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ANNUAL REPORT 2018

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.

Table of Contents

Message from the Chairman of the Board of Directors

I am pleased to present to you SSI's new annual report. It reflects an eventful year in which our employees and affiliates around the world once again showed great commitment to drive the success of our mission.

2018 was full of wins for SSI. The Board congratulates SSI's CICLOPS and National Center for Interactive Learning teams on their successful project augmentations in 2018 to further analyze Cassini mission data and expand the NASA@MyLibrary program. SSI's Research Branch welcomed 4 new scientists, bringing the total research staff and affiliates to 76 members. SSI continues to bring its STEM education programming to a wide audience, with 320,709 visitors to its traveling exhibits, 20,500 outreach event participants, 50,955 contacts at libraries for NCIL's STAR Net Library program portfolio, and over 3 million education website visitors.

We continue to bring in new skills and capabilities to the Board with the addition of Dr. Douglas Duncan in 2018. Throughout his career at the University of Colorado and as the director of Fiske Planetarium (2002-2018), Doug has had a record of success in identifying trends and managing strategic priorities for STEM education. His background in astronomy and public outreach will be especially valuable for SSI's combined focus in these areas. In fall of 2018, Larry Satkowiak stepped down after three years as our Board treasurer to fully retire and enjoy time with family. We appreciate Larry's dedicated service and feel fortunate that we had him as a treasurer because his expertise was tailor-made to SSI's nonprofit business environment. With his guidance, we made important advancements for the security of SSI's financials and planned ahead for some of the challenges that may face SSI in the future. The Board will continue to refresh its membership in 2019 to better reflect diversity and guide strategic vision.

The entire Board remains excited and optimistic about Space Science Institute's current capacity and future potential to expand and leverage its impact in the scientific community and diverse communities across the nation. We on the Board believe that a thriving research sector and equitable access to science foster the best kind of innovation and hope you will join us in supporting SSI's continued success in this arena.

William R. Purcell, Ph.D.

Message from the Executive Director

With great pride and admiration for the inspiring work done by our scientists, educators, and staff, we present Space Science Institute's 2018 annual report.

In this year's report, you'll read how SSI scientists are engaging in impactful studies such as analyzing the harsh "space weather" environment for orbiting satellites and participating in NASA's InSight mission to Mars. 2018 was also a big year for SSI-hosted workshops. Our scientists hosted collaborative technical workshops both domestically and internationally about Mars and space physics, and our STEM educators and partners delivered fantastic workshops under their Project BUILD and NASA@ My Library programs. SSI's National Center for Interactive Learning group launched their new "Discover Exoplanets" touring exhibit, which complements research done by SSI's Center for Extrasolar Planetary Systems. Computational thinking, space station downlinks with real astronauts, public talks – 2018 had it all!

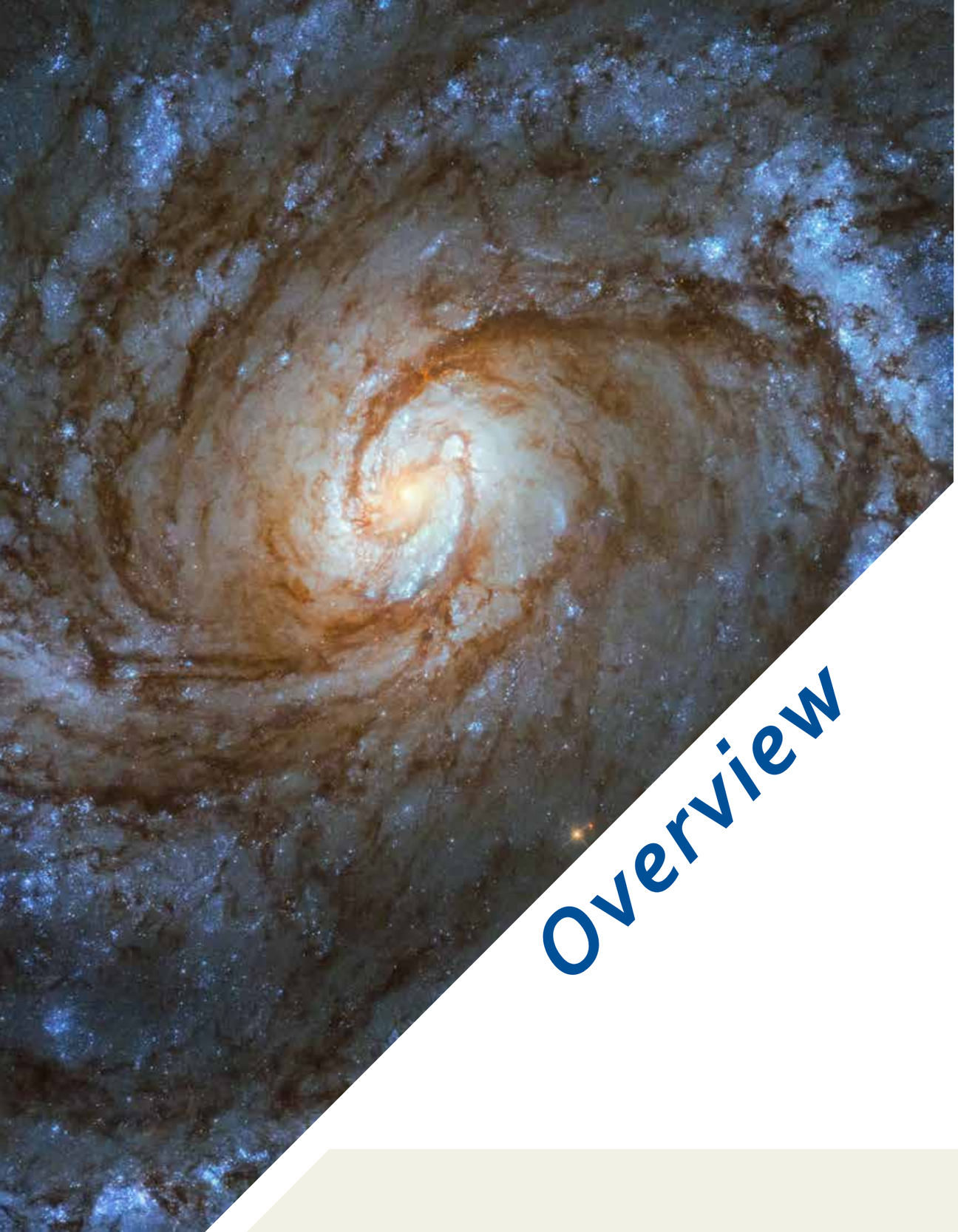
In 2018, we are pleased to report that half of the goals specified in the 2017-2019 Strategic Plan have already been completed; in fact, approximately 75% of the strategic goals are either fully completed or actively ongoing. We feel that the progress made by all departments toward the Strategic Plan this year has been very positive and has positioned us to be able to successfully complete the remaining goals possibly earlier than anticipated. This is important as we are going into our search for the new SSI headquarters in Colorado (move anticipated in 2019). Though harder to photograph for posterity, we also want to recognize the efforts of our dedicated support teams in Business, Information Systems & Technology, Human Resources, and Legal who stayed on top of 130+ awards, countless proposals, process documents, IT assets, and everything associated with our growing legion of principal investigators and staff.

SSI's goal as a nonprofit is to serve people with an abiding passion for the work they do -- work that stretches the bounds of human knowledge about the universe and our place in it. We share discoveries with communities across the country and strive to be inclusive in encouraging others to develop that same level of passion. We appreciate your support of our nonprofit mission and hope that you will consider volunteering with us in 2019.

Karly M. Pitman, Ph.D.

Front cover image credit: NASA

Our Mission image credit: NCIL/STAR Net/SSI



Overview

History & 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), Center for Mars Science (2014), and Center for Polarimetric Remote Sensing (2017).

Image credit: NASA/ESA/Hubble

Present

Today, SSI manages 76 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 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.

Global Reach: 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.

Base Map: The identification and distribution of aerosols in the Earth's atmosphere is shown in this dramatic, planet-wide visualization. Model Visualization Credit: NASA Earth Observatory, GEOS FP, Joshua Stevens

2018 Board Members

- Dr. Jack Burns, Professor & Vice President Emeritus for Academic Affairs & Research, University of Colorado
- Dr. Douglas Duncan, Astronomer, University of Colorado
- 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), General Counsel, Legal and Policy Specialist, Space Science Institute
- Dr. Marilyn Johnson, Former Science Director, Oregon Museum of Science and Industry
- Dr. Steve Jolly (Vice-Chair), 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

2018 Executive Advisory Committee

- Dr. Paul Dusenbery (Education/National Center for Interactive Learning)
- Dr. James Harold (Information Systems and Technology)
- Dr. Ralph Shuping (Associate Director/Research)
- Mr. Carl Wuth (Business Operations)

2018 Grants & Contracts

SSI gratefully acknowledges support from research and education grants and contracts from the following organizations in 2018:

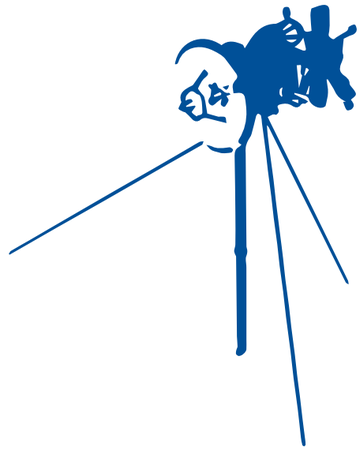
- JPL (Jet Propulsion Laboratory)
- Malin Space Science Systems
- NASA
- University of California, Los Angeles
- Universities Space Research Association
- National Science Foundation
- Space Telescope Science Institute
- University of Maryland
- Morgridge Family Foundation
- University of Houston
- DOE (Department of Energy)
- Urban Libraries Council
- Johns Hopkins University Applied Physics Laboratory
- Arizona State University
- University of Alabama
- University of Arizona
- Ohio State University
- Science Museum of Minnesota
- University of California, Berkeley
- University of Colorado, Boulder
- University of Colorado, Laboratory for Atmospheric and Space Physics
- Carnegie Institution of Washington
- University of Michigan
- University of New Hampshire
- Colorado Gives Foundation

Donors

SSI wishes to thank the generous individuals who contributed to the Space Science Institute in 2018:

- Jack Burns
- Todd Clancy
- Paul & Michelle Dusenbery
- Ann Goldman
- Jennifer M. Griest
- Marilyn Johnson
- Steve Jolly
- the McCallum family
- the Moberg-Wolff family
- Karly Pitman
- William Purcell
- the Shuping family
- Greg Wimpey
- Carl Wuth
- Anonymous (3)

We Discover & Explore



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.

Over the course of the almost 20 year Cassini mission to Saturn, the ISS camera team was responsible for roughly 65 percent of all science data collected. Congratulations to SSI's ISS team whose contract has been extended beyond the lifetime of the mission to continue their science analyses!

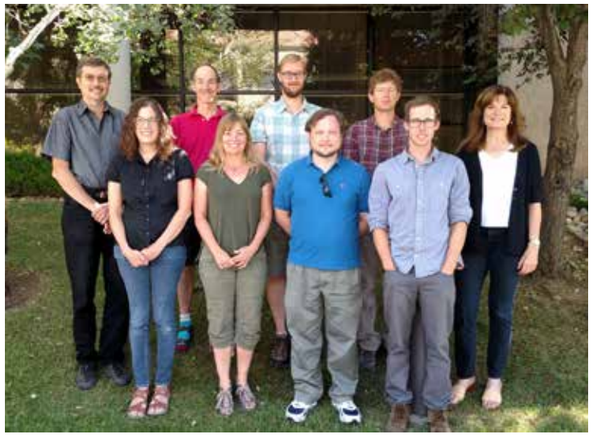


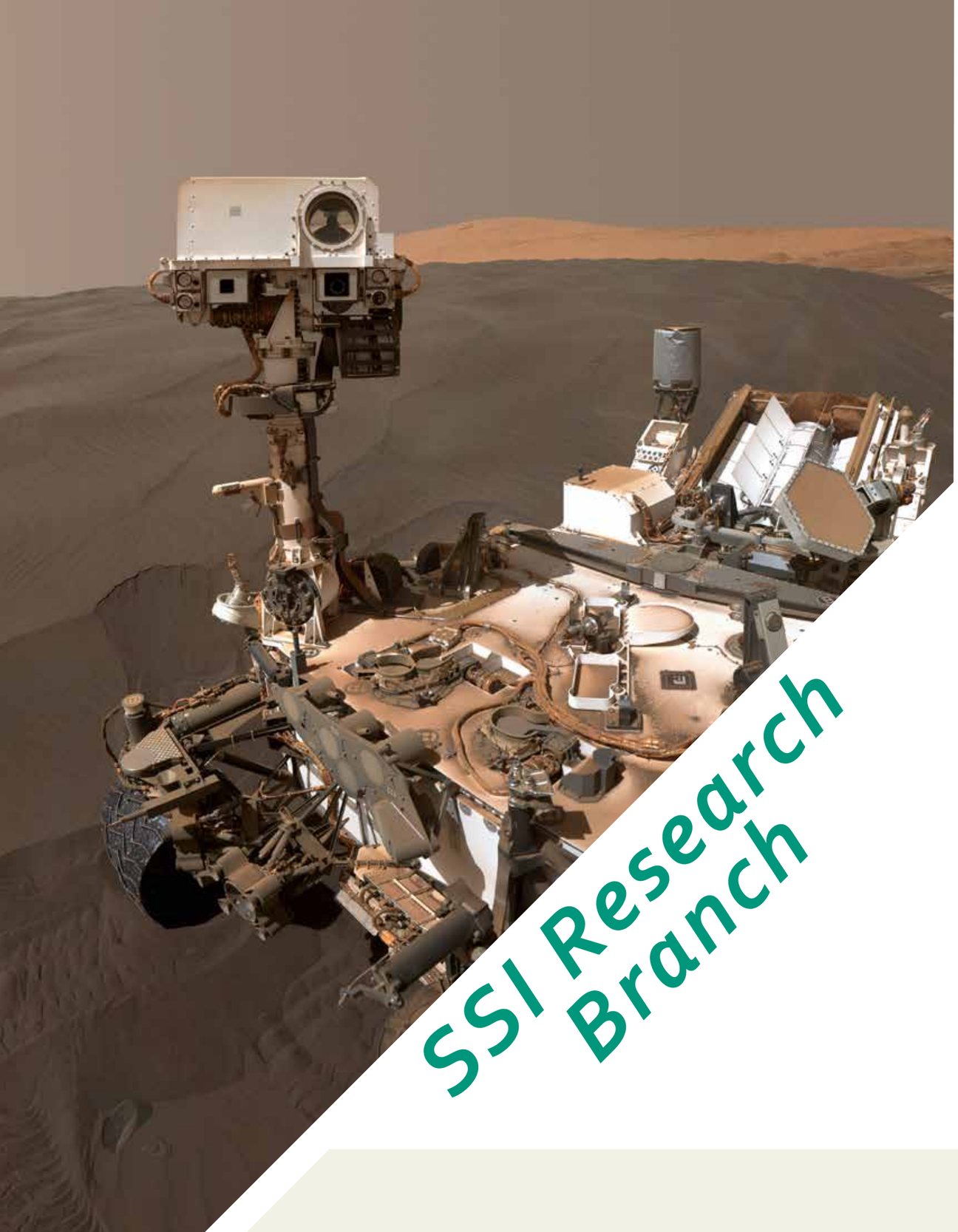
Image credit: NASA/JPL-Caltech/Space Science Institute

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. Through engagement with communities in Colorado and across the U.S., we seek to enhance general STEM literacy and access to STEM careers especially for underserved and underrepresented groups.

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.

On the left: Sachin Senoy conducting Solar Viewing at the NASA@ My Library ISS Downlink event in Greeley, CO. Image Credit: SSI/NCIL



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 2018 Our Research Branch welcomed 4 new scientists, bringing our total research staff to 76 members. 9 of these are located on-site at SSI's Boulder headquarters and the rest are distributed across the U.S. and several other countries. While any individual scientist may pursue the subject area of his or her choice, SSI's Research Branch also runs four "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), the Center for Extrasolar Planetary Studies (CEPS), and the Center for Polarimetric Remote Sensing (CPRS); see our center updates in the upcoming pages for recent activities.

2018 Impacts

Total members:	76 (50 funded/26 unfunded)
Papers published:	>180
Invited/Public talks:	>50
Proposals Submitted (PI+co-I):	144
Grants/contracts awarded:	48

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, Mars 2020 Rover (to be launched in 2020), TESS, and THEMIS.

Image credit: NASA/JPL-Caltech/MSSS - Image of the Day

Workshops

Mars Atmosphere Data Assimilation (MADA) Workshop

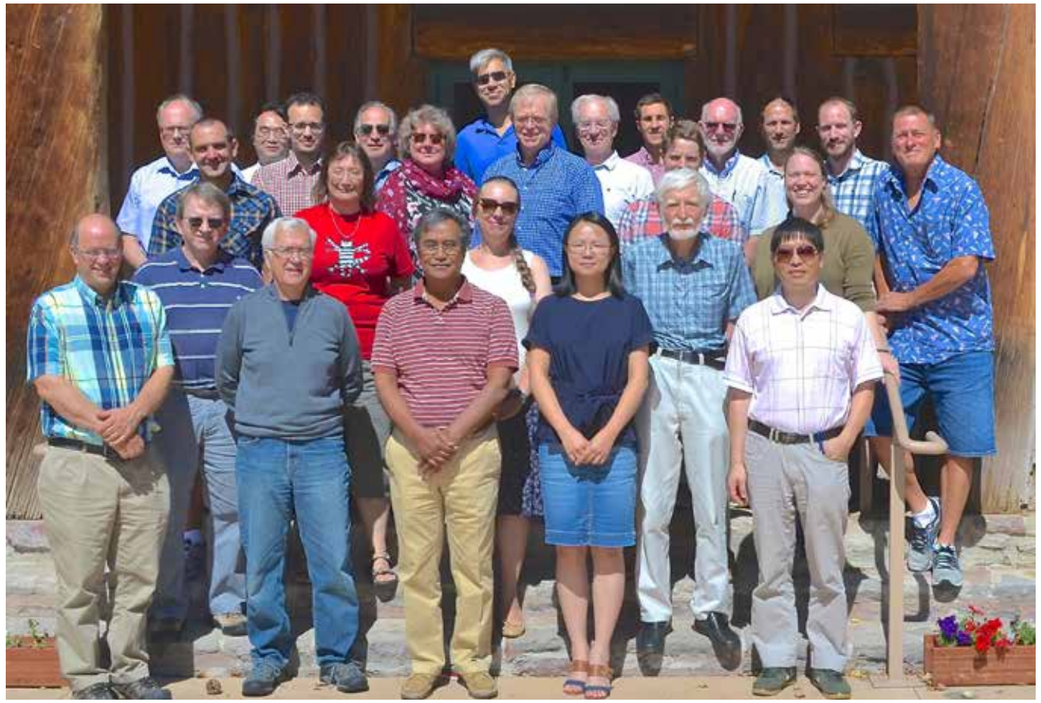
Luca Montabone, research scientist at SSI, had set himself the challenge to gather about 30 international "Martian" scientists in France to discuss Mars atmospheric data assimilation, which has been considered a niche topic until very recently. On August 29, 30, and 31, 2018, he successfully met the challenge by organizing the "Mars Atmosphere Data Assimilation" (MADA) workshop at the Savoie-Technolac Science & Technology Park, in the French city of Le Bourget-du-Lac, in the Alpine foothills. This workshop, sponsored by the French Centre National d'Etudes Spatiales (CNES), was attended by 28 scientists (including Luca and SSI senior research scientist Mike Wolff) and one CNES manager, coming from institutions based in the U.S., France, UK, Japan, UAE, Italy, and Belgium. SSI and the Laboratoire de Météorologie Dynamique/Sorbonne University in Paris (France) were scientific partners.

Data assimilation combines all available observations into a numerical model to reconstruct the best estimate of the state of a system. After more than ten Martian years of continuous atmospheric observations, the specific aim of the workshop was to connect those researchers working on the modeling techniques with those providing the data. It also welcomed a few researchers with specific experience in Earth data assimilation but interest in extra-terrestrial applications, and one researcher who works on the implementation of data assimilation for the atmosphere of Venus. For three days, the workshop attendants discussed what lessons they have learned so far, what challenges remain, and what opportunities lie ahead of them.

This workshop was meant to be a fully interactive and participatory event, not a standard conference. Its format featured oral presentations that could be interrupted by questions on the first day, group discussions on specific themes and a poster session on the second day, a wrap-up session on the third day, and several networking events. One such event was organized on August 29 in the evening in collaboration with two local economic entities. It featured a panel discussion on the opportunities for industrial and startup companies in the exploration of Mars and other space challenges. Luca and Mike were part of the panel, together with three other MADA participants, giving short talks and answering questions from an interested audience of local entrepreneurs. The event ended with a buffet dinner that provided all MADA scientists with an opportunity to exchange ideas with the entrepreneurs…and to enjoy typical local food, wine, and beer (including an Italian beer called "Marte", i.e., Mars in Italian)!

Through Luca and Mike, SSI got the opportunity to be known at the workshop as one of the key players in the U.S. "soft money" market for space research and education. If European researchers are still uncertain about the soft money tendency, some of the U.S. attendants seemed interested in the concept. Time will tell.
Below - photo of attendees.

"Exploring Systems-Science Techniques" Workshop held in New Mexico



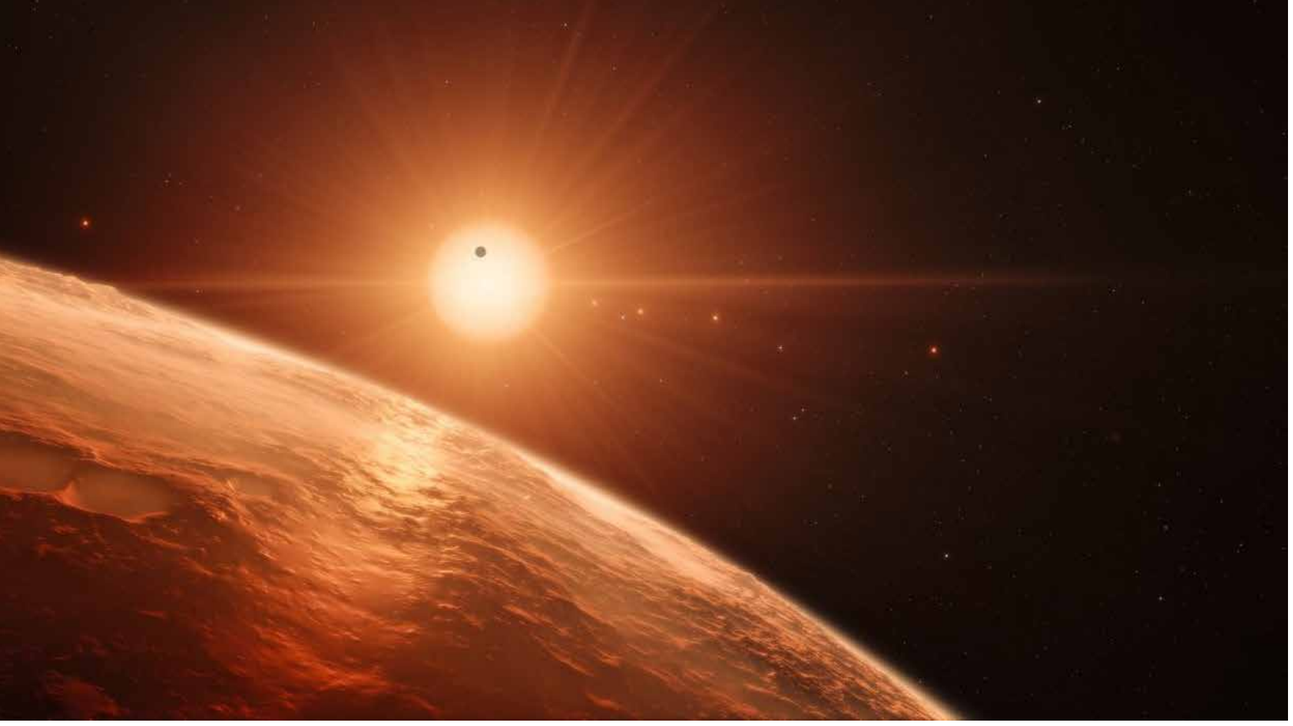
Joe Borovsky and Mick Denton from SSI, along with Enrico Camporeale (Netherlands), Jeff Thayer (University of Colorado), Juan Alejandro Valdivia (University Chile), and Simon Wing (Applied Physics Lab), convened a workshop on "Exploring Systems-Science Techniques for the Earth's Magnetosphere-Ionosphere-Thermosphere" July 24-26 in Los Alamos, New Mexico. Twenty-seven attendees from 5 countries gave presentations and discussed future plans for developing and implementing systems-science techniques. A Meeting Report will appear soon in the AGU newsletter EOS. The workshop was held in the historic Fuller Lodge in Los Alamos.

Space Physics Workshop

Mick Denton and Joe Borovsky organized a workshop on the topic "The Plasmasphere and Warm Plasma Cloak" that was held September 18-20, 2018 in Fuller Lodge, Los Alamos, New Mexico. 27 scientists from the US, Greece, Germany, and Belgium attended and presented talks, some of which can be found at http://gemelli.spacescience.org/mdenton/psh_workshop/
The workshop photo was taken outside of Fuller Lodge.

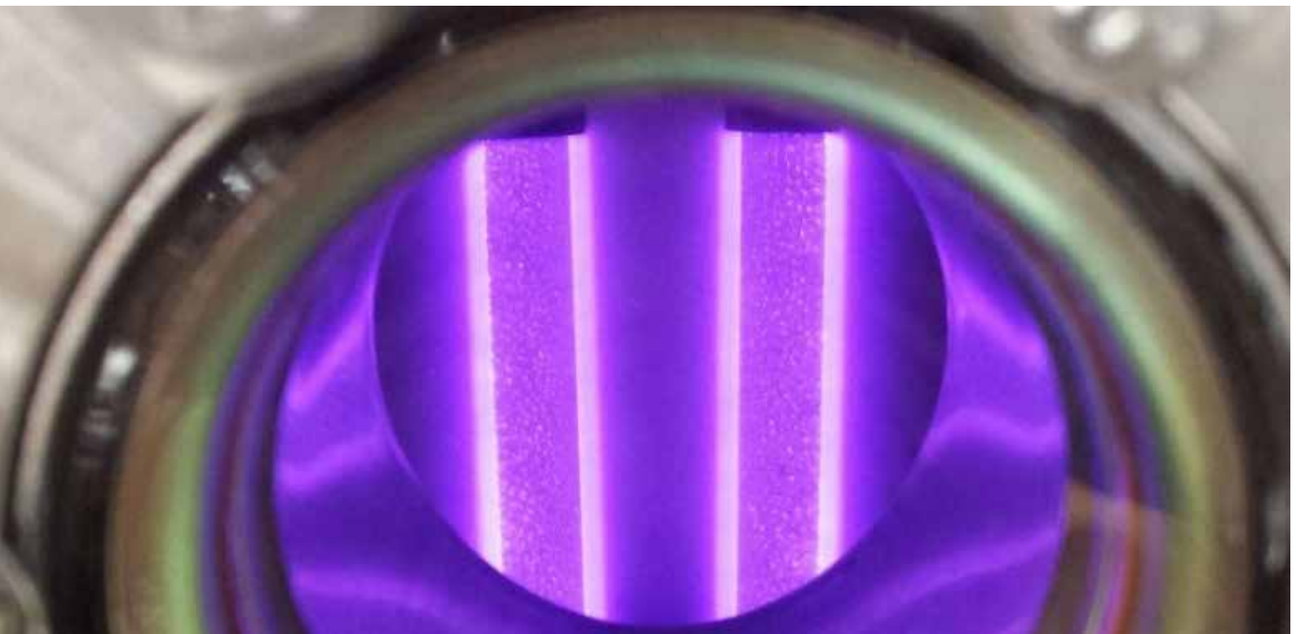
Research Center Updates

Neutrino Associated with Distant Blazar Jet
Illustration Credit: DESY, Science Communication Lab



This artist's impression shows the view from the surface of one of the rocky planets in the TRAPPIST-1 system.
Image Credit: ESO/N. Bartmann/spaceengine.org

A team led by Dr. Sarah Horst at Johns Hopkins University simulated exoplanetary conditions to explore the chemistry and production rate of UV-driven haze formation in the atmospheres of super-Earths and mini-Neptunes. CEPS researcher Dr. Julie Moses took part in the research, published in He et al. 2018 *AJ*; *ApJL*, and Horst et al. 2018 *Nat Astr.*
Image Credit: Sarah Horst Laboratory.

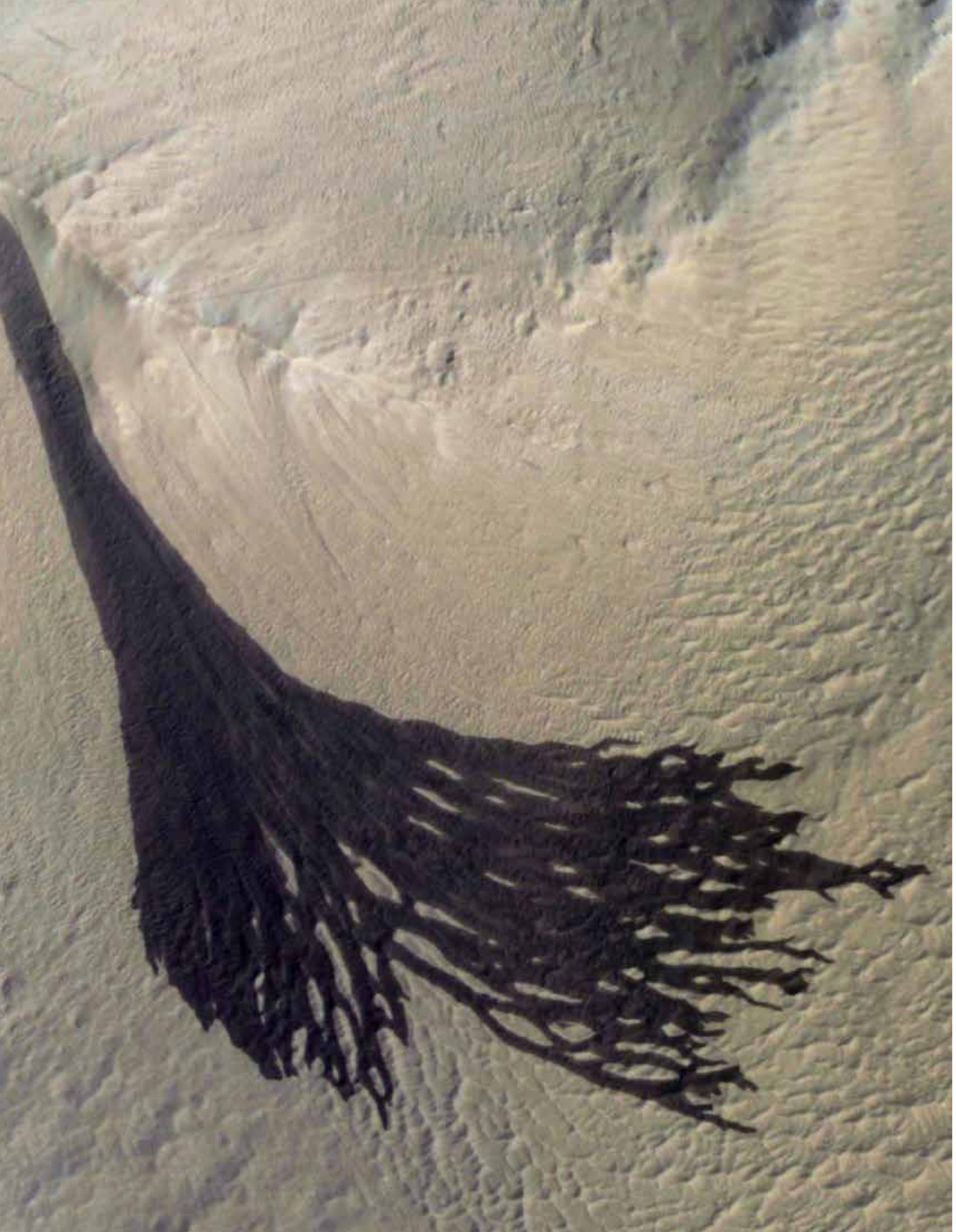


Center for Extrasolar Planetary Systems

The Center for Extrasolar Planetary Systems (CEPS) gathers SSI researchers that are interested in the exploration and characterization of diverse extra-solar planetary systems. CEPS provides a forum for its members to discuss recent scientific results and discoveries, collaborate on proposals and papers, and discuss and develop proposal strategies. Given the interdisciplinary nature of extrasolar planetary science, CEPS research covers a wide range of topics, including the study of exoplanet atmospheres and chemistry, young stellar objects, stellar formation, the formation of planetary systems, radiative transfer, the determination of planet-host star properties, and the analysis of the signatures of planetary formation as reflected in debris disks.

Today, the Center for Extrasolar Planetary Systems includes 13 scientists who in 2018 participated in nearly 40 peer-reviewed publications in scientific journals, along with numerous conference and workshop presentations, ongoing education and outreach activities, observing collaborations (including Hubble, Spitzer, IRTF, ALMA, and VLT), and several grant proposals.

Because CEPS members are scattered throughout the country, CEPS scientists keep in touch by email and periodic teleconferences. This includes opportunities for bringing in outside speakers to discuss their work, and for journal club-style discussions of recent scientific studies. 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 community.



Dark Slope Streaks on Mars
Image credit: HiRISE/MRO/LPL (U. Arizona)/NASA

Center for Mars Science

The SSI Center for Mars Science (CMS) is composed of SSI researchers studying various aspects of the Red Planet. CMS researchers are involved in multiple NASA and ESA missions including the Mars Reconnaissance Orbiter, the Mars Exploration Rovers, and the Mars Science Laboratory rover. CMS researchers can use the periodic CMS "Journal Club" teleconferences to present their results or to hear from guest speakers about their research. Journal Club speakers in 2018 included guest speaker Dr. Dr. Deanne Rogers of Stony Brook University speaking on: "Interpreting the Rock Record of Early Mars". SSI CMS researcher Dr. Mark Lemmon gave a presentation that summarized observations of the 2017 global dust storm on Mars.

Individual CMS researchers worked on a number of education and public outreach projects.

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 plasmas of the heliosphere. In calendar year 2018 the members of CSPP published 99 papers in refereed journals: 25 papers as primary authors and 74 papers as contributing authors. Research highlights in 2018 dealt with plasma instabilities, magnetic-field-line reconnection, magnetospheric systems science, space weather, simulation techniques, turbulence, and stratospheric ozone.

Two international workshops were organized in 2018 by Joe Borovsky and Mick Denton, both workshops held in the historic Fuller Lodge in Los Alamos: "Exploring Systems-Science Techniques for the Earth's Magnetosphere-Ionosphere-Thermosphere" July 24-26 and "The Plasmasphere and Warm Plasma Cloak" September 18-20.

In 2018 Research Scientist Mick Denton became a Senior Editor for the Journal of Atmospheric and Solar-Terrestrial Physics (JASTP).

Senior Research Scientist Peter Gary was elected as a Fellow of the American Geophysical Union in the class of 2018.

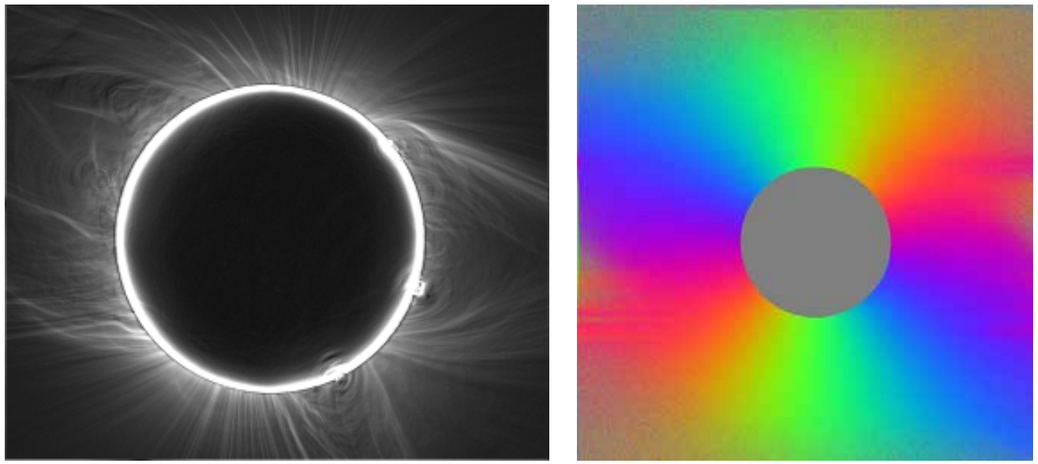
Image credit: NASA's GSFC, SDO AIA Team

Center for Polarimetric Remote Sensing

The Center for Polarimetric Remote Sensing (CPRS) is a home to an interdisciplinary tool within the planetary science community. We have entered a phase where polarimetry is proving is worth to the community and the researchers at SSI have been driving the field. SSI researchers have demonstrated that the properties of dust particles and planetary regolith can be retrieved from the polarization signatures of their scattered light and have used these properties to model the microphysical properties of cometary comae and lunar regolith. The success of these ventures has encouraged the Korea Astronomy and Space Science Institute (KASI) to incorporate a polarimetric camera on the Korean Pathfinder Lunar Orbiter (KPLO) whose mission is to map regolith properties of the Moon using polarized light. The PolCam was designed with input from SSI.

The polarimetric properties of Mars were mapped during the 2003 opposition by SSI scientists Mike Wolff and Gorden Videen. During this event, super-thin clouds were observed using the polarimetric signal. These clouds also exist on Earth and have been observed using the PARASOL satellite's polarization capabilities. The only other tool that can detect such clouds is lidar. SSI scientists are working with NASA Langley and KASI to design a constellation of CubeSats to demonstrate the capabilities of super-thin cloud and aerosol characterization using polarimetry. Detection of these clouds is important as their presence contaminates the returns from other satellite systems. For instance, they can affect the temperatures retrieved by the Atmospheric Infrared Sounder (AIRS) by as much as 10K and such clouds and aerosols are the principle limiting factor of the Orbiting Carbon Observatory.

SSI scientist Padma Yanamandra-Fisher is using polarimetry and a team of citizen scientists to answer an unresolved question in solar physics, namely why the solar corona is so much hotter than the visible surface of the photosphere. Since the inner corona is dominated by the K-corona scattering, which is polarized, polarimetric observations during total solar eclipses provides information about the distribution of polarization and therefore, the polarization brightness, which is related to the local electron density. The approach is to use multiple identical telescopes outfitted with polarimeters to increase the length of the corona and the data. This system allows us to probe the inner solar eclipse. Similar campaigns are being planned for the next continental eclipse in 2024.



Intensity of the solar corona (left) and the polarized brightness (right) captured by the citizen scientist project.

New Tools for Characterizing High Energy Electron Dynamics That Affect Space Weather

Dr. Michael Hartinger;
Los Angeles, CA

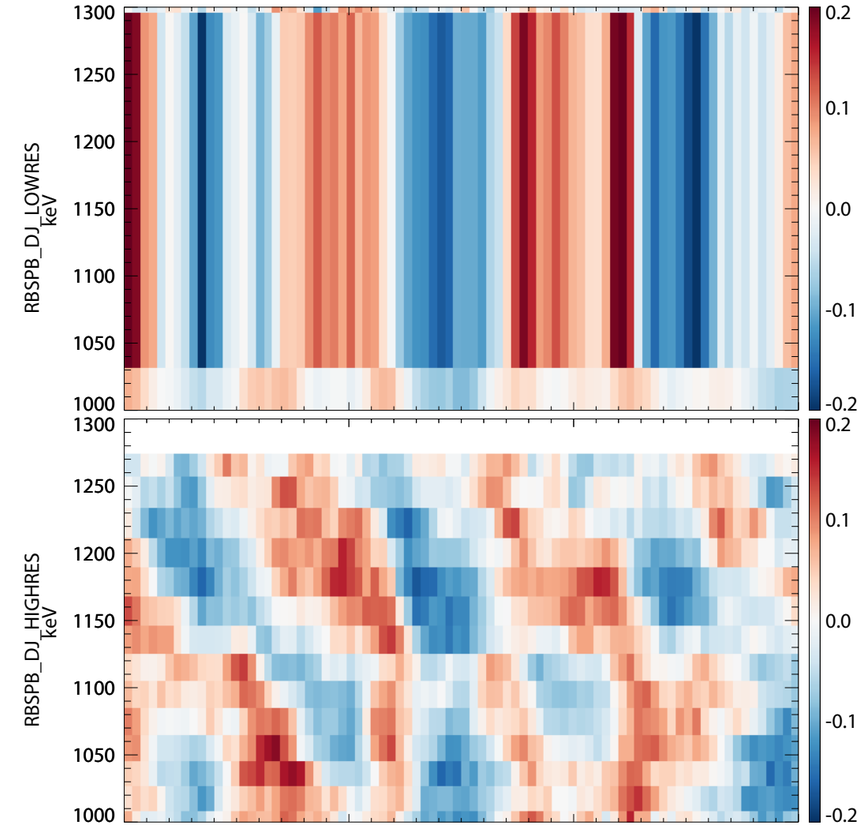
High energy electrons in the near-Earth space environment can play roles in space weather, for example by damaging orbiting satellites. Understanding and predicting the dynamics of these electrons is a high priority for NASA and a main objective of its Van Allen Probes mission, also known as the Radiation Belt Storm Probes (RBSP). At SSI, Dr. Michael Hartinger is leading a NASA Heliophysics Supporting Research project to investigate electron dynamics using multi-point measurements from RBSP and other spacecraft, in collaboration with a modeling team at the NASA Goddard Space Flight Center. As part of this project, Hartinger is exploring unique particle measurements and tools to understand the interactions between electrons and plasma waves in the Earth's radiation belts.

Van Allen Probes, also known as Radiation Belt Storm Probes.
Source: JHU/APL, NASA, https://www.nasa.gov/mission_pages/rbsp/mission/index.html

Plasma waves with periods of a few minutes interact with high energy electrons through a variety of processes. However, these interactions are obscured by a process known as "phase-mixing" where electrons with different energies behave differently, yet are mixed together in measurements that have finite energy resolution. Hartinger et al., [2018] showed how a unique dataset obtained from RBSP can dramatically increase the energy resolution of electron measurements, revealing a range of interactions that are obscured by measurements with lower energy resolution.

A unique design used by researchers at the Aerospace Corporation has made it possible for the RBSP Magnetic Electron Ion Spectrometer (MagEIS) to measure electrons with a range of energy resolutions. When the right conditions are met, electrons can be measured with unprecedented energy resolution. The figure below shows an example of the standard measurement and the high resolution measurement in a half hour interval. There are significant differences when comparing the top (standard channels) to the bottom (high resolution channels). For example, loop-like structures indicating unique electron dynamics appear in the high resolution channels, yet they are completely absent in the standard channels. Using these types of comparisons, Hartinger et al., [2018] showed that the high resolution measurements are crucial for characterizing electron interactions with plasma waves in the Earth's radiation belts.

(Cont'd)



Taken from Hartinger et al., 2018, Figure 3, Geophysical Research Letters. The top panel shows standard energy channels while the bottom is for the higher resolution channels – in each panel, the y-axis ranges from 1000-1300 keV while the x-axis is for time during the half hour interval. Red indicates higher electron fluxes relative to background while blue indicates lower.

The innovative design of the MagEIS particle detector is enabling unique investigations into radiation belt electron dynamics, revealing several interactions that were obscured or absent in earlier measurements. Read more about these data and their possible uses at Geophysical Research Letters: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2018GL080291

Hartinger, M. D., Claudepierre, S. G., Turner, D. L., Reeves, G. D., Breneman, A., Mann, I. R., et al. (2018). Diagnosis of ULF wave-particle interactions with megaelectron volt electrons: The importance of ultrahigh-resolution energy channels. Geophysical Research Letters, 45. https://doi.org/10.1029/2018GL080291

On the left: RBSP Night Launch
Image credit: Mike Killian Photography

InSight: Probing the Interior of the Red Planet

Dr. Steven Lee

Since the dawn of the Space Age, only Earth and its moon have been visited by more spacecraft than Mars. Beginning in 1960, about 40 missions (with about 60 spacecraft) have been launched toward the Red Planet. About one-third 40% have succeeded, at least in part. Though the spectacular successes make it look easy, exploring Mars has proven to be one of the most difficult endeavors humans have ever attempted.

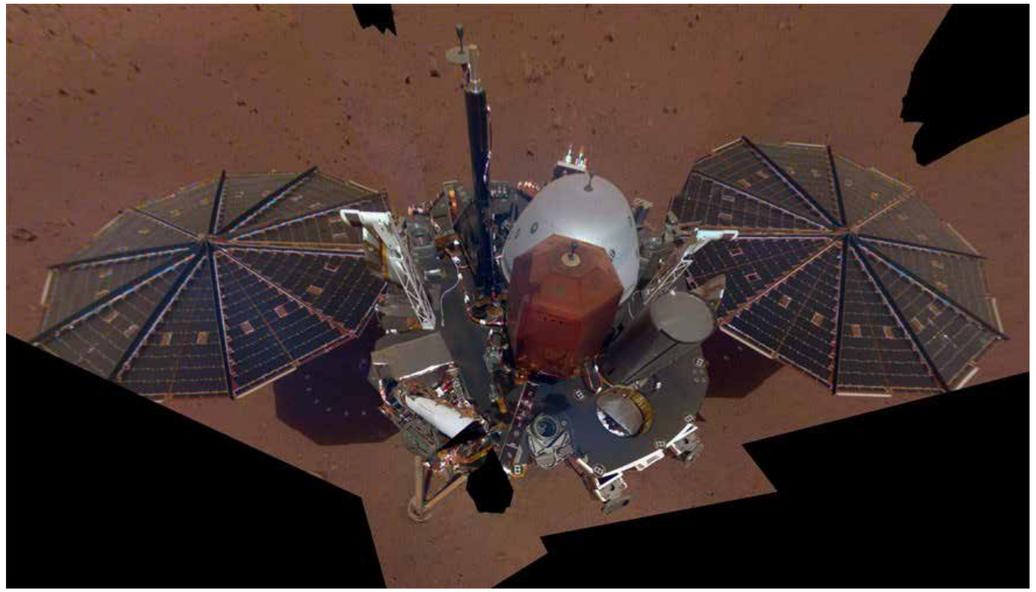
The wealth of data from these missions, and extensive observations from Earth, have given us a treasure trove of information about the present and past state of the Martian surface and atmosphere.

- Currently Mars is a frozen, dry, windswept desert. The thin atmosphere (mostly carbon-dioxide and only about 0.6% of Earth's sea-level pressure) holds little heat, leading to day/night temperature swings of about 100°C at the surface. Surface conditions do not support liquid water, so it either freezes or evaporates.
- The atmospheric pressure is low, but winds are still capable of forming widespread sand drifts and dunes, frequent dust devils, and occasional global-scale dust storms.
- Mars lacks a planetary magnetic field, allowing the solar wind to slowly strip away the upper atmosphere into space.
- Mars was very different billions of years ago, when the atmosphere was thicker and warmer; liquid water flowed, and conditions may have supported simple life-forms. (Think bacteria and algae, not Little Green Men!) Exploring the possibility of past life on Mars is a driving theme behind much of our current and planned exploration of the planet.

On November 26, 2018, about 500 visitors gathered at the Denver Museum of Nature and Science for an "InSight landing party".
Image credit: Rick Wicker (DMNS)

Despite all this exploration, details of the interior structure of the planet are still sketchy. How large is the core, and is it molten? What are the properties of the mantle? How thick is the crust? NASA's latest mission to Mars, InSight (Interior Exploration Using Seismic Investigations, Geodesy, and Heat Transport), is designed to fill these gaps in our knowledge through three primary experiments:

- SEIS (Seismic Experiment for Interior Structure) features an ultra-sensitive seismometer deployed from the lander onto the surface using a robotic arm. Prelaunch testing of SEIS in Denver detected the signature of ocean waves crashing along the California coast! Detailed analysis of ground vibrations, caused by "Marsquakes," meteoroid impacts, and even storms, will reveal much about the internal structure.
- HP3 (Heat Flow and Physical Properties Probe) is an array of temperature sensors that will use a self-hammering "mole" to burrow 2 to 3 meters into the surface. These observations will measure how the surface materials conduct heat and how much heat is flowing outward from the interior of the planet.
- RISE (Rotation and Interior Structure Experiment) uses InSight's radio connection with Earth to provide information about the Martian core through precise tracking of the location of the spacecraft on the surface as the planet rotates.



This is NASA InSight's first full self-portrait on Mars. It displays the lander's solar panels and deck. On top of the deck are its science instruments, weather sensor booms and UHF antenna.
The selfie was taken on Dec. 6, 2018. Image credit: NASA/JPL-Caltech.

(Cont'd)

The InSight spacecraft was designed, built, and tested right in our own backyard by Lockheed Martin Space in Littleton, CO. InSight was successfully launched on May 5, 2018 aboard an Atlas 5 launch vehicle provided by United Launch Alliance, based in Centennial, Colorado. On November 26, the Denver Museum of Nature & Science (DMNS) hosted a "landing party" for about 500 visitors to the museum. SSI senior research scientist Steve Lee provided background on the mission, and hosted an "expert panel" featuring one of the lead InSight engineers (Lockheed Martin Space) and a lead mission manager for the Atlas 5 launch vehicle (ULA). From the edge of our seats, we watched live NASA TV coverage of the "6 Minutes of Terror" as InSight slammed into the Martian atmosphere at 5.5 km/sec, descended under a supersonic parachute, then successfully performed a rocket-assisted soft landing on the surface! After a 7-month cruise (traversing 480 million km), InSight was met with cheers both in Denver and across the world as it arrived at its new home on Mars!

InSight is busily surveying its landing site, and is preparing to use its robotic arm to deploy the SEIS and HP3 instruments onto the surface. The two-year mission of data-gathering will then commence, adding to the ongoing story of a place that continues to capture imaginations and inspire space explorers of today, and tomorrow. Go, InSight!

Testing the InSight Mars Lander's solar arrays
Image credit: Lockheed Martin Space

InSight into Martian Atmospheric Processes

Dr. Mark Lemmon

SSI researcher Mark Lemmon was invited to join the Mars InSight lander's science team in August of 2018. InSight successfully landed on Mars on 26 November 2018, beginning a 2-year investigation of the Martian interior, using a seismic station and heat flow probe attached to the non-roving spacecraft. The first months of the mission were devoted to deployment of the seismometer and heat flow probe to the surface and drilling of the probe into the subsurface. Through the remainder of the mission, the probe will mostly sit still and listen for mars quakes, make meteorological and other measurements.

While the primary goals of the InSight team pertain to the geophysics of the Martian interior, Lemmon was selected as part of a participating-scientist-program call for proposals to increase the mission's return using existing capabilities. Most of the new science team members had a geophysical bent, but there were several atmospheric scientists, including Lemmon.

Early in designing the mission, the team had realized that the seismometer would be sensitive enough that nearby weather would interfere with the seismic signals that were supposed to carry information about the Martian core and mantle. So, a sophisticated weather station, derived from the Curiosity rover's REMS, or Rover Environmental Monitoring Station, was added. Because the seismic station would be always listening, the 'auxiliary payload' or weather station, would be always listening too—this results in the most complete weather record from Mars.

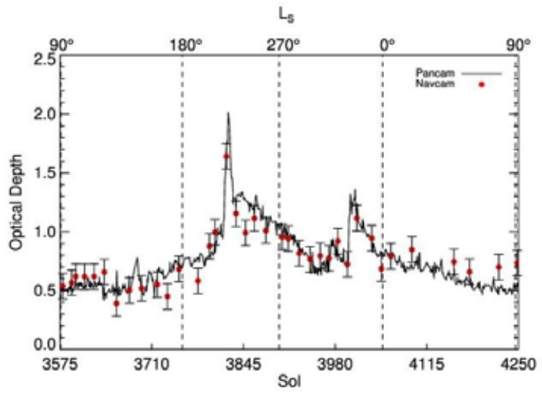
Another design constraint was that engineering cameras were needed for placement of the instruments on the surface, but there was no extra capability for a science camera. A camera that had to be aimed with motors was also not desired by the seismologists. However, the lander was solar powered, and the power engineers are highly motivated to understand which signals from the solar arrays indicate spacecraft issues, and which are simply responding to weather, such as dust storms. Thus, the call for new science team members prioritized an investigation that could use the limited available resources—2 engineering cameras, one fixed and one attached to the robot arm that deploys instruments—to measure the attenuation of sunlight by dust.

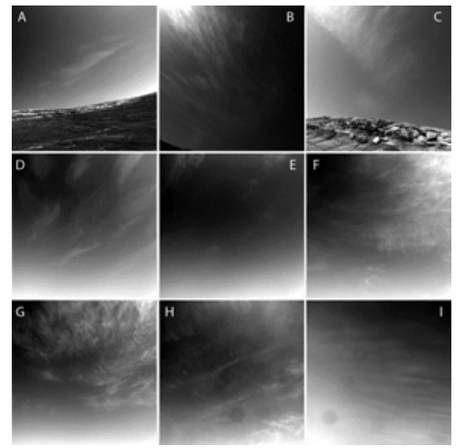
(Cont'd)

Lemmon's work on the mission involves taking sky images, and using them to derive atmospheric dust load using radiative transfer models. This is a pretty basic part of the tool kit for any atmospheric radiative transfer modeler. However, on InSight it was complicated by the need to deliver results to the power team on the same day the data are downlinked; and further complicated by the need to use a camera that could image the sky, but that would stop moving early in the mission. Chris Wolff, a Master's student of Lemmon's at Texas A&M University, had previously used 1 Mars year of engineering camera imaging from the Opportunity rover to measure optical depth from fixed sky images, and demonstrated the validity of the technique with nearly simultaneous measurements of dust load from solar imaging. That model, adapted to the InSight cameras, is now a part of the InSight image processing pipeline to allow rapid results.

Keeping the camera aimed at the sky opened the possibility of other investigations. Daytime imaging can be used to see clouds, especially during the winter/aphelion cloud season. Nighttime imaging may be able to see meteors, complementing the InSight team's goal to study impact rates and processes by observing the other end of the size distribution of things that hit Mars. The mission's other camera has a fish-eye lens and vies the lander's workspace and the southern horizon, so it is used to image and track dust devils.

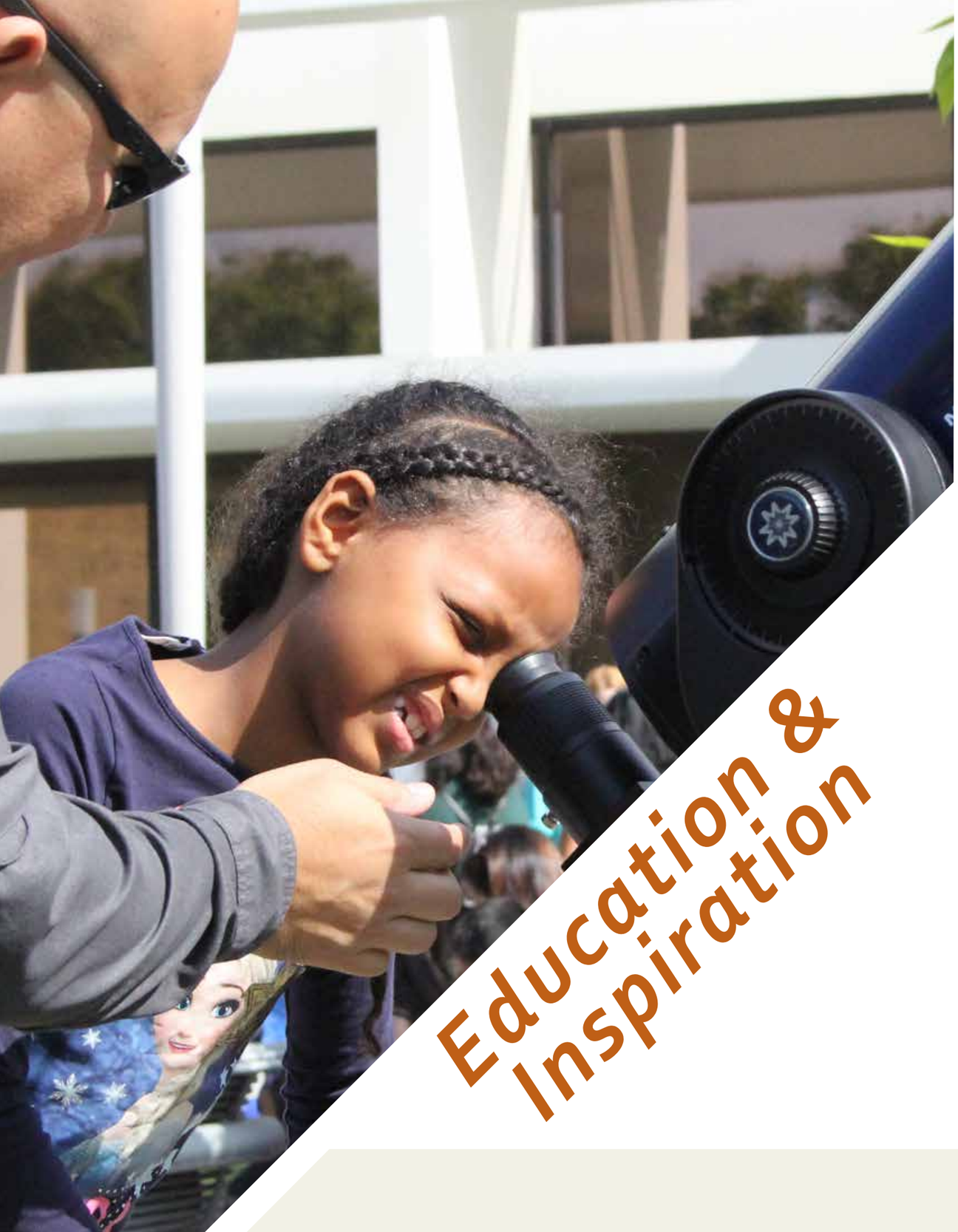
One of InSight's 7-foot (2.2 meter) wide solar panels was imaged by the lander's Instrument Deployment Camera, which is fixed to the elbow of its robotic arm. Image Credit: NASA/JPL-Caltech





Measurements of the dust load at the Opportunity rover site spanning almost 700 sols (Martian solar days) using direct solar extinction measurements (black line, Lemmon et al. 2015) and using fixed-aim sky imaging (Wolff 2017).

Image credit: NASA/JPL-Caltech



Education & Inspiration

National Center for Interactive Learning

SSI's ***National Center for Interactive Learning*** (NCIL) is led by Dr. Paul Dusenbery (Boulder Office). NCIL 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 and its recently developed STEM Activity Clearinghouse, the center has a national reach that numbers in the millions. NCIL (www.ncil.spacescience.org) is organized around four interdependent groups: 1) Exhibition Development, 2) Digital Learning, 3) Professional Development, and 4) Community Engagement.

The STAR Library Network (*STAR Net*) is NCIL's flagship STEM program serving the public library community. STAR Net focuses on helping library professionals facilitate STEM learning for their patrons by providing "science-technology activities and resources" (STAR) and training to use those resources. It began in 2009 and now numbers about 7,500 members. NCIL continues to publish a monthly *STAR Net* e-newsletter and has an active social media presence including Facebook, Twitter, YouTube, and Flickr.

In 2018, NCIL developed and launched a national touring exhibition called Discover Exoplanets in collaboration with the Space Telescope Science Institute and NASA's Jet Propulsion Laboratory. This tour, which began in August of 2018, represents the first time NCIL has encouraged informal learning organizations (museums and libraries) to work together to apply for the opportunity, and continue their collaboration while hosting the exhibition.

Image credit: SSI/NCIL

Professional Development & Community Engagement

The Professional Development Group (led by Keliann LaConte, Boulder Office) oversees training and activity development. *STAR Net*'s 5 workshops, 13 webinars, presentations at 11 conferences in 2018, and online resources serve as a primary source for ongoing professional STEM learning for library staff. During in-person training, participants try active STEM learning experiences firsthand and discuss facilitation strategies for the library setting. In 2018, 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. Virtual training has become a pivotal tool for NCIL in reaching their goal of strengthening the infrastructure of STEM education in libraries.

The goal of NCIL's Community Engagement Group (led by Anne Holland, Boulder Office) is to keep public and professional communities interested and engaged in the work we do, and to serve their needs. 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. *Community Dialogues* have recently become an important focus of *STAR Net*, with more than 150 *Dialogues* being conducted by public libraries across multiple NCIL programs. These *Dialogues* aim to help libraries identify potential partners, work more closely with underserved and underrepresented groups in their communities, and get a clearer pulse on the needs of the community they serve.

Image credit: SSI/NCIL

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 (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. Recent work has included Starchitect, a Facebook based "create a solar system" game, education games for library exhibitions, and apps designed to support librarians in exploring NASA STEM topics with their patrons.

Screenshot from the Starchitect Game.

NCIL Impacts for 2018

Traveling Exhibit Visitors (320,709)

• STAR Net's *Discover Tech* Library Exhibit (2 host sites):	19,095
• STAR Net's *Discover Space* Exhibit (3 host sites):	222,989
• STAR Net's *Explore Earth* Exhibit (5 host sites):	19,450
• STAR Net's *Explore Tech* Exhibit (5 host sites):	40,350
• STAR Net's *Explore Space* Exhibit (5 host sites):	18,825

• STAR Net Library Program Participants (Discover Exhibit Sites, Explore Sites, *NASA@ My Library*):	50,955
• In-person professional development activities:	330
• Webinar Participants:	
Unique Live Views:	673
YouTube Recording Views:	2,539
• STAR Net Online Community Members:	7,500
• NCIL Outreach Event Participants:	20,500

Education Website Visitors	Page Views
• Alien Earths	385,460
• Giant Worlds	28,617
• MarsQuest Online	132,223
• SciGames	67,517
• Space Weather Center	353,518
• Killer Asteroids	74,627
• Starchitect	218,518
• STAR Net	91,409
• STEM Activity Clearinghouse	49,927
• National Center for Interactive Learning	3,848
• Totals	**3,050,724**

Image credit: SSI/NCIL

2018 Highlights

Discover Exoplanets Exhibition is Now on Tour

Seven library and museum partners across the country (14 total sites) were selected to host the *Discover Exoplanets* exhibition. With the end of the Kepler K2 Mission, and the beginning of the TESS (Terrestrial Exoplanet Survey Satellite) Mission, this timely topic was very well received by museums and libraries that applied to host the exhibit, with more than 100 competitive applications being received! This exhibition is a partnership between NCIL and NASA's *Universe of Learning* program at the Space Telescope Science Institute. Host sites attended a professional development workshop at the Pueblo City County Library (Rawlings and Pueblo branches) where they learned about hands-on activities, met NASA/JPL exoplanet scientists, and were trained on how to set up the exhibit. Partner pairs are incredibly diverse, with rural and urban libraries, large science museums, tiny history museums, and even a local health clinic!

Host library and museum staff learn how to set up the exhibition components during the training workshop. Credit: SSI /NCIL

On the left: This kiosk hosts JPL's "Eyes on Exoplanets" interactive, as well as SSI's "Planet Famliies" game. Credit: SSI/NCIL

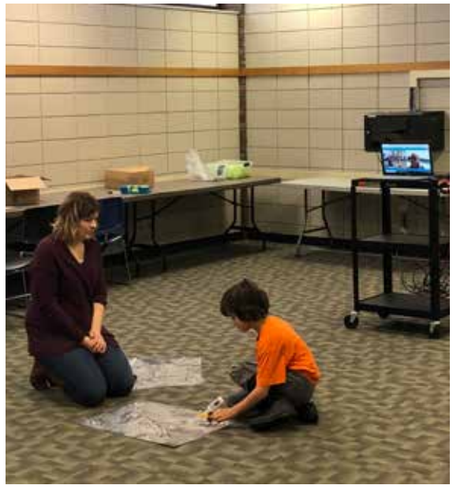
Professional Development Experiences for Librarians

In 2018, workshops were delivered as part of SSI/NCIL's Project BUILD and *NASA@ My Library* programs, in partnership with the American Society for Civil Engineers, University of Virginia, Cornerstones of Science, Pacific Science Center, and Education Development Center.

NCIL manages the NSF-funded Project BUILD (**B**uilding **U**sing an **I**nteractive **L**earning **D**esign) program. The project team engages youth (grades 2-5), their families, librarians, and professional engineers in an informal learning environment with age-appropriate, technology-rich STEM learning experiences fundamental to the Engineering Design Process. Partners include the University of Virginia, American Society of Civil Engineers (ASCE), Education Development Center along with six libraries in urban and rural communities. NCIL and its partners facilitated a workshop for library staff and ASCE volunteers in April 2018. Workshop participants then facilitated programs where 313 children and caregivers participated in a research study on STEM learning – while also practicing their engineering skills through kid-friendly activities!

Participants at the Project BUILD workshop proudly show off their structure. Credit: SSI/NCIL

On February 28 to March 1, 2018, over 80 *NASA@ My Library* Partners (including 4 state library staff and public library staff from 49 states) gathered for hands-on STEM professional development in Denver, CO. NCIL also partnered with the Lunar and Planetary Institute and 12 state libraries to launch a series of workshops in support of the 2019 Collaborative Summer Learning Program theme, A Universe of Stories. Credit: SSI/NCIL



NASA@ My Library partner, Pacific Science Center, oversaw training programs to help NASA subject matter experts develop their skills in discussion-based STEM learning. The subject matter experts then conducted 18 public programs – virtually – with libraries across the country.
Credit: Pacific Science Center

In 2018, the NCIL Professional Development team took the *STAR Net* Webinar Series to new heights. While NCIL webinars have always been recorded and archived, in 2018, NCIL began broadcasting webinars to the general public through YouTube's "Live Broadcast" feature. This effort proved to be a major turning point in NCIL's efforts to reach library staff around the country.

(Cont'd)

In 2018, NCIL presented 13 major webinars to a public audience. These webinars reached a total of **673** live, unique viewers through the Adobe Connect and Zoom platforms and an additional **2,539** viewers through YouTube. In total, STAR Net webinars were viewed well over 3,000 times. The most popular webinar of 2018, "Bringing a Universe of Stories to Your Library," had 106 unique live views and over 852 YouTube views. On average, each public webinar in the *STAR Net* Webinar Series reached approximately 250 patrons.

Towards the latter half of 2018, NCIL began focusing on developing webinars, activities, and other content to prepare libraries for the 2019 Collaborative Summer Library Program summer reading theme, "A Universe of Stories." Webinars focused primarily on this theme and thus delivered numerous presentations on resources and activities that could be utilized for programming in summer 2019.

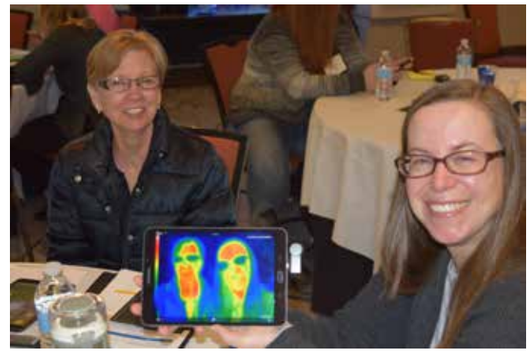
NCIL's STEM Activity Clearinghouse also underwent major, positive changes in 2018. NCIL staff put the Clearinghouse through a major overhaul in early 2018 and improved the website's functionality by updating the collections, adding new images and how-to videos, changing navigational features, and revamping the site's organization. Six brand-new, instructional How-to Videos were created for the STEM Activity Clearinghouse by NCIL and the Lunar and Planetary Institute. Numerous webinars were "spliced up" to create instructional videos for activities, as well. NCIL made a concerted effort in 2018 to ask library staff to leave helpful reviews of activities on the Clearinghouse – and it worked! In 2018 alone, 85 unique reviews were left on Clearinghouse activities. The STEM Activity Clearinghouse continues to be a "watering hole" for library staff looking for useful, vetted STEM activities, and NCIL staff continue to work to improve the website's functionality and usability.

Image Credit: SSI/NCIL

NCIL Develops Digital Experiences for Public Libraries

As part of the *NASA@ My Library* program, NCIL shipped preconfigured, remotely managed tablets to 75 partner libraries as part of the first facilitation kit. Since then, we have been producing a series of tablet apps that are remotely pushed out to these tablets. 2018 saw the delivery of "Seeing the Unseen", a multi-spectral exploration, an updated version of the "Space Stage" greenscreen app, as well as a series of apps to support using the tablet as a multi-sensor device: a magnetometer, light sensor, and support for a digital microscope. In addition, each partner received a thermal infrared camera that can be attached to the tablet. Development efforts for 2018 included several new apps, including "Lift Off" (a space themed, multi-player quiz game), and "Sizemology", an interactive scale game. These are intended for delivery in 2019 along with updates to several existing pieces to support data collection and evaluation.

In addition to our work on educational apps, NCIL has increased its focus on "Computational Thinking" and expanding the number of youth exposed to computing, programming, and their role in STEM. This has become an area of significant interest on multiple fronts, including within NSF (e.g., the STEM+C program), and within the White House (the 2018 America's Strategy for STEM Education report). In 2018, NSF funded a supplement project as part of STAR Net Phase 2 to integrate CT elements into STAR Net's Discover Space exhibition. The exhibition will launch in 2019, with a new emphasis on the role of computing in space exploration.



Library staff at the NASA@ My Library workshop in Feb. 2018 show off their tablets loaded with educational apps produced by NCIL. Credit: SSI/NCIL

On the left: Screenshot from the "Universe of Magnets" interactive. Credit: SSI/NCIL

STAR Net Team Participates in a Live Astronaut Downlink Event

The High Plains Library District (Greeley, Colorado), in collaboration with NCIL was selected by NASA to host a live in-flight education downlink from the International Space Station with Colorado's own NASA astronaut Serena Auñón-Chancellor. The 20-minute downlink event was held on October 18, 2018 and streamed live so that other public libraries and schools across the country could organize their own viewing events. The program was designed to inspire children to increase their interest and engagement in science and engineering. SSI/NCIL staff members were supported by funding from the *NASA@ My Library* program.

Three hundred 3rd and 4th grade students from Frontier Academy and Dos Rios Elementary participated in the live downlink and the hands-on science and engineering activities that followed. Children ages 8-12 from local schools and libraries and elsewhere across the U.S submitted questions for the live chat. Local kids were selected to ask questions during the downlink. It was estimated that over 15,000 people across the country participated in either the live portion or watched later on NASA TV.

NASA opportunities like this one have the potential to increase and sustain youth and public engagement in science and engineering. Public libraries are a natural venue to serve as a host. They are natural community gathering places and one of the few free resources available to the public. They also serve people of all races, ages, and socio-economic backgrounds.

Participating youth, teachers, library staff, and NCIL staff gather in the Riverside Community Center to hear from NASA astronaut Serena Auñón-Chancellor. Credit: SSI/NCIL

NCIL staff member, Brooks Mitchell, leads a hands-on activity that followed the downlink event. Credit: SSI/NCIL

Participants watching the downlink on a bookmobile in St. Johns County Florida. When their question was read by the astronaut, they "leapt into the air in excitement!" Credit: St. Johns County Public Library

Financial Summary

Space Science Institute • Summary Statement of Financial Position
as of December 31, 2018 and 2017

ASSETS	2018	2017
Assets		
Cash and cash equivalents	249,117	95,290
Accounts receivable	1,811,820	1,511,332
Prepaid expenses and deposits	131,434	93,536
Net furniture, equipment, and property	21,865	30,105
Total assets	**$ 2,214,236**	**$ 1,730,263**
LIABILITIES AND NET ASSETS		
Liabilities		
Accounts payable and accrued liabilities	1,170,293	663,328
Deferred revenues	231,850	189,309
Line of credit	500,000	525,000
Total liabilities	$ 1,902,143	$ 1,377,637
Net assets		
Unrestricted	306,348	343,553
Temporarily restricted	5,745	9,073
Total net assets	$ 312,093	$ 352,626
Total liabilities and net assets	**$ 2,214,236**	**$ 1,730,263**

Summary Statement of Activities
for the years ended December 31, 2018 and 2017

SUPPORT AND REVENUE	2018	2017
Grants, contracts, and cooperative agreements	8,606,532	7,546,599
Contributions	11,331	56,495
Exhibit income	229	166,966
Interest income	208	188
Total support and revenue	**$ 8,618,300**	**$ 7,770,248**
EXPENSES		
Program services	6,760,877	6,335,171
Fundraising	5,194	21,698
General and administrative	1,892,762	1,876,358
Total expenses	$ 8,658,833	$ 8,233,227
Change in net assets	(40,533)	(462,979)
Net assets, beginning of year	352,626	815,605
Net assets, end of year	**$ 312,093**	**$ 352,626**

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 Institute's financial position, changes in net assets, and cash flows. Accordingly such information should be read in conjunction with the Institute's audited financial statements for the years ended December 31, 2018 and 2017, from which the summarized information was derived. A copy is available upon request.

Image credit: Peter Patonai (Astroscape Photography)

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