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ANNUAL REPORT 2015

OUR MISSION

The Space Science Institute is shaping our future by enabling scientists to advance our understanding of Earth and the Universe; increasing science and technology literacy for people of all ages and backgrounds; and inspiring youth to pursue science-technology education and career opportunities.

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Message from the Chairman of the Board of Directors

As Board chair, I have been proud to be a custodian of a remarkable organization that enables scientists to do their best work and one that brings the excitement of science and technology to audiences across the nation.

SSI continues to transform the value it offers by providing the highest quality deliverables and service to our talented employees. In 2015, our researchers were awarded $4 million dollars in grants and supported 12 NASA and ESA missions and observatories. The Cassini imaging team produced 19,431 photos of the Saturnian system with 52 weekly releases to the public. SSI's education team reached 210,000 individuals through museum and library exhibits, provided STEM-focused professional development to 350 individuals, and engaged 946,338 users on its interactive, educational websites. Yet despite the large scale of its programs and span of influence, SSI is actually a small organization. We believe that any individual has the power to make a difference, and thus that a collection of exceptional individuals has the potential to do something great. The many successes outlined in this Annual Report are due to the efforts of the individuals who work here and who, in "thinking big," are living examples of that sentiment.

SSI welcomed its new Executive Director, Dr. Karly Pitman, in February 2015. Karly has the experience, passion and vision for both the research and education elements of SSI's mission, and has taken the reins in managing the organization and leading the development of our strategic plan. The Board is excited to be working with Karly in propelling SSI's ongoing space science research and STEM education initiatives into the future.

I would like to pay tribute to my fellow Board Directors for their continuing commitment to SSI; it has been a pleasure to serve with them all. In 2015, we were pleased to add Larry Satkowiak to the group as SSI's Board treasurer. Larry's commitment to science literacy, as well as his experience as past president and CEO of The Cable Center, are most welcome additions to our collective expertise.

We are quite proud of SSI's progress strategically, operationally and financially in 2015. On behalf of the Board, I would like to thank all of our employees and partners for their commitment and dedication to scientific advancement and STEM education.

William R. Purcell, Ph.D.

Cover Image :: Zeta Oph: Runaway Star, NASA, JPL-Caltech, Spitzer Space Telescope

Message from the Executive Director

As you will read in this report, the Space Science Institute is a fantastic organization that continues to hold leadership positions in all domains of space science and STEM education and public engagement. The work we do will have an impact not only in the present but also for future generations, so we strive to achieve the maximum impact with the resources entrusted to us.

Our strategic education partnerships are now starting to take root as we work together on library exhibits. As a partner with the American Library Association (ALA), SSI/NCIL has hosted exhibits in all 50 states, and across urban, suburban and rural areas in Colorado. In 2015, SSI hosted the inaugural STEM in Libraries Conference, bringing together for the first time libraries and STEM professionals with a shared goal of promoting STEM in libraries across the nation.

We are driving for better working conditions for scientists and engineering the workplace of tomorrow, one that encourages entrepreneurial spirit and work-life balance. In 2015, we offered new programs (Science Enhancement Fund, PI Equipment Fund) to help scientists purchase the tools to do their work, which are not often covered by grants. We welcomed affiliates to help begin or renew their scientific careers and we continue to help scientists work through retirement, across geographic boundaries, and near loved ones. We are proud to have mentored more than 55 college students and postdoctoral researchers to date, and to be able to give back to the communities that have invested in our development.

In 2015, government funding has essentially flatlined in science research and significantly declined in STEM education. The main challenge for SSI is how to survive during lean times and best support our people and programming. Our people are meeting this challenge head-on, thinking of ways to increase their competitive advantage and create new value. The Board and I will work together to help solve these tough problems through our strategic planning efforts in 2016.

I wish to thank our employees and Board for their dedicated efforts and for welcoming me into my new position. And I would like to especially thank our partners, donors, and stakeholders for continuing to support space exploration and our communities of practice.

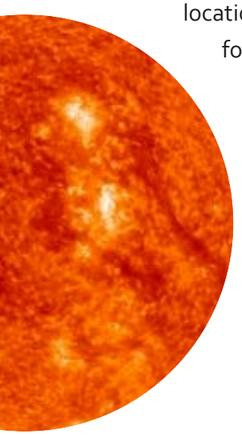
Karly M. Pitman, Ph.D.

Inside Cover :: Man gazing up at the Milky Way, https://pixabay.com/en/milky-way-rocks-night-landscape-916523/

OVERVIEW

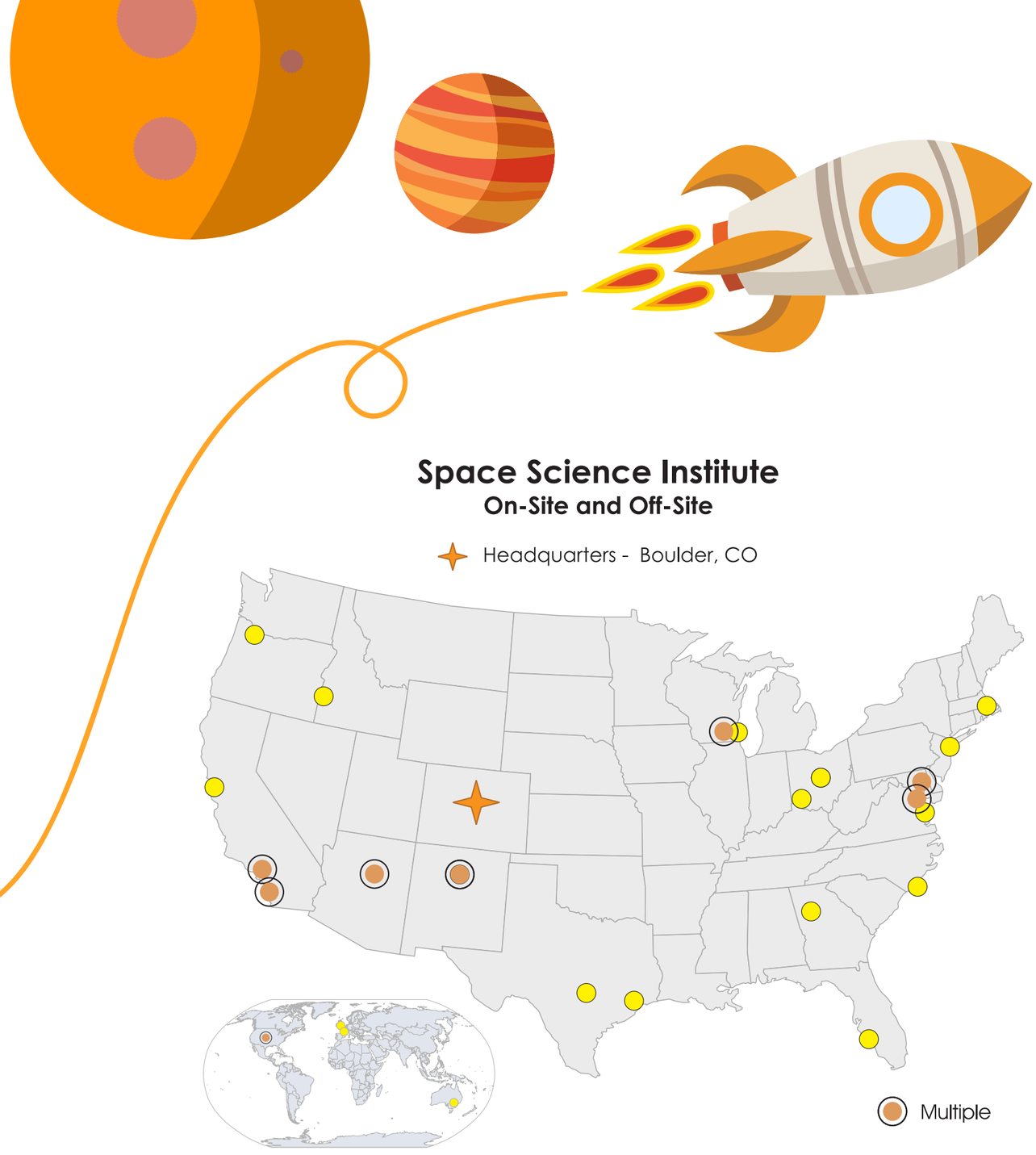
History and Background

In the early 1990s, when Dr. Paul Dusenbery was conducting space physics research at the University of Colorado Boulder (CU), he recognized that, with regard to space science, a glaring divide stood between the academic world and the general public—and that there was a need for a better link between the two. In response, Dr. Dusenbery engaged other scientists in the field and founded a 501(c)(3) nonprofit, the Space Science Institute (SSI), in 1992. In its initial startup, SSI had a staff of three scientists who focused on advancing research and promoting space science education. By 2000, SSI was garnering national recognition for its advancements in space science. In 2003, SSI moved from the CU campus to its current location on Walnut Street in Boulder, creating more space for business operations and for on-site research scientists. Through collaborations with NASA and the European Space Agency, SSI scientists secured participation on prestigious space missions, including the Mars Exploration Rovers (2003), Rosetta (2004), Cassini (2004), Mars Reconnaissance Orbiter (2005), Lunar Reconnaissance Orbiter (2009), Mars Science Laboratory (2011), Juno (2011), ExoMars Trace Gas Orbiter (2016), OSIRIS-REx asteroid study and sample return mission (to be launched in 2016), and Mars 2020 Rover (to be launched in 2020). SSI has since expanded its impact in science and education through the creation of SSI's National Center for Interactive Learning (2010), Center for Extrasolar Planetary Systems (2013), Center for Space Plasma Physics (2013) and Center for Mars Research (2014).



Present

Today, SSI manages over 50 scientists working in Colorado, nationally and internationally. SSI also develops educational products and conducts outreach with an ever-expanding network of partners, and it creates exhibits and electronic games that make engaging with science accessible, meaningful and fun for people of all ages and backgrounds. These programs support SSI's overall mission: to shape our future by enabling scientists to advance



Map Diagram :: SSI employees and affiliates work either on-site at SSI headquarters in Boulder or off-site at locations across the United States and internationally. SSI's education programs operate in all 50 states.

our understanding of Earth and the Universe; increasing science and technology literacy for people of all ages and backgrounds; and inspiring youth to pursue science-technology education and career opportunities. SSI's role in advancing understanding and opportunity in science, technology, engineering and mathematics (STEM) has been recognized through competitive awards (all currently active) from: the National Science Foundation (STEM Learning in Libraries); the NASA Jet Propulsion Laboratory; the Space Telescope Science Institute; the U. S. Department of Energy; and NASA.

2015 Board Members

- Ms. Ann Goldman, Co-Founder, Front Range Source
- Dr. Dick Green (ex officio), Former President / Chief Executive Officer, CableLabs, Inc.
- Dr. Marilyn Johnson, Former Science Director, Oregon Museum of Science & Industry
- Dr. Steve Jolly, Systems Engineering Director, Lockheed Martin Corporation
- Ms. Karen Leaffer (Secretary), Principal, Leaffer Law Group
- Dr. Karly Pitman (ex officio), Executive Director / Senior Research Scientist, SSI
- Dr. Bill Purcell (Chair), Senior Manager Advanced Systems, Ball Aerospace and Technologies Corporation
- Mr. Larry Satkowiak (Treasurer), Retired President and CEO of The Cable Center
- Ms. Maddie Zeigler, Education Consultant

2015 Executive Advisory Committee

- Dr. Paul Dusenbery (National Center for Interactive Learning)
- Dr. James Harold (Information Systems and Technology)
- Dr. Carolyn Porco (Cassini ISS Imaging Operations)
- Dr. Ralph Shuping (Research)
- Dr. Michael Wolff (Associate Director)
- Mr. Carl Wuth (Business Operations)

2015 Grants & Contracts

SSI gratefully acknowledges support from research and education grants and contracts from the following organizations in 2015:

Applied Physics Laboratory, Johns Hopkins
Arizona State University
Center for the Advancement of Science
Cornerstones of Science
Jet Propulsion Laboratory, Caltech
Malin Space Science Systems
NASA
National Institute of Health
National Science Foundation
Ohio State University
Princeton Plasma Physics Laboratory
SETI
Southwest Research Institute
Space Telescope Science Institute
State University of New York
University of Alabama in Huntsville
University of Arizona
University of California, Berkeley
University of California, Los Angeles
University of Delaware
University of Iowa
Universities Space Research Association
University of Southern California
University of Wisconsin, Madison
Villanova University

Donors

SSI wishes to thank the generous individuals who contributed in 2015:

- Allstate
- Amazon Smile
- Ball Corporation (Benevity Fund)
- Jennifer Barker
- Dr. R. Todd Clancy
- Colorado Gives
- Dr. Paul and Michelle Dusenbery
- Mark and Barbara Eggleston
- Emily Fuentes
- Ann Goldman
- Marilyn Johnson
- Steve Jolly
- Karen Leaffer (Rose Community Foundation)
- Grant Matheny
- Dr. Karly Pitman
- Dr. Bill Purcell
- Lawrence Satkowiak
- Dave Thomas
- Brian Warner
- Dr. Michael Wolff
- Dr. Padmavati Yanamandra-Fisher
- Madeleine "Maddie" Zeigler

Right Page :: This is what SSI supporter Eliana V. (age 3) thinks is out there in our galaxy. Eliana donated 1/3 of her life savings to SSI in 2015 to help space discovery. For her support, her interest, and her artwork, SSI thanks Eliana very much!

We EXPLORE & DISCOVER

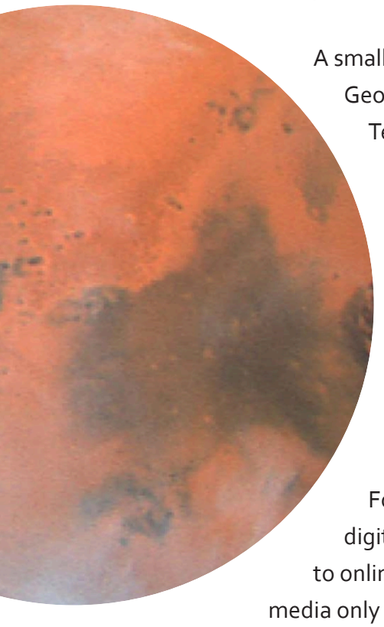
SSI researchers work on the cutting edge of international science. SSI's Research Branch is home to the world's experts in multiwavelength astronomy, Mars atmospheric and surface studies, cometary and outer Solar System research, and space plasma physics. Our researchers come to work here from across the U.S. and abroad, leaving prestigious jobs at universities and national labs (e.g., NASA's Jet Propulsion Laboratory, Caltech and Los Alamos National Laboratory) to pursue the kind of creative freedom and work-life balance that SSI offers. SSI scientists are key team members on high-profile robotic and spacecraft missions for NASA and the European Space Agency, as well as for the exoplanet finding space observatory Kepler, the Stratospheric Observatory for Infrared Astronomy (SOFIA), and the Hubble Space Telescope. SSI is a pioneer in remote employment; nearly 75% of our employees do their scientific observations and calculations while telecommuting, offering freedom of movement to present at conferences around the world and flextime to work throughout the day and night to better collaborate and observe.

SSI is also extremely proud of the work done by the Cassini Imaging Science Subsystem Instrument Operations team, based out of SSI's Boulder office. Approximately 50 scientists from the United States and Europe comprise the imaging team that uses cameras from the Cassini-Huygens mission to investigate many unique features of Saturn, its rings and moons. The Cassini ISS team is arguably the most productive of the Cassini instrument teams in delivering its wealth of data and images to scientists and the general public, and continues to deepen our knowledge about Saturn and the processes by which planets – and whole planetary systems – form and develop with time.

We EDUCATE & INSPIRE

SSI is home to the National Center for Interactive Learning, which leverages SSI's successful experience in research, museum, science center and library educational programs, public outreach, and digital technologies into accessible and inspiring learning opportunities. We believe that the key to improving our science, technology, engineering, and mathematics (STEM) workforce to meet 21st Century challenges is not just to focus solely on an individual student, or teacher, or even an individual classroom, but instead to explore how we can

transform whole communities in how they view and support STEM. NCIL employs a strategy of transforming 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.



A small sample of our strategic project partners in these efforts include: American Geophysical Union; American Library Association; Association of Science-Technology Centers; Astronomical Society of the Pacific; Ball Aerospace & Technologies; Cornell Laboratory of Ornithology; Denver Museum of Nature and Science; EdLab Group/National Girls Collaborative Project; Engineers without Borders; Institute for Learning Innovation; LEGO; Lunar & Planetary Institute; NASA Astrobiology Institute; NASA Goddard Space Flight Center; NASA's Jet Propulsion Laboratory, California Institute of Technology; National Academy of Engineering; National Renewable Energy Laboratory; and the Universities of Arizona, California and Colorado.

For over a decade, NCIL educators have also 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.

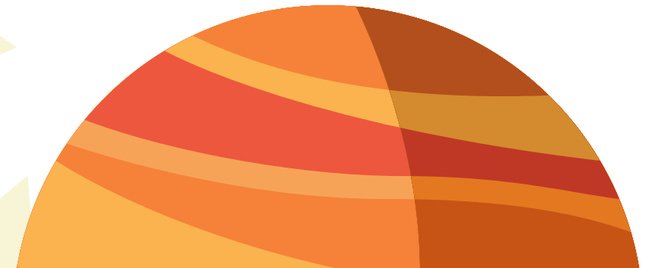
Our Vision for the Future

We at SSI believe that the present and future course of science and engineering in the United States rests 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.**

Pillar (1) poses a special challenge in the 21st century, as scientific fields are becoming too interdisciplinary to fit traditional research institutions and universities that in turn are currently struggling under the pressures of financial challenges and aging research facilities. By providing high quality organizational, legal, and administrative support, SSI makes it possible for researchers to do science wherever they are on the projects of their choice in scientific growth areas. Being smaller and more adaptable, SSI also offers a much higher scientific return on grant dollars invested than larger universities and laboratories: all funds received are spent on science and science education, not unnecessary frills.

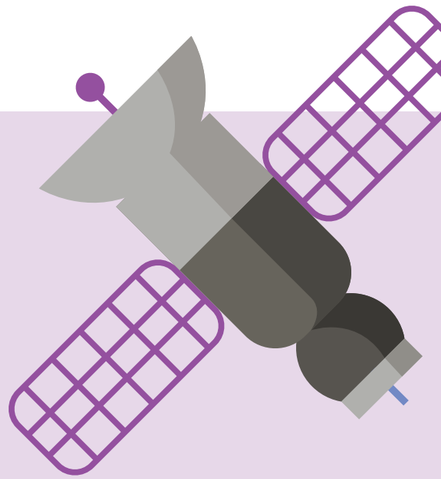
SSI is committed to sharing the joy of science and educating communities nationwide under Pillars (2) and (3). Continuing well into the future, there will be a transformation away from traditional classroom environments, toward a more engaging, "learning by doing" approach to youth education. 21st Century skills such as problem solving, critical thinking, STEM literacy, and collaboration 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). 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.



Left Page :: *Dark Sand Cascades on Mars, HiRISE, MRO, LPL (U. Arizona), NASA*

RESEARCH & DISCOVERY

RESEARCH BRANCH



Research Impacts

Total number of scientists and affiliates: 57
New researchers in 2015: 6
Papers published in 2015: > 45
Invited/Public Talks: >50
Proposals Submitted in 2015: 104
Grants awarded in 2015: $4,087,728

NASA and European Space Agency Missions Supported:
Hubble Space Telescope, Kepler (exoplanet space observatory), the Stratospheric Observatory for Infrared Astronomy (SOFIA), Mars Exploration Rovers, Rosetta, Cassini, Mars Reconnaissance Orbiter, Lunar Reconnaissance Orbiter, Mars Science Laboratory, Juno, ExoMars Trace Gas Orbiter, OSIRIS-REx asteroid study and sample return mission (to be launched in 2016), and Mars 2020 Rover (to be launched in 2020)

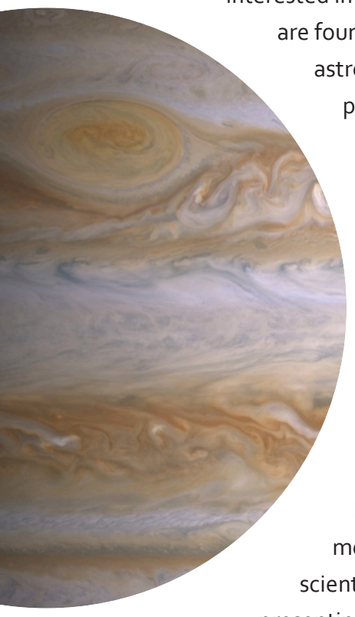
Research Center Updates

Center for Mars Science

The SSI Center for Mars Science serves as a venue for SSI Mars researchers to interact, learn of new developments related to Mars science, and to participate in educational and public engagement activities. The center has periodic "Journal Club" webinars where Center researchers or guest speakers can share some of their latest results. A recent Journal Club featured Dr. Francois Forget of France's Centre National de la Recherche Scientifique (CNRS) telling the group about the mission of the recently launched ExoMars Trace Gas Orbiter. Center lead, Dr. Bill Farrand, was a featured speaker at the ENVI Analytics Symposium, an event that brought together leading experts in remote sensing science to discuss technology trends and the next generation of solutions

for advanced analytics. On the education and public engagement front, Center personnel participated in SSI's 2015 Open House detailing aspects of Mars science to local school children, volunteered at preschool and elementary schools in the U.S. and Europe, and presented at the Denver Museum of Nature & Science and Denver's "Nerd Nite" public lecture series for adults.

Center for Extrasolar Planetary Systems



The Center for Extrasolar Planetary Systems (CEPS) provides a focus for SSI researchers interested in understanding extrasolar planets and the diverse systems in which they are found. 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 physical 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. CEPS members gather together remotely for occasional "journal-club" style telecons and presentations from speakers both internal and external to SSI.

In September 2015, Dr. Julianne Moses stepped down as the CEPS director, and passed the leadership mantle on to Dr. Savita Mathur. New SSI scientist Dr. Regner Trampedach joined the group, bringing the membership up to thirteen people. CEPS researchers have been productive scientifically, publishing 52 papers in refereed scientific journals in 2015, and presenting scientific results at numerous meetings and conferences. SSI CEPS members are scattered throughout the country, and communication has been through e-mail and periodic telecons: Dr. Savita Mathur gave a presentation on asteroseismology in October, and Dr. Julianne Moses gave a talk on the atmospheric composition of young, hot, directly imaged planets in November. The Center maintains a website (http://ceps.spacescience.org/home.html), accessible through SSI's main page, to highlight research being done by center members and to provide an interface with the public and other researchers in the exoplanet field.

Center for Space Plasma Physics

SSI's Center for Space Plasma Physics (CSPP) provides an umbrella for very broad NASA-sponsored and NSF-sponsored research efforts on plasma physics and the plasmas of the heliosphere. In calendar year 2015 the members of CSPP published 33 papers in refereed journals: 11 papers as primary authors and 22 papers as contributing authors. Research highlights in 2015 included theoretical and data-analysis studies of turbulence, a model of the Earth's particle environment, investigations on magnetic-field-line reconnection, examinations of structure in the solar wind, studies of kinetic plasma effects, investigations into plasma instabilities, and the development of numerical-simulation techniques.

In September 2015, two members of CSPP co-organized a 5-day international conference on "Unsolved Problems in Magnetospheric Physics" that was convened in Scarborough, England. A special issue of the Journal of Geophysical Research with the same title is in progress.

2015 Research Highlights

WIM with WHAM: Mapping Where Our Galaxy's Energy Travels

(Dr. L. Matthew Haffner; Verona, WI Office)

The grand machinery of galaxies is set in motion by some of the most basic forces in the universe at the smallest scales. A weak but inescapable pull of gravity between atoms and molecules compels interstellar gas to collapse and form stars, converting this stored power into light, heat, and high-speed particles in their cores. Throughout their lifetimes, the release of this processed matter and energy regulates the inevitable crush of gravity and sets up a complex feedback loop that allows galaxies to continue this cycle for billions of years. Byproducts of this ongoing process become the essential ingredients of planets and life itself.

Bright, ionized nebulae provide obvious evidence that feedback from massive stars shapes the interstellar medium (ISM) on local scales in star-forming galaxies. But the discovery and

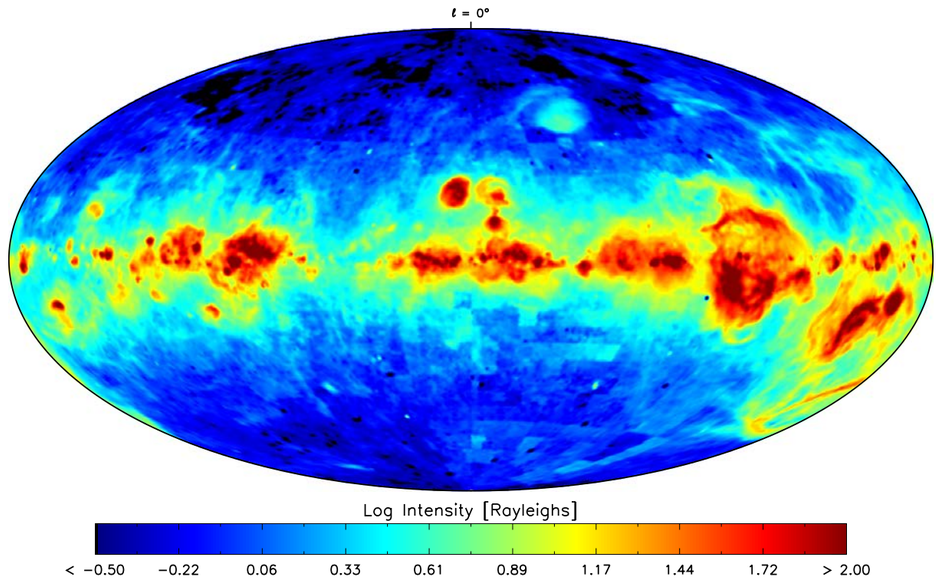
study of widespread ionized gas (plasma) over a wide range of warm to hot temperatures reveal that energy is deposited through other, large-scale processes. The disk of the Milky Way contains a thick (many thousands of light-years) layer of this plasma, dubbed the Warm Ionized Medium (WIM). Understanding how the WIM is distributed as well as the source for its ionization and heating has fueled observational and theoretical work for several decades.

SSI Senior Research Scientist Dr. L. Matthew Haffner has focused on characterizing the distribution and ecology of diffuse, ionized gas in and around the Milky Way. His broader science interests include a variety of aspects of the interstellar and intergalactic medium, the structure of the Milky Way, and the evolution of spiral galaxies. For the past 12 years, he has been principal investigator of the long-running Wisconsin H-Alpha Mapper (WHAM; Figure 1 above), a joint effort between the University of Wisconsin—Madison and SSI. Dr. Haffner and collaborators are using data collected from WHAM and models of the ISM to explore questions such as:

- Where does the energy produced in the star-forming regions of our Galaxy go?
- How does that energy propagate away from these birth sites?
- How does this energy change as it travels thousands of light-years through the Galaxy?
- How is it deposited back into the interstellar medium?

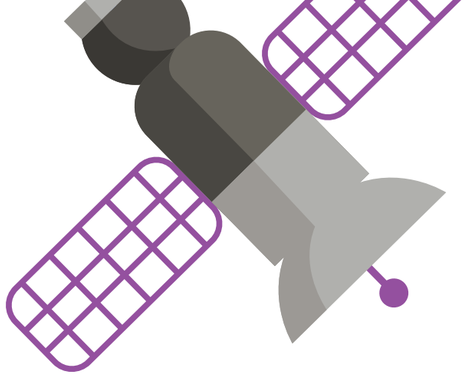
Ultraviolet and X-ray light leaking from the dense star-forming regions near the Galactic midplane (the center line of our Galaxy's huge spinning disk of stars) appears to be the primary source of energy powering the WIM. But another source may be energy released in supernovae, which occur on average about once a century in the Milky Way. Whether their energy is directly deposited into the WIM or not, supernovae do appear to be critical to provide the turbulence seen throughout the ISM that provides pathways for the energetic photons to escape the dense gas and dust near young, hot stars.

Since the WIM is very low density—only about 100,000 atoms per cubic meter—its emission is faint, making it difficult to detect and characterize with traditional astronomical instruments. WHAM leverages the high sensitivity of a Fabry-Perot spectrometer to diffuse (i.e., non



Left Page :: *Figure 1 - WHAM observing from Chile a week after installation in 2009. Light from the sky enters the steerable, periscope-like siderostat on the right and is guided by mirrors and a 0.6-m lens through the stainless steel tube into the spectrometer trailer on the left. The silver dome in the background is the NOAO Victor Blanco 4-m Telescope on the peak of Cerro Tololo.*

Above :: *Figure 2 - The WHAM Hα Sky Survey. This all-sky Aitoff map projection is centered at Galactic longitude 0°. A false-color, logarithmic intensity scaling helps the eye find detail throughout the huge contrast range depicted here (> 300). Each pixel in the map represents the total integrated hydrogen (Hα) emission in the ~4Å survey window, which records the radial velocity profile of gas ± 100 km/s around the solar neighborhood's local motion.*



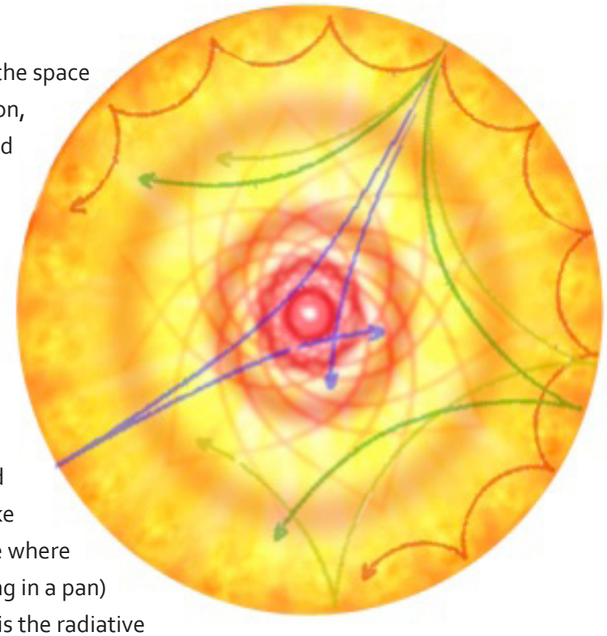
point-like) light and has enabled many breakthrough studies of the WIM. The instrument scanned the northern sky from Kitt Peak National Observatory (Arizona) for 11 years before moving south of the equator to Cerro Tololo Inter-American Observatory (Chile) in 2009. Combining data from the northern and southern skies, Dr. Haffner and his team has delivered the first all-sky kinematic (spectral) survey of very faint Hα deep red visible spectral lines caused by emission from ionized hydrogen (Figure 2). Although the angular resolution is modest at these wavelengths, it is extremely sensitive and its spectra allow the team to separate terrestrial emission from Galactic components, revealing that the diffuse hydrogen emission covers the sky. Spectra also enable the team to isolate astronomical structures along lines of sight where rotation separates spiral arms and to find ionized gas previously undetected in many interstellar clouds.

WHAM's high-sensitivity to diffuse emission has broadened its impact beyond just the WIM in the Milky Way. Its current major campaign from Chile will deliver the first survey of the extended ionized gas throughout the Magellanic System, a major pair of satellite galaxies of the Milky Way. Dr. Haffner and collaborators also use WHAM for a diverse range of space science topics, including: searching for ionized gas in dwarf spheroidal galaxies; long-term monitoring of Earth's geocoronal Hα emission; mapping the rotation curve of zodiacal dust in the Solar System; measuring extended emission from large-diameter comets; and producing the first kinematic map of the lunar sodium tail.

Probing the Deep End of the Milky Way With Asteroseismology

(Dr. Savita Mathur; Boulder, CO Office)

Stars are the building blocks of galaxies and the Universe. The study of the dynamical evolution of the stars at different ages and their chemical composition in the galaxy is a new field that is being developed thanks to large galactic spectroscopic surveys and space missions. This field is called "Galactic Archeology" and helps us to understand how the galaxies evolve.

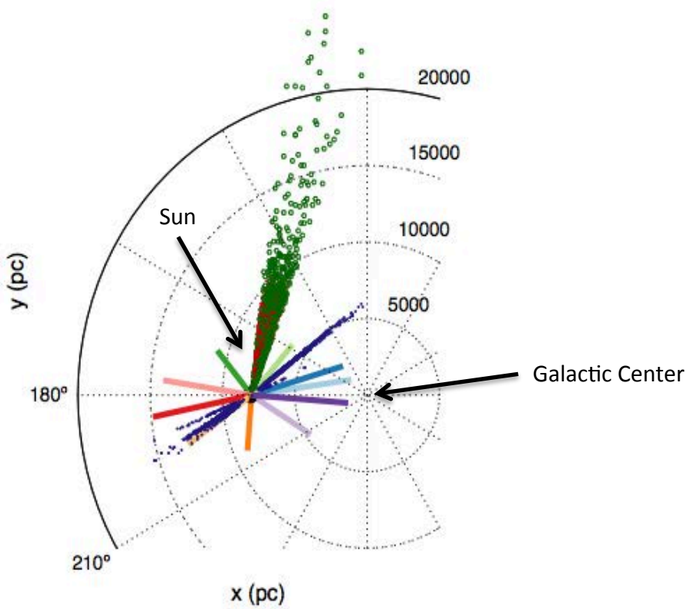


Very recently, the data collected by the space missions CoRoT (Convection, Rotation, and Transits) and Kepler have allowed asteroseismology (the study of the internal structure of pulsating stars by interpretation of their frequency spectra) to make very important breakthroughs. Asteroseismology is the only tool that enables us to directly probe the internal structure and dynamics of stars like the Sun and red giants that are more evolved stars. The outer envelope of a star like the Sun is called the convective zone where convective motions (like water boiling in a pan) carry the energy. The deeper region is the radiative zone where photons carry energy and interact with the plasma. A star is like a resonant cavity where two types of waves can propagate:

- Acoustic (p) modes are excited in the convective zone; their restoring force is pressure.
- Gravity (g) modes propagate in the radiative zone and their restoring force is buoyancy. Because the convective zone does not have stable layers, g modes cannot propagate there and their wave amplitude decreases with distance. As a consequence, g modes in solar-type stars are very difficult to detect, since they reach the stellar surface with very low amplitudes, as is the case in the Sun.

Oscillations manifest themselves by locally modifying the stellar surface. The surface of the star expands and contracts, producing a change in the temperature and thus luminosity. Helioseismology has already proved that by measuring and characterizing the oscillation modes of the Sun, we can infer its internal structure, such as the density profile or the position of the base of the convection zone and its rotation profile. Asteroseismology provides measurements of radii, masses, and ages with a better accuracy than classical methods.

Above :: *Figure 1 - Example of acoustic (p) modes propagating in a star after reflection on the stellar surface. The number of reflections provides the degree of the modes. Modes propagating in the internal region (radiative zone) are the gravity (g) modes. Credits IAC.*



SSI Research Scientist Dr. Savita Mathur has developed a software pipeline called A2Z, to analyze the thousands of stars that have been observed by the Kepler mission. This pipeline provides the global parameters of acoustic modes, such as their position and their spacing that are tightly linked to the mean density of the star and its surface gravity. Before the launch of the Kepler mission, a catalog called the KIC (Kepler Input Catalog) was built to provide estimates of stellar parameters such as the temperature, the gravity and the metallicity (i.e., the fraction of the star that is not hydrogen or helium) of the targets that were going to be observed by the mission. In collaboration with scientists at the CEA Saclay (France) and an undergraduate student, Dr. Mathur found that ~850 stars classified as dwarfs according to the KIC were actually Red Giants thanks to the detection of p modes in their power spectra. In addition of being misclassified, these stars happen to be fainter than the known sample of Red Giants in the Kepler sample. The parameters of these stars were re-computed using the seismic parameters determined with the A2Z pipeline. This sample of Red Giants is less massive than the known Red Giants, which is a characteristic of older stars. Moreover, the distances to these stars can be derived by fitting the observed parameters with stellar models. This work shows that many of these Red Giants are quite far away, up to the edge of our Galaxy. This result is very exciting because we can now apply asteroseismology to more distant stars and probe the Milky Way at different depths.

The next step is to obtain more accurate fundamental parameters of these stars such as the chemical composition. As a matter of fact, these stars are currently being observed by the 3rd Sloan Digital Sky Survey (APOGEE, Apache Point Observatory for Galactic Evolution Experiment), which will give us spectroscopic observations and allow us to measure the abundance of different chemical elements in these distant stars. Current galactic evolution models are based on stars that are a few kiloparsecs away from us. This new sample of stars that we have characterized allows us to probe the Milky Way more than ten times further away and thus represents a goldmine for galactic archeology. By combining the chemical composition, age and distance of stars, which is key information to build the theory behind the history and fate of galaxies, we will be able to look back at the beginnings of our own Milky Way.

Above :: *Figure 2 - Position of the misclassified stars (green points) in the Milky Way compared to the stars in the CoRoT (blue dots), Kepler (red dots), and K2 fields (solid lines).*

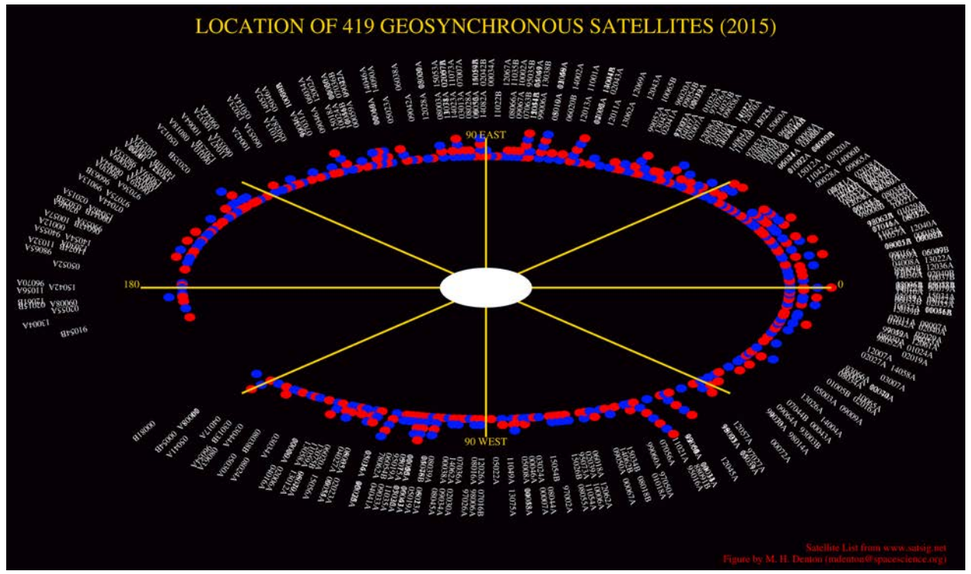
Predictions of Space Weather Effects at Geosynchronous Orbit

(Dr. Michael "Mick" Denton; Los Alamos, NM Office)

Geosynchronous orbit (GEO) is one of the most popular locations for satellite hardware. Satellites located in this orbit travel around the Earth with a period of 24 hours meaning that they always remain roughly above the same geographic location. Over 400 satellites, used for communications, scientific, and military purposes, are currently on orbit at GEO (Figure 1).

Knowledge of the space plasma flux environment at GEO is important when designing and operating such satellites because impacts from energetic electrons and ions can damage satellite hardware. Hence, being able to predict the plasma environment in this region is of great interest to satellite designers and operators. We recently developed a new model of the flux of electrons and ions at GEO, for energies between ~1 electron volt (eV) and ~40 keV, and how this varies as a function of local time, energy, geomagnetic activity, and solar activity [e.g., Figure 2; Denton et al., 2015]. The model is freely available to satellite operators and developers. The paper describing the model was recently chosen as a spotlight in the American Geophysical Union "Space Weather" journal and highlighted in the EOS periodical, also published by AGU. Further development of the model is planned in two areas:

1. Geomagnetic/Solar Conditions - Whilst the Kp index is a good proxy for general geomagnetic activity, it would be useful to be able to drive the model with upstream solar-wind conditions, such as the solar-wind electric field (-vswBz). Satellites located between Earth and the Sun provide measurements of this electric field in real-time around 1 hour before its arrival at Earth. Hence,



revising the model based on this parameter as an input will allow ~1-hour predictions of the electron and ion flux conditions at GEO - enough time for satellite operators to assess likely spacecraft effects.

2. Extend the Model Parameters

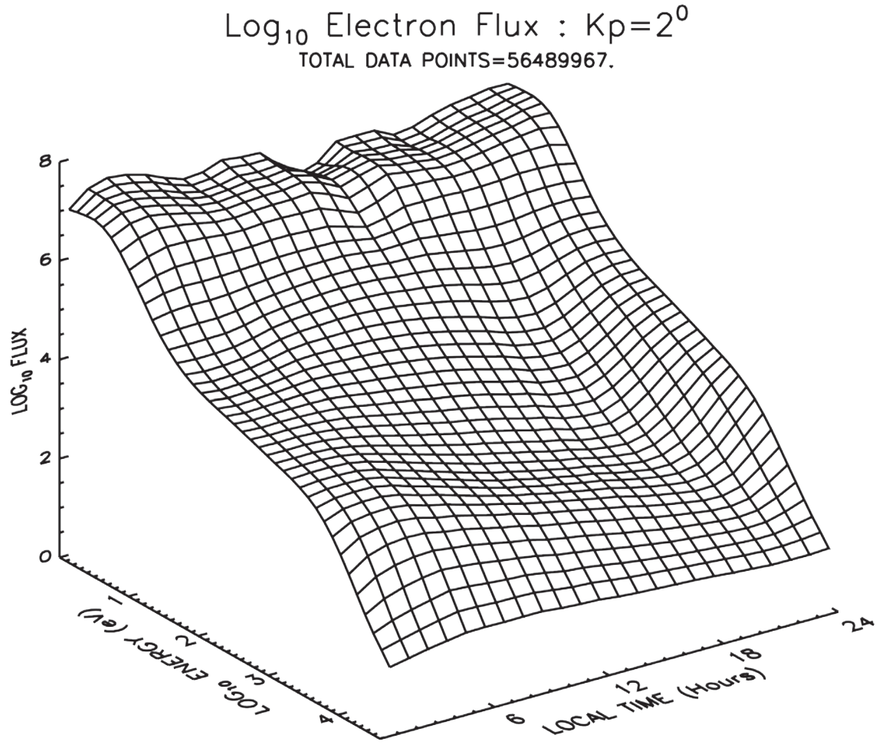
(a) Extending the model in spatial extent (inwards and outwards of GEO);
(b) Extending the energy range of the model (upwards from 40 keV);
(c) Extending the model to consider geomagnetic latitude (off-equator) effects.

While most satellites are located at GEO, a smaller number surround the Earth in other orbits, and at other latitudes. Extending the model to cover larger regions of near-Earth space, including off-equator locations, will ensure that satellite operators have access to predicted fluxes that cover almost all likely orbits.

Work in these areas was presented at the 2015 Fall American Geophysical Union meeting in San Francisco in December.

Above :: Model website and download: http://gemelli.spacescience.org/mdenton/

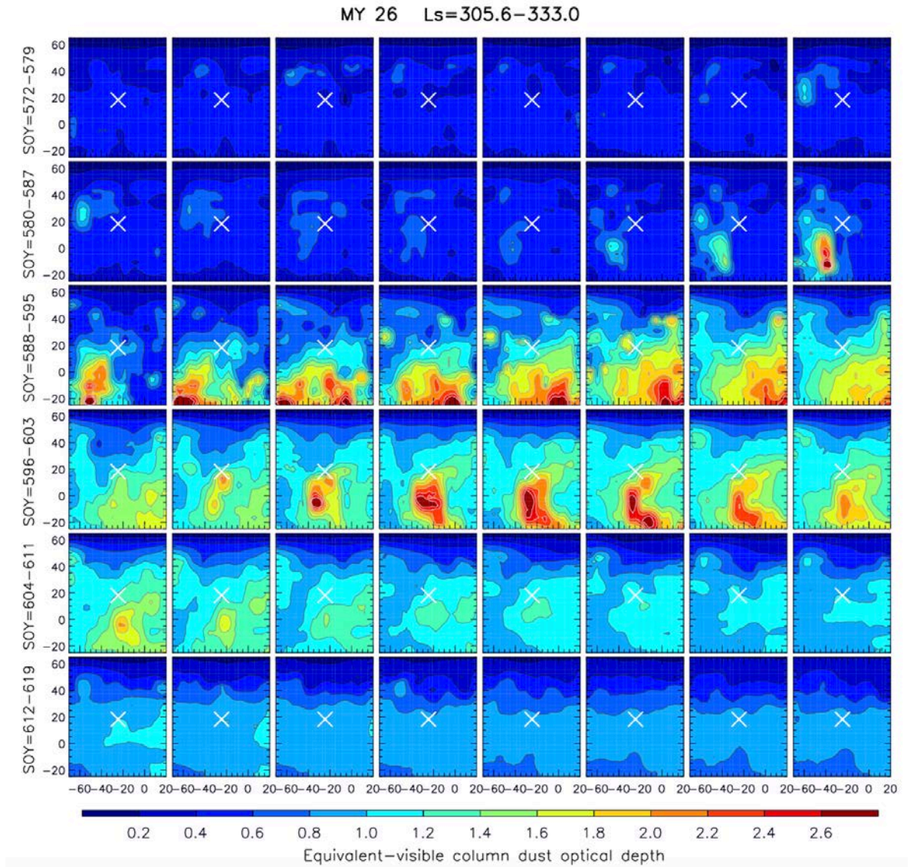
Right Page :: M. H. Denton, et al., An empirical model of electron and ion fluxes derived from observations at geosynchronous orbit, Space Weather, doi:10.1002/2015SW001168, 2015



Dusty Mars Unveiled

(Dr. Luca Montabone; Greenbelt, MD Office)

Mars is a dusty planet. Fine particles of dust (diameters less than a few millionths of a meter, or microns) and sand (diameters of a few hundred microns) almost entirely cover its surface. Dust particles, in particular, are small enough to be lifted up from the ground by surface winds, and to become airborne. There is always some dust in the Martian atmosphere all year round, which provides the sky with its characteristic reddish color. The dust cycle (lifting from the ground, transport in the atmosphere, and sedimentation back to the ground) is currently considered to be the key process controlling the variability of the Martian climate at seasonal and inter-



annual time scales, as well as the weather variability at much shorter time scales. This is due to the strong absorption of solar radiation by airborne dust particles, which produces local heating. This atmospheric heating is particularly enhanced during episodes of dust storms, which can manifest as local-scale storms, regional-scale storms, or even planetary-scale storms –one of the most dramatic meteorological phenomena in the Solar System!

SSI Research Scientist Dr. Luca Montabone and co-authors (including SSI Senior Research Scientist Dr. Mike Wolff) have worked with data from three different instruments aboard three different spacecraft orbiting Mars to create two-dimensional global maps of the dust distribution for almost every single "sol" (a Martian "mean solar day") of the past 9 Martian years –a period spanning almost 17 Earth years. Using atmospheric column dust optical depths (which are a measure of how opaque Mars's atmosphere is due to tiny suspended dust

particles) retrieved from NASA's Mars Global Surveyor Thermal Emission Spectrometer (MGS-TES), Mars Odyssey Thermal Emission Imaging System, (THEMIS) and Mars Reconnaissance Orbiter Mars Climate Sounder (MCS), Dr. Montabone and colleagues were able to reconstruct nearly the full history of the evolution of the dust in the Martian atmosphere at a reasonable resolution (a few degrees longitude by a few degrees latitude), including the onset and development of the regional- and planetary-scale dust storms. This multi-annual dataset is extremely useful for at least two practical purposes: 1) it can be used as a "dust scenario" to produce more realistic global climate model (GCM) simulations of the Martian atmosphere, and 2) it represents a long-running dataset of dust observations for statistical analysis and prediction at specific locations on the planet, where robotic missions – or possible manned missions – may land in the future.

Even using all available retrievals of column dust optical depth to date, there are still areas and times for Mars that cannot be fully covered by these daily dust maps. One example is the winter polar region of both hemispheres in the first three Martian years of observations by MGS-TES. So far, the reduced contrast between the surface temperature and the temperature of the first atmospheric layers during the Martian polar nights has constrained the quality of the dust retrievals. Dr. Luca Montabone, together with Dr. Mike Wolff and another colleague at the NASA Goddard Space Flight Center are now going to tackle this problem. Using one of the most state-of-the-art computer codes to obtain column dust optical depth from the observed infrared wavelength radiances, as well as using visible wavelength observations at

Left Page :: *The image shows the day-by-day evolution of a regional Martian dust storm, which occurred in mid-winter of the Martian year 26 (December 2003 – January 2004), reconstructed from TES, THEMIS, and MCS retrievals of atmospheric column dust optical depth (blue = less dust; red = more dust). NASA's Mars Exploration Rovers "Spirit" and "Opportunity" missed its peak by only few days during their descent and landing on the Martian surface, respectively on January 4th and January 25th, 2004. The European Space Agency's ExoMars 2018 rover might not be so lucky if a similar storm strikes at the candidate landing site (indicated by the white cross in each panel) during its landing. The column dust optical depth at visible wavelengths is referenced to the same pressure (610 Pascals) to eliminate topographic inhomogeneity. The solar longitude (Ls) is one of the time-keeping methods on Mars. It represents the angle described by the line connecting the Sun to the position of Mars in its orbit, relative to the planet's position at the northern spring equinox (Ls = 0°). The sol-of-year (SOY) represents the Martian calendar day in the range 1-668 (or 669) sols.*

different viewing angles, they hope to fill in the gaps in dust observations over the cold Mars polar regions. Their results might help answer questions about how much dust is able to get to these high latitudes in Martian wintertime, despite the presence of a very intense circumpolar circulation in the mid-atmosphere.

It is this strong winter circulation around the pole –otherwise known as a "polar vortex"– that also interests Dr. Luca Montabone and constitutes another topic of his research at SSI. The dynamics of this atmospheric circulation seems to be particularly affected by the presence of dust storms at sensitive times and locations. Given the lack of direct wind observations at Mars, information on the atmospheric dynamics can currently only be obtained indirectly through observations (e.g., by tracking the transport of aerosols or different chemical species), atmospheric models, or the combination of atmospheric models and observations. Data assimilation is the technique that combines observations and a global climate model to produce a best estimate of Mars's atmospheric state, allowing us to understand variables that are not directly observed, such as the wind components. This is the technique that Dr. Montabone uses in his attempt to unveil the secrets of Mars's atmospheric dynamics and its polar vortices, particularly when dust storms are at work.

Right Page :: *On sol (martian day) 4333 of its mission, the Mars Exploration Rover captured this image of a dust devil (small whirlwind) on the floor of Endeavour Crater in the Meridiani Planum region of Mars. Opportunity was perched on the floor of a break in the rim of Endeavour and was imaging potential driving locations when it captured this image with its Navigation Camera (Navcam). Credit: JPL/NASA.*

CASSINI IMAGING OPERATIONS

Cassini ISS Impacts

(by JPL fiscal year - Oct. 1, 2014 – Sep. 30, 2015)

Archiving

1. 19,431 images received, processed, and cataloged
2. 7 archive volumes delivered to and accepted by the Planetary Data System (PDS)
3. 10 improved camera pointing definition ("C-Kernel") files

Uplink Implementation

1. ~6 sequences implemented (and integrated)
2. 27 Spacecraft Activity Sequence Files (SASFs) merged, tested, and delivered
3. 27 Short-Form Output Files (SFOF)/C-kernel bundles containing the pointing and timing for each spacecraft movement in an observation delivered
4. 483 ISS observation pointing designs designed, tested, and corrected
5. 2250 observation commands (20.5% by CICLOPS)

Camera Commanding

1. 652 ISS camera trigger (IOI) files designed/tested/corrected and 18 IOI bundles merged, tested, delivered
2. 22,739 images taken (23.0% CICLOPS)
3. 10 ISS Support Imaging Observations designed for other teams

MISC Uplink Ops

1. ~60 Science Planning telecons attended
2. 31 Configuration Change Requests (CCRs) processed
3. 4 Waivers handled
4. 3 Engineering Change Requests (ECRs) handled
5. 6 Cassini Sequence Change Requests (SCRs) handled
6. ~12 Reaction-Wheel Assembly Bias Optimization Tool (RBOT) processes supported
7. ~12 Live Update processes supported

Image Products

1. 52 weekly image releases
2. 39 special image products
3. 25 Raw images
4. 19 "Looking Ahead" features (once-per-orbit mission activities reports)

Press Releases

1. 5 press releases
2. 8 image advisories

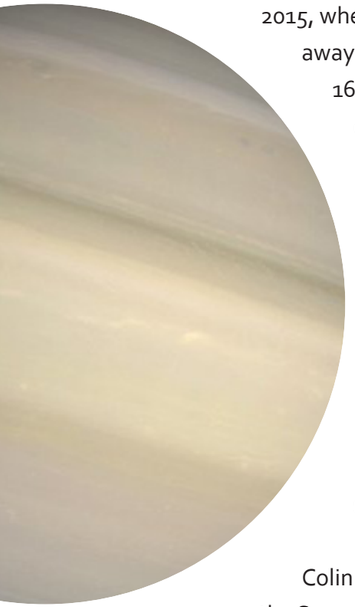
This section summarizes only a fraction of the amazing discoveries from the international Cassini-Huygens mission to Saturn, its moons and rings. SSI's own Dr. Carolyn Porco leads the Cassini Imaging Science Subsystem team and, with Cassini ISS deputy director of ISS Ops and outreach coordinator Steve Mullins, shares the latest findings on the Cassini Imaging Central Laboratory for Operations (CICLOPS) website (http://ciclops.org). Here are some of the team's greatest hits from 2015.

Top Page 28 :: Two orthographic projections facing toward terrain on the trailing hemisphere of Rhea are seen in this enhanced color view. The image at right represents one of the highest resolution color views of Rhea released to date.

Cassini Returns to the Realm of Icy Moons

A dual view of Saturn's icy moon Rhea, released on March 30, 2015, marked the return of NASA's Cassini spacecraft to the realm of the planet's icy satellites. This return followed nearly two years during which the spacecraft's orbits carried it high above the planet's poles.

The two views of Rhea on page 28 were taken about an hour-and-a-half apart on Feb. 9, 2015, when Cassini was about 30,000 to 50,000 miles (50,000 to 80,000 kilometers) away from Rhea. Cassini officially began its new set of equatorial orbits on March 16. Cassini's orbit remained nearly equatorial during 2015, and had numerous close encounters with Saturn's moons including a few last encounters ever for the mission.

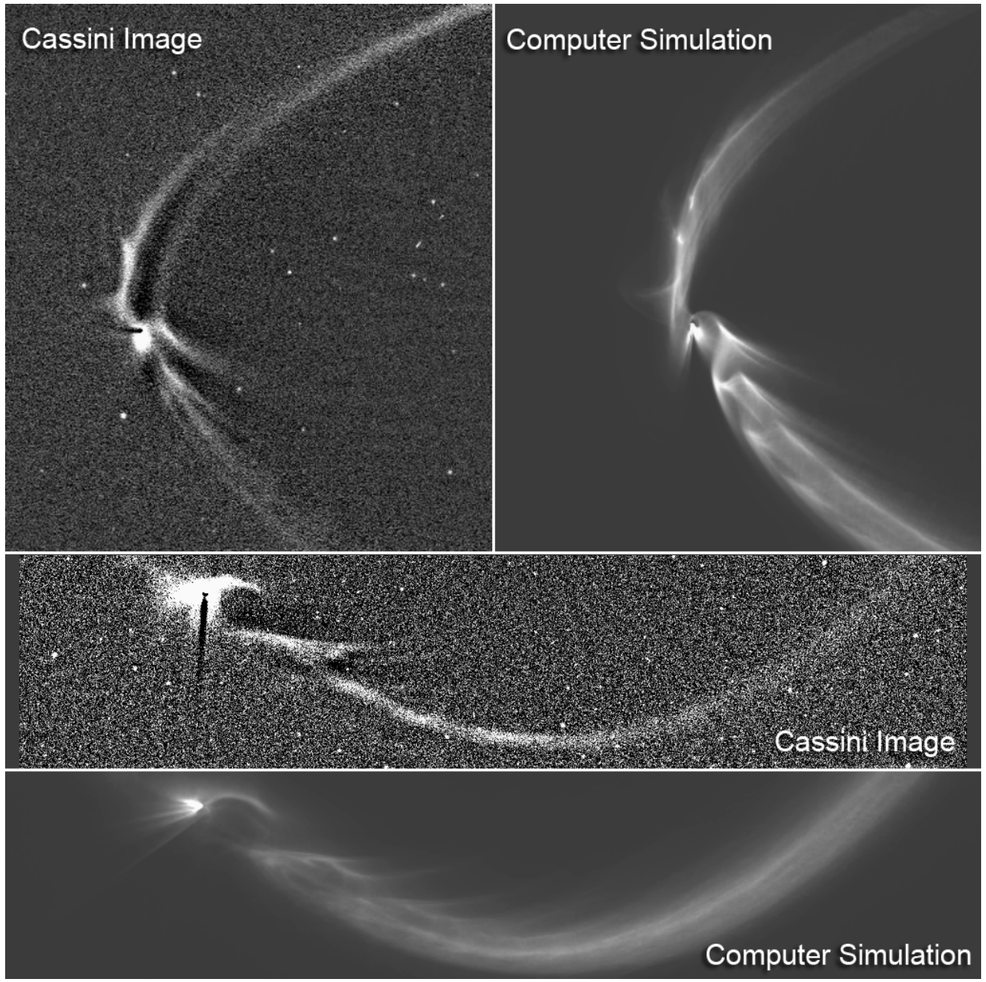


Icy Tendrils Traced to Their Source

Long, sinuous, tendril-like structures seen in the vicinity of Saturn's icy moon Enceladus originate directly from geysers erupting from its surface, according to scientists studying images from NASA's Cassini spacecraft. The results of the study were published in the Astronomical Journal in 2015, along with additional insights into the nature of the structures.

Colin Mitchell, lead author of the paper and a Cassini imaging team associate at the Space Science Institute, together with imaging team leader Carolyn Porco and fellow team associate, John Weiss - both of SSI -, used computer simulations to follow the trajectories of ice grains ejected from individual geysers. The geysers, which were discovered by Cassini in 2005, are jets of tiny water ice particles, water vapor and simple organic compounds.

Left Page :: This collage, consisting of two Cassini images of long, sinuous, tendril-like features from Saturn's moon Enceladus and two corresponding computer simulations of the same features, illustrates how well the structures, and the sizes of the particles composing them, can be modeled by tracing the trajectories of tiny, icy grains ejected from Enceladus' south polar geysers.

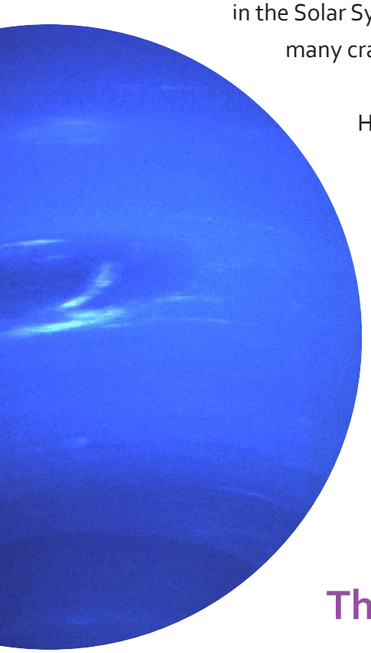


The team's simulations were able to show that tendril structures of different shapes correspond to different sizes of geyser particles, and were able to zero in on the sizes of the particles forming them. Examining images from different times and positions around Saturn, the team also found that the detailed appearance of the tendrils changes over time. The authors suspect that those changes in the tendrils' appearance likely result from the cycle of tidal stresses - squeezing and stretching of Enceladus as it orbits Saturn - and its control of the widths of fractures from which the geysers erupt. The stronger the tidal stresses raised by Saturn at any point on the fractures, the wider the fracture opening and the greater the eruption of material. The authors will investigate in future work whether this theory explains the tendrils' changing appearance.

Because of its significance to the investigation of possible extraterrestrial habitable zones, Enceladus is a major target for the final years of the Cassini mission. Many observations, including imaging of the plume and tendril features, and thermal observations of the surface of its south polar geyser basin, are planned during the next couple of years.

Farewell to Hyperion

On June 1, 2015 NASA's Cassini spacecraft returned images from its final close approach to Saturn's oddball moon Hyperion, upholding its reputation as one of the most bizarre objects in the Solar System. The views show Hyperion's deeply impact-scarred surface, with many craters displaying dark material on their floors.



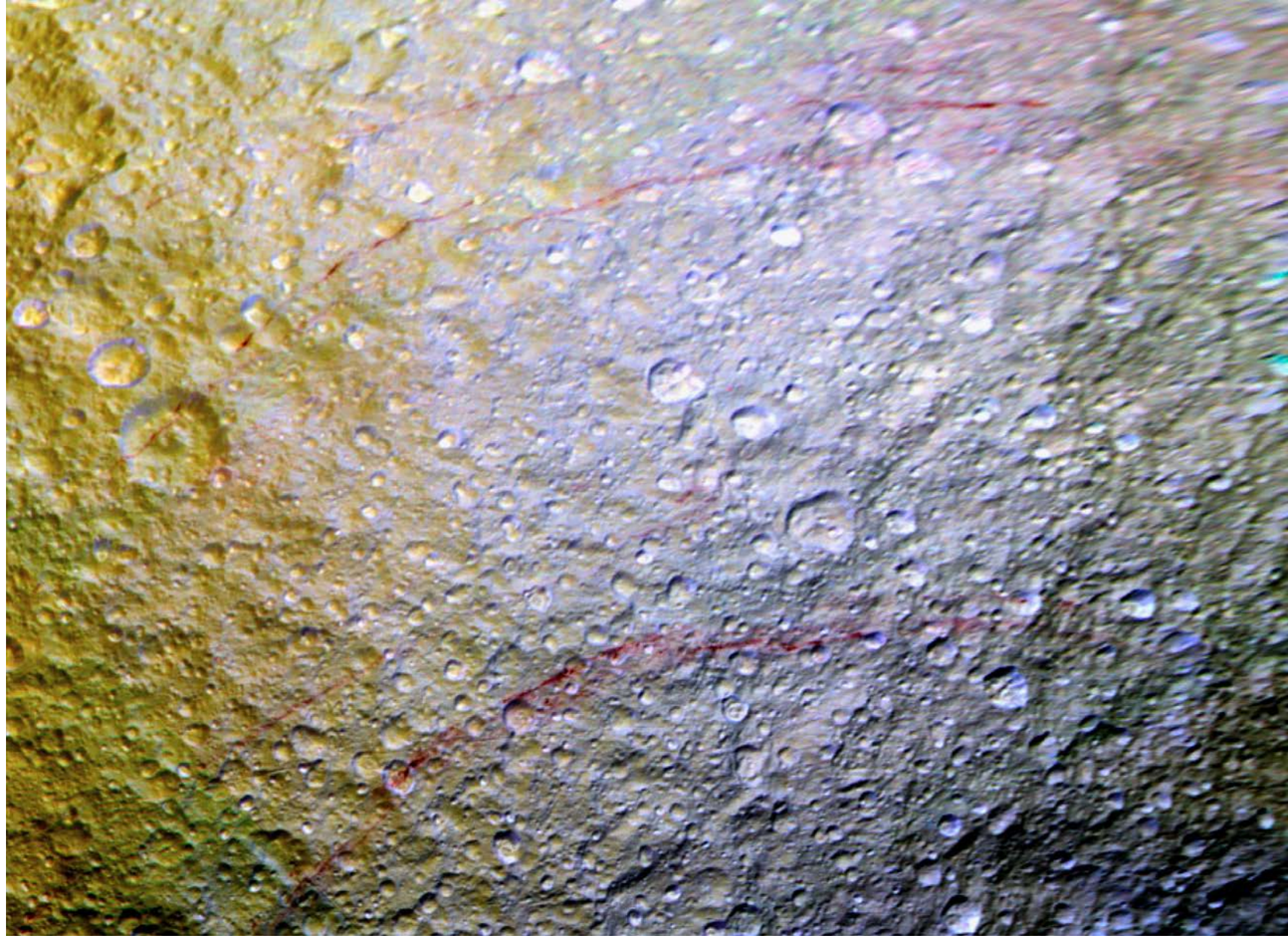
Hyperion is the largest of Saturn's irregular, or potato-shaped, moons and may be the remnant of a violent collision that shattered a larger object into pieces. Cassini scientists attribute Hyperion's peculiar, sponge-like appearance to the fact that it has an unusually low density for such a large object - about half that of water. Its low density indicates that Hyperion is quite porous, with weak surface gravity. These characteristics mean impactors tend to compress the surface, rather than excavating it, and most material that is blown off the surface never returns.

During the flyby, Cassini passed Hyperion at a distance of about 21,000 miles (34,000 kilometers) at closest approach.

The Colors of Tethys

Like graffiti sprayed by an unknown artist, unexplained arc-shaped, reddish streaks are visible on the surface of Saturn's icy moon Tethys in enhanced-color images from NASA's Cassini spacecraft. The red arcs are narrow, curved lines on Tethys' surface, and are among the most unusual features on Saturn's moons to be revealed by Cassini's cameras.

A few of the red arcs can be seen faintly in observations made earlier in the Cassini mission, but the color images obtained in April 2015, are the first to show large northern areas of Tethys under the illumination and viewing conditions necessary to see the arcs clearly. As the Saturnian system moved into its northern hemisphere summer over the past few years,

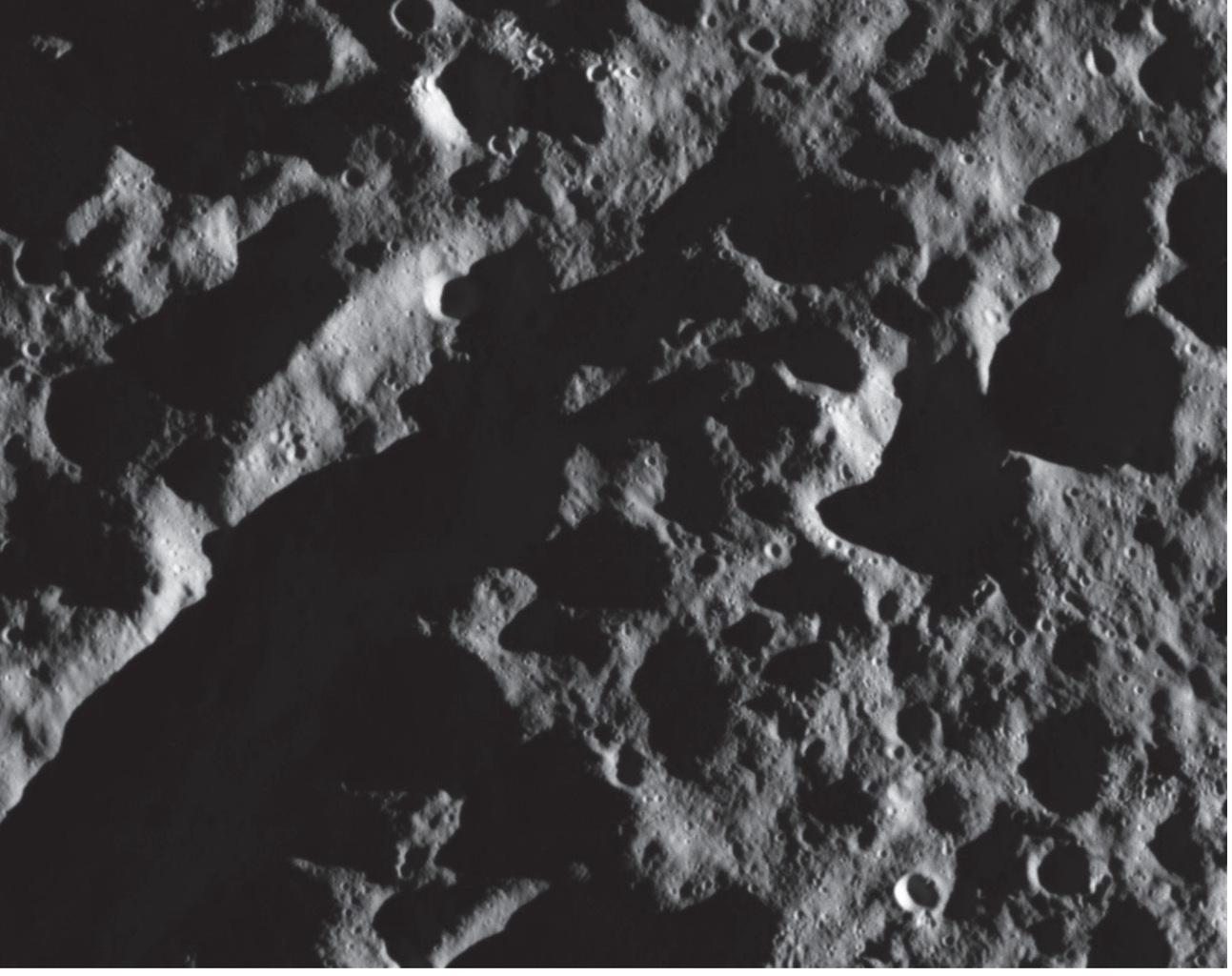


northern latitudes have become increasingly well illuminated. As a result, the arcs have become clearly visible for the first time.

The origin of the features and their reddish color is a mystery to Cassini scientists. Possibilities being studied include ideas that the reddish material is exposed ice with chemical impurities, or the result of outgassing from inside Tethys. They could also be associated with features like fractures that are below the resolution of the available images.

Except for a few small craters on Saturn's moon Dione, reddish-tinted features are rare on the other moons of Saturn. Many reddish features do occur, however, on the geologically young surface of Jupiter's moon Europa.

The Cassini team is currently planning follow-up observations of the features at a higher resolution.



Final Breathtaking Views of Dione

A pockmarked, icy landscape loomed beneath NASA's Cassini spacecraft in images taken of Saturn's moon Dione during the mission's last close approach to the small, icy world. Two of the new images show the surface of Dione at the best resolution ever.

Cassini passed 295 miles (474 kilometers) above Dione's surface at 11:33 a.m. PDT (2:33 p.m. EDT) on Aug. 17. This was the fifth close encounter with Dione during Cassini's long tour at Saturn. The mission's closest-ever flyby of Dione was in Dec. 2011, at a distance of 60 miles (100 kilometers).

Top Page 32 :: *Arc-shaped, reddish streaks cut across the surface of Saturn's ice-rich moon Tethys in this enhanced-color mosaic. The origin of the features and their reddish color is currently a mystery to Cassini scientists.*

The main scientific focus of this flyby was gravity science, not imaging, which made capturing the images tricky, as Cassini's camera was not controlling where the spacecraft pointed. Imaging scientists had just enough time to image Dione's surface at high resolution. Making use of the reflected sunlight from Saturn as an additional light source, the imaging team was able to reveal details in the shadows of some images.

Cassini's narrow-angle camera imaged Dione's near closest approach at an altitude of 334 miles, returning images with resolutions of between 10-12 feet per pixel, the highest resolution views of Dione's surface ever acquired by Cassini.

Cassini Finds Global Ocean in Saturn's Moon Enceladus

A global ocean lies beneath the icy crust of Saturn's geologically active moon Enceladus, according to new research using data from NASA's Cassini mission. Researchers found the magnitude of Enceladus' very slight wobble, as it orbits Saturn, can only be accounted for if its outer ice shell is not frozen solid to its interior, meaning a global subsurface ocean must be present.

The finding implies the fine spray of water vapor, icy particles and simple organic molecules that Cassini has observed coming from fractures near Enceladus' south pole is being fed by this vast liquid water reservoir. The research was presented in a paper published Sept. 15.2015, in the scholarly journal Icarus.

Cassini scientists analyzed more than seven years' worth of images of Enceladus taken by the spacecraft. They carefully mapped the positions of features on Enceladus - mostly craters - across hundreds of images, in order to measure changes in Enceladus' rotation with extreme precision.

Left Page :: *This view shows Dione's surface as a contrast-enhanced image in which features in shadow are illuminated by reflected light from Saturn. Image scale is 12 feet per pixel -- one of the mission's highest-resolution views of the Saturnian moon's icy surface*

As a result, they found that Enceladus has a tiny but measurable wobble as it orbits Saturn. Because the icy moon is not perfectly spherical - and because it goes slightly faster and slower during different portions of its orbit around Saturn - the giant planet subtly rocks Enceladus back and forth as it rotates. The team plugged their measurement of the wobble, called a libration, into different models for how Enceladus might be arranged on the inside, including ones in which Enceladus was frozen from surface to core. The result shows that there must be a global layer of liquid separating the surface from the core.

Scientists first detected signs of Enceladus' icy plume in early 2005, and followed up with a series of discoveries about the material gushing from warm fractures near its south pole. They announced strong evidence for a regional sea in 2014, and more recently, in 2015, shared results that suggest hydrothermal activity is taking place on the ocean floor.

Saturn's Geyser Moon Shines in Close Flybys

NASA's Cassini spacecraft completed three close flybys of Saturn's icy, ocean-bearing moon Enceladus, between Oct. and Dec. of 2015. The second of those flybys on Oct. 28th was highlighted by Cassini's closest ever dive through the active plumes of Enceladus, passing just 30 miles above its surface. Cassini's gas analyzer and dust detector instruments directly sampled Enceladus' plume of gas and dust-sized icy particles during the flyby. The analysis should provide important insights about the composition of the global ocean beneath Enceladus' surface and any hydrothermal activity occurring on the ocean floor. The potential for such activity in this small ocean world has made Enceladus a prime target for future exploration in search of habitable environments in the Solar System beyond Earth. Images taken during the close flyby had resolutions down to 52 feet per pixel.

The third flyby, which took place on Dec. 19th, marked Cassini's final close flyby of Enceladus for the mission, passing the moon's surface at a distance of 3,100 miles. Cassini will continue to monitor activity on Enceladus from a distance, through the end of its mission in Sep. 2017. Future encounters will be much farther away -- at closest, more than four times farther than this latest encounter.

The final flyby was the 22nd Enceladus encounter of Cassini's mission. The spacecraft's discovery of geologic activity there, not long after arriving at Saturn, prompted changes to the mission's flight plan to maximize the number and quality of flybys of the icy moon.

Right Page :: *During the mission's last close flyby, Cassini spacecraft peered out over the northern territory on Saturn's moon Enceladus, capturing this view of older, cratered terrain on the left and more youthful, wrinkled terrain on the right.*

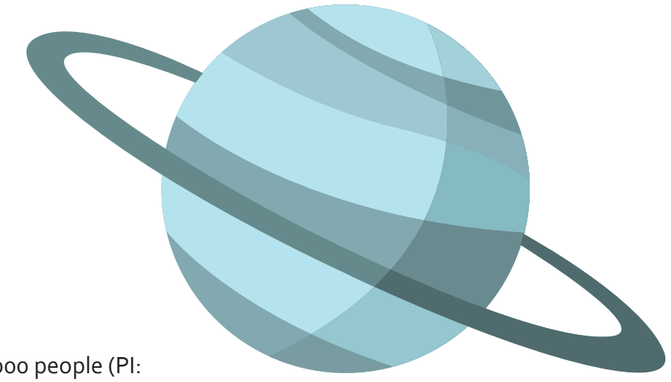
EDUCATION & INSPIRATION

NATIONAL CENTER OF INTERACTIVE LEARNING

The Space Science Institute's National Center for Interactive Learning (NCIL) is organized around four interconnected groups: 1) Exhibition Development, 2) Digital Learning, 3) Professional Development, and 4) Public Engagement. Providing effective STEM learning opportunities for all Americans is essential to creating an educated citizenry that understands 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. NCIL is leading the way for a new generation of STEM education platforms that 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, public 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. Visit www.nc4il.org for more information about our programs.

For over a decade NCIL educators have also 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.

Right Page :: *Starchitect was developed by the Space Science Institute with support by the National Science Foundation and NASA*



2015 Highlights

Starchitect

Starchitect fully launched in 2015, and has reached over 20,000 people (PI: James Harold; SSI Boulder Office). Supported by NSF and NASA, Starchitect is a stellar and planetary evolution game, playable on Facebook or externally. It uses the "sporadic play" model of games such as Farmville, where players may only take actions a few times a day, but may continue playing for months. This model is an excellent fit for teaching about the evolution of stars and planets: systems evolve in scaled real time (a million years to the minute), so that massive stars supernova within minutes, while stars like our sun live for weeks. In the meantime, players can pursue a wide

NCIL Impacts for 2015

In 2015, NCIL reached 210,000 individuals through five traveling STEM exhibitions, provided STEM-focused professional development to 350 individuals, and educational NCIL websites that have attracted over a million users.

Traveling Exhibit Visitors (210,000)

Great Balls of Fire Museum Exhibit (3 host sites):	**90,000**
Discover NASA Library Exhibit (2 host sites):	**45,000**
STAR_Net's Discover Earth Library Exhibit (2 host sites):	**45,000**
STAR_Net's Discover Tech Library Exhibit (1 host sites):	**20,000**
STAR_Net's Discover Space Pilot Exhibit (4 host sites):	**10,000**

Workshop (Conference + Exhibits) Participants: 290

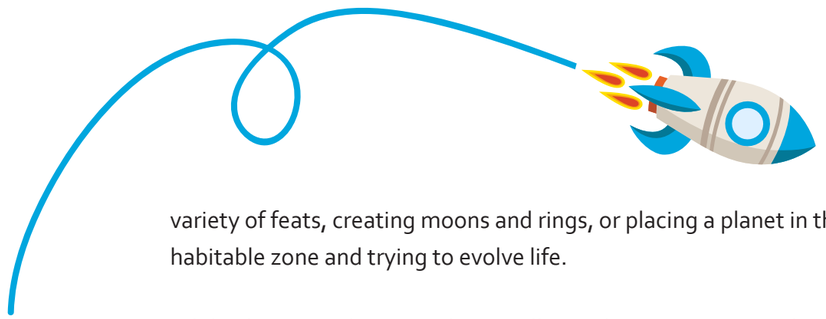
Webinar Participants: 310

STAR_Net Online Community Members: 1,200

NCIL Outreach Event Participants: ~6,000

Education Website Visitors

Website	Users	Page Views
Alient Earths	335,751	408,108
MarsQuest Online	223,611	252,264
Space Weather Center	218,973	264,785
Killer Asteroids	88,365	98,339
Giant Worlds	17,420	19,854
SciGames	20,382	26,641
STAR_Net Libraries	4,983	6,076
Starchitect	36,853	102,613
Totals	**946,338**	**1,178,680**

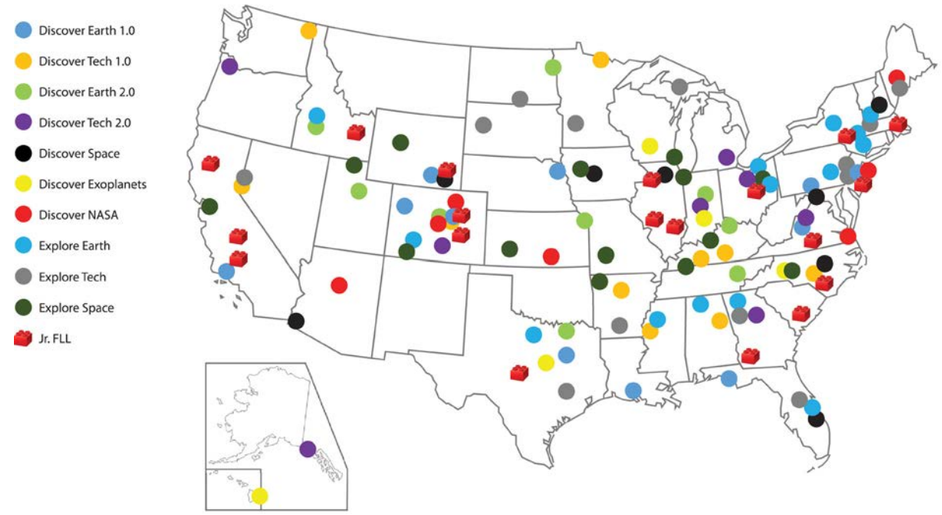


variety of feats, creating moons and rings, or placing a planet in the star's habitable zone and trying to evolve life.

While players are learning about stellar evolution, our team is learning about how these kinds of games can be used in education. We are using a mix of evaluation strategies, including data collected in-game, Facebook demographics, surveys, and interviews, in order to understand how the game is being used and how players are learning. Ultimately this will let us inform the education community about both

STAR Library Education Network (STAR_Net)

SSI's National Center for Interactive Learning (NCIL), in partnership with the American Library Association, Lunar & Planetary Institute, and the Afterschool Alliance, received broad implementation funding from NSF in 2014 for the STAR Library Education Network project (STAR_Net Phase 2). STAR stands for Science-Technology Activities and Resources. Principal Investigator (PI) Paul Dusenbery (Director of NCIL) is leading an experienced project team in substantially expanding the scope and reach of



Above :: STAR_Net program sites across the U.S.

its groundbreaking NSF-funded STEM library initiative. The 4-year program includes the following hands-on library exhibits: Discover Space, Discover Earth, and Discover Tech. Both urban and rural libraries that reach underserved audiences will be selected through a proven application process previously developed and managed by ALA. The project team has also developed a graphics-based small exhibits program (Explore Space, Explore Earth, and Explore Tech).

The Phase 2 program builds upon the successful training and outreach model developed for Phase 1. It includes hands-on activities for different age groups and provides library staff training (online and in-person) that introduces them to the STEM content of the exhibits, and guides them in developing complementary programming. A comprehensive outreach program is also planned and will be led by the Afterschool Alliance. The STAR_Net community of practice (CoP) has been significantly expanded to include many more members and resources (e.g. a STEM Resource Clearinghouse). Library staff and STEM professionals are encouraged to join this CoP and take advantage of the resources, forums, and blogs that have been added to the site (www.starnetlibraries.org).

The project's aim is to explore how public libraries and library staff can develop the capacity to offer standards-based STEM programs through collaborations with outreach provider s (e.g. Afterschool Alliance and ASTC) and STEM organizations (e.g. AAAS, Geological Society of America, American Society of Civil Engineers, ASTC; Engineers Without Borders). Capacity building will also take place through the project's CoP resources. The STAR_Net team's research focus is to investigate whether or not libraries are well suited to deliver STEM experiences to patrons from underserved and underrepresented populations and determine how common library structures can be leveraged to help libraries more intentionally deliver STEM content to those they serve. Phase 2 also aims to investigate how learning impacts seen in Phase 1 align with existing informal education learning models (e.g., Contextual Model of Learning).

From Our Town to Outer Space (FOTOS):

Bringing NASA science and engineering to underserved communities through a national public library exhibition program

Space exploration and research help us answer the age-old questions: *Where did we come from and are we alone?* NASA research programs are helping humanity understand the origin and evolution of galaxies, stars, and planets, and defining the conditions necessary to support life beyond Earth. FOTOS is funded by NASA's CP4SMP+ program. The overarching objective of FOTOS is to inform, engage, and inspire new public audiences (library staff and patrons) by sharing NASA's missions, challenges, and results. FOTOS is aligned with national STEM standards. It's an informal education program that will reach a broad audience of librarians, library patrons, and other members of the public with a special focus on underserved and underrepresented audiences. The 3-year pilot project includes: 1) a hands-on, museum-quality library exhibit (called Discover NASA: From Our Town to Outer Space) and tour (to 7 libraries across the country), 2) the development and broad dissemination of active learning activities for different age groups, and 3) library staff training (online and in-person) that introduces them to the STEM content of the exhibit and guides them in developing complementary programming. NCIL is partnering with the Education Development Center to provide formative and summative evaluation services.

Above :: *Patron enjoys Discover NASA exhibit at Louisville Public Library. Credit: NCIL/SSI*

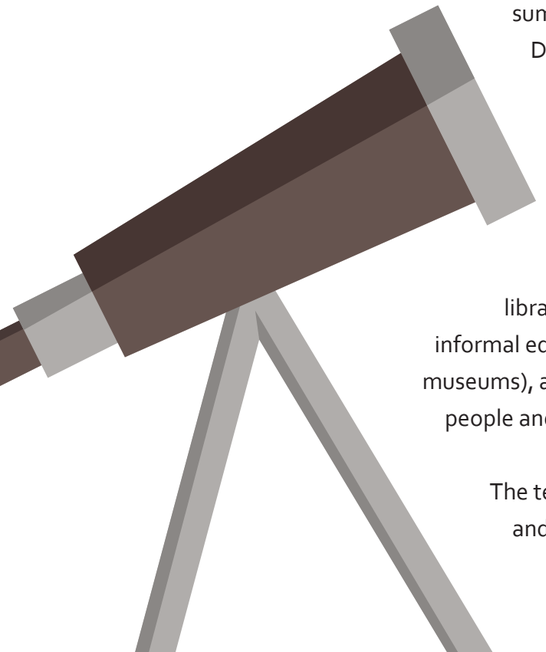
SCIENCE FOR THE PUBLIC

NASA@ My Library:

A National Earth and Space Science Initiative that Connects NASA, Public Libraries and their Communities

NASA@ My Library

Space Science Institute is proud to announce that it was chosen, along with 26 other organizations nationwide, for a cooperative agreement award from NASA's Science Mission Directorate to engage learners of all ages on NASA science education programs and activities. This 5-year project is called NASA@ My Library (PI: Paul Dusenbery; SSI Boulder Office). Partners include the Pacific Science Center, Cornerstones of Science, American Library Association, and the Laboratory for Atmospheric and Space Physics at the Univ. of Colorado. Formative and summative evaluation will be conducted by the Education Development Center. The project's overarching goal is to develop effective STEM programs in public libraries using NASA resources and subject matter experts that reach underserved populations (e.g., rural communities) and underrepresented groups. The project will establish systemic collaborations between the public library community (individual libraries, state libraries, and library associations), other informal education organizations (e.g., science centers and museums), and to NASA/Science Mission Directorate (NASA/SMD) people and programs.

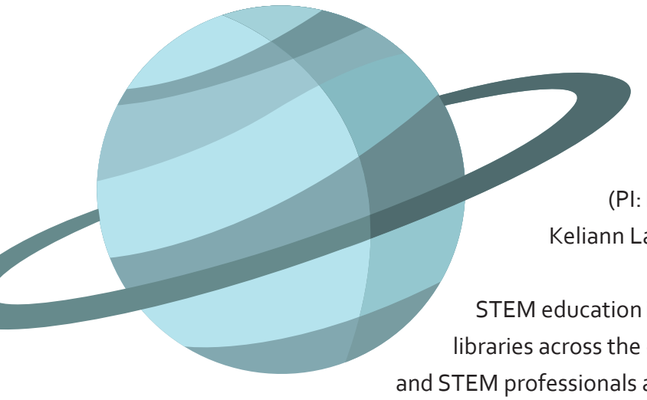


The teaming and leveraging partnerships will build a robust and sustainable national STEM library program to support and enhance NASA/SMD education efforts. The project team will form strong collaborations with NASA/SMD education programs and resources such as the Museum Alliance, Solar System Ambassadors, GLOBE, and Night Sky Network. Existing NASA Wavelength activities will be a core resource for the project's active learning experiences. The project evaluation has two objectives: 1) to document progress made toward the project goals, objectives, and outcomes described in this proposal, and 2) to provide the project team with feedback regarding progress toward achieving project goals so the team can make informed decisions about whether to continue, modify, or discontinue activities over the five-year period.

2015 Public Libraries & STEM Conference

Libraries across the country have been reimagining their community role and leveraging their resources and public trust to strengthen community-based learning and foster critical thinking, problem solving, and engagement in STEM. What started some years ago as independent experiments has become a national movement. NCIL in partnership with Lunar & Planetary Institute, received funding from the National Science Foundation for the first-ever Public Libraries & STEM conference that took place at the Sheraton Denver Downtown

Above :: *2015 Public Libraries & STEM Conference. Credit: NCIL/SSI*



Hotel in Colorado, August 20-22, 2015. The conference was supported by NSF (PI: Paul Dusenbery (Boulder Office) and Co-PI: Keliann Laconte (now at SSI's Boulder Office).

STEM education is having a transformational impact on libraries across the country. The conference brought library and STEM professionals and funders together to build productive relationships; explore promising practices in designing effective programs; help define a new 21st century vision of STEM learning in public libraries; and develop the foundation for a future evaluation and research agenda for libraries and their partners engaged in STEM education efforts. The conference's work and published proceedings will inform future development of informal STEM learning programs in libraries and their communities. The conference attracted approximately 150 participants. There was ample time for networking at conference events including visits to local points of interest such as the Denver Public Library and the Denver Museum of Nature and Science. Conference sessions were organized around five topics:

1. 21st Century Visions of STEM Learning in Public Libraries
2. Effective Collaboration Models between Libraries and STEM Organizations
3. Case Studies of Successful STEM Implementation in Libraries
4. Strategies for Reaching Groups Underrepresented in STEM Fields
5. Building a Foundation for Evaluation and Research for STEM Learning in Public Libraries

The results of a pre-conference needs assessment survey of libraries provided an important benchmark for discussing future plans. STEM and library experts also produced six "Background Reports" that highlight research in how people learn through out-of-school-time (OST) experiences; the power of collective impact; audiences that libraries are serving; and the ways libraries are continuing to evolve to meet their community's needs. In order to provide ongoing channels of communications between STEM organizations and libraries, a Leadership Forum has been established following the conference for leaders and decision-makers from both the public library and informal STEM education and research communities.

Right Page Top :: *Children exploring a STEM exhibit interactive, Space Science Institute*

Right Page Bottom :: *Participants doing an activity at the Public Libraries & STEM conference August 20-22, 2015*

Space Science Institute
Summary Statement of Financial Position
as of December 31, 2015 and 2014

	2015	2014
Assets		
Assets		
Cash and cash equivalents	$219,928	$214,224
Accounts receivable	1,438,688	1,283,184
Prepaid expenses and deposits	122,162	101,349
Net furniture, equipment, and property	11,955	13,903
Total assets	$1,792,733	$1,612,660
Liabilities and Net Assets		
Liabilities		
Accounts payable and accrued liabilities	$879,464	$556,590
Deferred revenues	154,757	269,486
Line of credit	450,000	491,869
Total liabilities	1,484,221	1,317,945
Net assets		
Unrestricted	305,862	294,715
Temporarily restricted	2,650	-
Total net assets	308,512	294,715
Total liabilities and net assets	$1,792,733	$1,612,660

Summary Statement of Activities
for the years ended December 31, 2015 and 2014

	2015	2014
Support and revenue		
Grants, contracts, and cooperative agreements	$7,060,079	$5,928,688
Contributions	11,097	7,388
Exhibit income	103,197	124,180
Interest income	89	111
Total support and revenue	7,174,462	6,060,367
Expenses		
Program services	5,505,117	4,580,649
Fundraising	24,240	92,486
General and administrative	1,631,308	1,503,814
Total expenses	7,160,665	6,176,949
Change in net asset	13,797	(116,582)
Net assets, beginning of year	294,715	411,297
Net assets, end of year	$308,512	$294,715

Left Page :: Starburst Galaxy Messier 94, ESA/Hubble and NASA

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, 2015 and 2014, from which the summarized information was derived. A copy is available upon request.

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