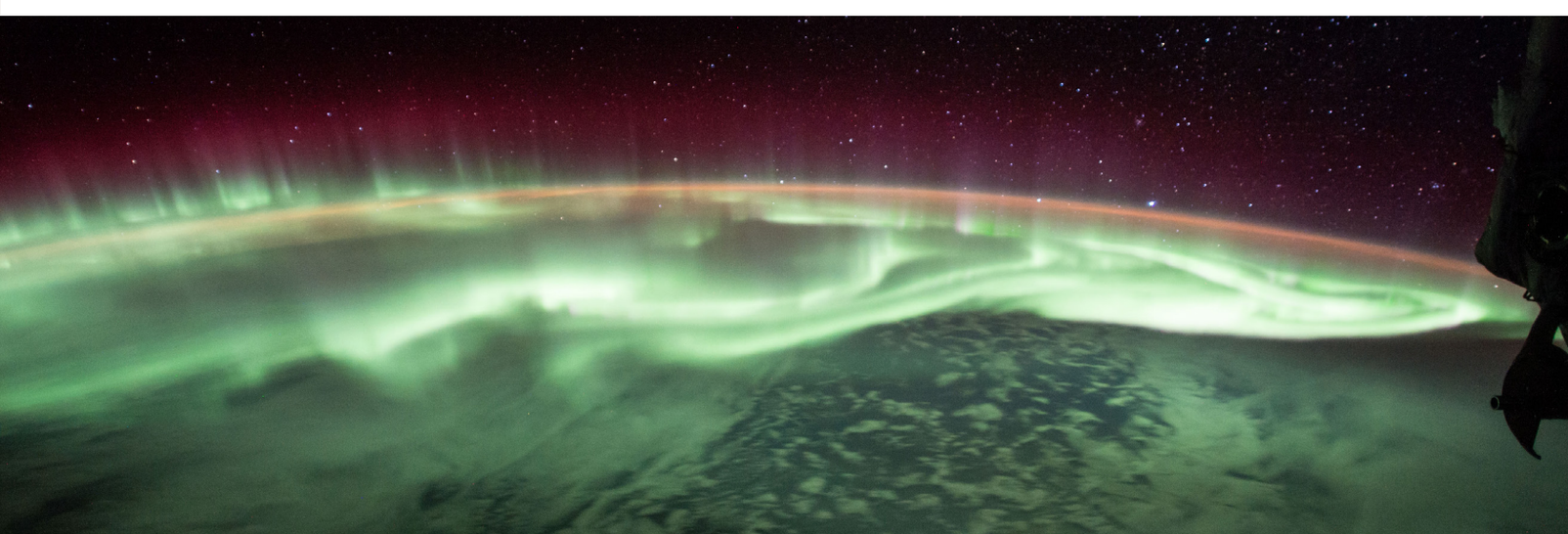
The NASA Solar Dynamics Observatory observes the Sun in a variety of wavelengths of light with instruments designed to understand the causes of solar variability and its impacts on Earth. Many of these capabilities are not possible for ground-based observatories—hence the need for a space-based observing platform. This image displays the Sun at a wavelength of 170.0 nanometers—in the ultraviolet range—and shows the lower level of the Sun's atmosphere, called the chromosphere. (Courtesy NASA GSFC/SDO/VSO)

Examining Earth's atmosphere

Scientists in the LASP Atmospheric Science Group study the composition, chemistry, dynamics, and radiative budget of the Earth's atmosphere, from the troposphere to the thermosphere. The group uses a wide variety of observations, including measurements from space-based instrumentation, rocket experiments, aircraft field campaigns, and high-altitude balloon platforms. Scientists analyze this data in conjunction with a number of different types of models, such as microphysical models, general circulation models, and coupled chemistry climate models, to investigate the Earth's weather and climate. Specific areas of interest include:

- Clouds and aerosols
- Tropospheric chemistry
- Stratospheric ozone
- Impacts of energetic particle precipitation and solar irradiance
- Dynamical coupling of different atmospheric regions
- Polar mesospheric clouds

NASA astronaut Jack Fischer captured this image of the aurora from 250 miles above the Earth onboard the International Space Station. LASP researchers study how charged particles from the Sun excite gases in the Earth's atmosphere to create these brilliant displays. (Courtesy NASA)



Engineering for exploration

LASP's Engineering Division has demonstrated capabilities at both the instrument and mission levels, including expertise designing and building spacecraft and flight instruments. Engineers at LASP are accomplished in the following areas:

- Project management and systems engineering
- Structure and mechanism design
- Stress and thermal analysis
- Space instrument optical designs and detector development for x-ray to infrared wavelengths
- Space electronics including microprocessors, FPGA, and ASIC acquisition
- Parts engineering and procurement expertise
- Extensive flight fabrication capability with certified assembly staff
- Flight software development
- Vacuum and thermal environmental testing facilities
- Verification and validation capability with NIST-traceable calibration standards
- Rigorous quality and safety assurance techniques
- ISO 9001 compliance

LASP's extensive test and calibration facilities include a fully equipped machine shop and metrology laboratory for mechanical fabrication; a NASA-qualified electrical assembly and polymeric lab for electronics and cable fabrication; multiple calibration labs for instrument characterization from x-ray to the infrared; several vacuum tanks for bakeout, thermal vacuum tests, and detector and instrument calibration; and various quality assurance inspection and cleaning laboratories, including five class-10,000 clean rooms for final instrument assembly. These facilities allow engineers to develop and test spacecraft and instruments on-site, often with mission operations staff in "test-like-you-fly" scenarios. The full-cycle capability of LASP, combined with more than seven decades of space research, has created a legacy of in-house knowledge. This experience, along with a focus on extensive testing before flight, is a key factor in LASP's superior on-orbit performance record.

LASP Engineering uses a cutting-edge mix of on-site facilities, skilled personnel, and close collaboration with scientists to build, test, and calibrate spacecraft, instruments, and components.

Students participate in all facets of LASP operations, from pursuing scientific research to constructing real-life satellite instruments to supporting our education and public outreach program. In this image, students operate spacecraft with guidance from LASP professionals.

Supporting space missions

The LASP Mission Operations and Data Systems (MO&DS) Division is responsible for spacecraft and instrument operations. The division also develops the computer, communications, and software systems necessary to operate spacecraft and process scientific data.

MO&DS staffs several mission operations centers and science operations centers for the day-to-day operations of spacecraft and instrument missions. LASP has one of only a few university-based mission operations centers. Professionals train and certify undergraduates to perform mission operations in concert with full-time staff. LASP mission operators have been responsible for NASA satellites and science payloads averaging more than $2 billion in value over the last decade.

Spacecraft and instruments run using specialized operational software, tailored to specific missions and instruments. Operational software ensures that temperature, energy levels, and other parameters on the spacecraft or instrument are running in an acceptable range. The software monitors the health of on-board systems; anything unusual is flagged and sent to mission operators who can look into potential causes and solutions.

Software engineers and data analysts in MO&DS serve at the interface between software and science, focusing on the development of data systems that generate, display, and perform quality-control corrections on scientific data. Scientists around the world then use these high-quality data products to further scientific understanding of atmospheric and space science.

Through these inclusive capabilities, from operations to data distribution, MO&DS both serves and supports LASP's scientific needs, helping to complete the full-cycle of space science.

LASP delivers education and public outreach programs to a variety of age groups. Here, students in the Rockets for Junior Astronauts program build a two-liter bottle water rocket as part of the Junior Aerospace Engineer camp. (Courtesy Matthew Jonas/Longmont Times-Call)

Supporting science with infrastructure

LASP receives extensive funding from a variety of federal, international, and commercial sponsors, and our administrative staff is key to managing complex programs and supporting the lab's scientific goals. LASP administrative capabilities serve to fulfill all of our sponsor's contractual, fiscal and infrastructure support and service requirements.

Government agencies also value LASP's emphasis on extending the reach of space science missions through education and public outreach. The lab provides educational development for kindergarten through high school, as well as opportunities for undergraduate and graduate students. LASP offers public tours, lectures, and events, and connects to the public through a range of social media platforms (@LASPatCU).

Sustaining science through technology

LASP IT experts work at the boundary between science and scientific data. Each day, multiple terabytes of data pass through LASP servers to support ongoing space missions and to provide data products to scientists from all over the world. LASP experts ensure fast and accurate data transfer, management, and archiving, as well as the development of software tools that support scientific data users.

LASP IT staff support science, engineering, and mission operations by developing and maintaining large-scale, robust data systems. An integrated information infrastructure ensures the fast and accurate collection, analysis, dissemination, and archiving of critical science data products.

Training the next generation in space exploration

CU Boulder students gain knowledge and experience at LASP, which makes them attractive candidates for professional positions after graduation and helps them become leaders in their chosen fields. Professionals provide mentorship for student-based space missions awarded to CU by organizations such as NASA, the National Science Foundation, and the Universities Space Research Association. Undergraduate and graduate students work closely with LASP engineers, scientists, and experts in all aspects of the organization:

- Framing scientific questions and using data and models to develop answers
- Building actual space science instrumentation, hardware, and complete satellites
- Planning spacecraft observation sequences
- Monitoring spacecraft performance
- Operating instruments and spacecraft
- Creating software tools for data analysis

Connecting academics, agencies, and industry

LASP employs scientific researchers, professional research support staff, and extensive numbers of students to implement programs. Many of the lab's scientists are also teaching faculty at CU Boulder in five academic departments:

- Aerospace Engineering Sciences
- Astrophysical and Planetary Sciences
- Atmospheric and Oceanic Sciences
- Geological Sciences
- Physics

LASP earns considerable competitive research funding through the government's top science agencies, including NASA, NOAA, and NSF. The lab also has a long history of successful collaborations with space industry leaders, both at home in Colorado and all over the world. LASP is a hub connecting CU Boulder, government agencies, and the space science industry. Proven success, an appealing location, and neighboring science institutions allow LASP to attract leading researchers, develop full-cycle space science missions, and provide unequalled learning opportunities for the scientists and engineers of the future.

Professional staff and students work together in the LASP Mission Operations Center, where they send commands to multiple spacecraft and instruments.

Our vision

To maintain world leadership status in identifying and addressing the key questions in planetary science, space physics, solar science, and atmospheric science.

LASP seeks to continuously maintain and improve the capability to pursue these questions using experimental, laboratory, theoretical, and information systems approaches. The laboratory is dedicated to building and maintaining a unique synergism of expertise in space science, engineering, and spacecraft operations. Through research projects, LASP participates actively in the training of the future leaders of space research and helps the University of Colorado to educate students with valued technical and scientific skills. The progressive development and use of innovative technologies and continuing participation in new research initiatives will help ensure a strong leadership role for LASP into the future.

LASP's Space Technology Research Center offers the cutting-edge laboratory space, clean room facilities, machine shop, and mission operations centers needed to excel at space exploration in the 21st century. The Space Sciences building—set back to the right—houses LASP scientists as well as the lab's largest conference facility. Not shown: The Astrophysical Research Laboratory is home to a 2,500 sq. ft. cleanroom with a 10 ft. diameter x 13 ft. long thermal vacuum chamber. The IMPACT center is home to scientists, engineers, and equipment—including a 3 megavolt linear electrostatic dust accelerator—that study the environments and impacts of interplanetary dust.

NASA's Europa Clipper mission is being designed to fly by Jupiter's icy moon Europa multiple times and investigate whether it possesses the ingredients necessary for life. LASP is providing the Surface Dust Analyzer (SUDA) for the mission. (Courtesy NASA/JPL-Caltech/SETI Institute)

Cover: *LASP's focus is the solar system: solar, atmospheric, and planetary sciences and space physics. (Courtesy NASA/JPL)*