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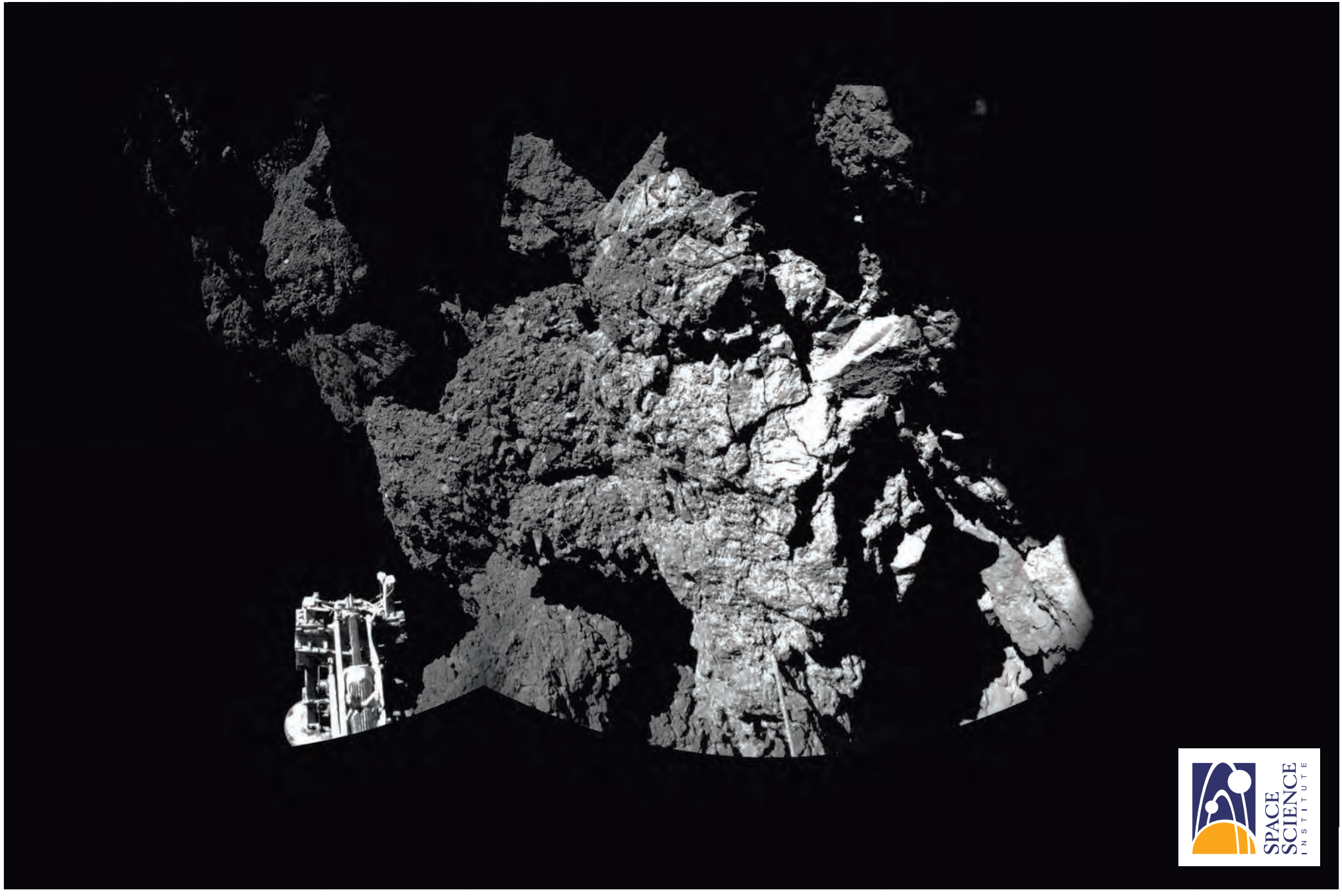
ANNUAL REPORT 2016



SPACE SCIENCE INSTITUTE

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.

Message from the Chairman of the Board of Directors

I am pleased to report that SSI delivered record performance in 2016, with strong growth in project reach and revenue. Our researchers were awarded $4 million dollars in grants and supported 12 space agency missions and observatories. The Cassini imaging team is up to over 26,000 photos and mosaics of the Saturnian system, releasing their best products weekly to the public. SSI's education team reached 495,186 individuals through 8 museum and library exhibits, provided professional development webinars to 1,236 individuals, and engaged 1.17 million users on its interactive, educational websites. We achieved this by providing the highest quality science, expanding into new growth markets, and building communities.

Your leadership continues to function well and is very clear and focused on its priorities. In 2016, the Board met regularly with senior SSI management and track progress against potential opportunities and obstacles. We have spent considerable time brainstorming ways to enhance sustainability for SSI outside of standard federal grants and in developing SSI's new 2017-2019 strategic plan with Executive Director Karly Pitman and members of the Executive Advisory Committee. The Board believes that having a clear and focused strategy, developed in conjunction with our highly motivated and talented staff to capitalize on the strengths of our innovative project ideas, will position SSI for long-term growth.

In 2016, we said goodbye to Board secretary Karen Leaffer. Karen's expertise in nonprofit law and board governance was invaluable to us during her terms and we thank her for her hours of service and dedication to SSI's mission. Replacing Karen is our new executive secretary (ex officio), Jennifer Griest. Jennifer is also an attorney whose practice focuses on federal grants and contracts law; she has advised SSI on numerous matters since 2007. We welcome Jennifer to her new role on the Board.

I would like to acknowledge our entire Board of Directors for their ongoing dedication to SSI, and on behalf of the Board, I would like to thank all of our people for exemplifying SSI's values and going the "extra mile" during 2016.

William R. Purcell, Ph.D.

Cover Image :: First Image from 67P/Churyumov-Gerasimenk Comet, Credit: ESA/Rosetta/NavCam

Message from the Executive Director

Since the early 1990's, Space Science Institute has grown from two employees to become an international powerhouse in space science and informal STEM education. We are very proud of the course SSI has taken, our team's accomplishments this year, and the direction we are heading.

SSI's researchers have been incredibly productive in 2016. We welcomed 10 new scientists in space physics, heliophysics, and Mars. SSI Mars scientists submitted CubeSat proposals as leads, thanks to our new friends at ExoTerra (Littleton, CO). Our Center for Space Plasma Physics is planning a workshop to be hosted in honor of SSI's Joachim Birn. SSI's Center for Extrasolar Planetary Systems boasts an impressive 80 publications, over 20 talks, and 17 proposals this year. Cassini began its Grand Finale orbits designed to catch the last images of Saturn's rings and finally plunge into Saturn's atmosphere. You can read about the best of fiscal year 2016 images processed by SSI's Cassini ISS camera team as well as the work of our featured astronomers later in this report.

SSI's National Center for Interactive Learning and SSI researchers have been hard at work in creating new STEM education tools and experiences. NCIL's STAR_Net project has connected over 4,000 U.S. public libraries with STEM activities, webinars, and professional development programming. We are especially grateful to NASA, the Moore Foundation, Google, and the Research Corporation for their support of NCIL's 2017 solar eclipse initiative. SSI has conducted outreach programs in Europe, led by Luca Montabone, and built bridges between professional and amateur astronomers (see feature on Padma Yanamandra-Fisher's work). SSI is venturing into virtual reality with Stage 2 Studios, and our digital gaming team continues to garner over a million hits for their products.

I am proud to lead an organization with a true passion to produce high caliber science, improve science literacy, and reach underserved audiences and future science enthusiasts. It's this commitment that will drive SSI forward in our 2017-2019 strategic plan. I would like to thank our employees and affiliates for their significant efforts over the past year, as well as their willingness to embrace change. And I wish to thank our volunteers, partners, donors, and stakeholders for the trust and support they continue to give us.

Karly M. Pitman, Ph.D.

Inside Cover :: Coronal emission during a total solar eclipse, Credit: Miloslav Druckmüller

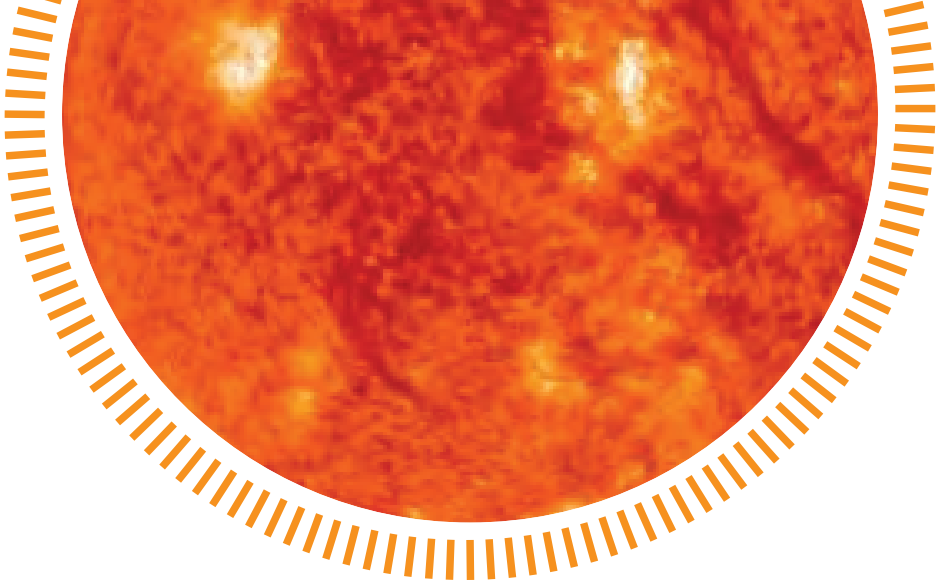
OVERVIEW

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 (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 Science (2014).

Present

Today, SSI manages 70 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 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



Space Science Institute

On-Site + Off-Site

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.

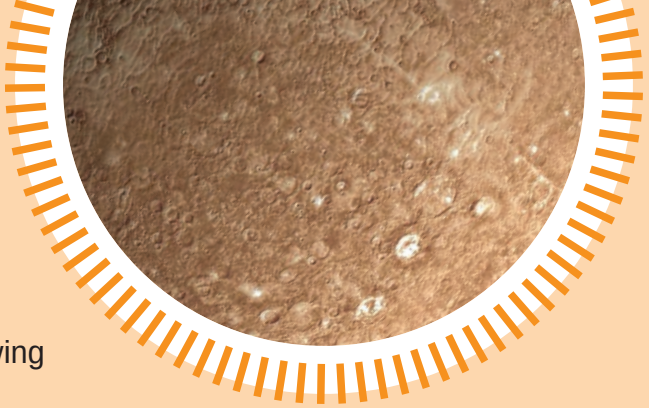
competitive awards (all currently active) from: the National Science Foundation (STEM Learning in Libraries); the NASA Jet Propulsion Laboratory; the Space Telescope Science Institute; the U. S. Department of Energy; and NASA.

2016 Board Members

- Ms. Ann Goldman, Co-Founder, Front Range Source
- Dr. Dick Green (ex officio), Former President and Chief Executive Officer, CableLabs, Inc.
- Ms. Jennifer Griest (Executive Secretary, ex officio), In-House Counsel, Legal, and Policy Specialist, Space Science Institute
- Dr. Marilyn Johnson, Former Science Director, Oregon Museum of Science and Industry
- Dr. Steve Jolly, Systems Engineering Director, Lockheed Martin Corporation
- Dr. Karly Pitman (ex officio), Executive Director / Senior Research Scientist, Space Science Institute
- 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

2016 Executive Advisory Committee

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



2016 Grants & Contracts

SSI gratefully acknowledges support from research and education grants and contracts from the following organizations in 2016:

JPL (Jet Propulsion Laboratory)
Malin Space Science Systems
NASA
NASA Ames Research Center
Johns Hopkins University
Applied Physics Laboratory
Arizona State University
CU Boulder
Smithsonian Astrophysical Observatory
SUNY
Southwest Research Institute
University of Alabama
UCLA
University of California
University of Delaware
Universities Space Research Association
Villanova
National Science Foundation
University of Wisconsin
Space Telescope Science Institute
City of Bedford (TX)
Jet Propulsion Laboratory
Moore Foundation
University of Arizona
CASIS
Ohio State University
SETI Institute
Science Museum of Minnesota
University of Michigan
Colorado Gives Foundation

Donors

SSI wishes to thank the generous individuals who contributed to the Space Science Institute in 2016:

- Myron McCallum
- Ann Goldman
- Jennifer Griest
- Dr. Paul Dusenbery
- Lawrence Satkowiak
- Dr. Ben Clark
- Dr. Padma Yanamandra-Fisher
- Dr. Karly Pitman
- Maddie Zeigler
- Dr. Marilyn Johnson
- Dr. Steve Jolly
- Eliana Villwock

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.

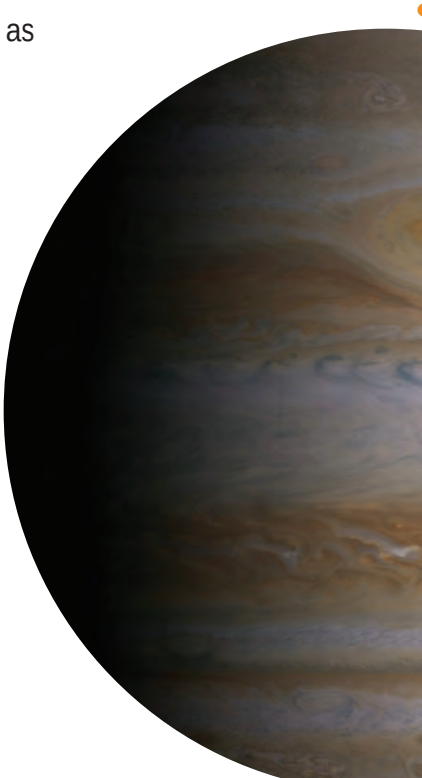
Right Page :: The Cartwheel Galaxy from Hubble. Credit: ESA, NASA, Hubble

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.



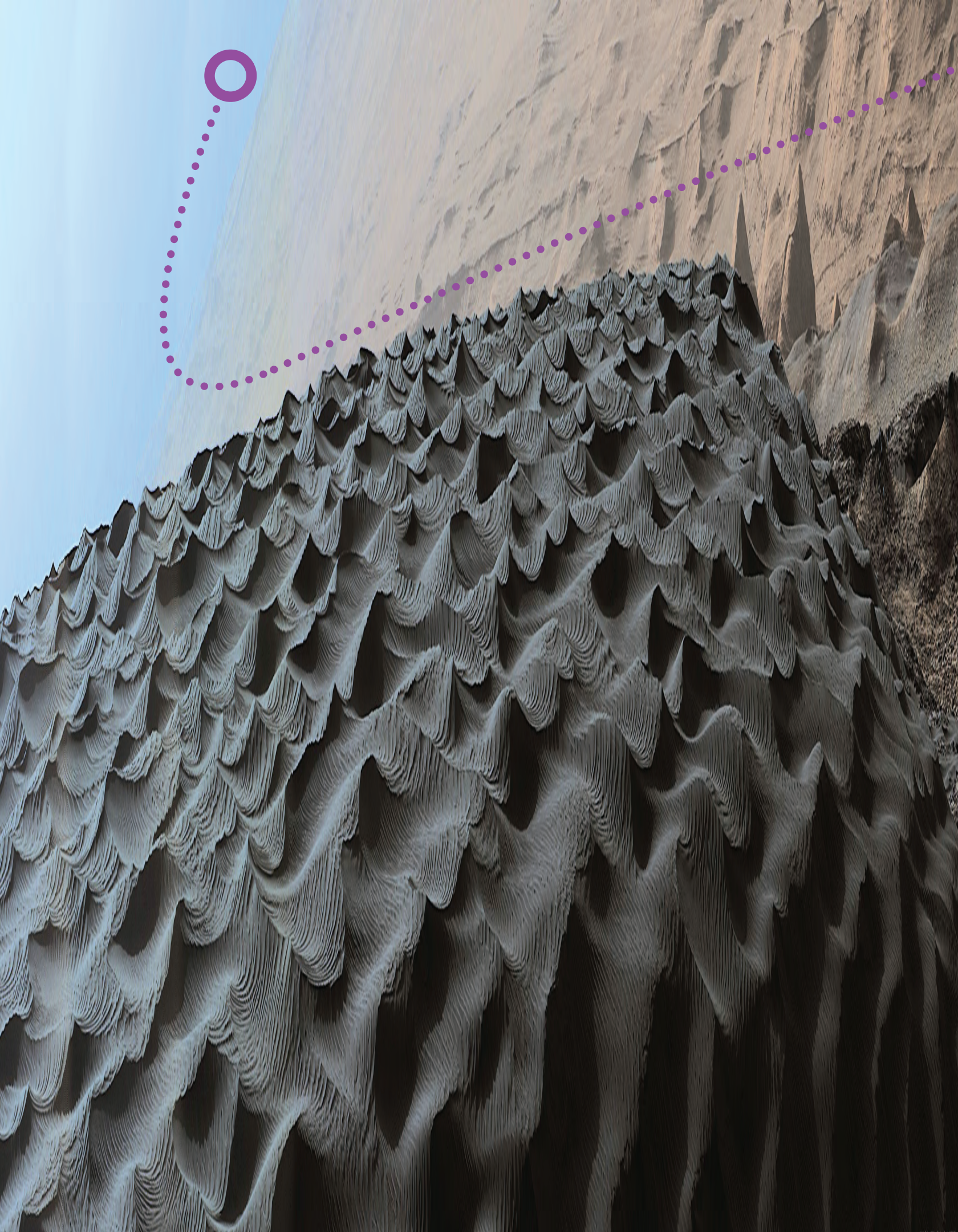
Our Vision for the Future

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. 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 Dunes on Mars (Horizontally Compressed). Credit: NASA, JPL-Caltech, MSSS*

SSI RESEARCH BRANCH

SSI's Research Branch scientists participate in a broad array of space science activities, including Earth science, space physics, planetary science, and astrophysics. Our research team's expertise continues to expand, and now encompasses investigations of phenomena on Earth and in the geospace environment surrounding our planet. Our scientists study the atmospheres and surfaces of other bodies in our Solar System as well as explore the early stages of the life cycles of stars and nascent planetary systems around other stars. We also study the mysteries of quasars and other types of distant galaxies.

In 2016, our Research Branch welcomed 4 new scientists and 6 new affiliates to bring our total research staff to 70 members. 9 of these are located on-site in at SSI's Boulder headquarters and the rest are distributed across the U.S. and several countries. While any individual scientist may pursue the subject area of his or her choice, SSI's Research Branch also runs three "Research Centers" to facilitate and promote collaborative research in topical areas of interest: the Center for Mars Science (CMS), the Center for Space Plasma Physics (CSPP), and the Center for Extrasolar Planetary Studies (CEPS); see our center updates below for recent activities.

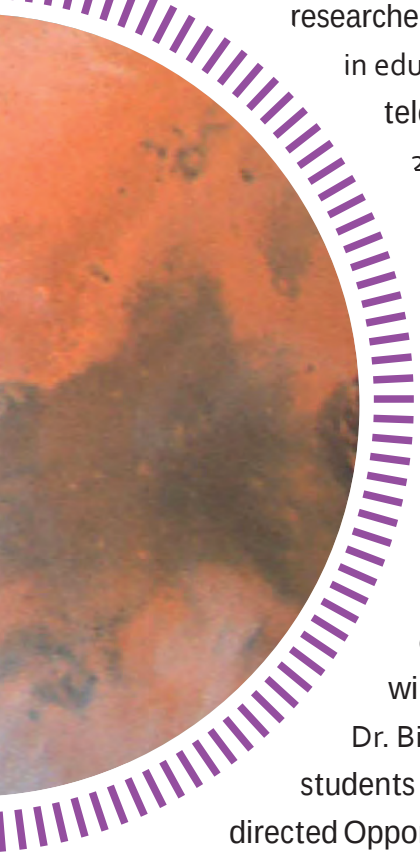
Impacts:

Total number of scientists and affiliates: 70
New researchers in 2016: 10
Papers published in 2016: > 200 (over 180 refereed)
Invited/Public Talks: > 60
Proposals Submitted in 2015: 98
Grants awarded in 2016: 33

NASA and European Space Agency Missions Supported:
Hubble Space Telescope, Kepler (exoplanet space observatory), 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 (2016), and Mars 2020 Rover (to be launched in 2020)

Research Center Updates

Center for Mars Science



In 2016, the SSI Center for Mars Science (CMS) continued to act as a venue for SSI Mars researchers to interact, learn of new developments related to Mars science, and to engage in education and public outreach activities. The center has periodic Journal Club telecons where center researchers, or guest outside researchers, share results. In 2016 Journal Club presentations included Dr. Francois Forget of the Laboratoire de Météorologie Dynamique (LMD) of France's CNRS on "The 2016 ExoMars Mission", new SSI Mars researchers Dr. Susan Sakimoto on "Modeling Plains and Small Edifice Volcanism on Mars", and Dr. Jorge Pla-Garcia on "Mesoscale meteorological modeling of Mars mission environments".

CMS researchers also continued to work on education and public outreach activities in their own communities. These activities include: Dr. Luca Montabone's work bringing science content to festivals in Aix-les-Bains, France; Dr. Mike Wolff working with two Wisconsin high school students to design and develop a stereo camera system using commercial-off-the-shelf components in order to test software and methodology that will ultimately be used for the Mars 2020 Mastcam-Z stereo camera; and CMS Director, Dr. Bill Farrand, working with a Lafayette, CO Centaurus High School teacher and her students on Mars related activities and educational programs, including plans for a student-directed Opportunity Rover Pancam observation.

Center for Space Plasma Physics

The Center for Space Plasma Physics (CSPP) provides an umbrella for very broad NASA-sponsored and NSF-sponsored research efforts on plasma physics and the heliosphere. In 2016, the members of CSPP published 61 papers in refereed journals (15 papers as primary authors and 46 papers as contributing authors) in an array of subjects including: turbulence, magnetic-field-line reconnection, magnetospheric modeling, solar-wind structure, space weather, Fourier theory, and kinetic plasma instabilities. A special issue of Journal of Geophysical Research (November 2016) entitled "Unsolved Problems in Magnetospheric Physics" was guest edited by CSPP member Mick Denton. Finally, the CSPP has been preparing for its first conference, entitled "Advancing Plasma Physics from the Sun to the Earth", to be held May 21-26, 2017 in Breckenridge, Colorado.

Below :: *The Soul of Star Formation (W5). Credit: José Jiménez Priego*

Center for Extrasolar Planetary Systems

The Center for Extrasolar Planetary Systems (CEPS) gathers a broad range of scientists that are interested in fields related to the understanding and the characterization of extra-solar planetary systems. CEPS member research includes the study of exoplanet atmospheres and chemistry, young stellar objects, star formation, planetary systems formation, radiative transfer, the determination of planet-host stars properties with asteroseismology, and the analysis of signatures of planetary formation as reflected in debris disks. CEPS provides a venue for SSI Researchers to brainstorm about science, collaborate on proposals and papers, and discuss proposal strategies.

Today CEPS counts 14 members with one new member that joined in 2016, Dr. Channon Visscher, who works on planetary chemistry. 2016 has been a very productive year for CEPS member with 80 refereed publications (9 as first authors), more than 20 talks in conferences or colloquia and 17 proposals submitted. CEPS members also mentor undergraduate and graduate students and are actively involved in outreach activities.

Since CEPS members are scattered around the US, the discussions happen through periodic telecons. In January 2016, we had an external speaker, Dr. Wilson Cauley, who gave a talk on the possible discovery of a bow shock around a hot Jupiter; in February, Dr. Travis Metcalfe presented the results of his recent paper on the rotation of old solar-like stars and what this tells us about our own Sun; Dr. Mike Sitko gave a talk on high spatial resolution astrophysics in April; in June, Dr. Channon Visscher presented his work on cloud chemistry in substellar atmospheres; and finally in October we had an onsite external speaker, Dr. Adam Kowalski, who gave a talk on Proxima Cen and its magnetic activity.

CEPS maintains a website (http://ceps.spacescience.org/home-page.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.

Pro-Am Ground-based Support of ESA/Rosetta Mission to Comet 67P/CG

Dr. Padma A. Yanamandra-Fisher
Senior Research Scientist, Rancho Cucamonga, CA Office

Dr. Yanamandra-Fisher served as the global coordinator of the amateur astronomer community in support of ESA/Rosetta mission to a comet, 67P/Churyumov-Gerasimenko (CG), from 2014 – 2016. What is the role of a global coordinator and why does a space mission need one? A global coordinator provides the bridge between the amateur and professional community by identifying and integrating the scientific needs of the

Figure 2 :: Examples of the unprecedented observations of the nucleus of comet 67P by Rosetta. Credit: ESA

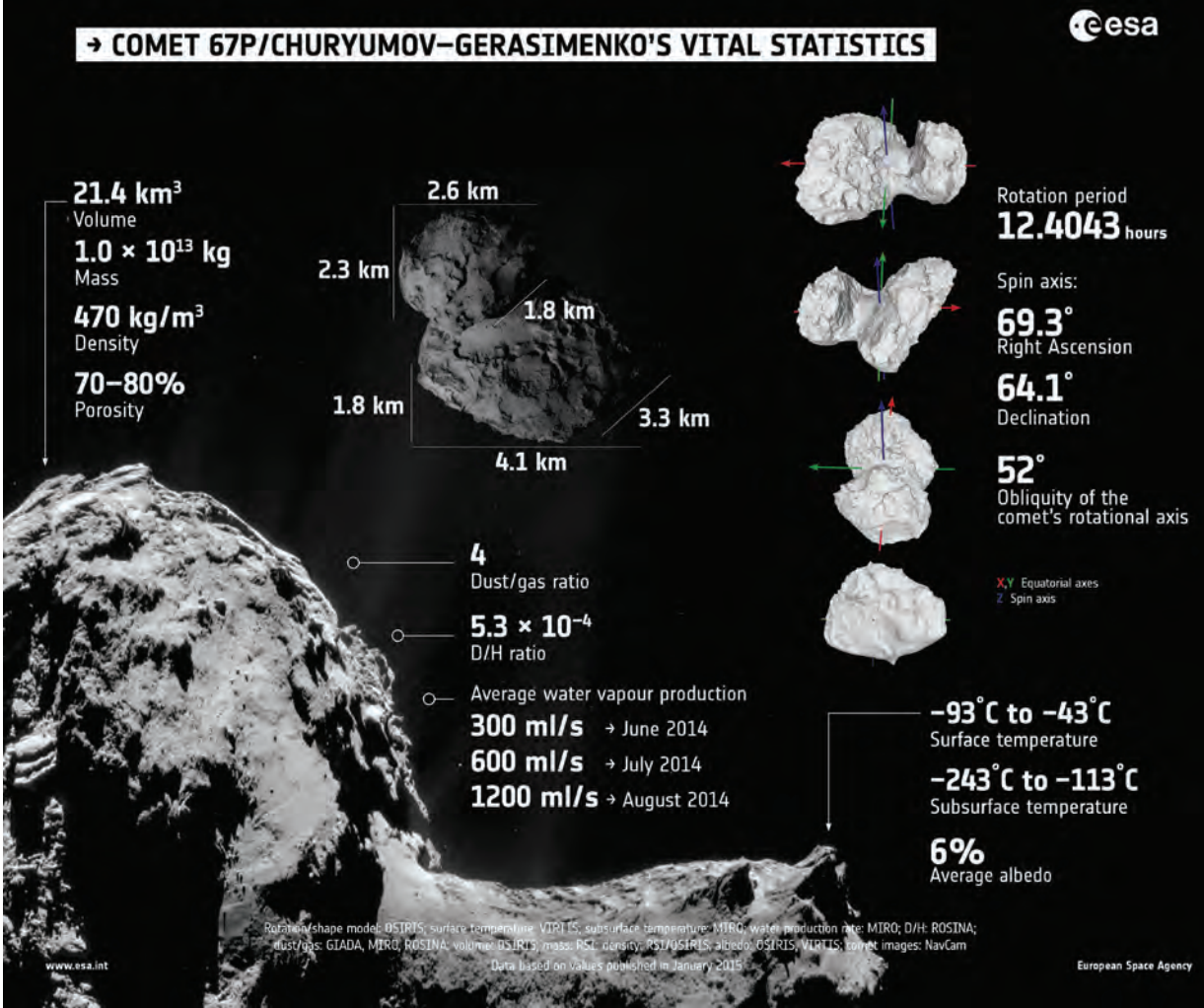
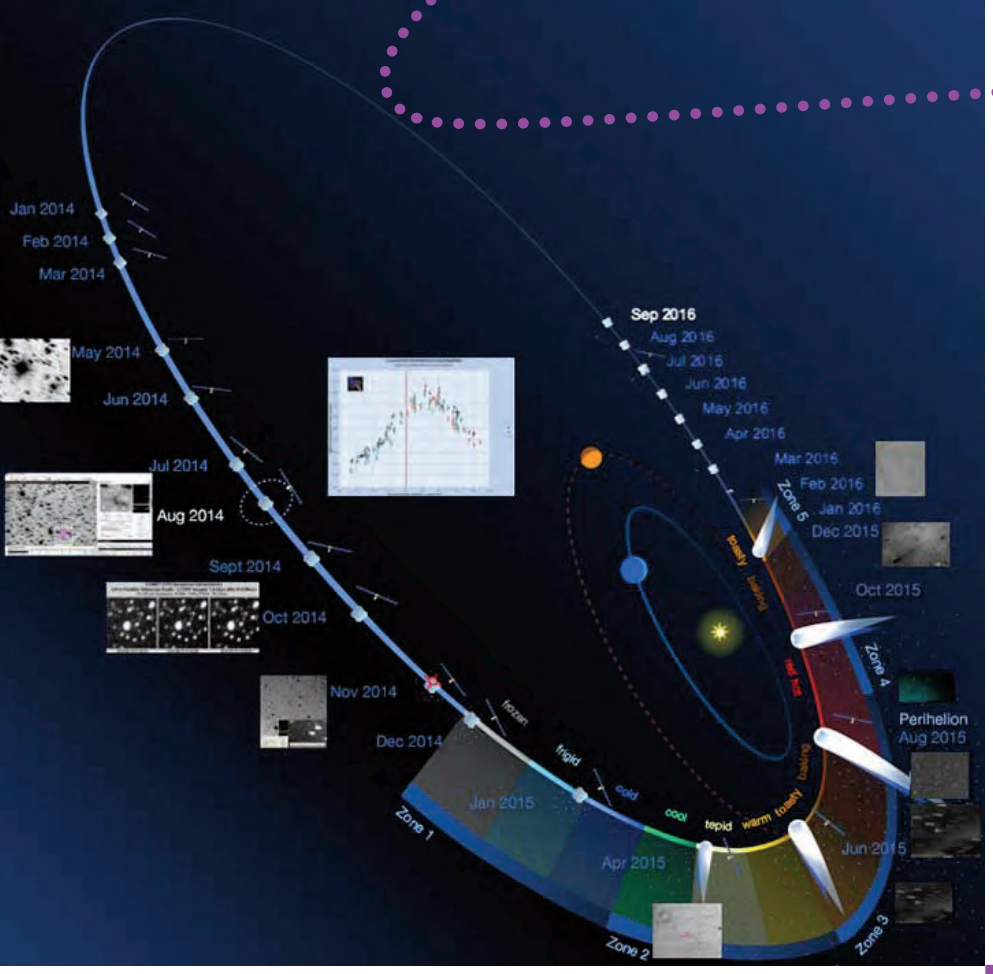


Figure 1 :: Artist's rendition of ESA/Rosetta mission to Comet 67P/CG: Rosetta orbiter, Philae lander, and the surface of comet 67P/CG. Credit: ESA



mission and fostering synergy between the mission team, and ground-based professional and amateur observers. This was a unique role both for the ESA/Rosetta mission and Dr. Yanamandra-Fisher, showcasing the mission to global audiences and enhancing the role/synergy of the amateur community contributions to science. The result was the largest collection of observations by global amateur comet observers that will be crowdsourced by professional observers for years to come.

Figure 3, Top Right :: *A summary of the ground-based amateur observations of comet 67P/CG from 2014-2016, illustrating the timeline of observations and evolution of various structures such as the long scale tail phenomena and post-outburst brightening of the coma. Below inset shows the global network of amateur observers. The contributions of the amateur community continued well into 2016.*

The goal of the ESA/Rosetta mission (Fig. 1) is to "unlock" the secrets of comets, which are believed to be primordial bodies left-over form the formation of our Solar System. Co-discovered by Churyumov and Gerasimenko in 1969, comet 67P/CG has an orbital period of 6.5 years. The most recent 2015 apparition, appearance of the periodic comet, was expected to fainter than in previous apparitions and to remain close the ecliptic plane, where most objects orbit in our Solar System. Global amateur astronomers' observations have been critical in supporting and filling in results from Rosetta (including in-situ results from Philae) as well as professional ground- and space-based astronomical observatories, which have led the most detailed characterization of a comet through its seasons to date (Fig. 2).

Two notable results from amateur astronomers' observations at post-perihelion (after the comet was closest to the Sun) were: 1) the evidence of long cometary dust tails and the apparent lack of an ion tail; and 2) the lingering brightness following outbursts on the nucleus of the comet (which was observed by the Rosetta spacecraft, but not observed on Earth because of the extended coma). These results were showcased on various social media platforms (from Facebook, Pinterest, Twitter, Flickr etc...). Dr. Yanamandra-Fisher created an innovative synergy between amateur and professional observers via PACA_Rosetta67P (PACA stands for Pro-Am Collaborative Astronomy).

Amateur astronomers are now included in several current missions (e.g., NASA/Juno, NASA/ESA/SOHO) and will play a very important role in the upcoming Total Solar Eclipse, on August 21, 2017, in which Dr. Yanamandra-Fisher will participate as both a scientist and coordinator of amateur astronomers.

Figure 1 :: The "Pillars of Creation" Credit: HST/NASA

The Surprising Future of Our Magnetic Sun

Dr. Travis Metcalfe, Senior Research Scientist, Boulder, CO Office

Our Sun is just one of a hundred billion stars in the Milky Way galaxy. Our front row seat on Earth allows us to study the Sun in much greater detail than is currently possible for other stars. However, this only gives us one snapshot in the life story of stars like the Sun. To piece together the whole story, we need to study other stars that are younger or older. SSI Senior Research Scientist Dr. Travis Metcalfe and collaborators recently used observations from the Kepler space telescope to discover something fundamental about the life story of stars that never would have come to light by studying our Sun in isolation.

Astronomers believe that the universe began with a Big Bang that produced only hydrogen and helium, with just a sprinkle of lithium, beryllium, and boron. All the other elements were manufactured inside stars, including the carbon that makes up our bodies, the nitrogen and oxygen in our atmosphere, and the silicon and iron that formed our planet. These chemical elements were dispersed into the galaxy when the first generation of stars exploded as supernovae, sending shock waves through space that created a second generation of stars like our Sun.

Stars appear to be born in clusters, inside giant clouds of gas and dust (Fig. 1). When the clouds contract under the influence of gravity, they splinter into smaller fragments that become individual stars. As each fragment contracts and heats up, it starts to rotate more quickly and its initial magnetic field becomes concentrated. Eventually, the core of each cloud fragment begins converting hydrogen into helium, and a star is born. Stars are formed with a range of sizes, which determines how fast they burn through their hydrogen. We can determine the age of a star cluster by measuring the sizes of stars that have already exhausted their fuel.

Clusters of stars eventually get mixed into the rest of the galaxy. To measure the age of an isolated star like the Sun, we need to probe the hot core where hydrogen is converted into helium throughout its lifetime. Bubbles of hot gas near the surface of the sun are constantly churning to release heat.

These turbulent motions create sound waves that travel into the star and back to the surface, causing tiny brightness variations that depend on the composition of the interior. We can determine the age of isolated stars by comparing the properties of waves that travel through the center with those confined to the outer layers.

Rotation and magnetism are intricately linked in stars. During a total eclipse, you can see the hot gas surrounding the sun that traces the solar wind (Fig. 2). This gas also reveals the underlying magnetic field, dominated by a strong bi-polar structure. The wind interacts with the large-scale field and gradually slows the rotation. But the surface of the sun does not rotate like a solid body, it is more like a fluid rotating faster near the equator than at the poles.

Figure 2 :: Coronal emission during a total solar eclipse, Credit: Miloslav Druckmüller

The resulting shear recycles the large-scale field into smaller scales that we observe as sunspots. Over time, rotation and magnetism in stars diminish together, each feeding off the other.

The Kepler space telescope changed our understanding of how rotation and magnetism evolve in stars like the Sun. After launching in 2009, Kepler spent four years monitoring the brightness of thousands of stars. Rotation in young star clusters observed by Kepler agreed with prior expectations, but the older isolated stars revealed a very different behavior. Beyond middle age, the rotation of stars no longer slowed over time, suggesting that the magnetic field must be concentrated in smaller scales. Additional measurements from telescopes on the ground

The Surprising Future of Our Magnetic Sun

Dr. Travis Metcalfe, Senior Research Scientist, Boulder, CO Office *Continued...*

confirmed a fundamental shift in the character of magnetism in older stars.

Using these observations, Dr. Metcalfe and his co-authors developed a new scenario for the evolution of stars beyond middle age. The evidence suggests that our Sun may have entered this new phase of evolution in the past several hundred million years, around the time that land-based life emerged on Earth. Life began earlier under the oceans, where it was shielded from the harmful effects of magnetic eruptions from a younger sun. If it's not just a coincidence, then older stars may be the best places in the galaxy to search for advanced civilizations.

Cassini ISS Impacts

by JPL fiscal year
Oct. 1, 2015 – Sep. 30, 2016

Archiving

1. 26,707 images received, processed, and cataloged
2. 7 archive volumes delivered to and accepted by the Planetary Data System (PDS)

Uplink Implementation

1. ~6 sequences implemented (and integrated)
2. 34 Spacecraft Activity Sequence Files (SASFs) merged, tested, and delivered
3. 34 Short-Form Output Files (SFOF)/C-kernel bundles delivered
4. 587 ISS observation pointing designs designed, tested, and corrected
5. 2760 observation commands (24.3% by CICLOPS)

CASSINI IMAGING OPERATIONS

Below :: *Prometheus and the Ghostly F Ring. Credit: Cassini Imaging Team, NASA/JPL/SSI*

Camera Commanding

1. 842 ISS camera trigger (IOI) files designed/tested/corrected
2. 24,680 images taken (estimated by counting planned images, does not account for data loss) (41.1% ISSOPS)
3. 9 ISS Support Imaging Observations designed for other teams

4. MISC Uplink Ops

1. ~60 Science Planning telecons attended
2. 57 Configuration Change Requests (CCRs) processed
3. 6 Waivers handled
4. 6 Engineering Change Requests (ECRs) handled
5. 8 Cassini Sequence Change Requests (SCRs) handled
6. ~12 Reaction-Wheel Assembly Bias Optimization Tool (RBOT) processes supported
7. Proximal Periapse exercise supported

Image Products

1. 52 weekly image releases
2. 17 special image products
3. 12 Raw images
4. Titan maps updated

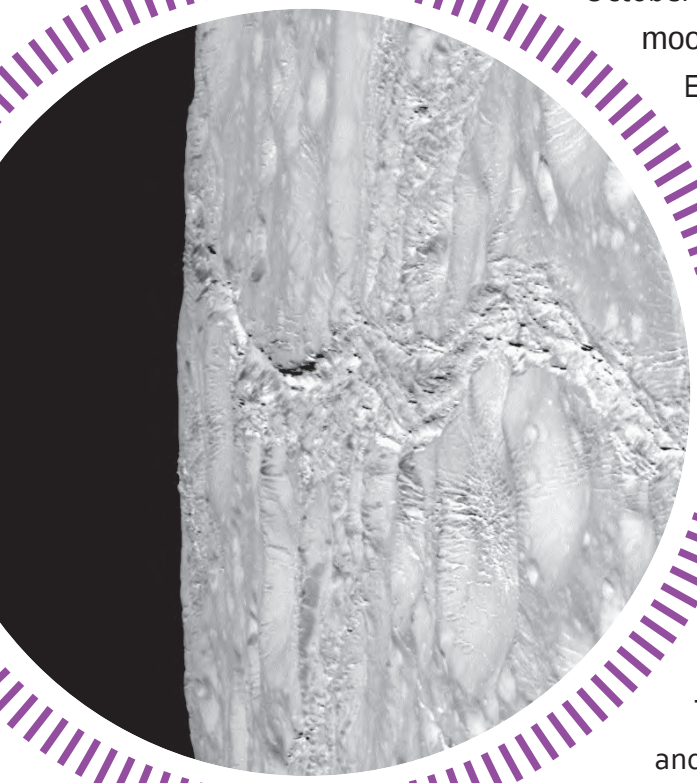
Press Releases

1. 1 press releases, 3 image advisories and 2 raw events

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 late 2015 through 2016.

Closest Northern Views And Close Southern Flyby Of Saturn's Moon Enceladus

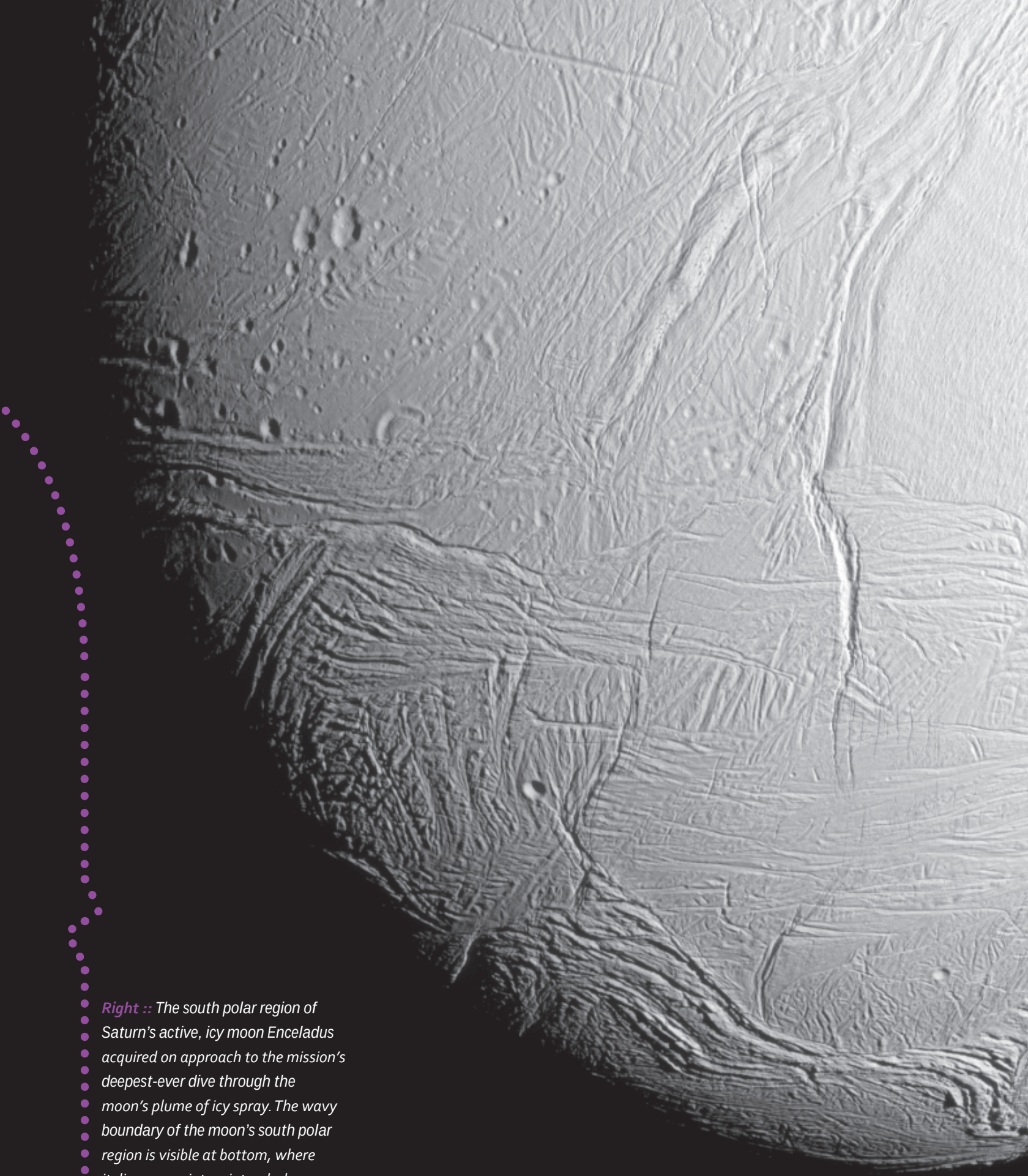
In October of 2015, NASA's Cassini spacecraft completed two close flybys of Saturn's icy, ocean-bearing moon Enceladus, returning its best-ever views of the northern extremes and ultra-close views of the active south pole.



The spacecraft obtained images of the northern extremes during its October 14 flyby, passing 1,142 miles (1,839 kilometers) above the moon's surface. Scientists expected the north polar region of Enceladus to be heavily cratered, based on low-resolution images from NASA's Voyager mission, but the new high-resolution Cassini images show a landscape of stark contrasts which feature a network or thin cracks that spread out and slice through the craters.

On October 28, 2015, Cassini made its deepest-ever dive through the Enceladus' plume of icy spray, sampling the chemistry of the extraterrestrial ocean beneath the ice at an altitude of just 30 miles (49 kilometers) above the moon's south polar region. Images returned from the flyby have resolutions down to 52 feet (16 meters) per pixel. These two close flybys of Enceladus were Cassini's third and second to last of the mission. The spacecraft's final close Enceladus flyby took place on December 19, 2015 at an altitude of 3,106 miles (4,999 kilometers) above the moon's surface.

Above :: *Scientists expected the north polar region of Enceladus to be heavily cratered, but high-resolution Cassini images show a landscape of stark contrasts. Thin cracks cross over the pole — the northernmost extent of a global system of such fractures. Before this Cassini flyby, scientists did not know if the fractures extended so far north on Enceladus.Credit: NASA/JPL/SSI*



Right :: The south polar region of Saturn's active, icy moon Enceladus acquired on approach to the mission's deepest-ever dive through the moon's plume of icy spray. The wavy boundary of the moon's south polar region is visible at bottom, where it disappears into wintry darkness. Credit: NASA/JPL/SSI

Below :: *Details of the pockmarked surface of Saturn's moon Prometheus (86 kilometers, or 53 miles across) are captured during a moderately close flyby on Dec. 6, 2015. This is one of Cassini's highest resolution views of Prometheus. Credit: NASA/JPL/SSI*

Right Top :: *This is one of Cassini's highest resolution views of the small moon Epimetheus captured during a moderately close flyby on Dec. 6 2015. Credit: NASA/JPL/SSI*

Bottom Right :: *During its final close flyby of Saturn's moon Enceladus, Cassini ISS captured this view featuring the nearly parallel furrows and ridges of the feature named Samarkand Sulci. Credit: NASA/JPL/SSI*

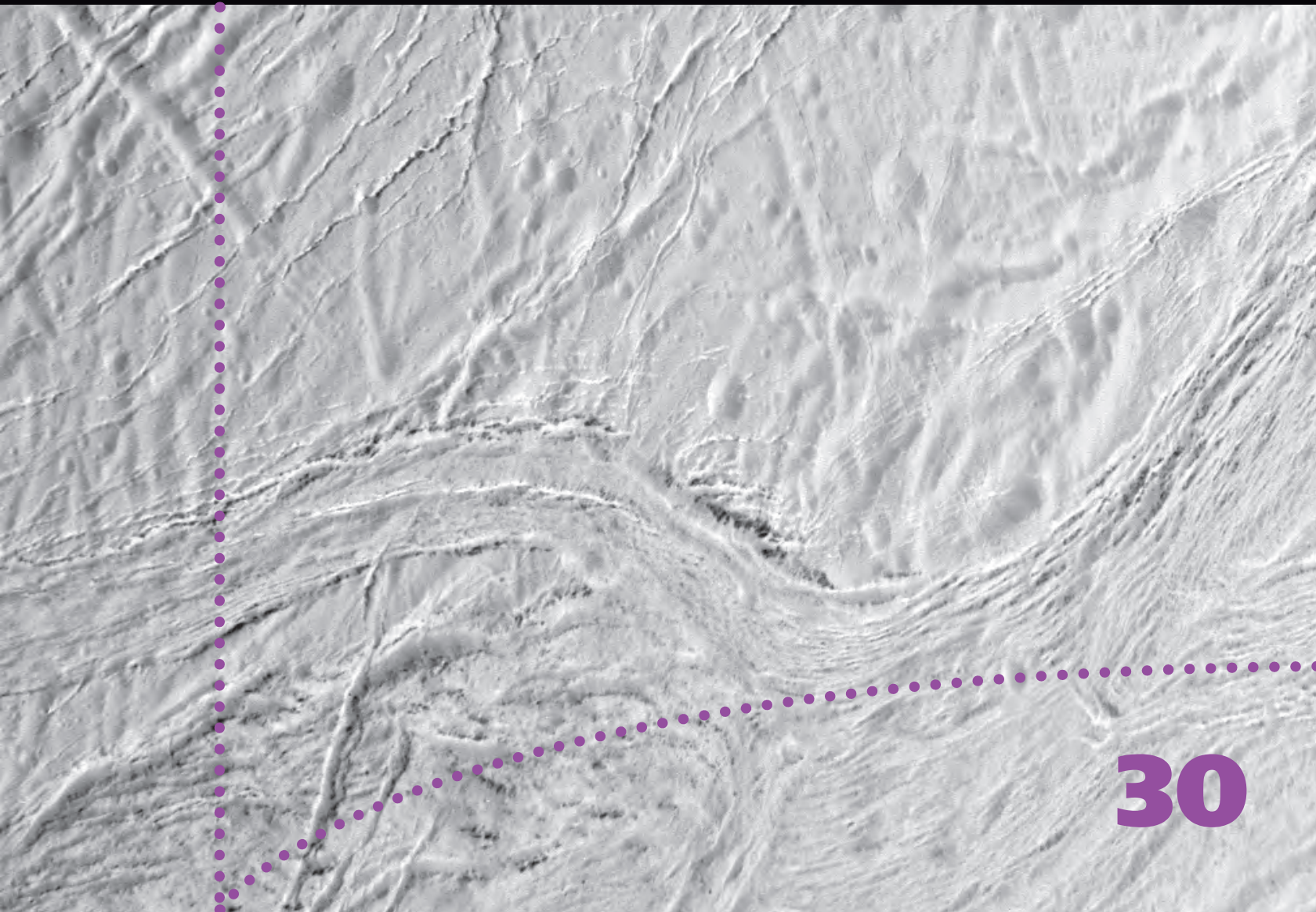
Ring Moon Rendezvous

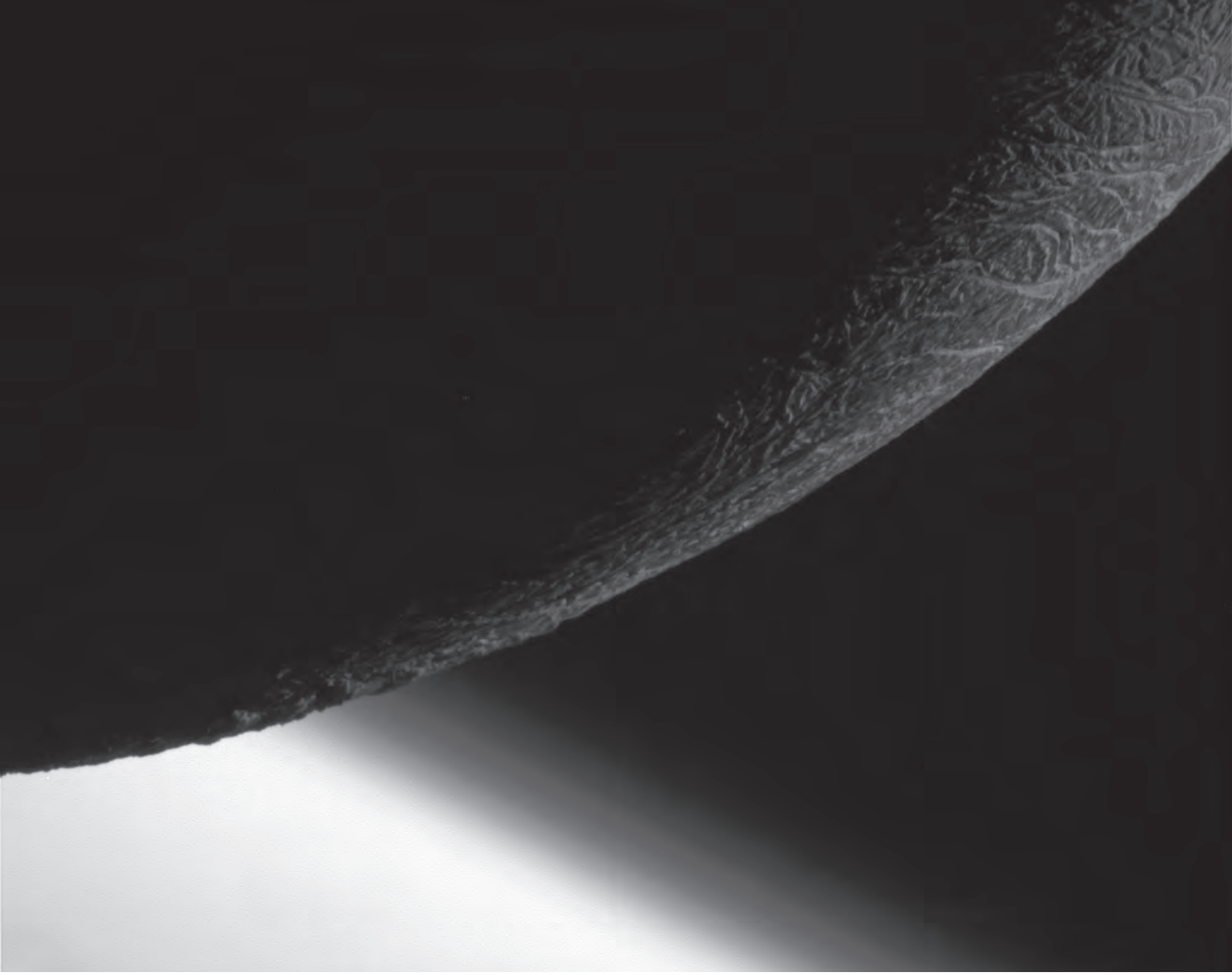
On Dec. 6, 2015, NASA's Cassini spacecraft made moderately close approaches to several of the small moons that orbit near the outer edges of Saturn's main ring system. Imaging throughout the day returned some of the best ever, highest resolution views of Atlas, Prometheus, and Epimetheus. The close approach altitudes ranged from 20,000-23,000 miles and returned images of resolutions ranging from 620-720 feet per pixel.

Cassini Completes Final Close Enceladus Flyby

On Dec. 19, 2015, NASA's Cassini spacecraft transmitted data and images from the mission's final close flyby of Saturn's geologically active moon, Enceladus. Cassini passed Enceladus at a distance of 3,106 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 last close encounter.





This 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.

After revealing Enceladus' surprising geologic activity in 2005, Cassini made a series of discoveries about the material gushing from warm fractures near its south pole. Scientists announced strong evidence for a regional subsurface sea in 2014, revising their understanding in 2015 to confirm that the moon hosts a global ocean beneath its icy crust.

Left Page :: *The Cassini spacecraft paused during its final close flyby of Enceladus to focus on the icy moon's craggy, dimly lit limb, with the planet Saturn beyond. Credit: NASA/JPL/SSI*

Cassini Begins Epic Final Year at Saturn

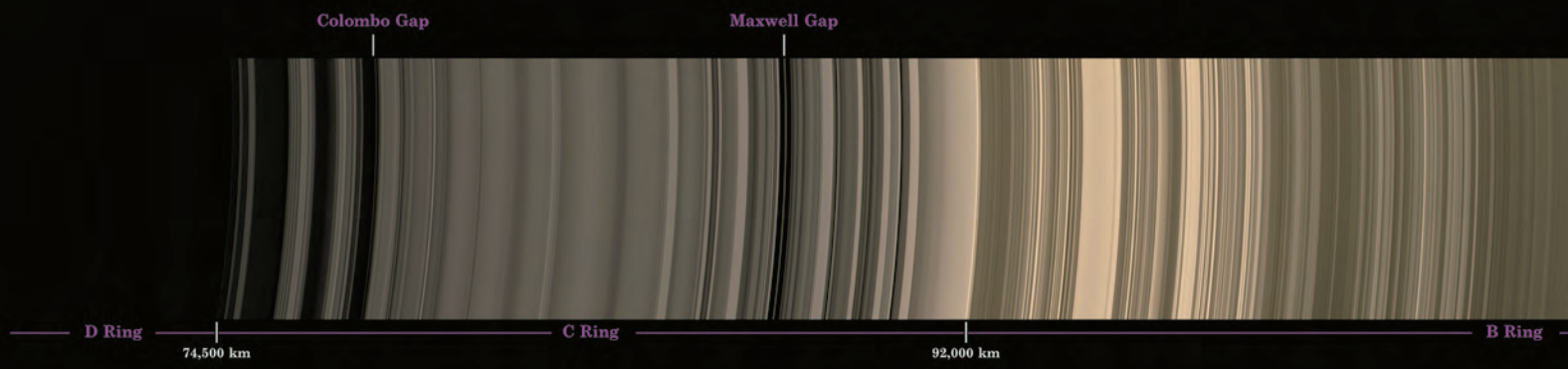
After more than 12 years studying Saturn, its rings, and moons, NASA's Cassini spacecraft entered the final year of its epic voyage. The conclusion of the historic scientific odyssey is planned for September 15, 2017, but not before the spacecraft completes a daring two-part endgame.

On November 30, 2016, Cassini's orbit sent the spacecraft just past the outer edge of the main rings of Saturn. Cassini will next complete a series of 20 orbits—one every seven days—called the F-ring orbits, because Cassini will approach to within 4,850 miles of the center of the narrow F-ring, with its peculiar kinked and braided structure.

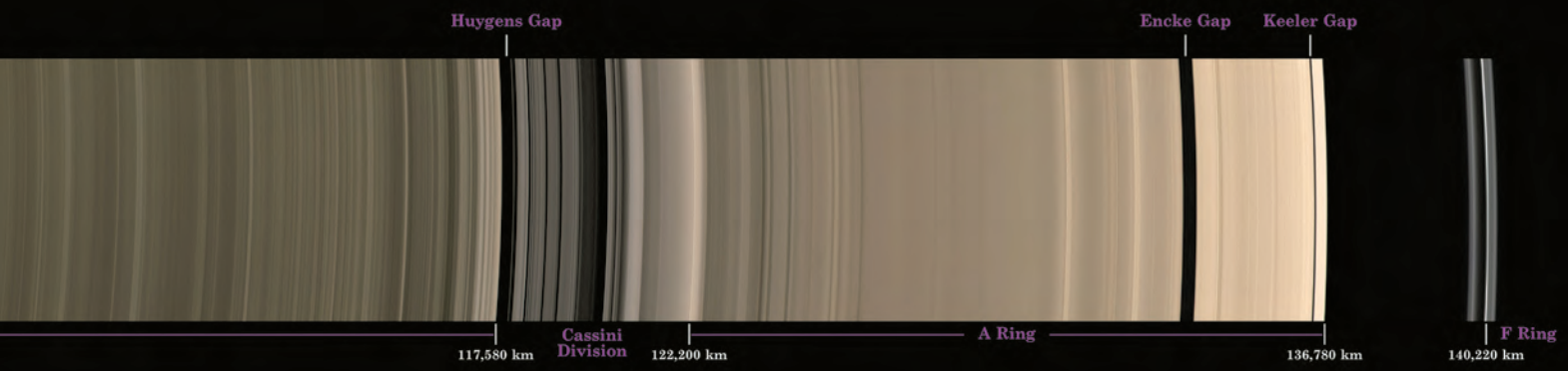
Since the beginning of 2016, mission engineers have been tweaking Cassini's orbital path around Saturn to position the spacecraft for the mission's final phase. They have sent the spacecraft on a series of flybys past Titan that are progressively raising the tilt of Cassini's orbit with respect to Saturn's equator and rings. This particular orientation enables the spacecraft to leap over the rings with a single (and final) Titan flyby in April 2017, to begin the Grand Finale.

The Grand Finale will come to a dramatic end on Sept. 15, 2017, as Cassini dives into Saturn's atmosphere, returning data about the planet's chemical composition until its signal is lost. Friction with the atmosphere will cause the spacecraft to burn up like a meteor soon afterward.

To celebrate the beginning of the final year and the adventure ahead, the Cassini team released a new movie of the rotating planet, along with a color mosaic, both taken from high above Saturn's northern hemisphere. The movie covers 44 hours, or just over four Saturn rotations.



Above :: *Ring Scan, Credit: Cassini Imaging Team, ESA, NASA/JPL/SSI*



Below :: *This view shows Saturn's northern hemisphere in 2016, as it nears its northern hemisphere summer solstice in May 2017. Saturn's year is nearly 30 Earth years long. During its time there, Cassini has observed winter and spring in the north, and summer and fall in the south. The spacecraft will complete its mission just after northern summer solstice, having observed long-term changes in the planet's winds, temperatures, clouds, and chemistry. Credit: NASA/JPL/SSI*

EDUCATION & INSPIRATION

NATIONAL CENTER for INTERACTIVE LEARNING

In the 21st Century, a basic understanding of science, technology, engineering, and math (STEM) is part of being an informed and engaged citizen. Science and technology are widely recognized as major drivers of innovation and industry. They are transforming our lives in ways that are hard to comprehend – in communication, energy, transportation, robotics, and health. Successfully addressing these challenges requires highly competent STEM professionals; students who are engaged with and proficient in STEM content and processes (e.g., critical thinking skills, engineering processes); and a public that is sufficiently STEM literate to understand the choices before them. STEM professions and the pipelines that produce those professionals lack ethnic diversity, even as the nation is undergoing a significant demographic shift.

SSI's informal education and public engagement group, *National Center for Interactive Learning* (NCIL), is led by Dr. Paul Dusenbery (SSI Boulder Office). This group is a leader in developing STEM-themed exhibitions and educational games and apps that can be deployed on websites, mobile devices (e.g. smartphones and tablets), and multi-touch tables. NCIL also employs a combination of in-person and online training methods to balance the need to reach a large audience, while laying the foundations for deep, ongoing learning in STEM and STEM facilitation. Through social media, online newsletters, and a recently developed STEM Activity Clearinghouse, the center has a national reach that numbers in the millions. NCIL's programs are organized around four interdependent groups: 1) Exhibition Development, 2) Digital Learning, 3) Professional Development, and 4) Community Engagement.

Professional Development and Community Engagement

The Professional Development Group (led by Keliann LaConte, SSI Boulder Office) oversees training for STEM informal educators and activity development. In 2016, monthly webinars were offered to public library staff to provide insights from leaders in the field, foster discussion between informal educators, and promote free educational resources. NCIL staff also participated in 8 conference sessions last year. The goal of NCIL's Community Engagement Group (led by Anne Holland, SSI Boulder Office) is to keep public and professional communities interested and engaged in the work we do. Activities include everything from local community outreach at science festivals and schools, to providing personal attention and assistance to members of our professional learning community, the STAR_Net Community of Practice. In 2016, STAR_Net continued to publish a monthly e-newsletter and began to publish an e-newsletter for libraries participating in the 2017 eclipse (see story below). STAR_Net also has an active Facebook presence.

NCIL Impacts for 2016

In 2016, NCIL reached nearly half a million individuals through eight traveling STEM exhibitions, provided STEM-focused professional development to over one thousand individuals, and educational NCIL websites that have attracted over a million views.

Traveling Exhibit Visitors (495,186)

Great Balls of Fire Museum Exhibit (3 host sites):	43,500
Discover NASA Library Exhibit (4 host sites):	76,620
STAR_Net's Discover Earth Library Exhibit (2 host sites):	71,127
STAR_Net's Discover Tech Library Exhibit (3 host sites):	98,492
STAR_Net's Discover Space Exhibit (3 host sites):	169,057
STAR_Net's Explore Earth Exhibit (4 host sites):	7,034
STAR_Net's Explore Tech Exhibit (4 host sites):	22,352
STAR_Net's Explore Space Exhibit (4 host sites):	6,964

STAR_Net Library Program Participants:	11,200
Workshop (Conference + Exhibits) Participants:	420
Webinar Participants:	1,236
STAR_Net Online Community Members:	3,300
NCIL Outreach Event Participants:	1,225
Booth Contacts:	1,310

Education Website Visitors

Website	Page Views
Alient Earths	356,928
MarsQuest Online	128,159
Space Weather Center	297,415
Killer Asteroids	52,130
Giant Worlds	20,437
SciGames	49,474
STAR_Net Libraries	35,642
Starchitect	127,730
Nc4IL	4,136
Totals	1,172,051

Digital Learning

NCIL has been exploring the potential of digital media for two decades, ranging from interactive experiences for museums and libraries to online games. The Digital Learning Group is led by Dr. James Harold (SSI Boulder Office). Digital media doesn't simply create more engaging experiences, it can allow learners to interact with data, explore simulations, and connect to each other through social media. Their potential only increases as portable, connected devices become more commonplace, allowing us to reach people in a variety of different environments and contexts.

Our approach is consistent with the Cyberlearning Task Force's recommendation for NSF to "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. Recent work has included Starchitect, a Facebook based "create a solar system" game, and apps designed to support librarians in exploring NASA STEM topics with their patrons.

Above :: *Screenshot from the Starchitect Game. Credit: NCIL/SSI*

HIGHLIGHTS 2016

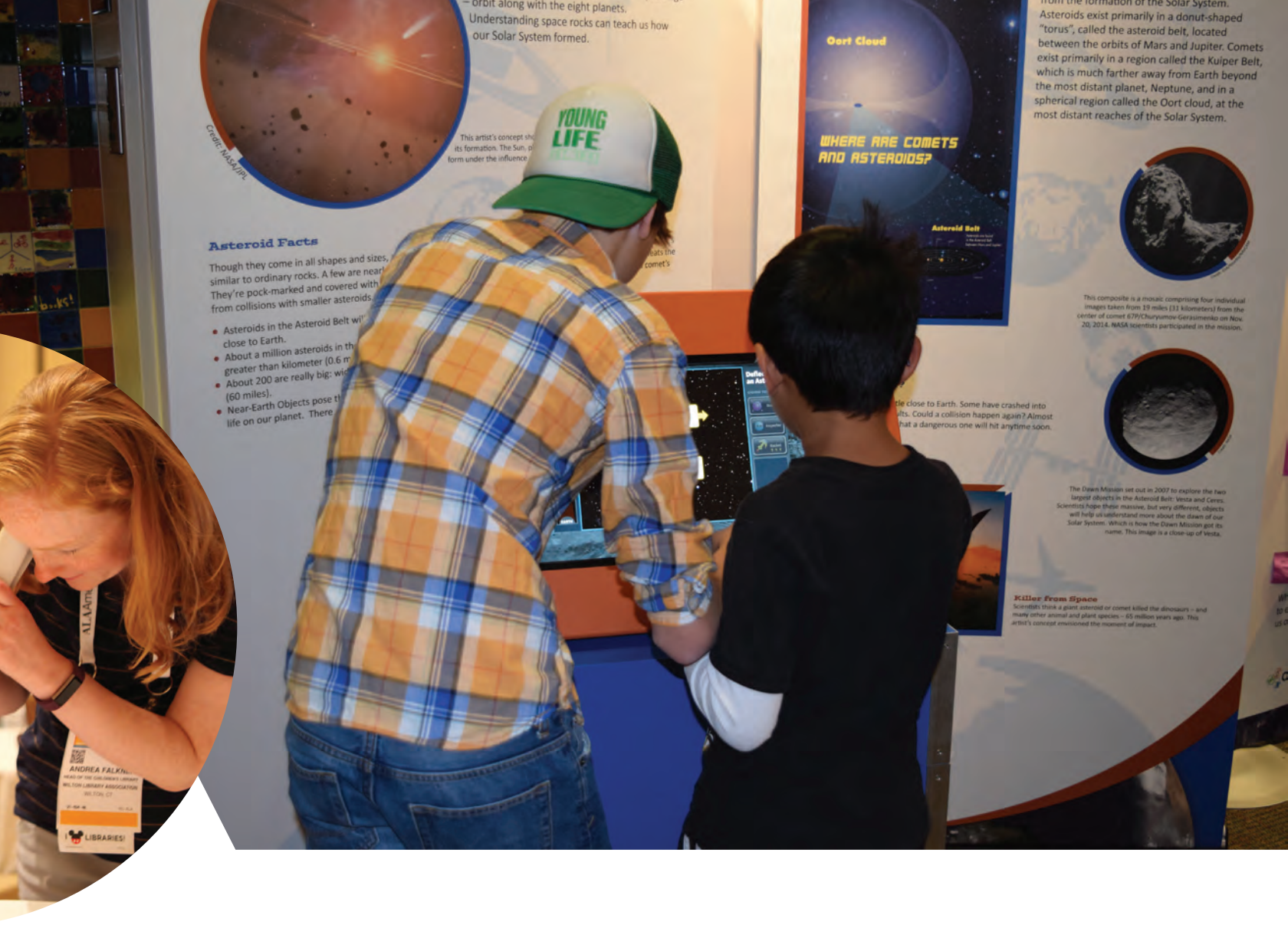
Implementing Effective STEM Programming in Public Libraries: Eight Recommendations

Report Prepared by Annette Shtivelband et al.

As part of NCIL's STAR Library Education Network (STAR_Net) program, funded by the National Science Foundation, the authors wrote a report that can be downloaded at http://www.nc4il.org/papers.html. STAR stands for Science-Technology Activities and Resources.

Public libraries are becoming an important place for informal science, technology, engineering, and mathematics (STEM) education for K-12 students and their families, as well as for adult education activities that support STEM workforce development. This report provides public librarians, administrators and collaborating organizations with a brief background on the role that libraries can play in fostering a healthy STEM education ecosystem, as well as promising practices for implementing effective STEM programs in public libraries.

Studies suggest that there is a need for STEM learning in communities and that public libraries are a key place for that learning to occur. By offering their services for free, libraries serve as a "public square," where members of a community can gather for information, education programming, and policy discussions. Increasingly, libraries' missions, initiatives, and services reflect their role in improving scientific literacy and supporting STEM learning and education standards, especially for those underrepresented in STEM fields. Patron attendance for STEM programs supports the popularity of this trend.



Public Libraries Engage Underrepresented Populations in STEM

Public libraries are particularly ideal for reaching underserved and underrepresented people and regions. Public libraries serve people of all races, ages and socio-economic backgrounds. In 2013, the Pew Research Center (PRC) conducted a survey of over 6,200 Americans to learn how people utilized public library services. The PRC survey found that 91% of Americans ages 16 and older believe public libraries are important to their communities. 76% reported that libraries are an important education resource for them and their families. Furthermore, African Americans (60%) and Hispanics (55%) were more likely to say that libraries are "very important" to them and their families as compared to Caucasian families (41%).

Center :: Strange New Planet activity at the 2016 ALA Conference. Credit: SSI/NCIL

Above :: Discover NASA Exhibit at the Louisville Public Library. Credit: SSI/NCIL

PUBLIC SCIENCE

Promising Practices for Public Libraries

While there are some promising practices for informal STEM education and programming in public libraries, the novel and innovative nature of STEM programming in these settings means that there is still much to learn. Informal STEM education programs typically have three goals: 1) cultivating students' interest in STEM; 2) building capacity to engage with STEM subjects; and 3) emphasizing the value of STEM learning. Program elements found successful by public library STEM programs include engaging youth, integrating youth feedback, involving caring mentors, offering a good physical location, and providing professional development opportunities for librarians. Based on promising practices found in the current literature, the following activities are recommended for public libraries:

1. Collaborate with STEM stakeholders that include educators, after-school staff and/or experts in informal STEM institutions;
2. Form partnerships with organizations that serve youth;
3. Target K-12 youth historically underrepresented in STEM and their families;
4. Make STEM programs accessible to and equitable for all youth;
5. Develop strong, lasting and caring adult-youth relationships;
6. Provide training and professional development opportunities to librarians that focus on STEM facilitation strategies;
7. Evaluate STEM programs, and monitor and track outcomes; and
8. Share results with stakeholders.

"My favorite thing was seeing people getting excited over the quiz game (adults too)! We also had a volunteer who stood up after our training and said, 'I have been to a lot of exhibits and this is the best I have ever seen!' That was fantastic to hear!"

—Library Staff Interview

Above :: *Discover NASA Exhibit at the Slover Public Library, Virginia. Credit: Slover Public Library*

Discover NASA: From Our Town to Outer Space

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. The FOTOS project led by SSI's NCIL group is funded by NASA's CP4SMP+ program. The overarching objective of FOTOS is to inform, engage, and inspire new public audiences (both library staff and patrons) by sharing NASA's missions, challenges, and achievements. It's an informal education program that reaches 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.

HIGHLIGHTS 2016 *continued*

STAR_Net Launches a New Website and STEM Activity Clearinghouse

In June 2016, NCIL launched a redevelopment of STAR_Net's online presence (led by Greg Mosshammer, SSI Boulder Office). A new website design, built on the WordPress platform, has changed STAR_Net's previous static version into a more dynamic and interactive experience. In addition, the redesign of e-mail newsletters and a stronger push in growing STAR_Net's social media presence has increased our effectiveness to communicate with both libraries and partners nationwide. Since increasing our online communications and combining community-related resources into our website that include events, webinars, blogs, activities, newsletters and forums, STAR_Net's traffic (page views) increased by over 350% compared to 2015.

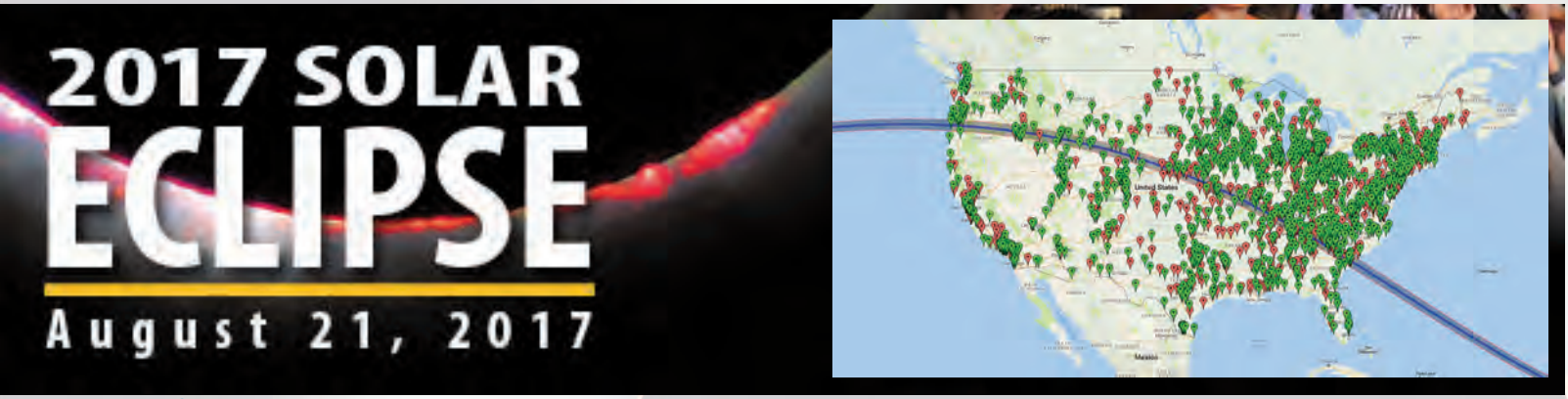
With funding from Cornerstones of Science through an Institute of Museum and Library Services (IMLS) grant, NCIL has developed a beta version of its STEM Activity Clearinghouse, which is accessed from the STAR_Net website. The Clearinghouse also includes hands-on activities for different age groups that relate to, and expand upon the STEM content of the STAR_Net traveling exhibitions. These field-tested STAR_Net activities are also paired with teacher and family guides for libraries to print and distribute to members of their community. Six new how-to videos developed by our STAR_Net partner, the Lunar and Planetary Institute, help library staff learn how to facilitate the activities.

As part of SSI's NASA@ My Library project (PI Dusenbery, SSI Boulder Office), NASA educational resources were identified and assembled as Clearinghouse "collections" around key national events, including the International Observe the Moon Night and the upcoming 2017 solar eclipse (see report below). Individuals from several organizations contributed to the selection process, including the Laboratory for Atmospheric and Space Physics, Cornerstones of Science, High Plains Library District (in Colorado), and Yuma County Library District (in Arizona).

Below :: The map below shows the location of over 1,700 participating STAR_Net libraries

The All-American Eclipse

On August 21, 2017, a spectacular total eclipse of the Sun will be visible across the continental U.S. for the first time since 1918. Every state will have at least 65% of the Sun covered by the moon, and lucky people on a narrow path from Oregon to South Carolina will see the stunning beauty of totality and remember it all their lives.



SSI was awarded a grant from the Gordon and Betty Moore Foundation to provide 1.26 million FREE eclipse glasses and other resources for 1,500 public libraries across the nation. The Research Corporation and Google pledged to add an additional 750,000 glasses, bringing the total to over 2 million glasses to be distributed to more than 2,200 libraries! These libraries will serve as centers for eclipse education and viewing for their communities. Libraries will be selected in 2017 through an application process managed by STAR_Net and the NASA@ MyLibrary initiative. The project team includes NCIL staff. The Project Director is Dr. Paul Dusenbery (SSI Boulder Office). Andrew Fraknoi (Chair of the Astronomy Department, Foothill College), Dennis Schatz (Senior Advisor, Pacific Science Center), and Douglas Duncan (Director of the University of Colorado's Fiske Planetarium) are co-Directors.

An Eclipse Education Kit which will be sent to each participating library is being developed that includes safe eclipse viewing glasses and educational materials. Currently, over 1,700 libraries have registered on the STAR_Net website (http://www.starnetlibraries.org/2017eclipse). The map above shows the location of the registered libraries. Red pins include the library name and website while green pins include info about the library as well as contact information so that STEM professionals (e.g. professional and amateur astronomers) can easily find libraries to partner with. Education materials in the Kit will also be made available on the STAR_Net website so that even libraries and organizations that do not receive the Kit will be afforded guidance on how to do public outreach. By engaging the American Library Association, Association of Rural and Small Libraries, and other library organizations like STAR_Net, we will ensure that libraries throughout the country are aware of the eclipse well in advance in order to plan a successful event.

Space Science Institute
Summary Statement of Financial Position
as of December 31, 2016 and 2015

	2016	2015
Assets		
Assets		
Cash and cash equivalents	$ 660,425	$ 219,928
Accounts receivable	1,196,673	1,438,688
Prepaid expenses and deposits	102,723	122,162
Net furniture, equipment, and property	17,972	11,955
Total assets	$ 1,977,793	$ 1,792,733
Liabilities and Net Assets		
Liabilities		
Accounts payable and accrued liabilities	$ 633,349	$ 879,464
Deferred revenues	103,839	154,757
Line of credit	425,000	450,000
Total liabilities	1,162,188	1,484,221
Net assets		
Unrestricted	323,552	305,862
Temporarily restricted	492,053	2,650
Total net assets	815,605	308,512
Total liabilities and net assets	$ 1,977,793	$ 1,792,733

Summary Statement of Activities
for the years ended December 31, 2016 and 2015

	2016	2015
Support and revenue		
Grants, contracts, and cooperative agreements	$ 7,483,571	$ 7,060,079
Contributions	496,512	11,097
Exhibit income	104,075	103,197
Interest income	148	89
Total support and revenue	8,084,306	7,174,462
Expenses		
Program services	5,813,383	5,505,117
Fundraising	14,600	24,240
General and administrative	1,749,230	1,631,308
Total expenses	7,577,213	7,160,665
Change in net assets	507,093	13,797
Net assets, beginning of year	308,512	294,715
Net assets, end of year	$ 815,605	$ 308,512

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, 2016 and 2015, from which the summarized information was derived. A copy is available upon request.

Left Page :: The Orion Nebula in Infrared from HAWK-I
Image Credit: ESO, VLT, HAWK-I, H. Drass et al.

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