LASP SPACE
Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**
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Features: **Juno enters Jupiter orbit • Cassini's fiery finish • CLARREO Pathfinder's observations • LASP rocket probes interstellar medium**

Letter from the director

Dan Baker

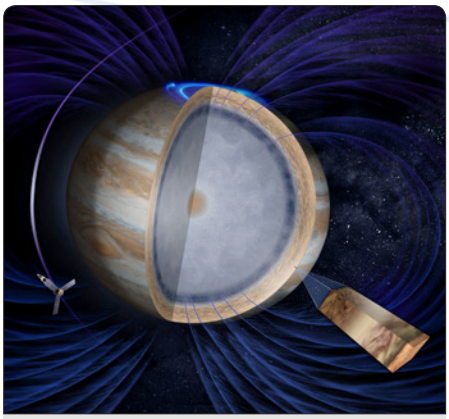
Systems in near-Earth space provide remote sensing capability, rapid communication, and knowledge of weather and global resources. A deeper understanding of the Sun, our home planet Earth, other parts of our solar system, and the universe beyond is both scientifically fascinating and economically imperative. The basic and applied research carried out within LASP contributes in myriad ways to our national well-being.

The year 2016 will see the election of a new president and arrival of a new administration. It is imperative that freshly elected government officials give appropriate attention to space-related issues now and in subsequent years. All the momentum built up in recent years for space exploration, space weather research, Earth monitoring, and commercial aerospace development must be maintained beyond the 2016 election.

Coloradoans have been blessed with congressional representatives and senators who tirelessly champion the nation's space program. LASP deeply appreciates this support. We must all work together to assure political continuity at this watershed moment in global space exploration.

IN FOCUS

Juno successfully enters Jupiter orbit



An artist's concept shows Juno avoiding Jupiter's dangerous radiation belts, measuring the interior, observing the atmospheric structure, and mapping magnetic fields (blue lines). *(Courtesy NASA/JPL)*

Launch is a scary time for all space missions. But getting into orbit around another planet is a nail-biting experience and the hazardous radiation belts around Jupiter's equator are particularly frightening. On July 4, NASA's Juno spacecraft successfully entered orbit around Jupiter and now relieved scientists are analyzing the highly anticipated first data from the mission.

Juno is the first solar-powered Jupiter mission and the first in a polar orbit. Scientists chose this orbit because the spacecraft needs to get close to the planet in order to detect the structure of Jupiter's interior. Juno zooms from pole to pole, skimming above the atmosphere while ducking under the radiation belts.

The mission has three main objects of study: Jupiter's interior, atmosphere, and polar magnetosphere. By measuring magnetic and gravity fields, Juno maps out the distribution of the gas giant's interior mass. The spacecraft maps water deep within the atmosphere by measuring the absorption of microwave energy from the hot, deep interior. The polar orbit provides the first opportunity to fly through regions where charged particles may be accelerated into Jupiter's atmosphere, producing its intense auroras.

After two 53-day orbits to better assess the Jupiter environment, Juno will settle into orbiting once every two weeks. The radiation should eventually fry Juno's electronics, so the plan is to send the spacecraft plummeting into Jupiter's atmosphere in February 2018, where it will burn up. Juno may surprise LASP scientists and the rest of the Juno team by providing additional data from its final moments.

For more information, visit the Juno website at https://www.nasa.gov/mission_pages/juno/main/index.html.

By Fran Bagenal, research scientist at LASP, Juno magnetospheres co-investigator, and co-chair of the Juno Magnetospheric Working Group.

Cassini's fiery finish

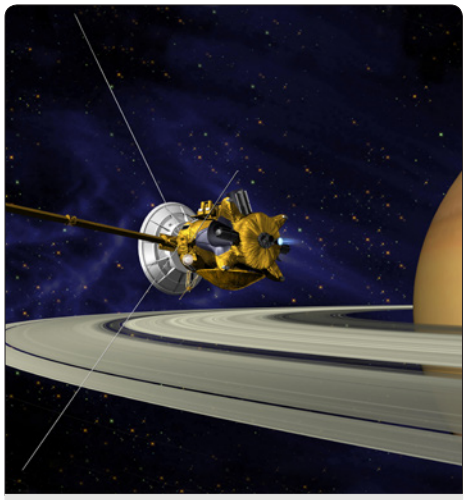
NASA's Cassini spacecraft has been exploring Saturn, its moons and rings, and the space around them since 2004. Launched in 1997, the mission will end on September 15, 2017 when the spacecraft dives into Saturn's atmosphere and burns up like a meteor.

The grand finale begins with close flybys of the F ring, followed by 22 orbits inside the rings where no spacecraft has traveled before. Cassini will gather new information providing clues to Saturn's mysterious origin and the formation of planets elsewhere.

The LASP-built and controlled Ultraviolet Imaging Spectrograph (UVIS) has contributed to many discoveries including Titan's hydrocarbon lakes, Enceladus's geysers, and mountain-sized clumps in Saturn's rings. Toward the end, UVIS will observe the aurora at Saturn's poles with the closest views ever orchestrated.

Cassini will send data throughout its final plunge, while scientists at NASA's Jet Propulsion Laboratory wait for the final signal. This fiery finale marks a worthy end for Cassini, one that will allow us to take more risk in order to uncover some of Saturn's long-held mysteries.

For more information, visit the Cassini-UVIS website at http://lasp.colorado.edu/home/cassini.



An artist's conception of Cassini during Saturn orbit insertion. *(Courtesy NASA/JPL)*

By Larry Esposito, Cassini-UVIS Principal Investigator, research scientist at LASP and professor of astrophysical and planetary sciences at CU Boulder.

CLARREO Pathfinder's unprecedented climate observations

LASP is playing a major role in the groundbreaking Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder mission, scheduled to deploy on the International Space Station (ISS) by 2020. The mission will substantially improve the accuracy of Earth radiation measurements that will advance our ability to detect climate change and identify its causes.

An artist's conception of the CLARREO Pathfinder on ISS Reflected Solar Instrument depicting Earth, solar, lunar, and cross-calibration modes of operation. *(Courtesy LASP)*

LASP was selected to build CLARREO's Reflected Solar (RS) instrument due to the success of the Hyperspectral Imager for Climate Science instrument (HySICS)—developed and balloon-flight-tested under NASA's Instrument Incubator Program—and based on the Earth Climate Hyperspectral Observatory (ECHO) proposal to the NASA Earth Ventures program, which was favorably rated as "selectable."

The RS instrument will measure solar radiation reflected from Earth in wavelength bands covering most of the solar spectrum. Its improved accuracy will enable the calibration of other climate sensors, setting the stage to monitor climate change from space, identify its underlying causes, and improve models to enable sound policy decisions.

LASP received the Pre-Phase A study award in June and will begin building the RS instrument in March 2017.

For more information, visit the CLARREO Pathfinder website at http://clarreo.larc.nasa.gov/about-pathfinder.html.

By Peter Pilewskie, director of the LASP-Goddard Sun Climate Research Center and professor of atmospheric and oceanic sciences at CU Boulder.

Mission & technical stats

- LASP operates five satellites.
- LASP operates 115 instruments on 16 spacecraft.
- LASP is currently developing 2 spacecraft and 11 instruments for 8 missions.

Student news

Sung Bae graduated with a bachelor's degree in computer science in the spring of 2016 and is now a software engineer, working on GIS applications, at SSP Innovations in Denver.

Andy Kren received his Ph.D. in atmospheric and oceanic science in May 2015. He is a research scientist at NOAA studying the use of unmanned aircraft systems data on mitigating gaps in satellite data to improve forecast models.

Anthony Shu received his Ph.D. in physics in the spring of 2015 and is currently working at Intel in Oregon.

Ryan Talley graduated in the spring of 2016 with a bachelor's degree in computer science and is now a software engineer at Lockheed Martin in Boulder.

Ethan Williams graduated with a bachelor's degree in physics in December of 2015. He is currently working with LASP simulating particle trajectories with SIMION for the Hyperdust and SUDA instruments.

LASP rocket probes interstellar medium

LASP's Colorado High-resolution Echelle Stellar Spectrograph (CHESS-2) instrument launched from White Sands Missile Range on February 21, 2016 aboard a NASA Black Brant sounding rocket. This was the second flight of the CHESS instrument, which studies the atomic and molecular structure of our local galactic neighborhood—the space between the stars.

CU Boulder graduate student Keri Hoadley led the assembly, calibration, and integration of the payload. She was also the "pilot," sending real-time commands to the rocket to center the target star within the aperture. CHESS observes stars that have been avoided by the Hubble Space Telescope (HST) and the Far Ultraviolet Spectroscopic Explorer (FUSE) due to brightness limitations. During the flight, the instrument acquired data from the hot star Epsilon Persei for the entire 400 seconds of available observing time.

The CHESS-2 data—which Hoadley is analyzing as part of her Ph.D. dissertation—revealed a host of atomic and molecular features in unmatched detail to give scientists a better understanding of the building blocks for future generations of stars and planets.

For more information about CHESS, visit http://lasp.colorado.edu/home/?p=19615.

By Kevin France, research scientist at LASP and an assistant professor of astrophysics and planetary sciences at CU Boulder.

CU Boulder graduate students Nick Kruczek and Keri Hoadley, and LASP research scientist Brian Fleming recover the CHESS-2 payload. *(Courtesy US Army, White Sands Missile Range)*

FIELD NOTES

Human rover tests aid Mars mission planning

LASP research scientist Brian Hynek co-led Mars rover analog field tests in Green River, Utah last April with the assistance of CU Boulder graduate students Sarah Black and John Gemperline, and post-doc Rebecca Thomas. This NASA project tested two modes of rover operations to determine which provides maximum science return from time- and resource-limited robotic missions.

On Mars missions, rovers generally operate in linear traverses; moving

Mission status

Instrument Development (Pre-Phase A)
- IIP Compact SIM (cSIM)
- MatISSE LAMA

Phase A/B (funded concept study)
- Europa Multiple-Flyby Mission/SUDA
- CLARREO Pathfinder
- TSIS-2

Phase C (design and fabrication)
- Emirates Mars Mission (EMM)

Phase D (assembly and test)
- GOES-S/EXIS, GOES-T/EXIS, GOES-U/EXIS
- GOLD
- TSIS-1
- Solar Probe Plus

Launch/Early Orbit [launch date]
- GOES-R/EXIS [Nov. 2016]
- MinXSS-2 CubeSat [Apr. 2017]

Prime Mission [end date]
- MinXSS-1 CubeSat [2017]
- MMS, four spacecraft [2017]
- STPSat-3/TCTE [2017]

Extended Mission [end date]
- AIM [2017]
- Cassini/UVIS [2017]
- QuikSCAT [2017]
- SDO/EVE [2017]
- SORCE [2017]
- THEMIS and ARTEMIS [2017]
- TIMED/SEE [2017]
- Van Allen Probes REPT/FIELDS [2017]
- MAVEN [2018]
- New Horizons/SDC [2018]
- Kepler/K2 [2019]

For more information on current missions, as well as full instrument and mission names, visit http://lasp.colorado.edu.

forward along a path to key targets and conducting limited operations along the way. Conversely, a geologist on Earth often completes a "walkabout" and then focuses in on the key targets.

Human rovers with instruments functionally equivalent to Mars rovers were used to test methodologies and protocols. One moved along a linear traverse and the other completed a walkabout survey before returning to important targets for further study.

The team compared the science return and accuracy of interpretations, then assessed how many Mars days it would have taken each rover to complete its mission. The results feed directly into operational planning for the Curiosity rover to maximize the science return from Mars.

Graduate geology student Sarah Black, human rover, collects visible near-infrared hyperspectral data of 170 million-year-old microbial mats. *(Courtesy LASP/John Gemperline)*

By Brian Hynek, research scientist at LASP and an associate professor of geological sciences at CU Boulder.

INNER SPACE

News

MinXSS CubeSat deployed from ISS

The Miniature X-Ray Solar Spectrometer (MinXSS) CubeSat was deployed successfully from the International Space Station on May 16.

The NASA-funded MinXSS—built and operated by LASP students and professionals as well as faculty from CU Boulder's Aerospace Engineering Sciences Department—will operate in Earth orbit for up to 12 months. It observes soft X-rays from the sun, whose flares can disturb the plasma in Earth's upper atmosphere, hampering radio and GPS signals in the region. About the size of a loaf of bread, MinXSS has already observed seven M-class flares and more than 40 C-class flares, far exceeding expectations for this mission. In August, the MinXSS CubeSat won Mission of the Year at the 2016 AIAA SmallSat Conference.

CubeSats are a new, low-cost tool for space science missions. In contrast to traditional missions that carry several custom-built instruments, CubeSats are designed to make narrowly targeted scientific observations with only a couple of instruments, and are often built from off-the-shelf components.

Fifth SDO calibration rocket flies

On June 1, the NASA 36.318 Black Brant IX sounding rocket launched from White Sands Missile Range in New Mexico. The LASP-built payload provided data for the fifth calibration of LASP's Extreme ultraviolet Variability Experiment (EVE) on the Solar Dynamics Observatory (SDO) orbiting Earth. SDO/EVE helps scientists understand the causes and impacts of solar variability. Watch a 17-minute video of the flight: http://lasp.colorado.edu/home/rocket.

Administrative stats

(August 11, 2016)

Scientific researchers	61
Tenure-track faculty	19
Professionals	276
Graduate students	48
Undergraduate students	101
Total	**505**
Open positions	18

For employment information, visit http://lasp.colorado.edu/home/about/jobs.

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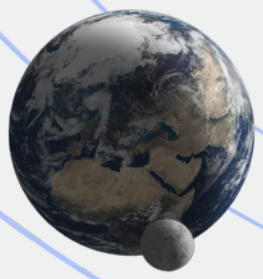

Because flight instruments degrade over time, they can be calibrated by sending duplicates above the Earth's atmosphere to compare measurements at the same point in time, looking at the same target.

LASP began as the Upper Air Laboratory in 1948 when scientists in the CU Boulder physics department used captured German V2 rockets to conduct atmospheric science. LASP's rocket program is still going strong today with the continued need for solar instrument calibration, as well as rocket-based science missions. LASP will launch additional SDO/EVE calibration flights every two years, with the next one planned for June 2018.

Public outreach

Social media connects people with LASP science, engineering

Despite a fascination with space exploration, many people don't have a basic understanding of the universe and find it even more challenging to understand the need for space research today.

Effective science communication has always been challenging, but tools for doing so have never been more plentiful or easy to adopt. Thus, LASP maintains an active social media presence to connect audiences with our science and engineering operations.

Scientists spend hours poring over data and preparing papers for publication. But the results may never reach beyond the scientific community and are too often inaccessible to the average reader. With one social media post, we can deliver highlights of our research to tens of thousands across the globe.

If a scientific discovery is made and no one hears about it, does it make a difference?

LASP online social forums attract people to a deeper investigation of our research. We engage audiences in conversations, educate them, and challenge them to understand real science and how we do it. To learn more, follow along with LASP on social media (@LASPatCU).

Achievement awards

Dan Baker was recognized as an American Institute of Aeronautics and Astronautics (AIAA) Fellow at the AIAA Aerospace Spotlight Awards Gala in Washington, DC on June 15. AIAA Fellows represent the best of the aerospace community. The distinction recognizes individuals for their notable and valuable contributions to the arts, sciences, or technology of aeronautics and astronautics.

The American Geophysical Union (AGU) chose **Tom Woods** to deliver the Eugene Parker Lecture at their Fall 2016 meeting in San Francisco. The lecture is part of the AGU's prestigious Bowie Lecture series. It recognizes outstanding scientists and is one of the highest honors accorded to members of the Space Physics and Aeronomy section of AGU.

CO-LABS selected LASP's nomination titled "**Dr. Daniel Baker Leads LASP Research on Critical Space Weather Forecasting Missions**" as the winner of the 2016 Governor's Award for High-Impact Research in the category of Earth Systems and Space Sciences. LASP was recognized at an awards ceremony on October 6 at the Denver Museum of Nature & Science.