National Aeronautics and Space Administration

# DISCOVER

## Jet Propulsion Laboratory

## California Institute of Technology

STUDENT RESEARCH REPORT

# Discover the Jet Propulsion Laboratory (JPL)

JPL has a long history of working with educational institutions. We believe that strong collaborative relationships with the academic community provide accelerated innovation for NASA's missions as well as the discovery of new science and technology opportunities for the future. In fact, JPL is responsible for some of the most significant innovations and discoveries in the past 50 years. These pages illustrate just a few of the many student projects taking place at JPL every year, and are a good example of our collaborative environment.

## About JPL

The Jet Propulsion Laboratory (JPL) is NASA's federally funded Research and Development Center, and is managed by the California Institute of Technology (Caltech). JPL's character is the result of five decades of history leading the United States' robotic space program, having grown up with the Space Age and having helped bring it into being.

JPL's core competency is the end-to-end implementation of unprecedented robotic space missions to study Earth, the Solar System and the Universe. We do this by developing and integrating world-class capabilities in science, engineering and technology, in partnership with other organizations and using our hands-on experienced workforce.

On the cover, left to right: Cason Male, George Murillo, Sherrisse Bryant, and Katrina Laygo.
This spread: View of the JPL campus.

# Inside

This page, left to right:
Jonas Zmuidzinas, a professor of physics at Caltech, is an expert in submillimeter astronomy and instrumentation.

Dan McCleese is the Principal Investigator for the Mars Climate Sounder on the Mars Reconnaissance Orbiter mission *(pictured on page 3)*.

# Welcome from the Chief Scientist and Chief Technologist

"We should see ourselves as celestial navigators who leave behind safe harbors to sail uncharted cosmic seas, going where no one has gone before, building what no one has built before and achieving what others have barely dared to dream."

**Charles Elachi**
**Director**
**Jet Propulsion Laboratory**

JPL has the responsibility and commitment to work with the academic community, to accomplish NASA's space exploration goals in the most cost-effective way and to achieve related educational goals to train the next generation of scientists and engineers. JPL has formed collaborations with many universities that have major commitments to strong educational and research programs in the space and Earth sciences that support the nation's overall exploration program. The goal is to capitalize on academic innovation to accelerate its infusion into space science and mission technologies.

JPL's unique environment provides the opportunity for scientists, technologists and engineers to interact broadly. Scientists benefit from a close teaming with the engineering community on the implementation of their ideas into instruments, systems and algorithms, and work with the technologists on innovative techniques and approaches for next-generation flight projects. Engineers and technologists develop the necessary components, systems and infrastructure that make the realization of missions possible. Scientists analyze data from space missions, and develop models and theories that lead to interpretation of the observed data and generation of new knowledge.

University collaborators have recognized the potential benefits that accrue from a relationship with JPL in terms of strengthened collaborative research and technology opportunities, access to unique JPL research programs, projects, people and facilities, and contribution to the education and training of students in space exploration disciplines.

We offer an exciting environment to students who want to be at the cutting edge of technology, engineering and science and the opportunity to put their knowledge into practice by working with our researchers and engineers as interns. The strong relationships that JPL builds through these contacts create a robust pipeline to hire our employees of the future. ■

**Dan McCleese**
Chief Scientist
Jet Propulsion Laboratory

**Jonas Zmuidzinas**
Chief Technologist
Jet Propulsion Laboratory

NASA's versatile Mars Reconnaissance Orbiter, which began orbiting Mars in 2006, has radically expanded our knowledge of the Red Planet. The mission has provided copious information about ancient environments, ice age scale climate cycles and present day changes on Mars by observing its surface, subsurface and atmosphere in unprecedented detail.

# How Do We Search for Evidence of Life on the Icy Surfaces of the Outer Solar System?

**JPL Project Leaders:** Paul Johnson, Robert Hodyss

**Student Partnership:** Victoria Chernow, Harvard University

The surfaces of icy planetary bodies are subject to a variety of particle and photon bombardment, which can chemically alter any chemical signature of life. In order for NASA to define search strategies and develop mission scenarios to look for evidence of extant or extinct life on these bodies, JPL is working on creating a detailed understanding of the physical chemistry within these icy environments.

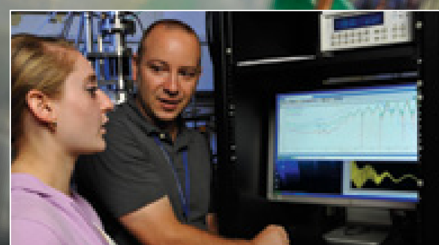
Victoria Chernow's studies in synthetic chemistry at Harvard University led to her involvement in JPL's research program concentrating on the photochemical processes of organic compounds as they relate to Solar System ices. As an intern, she spent 10 weeks at JPL studying amino acids as a representative class of organic compounds. Specifically, she investigated the photochemistry of cryogenic ice mixtures containing glycine, the simplest amino acid. Her goal was to determine the decomposition products of glycine as a function of the incident light wavelength.

Within a couple of weeks, after getting familiar with the equipment and taking required safety training, Victoria was doing independent lab work in support of this study. JPL mentors Paul Johnson and Robert Hodyss gave her guidance in terms of experimental direction, analysis and interpretation of results. Her experiments were conducted in a vacuum chamber where ices are deposited on a cryogenic sample window. Samples were then irradiated with a variety of UV lamps in order to emulate the chemical processes occurring on the icy surfaces of planetary bodies that are subjected to UV radiation. In addition, she used Fourier Transform Infrared (FTIR) spectroscopy to probe vibrational absorptions specific to particular molecular bonds, allowing her to monitor the destruction and creation of molecules in the ice. This is vital because organics present on or near the surface of an airless body are exposed to an energetic environment that generates similar degradation and transformation.

This study is crucial to our understanding of icy bodies, ultimately aiding the development of search strategies for life in these environments. Victoria's work during her internship will be extremely valuable in planning searches for biomarkers on icy surfaces that may be explored by future NASA missions. "It was simply amazing to be a part of a project and community that is working towards something very concrete, and with immediate, real-world applications." ■

"At JPL, I was introduced to a whole new realm of research. It was empowering to actually build and augment the instrumentation we used for experiments."

Victoria Chernow, Harvard University



Victoria Chernow discusses experiment results with mentor Robert Hodyss.


This spread: Victoria Chernow.

# Solar System Science

## JPL's planetary science research focuses on understanding the planets, satellites and smaller bodies in our Solar System.

Among the many successful missions that are providing a wealth of data for researchers are the Cassini orbiter to Saturn, the Mars Exploration Rovers, the Mars Reconnaissance Orbiter, the Mars Phoenix Lander, the Dawn mission to Vesta and Ceres and the Voyager mission to explore the Solar System.

Scientists at JPL study the atmospheres, surfaces and interiors of bodies in the Solar System to understand their origins and evolution. The techniques they employ include using radar to determine the physical characteristics of asteroids, measuring spectra from atmospheres of distant planets, studying rocks in situ on Mars and using spacecraft radio signals to determine the interior structure of the planets. Research is carried out from orbiters and planetary landers, in the laboratory and on places on Earth that have charac teristics of other planets. Researchers use field and lab studies in microbiol ogy and chemistry to prepare for future missions that will search for the signs of life beyond Earth. Some of these missions may sample the rocks and soil of Mars, probe the icy interior of Europa and ultimately sail the lakes of Titan. Giant planets such as Jupiter and Saturn hold the keys to understanding the formation and evolution of planetary systems. To find out how planets form, scientists at JPL research the myriad of smaller bodies in the Solar Sys tem, including large asteroids and comets. JPL geologists don t just study Earth: studies of volcanology, tectonics, mantle dynamics and mineralogy have been applied to other rocky planets in the Solar System in the ultimate search for signs that life once existed there. Using remote measurements and planetary probes, our scientists examine the atmospheres of planets and smaller bodies in our Solar System in order to better understand what drives the complex weather seen on planets like Jupiter, Saturn, Uranus and Neptune and the origins of the tenuous atmospheres of smaller bodies. ■


# Summer at the Ice Factory: A Student Transitions from Theoretical Models to Active Laboratory Research

**JPL Project Leader:** Julie Castillo Rogez

**Student Partnership:** Catherine Walker, University of Michigan

Water ice is present throughout the Solar System. Within the walls of these frozen planetary shells lies the promise of profound revelations about the evolution of our Solar System. Catherine Walker, a PhD student at the University of Michigan, attended JPL's Planetary Science Summer School in 2009. She was immediately impressed with JPL and sought an internship related to her research interests for the following year. She contacted Julie Castillo-Rogez and, during the summer of 2010, set out to thaw some of the great mysteries behind planetary ices.

Although ice microstructure is well known, the relationship between microstructure and certain physical properties is still poorly understood. Ice is unstable and difficult to handle, making cold temperature research challenging. With the guidance of Julie Castillo-Rogez at JPL's world-class laboratory known as the "Ice Factory," Catherine synthesized ice samples with various compositions, matching those observed or expected in planetary objects. Catherine conducted experiments of fatigue testing to simulate the role of tides in the deformation of terrestrial ice shelves to analyze the production of heat inside icy satellites, such as Jupiter's satellite Europa, which is believed to harbor a deep ocean. In addition, ultra-thin slices of the ice were also examined under a cryomicroscope for a unique view of how ice responds to stress on a submillimeter scale. These experiments provide a clearer understanding of how the ice on ice moons responds to the kind of tidal forces they experience during orbit and how heat is generated, or lost, within the ice.

Catherine's doctoral research on Enceladus' ice shell drew her to JPL's Planetary Science Summer School, as did the promise of gaining hands-on experience in actual experimental measurements. Up until then, her research had primarily been based on computer and theoretical modeling. "It's rare to get the chance to work in a laboratory, especially in the planetary sciences, when you're not involved with hardware." Catherine said. "My ultimate goal in life is to be an astronaut," she continued. "This experience, in a big way, has propelled my desire to work at JPL in the future. What a dream job that would be!" ■

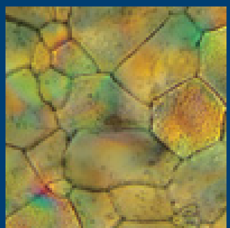
This page: Catherine Walker.

**Highlight on Postdoctoral Research**

## The Process of Making High Quality Ice for Scientific Research

**JPL Advisor:** Julie Castillo Rogez

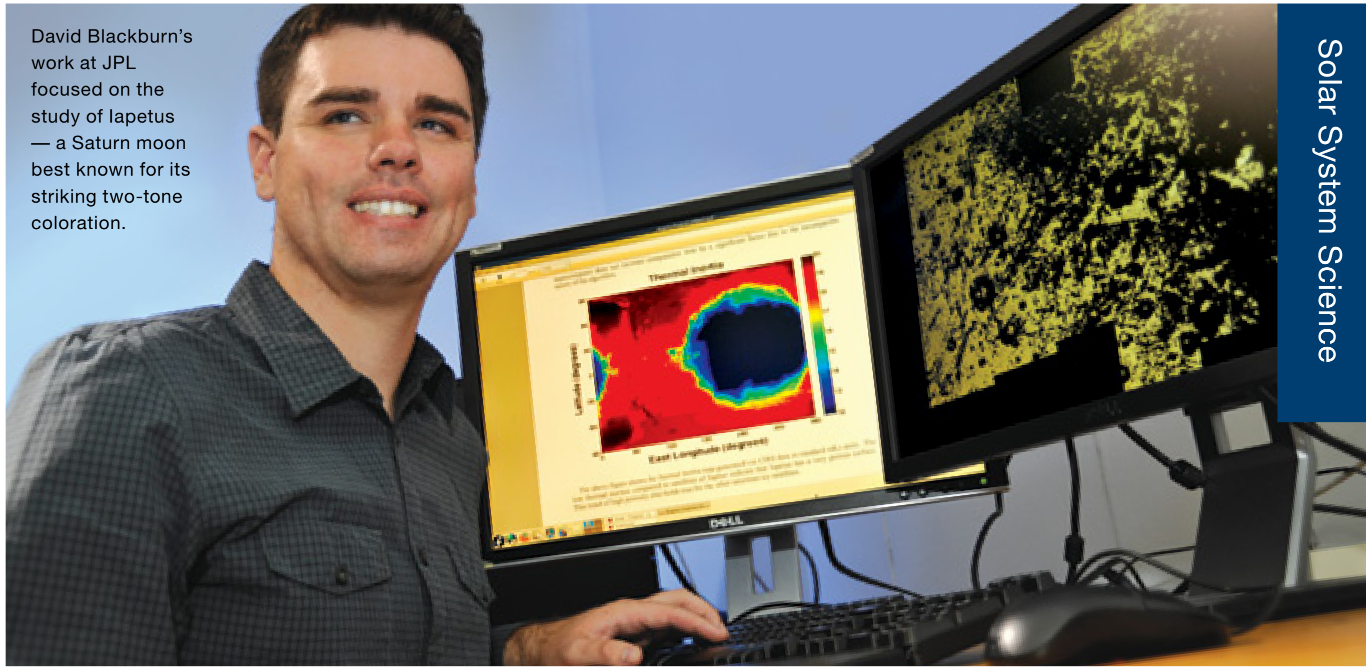
Mathieu Choukroun, Scientist, Planetary Ices Group



An ice sample observed by cryomicroscopy using polarized light.

After completing his PhD at the Université de Nantes, France, Mathieu Choukroun was lured by the international reputation of JPL, especially when it comes to exploring ice and icy bodies. With his expertise in exploring the cryogenic conditions on ices and icy satellites, he developed new cryogenic equipment and procedures to synthesize high quality ice samples. By using optical microscopy through a cryostage to keep the ice stable, he can analyze its composition and microstructure. This has dramatically influenced lab measurements and implications for icy bodies of the Solar System. Now a staff scientist with JPLs Planetary Ices Group, Mathieu s advances in the field of cryogenics have contributed to several research proposals selected by NASA. ■

Mathieu Choukroun places an ice sample for analysis.



David Blackburn's work at JPL focused on the study of Iapetus — a Saturn moon best known for its striking two-tone coloration.

## The Moons of Saturn: Wonderful and Weird

**JPL Project Leader:** Bonnie Buratti

**Student Partnership:** David Blackburn, University of Arkansas

Saturn has long been a source of studied fascination, as astronomers perpetually seek to probe the hazy mysteries that cloak this planet and its 53 icy moons. Saturn's wealth of satellites promises to be a fertile frontier of new discovery for students like David Blackburn, a PhD candidate from the University of Arkansas.

The Cassini spacecraft, which has been orbiting Saturn since 2004, has returned intriguing data about many of Saturn's frigid moons — one of the most unusual of which is Iapetus. Although it contains several unique characteristics worthy of study, the most striking is the two-tone coloration resulting from its dual hemispheres — one hemisphere is bright and icy like a typical Saturnian satellite, the other as dark as coal tar. This mysterious dichotomy was what David set out to explore.

It is now believed that the dark material apparent on Iapetus originated from small, dark particles that migrated from Saturn's tenuous outer ring. David's goal was to understand how the placement of this dark material changes after it is accreted onto the moon's surface. Specifically, he sought to explain how the polar caps form, and to what degree the dark material causes the migration of carbon dioxide and other ices on Iapetus. Using Cassini images and Visual Infrared Mapping Spectrometer (VIMS) data, David helped create the first bolometric Bond albedo map of the surface of Iapetus. This provided a global view of Iapetus' energy balance, enabling an accurate calculation of the heating of the moon and the associated sublimation of carbon dioxide and water ice.

"I have always been interested in the moons of Saturn," said David. "The experience gained from working at a NASA center is priceless. I feel like I have grown so much and gained great confidence by working here." After his internship, David kept in touch with his mentor, Bonnie Buratti. While in Arkansas, they teleconferenced weekly to discuss writing up peer-review publications from his work at JPL. She also became a member of his PhD dissertation committee. Upon successfully defending his doctoral dissertation in 2011, David joined JPL as a NASA postdoctoral fellow. The techniques and software he developed will now extend to other applications, including the Dawn mission. Dawn has begun orbiting the asteroid Vesta in 2011, undertaking the first close scrutiny of an asteroid. ■

# Earth Science

## Earth scientists at JPL carry out research to better understand Earth's atmosphere, land and oceans to make predictions of future changes.

JPLs Earth science researchers study the atmosphere, cryosphere (the parts of our planet where water is frozen), oceans and solid earth using a combina tion of spacecraft data, modeling and laboratory work: Atmospheric scientists at JPL use data from spaceborne instruments such as the Tropospheric Emis sion Spectrometer (TES) experiment on the Aura satellite, the Terra spacecraft s Multi angle Imaging SpectroRadiometer (MISR) instrument, the Atmospheric Infrared Sounder (AIRS) on Aqua, the Microwave Limb Sounder (MLS) on Aura, CloudSat and many others to study hurricanes, measure cloud properties and aerosol particles, observe stratospheric ozone, map the global distribution of temperature and water vapor in order to understand their role in climate change and many other tasks. These efforts are complemented by laboratory studies and state of the art process modeling. By studying ice sheets, glaciers, spring thaw patterns and mass balance of the sea ice cover using data from missions like GRACE (Gravity Recovery and Climate Experiment) and QuikSCAT (Quick Scatterometer), researchers are getting a clearer picture of the cryosphere and the processes that affect it.

Ocean science at JPL focuses on global and regional ocean circulation, as well as the interactions of the oceans with the atmosphere and sea ice. This involves in situ and remote sensing technology development, data analysis, numerical modeling, data assimilation, prediction and information management, based on data from missions such as Jason 1 and 2 and the recently launched Aquarius SAC/D. Solid Earth research at JPL includes work in geosciences and natu ral hazards, involving a wide cross section of researchers that specialize in re mote sensing, topography, geodesy, volcanology and hazard prediction. All of these research activities are supported by lab studies and modeling, and use data from multiple missions, including the Shuttle Radar Topography Mission (SRTM), the Advanced Spaceborne Thermal Emission and Reflection Radiom eter (ASTER) instrument aboard the Terra satellite and the GRACE mission. ■



This spread, left to right: Ian Jones, Jose Huerta, and Katrina Laygo.

# Navigating the Seas of Eco-Forecasting to Better Understand Atlantic Bluefin Tuna Habitats

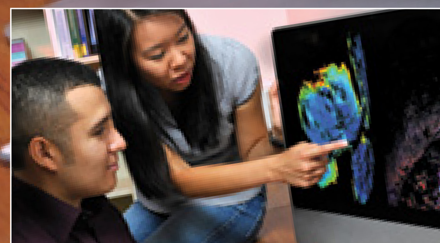
**JPL Project Leader:** Benjamin Holt

**Student Partnership:** Jose Huerta, Cal State University Northridge; Katrina Laygo, University of California, Los Angeles (UCLA); Ian Jones, University of California, Los Angeles (UCLA)

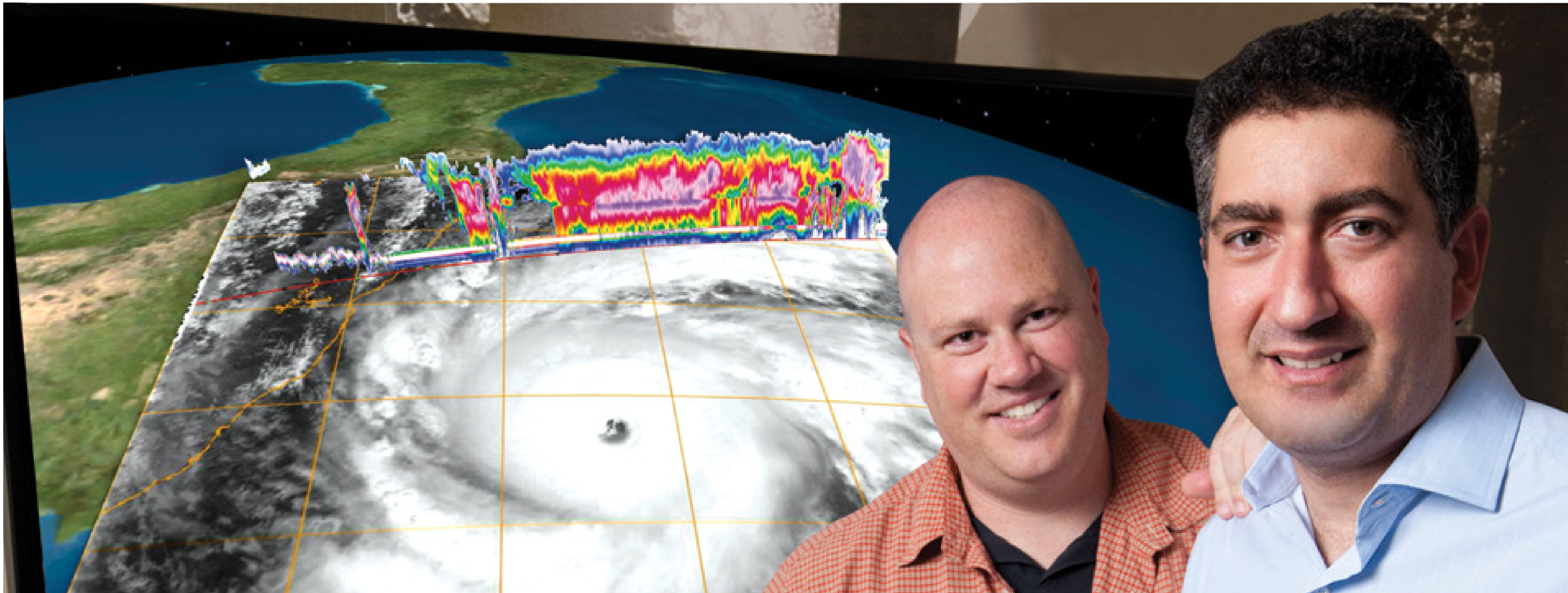
Commercial demands and environmental degradation of underwater habitats are threatening endangered species like the Atlantic bluefin tuna. With the Gulf of Mexico and the Mediterranean Sea as the only two known spawning sites in the world, scientists continue to seek better methods of ecological forecasting in order to better manage fishing catch allowances and avoid the collapse of the species. This is the challenge that students Jose Huerta, Katrina Laygo and Ian Jones undertook when they participated in NASA's DEVELOP Program. As part of the program, both NASA and partner associations assist students in utilizing NASA technologies to address local environmental issues. This trio of students was tasked to study satellite data to help improve the identification of the bluefin tuna's habitat, which, in turn, would improve how tuna populations are sampled for stock estimates. Key to their effort is the detection of *Sargassum*, a floating marine algae in which young tuna are known to develop. Their study focused primarily on whether synthetic aperture radar (SAR) could be used as a primary tool to detect the algae. SAR is known for its very fine resolution, as well as its ability to penetrate the marine cloud layer that often shrouds the ocean's surface. These students were the first to study SAR data in an experimental approach to identifying the tuna's habitat. Their preliminary findings show it has promise identifying *Sargassum*, but that more data points are needed to confirm the concept. A significant event had happened just prior to their summer at JPL, which helped to provide some of this needed material — the Deepwater Horizon oil spill in the Gulf of Mexico. National attention to the spill has provided a significant amount of both satellite and local observational data. Jose, Katrina and Ian took advantage of the opportunity to track *Sargassum* and the oil spill with extensive SAR coverage along with NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) on board Aqua and Terra. They also worked closely with Roffer's Ocean Fishing Forecasting Service in Florida and the University of Southern Mississippi regarding conservation efforts of the Atlantic bluefin tuna and its habitat in relation to the spill.

The efforts of groups such as these students have increased our understanding of the use of satellite data in identifying marine organisms in the ongoing quest to conserve marine biodiversity. ■

> "It is exciting to work in a program that shows how NASA research can be utilized to address environmental concerns and local policies."
>
> Katrina Laygo, UCLA Class of 2010
> NASA DEVELOP Program Center Lead



The team studied satellite data to help improve the identification of the bluefin tuna s habitat.



# JPL Provides a Path into the Research of Clouds and Climate Forecasting

**JPL Advisors: Joao Teixeira and Annmarie Eldering**

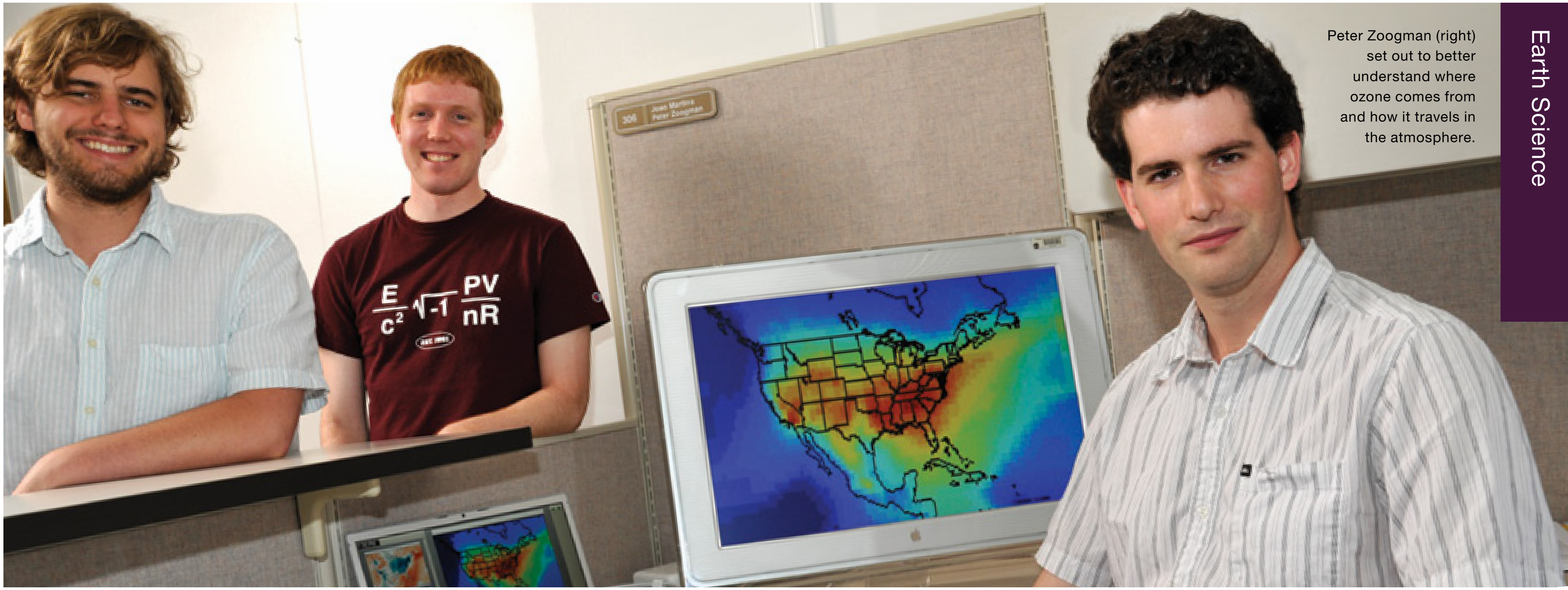
**Georgios Matheou, Scientist, Climate Physics Group**
**Brian Kahn, Scientist, AIRS Atmospheric Science Group**

Clouds, a magnificent phenomenon, are a result of the perpetual motion of the atmosphere. The complex motion of the atmosphere and ocean is one aspect of turbulence — often referred to as the last mystery of classical physics. While clouds and turbulence have been studied extensively, their detailed characteristics still remain obscure.

During his graduate studies at Caltech, Georgios Matheou investigated the mixing of dissimilar gases in a turbulent environment from the perspective of turbulent combustion. Recent and significant advances in computing power and computational science now enable detailed simulations of complex systems — an exciting and fast-paced area that Georgios chose to focus on. He quickly began to appreciate that his studies had significant implications in climate science. After completing his graduate studies, Georgios joined JPL as a postdoctoral scholar advised by Joao Teixeira, and then as a scientist in Joao's group. At JPL, Georgios works with scientists specializing in diverse fields of expertise with research encompassing remote sensing observations, theory and modeling — a synergistic approach that is a core strength at JPL.

Brian Kahn's career at JPL began during his graduate school studies at the University of California at Los Angeles (UCLA). His soon-to-be JPL doctoral co-advisor, Annmarie Eldering, was teaching a class on cloud microphysics that Brian was taking. She offered him the opportunity to investigate solar occultation data from space shuttle missions to study cirrus clouds at JPL. When the Aqua satellite was launched in 2002, it carried an instrument called the Atmospheric Infrared Sounder (AIRS), designed to improve weather forecasting. As soon as the data began to flow, it was apparent that AIRS was generating lots of new and exciting data. Brian was fortunate enough to look at it very early during the mission, and from that point on, his studies focused on cirrus clouds observed by AIRS. After completing his doctorate, Brian continued at JPL with a postdoctoral fellowship. In 2009, Brian was hired as a scientist at JPL. Some of the work he has participated in has spurred opportunities for new areas of research related to clouds and climate, possibly helping to illuminate the kinds of observations that need to be made in the next generation of satellite missions. ■

This page, left to right: Brian Kahn and Georgios Matheou.



Peter Zoogman (right) set out to better understand where ozone comes from and how it travels in the atmosphere.

With the guidance of mentors Dong Wu and Olga Kalashnikova, Matt Scholes (left) and Mark Chodas (right) spent a summer analyzing NASA satellite images to obtain cloud and dust plume heights using advanced computer software at JPL. The data they produced will help scientists better understand cloud plume formation and variability.

# A Breath of Fresh Air: New Research Tracks the Movement of Ozone

**JPL Project Leader:** Kevin Bowman

**Student Partnership:** Peter Zoogman, Harvard University

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Colorless and odorless, ozone is a gas that can affect virtually all surface life forms that breath air. It can attack the respiratory systems of humans as well as have damaging effects on crops, trees and vegetation. Regardless of its point of origin, wind can carry ozone and other pollutants that form in the atmosphere hundreds of miles away. As the impact of ozone intensifies, understanding where it comes from and how it travels is becoming an increasing concern. Thus, characterizing ozone's sources and predicting its evolution is one of the principal challenges of atmospheric chemistry and air quality management.

Peter Zoogman of Harvard University undertook this challenge during a summer internship at JPL. Recent satellite observations, such as those on the NASA Aura satellite, provide a tremendous global snapshot of the presence of ozone and its precursors. While satellites can't provide the whole picture, recent research has incorporated these data into numerical chemical weather models that can track where ozone is coming from and where it is going. In conjunction with these models, Peter used data from the Tropospheric Emission Spectrometer (TES), a JPL instrument, to perform a process known as "assimilation," which quantifies the way ozone travels from one place to another. Based on the lessons learned from current satellites, he then began to pose "what if?" questions in regards to capabilities for future satellites. As part of the Geostationary Coastal and Air Pollution Events Mission, Peter performed observational system simulation experiments (OSSE) to calculate new data points from next-generation satellites, and explored novel methods of predicting and understanding the impact of ozone on human health.

As the effort continues, we can all breathe a little easier as researchers like Peter continue to ask "what if?" ■

# Gravitational Lensing Sheds New Light on Dark Matter

JPL Advisor: Jason Rhodes
**JPL Project Leaders:** Eric Jullo, Postdoctoral scholar; Joel Berge, Postdoctoral scholar

**Student Partnership:** Sedona Price, Caltech; Nikhil Anand, UC San Diego

Dark matter makes up nearly a quarter of the mass and energy of the Universe. Abundant, yet elusive, it is invisible except through its gravitational pull on ordinary visible matter. When large quantities of dark matter clump together in massive galaxy clusters, it acts as an enormous magnifying glass for more distant galaxies billions of light years away. The presence of these dark matter clusters causes gravity to stretch and distort the light from galaxies beyond — a phenomenon known as gravitational lensing. At JPL, scientists have discovered a way to use gravitational lensing to better understand dark matter. “Gravitational lensing is the most promising probe of dark matter in the Universe,” said Eric Jullo, a postdoc at JPL. “However, certain systematic effects, ranging from astrophysical to instrumental errors, must be controlled and better understood as we continue to explore the properties of dark matter.”

Through a ten-week summer internship under the guidance of both Eric and Joel Berge, Nikhil Anand and Sedona Price worked to study the systematic effects involved in gravitational lensing. As part of their research, they analyzed the observations of gravitational lensing obtained from both the Hubble Space Telescope (HST) and the Subaru Telescope in Hawaii.

Nikhil interpreted Hubble images to map out dark matter distribution in the galaxy cluster MS1358. He built a catalog of these images, and then developed his own computer programming tools for analysis. Ultimately, he was able to select background galaxies whose shape is modified by gravitational lensing, and convert the shapes of those background galaxies into a map of the dark matter cluster. Sedona implemented the Principal Component Analysis method to estimate the Telescope Point Spread Function (PSF), which changes the shape of galaxies and provides accurate modeling crucial to the precise measurement of the gravitational lensing effect. After extensive testing, she applied her method to the 20 square degrees of the Subaru survey, which enabled her to further study dark matter structures.

This team’s groundbreaking research has become vital to the characterization of dark matter properties in galaxy clusters, and brings us ever closer in the continuing quest to explore the darkest corners of the Universe. ■

> “It was very rewarding to take part in real astrophysical research questions, and to see how astrophysical research is done.”
>
> Sedona Price, Caltech

Nikhil Anand worked to map out dark matter distribution in the galaxy cluster MS1358.

This spread, left to right: Sedona Price, Eric Jullo, Joel Berge and Nikhil Anand.

# Astrophysics & Space Science

## Our astrophysics and space scientists study the physics and origins of our galaxy, and ultimately the Universe.

Among the many missions that are providing a wealth of data to the research community are the Hubble Space Telescope, the Spitzer Space Telescope, the Galaxy Evolution Explorer (GALEX), the Wide-field Infrared Survey Explorer (WISE) and the joint ESA NASA Planck and Herschel missions.

JPLs cosmology researchers investigate the nature and evolution of the early Universe. This includes observing the cosmic microwave background and measuring dark energy. An important part of this work is developing more and more sensitive instruments to detect subtle features in the early Uni verse. To improve our understanding of black holes and binary systems, re searchers search for gravitational waves (ripples in spacetime) and perform sensitive tests of general relativity. On large scales, the Universe consists of clusters of galaxies. Galaxies are treated as coherent, self contained sys tems of dark matter, stars and gas. At JPL, we study their structure and how they evolve over billions of years. Understanding how galaxies, especially the Milky Way, formed and evolved is key to understanding an ancient part of mankind's own origins. Closer to home, we are actively involved in research on the origins of individual stars and planets. Work in this area uses tele scopes and advanced models to study the formation and death of stars and the physical and chemical processes in the spinning clouds of gas and dust where these stars are born.

Additionally, JPL is involved in the direct detection and characterization of planets around other stars through the development of coronagraph imag ing and spectroscopic techniques. In our own Solar System, we investigate how the habitability of planets is affected by the Sun s variability and its in teraction with planetary magnetic fields and atmospheres. This includes the study of the Sun and the solar wind and their interactions with the magneto spheres of Earth and the other planets and comets. To support this research, physicists provide basic atomic and molecular collision data relevant to high electron temperature plasmas (solar and stellar atmospheres), to cometary atmospheres and to the interstellar medium. ■

## New Studies in Strong Gravitational Lensing Bring Clarity to Centuries-old Questions

**JPL Project Leaders:** Leonidas Moustakas, Art Congdon

**Student Partnership:** Hillary Walker, Williams College

Gravitational lensing, or the deflection of light by mass, is a concept first considered by Newton centuries ago and long predicted by Einstein centuries later. Today, strong gravitational lensing is rapidly becoming a powerful tool in the study of the Universe and distant galaxies that date back to the dawn of cosmic time. Strong gravitational lensing is a visually stunning phenomenon that occurs when multiple rays of light from a chance background galaxy or quasar are focused simultaneously so that the same distant object appears as multiple images of itself. Much can be learned by these rare observances.

Through Caltech's Summer Undergraduate Research Fellowship (SURF) Program, Hillary Walker worked closely with her mentors to study the critical relationship between the environment in which a lens lives, along with its consequent "shear," or gravitational tide, and the time delay, which relates to the actual photon travel times between lensed images. To do so, she created strong gravitational lens models to study real observed lens systems, a major milestone. This study is important because it can be very difficult (if not impossible) to study the neighborhoods that individual galaxies live in. It can be like a house in a neighborhood with several other houses that can influence how the house appears, but which are more or less invisible to the naked eye. Thus, the study of their gravitational signatures helps us infer their presence and their character, including geometry, brightness and photon travel times.

The advances being made in this study can lead to exciting new answers to questions that have been asked for centuries, such as, how can we gain meaningful measurements of the particle nature of dark matter? And, how can we measure the expansion and acceleration rate of the Universe? ■

This page, left to right: Hillary Walker and Leonidas Moustakas.

Highlight on Student Research

## Designing an Interactive Learning Tool for Gravitational Lensing

**JPL Project Leaders:** Leonidas Moustakas, Dan Goods

**Student Partnership:** Madeleine Gallagher, UCLA

Illustration depicting Madeleine s interactive installation, Halo Benders.

Who knew that so much could be learned by looking at the bottom of a wine glass? As an artist work ing in electronic media and design, Madeleine Gallagher developed a project to communicate the con cepts of gravitational lensing to audiences unfamiliar with astro physics. Her final project, Halo Benders, is an immersive interac tive installation that allows people to intuitively explore and visualize the notion of dark matter by its visual effect on light. The research that led to her final project involved a thorough study of the effects of refractive geometry on distant light sources through what is known as the wine glass experiment. By reproducing similar geo metric effects in a simulated star field, she created a space where people can play the role of the distant light source and interact, via a live video feed and real time OpenGL effects, with documented gravitational lens patterns such as arcs, cloverleafs and the elusive double Einstein ring. ■

Madeleine Gallagher used the bottom of a wine glass as a basis to develop her final project, Halo Benders.

Scott Barrows (left) discusses theory with his mentor Daniel Stern (right) in the Caltech Astrophysics Library.

## The Search for Evidence of Dual Black Holes in Merging Galaxies

**JPL Project Leader:** Daniel Stern

**Student Partnership:** Scott Barrows, University of Arkansas

During the summer of 2010, Scott Barrows was given the opportunity to work with Daniel Stern, a JPL researcher in the Evolution of Galaxies group. The project Scott worked on grew out of a fortuitous alignment between Scott's graduate thesis work and a recent spectroscopic observation of a peculiar extragalactic source obtained by JPL scientists, including Daniel Stern. In his internship, Scott set out with the primary goal of completing analysis of this interesting source to include in his thesis.

The spectroscopic observation in question was a particularly exciting discovery, as it appears to be the result of a merger between two large galaxies, and may contain two supermassive black holes that will eventually merge with each other. Binary black holes are of extreme interest for many astronomers because they represent an important stage in galaxy evolution, and critical evaluation of these cases is necessary.

While completing his primary project, Scott was able to work with a variety of raw data collected from the Keck Telescope in Hawaii. Under Daniel Stern's guidance, Scott learned how to reduce and calibrate imaging and spectroscopic data, and gained experience handling data for a number of other extragalactic sources.

Additionally, Scott routinely met with collaborators at Caltech who were working on similar issues of galaxy evolution. There, Scott was able to participate in daily journal clubs that discussed recent results in the field of astronomy. An important aspect of Scott's time at JPL was a variety of meetings, both with Stern and other scientists at JPL and Caltech, where the interpretation of data was examined critically.

Later that year, Scott was able to participate in an observing run at the Palomar Observatory to gather spectroscopic data for other sources that may also be merging galaxies. Ultimately, this project benefited Scott enormously toward the completion of his thesis work, but even more importantly gave him valuable experience analyzing data and communicating with top researchers in the field. The results of his work have been presented at the 217th meeting of the American Astronomical Society. ■

# Observational Systems

## JPL is developing detectors and instrument systems to enable scientific investigations into the origin, state and fate of Earth, planets, and the Universe.

Ongoing work at JPL includes large aperture telescopes and radar systems that will be used to help future Earth and planetary missions collect essen tial data. JPLs Observational Systems researchers develop detectors and focal plane systems, including integrated cooling, which push performance to physical limits while maintaining high sensitivity and allowing precision calibration. We study remote sensing systems that incorporate the relevant optics, detectors and heterodyne techniques, to provide cameras, spec trometers, radiometers and polarimeters across most of the electromagnetic spectrum, as well as submillimeter imaging arrays, hyperspectral imaging systems and atomic quantum sensors. In addition to these passive systems, we develop active remote sensing experiments to probe environments using radio frequency radars, GPS signals, and laser based ranging, absorption and spectroscopic systems.

Technologists at JPL also develop the software required by the observing systems we employ. This software controls instruments, processes data on board spacecraft and supports the analysis and interpretation of data back on Earth. For missions that visit Solar System bodies, we also develop in situ sensing instruments that probe the state and evolution of these bodies by investigating physical properties, morphology, chemistry, mineralogy and isotopic ratios, as well as by searching for organic molecules and for evidence of previous or present biological activity. Many missions require telescopes and radar systems with large collecting apertures. Researchers at JPL inves tigate a variety of techniques to advance the study of lightweight apertures, lightweight and precision controlled structures, integrated and low tempera ture thermal control, advanced metrology, wavefront sensing and control and precision pointing systems. ■

This spread: Hanieh Amoozegar.

# Studying Organic Molecules to Examine Life As We Know It…And Life We Don't Yet Know

**JPL Project Leader:** Luther Beegle

**Student Partnership:** Hanieh Amoozegar, UC Berkeley

The search for life on other planets continues to be one of NASA's highest priorities. Discovering life elsewhere in the Solar System not only leads to a better understanding of the distribution of life throughout the Universe, but also about the origin of life, as we know it, here on Earth. Evolutionary biologists, like Hanieh Amoozegar, are looking at new ways to use what we do know about the fundamental elements of our life forms to detect forms of life yet to be discovered.

It can be argued that all life requires certain critical elements to exist — namely, water, energy and organic molecules such as amino acids. If scientists are able to characterize the distribution of organic molecules in a sample, they hope this could lead to the detection of the most basic forms of life. However, the process of distinguishing between organic molecules created through biological processes and those created through non-life processes remains a murky proposition.

Salts, which are known to cause distortion, interference or contamination within a sample, are found virtually everywhere on aqueous bodies. In order to obtain a "clean" sample, a method of salt removal is required. As part of her quantitative analysis to differentiate between life-forming amino acids and non-life amino acids, Hanieh pursued various strategies to desalinize protein samples and sequence the amino acids in order to ensure the extraction process could, one day, be done on other planetary bodies.

As part of this research, an Electrospray Ionization Mass Spectrometer was used to ionize material directly out of one sample solution. As this technique favors the ionization of salts over organic material, salt remediation was necessary for more accurate quantitative analysis. Hanieh created binary samples consisting primarily of salt and a trace amount of an organic material under the guidance of Luther Beegle of JPL. She then employed various salt remediation methods to determine which was best suited for future research.

Ultimately, this work is intended to assist in developing better flight hardware capable of identifying signs of life on Mars. "I get so excited every time someone asks me to tell them about my research at JPL. I got to play a part in the discovery of possible extraterrestrial life. Not too many people can say that." ■

"As an evolutionary biologist, my research in astrobiology at JPL helped pave the road toward my future endeavors in this field."

Hanieh Amoozegar, UC Berkeley

Hanieh pursued strategies to desalinize protein samples In order to sequence its amino acids.

# In the Search for Life on Other Planets, "Lab-on-a Chip" Systems Prove Big Things Come in Small Packages

**JPL Project Leader:** Peter Willis

**Student Partnership:** Sherrisse Bryant, Louisiana State University

Sherrisse Bryant, then a chemistry graduate student, joined the research team at JPL's Microdevices Laboratory for a ten-week period in 2010 to help develop miniaturized chemistry instruments, intended for exploring other terrestrial worlds. These "lab-on-a-chip" technologies are designed to analyze small drops of liquid to determine if they contain minute molecular traces associated with living processes. Of particular interest are amino acids, the building blocks of all life forms on Earth. With amino acids present in virtually every living system on Earth, the obvious question remains — would the prevalence of amino acids on other planets, such as Mars, indicate the existence of past or, even present, forms of life?

Sherrisse performed a series of experiments aimed at automatically controlling and operating a chip-based device that might someday be implemented on Mars. Her challenge was to drop a liquid sample on the surface of a microchip, then run a complete analysis, with no human intervention. "The miniature chip-based devices I worked on can perform all the steps necessary for automated chemical analysis, allowing us to take the lab to the sample, instead of bringing the sample to the lab," said Sherrisse. "It was thrilling to be a part of this breakthrough technology."

Now a PhD candidate at Louisiana State University, Sherrisse continues to pursue her passion for scientific research and credits the collaborative work environment at JPL, as well as the support of her mentor and fellow research team members. Meanwhile, JPL has continued the work of developing lab-on-a-chip systems and recently published an article on this research in NASA's New Technology Reports, with Sherrisse as co-author. Yes, big things are happening in micro-technology. ■

This page, left to right: Peter Willis and Sherrisse Bryant.

Todd Veach (right) worked with mentor Shouleh Nikzad (left) to develop advanced detector modules at JPLs Microdevices Laboratory (MDL).



# A New Vision for Imager Devices and Detector Modules

**JPL Project Leader:** Shouleh Nikzad

**Student Partnership:** Todd Veach, Arizona State University

Todd Veach stands with the vacuum test-based imaging system that he repurposed. It allows for more rapid testing of a large number of imaging devices — essential to future missions requiring large focal plane arrays.

Future missions, in support of astrophysics, cosmology, Earth science and the search of Earth-like planets, are planning to use telescopes with the largest focal plane arrays created to date. With large focal planes as their "eyes," vast areas of the sky can be surveyed, allowing them to collect data from a very wide field of view making for efficient use of time in space. These giant eyes can be tiled together using detector modules, an enabling technology, that employ advanced detectors.

Todd Veach, a graduate student in astronomy from the Arizona State University School of Earth and Space Exploration, had been working on detector development for several years when a collaboration was enabled through funding from JPL's Strategic University Research Partnership (SURP) to develop a modular imager cell.

Included with this award was a fellowship allowing Todd to spend an illuminating summer with JPL's Advanced UV/Vis/NIR Detectors and Imaging Systems Group developing advanced detector modules. These modules have the promise of unprecedented performance for future NASA missions that will require very large focal plane arrays.

Todd's primary focus during his time at JPL was the development of a modular imager cell to characterize advanced detectors in the broad spectral range of ultraviolet (UV) to near-infrared (NIR). As part of this research, Todd also repurposed a vacuum test-based imaging system *(pictured left)*, which was used to streamline high-volume testing of imagers specially processed in JPL's Microdevices Laboratory (MDL).

"The most rewarding experience I had at JPL was learning from my mentors, Shouleh Nikzad, Steve Monacos and Blake Jacquot, who are experts in the field of imaging detector technology," said Todd. "Working at JPL allowed me to learn from these preeminent professional researchers, who taught me how to hone and polish my own research techniques, which ultimately made me a better scientist."

Part of Todd's work at JPL resulted in a presentation at the AAS (American Astronomical Society) meeting. Todd is continuing to work with JPL, which notably has led to a ride for the detector and associated electronics on a sounding rocket experiment scheduled to fly in 2012. ■

# Digging for More: Breakthroughs Toward a Robotic Sample Acquisition Mission on Mars

**JPL Project Leader:** Paul Backes

**Student Partnership Team:** Cason Male, Stanford University; Robert Paolini, Caltech; Ruslan Kurdyumov, Caltech; Heriberto Reynoso, University of Southern California; Colin Ely, Caltech

It is the fourth planet from the Sun, with two moons and a hazy pinkish sky. It is a cold, rocky, barren wasteland. Yet, it is the most Earth-like planet in our Solar System at half Earth's size. It is Mars. Like Earth, Mars has polar ice caps and clouds in its atmosphere. It has seasonal weather patterns, volcanoes, canyons and other characteristics reminiscent of our own planet, signaling it might have once supported life. And, that it could again.

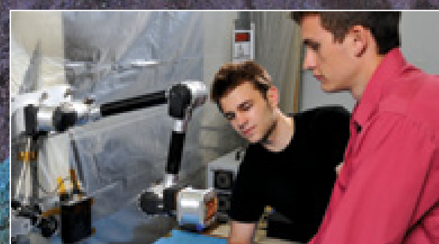
In the hopes of yielding more clues about the life-sustaining potential of our planetary cousin, a sample-caching mission to Mars is currently under consideration by NASA for a 2018 launch opportunity. JPL's Mobility and Manipulation Group worked with a team of students to develop a system of robotic sample acquisition and caching, that would enable the return of Martian samples to Earth. In a coordinated series of missions, a rover would acquire core and soil samples, storing them within a protective canister. It would traverse to a benign landing area and place the sample canister on the ground. Subsequent missions would then revolve around retrieving the sample for its ultimate return to Earth.

To facilitate the first phase in achieving this goal, the caching mission rover would need a Sample Acquisition and Caching (SAC) subsystem. This was the primary area of focus for this group of summer interns and each student played a pivotal role. Colin Ely supported assembly and testing. Ruslan Kurdyumov developed adaptive controls to enable the system to adjust to the local environment. Heriberto Reynoso developed an operator interface for generating commands. Cason Male developed autonomy software for the robotic arm for collecting and transferring samples to the caching subsystem. And, Robert Paolini developed control and autonomy software for the caching subsystem. "It was an incredible experience seeing the system I programmed work before my eyes," said Robert. "It's even more amazing that our civilization is able to launch and land robots on another planet to collect data for us."

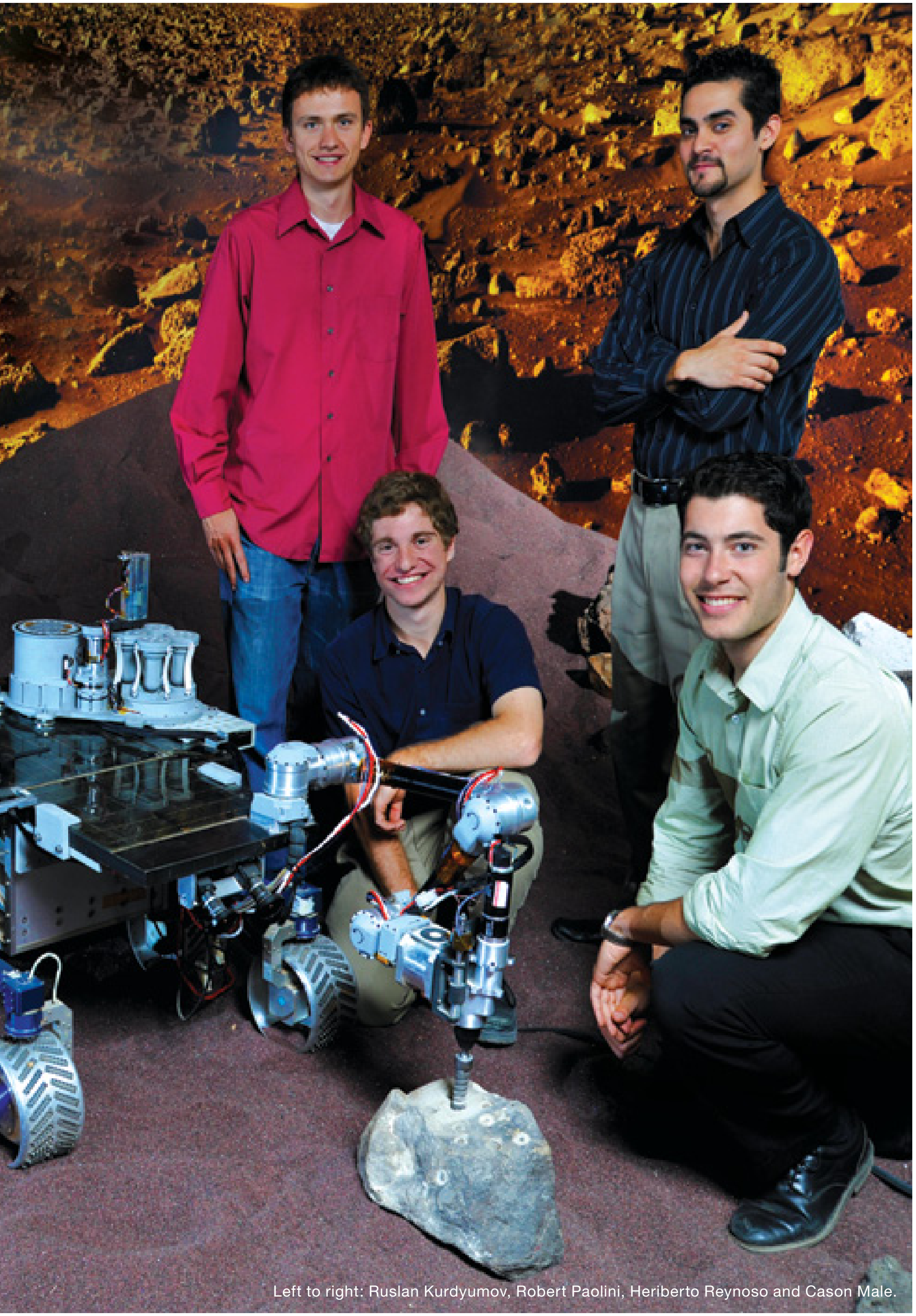
These students' contributions helped demonstrate for the first time that robotic sample acquisition and caching is feasible on Mars, potentially yielding new answers about this strange red planet that continues to captivate our imagination. ■

"JPL is unique. An idea can go through design, implementation, testing, then analysis — an intricate process rarely duplicated in the aerospace industry."

Heriberto Reynoso, University of Southern California



Ruslan Kurdyumov (right) demonstrates the adaptive controls he developed to Colin Ely (left).



Left to right: Ruslan Kurdyumov, Robert Paolini, Heriberto Reynoso and Cason Male.

# Exploration Systems

## A key activity at JPL is the development and application of advanced technologies to support NASA's exploration endeavors.

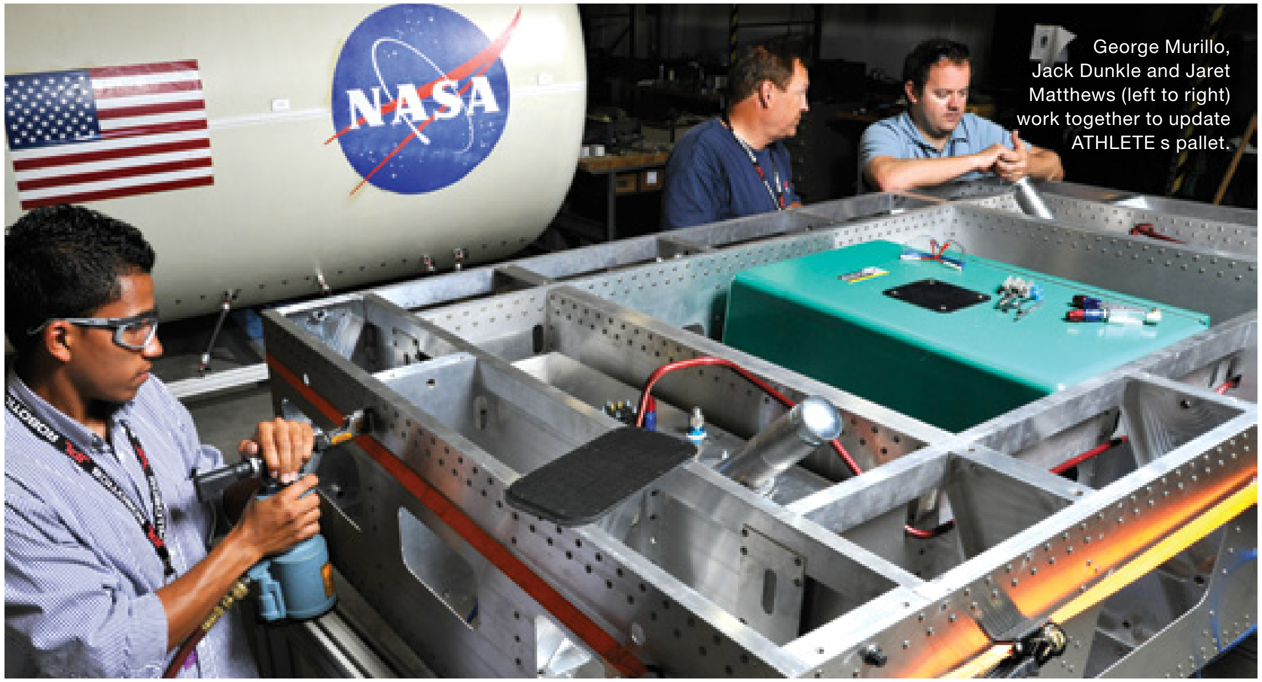
Researchers and engineers work together at JPL to produce the complex systems that enable our scientific missions. These efforts allow us to develop reliable, cost effective and cutting edge spacecraft systems. Technologists develop advanced propulsion and power systems for future deep space and extreme environment planetary missions. We study in situ exploration systems to enable planetary surface and small body exploration and allow samples to be acquired and returned to Earth. Robotics experts design systems that provide mobility on planetary surfaces, carrying sophisticated instruments that can collect, examine and manipulate samples for future return to Earth. An important component of our space systems is the software and avionics that enable fundamental mission capabilities such as commanding, fault protection and control critical functions such as entry, descent and landing. Additionally, JPL is developing software tools to drive future missions, and to acquire and analyze scientific data.

At JPL, we produce survivable electronic and mechanical systems for missions that will require reliable operations under extreme radiation, temperature, pressure and particulate environments. Precision formation flying research at JPL aims to develop precision control of spacecraft systems. Deep space navigation research at JPL is concerned with finding innovative ways to successfully send both orbiters and landers to different planets in the Solar System. Future missions will not only rely on current deep space navigation capabilities, but will require substantial extensions of existing technologies. Researchers are developing new techniques and technologies in the areas of low thrust navigation, precision tracking and guidance, and autonomous navigation to make these future missions possible. The scientific performance of all missions depends on communications systems that are responsible for sending scientific data from spacecraft back to Earth. Deep space communications research at JPL focuses on optical communications, information processing and the Deep Space Network. ■

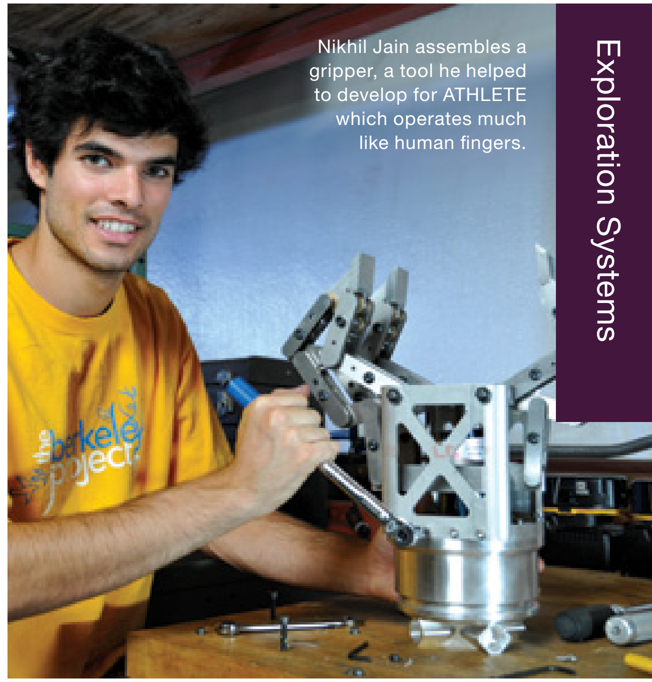

"At JPL, I learned that design is not a one time step, but a multi-step method that takes time and patience. Redesigning is the key component to creating not only a successful product, but a smart, efficient product."

George Murillo
Stevens Institute of Technology

Left to right: Zachary Ousnamer, Nikhil Jain, Julie Xie, and Carrine Johnson.



George Murillo, Jack Dunkle and Jaret Matthews (left to right) work together to update ATHLETE s pallet.



Nikhil Jain assembles a gripper, a tool he helped to develop for ATHLETE which operates much like human fingers.



# Covering New Ground in Robotics and Space Exploration

**JPL Project Leaders:** Jaret Matthews, Julie Townsend

**Team Members:** Nikhil Jain, UC Berkeley; Carrine Johnson, MIT; George Murillo, Stevens Institute of Technology; Julie Xie, Harvard University; Zachary Ousnamer, University of Michigan

To support a return to the Moon, NASA would need to build a lunar outpost where astronauts can live and work. Key to this endeavor will be ensuring that supplies, hardware and other logistical components can be supplied when needed.

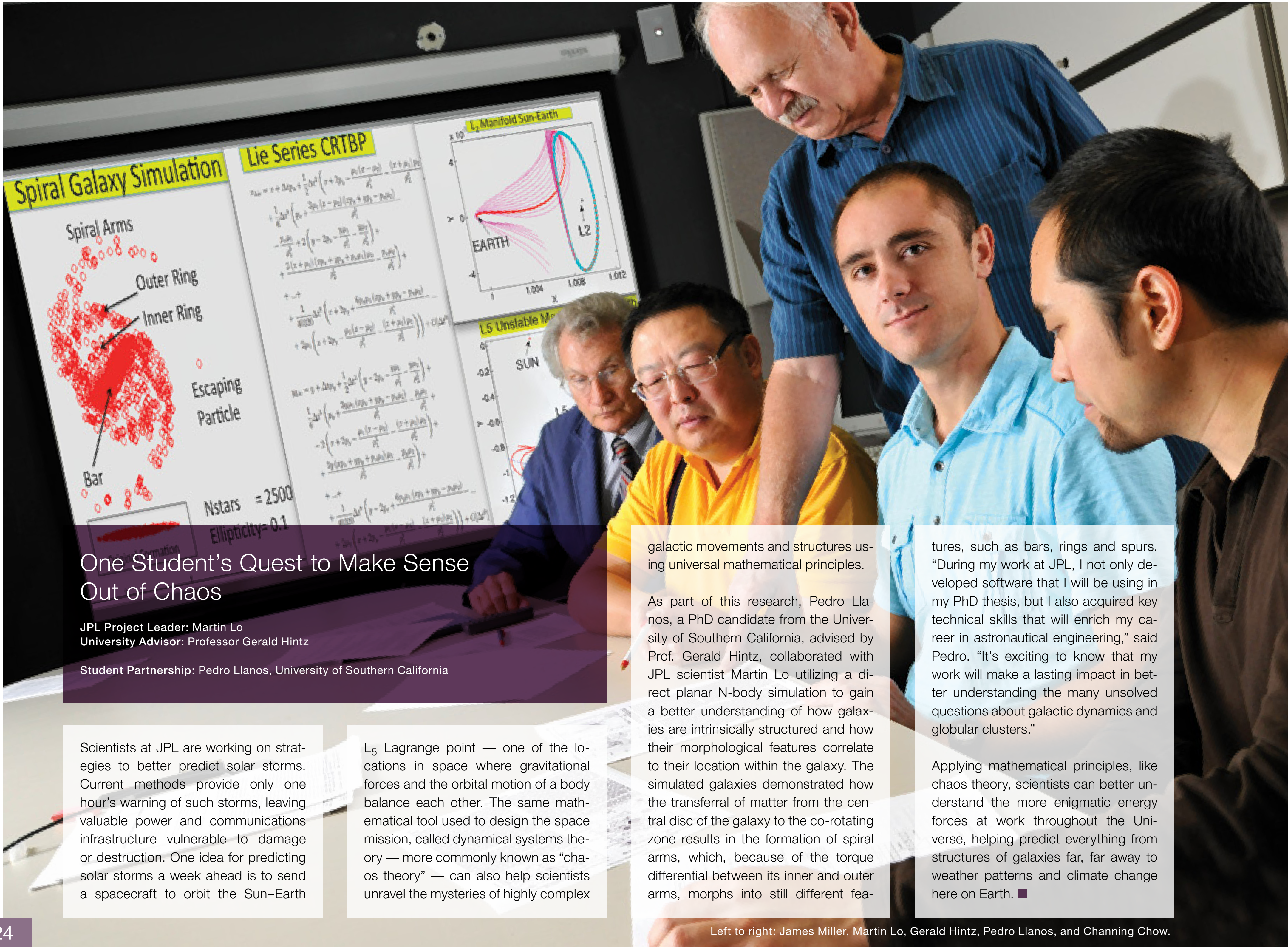
Better known as ATHLETE, NASA's All-Terrain, Hex-Limbed, Extra-Terrestrial Explorer vehicle represents a new approach to unloading, transporting and handling cargo for lunar and Martian missions. With six limbs that can function as either wheels, "legs" or "arms," depending on the surroundings, ATHLETE is a highly maneuverable and adaptable robot capable of navigating a variety of terrains and environments.

In addition to its obvious space exploration applications, its ability to land and deposit payloads at essentially any desired site enables NASA to build and effectively service a lunar outpost where astronauts can live and work for extended periods of time.

As part of JPL's summer internship program, a fortunate group of students had the opportunity to be involved in various aspects of this groundbreaking work. In one project, students helped develop a set of tools to assist ATHLETE in performing a number of complex functions. One such tool was a gripper, a device used to capture and manipulate objects, such as cylindrical pipes and rods meant for construction purposes. In place of a common "pinching" mechanism, the under-actuated gripper relies upon a single rotary input to operate three independently rotating linkages that operate much like human fingers. This spring-loaded, multi-linked system provides ample dexterity for a broad range of operations. When asked about his work on ATHLETE, Nikhil Jain replied, "There are very few places where one can work on such high-tech and unique equipment. This experience really focused my interests on robotics and mechatronics."

ATHLETE was also tested for its ability to traverse long distances and navigate various terrains. Students created command sequences that allowed ATHLETE to safely and efficiently step over large obstacles, such as a cattle fence, during a trek through the Arizona desert, while keeping its cargo pallet level. In another phase of field-testing, a separate team of students created a covered cage for each of the ATHLETE's pairs of legs to house computers and other wiring that require protection from severe weather conditions. Yet another study focused on updating the design of the ATHLETE pallet, which not only serves as a docking station for each of its rovers but also functions as a battery recharger. In this project, students designed the pallet to specs and simulated various loading scenarios. In addition, automated motorized jack-stands were constructed that are used to lift and level ATHLETE's cargo pallet.

Although the advances being made in robotic space exploration may sound like science fiction, at JPL, this science is for real. ■




# One Student's Quest to Make Sense Out of Chaos

**JPL Project Leader:** Martin Lo
**University Advisor:** Professor Gerald Hintz

**Student Partnership:** Pedro Llanos, University of Southern California

Scientists at JPL are working on strategies to better predict solar storms. Current methods provide only one hour's warning of such storms, leaving valuable power and communications infrastructure vulnerable to damage or destruction. One idea for predicting solar storms a week ahead is to send a spacecraft to orbit the Sun–Earth $L_5$ Lagrange point — one of the locations in space where gravitational forces and the orbital motion of a body balance each other. The same mathematical tool used to design the space mission, called dynamical systems theory — more commonly known as "chaos theory" — can also help scientists unravel the mysteries of highly complex galactic movements and structures using universal mathematical principles.

As part of this research, Pedro Llanos, a PhD candidate from the University of Southern California, advised by Prof. Gerald Hintz, collaborated with JPL scientist Martin Lo utilizing a direct planar N-body simulation to gain a better understanding of how galaxies are intrinsically structured and how their morphological features correlate to their location within the galaxy. The simulated galaxies demonstrated how the transferral of matter from the central disc of the galaxy to the co-rotating zone results in the formation of spiral arms, which, because of the torque differential between its inner and outer arms, morphs into still different features, such as bars, rings and spurs. "During my work at JPL, I not only developed software that I will be using in my PhD thesis, but I also acquired key technical skills that will enrich my career in astronautical engineering," said Pedro. "It's exciting to know that my work will make a lasting impact in better understanding the many unsolved questions about galactic dynamics and globular clusters."

Applying mathematical principles, like chaos theory, scientists can better understand the more enigmatic energy forces at work throughout the Universe, helping predict everything from structures of galaxies far, far away to weather patterns and climate change here on Earth. ■

Left to right: James Miller, Martin Lo, Gerald Hintz, Pedro Llanos, and Channing Chow.

# Students Take Propulsion Concepts for Space Travel Up, Up, and Away

**JPL Project Leaders:** Richard Hofer, Ira Katz

**Student Partnership:** Ken Gmerek, University of Michigan; Daniel White, MIT

JPL's Electric Propulsion Group (EP) is developing new technologies to power up exciting advancements in space transportation and exploration. This group identifies and evaluates the feasibility of advanced propulsion concepts involved in space transportation, with the ultimate goal of extending human presence throughout the Solar System. Undergraduate and graduate students have the opportunity to perform basic and applied research through experimental and numerical investigations that can have real-world applications, allowing science to reach higher and go farther.

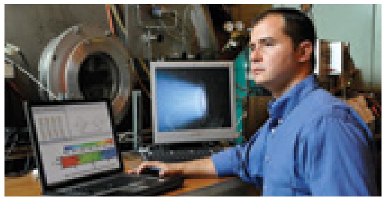
Ken Gmerek, an undergraduate student from the University of Michigan, gained experience working with the Pulsed Plasma Lubricator (PPL), a device designed and developed by his mentor, Richard Hofer. Using this thruster-derived technology, Ken designed, fabricated, instrumented and executed an experiment to assess the lifetime of lubricating films deposited by the PPL on a mechanical assembly. Examining in situ lubrication of a working mechanism in a Martian environment, this experiment demonstrated how thin-films deposited by the PPL provide lubrication and wear resistance equal to, or exceeding, that of films applied using commercial dry lubricants. His results indicated that PPL technology developed for flight could greatly extend the lifetime of mechanical assemblies. This technology has both terrestrial and extraterrestrial applications for future NASA lunar and Martian missions.

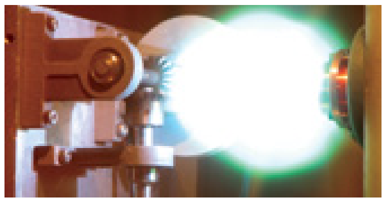
In another project, Dan White, a graduate student from the Massachusetts Institute of Technology (MIT), utilized ion optics codes, developed by his mentor Ira Katz, to study the erosion characteristics of ion thrusters operating at several hundred kilowatts and specific impulses in excess of 50,000 seconds. The code was modified to simulate the flow of ions through the accelerating grids of four-grid ion thrusters, demonstrating that lifetimes exceeding 100,000 hours are, in fact, achievable. This could someday lead to propulsion systems that allow humanity to venture outside our own Solar System.

The work of these students and the EP Group will surely enhance our ability to discover distant worlds throughout our Solar System and beyond. ■

"Through my work at JPL, I now have the confidence that I can be a successful engineer in the aerospace industry. Networking with both JPL employees and students from other universities was also an invaluable experience."

**Ken Gmerek**
**University of Michigan**





Above: Graduate student Dan White used JPL ion optics codes to predict the lifetime of ion thrusters operating at extremely high specific impulse (50,000 seconds).

Below: The Pulsed Plasma Lubricator (PPL) in operation for an experiment to characterize the lifetime of lubricating films deposited by the PPL on a mechanical assembly.


Ken Gmerek (right) worked with the PPL on a lubrication experiment to test lifetimes of mechanical assemblies.

Left to right: Kevin Chou, Ryan Clegg, Ethan Sox, Charles Galey, David Austerberry, Danielle DeLatte, Nathan Butler, Natalie Accardo, Payam Banazadeh, Fernando Saca, Mary Knapp, Alessandra Babuscia, Laurence Bodek, and Gary Marx of the MoonRise team.

# Bright Minds Explore the Far Side of the Moon

**JPL Sponsor and MoonRise Capture Lead:** Leon Alkalai
**JPL Project Leader:** Brian C. Schratz
**Guest Faculty:** Kourosh Rahnamai, Western New England College

**Student Team Members:** Danielle DeLatte, MIT; Mary Knapp, MIT; Natalie Accardo, Washington University; David Austerberry, Creighton University; Alessandra Babuscia, MIT; Payam Banazadeh, University of Texas at Austin; Laurence Bodek, Western New England College; Nathan Butler, Pennsylvania State University; Kevin Chou, MIT; Ryan Clegg, Washington University; Charles Galey, University of Wyoming; Jeremy Klein, Washington University; Gary Marx, University of Michigan; Fernando Saca, University of Michigan; Ethan Sox, La Cañada High School

Members of the MoonRise team gather after their final summer presentation at JPL.

Just, exactly, how many impacts does the Moon experience? Fifteen students from around the country — high-schoolers through graduate-level students — spent a summer internship at JPL developing an innovative concept for a Student Collaboration Project to help answer that question. That concept was included as part of a proposed JPL mission, named MoonRise, which was one of three finalist projects competing for an opportunity to qualify for NASA's New Frontiers Program, which would explore the far side of the Moon in hopes of unlocking secrets of the early history of the Moon and the Solar System.

Although not selected for this round of New Frontiers missions, MoonRise would have scrutinized the age of the South Pole Aitken (SPA) Basin, the oldest and largest impact basin on the Moon. The mission planned to gather samples from the Basin and return them to Earth for detailed analysis, which would open a window into the history of the early development of the Moon, as well as into our Solar System planetary formation.

Receiving several crash courses in lunar science and spacecraft design, the team of students worked alongside MoonRise scientists and engineers, bringing their own unique interests, specialties and backgrounds. They were, intentionally, given few constraints. The end result of this diverse and collaborative effort was IRIS (Impact Recording and Imaging System). It would have been implemented aboard MoonRise's communications satellite, which would orbit the Moon and relay critical data between Earth and the project's lunar lander. To characterize the lunar impact environment, IRIS planned to use two imagers to monitor in real time the luminosity of impact flashes from meteorites, asteroid break-ups and other solar system events that cause debris to collide with the Moon's surface. The measurement of flash luminosity allows for the determination of impactor mass, velocity and seismologic properties to yield additional insight into the impact hazard for the Earth-Moon system and for future planning for long-term lunar habitats.

MoonRise leveraged JPL's long history of hosting teams of summer students to develop novel mission and instrument concepts. And, for the first time, the students' work was included in the formulation phase of a JPL mission, reflecting the ultimate goal of involving students in all facets of a project — from formulation to design, from construction to integration, from testing to operation. The development of IRIS is yet another example of JPL's and NASA's commitment to giving students hands-on experience in the development of space-based missions that return scientific progress while inspiring new generations of scientists and engineers, as they lay claim to the next frontier of discovery. ■

"JPL is so rich in concepts and experience that it greatly helps you develop your own unique ideas. My inside look at how space missions come together will help me as I design small satellite missions in my graduate work."

Mary Knapp, MIT

Left to right: Mary Knapp and Danielle DeLatte.

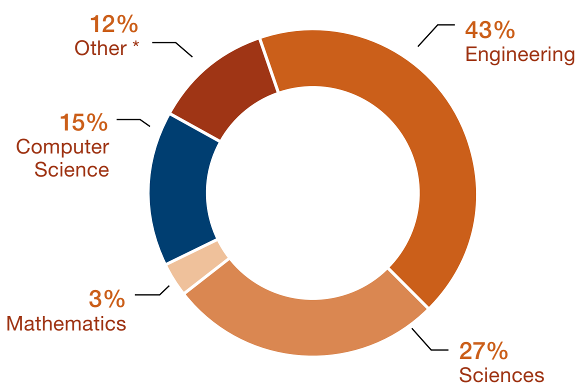
# Data & Demographics

## JPL hosts several hundred students every year through a variety of programs managed by the Education Office, Human Resources or the Office of the Chief Scientist.

Opportunities at JPL are offered through a wide range of student programs, sponsored by NASA, JPL and Caltech. These programs are geared to students who are interested in the fields of science, technology, engineering and mathematics (STEM). Students accepted into all of our programs come to JPL to conduct research projects and work closely with scientists and engineers. The main goal of these programs, depending on a student's level, is to introduce students to, or further their pursuit of, careers in fields that involve science and engineering.

### 2010 Summer Research Internships Organized by Academic Pursuit (%)

Every summer, the JPL campus is bustling with a vibrant student population representing a healthy range of academic disciplines.

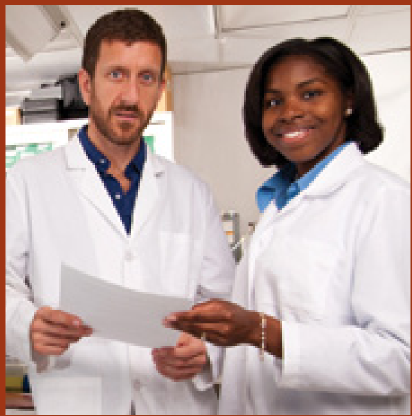



** Other represents a wide scope of disciplines including but not limited to communications, business and design.*

**The following universities have the strongest undergraduate and graduate student participation in JPL's student programs:**

Arizona State University*
University of Arizona*
University of Arkansas
Boston University
Brigham Young University
Brown University
California Institute of Technology
University of California*
California Polytechnic State University
California State University
University of Southern California*
Carnegie Mellon University*
University of Colorado
Colorado State University
Columbia University
Cornell University
Dartmouth College*
Embry-Riddle Aeronautical University
University of Florida
Georgia Institute of Technology
Harvard University
Iowa State University
University of Idaho
Louisiana State University
University of Maryland
Massachusetts Institute of Technology*
University of Michigan*
Montana State University
Northeastern University
Ohio State University
Penn State University
Princeton University*
Purdue University
Rensselaer Polytechnic Institute
Regis University
Rutgers State University of New Jersey
Stanford University*
University of Tennessee
University of Texas
Tufts University
Washington University in St. Louis
University of Washington
University of Wisconsin
Yale University

** Has a formal strategic relationship with JPL with major commitments to space exploration.*



## Supporting Diversity in Our Student Population

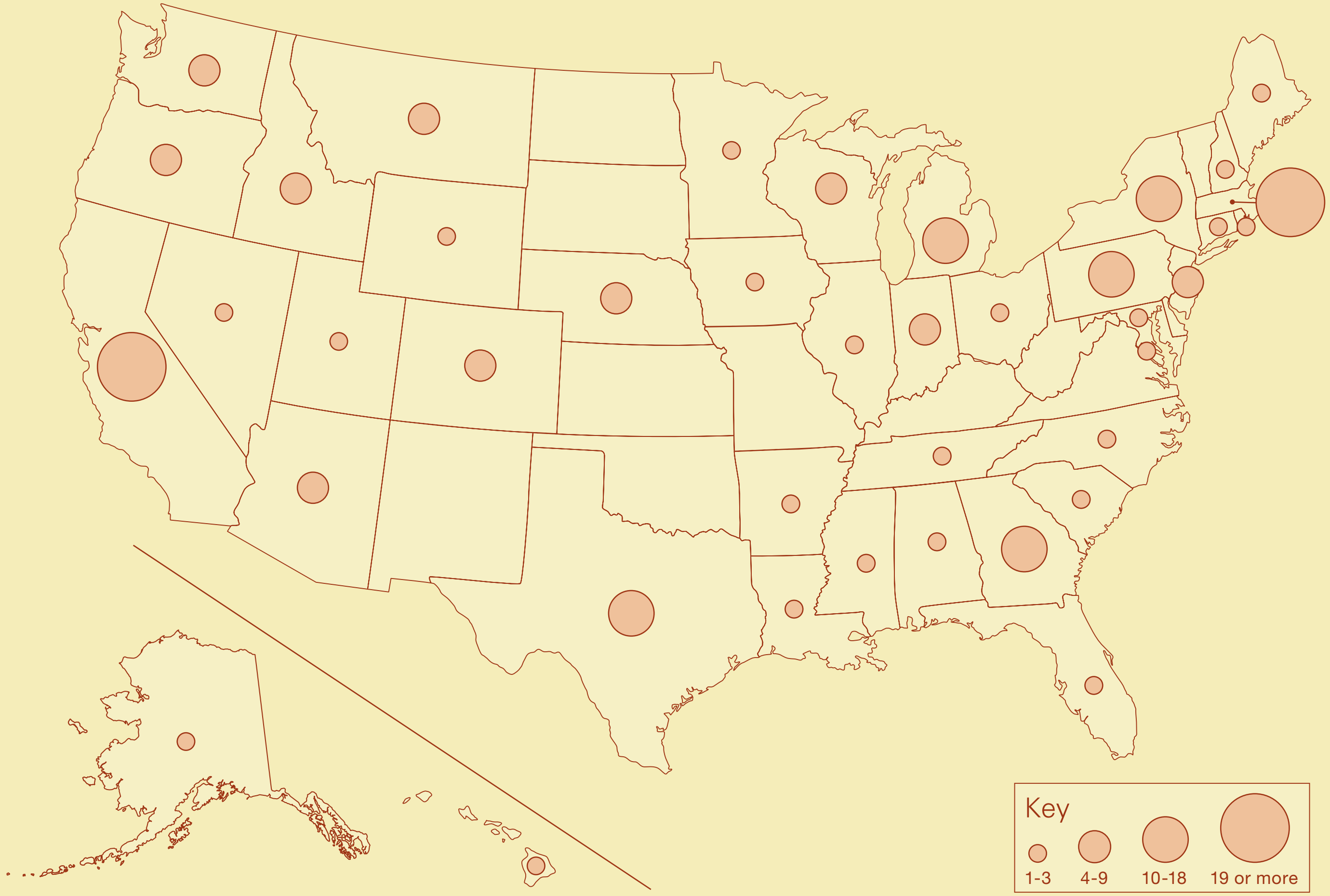
JPL hosts numerous programs designed to increase the awareness, knowledge and participation of underrepresented and underserved groups in science, technology, engineering and mathematics disciplines and careers.

**List of Programs**

- Achieving Competence in Computing, Engineering and Space Science Program (ACCESS)
- The Motivating Undergraduates in Science and Technology Program (MUST)
- Curriculum Improvement Partnerships Award for the Integration of Research
- Minority Initiatives Internship Program
- MURF Undergraduate Research Fellowships
- NASA Harriet Jenkins Pre doctoral Fellowship Project

***To learn more, please visit www.jpl.nasa.gov/education/highereducation/***

In the summer of 2010 alone JPL has worked with about 380 students from most states throughout the United States. JPL is also proud to host students from other nations.



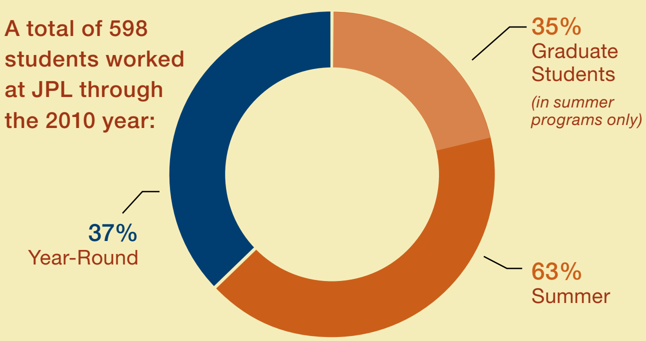

## Postdocs at a Glance

**As of July 2011, currently active postdocs are involved in the following studies at JPL:**

| | |
|---|---|
| Planetary science | 15 |
| Earth science | 41 |
| Astrophysics and space science | 28 |
| Exploration systems | 6 |
| Observation systems | 15 |
| **Total active postdocs** | **105** |

## Students at a Glance

**A total of 598 students worked at JPL through the 2010 year:**



# Student Partnership and Employment Opportunities at JPL

A number of portals are available for students to explore collaborative research programs, internships, employment and other opportunities at JPL and NASA.

Postdoctoral fellows Morgan Cable (left) and Fernanda Mora (right) are helping to develop lab on a chip technologies at JPLs Microdevices Laboratory.

**Education Office Internship and Fellowship Programs**
The Education Office handles internships and fellowships programs sponsored by a variety of colleges, universities and NASA. These programs are open to high-school, undergraduate and graduate students who are interested in engineering, science, mathematics and technology and want to spend a summer or part of the academic year at JPL. All programs have application deadlines and eligibility requirements.

*For details, please visit* ***jpl.nasa.gov/education/internships***

**Employment Opportunities through JPL's Human Resources**
The Human Resources department handles employment programs for students, with opportunities available year-round. These students are employees who have been hired to perform specific jobs, which provide an opportunity to gain experience working side by side with JPL technical and administrative staff.

*For current openings, please visit*
***careerlaunch.jpl.nasa.gov/ci20/index.jsp?applicationName=jplCA***

**JPL's Director Research and Development Fund (DRDF)**
This program provides opportunities for collaborative research with universities and other external organizations, and welcomes student participation. Specifically, the Strategic University Research Partnership (SURP) is a subset of DRDF that focuses on ten strategic universities with whom JPL has established a sustained collaborative program through a memorandum of understanding. As part of the collaboration, JPL supports classes teaching a number of disciplines relevant to space engineering and

Mount Wilson Observatory is open to JPL for reseach.
*Image courtesy Dave Jurasevich.*

science. DRDF and SURP awards are made through an annual call for proposals, prepared jointly by JPL researchers and academic faculty. Both programs support student involvement in research, performed either at their home institution or at JPL.

*Information on the programs can be found at* ***drdf.jpl.nasa.gov*** *and* ***surp.jpl.nasa.gov***

*For information on the array of research disciplines available at JPL, please visit* ***scienceandtechnology.jpl.nasa.gov***

### NASA Office of the Chief Technologist

The newly created NASA Office of the Chief Technologist offers research grants available to graduate students interested in space technology in support of the future space science and exploration needs of NASA. As part of the award, students will have the opportunity to spend some time at NASA Centers and the Jet Propulsion Laboratory.

*More information can be found at* ***nasa.gov/offices/oct/early_stage_innovation/grants/index.html***

### The Center for Academic Partnerships (CAP)

CAP provides seed funding to catalyze academic collaborations through visits by faculty and/or students at JPL to become familiar with our environment and opportunities. In addition to short-term visits, CAP supports student internships of ten weeks duration available throughout the year.

### The JIFRESSE Joint Institute

This collaboration between JPL and UCLA focuses on climate research, and provides the opportunity for UCLA students to participate in joint research involving faculty and JPL researchers affiliated with JIFRESSE. As a part of the collaboration, UCLA students have access to JPL's facilities and personnel to enrich their curricula and gain experience with satellite data and other space-based assets.

*For additional information, visit* ***jifresse.ucla.edu***

### Postdoctoral Research

JPL hosts a number of postdoctoral programs, allowing recent graduates to spend a maximum of three years working with our community on independent research projects. You can be a postdoc at JPL primarily through the NASA Postdoctoral Program (NPP), the Caltech Postdoctoral Scholar Program and the JPL Postdoctoral Associate Program. Additionally, we host candidates from other programs including Spitzer, Sagan and Einstein Fellows.

*For information about these programs, please visit*
*NASA (NPP):* ***nasa.orau.org/postdoc/potential/appinfo.htm***
*Caltech:* ***postdocs.jpl.nasa.gov/programs/caltech, and***
*JPL:* ***postdoc.jpl.nasa.gov/programs/jpl***

### Additional Opportunities

Above and beyond the programs listed above, a number of informal opportunities are available to students whose faculty have received a grant from a NASA Research and Analysis program that has a JPL co-investigator. In many instances, those collaborations naturally lead to the possibility for the students to spend some time at JPL working directly with the JPL collaborators, adding a new perspective to the students' academic research by opening a window into our environment. ■

Students Zachary Ousnamer (left) and Nikhil Jain (right) help take JPLs ATHLETE out for a test run.

This spread: Aerial view of the JPL campus.

National Aeronautics and Space Administration

**Jet Propulsion Laboratory**
California Institute of Technology
Pasadena, California

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