

ANNUAL REPORT 2013

Space Science Institute · 4750 Walnut Street · Suite 205 · Boulder, Colorado 80301 · 720.974.5888 · www.space-science.org





Overview

Financial Report

Research

Flight Operations

National Center for Interactive Learning

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 Chairman of the Board of Directors

It is an honor and a privilege to serve as Chairman of the Board of the Space Science Institute (SSI). I have the good fortune to serve with a group of exceptional board members who donate their time and expertise to assist SSI. We all serve with pride and we all are committed to supporting SSI and its outstanding scientific and educational efforts and programs.

SSI is recognized throughout the scientific community as a center for innovation and world-class research. I'm especially proud of our work that supports the many exploratory missions on the forefront of scientific endeavors. It is also a great privilege for me to know and work with the cadre and

community of outstanding scientists that are members of SSI. Their contributions to scientific knowledge are recognized in many fields of research.

In 2013, SSI's Board was committed to expanding the scope and reach of its educational program that has been an essential and continuing effort within SSI. The education and outreach program supports museums and public libraries as well as on-line distribution of educational resources and activities. That effort has continued with renewed emphasis within SSI's National Center for Interactive Learning. SSI has fostered an environment in which scientists and educators work together to serve the public need for quality education in science and technology, an effort that continues to be a primary goal of SSI. This annual report summarizes SSI's accomplishments in 2013 and outlines the promise of the scientific and educational activities that SSI is pursuing in the years ahead.

Richard R. Green, Ph.D.

Message from the Executive Director

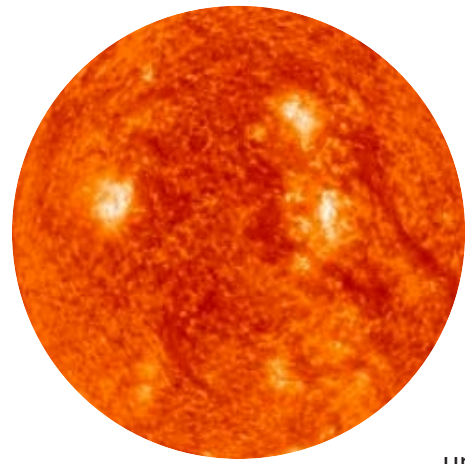
Inspire. Explore. Discover. These words describe our work in both scientific research and education. In fact, they define the essence of our mission: to integrate world-class research with an innovative education program within a single institution. SSI's creative environment, flexibility and reputation draw world-class scientists to the Institute. Cooperation between SSI's scientists and educators enables us to develop education and outreach programs with engaging science content that reach people worldwide through hands-on museum and public library exhibitions and digital learning programs on the internet.

SSI's researchers participate in robotic missions such as the Mars Science Lander and Mars Exploration Rovers, as well as in-flight missions such as Hubble, NuSTAR, Fermi, and SOFIA. SSI's Cassini Imaging Central Laboratory for Operations (CICLOPS) is responsible for operating the imaging science experiment on the Cassini mission to Saturn. SSI's National Center for Interactive Learning manages two traveling exhibitions for science museums and is the lead organization for a national public library project. Two educational apps were released in 2013 and we are developing a Facebook game that will teach players about the evolution of stars and planets. We seek and encourage strong ties to corporations, foundations, and institutions nationwide. I invite you to join our voyage of discovery.

Paul B. Dusenbery, Ph.D.



*Cover Image :: NASA's Curiosity rover drives across a dune on Mars. Credit: NASA/JPL
Inside Cover Image :: Hubble's Panoramic View of a Turbulent Star-making Region. Credit: NASA/ESA/STScI*



OVERVIEW

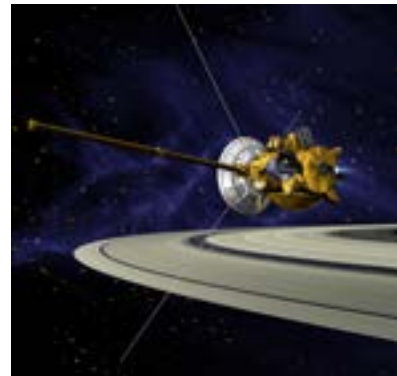
Humans are driven to explore. We are inspired by fundamental questions: *Are we alone? Could we live on other planets? How does our amazing planet change and evolve?* Few things capture our imaginations more than the mysteries of space and the wonders of our own planet. The search for life beyond Earth 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.

The Space Science Institute is a nonprofit, public benefit 501(c)(3) corporation founded in 1992 and began operations in 1994. SSI has five major branches: Research, Cassini Flight Operations, National Center for Interactive Learning (NCIL), 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.

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



RESEARCH

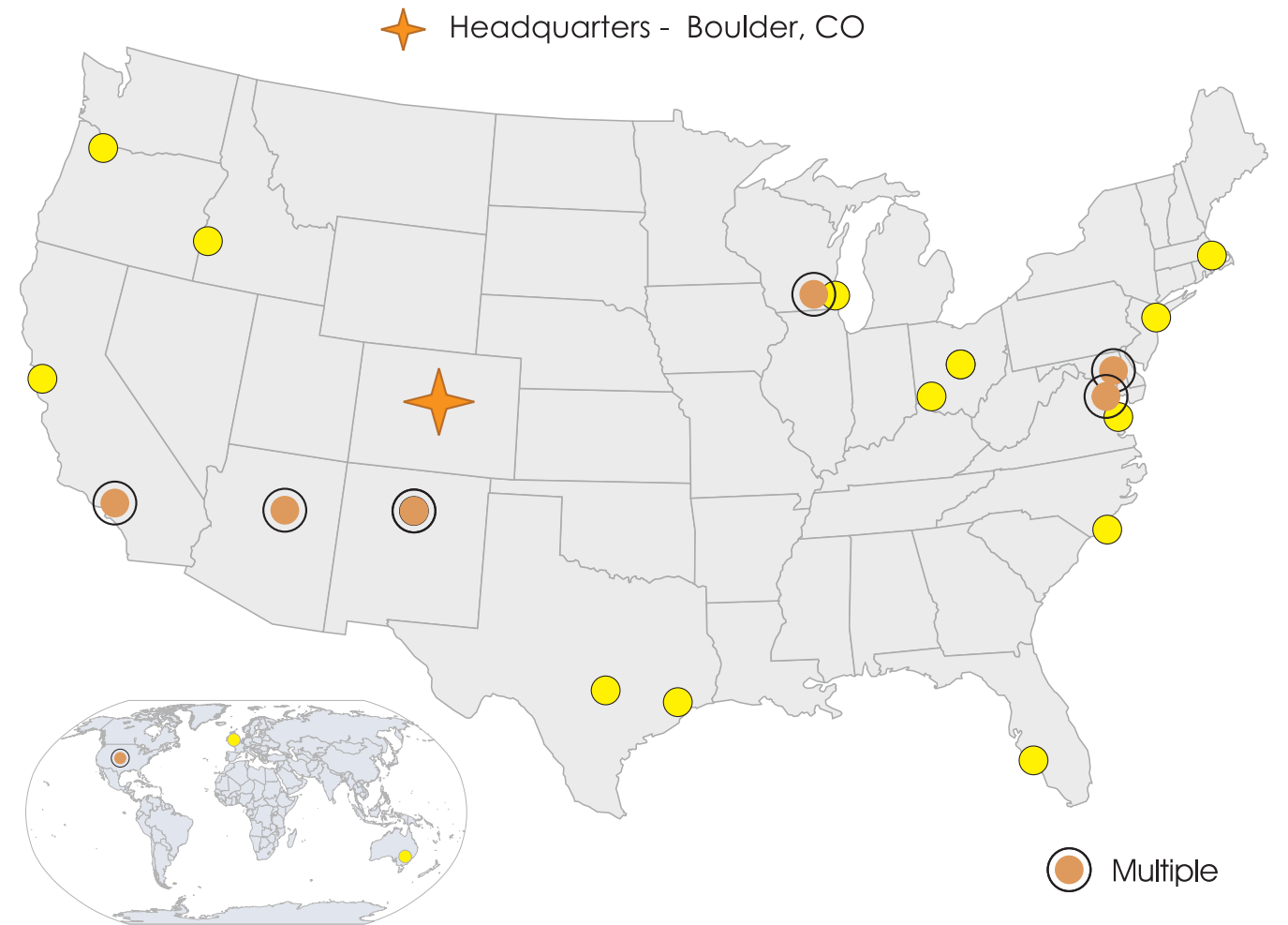


FLIGHT OPS



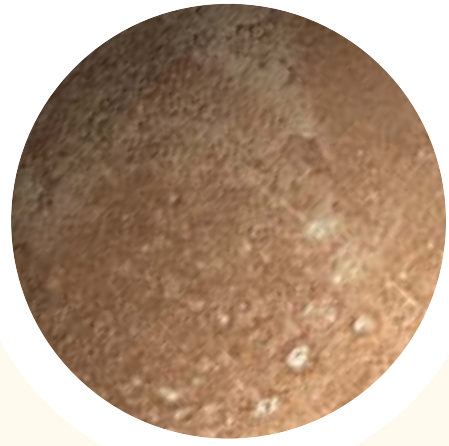
NCIL

Space Science Institute On-Site and Off-Site



"When we try to pick out anything by itself, we find it hitched to
everything else in the universe."

John Muir
"My First Summer in the Sierra" 1911



2013 Board Members:

- Dr. Paul Dusenbery, Executive Director, Space Science Institute
- Mr. Mark Eggleston (Treasurer), Vice President of Finance, CableLabs, Inc.
- Ms. Ann Goldman, Co-Founder, Front Range Source
- Dr. Dick Green (Chair), 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
- Ms. Karen Leaffer (Secretary), Principal, Leaffer Law Group
- Dr. Bill Purcell, Senior Manager Advanced Systems, Ball Aerospace and Technologies Corporation
- Ms. Maddie Zeigler, Education Consultant

2013 Branch Directors:

- Dr. Paul Dusenbery (National Center for Interactive Learning)
- Dr. James Harold (Information Systems and Technology)
- Dr. Carolyn Porco (Flight Operations)
- Dr. Michael Wolff (Research)
- Mr. Carl Wuth (Business Operations)

SSI acknowledges the 2013 grants and contracts from the following organizations:

Applied Physics Laboratory
Arizona State University
Ideum
Jet Propulsion Laboratory/NASA
NASA
National Science Foundation
Planetary Science Institute
SETI
Science Systems & Applications, Inc.
Smithsonian Astrophysical Observatory
Southwest Research Institute

Space Telescope Science Institute
USRA
University of Arizona
University of California/Berkeley
University of California/Los Angeles
University of Southern California
University of Maryland
University of Washington
University of Wisconsin
Villanova University

SSI wishes to thank the generous individuals who contributed to the Space Science Institute in 2013:

- Paul and Michele Dusenbery
- Mark Eggleston
- Ann Goldman
- Richard Green
- Marilyn Johnson
- Steve Jolly
- Karen Leaffer
- Maddie Zeigler



**Space Science Institute
Summary Statement of Financial Position
as of December 31, 2013 and 2012**

	2013	2012
Assets		
<i>Assets</i>		
Cash and cash equivalents	\$ 207,020	\$ 116,355
Accounts receivable	1,186,592	1,286,068
Prepaid expenses and deposits	67,856	88,320
Net furniture, equipment, and property	18,745	25,351
<i>Total assets</i>	<u>\$ 1,480,213</u>	<u>\$ 1,516,094</u>
Liabilities and Net Assets		
<i>Liabilities</i>		
Accounts payable and accrued liabilities	\$ 375,859	\$ 634,476
Deferred revenues	351,187	490,109
Line of credit	341,870	-
<i>Total liabilities</i>	<u>1,068,916</u>	<u>1,124,585</u>
<i>Net assets</i>		
Unrestricted	405,802	384,462
Temporarily restricted	5,495	7,047
<i>Total net assets</i>	<u>411,297</u>	<u>391,509</u>
<i>Total liabilities and net assets</i>	<u>\$ 1,480,213</u>	<u>\$ 1,516,094</u>

**Summary Statement of Activities
for the years ended December 31, 2013 and 2012**

	2013	2012
Support and revenue		
Grants, contracts, and cooperative agreements	\$ 5,746,316	\$ 5,723,763
Contributions	11,400	6,960
Exhibit income	147,500	216,498
Interest income	149	259
Other income	-	99
<i>Total support and revenue</i>	<u>5,905,365</u>	<u>5,947,579</u>
Expenses		
Program services	4,488,176	4,574,203
General and administrative	1,397,401	1,333,185
<i>Total expenses</i>	<u>5,885,577</u>	<u>5,907,388</u>
Change in net assets	<u>19,788</u>	<u>40,191</u>
Net assets, beginning of year	<u>391,509</u>	<u>351,318</u>
Net assets, end of year	<u>\$ 411,297</u>	<u>\$ 391,509</u>

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, 2013 and 2012, from which the summarized information was derived. A copy is available upon request.

Left Page :: Earth from space showing a variety of terrestrial, oceanic, and atmospheric features. Credit: NASA/NOAA



Below :: Visitors to the Great Balls of Fire exhibit. Credit: NCIL @ SSI

We DISCOVER

In today's marketplace of ideas, SSI is a pioneer in remote employment, a mode that is particularly conducive to supporting researchers and, in turn, promoting scientific discovery.

In this environment, 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). Approximately 50 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.



We EDUCATE

America has a strong foundation of scientific inquiry and innovation on which to build. But it is the workforce of tomorrow that must meet the 21st Century challenges facing our nation and the world. The key to improving our STEM workforce is not to focus solely on an individual student, or teacher, or even an individual classroom, but to explore how we can transform whole communities in how they view and support STEM. NCIL employs a strategy of *transforming*

Below :: An artist's concept of the planets in the Kepler-37 system compared to the moon and planets in our solar system. Credit: NASA/Ames/JPL-Caltech



Searching For Alien Earths

In February 2014, NASA announced the discovery of the smallest known planet outside of our solar system, around a star called "Kepler-37". The alien world is smaller than Mercury, nearly as small as Earth's moon, and is part of a three-planet system. SSI Research Scientist Travis Metcalfe (Boulder, CO Office) used observations from the Kepler space telescope to pin down the precise sizes of the planets from the natural vibrations of their parent star, using a technique known as astero-seismology.



communities as a way of addressing two critical needs facing our country: 1) Enhancing general STEM literacy because public policy matters often involve complex STEM-related issues and 2) Increasing the number of young people pursuing STEM careers by providing opportunities and encouragement to those who are underserved and underrepresented in STEM disciplines.

For over a decade, NCIL educators have been exploring the potential of digital media, ranging from interactive experiences for museums and libraries to online games and now smartphone and tablet apps. The potential of digital media only increases as portable, connected devices become more commonplace, allowing us to reach people in a variety of different environments and contexts. This means an increased opportunity to impact formal education and to reach people in all walks of life raising the general science literacy of the public. Our approach is reinforced by NSF's Cyberlearning Task Force, which recently recommended that educators "emphasize the transformative power of information and communications technology for learning, from K to grey", and explore technologies that allow interaction with scientific data and visualizations while bridging multiple learning environments.

Our Vision for the Future

The nature of STEM education is undergoing profound changes. Discovery, innovations, and inventions are the keys to a healthy and prosperous future, and science research has a critical role to play in that future. Science and engineering in the United States rest on three pillars:

1. **A strong research infrastructure;**
2. **A scientifically literate populace that supports investments in research; and**
3. **A pipeline of future STEM professionals.**

By providing high quality organizational, legal, and administrative support, SSI makes it possible for researchers to conduct research outside traditional universities and research institutes,

Our patrons **LOVED** the exhibit while it was here, and have been very enthusiastically attending related STEM programs that we have planned since then.

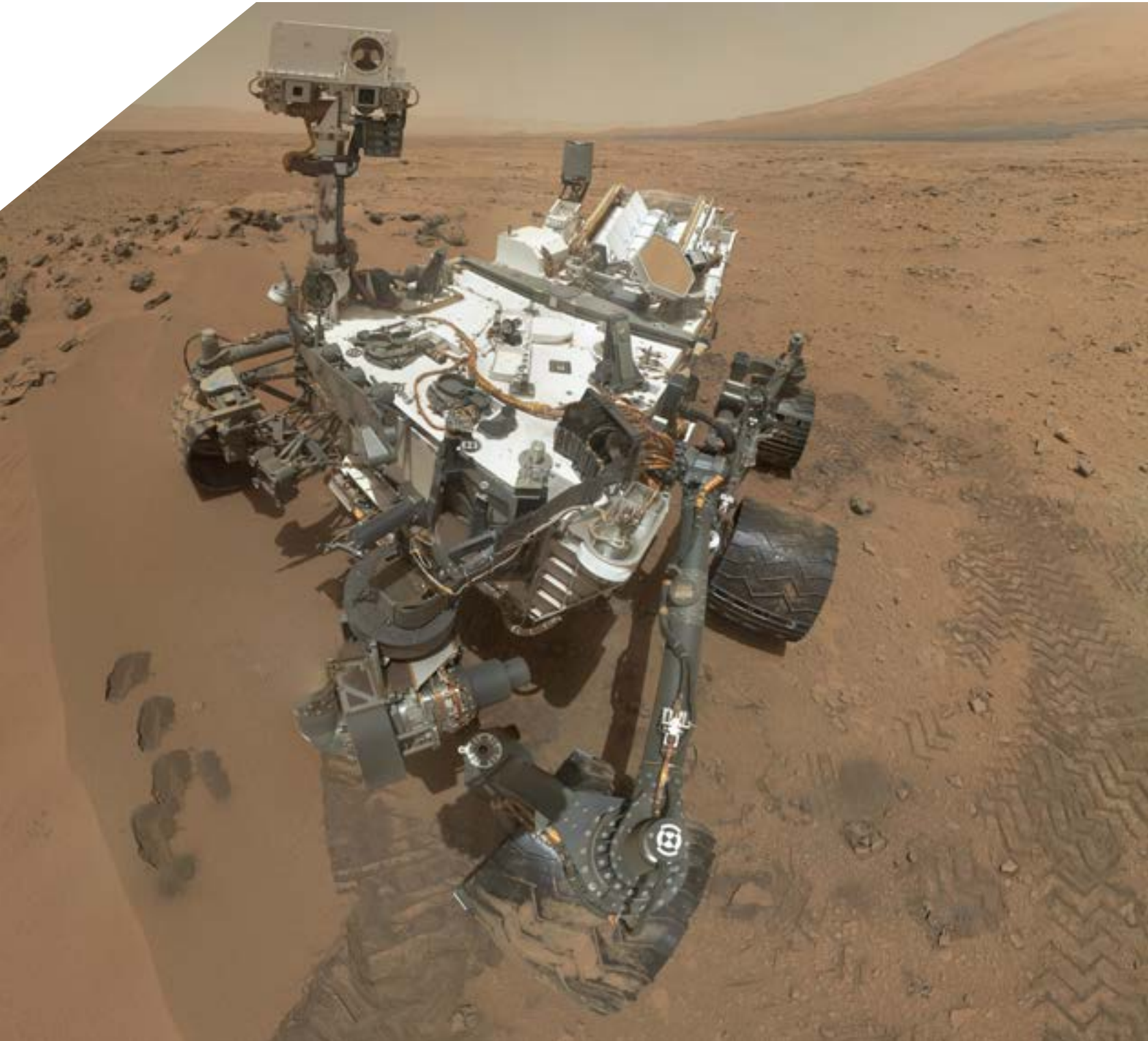
- STAR_Net librarian

including long-distance collaborations with colleagues in the U.S. and abroad. Traditional research institutions and public universities are struggling under the pressures of financial challenges and aging research facilities. SSI provides a non-traditional research structure, namely, the ability to work remotely from a "bricks and mortar" institution. This offers a unique personal and professional flexibility to top-notch scientists, who might otherwise leave research entirely.

The education system in the United States is currently experiencing one of the largest shifts in recent memory. Continuing well into the future, there will be a transformation away from traditional classroom environments, toward a more engaging, "learning-by-doing" approach to youth education. Skills such as problem solving, critical thinking, STEM literacy, and collaboration, or *21st Century* skills, are highly related to student success and are beginning to appear in curricula across the nation (in both formal and informal learning environments like science centers, museums, and public libraries). The U.S. will not be able to meet the STEM workplace demands of the future if we are not able to engage, inspire, and educate our growing diverse populations in a variety of STEM disciplines.

SSI and its research, education, and community partners are committed to addressing the *21st Century* challenges facing our nation (e.g., climate change, decreasing biodiversity, access to clean water, threats to human health) by advancing scientific understanding, engaging the public in STEM learning opportunities, and inspiring youth to pursue STEM careers. The STEM workforce of tomorrow requires highly competent STEM professionals and a public that is sufficiently STEM literate to assess the choices before them. Beyond addressing the challenges of today, STEM achievement is an investment in tomorrow's innovators and innovations.

RESEARCH



Left Page :: The NASA Curiosity rover explores the Martian surface, including wind-blown dust. Mt. Sharp is in the background. Credit: NASA, JPL-Caltech, MSSS, MAHLI

SSI's Research Branch scientists investigate physical phenomena in a broad range of space related fields: earth science, space physics, planetary, exoplanetary science, and astrophysics. For example, SSI researchers study processes on Earth's surface, on the Sun and in the solar wind through its interaction with Earth's magnetosphere. They seek to understand the origin and evolution of comets and asteroids whose collisions with other bodies may have profound effects on life on Earth. Their observational and theoretical work probes the atmospheres and surfaces of other bodies in our solar system, such as Saturn, Jupiter and their moons. SSI scientists also investigate how stars and their planetary systems form, particularly in the context of the hundreds of planets discovered to be orbiting other stars. Additional research focuses on our own Milky Way Galaxy and other, more distant galaxies that contain massive black holes in their centers.

SSI researchers use state-of-the-art space facilities, for example, the Kepler, Herschel, Fermi, NuSTAR, Spitzer and Hubble space telescopes. Efforts also include work on instrumentation for the James Webb Space Telescope, the successor to the Hubble to be launched in 2018. They employ data produced by the numerous spacecraft on and around Mars: the Mars Science Laboratory, Mars Exploration Rovers, Mars Odyssey, and Mars Reconnaissance Orbiter missions. Closer to home, SSI researchers use the new astrophysical facility SOFIA, an airborne observatory, and high-altitude facilities such as those on the dormant volcano of Mauna Kea, Hawaii as well as the Atacama Desert of Chile.

SSI's researchers are supported through a mixture of grants and contracts awarded by the federal government, primarily NASA and the National Science Foundation (NSF). Our organization and infrastructure facilitate collaborations between individuals in different areas of research (e.g., comets and exoplanets) who might typically be separated into different departments at academic institutions. This entrepreneurial spirit motivates our search for new and creative projects at the forefront of scientific research.

Research Center Updates

In 2012, SSI formed three new research centers: *Center for Space Plasma Physics* (CSPP); *Center for Extrasolar Planetary Systems* (CEPS); and *Center of Mars Science* (CMS). The mission of CSPP is to carry out scientific research that will increase our understanding of fundamental and applied aspects of space plasmas. The mission of CEPS is to capitalize on the need to combine multiple fields of study in order to carry out scientific research that



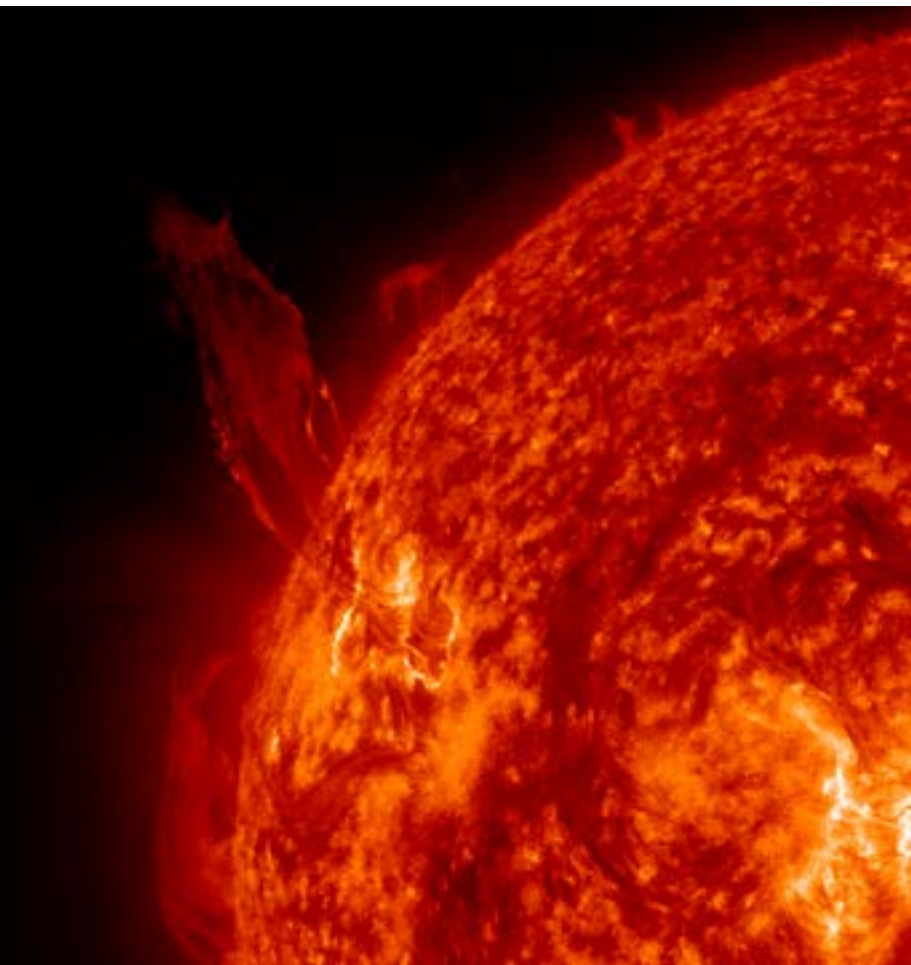
characterizes the fundamental properties of extrasolar planets and the systems in which they are found. The focus of CMS is to provide synergistic science opportunities between existing Mars surface and atmospheric research efforts.

Center for Space Plasma Physics

(CSPP Chair, Dr. Joe Borovsky, Los Alamos, NM Office).

In 2013, CSPP initiated a diverse research effort involving theory, spaceflight-data analysis, and ground-based experiments aimed at increasing our understanding of the plasma physics of the solar wind and Earth's magnetosphere and ionosphere. Research highlights

include the development of novel spacecraft-data analysis techniques that examine the nature and characteristics of plasma waves and fluctuations at very small scale sizes, the development and analysis of computer simulations of these types of waves in the solar-wind plasma, advancing the theoretical understanding of magnetic-field-line reconnection in plasmas, and the application of reconnection theories to the interaction of the solar wind with Earth's magnetosphere. Related research highlights for the ionosphere were the development of techniques to exploit ionospheric radar, optical, and magnetic-field measurements to remotely monitor the rate of magnetic-field-line reconnection



Left Page :: An erupting prominence escapes the Sun. Credit: Solar Dynamics Observatory/NASA

between the solar wind and Earth's magnetosphere and the optical observation of the airglow from energetic electrons precipitating from the magnetosphere into the upper atmosphere triggered by the turn-on of a powerful military ground-based VLF transmitter. In 2013, the 7 members of CSPP published 28 papers in refereed journals: 13 papers as primary authors and 15 papers as contributing authors.

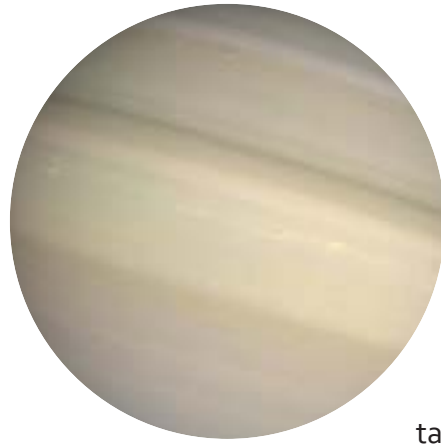
In September 2013, CSPP hosted a week-long, SSI-sponsored, international workshop entitled "10th Cambridge Workshop on Magnetic Reconnection" (<http://www.space-science.org/icwm/>). The workshop, organized by Dr. Joachim Birn, was held at the historic Hotel La Fonda in Santa Fe, NM. The Cambridge Workshop series originated in 2004 as a month-long workshop in Cambridge, England. Because of the success of this event, participants decided to continue collaboration through annual weeklong workshops, alternating between Europe and the United States. The focus of the Santa Fe workshop was three-fold: recent progress in reconnection physics, outstanding questions, and future research.

Center for Extrasolar Planetary Systems

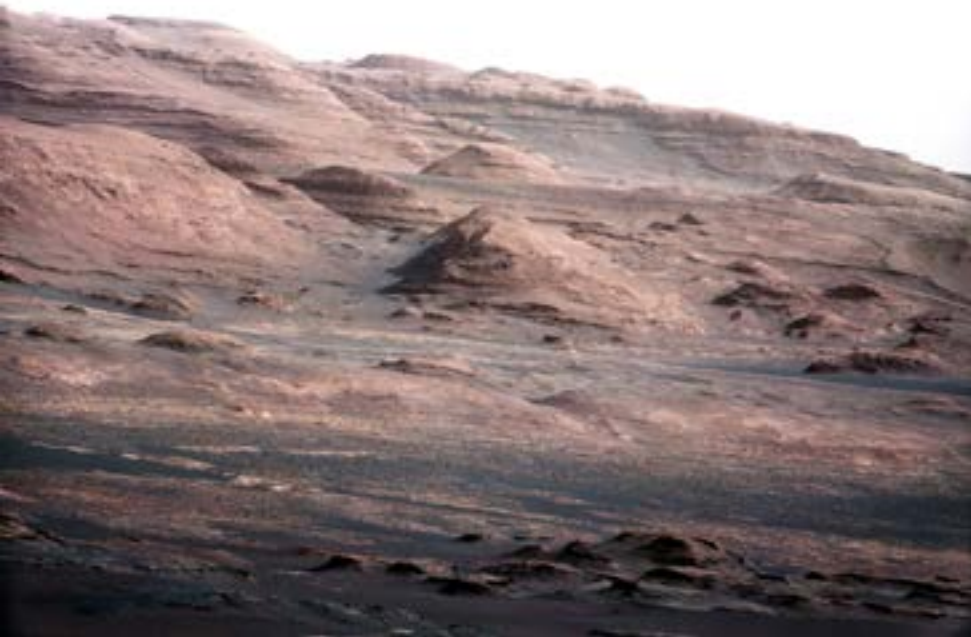
(CEPS Chair, Dr. Julianne Moses, Seabrook, TX Office).

The study of extrasolar planets and planetary systems is one of the fastest growing and most exciting fields within astronomy and astrophysics. Recognizing the importance and timeliness of the field, SSI inaugurated the *Center for Extrasolar Planetary Systems* (CEPS) in 2012 as part of SSI's long-term strategic plan. Because the field is by nature multidisciplinary, CEPS brings together astronomers, physicists, atmospheric scientists, and planetary scientists to provide a forum for the exchange of ideas and expertise. Current research focus areas for CEPS include studies of the properties of planet-hosting stars, the chemistry and physics of exoplanet atmospheres, the influence of the host star on the planet and/or system characteristics, the formation and evolution of planetary systems, and the signatures of planetary formation as reflected in debris disks.

In 2013, the twelve CEPS members published more than 30 refereed scientific articles on extrasolar planetary systems, including papers on astero-seismology and related analyses of Kepler host stars, observational and theoretical characterization of protoplanetary disks, and combined theoretical and observational studies of exoplanet atmospheric composition. CEPS members are scattered throughout the country, and communication has been through email and periodic telecons. Recent meetings have included presentations by Dr. Julianne Moses on exoplanet composition, Dr. Dean Hines on planetary systems



associated with white-dwarf stars, and Dr. Mike Wolff on radiative transfer and exoplanets. Telecons typically include discussions of funding resources and potential collaborative activities. Throughout 2013, individual CEPS members have interpreted data from space-based and ground-based telescopes, performed theoretical modeling calculations, written journal articles, presented conference talks, and submitted proposals to NASA, NSF, and various other funding agencies, including observatories. Such activities will continue in the coming years as CEPS members seek to further our understanding of the amazing diversity of planetary systems beyond our solar neighborhood.



Center for Mars Science

(CMS Chair, Dr. Bill Farrand, Boulder, CO Office).

CMS launched in the fourth quarter of 2013. With the breadth of expertise in different aspects of Mars science, CMS looks forward to collaborating on future endeavors. In the inaugural quarter of operation, CMS initiated a discussion amongst its members about what those future endeavors might be.

CMS did have an initial “Journal Club” teleconference discussion by Dr. Wolff on evidence for the presence of only a very small amount of methane in Mars’ atmosphere, contrary to some reports of significant amounts. Among other activities, CMS plans to establish regular journal club teleconferences.

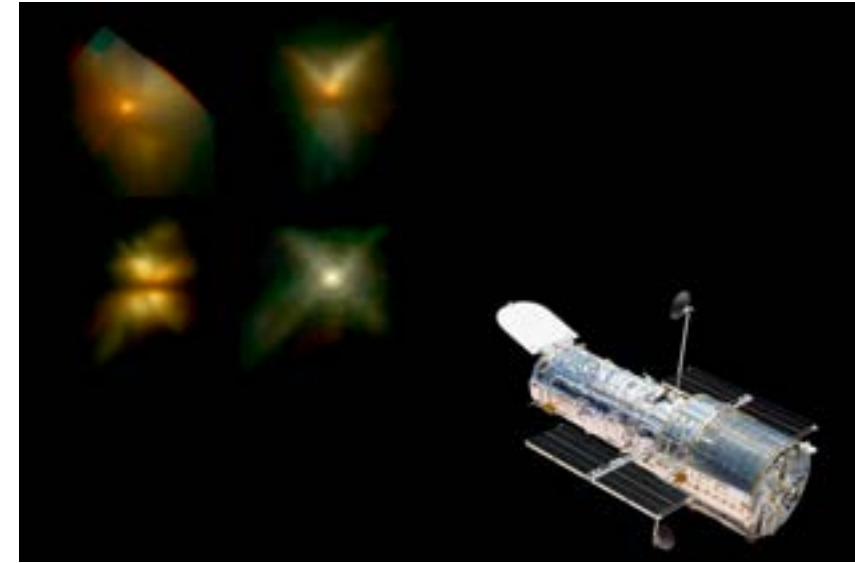
Above :: The Mt. Sharp region of Mars taken by NASA’s Curiosity Rover. Credit: NASA/JPL

Below :: Hubble Space Telescope observing the scattered light of YSOs at near-infrared wavelengths. Credit: STScI & D. Padgett/NASA/GSFC

2013 Research Highlights

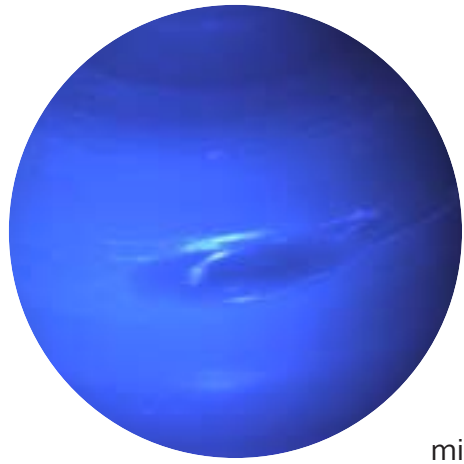
From Dust Grains to Planets

Young stellar objects (YSOs) are stars in the earliest stages of development. They evolve from a state dominated by a circumstellar envelope, which eventually collapses along magnetic field lines onto a disk surrounding the central star. The disk material itself falls onto the evolving young star. Planets form and grow in the disks from dust grains that begin with the very small sizes found in the interstellar medium. That is to say, planets begin with particles of sizes typically less than 1 micrometer to sizes of greater than 6000 km. Light from the forming central star is reflected from the small dust grains surrounding the star to produce distinctive light signatures (known as polarization). Studying the polarized light in these regions provides insight into the size and spatial distribution of the dust grains. These properties change as the YSO evolves.



SSI Research Scientist Dr. Erica Rodgers (Yorktown, VA Office) uses observations from the Hubble Space Telescope’s Near Infrared Camera and Multi-Object Spectrometer (NICMOS) to study the dust grains in YSOs. A radiation transfer model developed by SSI Senior Research Scientist Dr. Barb Whitney (Madison, WI Office) is used to simulate the processes mentioned above. These model results are compared to actual YSO brightness observations, and NICMOS polarization and scattered light imaging observations.

Dr. Rodgers’ research indicates that as the YSOs get older, the dust grains in the circumstellar disk get larger and then begin to settle in the midplane of the disk. These are early signs of planet formation, and confirm previous hypotheses. Rodgers also has also confirmed that the use of simple “shapes” for the dust grains of various sizes does not provide an accurate representation of the real dust grains. One must utilize more realistic particle shapes, as Dr. Rodgers is doing in order to probe the YSO environments.



Extrasolar Planetary Atmospheres: Cloudy With a Chance of Dustballs

As of March 2014, a total of 1771 planets have been detected outside our own solar system, not including an additional few thousand “planetary candidates” identified from NASA’s Kepler mission. Some of these extrasolar planets periodically move (or “transit”) in front of and behind the host star, causing a slight dip in the amount of light seen from the system. When an exoplanet passes in front of its star, the stellar light passes through the planet’s atmosphere on its way to the observer, and the wavelength dependence of the signal provides information about the presence of absorbing gases or clouds in the planet’s atmosphere. When the exoplanet passes behind the star, the contribution light from the planet drops out of the signal, and again, comparisons of the wavelength dependence of the observed emission before and during this occultation provide information about the planet’s atmospheric composition. Observations of transiting exoplanets have allowed the detection of specific atoms and molecules in the atmosphere of these planets, as well as aerosol particles (like dust or clouds).

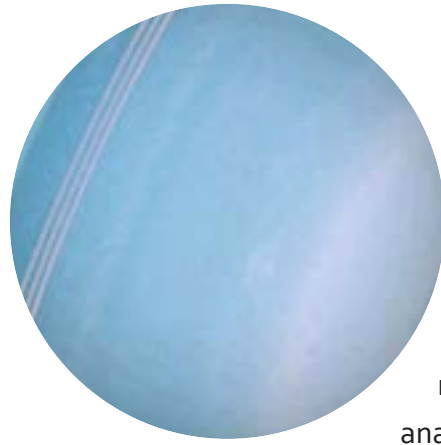


Left Page :: This artist’s conception shows sunrise over CoRoT-7b, the smallest known extrasolar planet. Credit: NASA/GSFC

SSI Senior Research Scientist Dr. Julianne Moses (Seabrook, TX Office) studies the atmospheric chemistry and composition of extrasolar planets through comparisons of theoretical models with ground-based and spacecraft-based transit observations. Characteristics such as the planet’s mass, orbital properties, bulk elemental composition, evolutionary history, and incident stellar radiation combine to produce specific atmospheric temperatures and composition. Dr. Moses has developed a complex thermochemical and photochemical kinetics and transport model to investigate how chemical processes regulate and modify the observable atmospheric composition as a function of these planetary characteristics. Many of the observed transiting exoplanets orbit very close to their host stars, leading to very hot atmospheres that are expected to contain exotic clouds composed of silicate dust or salts rather than our more familiar water vapor or ice clouds found in our solar system. The gas composition above the clouds also differs markedly from that of our “local” planets. These very interesting transit signatures are found for many exoplanets, including those between the size of Earth and Neptune – a size range that appears to dominate the exoplanet population within our galaxy. These intermediate-sized exoplanets represent a new intriguing class of planet, and Dr. Moses is investigating how the expected variable bulk hydrogen content on these planets can lead to highly diverse, often exotic, atmospheric compositions compared with solar system standards. Her theoretical models help with the interpretation of data from current spacecraft missions (e.g., *Spitzer and Hubble Space Telescope*), as well as planning for future missions (e.g., *James Webb Space Telescope*).

Exploring the Endeavour Crater on Mars

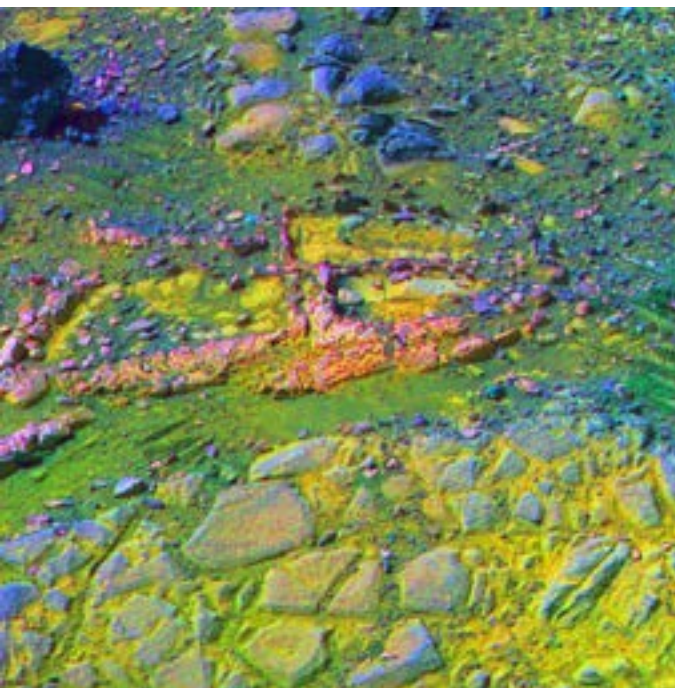
Despite being its 11th year of exploring the Martian region known as Meridiani Planum, the Opportunity rover continues to provide exciting scientific discoveries. SSI Senior Research Scientist Dr. Bill Farrand (Boulder, CO Office), a science team member since 2002, has been involved in directing Opportunity activities (as well as the companion rover, Spirit) such as driving, imaging, and exploring. Opportunity is now investigating terrain older than any previously explored. It has been exploring the rim of the ancient 22 km diameter Endeavour crater. In mid-2013, Opportunity finished examining the first segment of the crater rim known as Cape York and made its way to the next portion, known as Solander Point. Before leaving Cape York, Opportunity made a number of profound discoveries, including the characterization of light-toned fracture filling material containing abundant hydrated silica and Al-bearing smectite clays (not unlike swelling clays that fracture sidewalks and driveways along the Front Range of Colorado). Measurements of the chemistry of those materials were made with the rover’s Alpha Particle X-Ray Spectrometer (APXS), with SSI Senior



Below :: A spectrally transformed image of an area on the rim of Endeavour Crater that was examined by Opportunity. Credit: NASA/JPL-Caltech/Cornell/ASU

Research Scientist Dr. Ben Clark (Littleton, CO Office) playing a key role in the analysis of those results.

Additional information on the nature of the outcrop and surrounding materials was provided by multispectral images collected by the rover's Pancam imager. Dr. Farrand has played a major role in the analysis of the images obtained by the Pancam camera. An example of his work is shown in the attached figure, which combines the data from 11



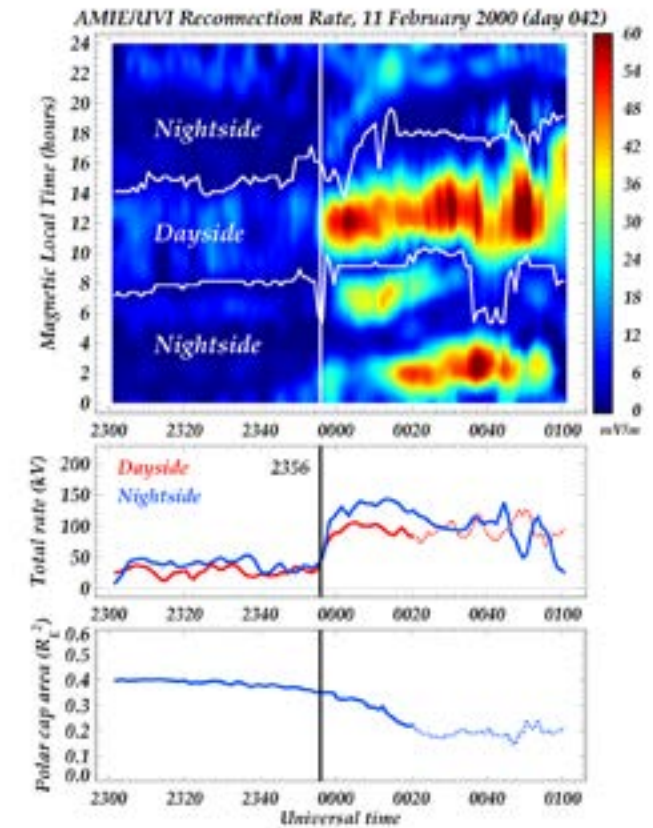
visible and near infrared channels or wavelength bands. The Pancam imagery highlights the unique character of the material that fills the fractures in the rocks. Spectra of this material indicate the presence of bound water, a very important clue in understanding the past climate of Mars. By comparing the Opportunity data to measurements of terrestrial analog materials, Dr. Farrand is better able to assess the type of environment in which this vein material formed. Information provided by the APXS, as analyzed by Dr. Clark, indicates that the clay and hydrated silica materials likely formed in a neutral pH environment that could have been hospitable to life. Both Drs. Farrand and Clark are co-authors on a paper published earlier this year in *Science* that examines these results in detail.

Magnetic Reconnection after Solar Wind Dynamic Pressure Enhancements

The continuous flow of charged particles emanating from the Sun is called the solar wind. The dominant mechanism by which mass, energy, and momentum flow from the solar wind to the Earth's magnetic environment, or the magnetosphere, is magnetic reconnection. Magnetic reconnection at the interface between the solar wind and the magnetosphere, called the magnetopause, changes the magnetic field topology at the dayside (from closed

Below :: Reconnection rate as a function of UT and MLT for 11-12 February 2000. Credit: A. Boudouridis

magnetic field lines with both feet on Earth to open field lines with one foot in the solar wind) and transports magnetic flux to the nightside. Subsequent reconnection at the nightside, the so-called magnetotail, closes the open field lines again and returns the magnetic flux to the dayside. The magnetic reconnection rates on the dayside and nightside magnetosphere control the field topology and the state of the system. This manifests through a multitude of processes such as particle precipitation at high latitudes, generation of electrical currents, and plasma convection. It is therefore of primary importance to understand the main drivers of magnetic reconnection in Earth's magnetosphere, and the rates by which magnetic reconnection occurs.



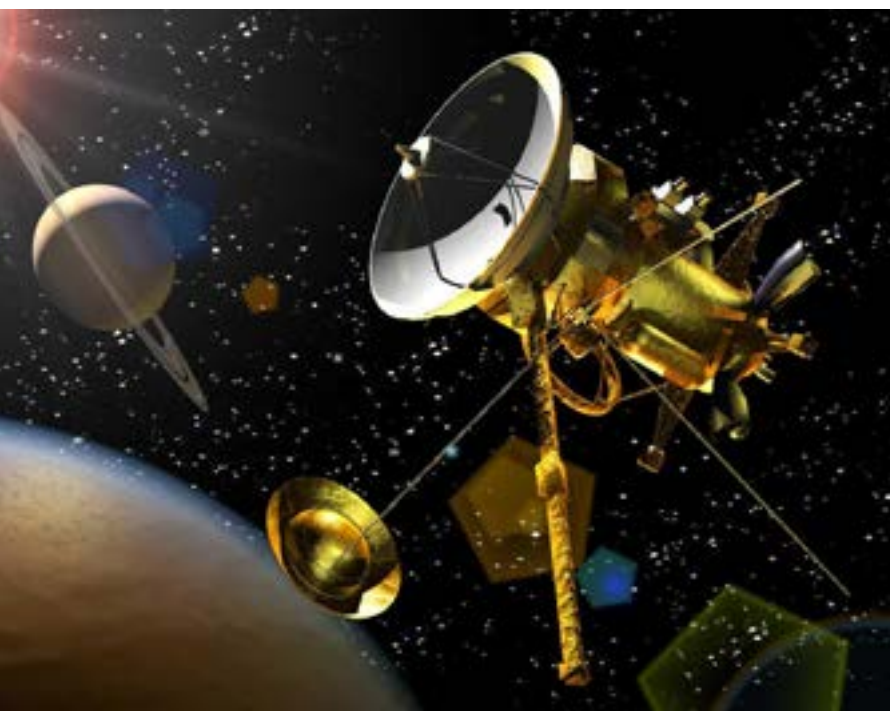
SSI Research Scientist Dr. Athanasios Boudouridis (Boulder, CO Office) has been studying one of these drivers, namely sudden solar wind dynamic pressure enhancements or pressure fronts, for the past decade. He found that solar wind dynamic pressure fronts can intensify the auroral brightness, reduce the size of the polar cap, enhance ionospheric convection, and intensify magnetospheric and ionospheric current systems. All these phenomena are consistent with the enhanced reconnection rate on the dayside. The reduction of the polar cap size, however, implies enhanced nightside reconnection at a rate higher than that on the dayside. Based on the above observations, Dr. Boudouridis has postulated that enhanced nightside reconnection occurs after pressure fronts due to the compression of Earth's magnetotail.

Recently, Dr. Boudouridis used a well known technique to measure the reconnection rate separately on the dayside and the nightside, before and after a dynamic pressure front at 2356 Universal Time (UT) on 11 February 2000. The results are shown color-coded in the attached figure (top panel) as a function of UT and Magnetic Local Time (MLT). The white lines delimit the dayside and the nightside rates. Integrating the two rates in MLT gives the total dayside (red) and nightside (blue) rates in the middle panel. It can be seen that the nightside rate is initially higher than the dayside rate, and as a result the polar cap area (bottom panel) is reduced. This is exactly what was observed for this and other cases by Dr. Boudouridis in the past.



FLIGHT OPS

The Cassini Imaging Central Laboratory for Operations (CICLOPS) is located at SSI's Headquarters Office in Boulder, CO. CICLOPS is led by Cassini Imaging Team leader Dr. Carolyn Porco. It 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.



Launched in 1997, the Cassini-Huygens mission continues to change our view of the Saturn system. Since its encounter with Jupiter in 2000/2001, and especially since dropping into orbit around Saturn in 2004, Cassini images have 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. 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

Left Page :: An artist's conception of the Cassini spacecraft at Saturn. Credit: NASA

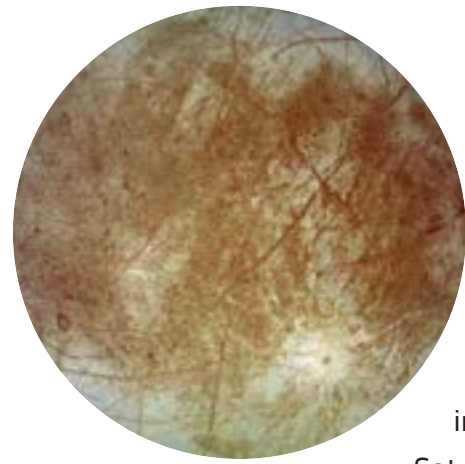
revelation that Saturn's small, icy moon Enceladus may possess underground reservoirs of liquid water has widened our perception of the range of environments that might be hospitable for life.

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

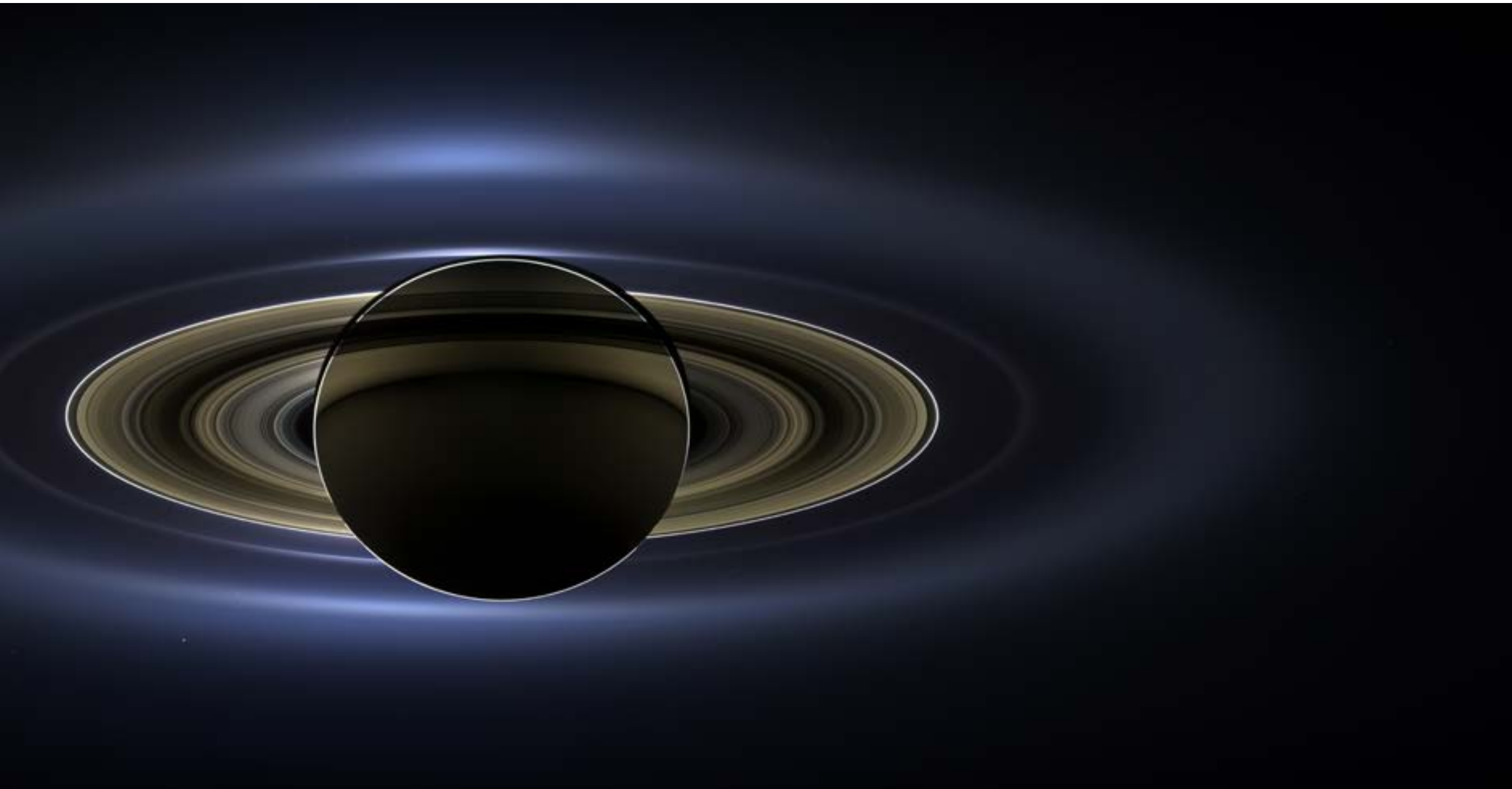
The Day Earth Smiled

In an attempt to improve upon the iconic Pale Blue Dot picture of Earth taken by the Voyager spacecraft in February 1990, Cassini Imaging Team Leader Dr. Carolyn Porco, together with her research associates and CICLOPS staff members looked for the best opportunity to take an image of Earth from Saturn orbit. Cassini does not attempt many images of our planet because it is so close to the sun as seen from Saturn that an unobstructed view would damage the spacecraft's sensitive detectors. Consequently, Porco and her collaborators searched the Cassini trajectory for a time when the sun would slip behind Saturn from Cassini's point of view. Such a time came on July 19th for a rare and special event that was celebrated worldwide. On that date Cassini turned its cameras towards Saturn and captured a spectacular mosaic of the Saturn system, the first in which Saturn, its moons and rings, and Earth, Venus and Mars, are all visible. Successful social media campaigns promoted the July 19th event and, encouraged by Dr. Porco, people around the globe stopped, looked up and greeted Cassini cameras in a worldwide photo op.



Below :: From Saturn's shadow Cassini captures a backlit Saturn system in this rare mosaic featuring Earth in the lower right quadrant of the image. Credit: Cassini Imaging Team and NASA/JPL/SSI

The panoramic mosaic released on November 12, 2013, shown below, shows the view of Saturn as it would be seen by human eyes. The mosaic was made by stitching together 141 wide-angle images. The image sweeps 404,880 miles (651,591 kilometers) across Saturn and its inner ring system. In an annotated version of the mosaic numerous points of interest are labeled. Earth, Venus, Mars, seven Saturnian moons, all of Saturn's rings out to the E ring and 809 background stars can all be seen. Zooming into the image reveals even more subtle details in the mosaic, from the spectacular icy plumes on Enceladus to shadows casted on the bright E ring from various visible moons.



Cassini Highlights Section (all photos/artwork) :: Cassini Imaging Team and NASA/JPL/SSI

2013 Cassini Highlights

Cassini Sights Titan's Northern Land of Lakes

In 2013 NASA's Cassini spacecraft was able to obtain new pictures of the liquid methane and ethane seas and lakes that reside near Titan's north pole. The images reveal clues about how the lakes formed and about Titan's Earth-like "hydrologic" cycle, which involves hydrocarbons rather than water.

Several factors combined in 2013 to give Cassini instruments great observation opportunities which until then had only provided partial distant views of the area. Sunlight has begun to

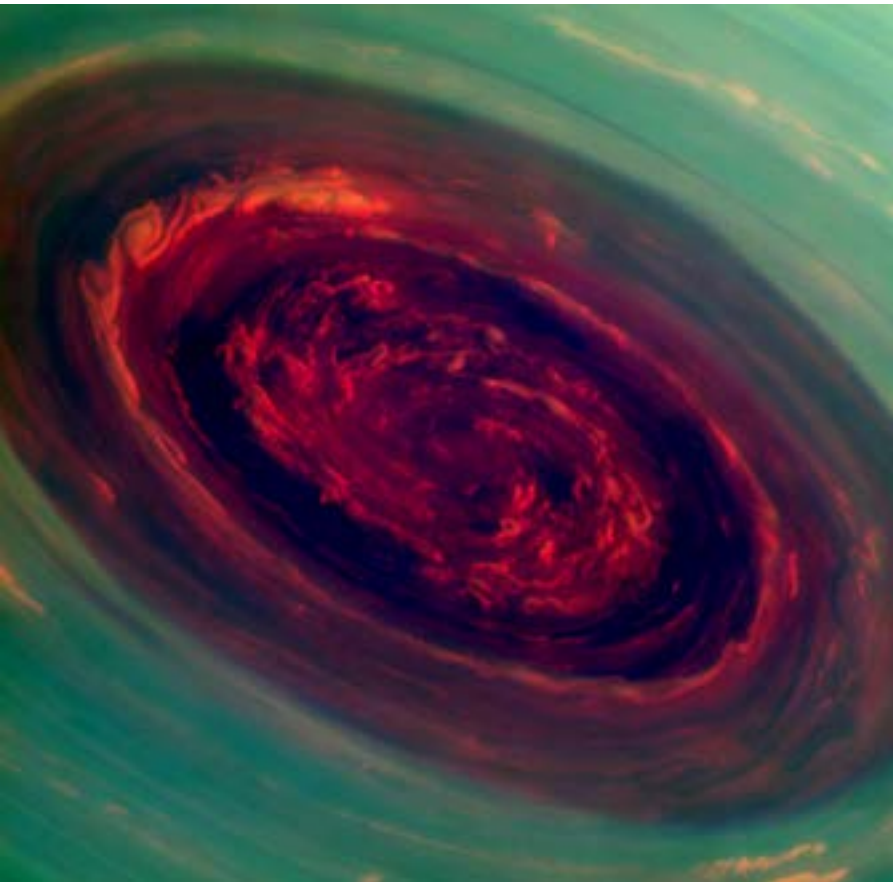
pierce the winter darkness that shrouded Titan's north pole at the time of Cassini's arrival in the Saturn system nine years ago. A thick cap of haze that once hung over this region has also dissipated as northern summer approaches. And Titan's beautiful, nearly cloudless, rain-free weather continued during Cassini's flybys this past summer.

A colorized mosaic from the visual and infrared mapping spectrometer reveals differences in the composition of material around the lakes. The data suggest parts of Titan's lakes and seas may have evaporated and left behind the Titan equivalent of Earth's salt flats. Only at Titan, the evaporated material is thought to be organic chemicals originally from Titan's haze particles that once dissolved in liquid methane. A bright area in the new near-infrared images suggests that the surface of Titan's northern terrain is unique from the rest of Titan and might explain why almost all of the lakes on Titan are found in the north. This area has not previously been visible in the data.



The Red Rose of Saturn

The arrival of spring in Saturn's northern hemisphere, and the approach towards summer, has peeled back the darkness of winter and given Cassini direct views of Saturn's giant, swirling, hurricane-like vortex at its northern pole. False color images and a movie released in 2013 are some of the first sunlit views of the vortex captured by Cassini's cameras.

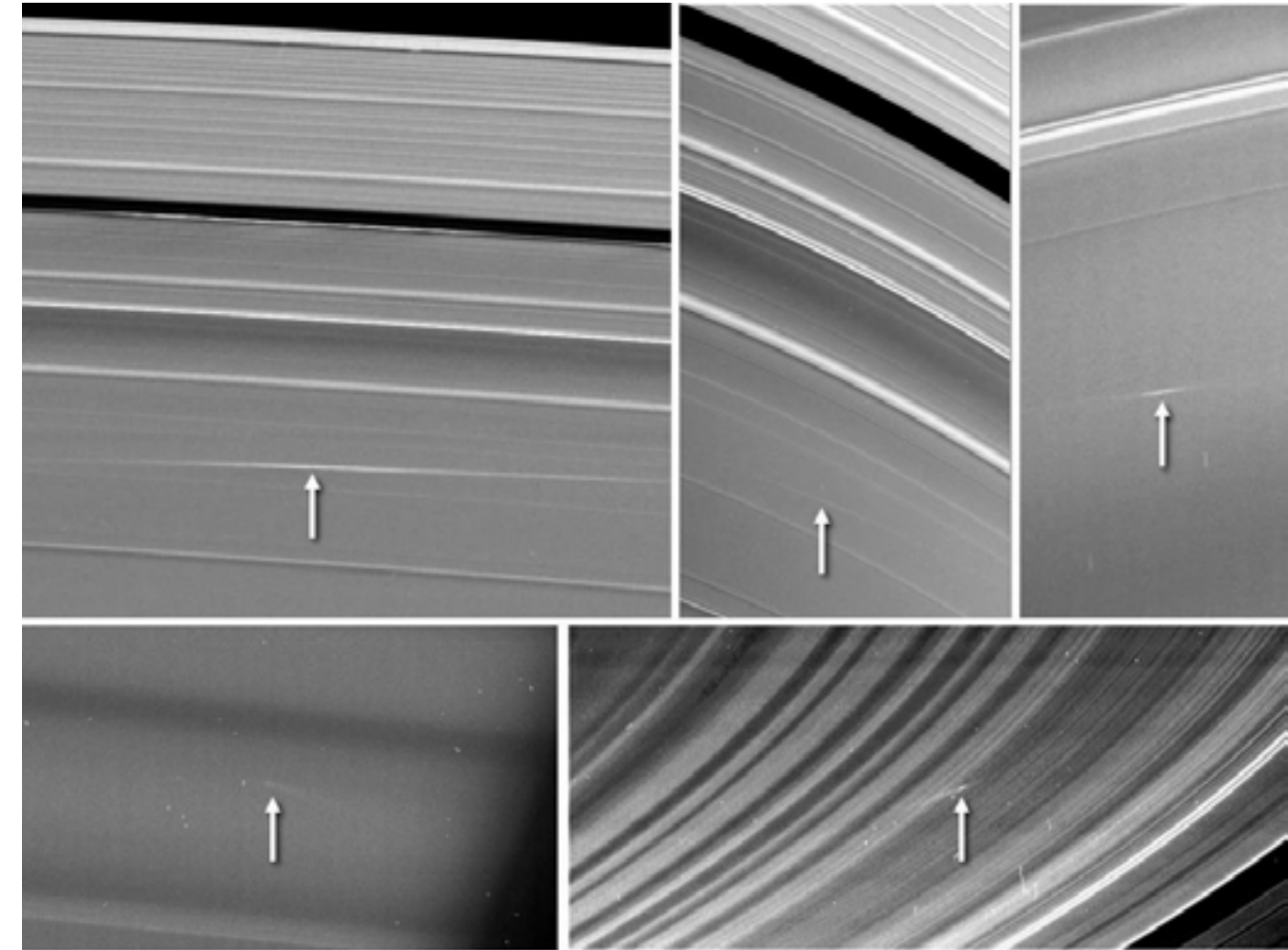


The eye of the vortex is about 1,250 miles (2,000 kilometers) wide, 20 times larger than the average hurricane eye on Earth. Thin, bright clouds at the outer edge of the vortex are traveling 330 miles per hour (150 meters per second) and swirl inside a large, mysterious, six-sided weather pattern known as the hexagon. Differences and similarities exist between Saturn's north polar vortex and hurricanes on Earth. Scientists will be studying the vortex and learning how these Saturnian storms use water vapor which could provide insight about how terrestrial hurricanes are generated and sustained on Earth.

NASA Probe Observes Meteors Colliding with Saturn's Rings

The Cassini spacecraft has provided the first direct evidence of small meteoroids breaking into streams of rubble and crashing into Saturn's rings. These observations, which appeared in a paper released in 2013, make Saturn's rings the only location besides Earth, the moon,

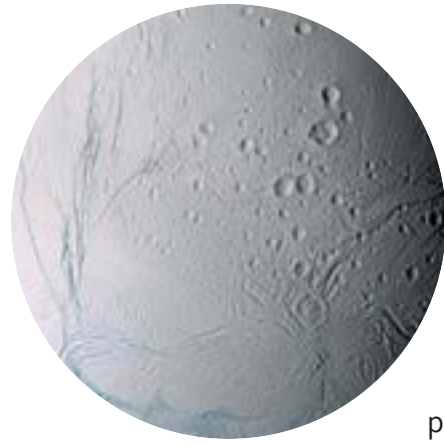
and Jupiter where scientists and amateur astronomers have been able to observe impacts as they occur. Studying the impact rate of meteoroids from outside the Saturn system helps scientists understand how different planet systems in the solar system formed.



The meteoroids at Saturn range from about one-half inch to several yards (1 centimeter to several meters) in size. It took scientists years to distinguish tracks left by nine meteoroids in 2005, 2009 and 2012. Saturn's rings act as very effective detectors of many kinds of

Left Page :: The Rose of Saturn is actually a gigantic vortex swirling at Saturn's north pole. Seen here in false color, the red color indicates low clouds and green indicates higher ones.

Above :: Five images of Saturn's rings, taken by Cassini between 2009 and 2012, show clouds of material ejected from the impact of small objects into the rings. The angle that the clouds are canted gives the time elapsed since the cloud was formed.



surrounding phenomena, including the interior structure of the planet and the orbits of its moons. Scientists can study the corrugations and shearing clouds in the rings and determine at what rate small particles are impacting the rings. The results from the published paper imply that current-day impact rates for small particles at Saturn are about the same as those at Earth, two very different neighborhoods in our solar system.

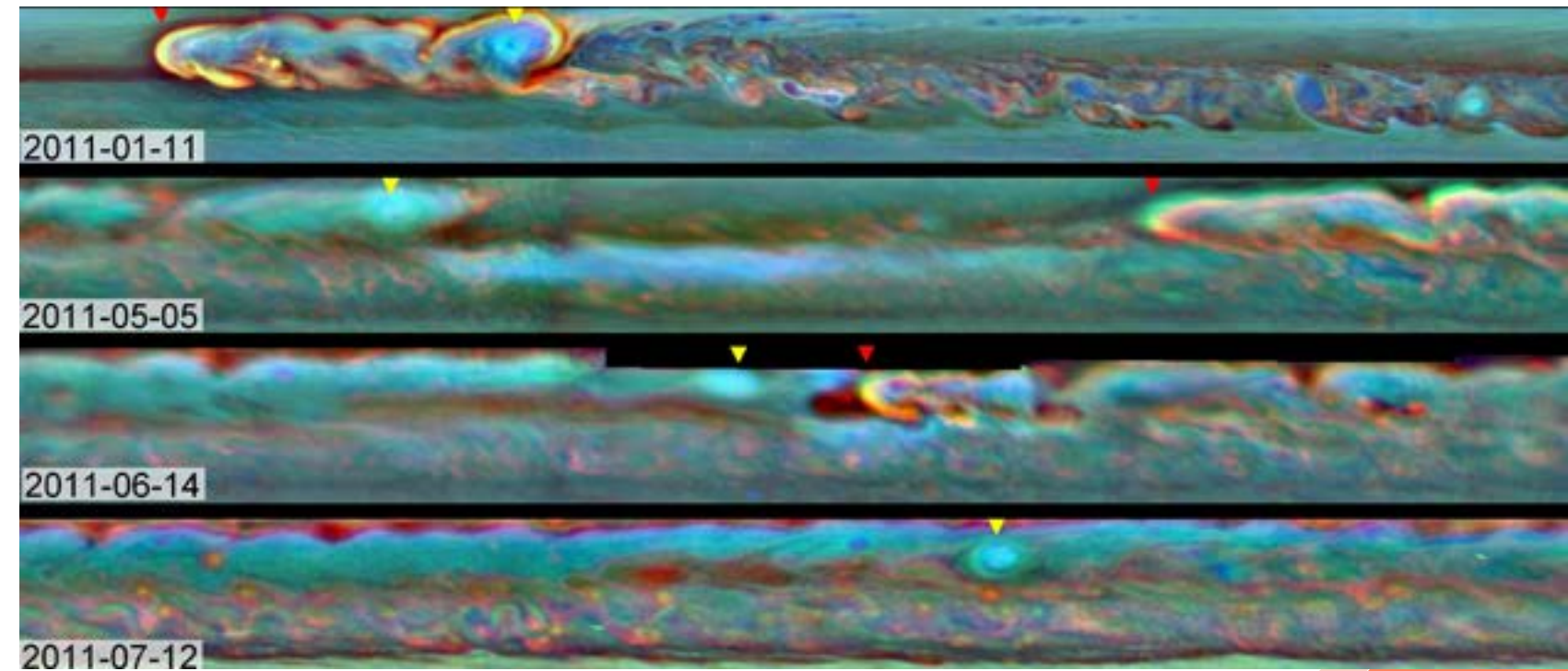
Below :: These images show the evolution of a massive thunder-and-lightning storm that circled all the way around Saturn and fizzled out when it ran into its own tail. The head of the storm cloud is indicated with a red triangle. A yellow triangle indicates the vortex.



Storm Chokes On Its Own Tail

A paper release by scientists from NASA's Cassini mission described how a massive storm, first observed in 2010, churned around Saturn for 267 days before finally running into its own wake, sputtering out soon after. It was the first time scientists have observed a storm consume itself like this anywhere in the solar system. Storms on Earth have never run into their own wakes - they encounter topographic features like mountains first and expend themselves. But Saturn has no land to stop its hurricanes. The bright turbulent storm head was able to chomp all the way around the planet.

Above :: A mosaic of images from Cassini shows the trail of a great northern storm on Saturn. The head of the storm is the set of bright clouds near the left of the image. A vortex spawned by the storm shortly after it erupted can be seen in the middle. The head of the storm moved very swiftly westward, while the vortex followed more slowly.



NATIONAL CENTER FOR



The National Center for Interactive Learning (NCIL) is dedicated to expanding the understanding and participation of families, youth, educators, and citizens in science and technology through innovative programs and learning research. Dr. Paul Dusenbery is the Director of NCIL, which is organized around five interconnected groups: **1) Exhibition Development, 2) Digital Learning, 3) Professional Development, 4) Community Outreach, and 5) Learning Research and Evaluation.**

NCIL is leading the way for a new generation of STEM education platforms and makes science accessible to new audiences. NCIL fosters collaboration between STEM professionals and educators to bring the wonder 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., *Giant Worlds: A Journey to the Outer Solar System* and *Great Balls of Fire: Comets, Asteroids, and Meteors*) and library exhibitions (e.g., *Discover Earth* and *Discover Health*); award-winning

INTERACTIVE LEARNING

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

educational films (e.g., *Are We Alone?*), videos, and websites; hands-on teaching resources and activities; and educator workshops and webinars.

NCIL 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. Visit www.nc4il.org for more information.

Left Page :: A panorama of the Alien Earths exhibit produced by NCIL. Credit: NCIL @ SSI

NCIL Impacts for 2013

Traveling Exhibit Visitors (418,045)

Great Balls of Fire museum exhibit (3,500 sq. ft.):	62,743
Great Balls of Fire museum exhibit (1,500 sq. ft.):	59,000
Discover Earth library exhibit (5 host sites):	244,010
Discover Tech library exhibit (5 host sites):	52,292

Library Program Participants: 26,401
(including children’s STEM activities, lectures, and adult programs)

Librarian Workshop Participants: 200

Librarian Webinar Participants: 210

NCIL Outreach Event Participants: 845

Education Website Visitors

Website	Visits	Page Views
www.alienearths.org	293,197	497,310
www.marsquestonline.org	170,460	491,609
www.spaceweathercenter.org	148,414	386,196
www.killerasteroids.org	70,729	150,323
www.giantworlds.org	11,276	22,072
www.scigames.org	6,684	10,708
www.starnetLibraries.org	2,781	6,399
www.community.starnetlibraries.org	2,572	6,003
Totals	710,138	1,579,768

2013 Highlights

Building Worlds and Learning Astronomy on Facebook

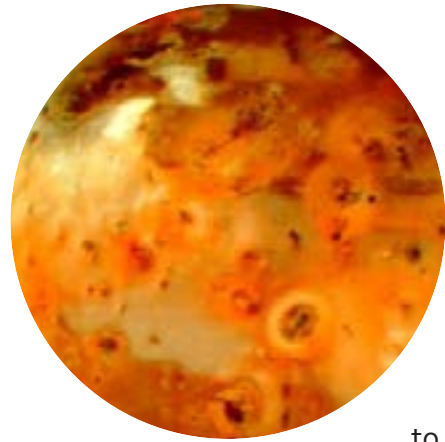
Dr. James Harold and Senior Programmer Evaldas Vidugiris (at the Boulder, CO Office) and Dr. Dean Hines (Parkville, MD Office) are developing *Starchitect*, an end-to-end stellar and planetary evolution game for the Facebook platform. Supported by NSF and NASA, and based in part on *MyStar* (a prototype funded by the Space Telescope Science Institute), our game uses a “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 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.

Efforts in 2013 were focused on making the game ready for formative and closed beta testing. It’s now complete for its initial launch: players can build stars, planets, and moons; earn “feats” to acquire new items in the game (e.g., cloud and terrain textures); view Facebook Friends’ systems; and soon post photos of their own systems to their walls. A full tutorial is also in place to walk players through their initial experience. After initial launch in 2014, the game will continue to evolve for at least an additional year. In 2015, we will be launching a second version that is external to Facebook, focused on use by middle school students.

Above :: A screenshot of the Starchitect game. Credit: NCIL @ SSI



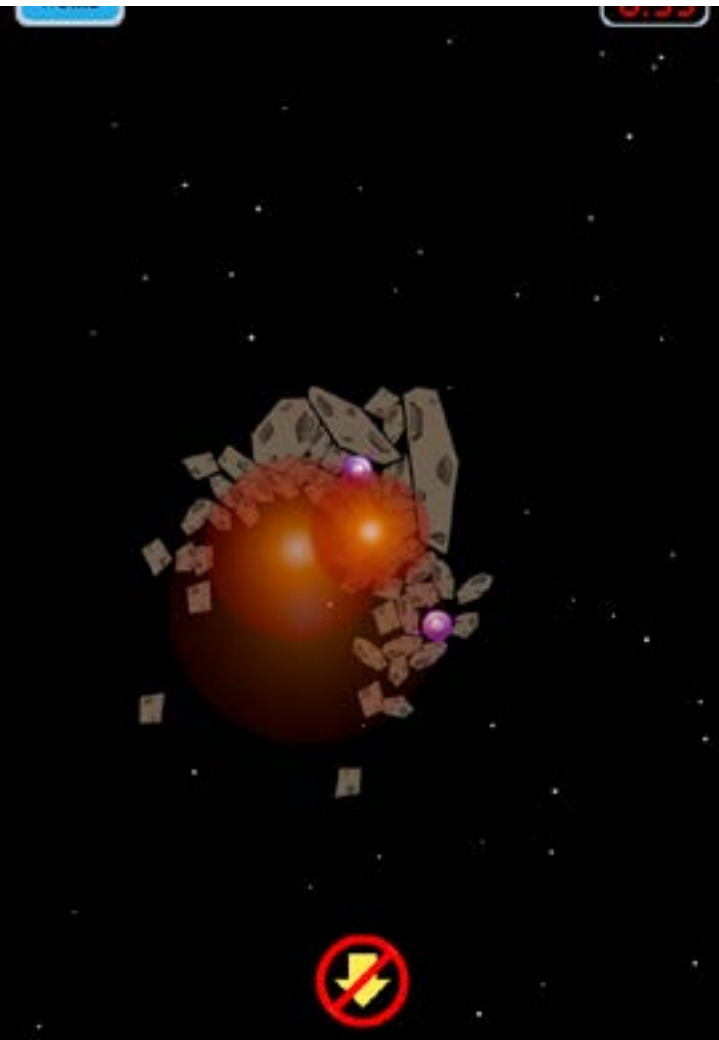
Below :: Gameplay in the Rubble! App. Credit: NCIL @ SSI

NCIL launched its first two educational mobile games, *Star Maze: the Great Escape* and *Rubble!*

Star Maze is an adaption of one of NCIL's online activities, expanded to include 27 different maze levels and over a hundred hint phrases relating to astronomy, the sun, and space weather. The app can be used as an educational game to supplement classroom discussions on the sun, stars, and astronomy, and the hint phrases borrow from both the American Association for the Advancement of Science's *Benchmarks for Science Literacy* and NASA's *Heliophysics Concept Map*.

Rubble! is an adaptation of a kiosk activity developed for the NSF- and NASA-funded *Finding NEO* and *Great Balls of Fire* exhibitions that uses a physics engine to simulate a "rubble pile" asteroid bound for Earth. Players can use multiple techniques to try to deflect the asteroid, but risk breaking it into pieces that will be harder to control.

Both apps are free and available now on the iOS App Store, Google Play for Android, and the Amazon App Store. You can find direct store links and more information at <http://www.scigames.org/apps.php>. Development for both apps was supported by NSF and NASA.



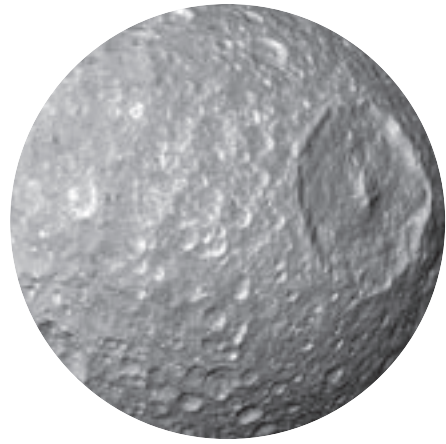
Below :: Discover Earth at Laramie County Public Library (LCPL) Cheyenne, WY. Credit: LCPL



Science-Technology Activities & Resources For Libraries

The essential mission of most public libraries is to serve their communities with lifelong learning opportunities. With thousands of libraries, there is an enormous potential for engaging underserved youth and their families in fostering an appreciation and deeper understanding of science and technology topics. To utilize this largely untapped resource, NCIL, in partnership with the American Library Association (ALA), the Lunar and Planetary Institute (LPI), and the National Girls Collaborative Project (NGCP), received funding from NSF to create a new national education project for libraries that focuses on building STEM skills through developing "science-technology activities and resources" (STAR). This project, known as the STAR Library Education Network (STAR_Net), is a hands-on learning program for libraries and their communities across the country. Other key partners included Evaluation & Research Associates (ERA) who conducted the summative evaluation, University of Colorado, Engineers Without Borders-USA, the National Renewable Energy Lab,





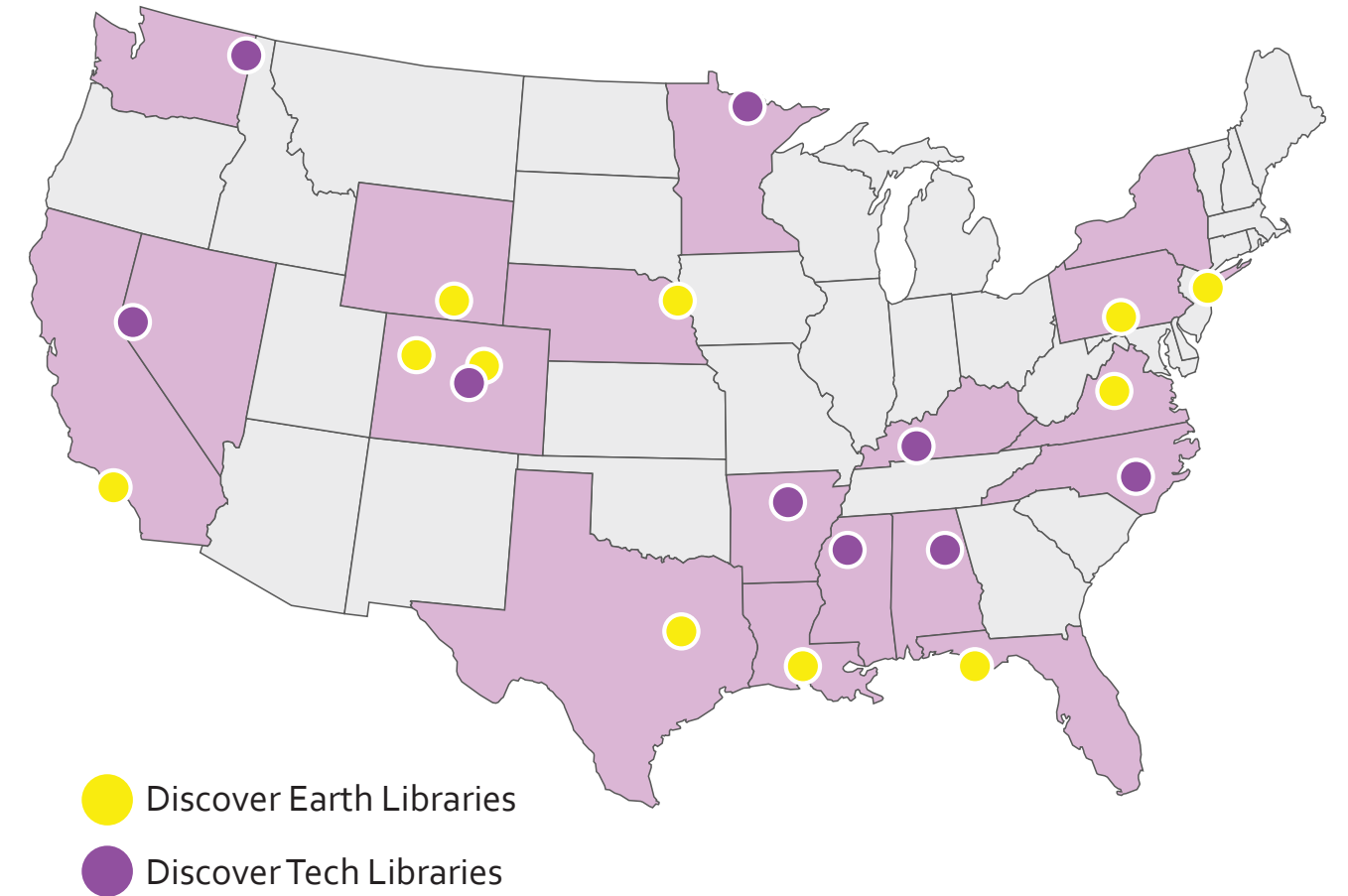
Louisville Public Library, and many others. For more information visit www.starnetLibraries.org.

Hundreds of library staff and STEM professionals are also joining STAR_Net's online community of practice (CoP) where they can download STEM resources and collaborate with one another.

Currently, there are nearly 500 members. To date, over 450 library staff participated in online webinars and in-person workshops. See www.community.starnetLibraries.org for more information.



Discover Earth & Discover Tech Host Libraries

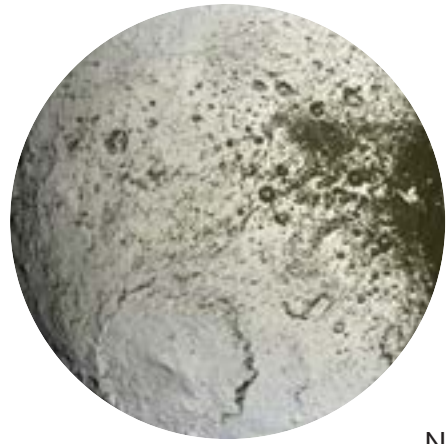


STAR_Net education programs are designed with the goal to inspire lifelong learning through inquiry and play. They included museum-quality, interactive exhibits, along with a rich variety of programming developed by library staff or external partners. Over 140 libraries applied to ALA to host the project's two interactive traveling exhibits (*Discover Earth: A Century of Change* and *Discover Tech: Engineers Make a World of Difference*), though 19 libraries were selected for the tour. Libraries that were not selected still have access to STAR_Net's extensive educational resources and materials through the online community. The project team is currently planning an extended tour to several more libraries in 2014/2015.

The figure above shows the location of the *Discover Earth* and *Discover Tech* libraries. The exhibit tours were managed by ALA. Each host library had one of the exhibits for 2 months. The Louisville Public Library (in Colorado) served as the inaugural

Above :: Discover Earth and Discover Tech tour locations

Left Page :: Library patrons participate in a Discover Earth program. Credit: NCIL @ SSI



site for both exhibits and was used for formative evaluation studies. Additional programming included the development of active learning experiences related to the content of the exhibits for different age groups (led by LPI). The project also developed a training program for librarians and an online community of practice (CoP) of librarians and STEM professionals. An outreach program was developed by the EdLab Group using resources from NGCP. Through 2013, 412,000 patrons visited the exhibits and an additional 35,000 participants attended hundreds of programs offered by host libraries and their community partners.

Both exhibitions supported free-choice learning. Adults and children could look at the exhibits whenever they chose for as little or as long as they liked, and could easily return to interact with different parts of the exhibit again. Several teachers and parents reported that the exhibits supported what students were learning during the school day in traditional classrooms or through home schooling. The exhibits also supported intergenerational learning. Parents, children and even grandparents were frequently observed learning together.

Key findings from the summative evaluation conducted by ERA included the following: 1) STAR_Net professional development helped *Discover Earth* and *Discover Tech* librarians host the exhibits and deliver informal science education programming; 2) The redesigned STAR_Net CoP website continues to increase its reach; 3) All of the libraries implemented informal science activities while



Above :: A young engineer at work in NCIL's *Discover Tech* exhibit. Credit: NCIL @ SSI

Right Page :: Students learning about human anatomy at an outreach event. Credit: Robert Russell

they hosted the *Discover Earth* or *Discover Tech* exhibit, and at least two-thirds of the libraries reported that they had offered additional STEM programming after the exhibit had left their libraries; 4) STAR_Net succeeded in reaching the targeted library participants and audiences at the host libraries; and 5) Many library patrons at the host libraries became more interested, knowledgeable, and engaged in the STEM topics presented in the exhibits and related programming.

NCIL's New Health Education Initiative

NCIL has launched a new initiative under the STAR_Net project called *Discover Health: A Bilingual Healthy Living Program for Colorado Libraries and their Communities*. *Discover Health* is currently in the pilot phase, with "suitcase interactives" developed by the Pacific Science Center touring both the Louisville and Longmont Public Libraries in early 2014. *Discover Health* addresses obesity, cardiovascular disease, and healthy eating and living habits and will become a Colorado-wide program in 2014.





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