ANNUAL REPORT 2012

SPACE SCIENCE INSTITUTE

Space Science Institute . 4750 Walnut Street . Suite 205 . Boulder, Colorado 80301 . 720.974.5888 . www.spacescience.org

OUR MISSION

The Space Science Institute addresses 21st Century challenges by advancing scientific understanding of Earth and the Universe; engaging the public in science-technology learning opportunities; and inspiring youth to pursue science-technology careers.

MESSAGE FROM THE DIRECTOR

Inspire. Explore. Discover. These words describe our efforts in both scientific research and education. In fact, they define the essence of our mission: to integrate world-class research with an innovative education program within a single institution. The SSI Board of Directors, with its experience in a range of business, science, and educational areas, provides guidance and vision to our enterprise. SSI's creative environment, flexibility and reputation draw world-class scientists to the Institute. Cooperation between SSI's scientists and educators enables us to develop education and outreach programs with strong, forefront science content that reach people worldwide through hands-on museum and public library exhibitions and digital learning programs on the internet. SSI's 2012 revenues were $5.9M.

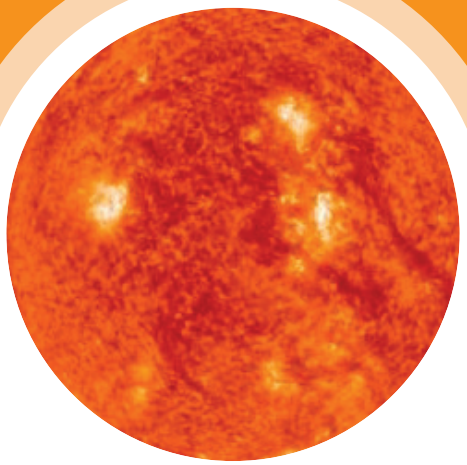
SSI's scientific Research Branch (Director, Dr. Michael Wolff) includes scientists participating in robotic missions such as the Mars Science Lander, Mars Exploration Rovers, and in-flight missions such as Hubble, NuSTAR, Fermi and SOFIA. They are also involved in ground-based observation programs using national and international facilities such as the observatories on Mauna Kea, Hawaii and the high plains of the Atacama desert in Chile. The science we do reaches beyond our own Solar System, from exoplanets around other stars to dark energy and the fate of the universe. Eleven new researchers joined the Research Branch last year. Our research staff competed successfully for 24 new grants and contracts, totaling over $4 million dollars, in 2012.

SSI's Flight Operations Branch (Director, Dr. Carolyn Porco) is home to the Cassini Imaging Central Laboratory for Operations (CICLOPS), the center for uplink and downlink operations for the imaging science experiment on the Cassini mission to Saturn. Cassini's landmark exploration of the ringed planet, its mysterious moons, stunning rings, and complex magnetic environment has been an enormous and highly visible scientific success. CICLOPS team members and the Cassini mission scientists and engineers are halfway through execution of the seven-year Cassini Solstice Mission which will end in 2017.

SSI's *National Center for Interactive Learning* (Director, Dr. Paul Dusenbery) is organized around five interconnected groups: 1) Exhibition Development, 2) Digital Learning, 3) Professional Development, 4) Community Outreach, and 5) Learning Research and Evaluation. The national traveling exhibition *Great Balls of Fire: Comets, Asteroids, and Meteors* (supported by NSF and NASA) is on tour. The *Discover Tech: Engineers Make A World Of Difference* library exhibit (part of the NSF-funded STAR_Net project) opened in the Fall at the Louisville Public Library in Colorado. Over 300 members have joined STAR_Net's online community. As this report was being prepared, a spectacular meteor landed in Chelyabinsk, Russia on February 15, 2013, resulting in a 30-fold increase in visitors to NCIL's website, www.killerasteroids.org.

In 2012, SSI began to develop a new 2013-2016 Strategic Vision and Operations Plan, based on recommendations by development consultants retained by the Board in 2011. The new plans reflect the internal and external factors that impact our development and fundraising efforts. They include both short-term and long-term objectives, strategies, and revenue/expense projections. Our headquarters location in Boulder, Colorado, enables us to maintain strong collaborations with a number of the major players in the research, education, and aerospace industries, including the University of Colorado, NOAA's Space Weather Prediction Center, National Center for Atmospheric Research, Lockheed Martin, and Ball Aerospace. However, our impact goes far beyond Colorado. We seek and encourage strong ties to corporations, foundations, and institutions nationwide. Come join our voyage of discovery.

Paul B. Dusenbery, Ph.D. - Executive Director



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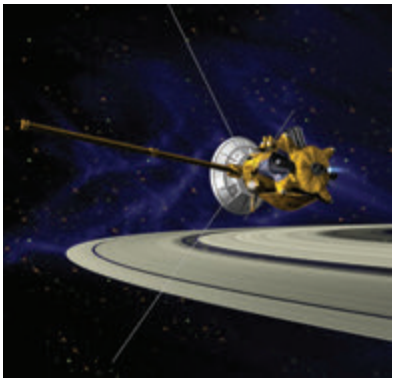
FLIGHT OPS



NCIL

The Space Science Institute (SSI) is a nonprofit, public benefit 501(c)(3) corporation founded in 1992. SSI has five major branches: Research, Cassini Flight Operations, National Center for Interactive Learning, Business Operations, and Information Systems and Technology (IST). SSI is on the leading edge of creating affordable, efficient, and far-reaching models for earth and space science research and science, technology, engineering, and mathematics (STEM) education. In the coming years, our potential to make science accessible to large numbers of people, including underserved communities, is enormous. The key to our approach is that we offer the full continuum of discovery and education – we conduct world-class scientific research and we make it accessible to a broad population.

Humans are driven to explore. We are inspired by fundamental questions: Are we alone? Could we live on other planets? Will the universe expand forever? Few things capture our imaginations more than the mysteries of space. Society benefits from the pursuit of new knowledge: the search for life beyond Earth begins with understanding how our own planet works. The excitement of earth and space science offers a compelling hook for engaging the public in science and inspiring a new generation of innovators.

SSI is responding to a crisis in research, public science literacy, and STEM education.

Discovery and invention are the keys to a healthy and prosperous future and space science has a critical role to

Cover Image :: *Giant Worlds: A Voyage to the Outer Solar System exhibition in Orlando, FL. Credit: NCIL*
Inside Cover Image :: *Horsehead Nebula. Credit: JPL/NASA, NOAO, ESA & The Hubble Heritage Team, (STScI/AURA)*
Image Page 34 :: *The giant star Zeta Ophiuchi. Credit: NASA/JPL-Caltech*

play. The future of science and engineering in the United States depends heavily on:

- A strong research infrastructure.
- A scientifically literate populace that supports investment in research.
- A pipeline of future research scientists and engineers.

Today, all three are at risk. Traditional research institutions and public universities are struggling under the pressures of a poor economy and ageing research facilities. The public's overall science literacy is shockingly low. Over half of American adults do not know how long it takes Earth to go around the Sun. In 2011, our children ranked 32nd out of 65 countries in mathematics, and only 32% of American high school graduates were proficient in mathematics. Universities are graduating more visual arts and performing arts majors than engineers. In short, we are no longer leading other nations; instead, we are falling behind them.

We INSPIRE

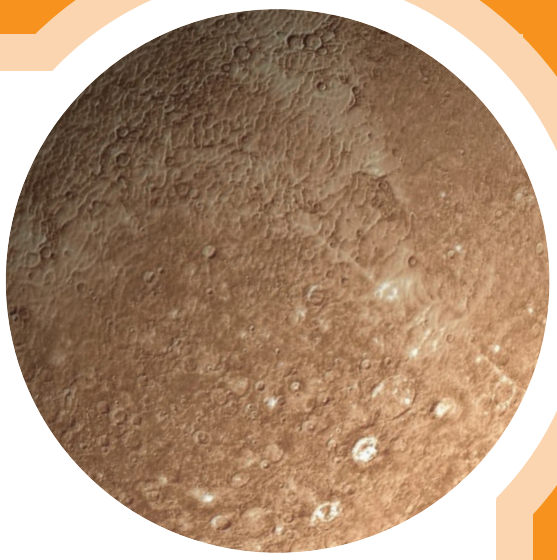
SSI is in the "inspiration" business. Astronomy and space physics are "gateway" sciences. The impact of our research and education programs is increased access to STEM learning for an audience that is cross-generational and often underserved. We don't know who will be inspired to be a scientist, engineer, flight operations specialist, or maybe just a person who is interested in STEM topics. What we do know is that our programs have the potential to ignite their curiosity and inspire them to learn more about the world around them.

We DISCOVER

In today's marketplace of ideas, SSI has been a pioneer in remote employment, a mode that has been particularly conducive to supporting researchers and, in turn, promoting discovery. In this environment, our science thrives. Scientists in our Research Branch are participating in robotic missions to Mars and Saturn and in space observatory missions such as Kepler and Hubble. Our Flight Operations Branch is home to the Cassini Imaging Central Laboratory for OperationS (CICLOPS). Led by Cassini Imaging Team leader Dr. Carolyn Porco, fourteen scientists from the United States and Europe are deepening our knowledge about Saturn and the processes by which planets – and whole planetary systems – form and develop. In 2012, SSI formed two new centers. The mission of the *Center for Space Plasma Physics* (CSPP) is to carry out scientific research that will increase our understanding of fundamental and applied aspects of space plasmas. The mission of the *Center for Extrasolar Planetary Systems* (CEPS) is to capitalize on the need to combine multiple fields of study in order to carry out scientific research that characterizes the fundamental properties of extrasolar planets and the systems in which they are found.

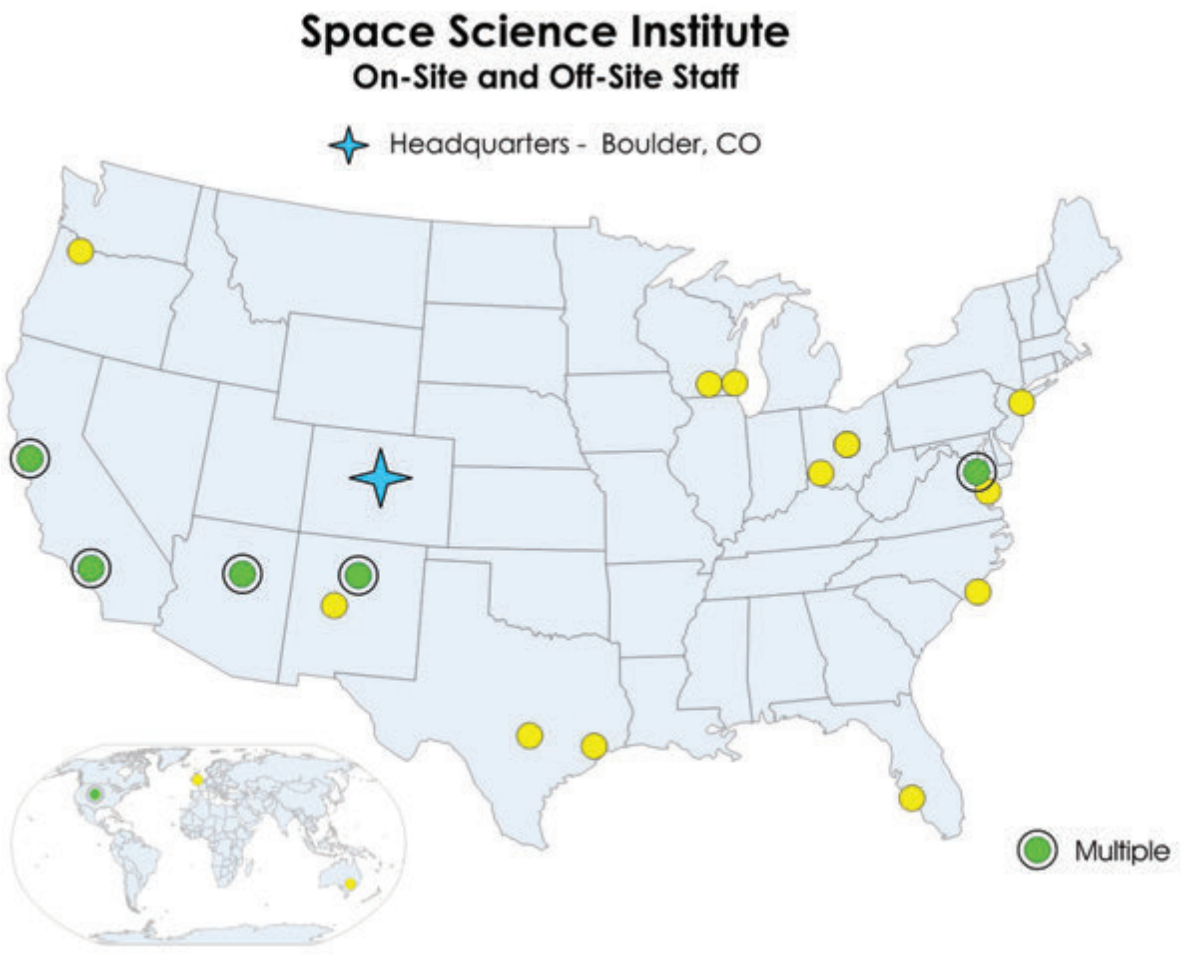
We EDUCATE

Providing high quality STEM learning opportunities for all Americans is essential to creating an educated citizenry who understand the complex issues confronting our nation and the world. STEM professions and the pipelines that produce those professionals lack ethnic diversity, even as the nation is undergoing a significant demographic shift. SSI's *National Center for Interactive Learning* is leading the way for a new generation of STEM education platforms that will make science accessible to new audiences. We foster collaboration between scientists and educators to bring the wonder of discovery directly to people wherever they are. We bridge the worlds of public schools, libraries, museums, and the Internet. Our programs span a range of audience needs and delivery methods, including traveling museum and library exhibitions; award-winning educational films, videos, and websites; hands-on teaching resources and activities; and educator workshops. We are now tapping into the enormous popularity of Facebook games to teach a large and diverse audience about the evolution of stars and planets. A simultaneous research and evaluation program will examine both the effectiveness of this game as a learning tool



as well as the broader potential of this gaming approach for the educational community.

The map below shows where SSI employees are located in the United States, Europe and Australia.

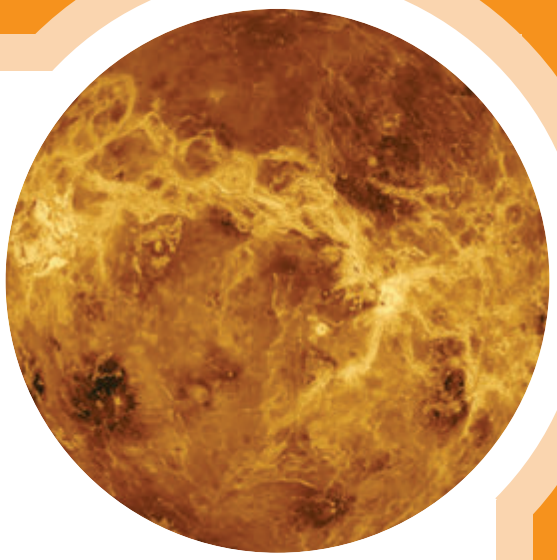


Board Member Dick Green Is Honored with a Primetime Emmy Engineering Award

Former CableLabs president and CEO Dick Green, was among the recipients of the Academy of Television Arts & Sciences' 64th Primetime Emmy Engineering Awards. Green, who headed CableLabs from its inception in May 1988 until his retirement in 2009, was the recipient of the *Charles F. Jenkins Lifetime Achievement Award*, which honors "a living individual whose ongoing contributions have significantly affected the state of television technology and engineering," ATAS said. In announcing the award, ATAS noted that Green "guided the cable industry through the transition from its analog roots to the broadband architectures of today, stressing interoperability and standardization across a broad range of operators and suppliers."

2012 Board Members:

Dr. Paul Dusenbery (Chair), Executive Director, Space Science Institute
Dr. Dick Green, Former President and Chief Executive Officer, CableLabs, Inc.
Dr. Marilyn Johnson, Science Director, Oregon Museum of Science and Industry
Dr. Steve Jolly, Systems Engineering Director, Lockheed Martin Corporation
Mr. Mark Eggleston (Treasurer), Vice President of Finance, CableLabs, Inc.
Dr. Bill Purcell (Secretary), Senior Manager Advanced Systems, Ball Aerospace & Technologies Corporation
Ms. Maddie Zeigler, Education Consultant



SSI also wishes to thank the generous individuals and corporations who contributed to the Space Science Institute in 2012:

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Mark and Barbara Eggleston
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Drs. Marilyn Johnson and Edward Epp
Dr. Steve and Bonnie Jolly
William and Bernadette Purcell

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California Institute of Technology
Cornell University
Ideum
Institute for Learning Innovation
Jet Propulsion Laboratory/NASA
Museum of Science, Boston
NASA
National Science Foundation
Planetary Science Institute
SETI
Science Systems & Applications, Inc.
Smithsonian Astrophysical Observatory
Southwest Research Institute
Space Telescope Science Institute
UCLA
USRA
University of Arizona
University of Southern California
University of Maryland
University of Wisconsin

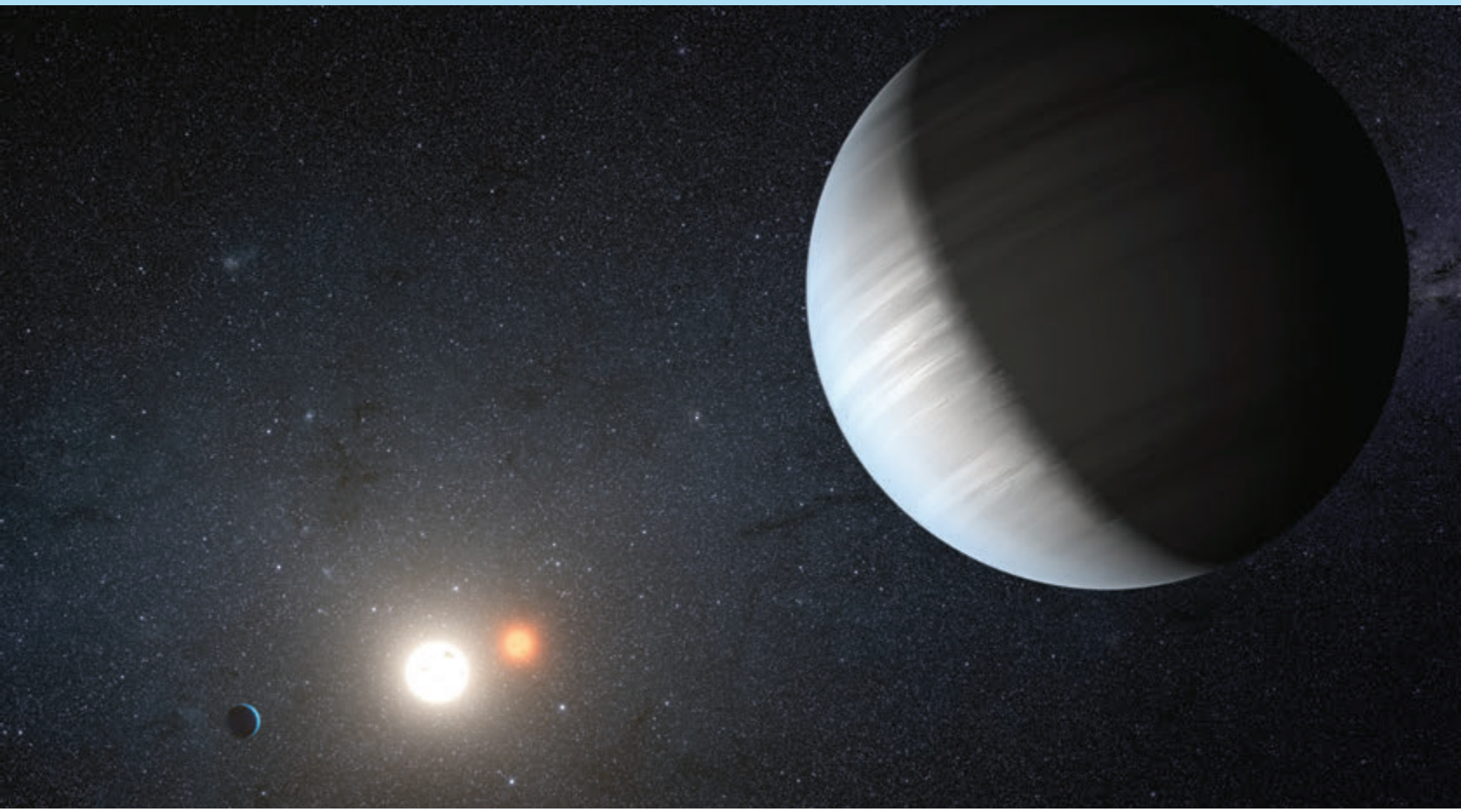
RESEARCH

SSI's Research Branch scientists investigate physical phenomena in a broad range of space science fields: earth science, space physics, planetary science, exoplanetary science, and astrophysics. SSI researchers study the processes on Earth's surface, on the Sun and in the solar wind through its interaction with Earth's magnetosphere. Scientists seek to understand the origin and evolution of comets and asteroids whose collisions with other bodies may have profound effects on life on Earth. Observational and theoretical work probes the atmospheres and surfaces of other bodies in our Solar System, such as Saturn, Jupiter and their moons. A prime goal of researchers is to understand how stars and their planetary systems form, especially now that astronomers have found hundreds of exoplanets orbiting other stars. Researchers also study our own Milky Way Galaxy and other, more distant galaxies that contain massive black holes in their centers.

Below :: *The Aurora Borealis, or Northern Lights, shines above Bear Lake, Eielson Air Force Base, Alaska. Credit: J. Strang*

SSI researchers use the most technologically advanced and powerful space facilities for their research, for example, Kepler, Herschel, Fermi, NuSTAR, Spitzer and Hubble space telescopes. A new group of six researchers explores space plasmas in our own Solar System. Seven SSI researchers focus on Mars research through active participation and science team membership in the Mars Science Laboratory, the Mars Exploration Rovers, and the Mars Reconnaissance Orbiter missions. An unprecedented "sky crane" landing delivered the Mars Science Laboratory to the Martian surface in August 2012. SSI researchers are involved in the operation and use of the new astrophysical facility SOFIA, an airborne observatory. One SSI researcher is working on

Below :: *This artist's concept illustrates Kepler-47, the first transiting circumbinary system – multiple planets orbiting two suns – 4,900 light-years from Earth, in the constellation Cygnus. Credit: .NASA/JPL-Caltech/T. Pyle*



instrumentation for the James Webb Space Telescope, successor to the Hubble Space Telescope, which will be launched in 2018. Many researchers also use high-altitude facilities such as those on the dormant volcano of Mauna Kea, Hawaii and the Atacama desert of Chile which are above most of the water vapor in Earth's atmosphere.

SSI's researchers support themselves through a mixture of grants and contracts awarded by national organizations, primarily NASA and the NSF through competitive peer review. SSI researchers participate in proposals for space missions and instrument development for new or existing facilities. This entrepreneurial spirit motivates our search for new and creative opportunities at the forefront of scientific research. Our organization and infrastructure facilitate collaborations between individuals in different areas of research (e.g., comets and exoplanets) who might be separated into different departments at academic institutions.

Below :: *The Kepler space telescope follows Earth around the Sun, searching for alien worlds orbiting other stars in our Galaxy. Credit: NASA/Kepler mission/Wendy Stenzel.*

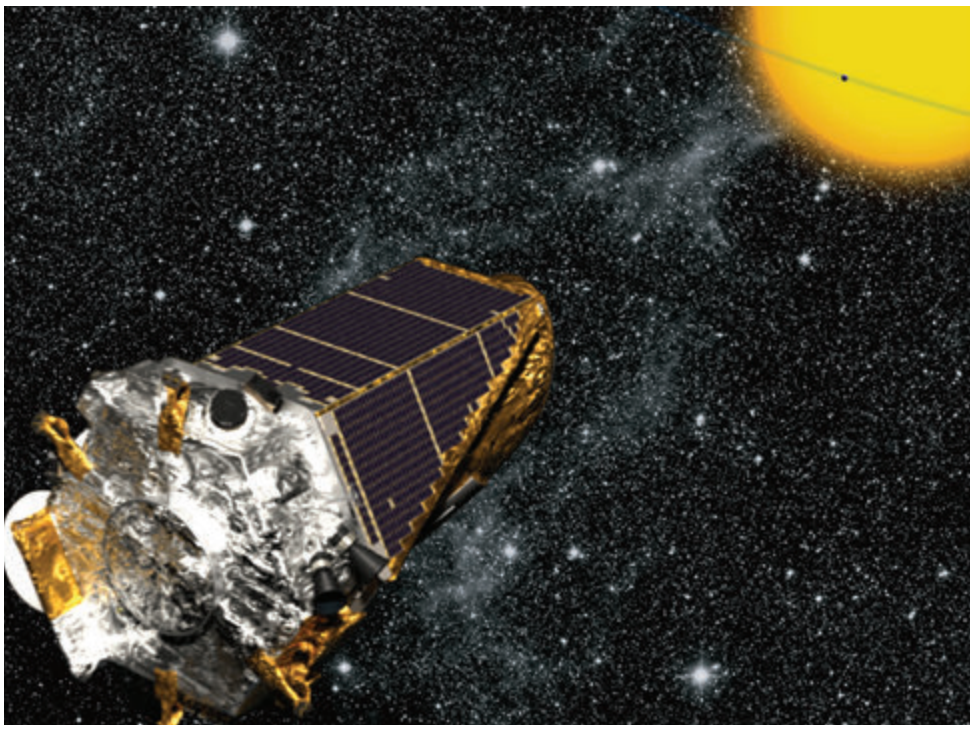
SSI's Off-Site Research Option

For some researchers, the opportunity to conduct scientific research outside the traditional university or research center is ideal. The long-distance nature of much scientific collaboration lends itself well to remote employment. Videoconferencing through their own computers allows scientists to confer with collaborators at remote mountaintop observatories, in the next state, or across the ocean. Access to world-class computing facilities may be obtained by proposal to national supercomputer laboratories. Academic journals and professional proceedings are available electronically through subscriptions, with hot new papers posted daily on the ArXiv preprint server http://www.arxiv.org for immediate public download.

2012 Research Highlights

Characterizing the Parent Stars of Alien Worlds

The past two decades have witnessed accelerating progress on one of the most fundamental questions in astronomy: Are we alone in the Universe? The initial discoveries of planets around distant stars were made using the "wobble method" in the 1990's, where the orbit of the planet induces a reflex motion of the parent star. This technique is most sensitive to massive planets in the smallest orbits. As a result, the earliest discoveries were dominated by "hot Jupiters" which are quite unlike the planets in our Solar System. In the 2000's some alien

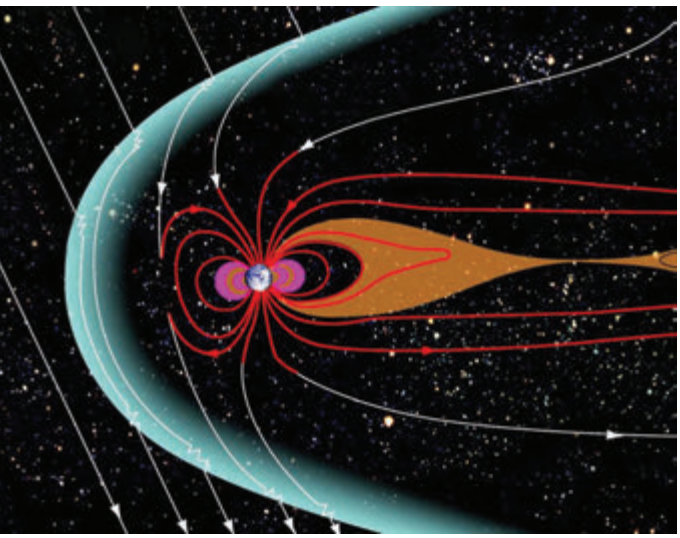


worlds were discovered as they passed directly in front of their parent stars, causing a brief dip in the stellar brightness. This "transit method" determines the size of a planet relative to its parent star. The launch of NASA's Kepler space telescope in 2009 shifted the emphasis of planet hunting from individual discovery to statistics. By monitoring more than 150,000 stars almost continuously for several years, Kepler has discovered 2,740 possible planets around more than 3000 stars, and it is estimated that 80-90% will eventually be validated as genuine planetary detections. The Kepler mission has clearly taught a key lesson: planets are ubiquitous in the Galaxy, with small planets like Earth representing the rule rather than the exception for stars like our Sun.

SSI Research Scientist Travis Metcalfe (Boulder, CO Office) uses observations from the Kepler space telescope to help characterize the parent stars of newly discovered worlds. Boiling motions in the outer layers of stars like the Sun create sound waves that travel deep into the interior and bring information to the surface in the form of periodic brightness variations. Like a giant musical instrument, each star resonates not just with one musical note but with an entire symphony of discrete harmonics across a wide range of frequencies. Just as the human ear can easily distinguish between the sound of a violin and a cello, Kepler uses the brightness variations exhibited by a star to infer its size and basic structure. By passing the signal through the equivalent of a stereo equalizer, it can be separated into its constituent harmonics to reveal more subtle information about the star including composition and age. Kepler has produced these seismic measurements for hundreds of stars, including many that host planetary systems. Metcalfe develops analysis programs for supercomputers, employing artificial intelligence algorithms to determine the properties of Kepler stars and their orbiting planets. He supplements the Kepler data with ground-based observations in order to infer the magnetic activity of the stars, which is another factor in assessing planetary habitability.

Below :: *Schematic of the interaction of the solar wind (blowing from left to right) and Earth's magnetic field that shows the magnetic-field lines of the solar wind becoming connected to Earth. Credit: NASA*

Space Weather: The Connection of Earth and the Solar Wind

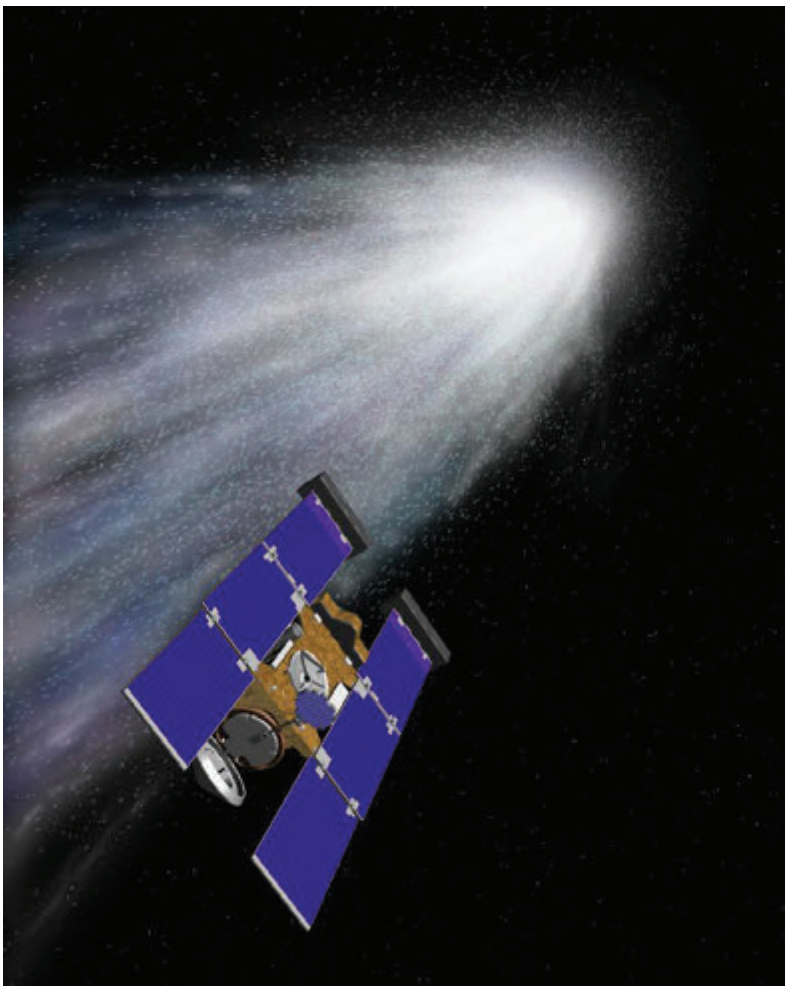


The Sun emits a "wind" of particles that interact with the magnetic field of Earth. This supersonic solar wind compresses Earth's magnetic field on the dayside and draws it out into a long "tail" on the nightside, as seen in the figure to the left. The processes involved also fill this deformed region with very energetic, charged particles known as plasma. An important aspect of the solar-wind interaction is the reconnection of the magnetic fields of the Sun and Earth, both in terms of the energy input and the population of particles. Such details can be very important in understanding how changes in the solar wind, also called "space weather," can affect Earth and its inhabitants. For example, geomagnetic storms are multi-day intervals of intense activity in Earth's magnetosphere that threatens spacecraft assets and power grids, as well as interfering with navigation and communications.

To study the very important interactions between the Sun and Earth, SSI has recently formed the *Center for Space Plasma Physics*. With over 150 collective years of plasma-physics research experience, this 6-member team combines their efforts to study key aspects of Earth's magnetosphere and its interactions of the Sun and the solar wind. Joachim Birn (Los Alamos, NM Office) uses computer simulations and spacecraft measurements to study the important reconnection processes. Athanasios Boudouridis (Boulder, CO Office) analyzes solar-wind weather events to constrain dayside and nightside magnetospheric phenomena. Employing large datasets, Mick Denton (Manchester, UK Office) constructs conceptual pictures of the magnetospheric behavior during geomagnetic storms. The connection of these space storms to Earth's magnetosphere is further examined by Joe Borovsky (Los Alamos, NM Office), whose work focuses on the feedback of the trapped charged particles onto the coupling with the solar wind. Understanding the properties and the evolution of the solar wind as it moves from the Sun to Earth is also a very important piece of the puzzle. John Podesta (Fort Myers, FL Office) studies solar wind turbulence with state-of-the-art mathematical models. Peter Gary (Los Alamos, NM Office) characterizes the internal dynamics of the solar wind in an effort to understand the energy budget of the critical solar wind-Earth interactions.

Exploring a Cometary Mystery with Polarized Light

When the Stardust mission retrieved particles from comet Wild 2 and returned them to Earth embedded in aerogel, researchers got quite a surprise. The carbon-containing particles that had been seen in every other mission and sample-retrieval campaign, from measurements of comet Halley to interplanetary dust particles collected in the upper atmosphere and Antarctic snow, were not present in the expected numbers. In contrast, during the comet Wild 2 flyby, a large amount of carbonaceous matter was found in all 29 particles analyzed by another instrument also onboard the spacecraft, the Cometary and Interstallar Dust Analyzer mass spectrometer. Most of those particles were found at distances far from the nucleus. One clue to this "mystery of the missing carbon" may be obtained with polarized light images of the comet. The polarized light characteristics depend on particle composition and morphology. With polarized light images of the cometary coma, we see that different regions of the coma have different levels of polarization. To produce such polarization differences, the inner regions must contain different material properties from the jets and outer regions of the coma.



SSI Researcher Gorden Videen (Silver Spring, MD Office) has modeled the interaction of light with highly irregular agglomerated debris particles,

Above :: *Artist's impression of the Stardust spacecraft encountering comet Wild 2. Captured particles embedded in aerogel were returned to Earth in a capsule for analysis in laboratories. Credit: NASA*

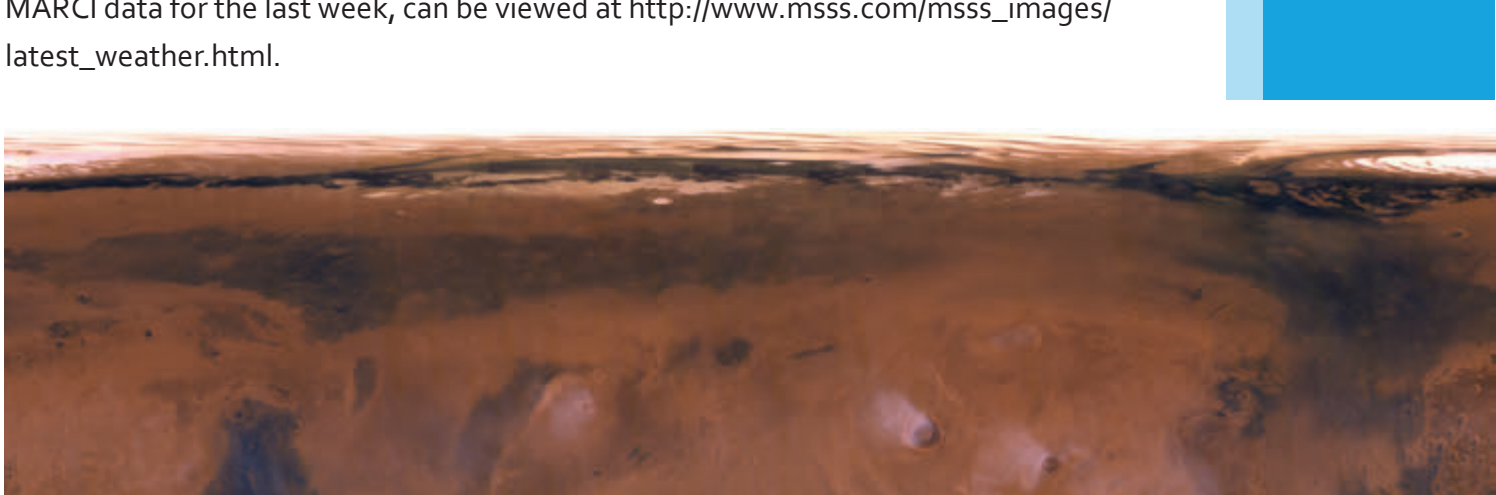
representing realistic cometary particles, in order to explain the observed polarization differences. Particles having sizes comparable to the wavelength of optical light must dominate the signal. Moreover, these particles do not strongly absorb visible light, indicating that they do not contain significant amounts of carbon. Gorden Videen's results are consistent with both the carbon-depletion of particles returned to Earth by the Stardust mission and the carbon-richness of particles measured by the onboard Cometary and Interstellar Dust Analyzer mass spectrometer. The physical mechanisms that remove the carbonaceous particles near the nucleus are not understood. Evidence suggests that this depletion of carbon-bearing particles may be caused by near-surface processes directly stimulated by sunlight or through long-term settling of particles within the coma. Because carbon-rich particles absorb light more than carbon-depleted particles, the resulting variation in radiation pressures may cause differentiation. Ultimately, the combination of modeling and observations may provide clues to the origin of dust particles in the cometary coma.

Connecting Dust, Wind, and Past Climates on Mars

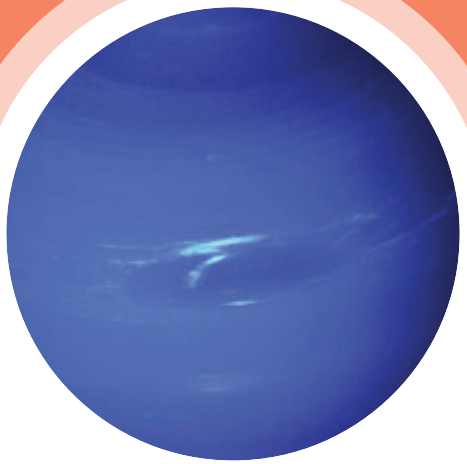
The current lack of flowing water or volcanic activity on Mars makes aeolian (wind-driven) transport of sediment the primary agent of geologic change today. Earth- and spacecraft-based observations have revealed numerous variable albedo features that are attributed to redistribution of bright dust on the surface. Long-term atmospheric dust transport may also be responsible for massive sediment deposits, particularly in the polar regions where condensation of volatiles may lead to rapid deposition of suspended dust. Regional dust storms and occasional global-scale dust events readily provide the source of particles needed to create or sustain these various features across the planet. Investigation of Martian aeolian processes and features requires an understanding of details of the atmospheric "dust budget", which includes the location, genesis, timing, and frequency of large dust-lifting events.

Since mid-2006, the Mars Color Imager (MARCI) onboard the Mars Reconnaissance Orbiter (MRO) has returned daily sequences of images which, over the course of a few weeks, cover the entire illuminated surface of Mars. Each day, MARCI "stares" at the surface directly under the spacecraft, returning 13 continuous "strip images" in seven wavelengths (five violet to near-infrared filters and two ultraviolet filters). Because the observations from a single day contain gaps between strips, one must include a series of days to produce a seamless mosaic, such as shown in the figure on page 16.

SSI scientist and MARCI Co-Investigator Steve Lee (Boulder, CO Office) has led the development and analyses of this type of MARCI data product to better constrain the "dust budget" mentioned above (SSI colleagues and fellow MARCI team members Todd Clancy (Bald Head Island, NC Office), Phil James (Prescott, AZ Office), and Mike Wolff (Brookfield, WI Office) focus on other aspects of the MARCI dataset). MARCI, the first "full color" camera to operate in Mars orbit, has revealed a number of dramatic surface changes. These areas continue to be monitored to determine the timing and amount of sediment transport needed to explain the variable features. The observations are being used to address seasonal versus longer-term climate variability leading to the "changing face of Mars". A weekly report of the "weather on Mars", along with a "spinning globe" movie of MARCI data for the last week, can be viewed at http://www.msss.com/msss_images/latest_weather.html.



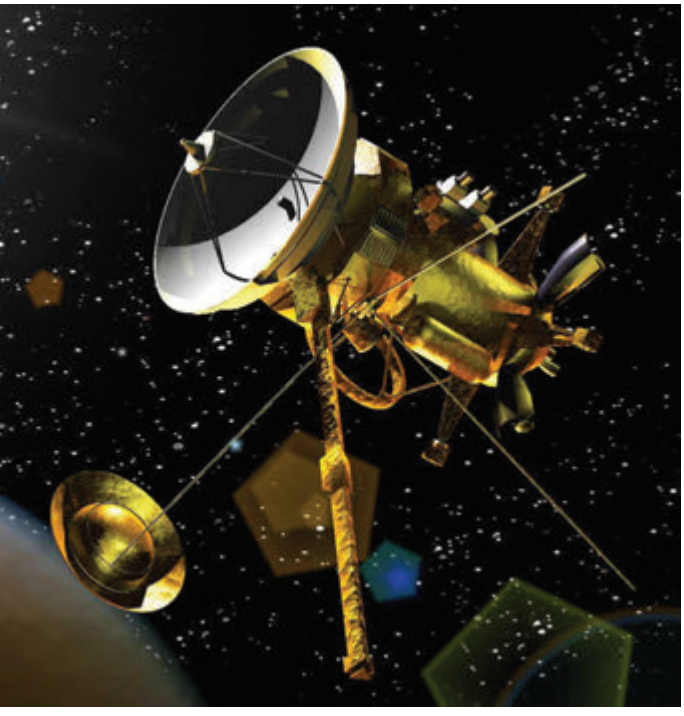
Above :: *The surface of Mars is shown in a full color MARCI global mosaic. Lighter colored features near the volcanos are water-ice clouds. Data obtained during June 2008 were combined in this mosaic. The spatial resolution is about 1 km per pixel. Credit: SSI/MSSS/NASA*



FLIGHT OPS

The Cassini Imaging Central Laboratory for OPerationS (CICLOPS) is located at SSI's Headquarters Office in Boulder, CO. CICLOPS is the center for uplink and downlink operations for the imaging science experiment on the Cassini mission to Saturn. All images produced by the two powerful telescopic cameras onboard Cassini (the Imaging Science Subsystem) make their way across more than a billion and a half kilometers (1 billion miles) of space to be archived in databases at CICLOPS and made available to imaging team members across the globe, researchers, and the public.

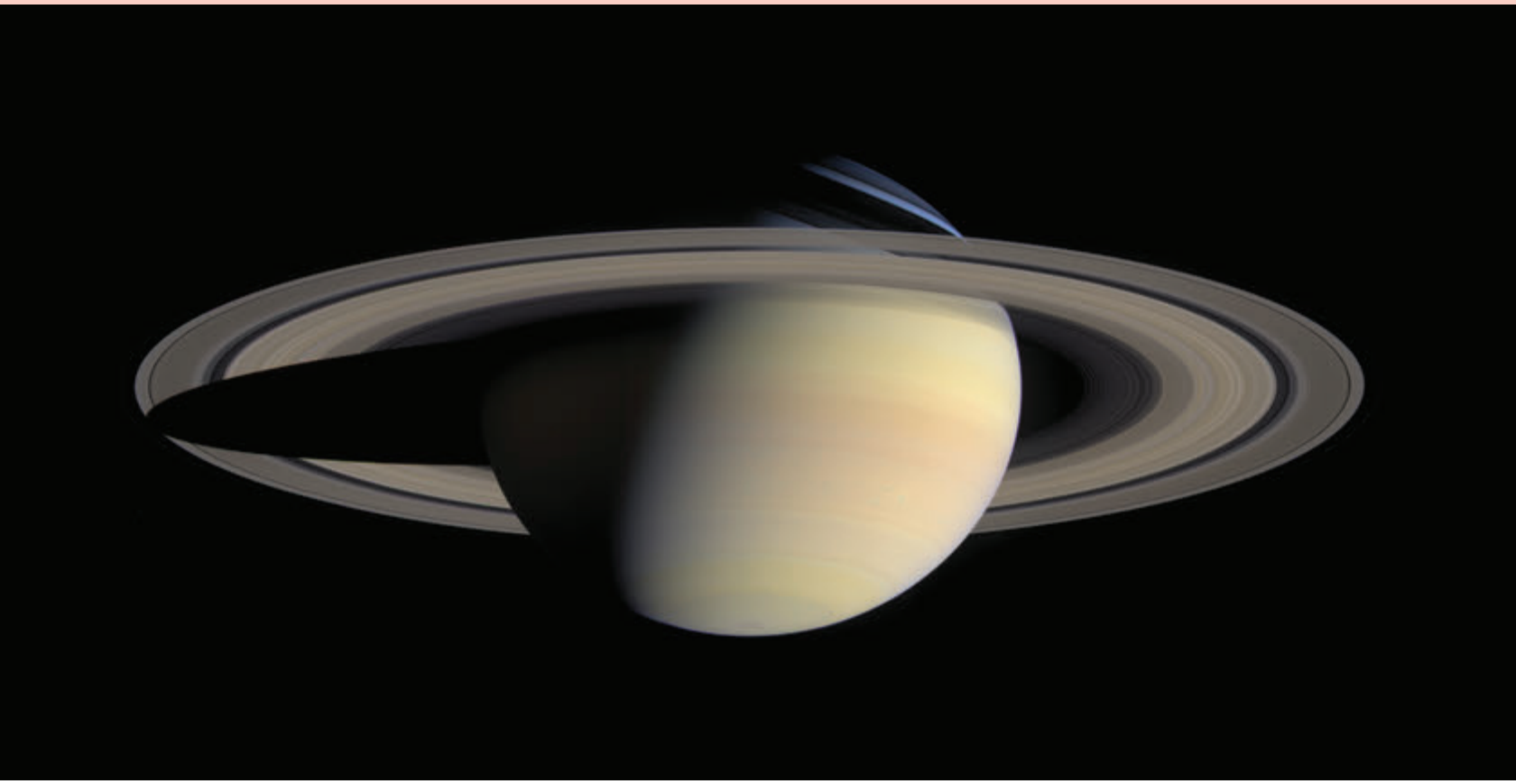
Below :: *A schematic of the Cassini spacecraft. Credit: Cassini Imaging Team and NASA/JPL/SSI*



The Cassini-Huygens mission continues to change our view of the Saturn system. Since arriving at Saturn in the summer of 2004, the intrepid spacecraft has completed numerous close flybys of Saturn's moons, providing new perspectives and a wealth of data about this unique collection of objects. Cassini has monitored powerful lightning-generated radio outbursts and cloud activity produced by giant storms on Saturn that dwarf those on Earth. The Huygens probe landing on haze-shrouded Titan and Cassini's continuing survey of this moon from space have provided tantalizing glimpses of a world that is at once remarkably earthlike yet also frigid and alien. The startling revelation that Saturn's small, icy moon Enceladus may possess underground reservoirs of liquid water has widened our perception of the range of environments that might be hospitable for life.

Images taken by Cassini are selected for release to the public at CICLOPS. Chosen images and movie sequences

Below :: *The planet Saturn. Credit: Cassini Imaging Team and NASA/JPL/SS*



are processed to ensure quality, including the best possible color. The final products are posted to the CICLOPS website (http://ciclops.org) for distribution to the waiting world. Also posted on the website are imaging news stories, upcoming mission events, public discussions, Saturn-inspired artwork, and more.

Cassini's landmark exploration of the ringed planet, its mysterious moons, stunning rings, and complex magnetic environment will continue through 2017 when the spacecraft's third and final mission will come to an end. CICLOPS team members and the Cassini mission scientists and engineers are now hard at work executing the seven-year Cassini Solstice Mission, the second extension beyond Cassini's prime mission (which ended in 2008).

The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency, and the Italian Space Agency. The Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, manages the Cassini-Huygens mission for NASA's Science Mission Directorate, Washington, D.C.

Below :: *This 2004 image shows a short trail, or "mini-jet," of icy particles dragged out from Saturn's F ring.*
Credit: Cassini Imaging Team and NASA/JPL/SSI

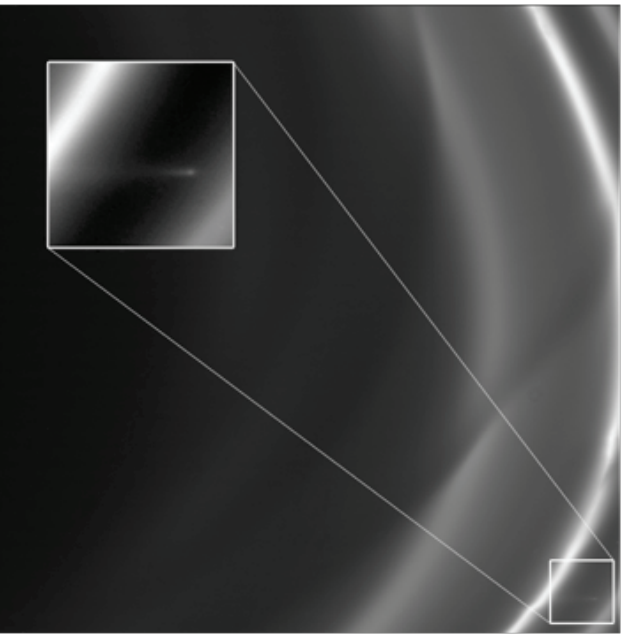
Cassini/Saturn Research

Led by Cassini Imaging Team leader Dr. Carolyn Porco, CICLOPS came to SSI in August 2003. Fourteen scientists from the United States and Europe comprise the imaging team that uses Cassini's cameras to investigate many unique features of the Saturn system. The Imaging Team continues to publish findings from their investigations, deepening our knowledge about Saturn and the processes by which planets—and whole planetary systems—form and develop with time.

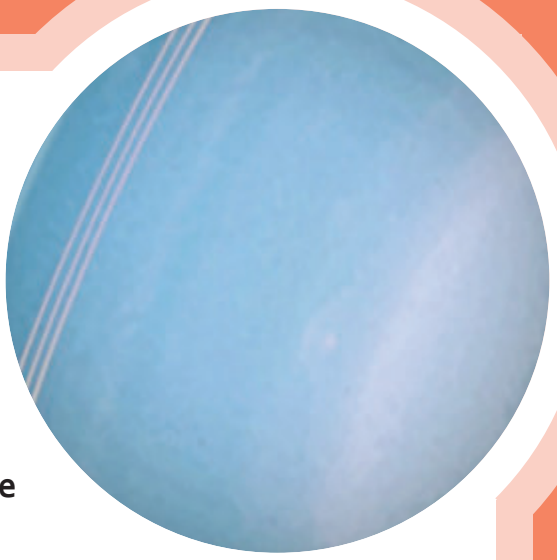
In 2012, Cassini images graced the pages of scores of magazines and websites around the globe. The mission continues to generate exciting science and exquisite imagery from the Saturn frontier.

2012 Cassini Highlights

Tiny Moonlets Populate Saturn's F Ring



Images from Cassini have revealed half-mile-sized (kilometer-sized) objects punching through parts of Saturn's F ring, leaving glittering trails behind called "mini jets". These images, like the one on the left, show scientists that the F-ring region is full of various sized objects that interact with the ring. Larger objects like Prometheus (as long as 92 miles, or 148 kilometers, across) can create channels, ripples and 'snowballs' (small, loosely aggregated objects) in the F ring, but scientists didn't know what happened to these after they were created. Larger snowballs are broken up, but smaller ones can survive and, because of their differing orbits, go on to pass through the F ring at slow speeds of about 4 mph (2 meters per second). The collisions drag glittering ice particles out of the F ring, leaving trails 20 to 110 miles (40 to 180 kilometers) long. After the discovery of these trails, scientists went through 20,000 other Cassini images and found 500 more examples of mini jets from the past 7 years. In some cases, the objects traveled in packs, creating mini-jets that looked quite exotic, like the barb of a harpoon. Studies of the F-ring help scientists understand

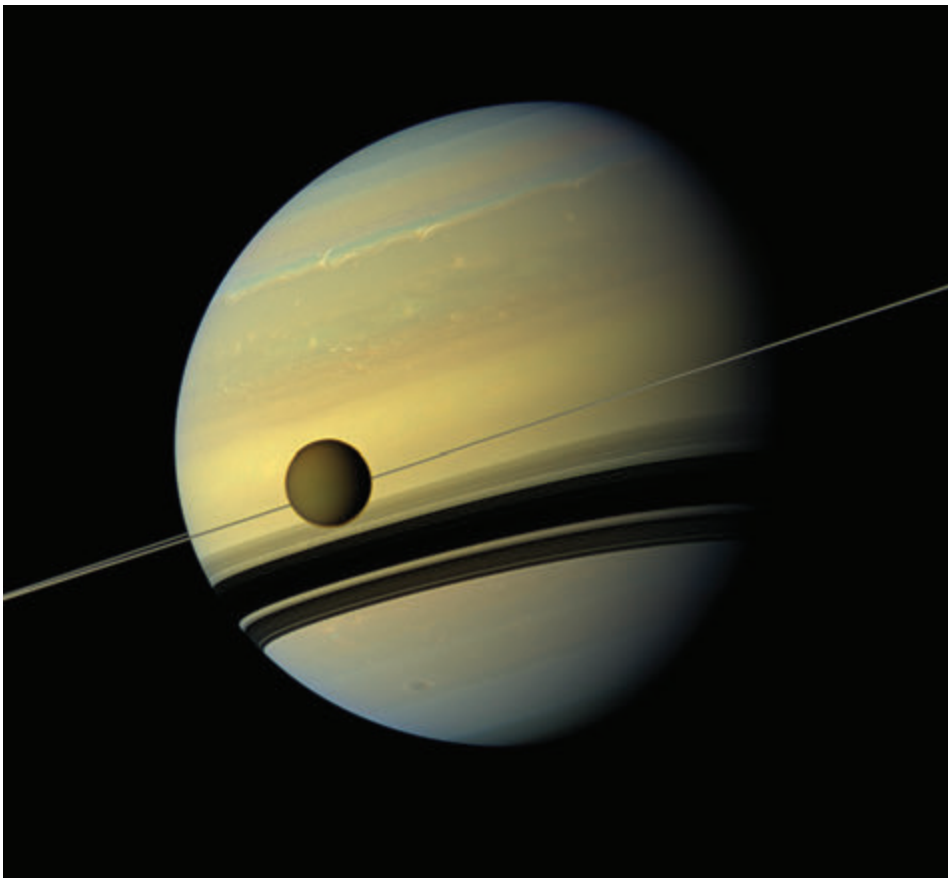


the activity that occurs when Solar Systems evolve out of dusty disks that are much larger but similar to the disks around Saturn.

Saturn and Its Largest Moon Reflect Their True Colors

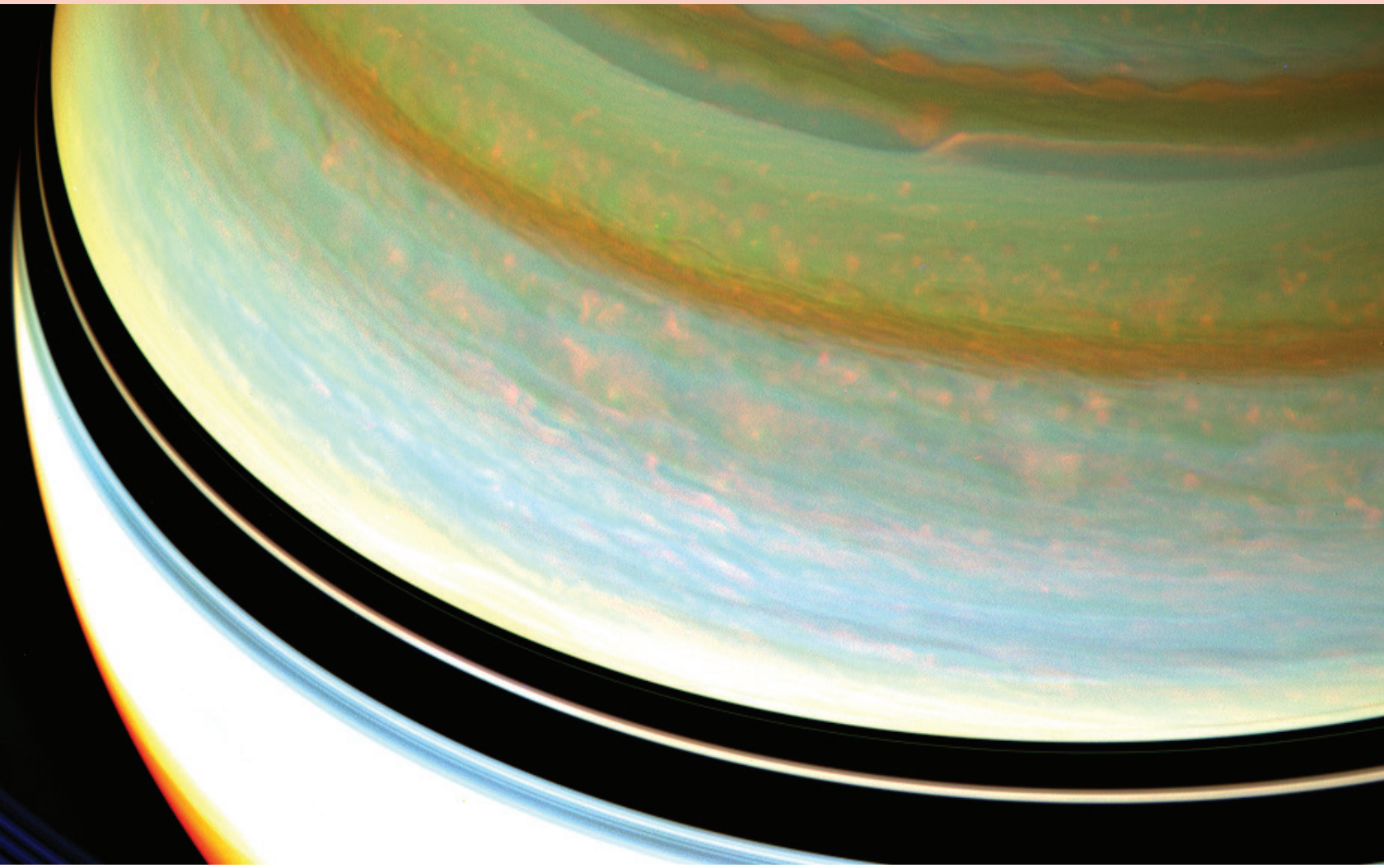
Upon Cassini's arrival at Saturn eight years ago, Saturn's northern winter hemisphere was an azure blue. Now, with winter encroaching on the planet's southern hemisphere and summer on the north, the color scheme is reversing. In 2012, Cassini's wide-angle camera captured a series of natural color images that depict the spectacular color change.

Launched in 1997, Cassini went into orbit around Saturn on July 1, 2004. It is in its second extended mission, known as the Solstice Mission, and one of its main goals is to analyze seasonal changes in the Saturn system. In 2012 Cassini entered into a new inclined – or tilted – orbit which has allowed scientists to see new phenomena like Titan's south polar vortex and changes wrought by the passage of time and seasons. Cassini scientists are looking forward to taking new breathtaking images and making new discoveries during the remainder of Cassini's mission.



Above :: *A giant of a moon appears before a giant planet undergoing seasonal changes in this natural color view of Titan and Saturn. Blue hues are fading in the north and intensifying in the south. Credit: Cassini Imaging Team and NASA/JPL/SSI*

Below :: *Clouds associated with a jet stream can be seen as a thin, bright orange line in the upper right of this false-color image taken from the Cassini spacecraft. Credit: Cassini Imaging Team and NASA/JPL/SSI*



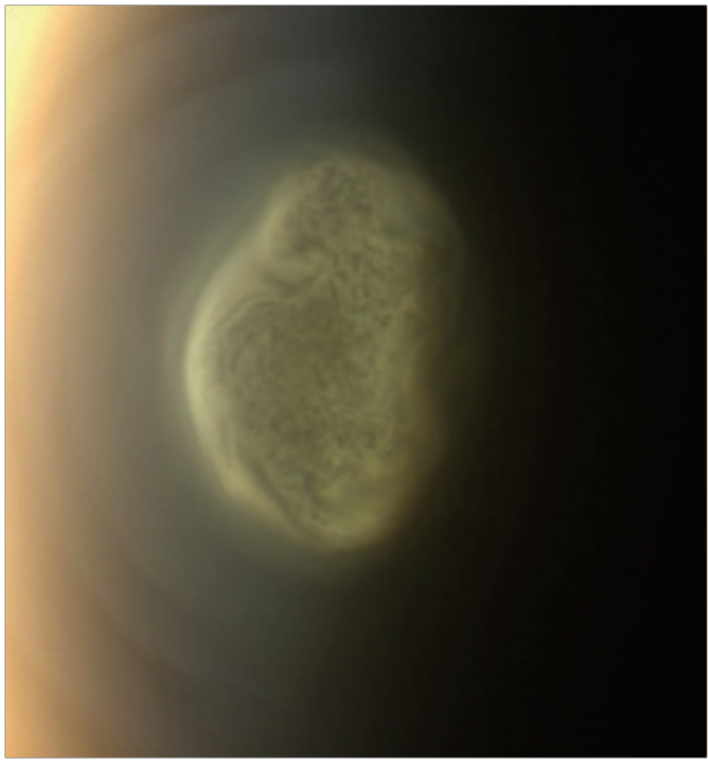
Cassini Shows Why Jet Streams Cross-Cut Saturn

One of Cassini's main goals has been to understand what drives the meteorology on Saturn and other gaseous planets. This year, using Cassini images from 2005-2012, scientists were finally able to determine the source of energy for the turbulent jet streams that churn east and west across Saturn's atmosphere. Scientists discovered that, unlike Earth where sunlight powers the meteorology, internal heat on Saturn powers the planet's jet streams. Heat from the deep interior stirs up water vapor, which rises and ultimately condenses at higher altitudes, releasing heat as it makes clouds and rain. This process leads to temperature differences in the atmosphere, which in turn, create small vortices called eddies. These eddies, in turn, accelerate the jet streams like rotating gears driving a conveyor belt.

Using Cassini's cameras, scientists observed eddies at two different altitudes and determined that lower altitude eddies were stronger than upper altitude eddies. Thus, they could discount heating from the Sun and infer instead that the internal heat of the planet is ultimately driving the acceleration of the jet streams. Condensation in mid-latitude storms happens on both Saturn and Earth. Storms on Earth are primarily driven by the Sun's heating and do not usually occur because of the condensation of water. The opposite occurs on Saturn.

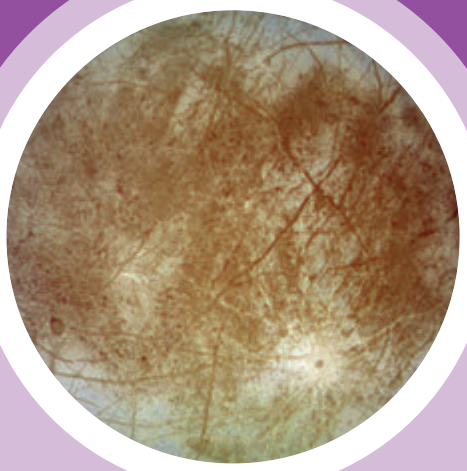
Cassini Finds A Vortex Forming Over Titan's South Pole

On June 27th, with Cassini in a new inclined orbit, imaging scientists found a vortex swirling in the atmosphere high over Titan's south pole. True color images of the vortex were captured along with a movie that shows one full rotation of the vortex over a 9-hour period. Titan's south polar vortex is extraordinary in that it contains what appears to be a cloud of condensing organic material, or material that contains carbon, hydrogen and nitrogen, that is visually mottled by open cell convection. In open cells, air sinks in the center of the cell and rises at the edge, forming clouds at cell edges.



Since Cassini arrived in the Saturn system in 2004, Titan has had a visible "hood" high above its north winter pole. But now with the seasons changing and the high southern latitudes moving into winter, the formation of the vortex may be the start of what will be a south polar hood. Future observations will shed light on the processes that occur in Titan's upper atmosphere.

Above :: *This true color image captured by Cassini before a distant flyby of Saturn's moon Titan, shows a south polar vortex, or a mass of swirling gas around the pole in the atmosphere of the moon. Credit: Cassini Imaging Team and NASA/JPL/SSI*



NATIONAL CENTER

Guiding Principles

- **Inspire learners of all ages, ethnicities, and learning modalities with the thrill of scientific discovery**
- **Integrate STEM research and STEM education**
- **Ensure scientific accuracy in all activities**
- **Rigorously evaluate and disseminate results**
- **Cultivate mutually beneficial partnerships in STEM and education communities**
- **Contribute significantly to educational research**

NCIL is dedicated to expanding the understanding and participation of families, youth, educators, and citizens in science and technology through learning research and innovative programs. Dr. Paul Dusenbery is the Executive Director of SSI and the Director of NCIL. NCIL is organized around five interconnected groups: 1) Exhibition Development, 2) Digital Learning, 3) Professional Development, 4) Community Outreach, and 5) Learning Research and Evaluation. Visit www.nc4il.org for more information.

NCIL staff foster collaboration between STEM professionals and educators to bring the wonder

Below :: *Great Balls of Fire: Comets, Asteroids, and Meteors exhibition in Richmond, VA. Credit: NCIL*

FOR INTERACTIVE LEARNING

of science and engineering directly to people. We bridge the worlds of public schools, libraries, museums, and the Internet. Our programs span a range of audience needs and delivery methods, including traveling museum exhibitions (e.g. *MarsQuest*, *Alien Earths*, and *Giant Worlds*); award-winning educational films (e.g. Are We Alone?), videos, and websites; hands-on teaching resources and activities; and educator workshops and webinars.

Our programs are designed to be accessible to all and to inspire the next generation of STEM innovators. Our programs impact rural and urban communities nationwide as well as underserved audiences. All of our education work is guided by a robust evaluation program that is developing best practices for interactive learning and enabling us to disseminate the most successful programs nationally.

"Few things in my three decades as a librarian have been more rewarding to me than having my library serve as the inaugural site for the interactive library exhibitions developed by the Space Science Institute's National Center for Interactive Learning. Discover Earth and Discover Tech were embraced by library users, many of

Building on the success of a Colorado-wide tour of NCIL's *Discover Space* exhibition, we established the STAR Library Education Network (STAR_Net) as a hands-on learning program for libraries and their communities. This NSF-funded program, in partnership with the American Library Association, the Lunar and Planetary Institute, and the National Girls Collaborative Program, will reach underserved youth and their families with informal STEM learning experiences. Over the next 18 months, two new exhibitions–*Discover Earth* and *Discover Tech*–will travel to eighteen libraries across the United States.

NCIL Impacts for 2012

Traveling Exhibit Visitors (333,164)

Large *Great Balls of Fire* museum exhibit (2 host sites): 130,723
Small *Great Balls of Fire* museum exhibit (2 host sites): 40,439
Discover Earth library exhibit (5 Host sites): 94,354
Discover Tech library exhibit (3 Host sites): 67,648

Education Website Visitors (426,962)

www.alienearths.org	167,995
www.marsquestonline.org	110,716
www.spaceweathercenter.org	110,036
www.killerasteroids.org	26,649
www.giantworlds.org	6,394
www.scigames.org	5,172

Workshop Participants (78)

Education Webinar Participants (166)

Outreach Event Participants (145)

whom visited time after time." -

Beth Barrett, Director, Louisville Public Library, Colorado

Hundreds of librarians and STEM professionals are also joining STAR_Net's online community where they can download STEM resources and collaborate with one another. See www.STARnetLibraries.org for more information.

We are capturing people's attention by using the latest social media. For example, we're tapping into the enormous popularity of Facebook games by developing one that will teach players about the evolution of stars and planets. Each player will be able to select a region of the galaxy in which to build a star and planets. Then he or she can watch as the system evolves. Successful systems will generate currency for players, allowing them to invest in more stars and planets, seed life, and customize their worlds. A simultaneous research and evaluation program will examine both the effectiveness of this game as a learning tool, as well as the broader potential of this gaming approach for the educational community.

2012 Highlights

Social Interaction and Technology in Museum Settings

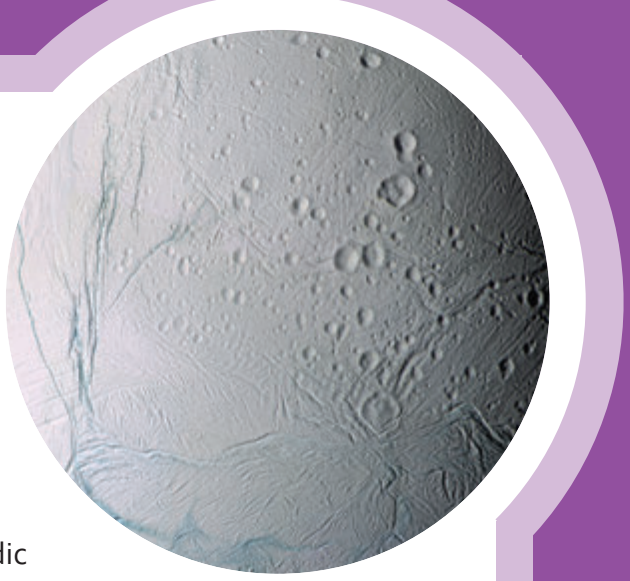
Open Exhibits is a National Science Foundation sponsored initiative that looks to transform the way in which museums and other informal learning institutions produce and share computer-based exhibits. Open Exhibits is both a collection of software and a growing community of practice. Over the past year, the Open Exhibits research team (Kate Haley Goldman, Silver Springs, MD Office and Jessica Gonzalez, Albuquerque, NM Office) has been gathering data at project partner sites. The research focuses on how the introduction of a multitouch surface interactive within the exhibit space impacts interaction, including such questions as, do visitors use the table? What prevents them from using the table if they do not interact with it? How social are visitors when using the table? Does table usage differ from the use of a wall-mounted multitouch display?

Below :: *Young visitors interact with a multitouch display at the New Mexico Museum of Natural History. Credit: Open Exhibits*

We completed data collection at three sites: The New Mexico Museum of Natural History, the Maxwell Museum of Anthropology, and the Indian Pueblo Cultural Center. Data collection involved setting up signage to alert visitors to the research project, tracking them through the exhibit space, and informing them about the nature of the research and gaining their written consent. We observed visitors interaction with the table and then interviewed them using a semi-structured interview protocol. In September 2012 we developed a data collection schedule and began to collect approximately 30 interviews at each of the three sites. During this time we also identified, tested, and purchased open source dialog analysis software for the purpose of analyzing future dialog at the table. We completed the first round of analysis of that data and drafted reports, which will be disseminated in the coming months. In addition, we have crafted two other studies and received the appropriate clearances to conduct them. The first study is a comparison of content on a wall-based touchscreen and the table. This cued study has begun at the New Mexico Museum. The second study will also be conducted at this museum, and will use a security-camera to research the attraction and staying power rates of the table.

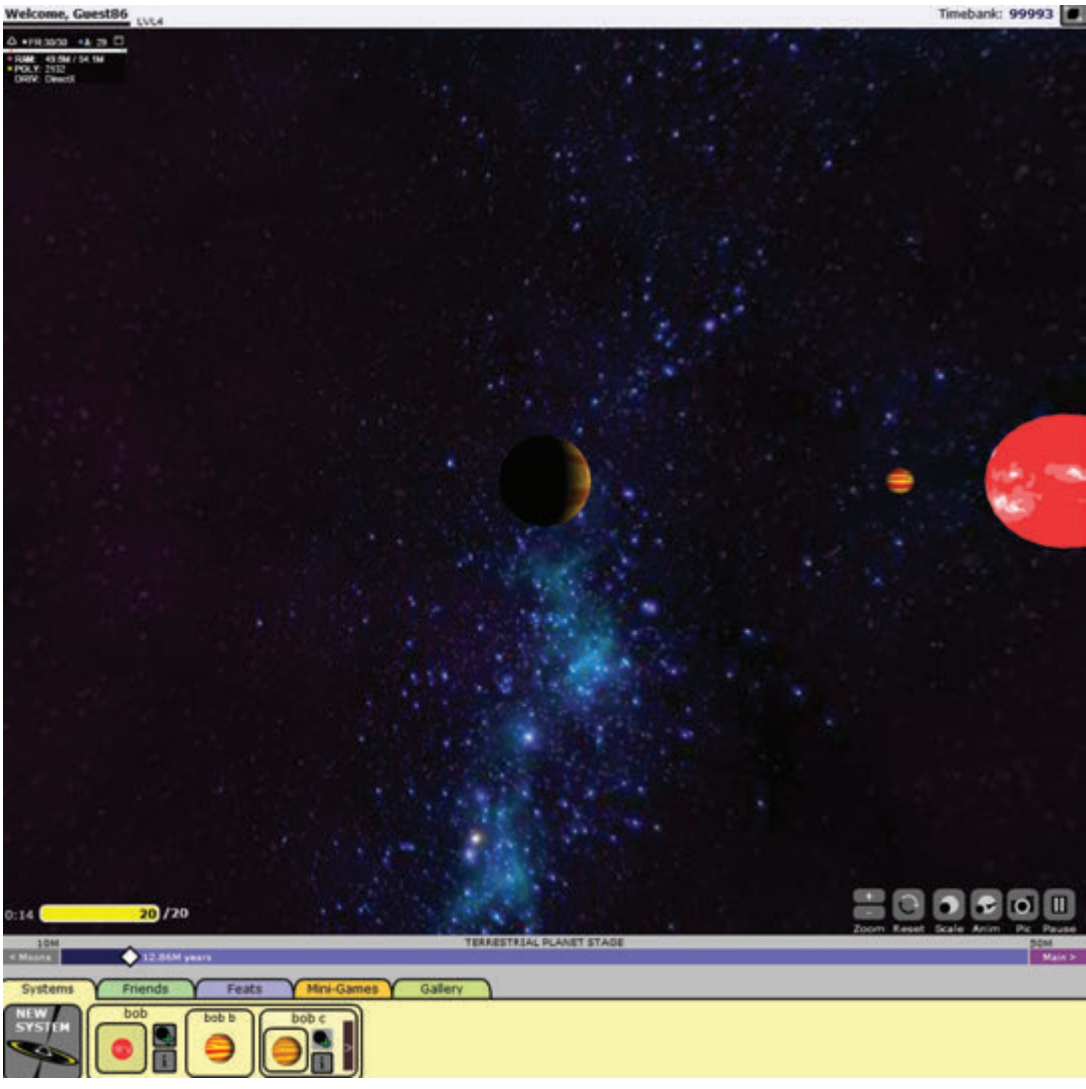
Building Worlds and Learning Astronomy on Facebook

James Harold, Evaldas Vidugiris and C.J. Harrington (all three at the Boulder, CO Office) and Dean Hines (Parkville, MD Office) are developing an end-to-end stellar and planetary evolution game for the Facebook platform. The idea of using games in education is not new. Their demonstrated ability



to engage players, scaffold content, and create virtual worlds makes them an attractive potential tool for learning. But the explosive growth of social networking sites has changed the gaming landscape. Top Facebook games can have tens of millions of players per month, while simultaneously attracting a diverse demographic. In addition, games such as Farmville have introduced the notion of "sporadic play" games, in which the player may only take an action a few times a day, but continuing playing for months.

Supported by NSF and NASA, and based in part on "MyStar" (a prototype funded by the Space Telescope Science Institute), our game uses the sporadic play model to engage players in the creation and evolution of a Solar System. Players build their stars and planets, and watch as the systems evolve in scaled real time (a million years to the minute). Massive stars will supernova within minutes, while lower mass stars like our Sun will live for weeks, possibly



Above :: A screenshot of the NSF-funded Facebook game. Credit: NCIL

Below :: *Great Balls of Fire exhibition at the Flandrau Science Center and Planetarium (FSCP). Credit: FSCP*

evolving life before passing through a red giant stage and ending their lives as white dwarfs. Successful systems can be photographed and posted to the player's wall. The game will introduce players to a wide spectrum of astronomy concepts while simultaneously providing us with a platform for exploring the educational effectiveness of sporadic play games embedded in social networks. The game is currently still in development, but should be in early release within a year.

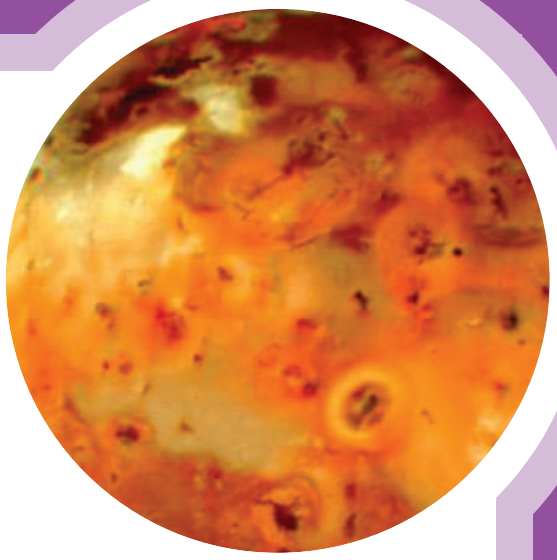
NASA Brings *Great Balls of Fire* Exhibition to Tucson

In 2016, NASA's OSIRIS-REx mission will send a spacecraft to an asteroid to map its surface and collect samples before returning to Earth. By analyzing samples from the asteroid, scientists hope to better understand the formation of our Solar System. In the Fall of 2012, the mission brought NCIL's *Great Balls of Fire* exhibition about asteroids, comets, and meteors to the University of Arizona's Flandrau Science Center and Planetarium in Tucson (see www.GreatBallsOfFireExhibit.org).

With help from the mission, planetarium staff enhanced the exhibit with additional signage, videos, and artifacts highlighting OSIRIS-REx and its connection to the exhibit's science content. University and mission scientists participated in a series of talks related to the mission and *Great Balls of Fire*. NASA also trained volunteers, such as UA students, to be OSIRIS-REx ambassadors. The ambassadors then facilitated tours and conducted hands-on activities with visitors. To reach a broad audience, OSIRIS-REx provided financial support to bring area school children to the exhibition on field trips. Once the students arrived at Flandrau, the ambassadors gave them the star treatment.

Hands-on exhibits are fun. But just as important are the conversations and interactions that visitors have while engaging with exhibit components. OSIRIS-REx and Flandrau worked together to engage

visitors and make those conversations happen. There was also a payoff for Flandrau, which has a minimal marketing budget. The planetarium saw a significant jump in its visitor numbers simply from word-of-mouth advertising as a result of hosting the *Great Balls of Fire* exhibition and providing a great visitor experience.



STAR★net

Science-Technology Activities & Resources For Libraries

The STAR Library Education Network (STAR_Net) is a national program led by the Space Science Institute's *National Center for Interactive Learning*. STAR stands for Science-Technology Activities and Resources. Core partners include the American Library Association, Lunar and Planetary Institute, and the National Girls Collaborative Project. Other collaborators include the National Academy of Engineering, Engineers Without Borders-USA, IEEE-USA, the National Renewable Energy Lab, American Geophysical Union, Geological Society of America, public libraries, and many more partners. Phase 1 of the STAR_Net project is supported through a grant from the National Science Foundation.

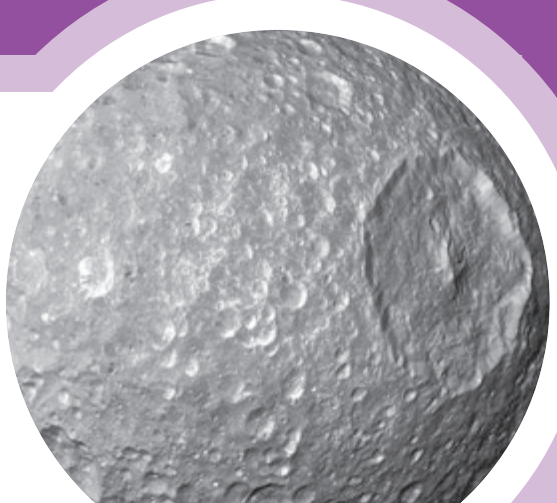
STAR_Net education programs have been designed with the goal to inspire lifelong learning through inquiry and play. The project has developed two interactive

Below :: *Discover Earth at Laramie County Public Library (LCPL) Cheyenne, WY. Credit: LCPL*

traveling exhibits – *Discover Earth: A Century of Change* and *Discover Tech: Engineers Make a World of Difference* – accompanied by a variety of education and outreach programs such as a training program for librarians, an outreach program for classroom teachers and out-of-school instructors, and a Community of Practice (CoP) network of librarians and STEM professionals (currently, over 300 members nationwide). For more information visit www.STARnetLibraries.org.

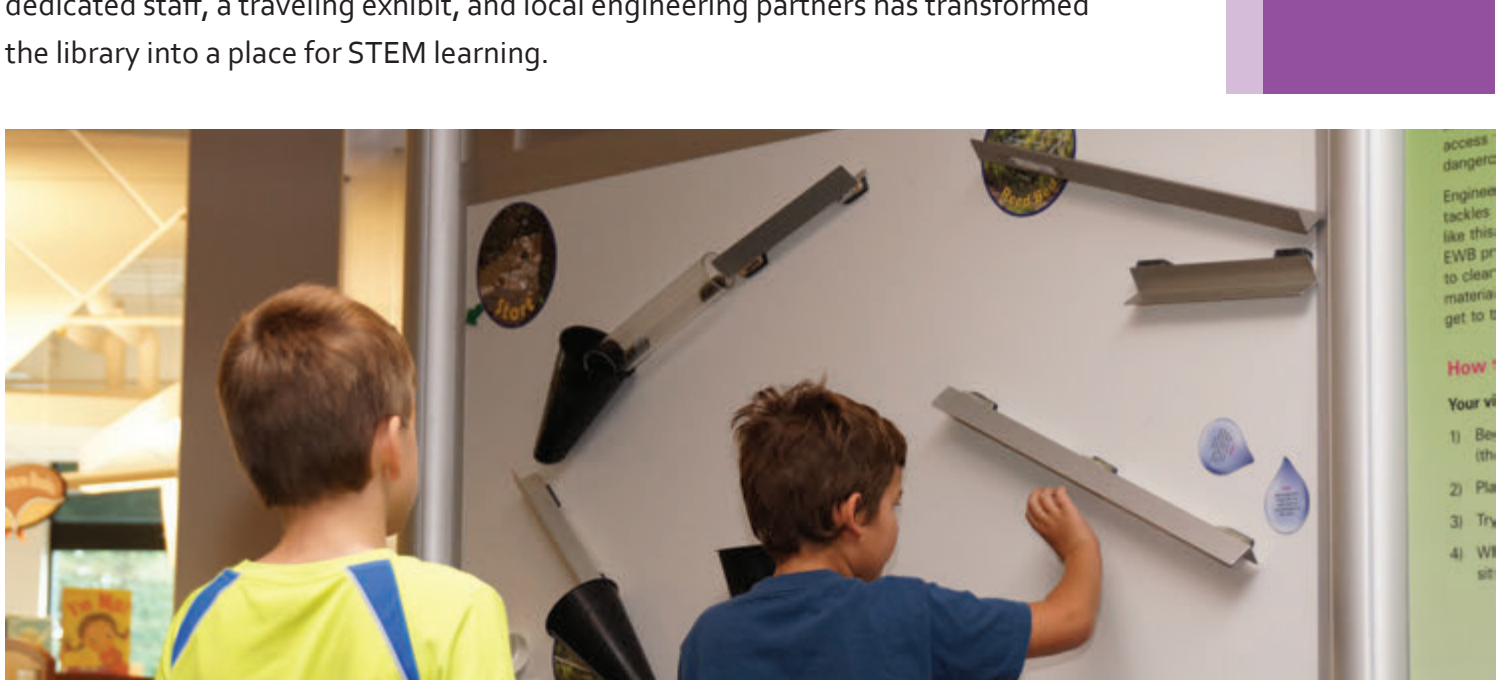
Discover Earth Exhibition

Through the end of 2012, *Discover Earth* has traveled to the Louisville Public Library in Louisville, CO; the TLL Temple Memorial Library in Diboll, TX; the Winnebago Public Library in Winnebago, NE; the Garfield County Public Library in Rifle, CO; the Laramie County Public Library in Cheyenne, WY; and East Meadow Public Library in East Meadow, NY on Long Island. In East Meadow, the exhibit arrived just a few days after Superstorm Sandy devastated the town and surrounding areas in late October 2012. Many residents lost their homes, and many more (including the library director) were at least temporarily displaced. The opening event, a few days after Thanksgiving, drew a crowd of approximately 1,100; many of whom were so engrossed in the exhibit that it was hard to get them to leave at closing time. According to Jude Schanzer, public relations director at East Meadow, the exhibit was "truly a godsend. What a teaching advantage we have." Library Director Carol Probeyahn said "Providing the *Discover Earth* exhibit to the community has widened our staff and patrons' definition of what a library can and should be."



Discover Tech Exhibition

Through the end of 2012, *Discover Tech* has traveled to the Louisville Public Library in Louisville, CO; the Spokane Public Library in Spokane, WA; and the Mary Wood Weldon Public Library in Glasgow, KY. While in Glasgow, KY, the *Discover Tech* exhibit had a large impact. In a community of only 14,000 residents, 2,300 people visited the exhibit (1,300 of them being school field trips), almost 15% of the town's population. To accommodate the large numbers of school visitors, the library opened an hour early for a few weeks, and non-program staff helped to guide students and teachers through the exhibit and activities. The town of Glasgow has no science center. But the combination of a dedicated staff, a traveling exhibit, and local engineering partners has transformed the library into a place for STEM learning.



Above :: *Discover Tech at Louisville Public Library. Credit: NCIL*

FINANCIAL REPORT

Space Science Institute
Summary Statement of Financial Position
as of December 31, 2012 and 2011

	2012	2011
Assets		
Assets		
Cash and cash equivalents	$ 137,474	$ 752,768
Accounts receivable	1,264,949	1,027,440
Prepaid expenses and deposits	88,591	77,543
Net furniture, equipment, and property	25,351	35,431
Total assets	$ 1,516,365	$ 1,893,182
Liabilities and Net Assets		
Liabilities		
Accounts payable and accrued liabilities	$ 634,477	$ 489,474
Deferred revenues	490,108	687,390
Line of credit	-	365,000
Total liabilities	1,124,585	1,541,864
Net assets		
Unrestricted	384,733	346,318
Temporarily restricted	7,047	5,000
Total net assets	391,780	351,318
Total liabilities and net assets	$ 1,516,365	$ 1,893,182

Summary Statement of Activities
for the years ended December 31, 2012 and 2011

	2012	2011
Support and revenue		
Grants, contracts, and cooperative agreements	$ 5,723,764	$ 5,943,200
Contributions	6,960	9,950
Exhibit income	216,500	137,000
Interest income	259	364
Other income	99	267
Total support and revenue	5,947,582	6,090,781
Expenses		
Program services	5,932,230	6,020,806
General and administrative	(25,110)	34,548
Total expenses	5,907,120	6,055,354
Change in net assets	40,462	35,427
Net assets, beginning of year	351,318	315,891
Net assets, end of year	$ 391,780	$ 351,318

The summary financial information does not include sufficient detail or disclosures to constitute presentation in conformity with accounting principles generally accepted in the United States of America. If the omitted detail or disclosures were included, they might influence the user's conclusions about the Organization's financial position, changes in net assets, and cash flows. Accordingly such information should be read in conjunction with the Organization's audited financial statements for the years ended December 31, 2012 and 2011, from which the summarized information was derived. A copy is available upon request.

WWW.SPACESCIENCE.ORG

Space Science Institute . 4750 Walnut Street . Suite 205 . Boulder, Colorado 80301 . 720.974.5888 . www.spacescience.org