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ANNUAL REPORT 2020





The Horsehead Nebula in Infrared from Hubble
Credit: NASA, ESA, and The Hubble Heritage Team (STScI/AURA)

Our Mission

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

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Cover Image: In this Hubble portrait, the giant red nebula (NGC 2014) and its smaller blue neighbor (NGC 2020) are part of a vast star-forming region in the Large Magellanic Cloud, a satellite galaxy of the Milky Way, located 163,000 light-years away. The image is nicknamed the "Cosmic Reef," because it resembles an undersea world. Credits: NASA, ESA and STScI

Message from the Executive Director and Board of Directors

In 2020, SSI proved that we can perform and achieve tremendous impact, no matter what challenge comes our way. The COVID-19 pandemic that caused significant disruption to countries across the world reached our organization in 2020. Having been a pioneer in remote employment for 25+ years, our nonprofit was in a better position to weather the state of emergency than most. Our scientists were dominantly telecommuters prior to COVID-19 and equipped with the home office resources and work habits to enable them to continue working almost as normal, minus the domestic and international travel inherent in collaboration. Those of you who also shifted to remote work this year will appreciate the difficulties of focusing on work from a home environment; just imagine the concentration it takes to work on a spacecraft mission or project from NASA under those conditions! But under those conditions, SSI's Research Branch published even more papers than they did in 2019, over 170 refereed and non-refereed publications, submitted more proposals (101!), and landed 29 proposal wins in 2020. Amazing results from SSI researchers in 2020 are featured in this report, including the discovery of water on the Moon by a team of astronomers including SSI's Sachin Shenoy using the SOFIA airborne infrared observatory, Ahmed Mahjoub's planetary chemistry analogue experiments at NASA's Jet Propulsion Laboratory, and Tim McConnochie's Martian atmosphere work as a participating scientist on NASA's Mars 2020 Perseverance Rover. In 2020, SSI's Research Branch welcomed 5 new principal investigators for a total of 73 scientists and offered opportunities for 2 new postdoctoral research associates and 1 student research assistant to begin their careers.

SSI's NCIL team pivoted quickly to help our key community stakeholders in response to COVID-19. Community centers such as libraries had to close to the public during COVID-19, leaving library staff furloughed and onsite hands-on educational programming suspended. As described in Stephanie Vierow-Fields's article on page 54, SSI's National Center for Interactive Learning provided libraries across the U.S. with STEM education content that could be delivered virtually to patrons, professional development training and webinars that could count toward librarians' work hours, a forum for the library community to exchange ideas on how to pivot during the pandemic, and 23,000 "Take and Make" take-home STEM education kits for curbside checkout at libraries. By offering these informal STEM education resources to the public libraries, the SSI/NCIL team was able in turn to help families looking for enrichment to remote K-12 learning and to focus on broader social issues such as combating unconscious bias and being culturally responsive in STEAM programming (e.g., offering bilingual resources to reach Spanish speaking families; gender equitable STEAM activities). In 2020, SSI formed an official diversity working group to assist in traceability of our diversity, equity, inclusion, and accessibility (DEIA) initiatives and how they align with SSI's nonprofit mission, and reaffirmed our commitment to this mission with a Board approved statement on diversity.

Our support teams in Business, IT, HR, and Legal showed tremendous commitment during 2020, providing dedicated support to the programmatic team and holding down the fort at SSI HQ during the height of COVID-19. Our team at SSI headquarters in Boulder was nearly completely displaced from their offices and their normal working patterns. The onsite team streamlined operations to successfully ensure the health and safety of our employees, affiliates, and vendors and provide continuity so that project work could continue. We thank those staff members who came in during the worst and brought their best.

SSI's Board of Directors welcomed a new member, Amanda Fisher, in 2020. Amanda serves as Manager of Gender Equity Initiatives, a position held jointly between the Association of Science and Technology Centers (ASTC) and the National Girls Collaborative Project (NGCP). She previously held science communication, learning and community engagement, and STEM program curriculum and development specialist positions at the Oregon Museum of Science and Industry. Her background and expertise in gender equitable STEM programming and underrepresented and underserved community outreach will be extremely valuable to our Board and SSI's nonprofit mission to reach people of all ages and backgrounds. Dr. Marilyn Johnson, former director of the Oregon Museum of Science & Industry, also finished out her final term on SSI's Board of Directors in 2020. We thank Marilyn for her many years of service and invaluable insights into the world of STEM education, and for bringing Amanda aboard!

Reflecting on the achievements of 2020, we made the best of the situation we were in, continued to inspire, serve, and execute on mission, and are still healthy and happy. Not all nonprofits have been as fortunate and we count our blessings as we continue on this journey. We appreciate the partnership that you have shown to us and your continued support and wish you good health and positive spirits.



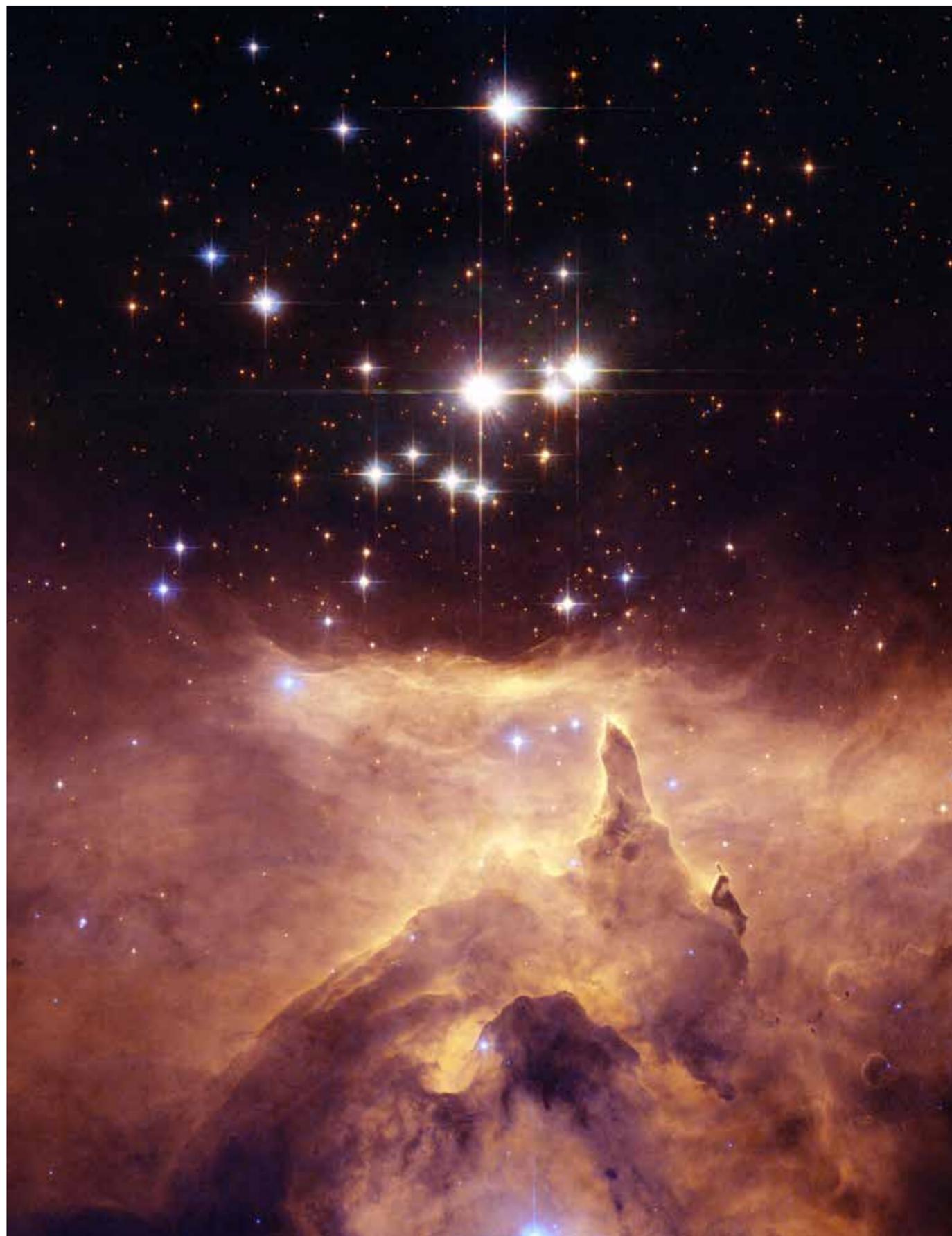
Karly Pitman, Ph.D.
(Executive Director)



Steven Jolly, Ph.D.
(Chair)



William R. Purcell, Ph.D.
(Vice-chair)



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 Boulder, creating more space for business operations and for onsite research scientists and STEM educators. Through collaborations with NASA, the European Space Agency, and other institutes, SSI scientists have secured participation in prestigious space missions and observatories, including the Mars Exploration Rovers, Rosetta, Cassini, Mars Reconnaissance Orbiter, Mars Global Surveyor, Hubble Space Telescope, THEMIS, Lunar Reconnaissance Orbiter, Mars Science Laboratory, Juno, Stratospheric Observatory for Infrared Astronomy, ExoMars Trace Gas Orbiter, OSIRIS-REx, Emirates Mars Mission and Mars 2020 Rover (launched in 2020), and James Webb Space Telescope (to be launched in 2021).

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), Center for Polarimetric Remote Sensing (2017), and Center for Data Science (2019).

*Left Image: NGC 6357: Cathedral to Massive Stars
NASA, ESA and Jesús Maíz Apellániz (IAA, Spain); Acknowledgement: Davide De Martin (ESA/Hubble)*

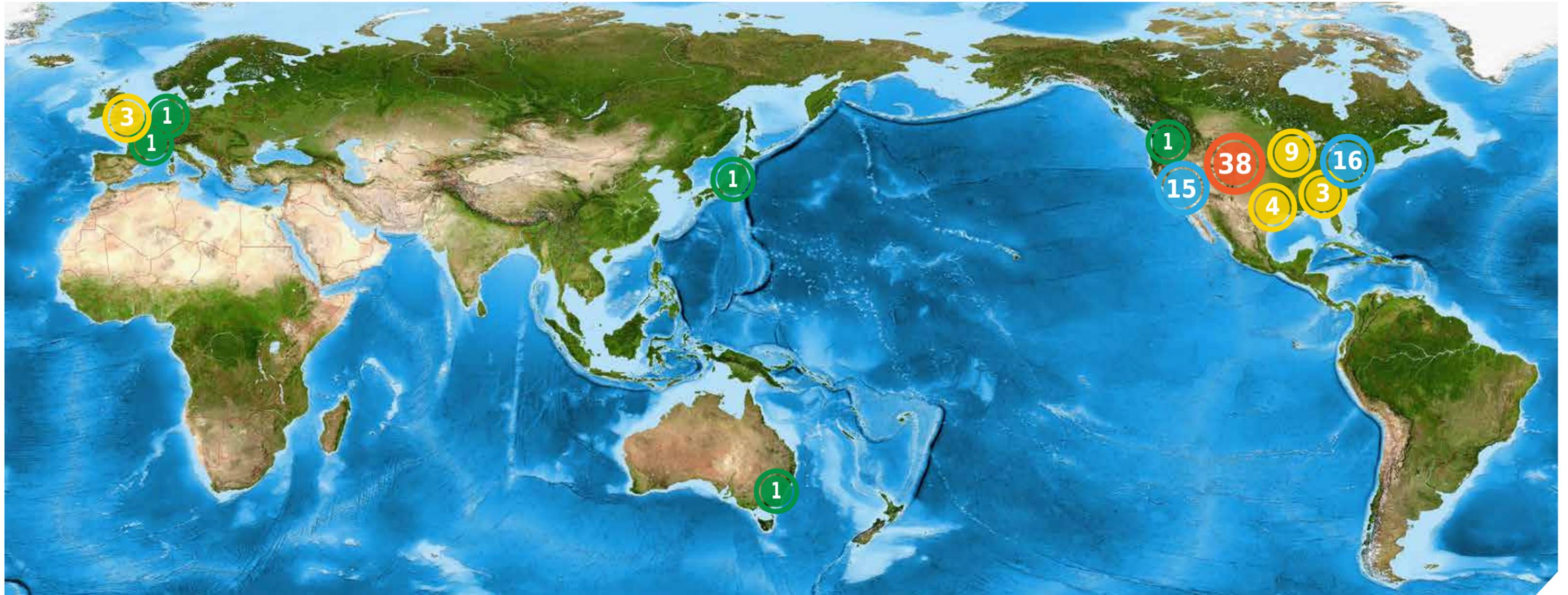
Present

Today, SSI manages 73 scientists, 10 educators, and 10 operations staff, working in Colorado, nationally and internationally. SSI is a leader in developing innovative science, technology, engineering, and math (STEM) programs that make engaging with science accessible, meaningful and fun for people of all ages and backgrounds. SSI's science research and education programs support its overall mission: to shape our future by enabling scientists to advance our understanding of Earth and the Universe; to increase science and technology literacy for people of all ages and backgrounds; and to inspire youth to pursue science-technology education and career opportunities. SSI's role in advancing science understanding and pushing the frontiers of STEM learning has been recognized through competitive awards from NASA; the National Science Foundation; the NASA Jet Propulsion Laboratory; the Space Telescope Science Institute; and the U. S. Department of Energy, among other funders.

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.

*World Pacific Rim satellite image map
Credit: Worldmapsonline.com*



2020 Board Members

- Dr. Jack Burns, Professor & Vice President Emeritus for Academic Affairs & Research, University of Colorado
- Dr. Douglas Duncan, Astronomer, University of Colorado
- Ms. Nancy Geyer, Retired Executive Director and CEO, Museum of Boulder
- Ms. Amanda Fisher, Manager, Association of Science and Technology Centers
- 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 (Chair), Systems Engineering Director, Lockheed Martin Corporation
- Dr. Karly Pitman (ex officio), Executive Director / Senior Research Scientist, Space Science Institute
- Dr. Bill Purcell (Vice-Chair), Senior Manager Advanced Systems, Ball Aerospace and Technologies Corporation
- Mr. Gary Zarlengo (Treasurer), Small Business Consultant

2020 Executive Advisory Committee

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

2020 Grants & Contracts

SSI gratefully acknowledges support from research and education grants and contracts from the following organizations in 2020:

- NASA
- Arizona State University
- Boston University
- JPL (Jet Propulsion Laboratory)
- Malin Space Science Systems
- Northern Arizona University
- Smithsonian Astrophysical Observatory
- Space Telescope Science Institute
- Laboratory for Atmospheric and Space Physics
- Los Alamos National Laboratory
- Universities Space Research Association
- University Corporation for Atmospheric Research
- University of Alabama, Huntsville
- University of Arizona
- University of California, Los Angeles
- University of Colorado
- University of Houston
- University of Iowa
- University of Maryland
- National Science Foundation
- University of New Hampshire
- Institute of Museum and Library Services
- Urban Libraries Council
- Department of Energy

2020 Colorado Gives Donor List

SSI wishes to thank the generous individuals who contributed to the Space Science Institute in 2020:

- William Purcell
- Douglas K. Duncan
- R. Todd Clancy
- Ron and Lisa Doyle
- Steve and Kate Hartsock
- Gregory Wimpey
- Damian A. Crevello
- Christine Woo
- Steve Jolly
- Melissa Shenoy
- Rob Shapiro and Karen Bliss
- Alexey Pankine
- Carl Wuth
- Neal Miller
- Amanda Fisher
- Nancy Geyer
- Paul Dusenbery
- Dr. Jack O. Burns
- Nicholas Heavens
- Karly Pitman
- Michael Wolff
- Padma Yanamandra-Fisher
- Jennifer Griest
- Thomas Lippert
- Kerry Lightenburger
- Anonymous (8)

We Discover & Explore

SSI researchers work on the cutting edge of astrophysical, planetary, and space plasma sciences. The Research Branch is home to world experts in multiwavelength astronomy, Mars atmospheric and surface studies, cometary and outer Solar System research, and heliospheric 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.

We Educate & Inspire

SSI is home to the National Center for Interactive Learning, which leverages SSI's successful experience in developing and implementing interactive STEM programs for museums, science centers and public libraries. NCIL also has a robust public outreach program and has developed a variety of digital and online programs that reach millions of people annually. 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 Library Association (ALA), Chief Officers of State Library Agencies (COSLA), Association of Science-Technology Centers, the Afterschool Alliance, Pacific Science Center, Cornerstones of Science, American Society of Civil Engineers, Lunar and Planetary Institute, University of Colorado, University of Virginia, Arizona State University, Engineers Without Borders-USA, the National Renewable Energy Lab, American Geophysical Union, Association of Rural and Small Libraries, and many more.



*Filaments of the Cygnus Loop
Credits: ESA/Hubble & NASA, W. Blair; Acknowledgement: Leo Shatz*

Discovery & Exploration

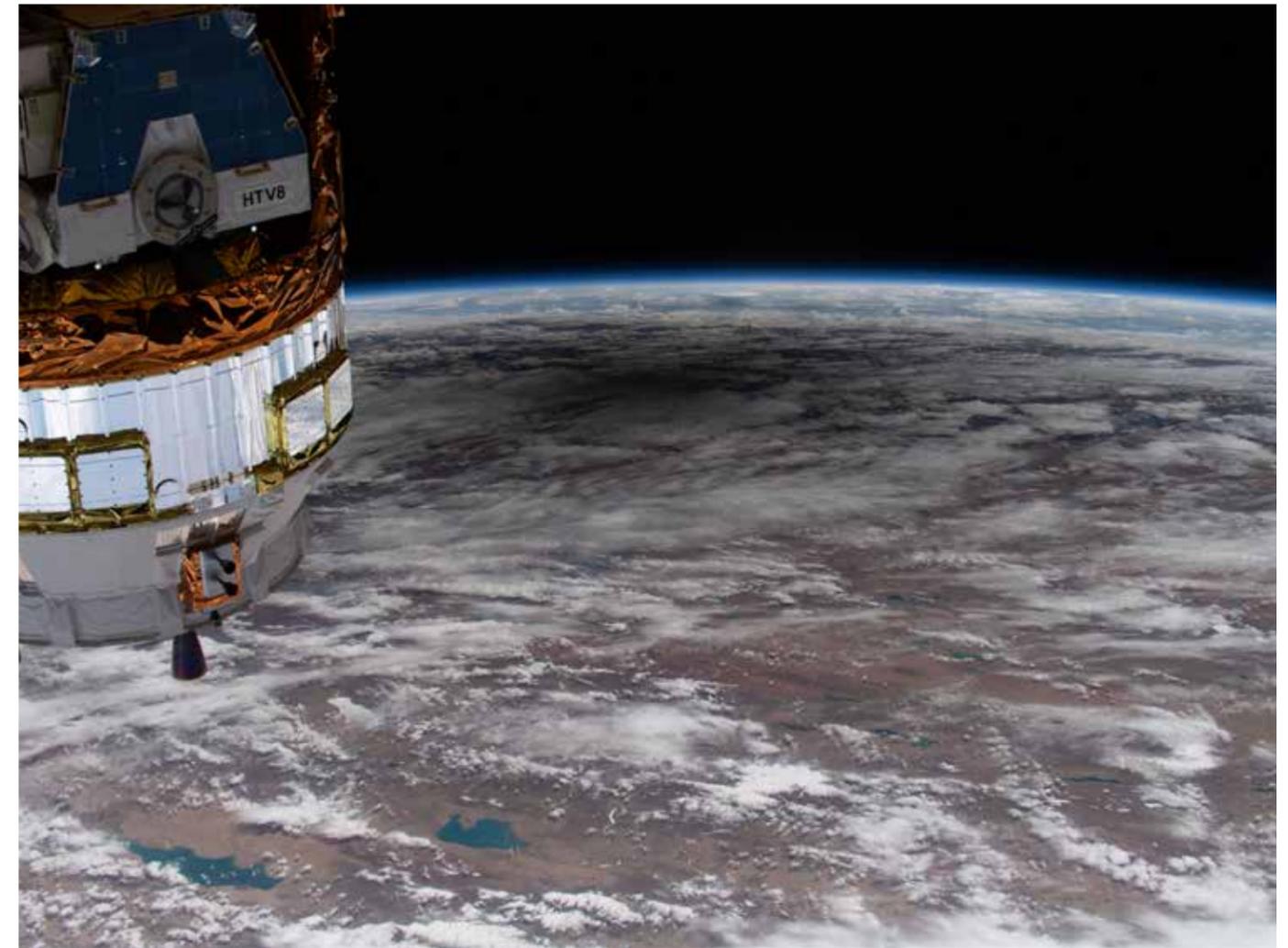
SSI Research Branch

SSI's Research Branch scientists participate in a broad array of space science activities, including Earth science, space physics, planetary science, and astrophysics. Specific areas of expertise include Martian atmosphere and geology, extrasolar planets, helio- and asteroseismology, Earth's magnetosphere, and multiwavelength astronomy.

In 2020, the Research Branch welcomed 5 new principal investigators, for a total of 73 scientists. In addition we brought on 2 new post-doctoral research associates and 1 student research assistant. Ten of the 73 scientists are located on-site at SSI's Boulder headquarters with the rest distributed across the U.S. and internationally. Sadly SSI and the astronomy community in general suffered a tragic loss at the end of 2020 when Research Scientist Babar Ali passed away unexpectedly (see "In Memoriam" below).

While any individual scientist may pursue the subject area of their choice, SSI's Research Branch also runs five "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), the Center for Polarimetric Remote Sensing (CPRS), and the newly created Center for Data Science (CDS). See center reports below for more detail on center activities.

SSI scientists were awarded 27 new grants and contracts in 2020, primarily from NASA and NASA-funded primes, including significant awards in space plasma physics (PIs: Joe Borovsky, Michael Hartinger, Seth Dorfman, and Vadim Roytershteyn), planetary atmospheres (PIs: Julie Moses and Frank Mills), Martian geology (PI: Bill Farrand), and stellar atmospheric modeling (PI: Regner Trampedach).



*Eclipse under the ISS
Credit: NASA ISS Expedition 63*

2020 Impacts

Total scientists:	73
Papers published:	>170 (refereed and non-refereed)
Invited/Public talks:	>40
Proposals Submitted (PI+Co-I):	101
Grants/contracts awarded:	29

Missions Currently Supported:

- Mars Curiosity Rover (PI: Ben Clark),
- Mars Perseverance Rover (PIs: Michael Wolff, Mark Lemmon, Ben Clark)
- Emirates Mars Mission (Al-Amal Hope; PI: Michael Wolff)
- OSIRIS-REx (PIs: Ben Clark, Dayton Jones),
- Stratospheric Observatory for Infrared Astronomy (SOFIA, PI: Sachin Shenoy)

Research Center Updates

Center for Data Science

The Center for Data Science (CDS) is an initiative to bring together domain experts in space sciences and highly skilled computer scientists sharing a common interest in Data Science (DS) and Machine Learning (ML).

The group, consisting of nearly 30 scientists from all fields of space science and computer science, has been convening since December 2019 when the Center was established. Members of the group shared various NASA and NSF funding opportunities that encourage application of DS and ML techniques in data analysis and modeling and presented introductory lectures on the basic methodology in DS/ML and current trends in their applications in space sciences. The group also had tutorials with hands-on experience with ML algorithms.

In October 2020, the group started planning a virtual international conference on “Applications of Statistical Methods and Machine Learning in the Space Sciences,” which will be held in 2021 (<http://spacescience.org/workshops/mlconference2021.php>). SSI applied for NSF funding to cover some costs of the conference, including registration fees for students and early career researchers. The Center for Data Science expects to publish the conference proceedings as a special issue in a leading journal relevant to the conference.

As an organization of scientists, CDS plans to continue its activities in an attempt to inspire the scientific community to utilize key insights on emerging technologies such as artificial intelligence (AI) that have profound impacts on the way scientific problems can be addressed and modeled.

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 2020 the members of CSPP published 91 papers in refereed journals: 33 papers as primary authors and 58 papers as contributing authors.

Research highlights published in 2020 dealt with topics as diverse as: the Earth’s substorm current wedge, the electron temperature of the solar wind, decaying turbulence, electromagnetic ion cyclotron (EMIC) wave occurrence, ultra low frequency (ULF)-wave electric fields, turbulent reconnection, transrelativistic reconnection, tokamak stability, and review papers on the outstanding questions in magnetospheric physics and in solar-wind physics.

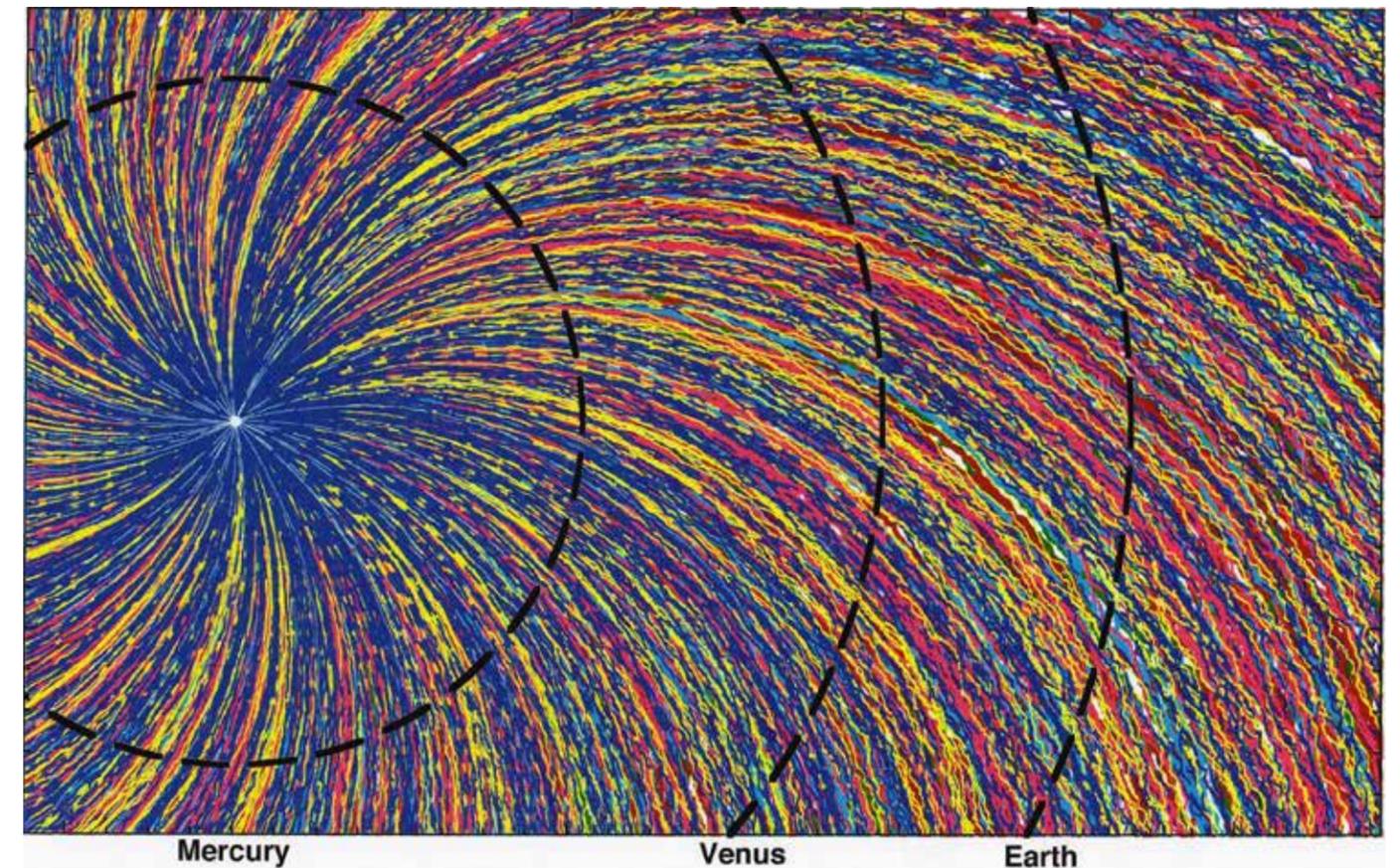


Illustration of the structure of the solar wind by SSI Senior Research Scientist Joe Borovsky. The spiral figure has several elements that are “to scale:” the diameters of the planets’ orbits, the size of the Sun, and the diameter and wiggle angles of the differently-colored plasma tubes at the orbit of Earth.

Center for Extrasolar Planetary Systems

The Center for Extrasolar Planetary Systems (CEPS) brings together SSI researchers who 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.

The Center for Extrasolar Planetary Systems includes 12 scientists who in 2020 participated in over 60 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*, *VLT*, and

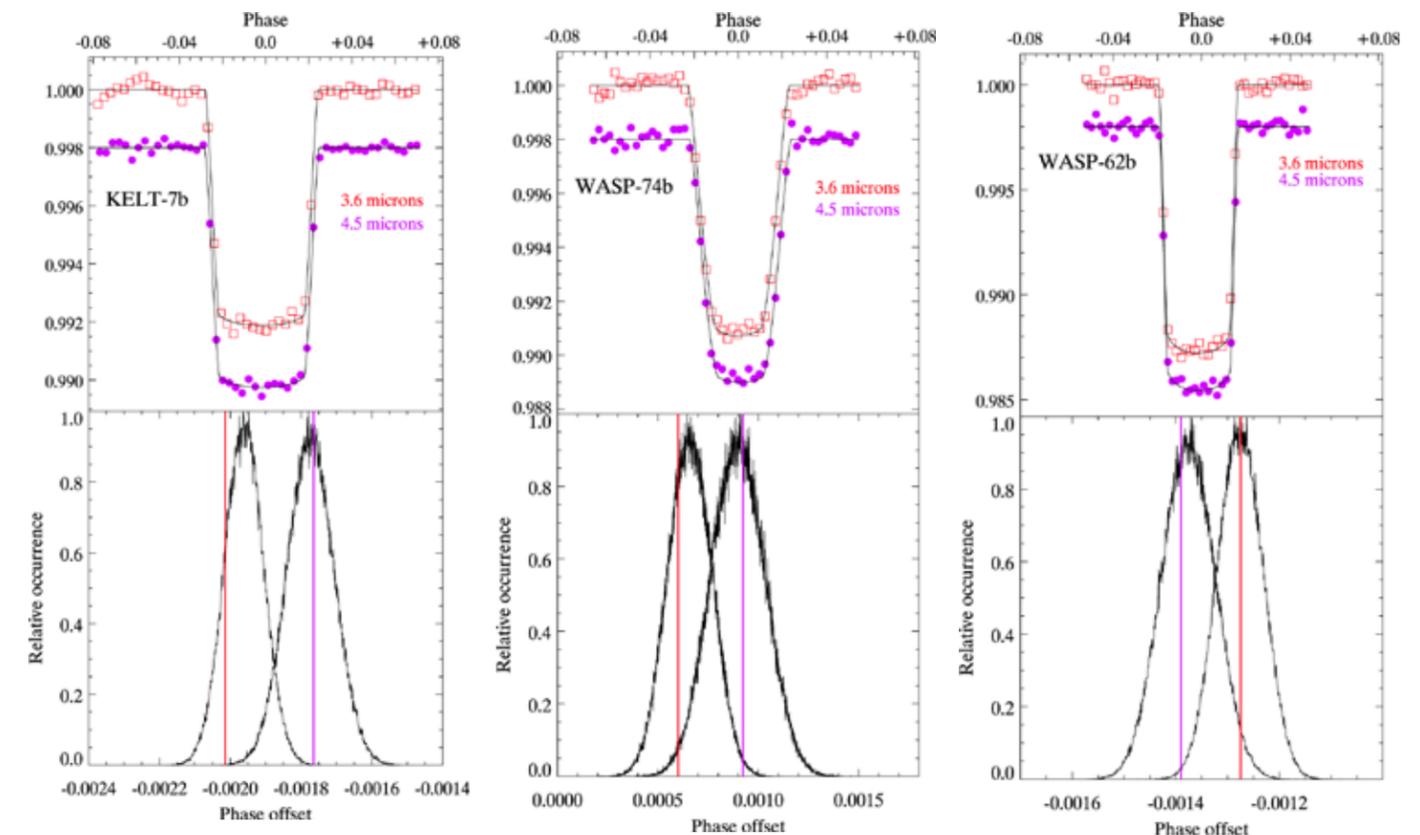


A number of studies conducted by CEPS members explored chemical and physical processes taking place in the atmosphere of WASP-43b, a hot Jupiter with a 19-hour orbit around a K-type star. Credit: ESO/L. Calçada.

ARIEL), and several grant proposals, and look forward to new opportunities with the anticipated (Nov 2021) launch of the *James Webb Space Telescope*.

Research highlights in 2020 include co-authorship of an extensive review of atmospheric escape processes and planetary evolution (Heavens, in Gronoff et al. 2020), a study exploring how factors beyond the effective temperature of a planet, including mass, age, and tidal heating, can have a significant effect on the thermal profile and observed chemical composition of exoplanets (Visscher, in Fortney et al. 2020), a statistical study of numerous secondary eclipses from *Spitzer* data (Fraine, in Garhart et al. 2020), as well as the behavior of non-uniform and non-reflective clouds in the atmosphere of a hot Jupiter (Fraine et al. 2020), the detection of a gap-ring structure in a protoplanetary disk (Sitko, in Seongjoong et al. 2020) and a number of published studies exploring pathways for haze formation in the upper atmospheres of exoplanets (Moses, in Moran et al 2020, He et al. 2020a,b).

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.



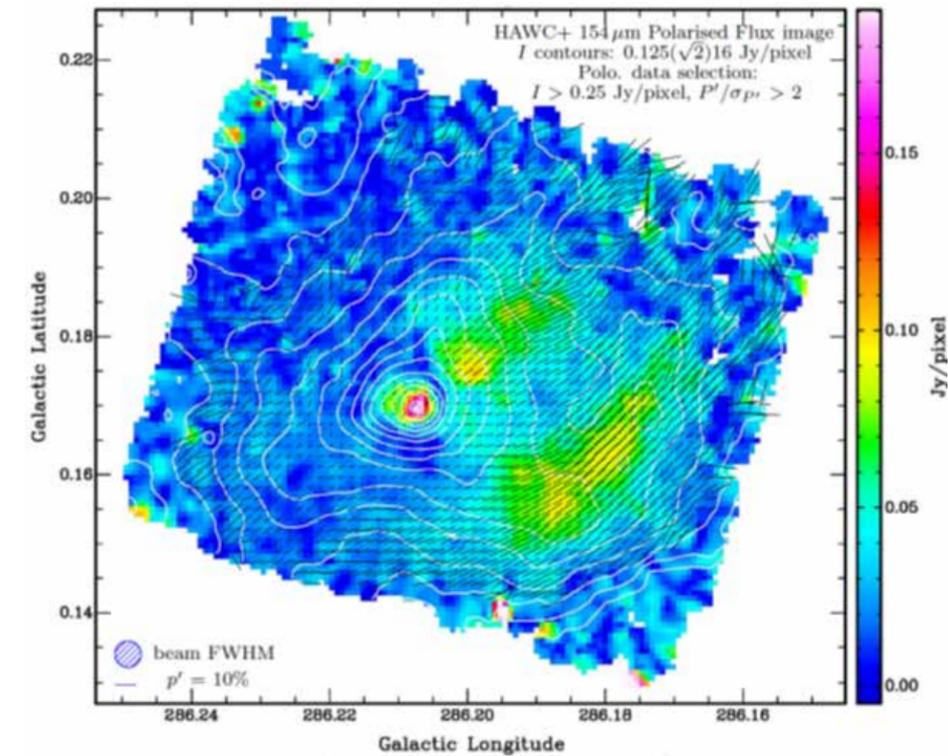
Statistical Characterization of Hot Jupiter Atmospheres Using *Spitzer*'s Secondary Eclipses
Provider: AAS Journals

Center for Polarimetric Remote Sensing

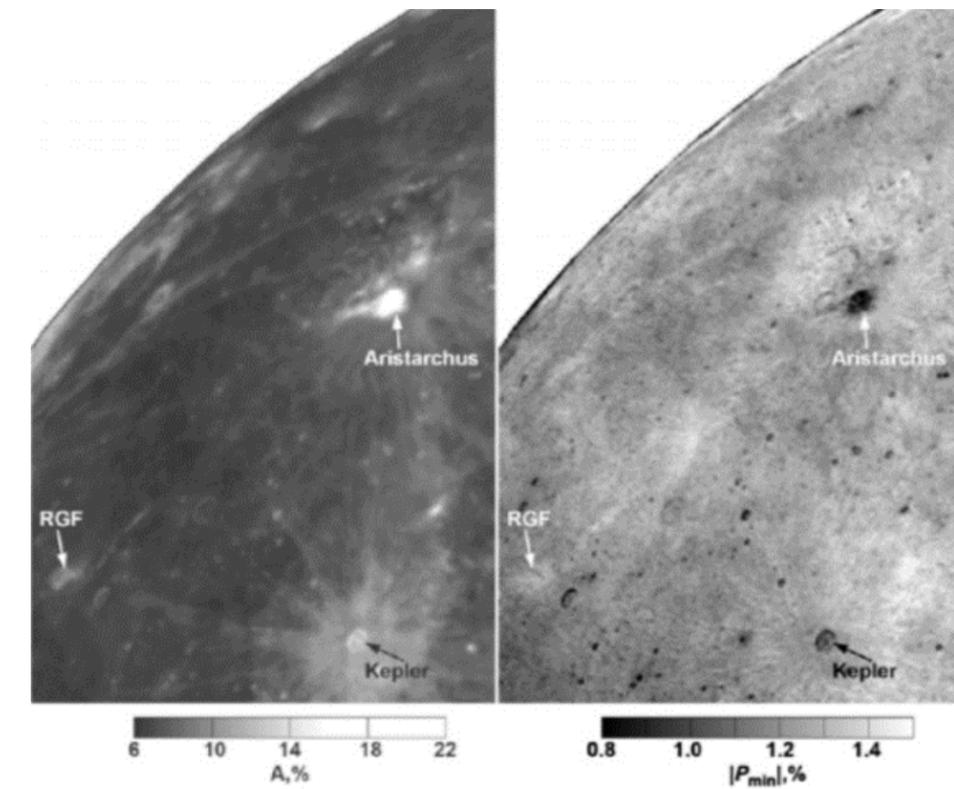
The Center for Polarimetric Remote Sensing (CPRS) continues to extend their influence into other fields as more scientists recognize the added value of polarimetric measurements. Gearing up for the launch of the Korean Pathfinder Lunar Orbiter (KPLO) in August 2022, the first lunar mission equipped with a polarimeter, NASA selected nine scientists to join the mission as participating scientists, two of which are members of the SSI's CPRS. Dr. Bill Farrand will be using polarimetric data to distinguish and characterize pyroclastic deposits using the PolCam instrument, while Dr. Gordon Videen will be performing experimental polarimetric measurements and modeling from lunar regolith simulants to help analyze the PolCam data to characterize the lunar regolith properties.

Similar PolCam instrumentation is currently being implemented into two CubeSat instruments that will characterize Earth's aerosols and super-thin clouds that affect Earth's weather. These instruments are being developed in collaboration with NASA and the Korea Astronomy and Space Science Institute (KASI) and have a planned launch in 2022. The recognition of the extent and influence of super-thin clouds on the weather and climate is relatively new. These clouds cover approximately 50% of the Earth and their presence can affect satellite-based ground-temperature measurements by 10-20°C. Polarimetry provides the only known means of rapidly mapping these clouds' extent.

Polarimetry provides a means of characterizing clouds of dust, like that seen in debris disks and cometary comae. While the visible light we see is predominantly the result of light scattering, the radiation at longer wavelengths is the result of emission. These two different processes add complications to the analyses, but also can provide different and complementary information. The SOFIA/HAWC+ is expected to be a workhorse for CPRS researchers as it provides unique imaging capabilities at emission wavelengths from 40 μm to 300 μm . Dr. Peter Barnes recently used the SOFIA/HAWC+ system to map the magnetic field structures of dense molecular clumps in the Carina Giant Molecular Cloud in order to constrain their role in the early evolutionary stages of star formation.



SOFIA/HAWC+ map of cloud BYF 73 showing the magnetic field structure.



Images of Albedo (left) and the magnitude of the polarization minimum of the northwestern portion of the lunar disk in green light from Shkuratov et al. (2008). In some regions, these quantities are correlated, like the Reiner Gamma Formation (RGF) and in others, they are anticorrelated, like the craters Kepler and Aristarchus. The KPLO PolCam mission will result in high-resolution maps of the lunar polarimetric properties that will be used to obtain information about the lunar regolith.



Laboratory simulations of chemistry and spectroscopy of organics in small icy bodies

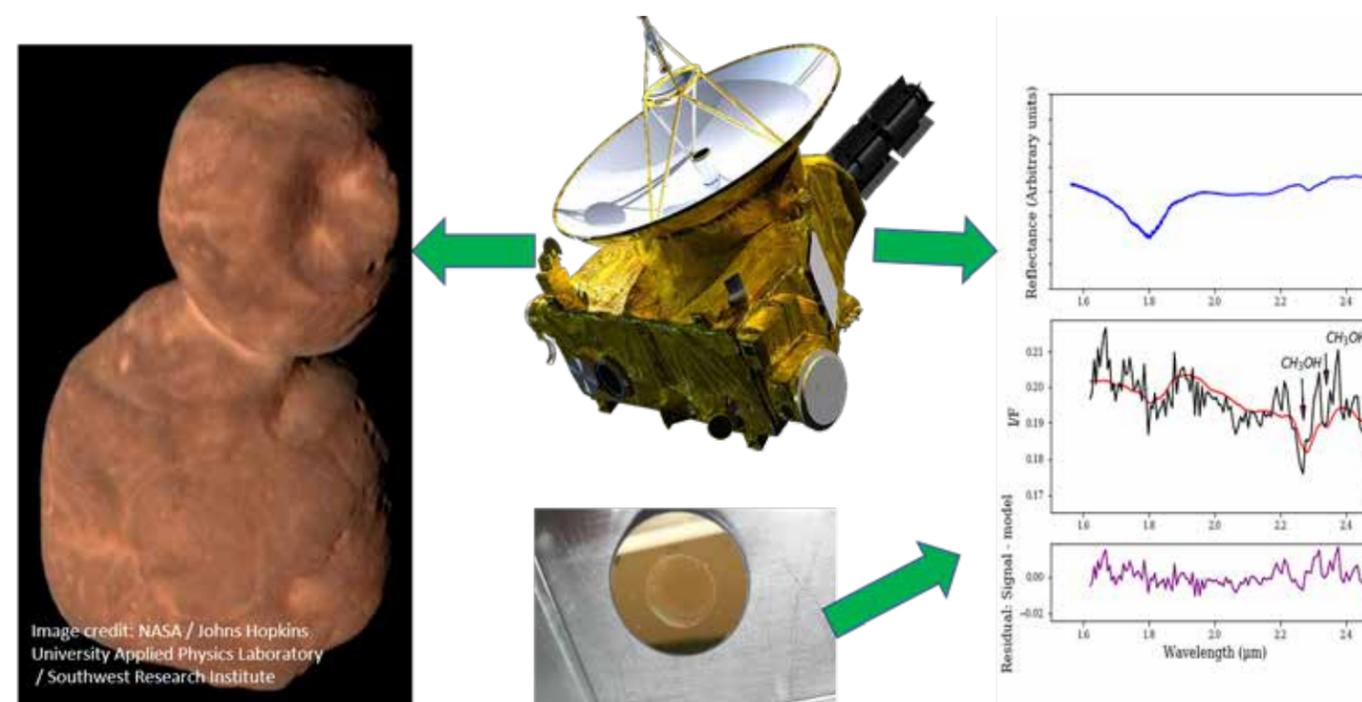
Dr. Ahmed Mahjoub;
Pasadena, CA

Small bodies are the legacy left from the building blocks that accreted to create planets in the early solar system some 4.5 billion years ago. Studying the chemical composition of small objects provides a particular perspective on the chemical and dynamical processes that shaped our Solar System. The icy surfaces of these airless objects are exposed to irradiation and thermal processing that may have modified the surface, leaving behind clues about the conditions under which our Solar System was formed. Furthermore, laboratory irradiation of planetary ice analogs has proven to be a plausible pathway to produce organic residues. Indeed, photolysis and radiolysis of cosmically abundant, simple organic molecules in solid phase trigger a complex chemistry leading to the production of refractory polymers. The spectral and chemical properties of these macromolecules depend on the initial composition of the ice as well as the nature and dose of irradiation processing. Accordingly, such polymers may contain clues about the origin and history of small icy bodies in the solar system.

Using an experimental setup available at NASA's Jet Propulsion Laboratory, Dr. Ahmed Mahjoub and his colleagues create simulants of ice mixtures relevant to small icy bodies of the Solar System as well as the gases from which the Sun and planets formed by condensation (in the early Solar Nebula). These laboratory activities, funded by NASA's Rosetta Data Analysis Program and Discovery Data Analysis Program, aim to provide more insight into chemical complex processes initiated by ultraviolet (UV) photons and bombardment by cosmic particles and leading to the formation of complex organic molecules and refractory organic residues. A particular interest is given to organo-sulfur chemistry, because of the lack of studies investigating this type of chemistry for astrophysical applications and its potential

in prebiotic synthesis of building blocks of life and as tracer for specific regions and specific environments of the early Solar System.

On January 1st 2019, the New Horizons spacecraft flew by (486958) Arrokoth, a small body in the Kuiper Belt that is the most distant object ever explored by a spacecraft. A strong unidentified absorption band was observed in the spectrum of Arrokoth at a wavelength of 1.8 μm . In a recent laboratory study, we reported experimental evidence suggesting that the near-infrared (NIR) wavelength spectrum of Arrokoth is indicative of sulfur-rich organic residue (Mahjoub et al. APJL, 2021, 914, L31). The spectra of organic residues produced by irradiating ice mixtures "with H₂S" CH₃OH:NH₃:H₂S:H₂O (3:3:3:1) and "without H₂S" CH₃OH:NH₃:H₂O (3:3:1) were measured to study the effect of H₂S. The "with H₂S" sulfur-rich laboratory-synthesized organic residue displays an absorption band at 1.8 μm that is absent in the spectrum of "without H₂S" sample. This feature matches the Arrokoth spectrum better than any other expected material (figure below). This suggests the past presence of H₂S ice on the surface of Arrokoth and a role for Kuiper Belt Objects (KBOs) as a key reservoir of sulphur in the early Solar System. These results illustrate the importance of laboratory studies in understanding not only the observed spectra of icy bodies, but also the abundances and history of key atomic and molecular species in our Solar System.



Color composite image of Arrokoth (left), New Horizons spacecraft (top middle) and organic residue analog produced in our laboratory (bottom middle), the spectrum of the laboratory-produced residue (right, top panel) matches the New Horizon spectrum of Arrokoth's surface (right, middle panel).



Studying the Martian Skies with the Perseverance Rover's SuperCam

Dr. Timothy McConnochie;
Rochester, NY

In November 2020, SSI 's Dr. Timothy McConnochie was selected as a participating scientist on NASA's Mars 2020 Perseverance Rover mission, which is scheduled to land on February 2021. He is investigating gases, dust, and ice clouds in the Martian atmosphere by looking at the sky with the SuperCam instrument suite's spectrometers.

SuperCam has many capabilities, but its main job is to measure the chemical composition of rock and soil on the Martian surface, in many cases by using a laser beam to light up a target. SuperCam's contribution to NASA's Perseverance mission is a collaboration of Los Alamos National Laboratory (LANL) and the IRAP astrophysics and planetology research institute (in Toulouse, France; see <https://mars.nasa.gov/mars2020/spacecraft/instruments/supercam/> for more information).

Spectrometers work by, essentially, turning a beam of light into a rainbow and then analyzing variations, sometimes very tiny variations, in the brightness of that rainbow. Gases in the atmosphere can absorb light at very specific colors, i.e., at certain wavelengths of light. SuperCam will detect the very small absorptions of water vapor (H₂O), molecular oxygen (O₂), and Carbon Monoxide (CO), as well as

larger absorption of light at certain wavelengths by Carbon Dioxide (CO₂). Dust and clouds in the Martian air also affect the color of the sky, and in a much more obvious way than the absorptions by gases. SuperCam covers a particular broad range of colors (i.e., wavelengths) extending from ultraviolet light ("bluer" than visible blue or violet) to visible light to infrared light ("redder" than visible red), which makes it particularly good at distinguishing water-ice clouds or haze from dust clouds or haze, and at studying the nature of the dust grains and ice crystals that make up the clouds and haze. SuperCam doesn't need to use its lasers to measure any of these gas absorptions or cloud and dust colors, which may seem less exciting but really is just an example of how versatile SuperCam is.

SuperCam measurements of atmospheric gases, especially water vapor and molecular oxygen, will help with understanding the samples of Martian materials that Perseverance will collect to prepare for their return to Earth by a future mission. Water vapor and molecular oxygen in the Martian atmosphere interact chemically with surface materials and may help explain the composition of soils and the surface coatings on rocks. Studying molecular oxygen may also help understand the causes of its unexpectedly variable abundance. (See <https://www.nasa.gov/feature/goddard/2019/with-mars-methane-mystery-unsolved-curiosity-serves-scientists-a-new-one-oxygen> for more about this.) Furthermore, the dust in the Martian air accumulates on Martian surface materials, so understanding the airborne source of that dust will also help with analyzing returned samples. And that dust is also a hazard that must be understood to enable human exploration of Mars.



The included photo (credit: NASA/JPL/MSSS) was captured by the Perseverance's Lander Vision System as the rover approached its landing site. The frame captures both the Jezero crater delta in the upper right and the hazy Martian atmosphere fading to the black of space at the lower left. Many more images, video, and audio captured by Perseverance are available here: <https://mars.nasa.gov/mars2020/>.

NASA's SOFIA Discovers Water on Sunlit Surface of Moon

In Oct. 2020, NASA announced that the Stratospheric Observatory for Infrared Astronomy (SOFIA) has confirmed, for the first time, water on the sunlit surface of the Moon. This discovery indicates that water may be distributed across the lunar surface, and not limited to cold, shadowed places. SSI Senior Research Scientist Sachin Shenoy was a co-author on the Nature Astronomy paper by Honniball et al. detailing the observations.

SOFIA, a modified Boeing 747SP jetliner with a 106-inch diameter telescope, offered a new means of looking at the Moon by flying above 99% of the water vapor in Earth's atmosphere to get a clearer view. Using its Faint Object infraRed CAmera (FORCAST), SOFIA was able to pick up the specific wavelength unique to water molecules, at 6.1 microns, and discovered the lunar water in Clavius Crater.



This illustration highlights the Moon's Clavius Crater with an illustration depicting water trapped in the lunar soil there, along with an image of NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) that found sunlit lunar water. Credit: NASA/Daniel Rutter

In Memoriam: Dr. Babar Ali



SSI Affiliate Research Scientist Babar Ali was an astronomer, senior data scientist, and machine learning engineer. Babar combined a successful career in industry with his astronomical research, which focused on the formation and evolution of protostars.

Babar did his undergraduate degree in astronomy and physics at the University of Arizona and earned his Ph.D. in astronomy from The Ohio State University. In his dissertation, he developed a spectral classification scheme for stars in the near-infrared wavelength regime and used this method to decipher the nature of young stars in the nearby Orion

star-forming region. He also held a graduate professional certificate in Data Mining & Applications from Stanford University, which he leveraged toward a career in machine learning at startups in the Los Angeles area.

As an astronomer, Babar worked on observing campaigns, algorithm development, and archival databases for ESA/NASA's Infrared Space Observatory, Herschel Space Observatory, and Infrared Processing & Analysis Center (IPAC) at the University of Rochester and Caltech as a staff scientist before joining SSI in 2014. He was also the recipient of three NASA Public Service Group Achievement Awards and a science mentor for the NASA IPAC Teacher Archive Research Program. Babar's work outside of astronomy straddled applications of data science to disparate fields such as finance, digital marketing, and the automotive industry. He served as a volunteer data scientist for DataKind, studying wheat field signatures in MODIS and CHIRPS satellite imagery data by clustering the temporal pattern of vegetation and rainfall.

Babar passed away unexpectedly in December 2020. This is a tremendous loss not only to our institute, but to the wider astronomical and data science communities, to which he contributed so much.

Education & Inspiration

National Center for Interactive Learning



A Ready, Set, Create participant explores a Designed to Survive activity as part of Project BUILD.
Credit: High Plains Library District

SSI's **National Center for Interactive Learning** (NCIL) is led by Dr. Paul Dusenbery (Boulder Office). NCIL is a leader in developing science, technology, engineering, art, and mathematics (STEAM) educational resources, including exhibitions, active learning programs, and educational games. 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 STEAM facilitation. [NCIL](#) is organized around four interdependent groups: 1) Exhibition Development, 2) Community Engagement, 3) Professional Development, and 4) Digital Learning. Group 1 activities in 2020 were mostly part of the National Science Foundation funded STEAM Equity project, which is described in the Active Programs Section below. Groups 2-4 are also summarized below. During 2020, our nation and world had to confront the worst pandemic in more than a century: COVID-19. The pandemic impacted all facets of society from businesses and schools to libraries and museums. **This report describes some of the ways that NCIL was able to pivot quickly and help support our key stakeholders, especially public libraries and their communities.**

National Reach Through Federally Funded Projects



STAR Net and NASA exhibit at the 2017 ALA conference. Credit: NASA

The [STAR Library Network](#) (STAR Net) is NCIL's flagship STEAM program serving the public library community. It is a hands-on learning network for libraries and their communities across the country. 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 over 8,000 members. The community can access webinars, monthly newsletters, blogs, partnership opportunities, facilitation guides, book recommendations, and much more, including STAR Net's *STEM Activity Clearinghouse*. It also has an active social media presence including Facebook, Twitter, YouTube, and Flickr. STAR Net's website (see STAR Net Phase 2 summary below) also includes an area called *STEM in Libraries* that has resources for emerging and established library leaders. Topics include family/adult programming, expanding diversity, and collaboration ideas.

STAR Net is built upon a strong network of collaborators and partners, led by NCIL. Partners include the American Library Association's Public Programs Office, American Society of Civil Engineers, Chief Officers of State Library Agencies, Cornerstones of Science, Education Development Center, Lunar and Planetary Institute, Institute for Learning Innovation, Twin Cities PBS, University of Colorado, University of Virginia, and many others. Federal funding, primarily from NSF and NASA, have supported most STAR Net projects over the last 10 years. Active STAR Net projects during 2020 are described below.



The Clearinghouse has been a one-stop shop for free and vetted library-focused STEAM activities and related-resources since 2016. The STAR Net Professional Development team takes an agile approach to the Clearinghouse by iterating on its catalog, features, and functionality based on demand and feedback from library staff. Activities have been added to the Clearinghouse systematically over the last five years in correlation to major STEM events (the 2017 Great American Eclipse or the 2019 STAR Net Summer of Space campaign, for example) and emerging themes and trends in the library world. The Clearinghouse now serves as a portal for library staff to access over 530 interactive activities from vetted, reliable sources like NASA or the American Society of Civil Engineers (ASCE). Eighty-four activities were added to the Clearinghouse collection during 2020.

The STAR Net team responded to the COVID-19 pandemic in 2020 by adding new features and resources to the Clearinghouse that would help empower library staff to continue offering their patrons safe learning experiences outside of traditional in-person programming. In the spring of 2020, a new "Take & Make" collection was added to help library staff find suitable activities for their patrons to do at home. Additionally, new bilingual resources (including facilitation guides, family guides, and how-to videos) were catalogued and added to help library staff reach Spanish-speaking families.

Community Engagement

The goal of NCIL's Community Engagement Group (led by Anne Holland, Boulder Office) is to engage public and professional communities in the work we do, and to encourage public libraries to work with (not for) their communities to address local needs. Activities range from community outreach at science festivals and schools locally in Colorado, to providing personal attention and assistance to members of our professional learning community across the country through the *STAR Net* Community of Practice. [Community Dialogues](#) are an important focus of *STAR Net*, with more than 250 *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. *Dialogues have gone virtual during the pandemic, with many libraries stepping up to become hubs, linking community services such as free meals, testing, and vaccine clinics with their local population.*

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. The potential only increases as portable, connected devices become more commonplace, allowing us to reach people in a variety of different environments and contexts. During late 2020, planning began on revamping NCIL's [scigames.org website](#).



SciGames is a collection of digital games and apps that consists of a number of computer-based interactives from the *STAR Net* Phase 2 Discover Space/Exploring Space traveling library exhibits. Examples include the development of two Mars rover activities that serve as simple introductions to coding, and several computational model-based interactives such as *Planet Families* (an orbital mechanics simulator) and *What If It Hit My Town* (an asteroid impact simulator). This webpage and its resources are promoted on the *STAR Net* website and in its monthly newsletter.

Professional Development

The Professional Development Group (led by Keliann LaConte, Boulder Office) oversees training and activity development. *STAR Net* engaged library, education, and STEM professionals nationwide through 25 webinars and networking events. NCIL staff facilitated six sessions at virtual conferences in 2020. In 2020, professional development activities focused on diversity, equity, and inclusion. The Avarna Group explored [Grappling with Unconscious Bias in the Library Setting](#) on January 21, 2020, STEAM Equity project advisors provided tips from on [Culturally Responsive STEAM Programming](#) on September 15, 2020, and [Closing the Gender Gap](#) on September 1, 2020 featured gender-equitable STEAM activities and strategies from the Twin Cities PBS show, *SciGirls*. *STAR Net* webinars also provided a platform for library professionals to share resources and strategies for pivoting to virtual programs during the pandemic. For example, [Virtual Night Sky Programs for "Imagine Your Story"](#) on June 18, 2020 featured pandemic adaptations from Liliana Alonso and Belinda Calvillo of the Pasadena Public Library, Texas and staff at the Lunar and Planetary Institute.



NASA STEM Workshop in Arizona.
Credit: SSI/NCIL

Facilitating Your Program

- Avoid reading from a script – make people feel “at home”
- Read out the chat box
- Be flexible!! Don't stop a good conversation!
- What facilitation tips do you have?



NCIL staff helped library professionals adapt to the COVID-19 pandemic through professional development on virtual and phone programs, such as at the [Virtual Programs 101: Behind the Scenes with STAR Net](#) webinar on May 28, 2020.

Active Education Projects in 2020

NCIL had five major projects that were active in 2020: *STAR Net Phase 2*, *NASA@ My Library*, *Project BUILD*, *STEAM Equity*, and *We Are Water*.



Discover Tech exhibit at the Ypsilanti District Library in Michigan. Credit: Ypsilanti District Library

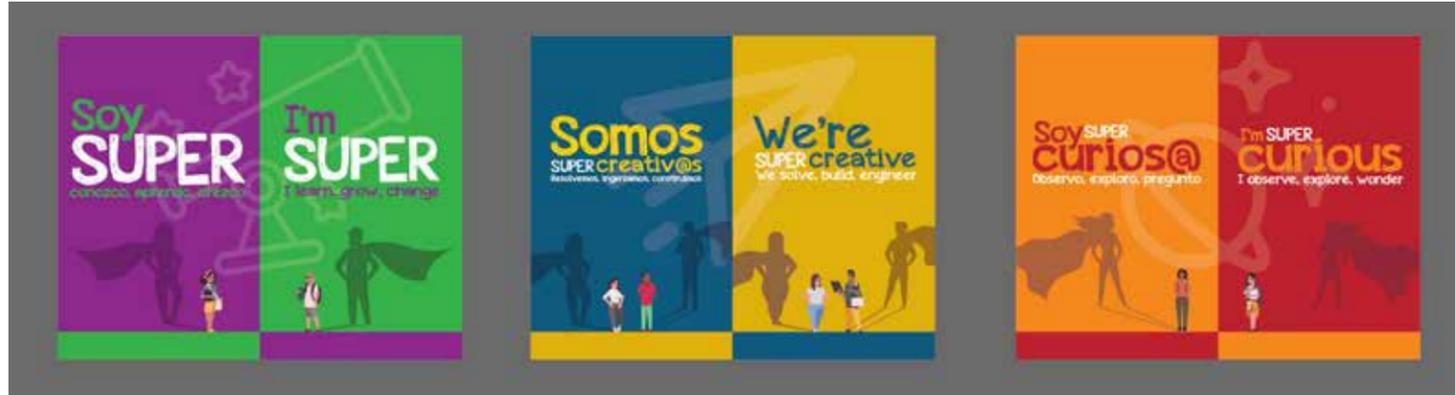
STAR Net Phase 2 (PI: Dusenbery) is funded by the National Science Foundation. The *STAR Net* [website](#) underwent a major overhaul in late 2020. This update included the creation of a new backend, addition of a more modern design, updates to existing content, and modifications to the website layout and structure based on usage data. Site navigation was modified to create more calls to action, and to provide highlights and multiple entry points into the most frequently used areas of the site (such the *STEM Activity Clearinghouse*, *Blogs*, *Archived Webinars* and *Community Dialogue Resources*). Based on data that highlighted which areas of the website were most frequently visited, the updated website focuses on wrapping content around high-visibility STEM events and campaigns. Another area that was enhanced based on frequency of visits was the Diversity, Equity, Inclusion & Accessibility page. This page highlights resources from multiple stakeholders within the wider library community, as well as Community Dialogue resources (see Community Engagement summary above) developed by the *STAR Net* team.

NASA@ My Library (PI: Dusenbery) is funded by NASA Science Mission Directorate's Science Activation program. Through this project, NASA, public libraries, and state library agencies work together to increase and enhance STEM learning opportunities for millions of library patrons throughout the nation, including geographic areas and populations that are currently underserved in STEM education. Team members include SSI's National Center for Interactive Learning, ALA's Public Programs Office, Cornerstones of Science, Lunar and Planetary Institute, and Education Development Center. The project engages key stakeholders (e.g., NASA subject matter experts or SMEs, public library partners, and state library partners) centered on high-profile NASA, Earth, celestial, and library events (e.g., 2017 solar eclipse, Earth Day, and summer learning events at libraries like the Summer of Space campaign in 2019). **Due to COVID-19 impacts on libraries and their communities during 2020, the NASA@ My Library team hosted a series of informal chats with library staff to identify how the project team could best support them in their transition to online and curbside work. A website (*STEAM Ahead @ Home*) and a Facebook group were created to highlight at-home activities that libraries could share with their patrons. Read more about COVID-19 impacts in the Highlight Section below. In 2020, the project finished its collaboration with 18 state library agencies that circulated several NASA STEM Kits to hundreds of public libraries. A guide was produced that summarized best practices that could help other state library agencies in circulating their own STEM kits. Read more about this collaboration in the Highlights Section.**

Project BUILD (PI: Dusenbery) partners include SSI's National Center for Interactive Learning, University of Virginia, American Society for Civil Engineers (ASCE), and Education Development Center. This NSF-funded program engages children in grades 2-5 and their families in age-appropriate, technology-rich STEM learning experiences (called Ready - Set - Create) that are based on the Engineering Design Process. The ultimate goal of the program is to increase youths' awareness of and motivation to pursue STEM-related educational and career pathways, especially for youth from rural and/or geographically isolated areas and populations traditionally underrepresented in STEM. The project utilized several mechanisms to reach this goal including Community Dialogues, circulating kits, and library programs. In 2020, a new webpage was developed using engineering resources from this project and its partners ([Engineering Resources for Library Programs](#)). The webpage is organized into specific areas such as Facilitated Learning, Interactive Activities, and Training. (cont'd)



In response to COVID, NCIL and ASCE developed a new initiative entitled *Dream-Build-Create* aimed at youth in grades four and up. This virtual program included viewing a documentary film and participating in panels with young engineers who shared their STEM journey. This virtual program is described in the Highlight Section.



STEAM Equity (PI: LaConte). With funding from NSF, NCIL, the [American Library Association](#) (ALA), Twin Cities PBS (TPT), [Institute for Learning Innovation](#) (ILI) and [Education Development Center](#) (EDC) launched *STAR Net's* STEAM Equity project. Twelve public libraries and their rural communities are participating in the project: Berryville Public Library (Berryville, Arkansas); Safford City-Graham County Library (Safford, Arizona); Madera County Library (Madera, California); Montrose Regional Library District (Montrose, Colorado); Palm Springs Public Library (Palm Springs, Florida); Burley Public Library (Burley, Idaho); Blue Island Public Library, Blue Island, Illinois; Los Lunas Public Library (Los Lunas, New Mexico); Pioneer Library System Foundation (Norman, Oklahoma); Mt. Angel Public Library (Mount Angel, Oregon); Hondo Public Library (Hondo, Texas); and North Central Regional Library (Wenatchee, Washington). Each library will host three bilingual traveling STEAM exhibitions and develop associated programs and outreach kits with their collaborators and community members.

The STEAM Equity project is designed to be particularly responsive to the rich perspectives of families with Latinx, Hispanic, or Spanish identities. With more than [60 million individuals](#), the Hispanic/Latinx population is now the U.S.'s largest ethnic minority group and the [fastest growing](#) segment of the rural population. However, [Latinos earned 13.5 percent of science and 10 percent of engineering bachelor's degrees](#) nationwide and make up only 7.5 percent of the [U.S. science and engineering workforce](#). Latinas are even more underrepresented, making up only about 2 percent of [STEM occupations](#). Our vision for the STEAM Equity project is to empower tweens and their families around equitable STEAM learning and career paths by leveraging their existing strengths, interests, and diverse cultures.

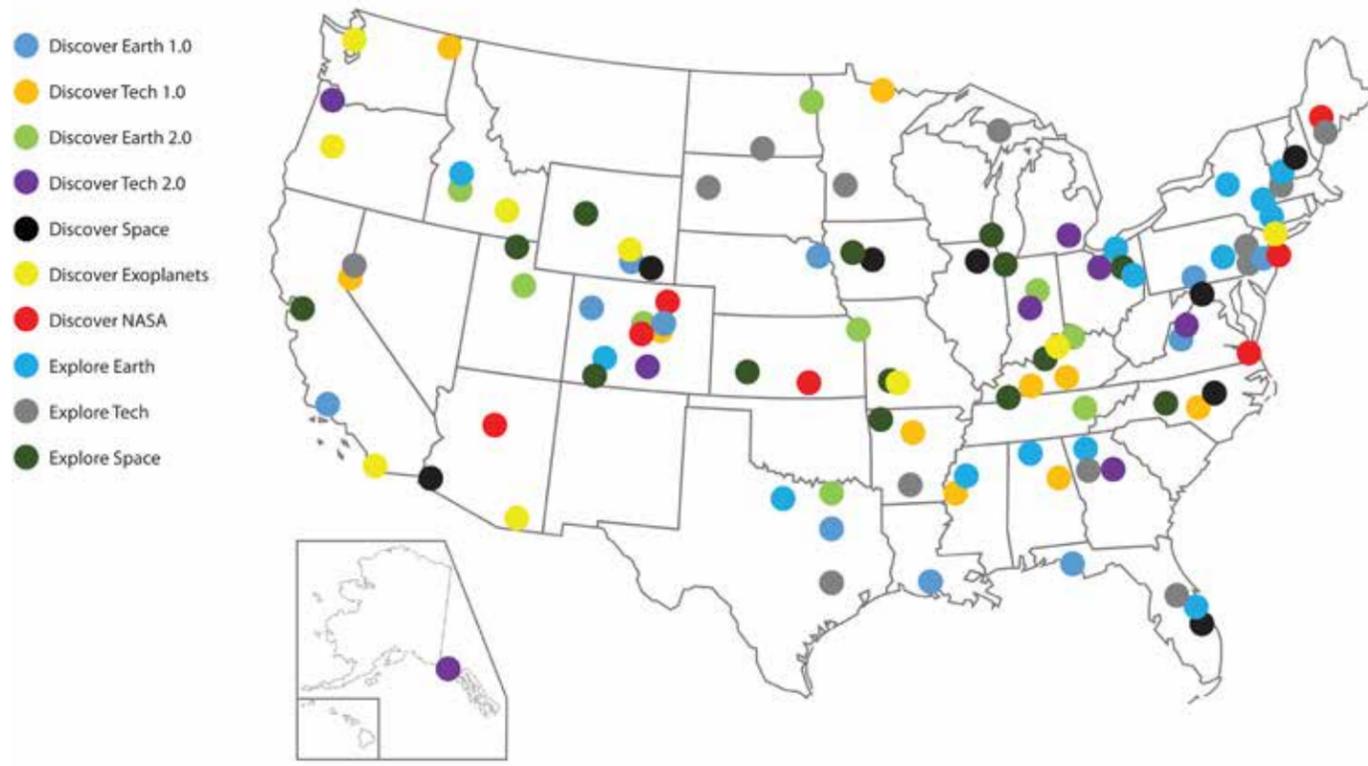


We are Water (PI: LaConte, NSF project: Water in the Four Corners Region: Libraries and Exhibits Connecting and Engaging Communities with Their Water Systems) is led by the Education & Outreach program at the University of Colorado's Cooperative Institute for Research in Environmental Sciences (CIRES) in partnership with the Space Science Institute's *STAR Net* team. This project brings a traveling exhibit and interactive programs to rural, Latinx, and Indigenous communities in the Four Corners Region of the U.S. and engages community members in conversations about their personal and community connections to local water topics. NCIL staff curated water-related STEAM learning resources produced through prior *STAR Net* projects and by the National Park Service, universities and museums in the Four Corners Region, and other trusted sources. Those activities that are suitable for the library setting form the basis of a growing new collection on the [STEM Activity Clearinghouse](#). **Partner library staff helped adapt an existing *STAR Net* activity, "A Century of Change," for use during the pandemic and beyond.** Community members in the Four Corners region began informing the development of a gardening activity that employs "waffle garden" techniques used by Indigenous Peoples of the American Southwest, including the Diné (Navajo), A:shiwí (Zuni), Zia Pueblo, and Laguna Pueblo, to successfully grow crops in the semi-arid environment for generations.

"[The Community Dialogues] definitely brought us to the forefront as far as a library that's offering these types of materials...they know that we have these programs...and they didn't know that before."

~STAR Net Librarian

NCIL Impact Numbers for 2020



STAR Net exhibition host library sites. Credit: SSI/NCIL

Traveling Exhibit Visitors

STAR Net's Explore Space Exhibit (2 host sites):	45,000
STAR Net's Discover Exoplanets Exhibit (4 host sites):	132,087
Total Number of Visitors:	177,087

STAR Net Library Program Participants: 64,180

In-person Professional Development Participants: 751

Webinar Participants

Unique Live Views: 1,400
 YouTube Recording Views: 1,993

STAR Net Online Community Members: 8,200

NCIL Outreach Event Participants: 1,395

Exhibition Website Visitors

Page Views:

Alien Earths:	190,858
Giant Worlds:	30,251
MarsQuest Online:	38,884
SciGames:	143,580
Space Weather Center:	153,276
Killer Asteroids:	50,365
Starchitect:	225,659
STAR Net:	99,152
STEM Activity Clearinghouse:	108,163
National Center for Interactive Learning:	4,333

Total Pageviews: 1,044,521

Local and National Education Impacts

Colorado:

Date	Location	Activity	Attendance
*2020 NCAR Year to Date Totals	National Center for Atmospheric Research, 3090 Center Green Dr. Boulder, CO 80301 // Boulder County	Three of SSI/NCIL's exhibits, "Planet Families," "Magnet Mini-Golf," and "Space Weather," were regular pieces in NCAR's visitors center. Attendance estimates for these and all other exhibits below provided by Anne Holland (SSI).	400
*1/27/2020	Univ. of Colorado Boulder, JILA Auditorium, 440 UCB, Boulder, CO 80309 // Boulder County	SSI/WDRC's Travis Metcalfe spoke on "The Evolution of Stellar Dynamos and Planetary Habitability" at CU Boulder: https://aps.colorado.edu/cgi-bin/colloquium/flyer.pl?id=5&term=Spring2020	~20-30
*2/17/2020	Little Thompson Observatory (Berthoud High School), 850 Spartan Ave, Berthoud, CO 80513 // Larimer/Weld Counties	Video of SSI's Dayton Jones speaking at Little Thompson Observatory's public star night on the future of radio astronomy, the Square Kilometre Array, and the Next Gen VLA: https://www.youtube.com/watch?v=tOzeaCk6Wx8	~15 onsite + 22 views on YouTube
*4/1/2020	Denver, CO (Virtual)	SSI/NCIL gave a "Comets, Asteroids and Meteors" presentation for the Academy of Lifelong Learning	115
*5/1/2020	Denver, CO (Virtual) // Denver and Boulder Counties	SSI/NCIL hosted a Google Hangout with Colorado Libraries	21
*5/3/2020	Denver, CO (Virtual) // Denver and Boulder Counties	SSI/NCIL at Colorado Association of Libraries Board Meeting	16
*5/15/2020	Denver, CO (Virtual) // Denver County	SSI/NCIL presented at University of Denver Research Symposium: "Conducting Action Research through Community Dialogues in Public Libraries"	142
*7/10/2020	Boulder, CO (Virtual) // Boulder County	SSI/NCIL at Colorado Association of Libraries Board Meeting	14
*7/17/2020	Denver, CO (Virtual) // Denver County	SSI/NCIL presented at Colorado Association of Libraries Power and Privilege at Play Conference Session: "Girl Powered STEM Learning"	82
*7/28/2020	Denver Museum of Nature & Science, 2001 Colorado Blvd, Denver, CO 80205 // Denver County	SSI's Mike Wolff and Steve Lee presented "Looking For Life on Mars" re: the NASA Mars 2020 mission at DMNS. Event featured by 303 Magazine as "21 Things to Do in Real Life and Virtually This Week in Denver"	387 unique IP addresses on Facebook Live
*8/14/2020	Boulder, CO (Virtual) // Boulder County	SSI/NCIL at Colorado Association of Libraries Board Meeting	14
*8/28/2020	Hudson, CO (virtual) // Weld County	SSI/NCIL presented "Story-time with the Mars Rover" for the public	38
*9/2/2020	Hudson, CO (virtual) // Weld County	SSI/NCIL gave "Night Sky Tonight" presentation for the public	25
*9/10/2020	Boulder, CO (Virtual) // Boulder County	SSI/NCIL presentation at Colorado Association of Libraries: "Level up your facilitation and be a "Guide on the Side" for Virtual and in-person STEAM Programming"	85 (estimate)
*9/10/2020	Boulder, CO (Virtual) // Boulder County	SSI/NCIL's Colorado Association of Libraries Presentation: "Breaking Down Barriers; Computational Thinking for Tweens"	35 (estimate)
*9/11/2020	Boulder, CO (Virtual) // Boulder County	SSI/NCIL's Colorado Association of Libraries Presentation: "Creating Quality Surveys to Evaluate Library Programs"	35 (estimate)
*9/11/2020	Boulder, CO (Virtual) // Boulder County	SSI/NCIL's Colorado Association of Libraries Presentation: "Community Dialogue Strategies"	35 (estimate)
*2020	Westminster, CO // Adams County	SSI's Mike Wolff is mentoring a student worker, Kyle Connour.	11

Local and National Education Impacts

National / Virtual:

Date	Location	Activity	Attendance
*4/15/2020	National Virtual Event // Boulder County and national	SSI/NCIL conducted "Community Dialogue Check-In" virtual presentation for the public	27
*4/21/2020	National Virtual Event // Boulder County and national	SSI/NCIL conducted "STAR Net Social Hour to Discuss COVID Pivots" virtual presentation with community partners	41
*4/22/2020	National Virtual Event // Boulder County and national	SSI/NCIL conducted "STAR Net Social Hour to Discuss COVID Pivots" with virtual presentation with community partners	31
*4/30/2020	National Virtual Event // Boulder County and national	SSI/NCIL conducted "Conducting Community Dialogues in Public Libraries" virtual presentation with community partners	19
*5/7/2020	National Virtual Event // Boulder County and national	SSI/NCIL gave virtual presentation on "Conducting Community Dialogues in Public Libraries"	22
*5/28/2020	National Virtual Event // Boulder County and national	SSI/NCIL presented "Virtual Programs 101: Behind the Scenes with STAR Net"	121
*6/25/2020	National Virtual Event // Boulder County and national	SSI/NCIL American Libraries Association Annual Conference Presentation: "Working with Subject Matter Experts in YOUR Library"	72
*7/18/2020	East Meadow, NY (Virtual)	SSI/NCIL presented "Story time with the Mars Rover" for the public	33
*7/28/2020	Denver Museum of Nature & Science, 2001 Colorado Blvd, Denver, CO 80205 // Denver County	SSI's Mike Wolff and Steve Lee presented "Looking For Life on Mars" re: the NASA Mars 2020 mission at DMNS. Event featured by 303 Magazine as "21 Things to Do in Real Life and Virtually This Week in Denver"	387 unique IP addresses on Facebook Live
*8/2/2020	Montana (Virtual)	STEM Facilitation in Public Libraries Workshop	62
*8/14/2020	Boulder, CO (Virtual) // Boulder County	SSI/NCIL at Colorado Association of Libraries Board Meeting	14
*9/2/2020	Hudson, CO (virtual) // Weld County	SSI/NCIL gave "Night Sky Tonight" presentation for the public	25
*9/11/2020	Boulder, CO (Virtual) // Boulder County	SSI/NCIL's Colorado Association of Libraries Presentation: "Community Dialogue Strategies"	35 (estimate)
*2020 ytd webinar numbers	Boulder and National	SSI/NCIL presented 19 total education webinars across various topics	3,582
*2020 ytd Discover Exoplanets Exhibit	New York City, Queens, Oldham, KY	Discover Exoplanets traveling exhibition tour sites (4 total)	3,449

"Public libraries are a pillar of education for all. We have an opportunity and a responsibility to offer educational experiences for our communities. STEM learning is part of this and highly important for the continued development and health of our society, both intellectually and economically."
~ STAR Net Librarian

"I was really grateful to see that [the STAR_Net activities were] such a robust, well thought out, nicely designed curriculum...It's truly discovery-based...This curriculum is very hands-on and it's very inexpensive. The project itself has just been fantastic."
~STAR Net Librarian

2020 Highlights

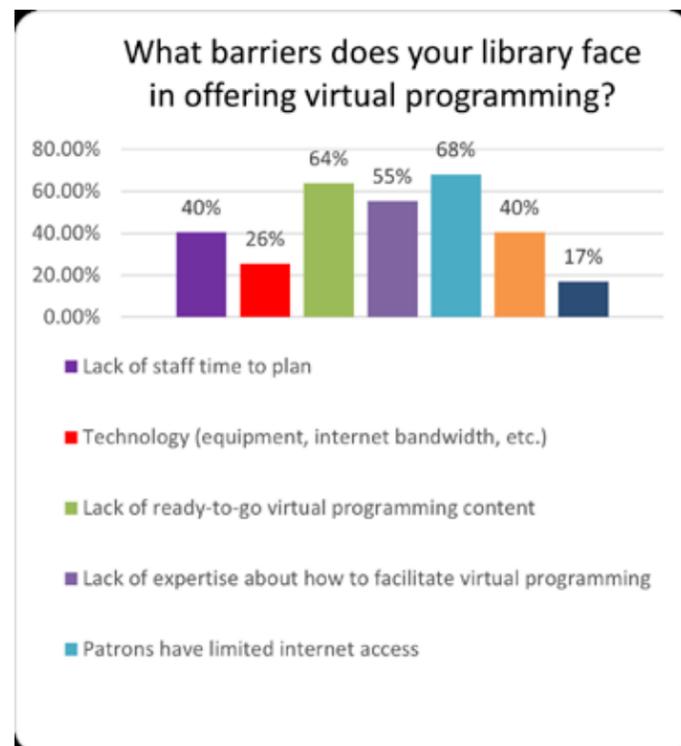


Libraries Respond to the COVID-19 Pandemic

Stephanie Vierow-Fields,
SSI/NCIL Boulder Office

Before the COVID-19 pandemic that swept the United States beginning in March of 2020, libraries provided a variety of resources to the public including access to onsite social workers, hands-on educational programming, and innovative digital learning. Many were open seven days a week with several staff members to assist patrons with everything from job applications, internet access for homework, or a safe space between school and home.

COVID-19 has had a profound impact in library operations, like it has for so many informal learning institutions. Since the first documented cases in January 2020,



NASA@ My Library COVID Response Survey.
Credit: NCIL/SSICredit: SSI/NCIL

many public libraries across the country have shuttered their doors, furloughed workers, and ceased in-person programming. Closings had the largest impact on library operations. According to the Public Library Association survey conducted between March 24 - April 1, 2020, 98% of libraries had closed to the public (Public Library Association, 2020). Within that demographic, 35% expected to be closed indefinitely while 47% expected to be closed between two weeks to two months.

Virtual programming is the biggest shift libraries have been forced to make due to the pandemic. Pre-COVID, library staff expressed apprehension about virtual programming. It was not a well-utilized

type of program, only offered occasionally. However, because of the shutdowns to in-person interactions due to COVID-19, the shift has caused complications among library staff. When asked if their library was interested in facilitating virtual/online STEAM activities, 90% of libraries in the *NASA@ My Library* project answered yes. In their comments, however, some expressed hesitancy to the implementation.

A secondary barrier during the COVID-19 pandemic was the lack of ready to go virtual programming content. Previously, virtual programs were a one-off feature in library programming; an opportunity to interact with a high-profile event such as an Educational Downlink with a NASA astronaut or when a scientist called into a rural community to present about their science. During the pandemic, libraries struggled because they did not have enough content to host virtual programs frequently (daily or weekly). They were limited on time to plan, lack of experience on hosting virtual programs, and unsure how to promote them.



STEAM Ahead @ Home was an opportunity to consolidate resources into one area for libraries to access. Created as a webpage on the *STAR Net* website, *STEAM Ahead* was divided into four separate areas: 1) Ready to share activities with patrons, 2) Virtual program ideas, 3) Professional development resources to strengthen library staffs' skills, and 4) the *NASA @ Home* website and its extensive collection of resources. Four Wiki pages were developed to help library staff build their professional community. They could ask questions about curbside checkouts or "Take and Make" activities, develop new partnerships, learn about safe opening procedures, or how to implement safety guidelines. They could also interact through a private Facebook group where ideas, resources, and activities were posted. In addition, a specialized collection on *STAR Net's* STEM Activity Clearinghouse was created to specifically highlight activities that could be converted to "Take and Make" kits. (cont'd)

Finally, a shift to curbside distribution dramatically influenced libraries during the pandemic. With the ability to provide tangible resources, libraries have continued to reach their audiences through “Take and Make” kits and activity guides. Their distribution also allowed for interactions with new community partners including food banks, school districts, and community centers. The *NASA@ My Library* project was able to provide over 23,000 “Take & Make” kits to over 600 libraries to supplement their “at home” STEAM programming. This was accomplished with just a few staff members led by Anne Holland. NCIL’s experience with producing STEAM Kits and disseminating them broadly was invaluable.

Over a year after the start of the pandemic, libraries have adjusted to hosting more virtual programming. They are utilizing partnerships, offering pre-recorded programs, and even participating in virtual conferences for professional development. While their hours are cut, their buildings shut down, or they are forced to work from home, library staff members have shown a great resiliency in keeping their operations from suffering greatly. These shifts highlight the adaptability of library staff to address their community needs, even in a time of crisis.



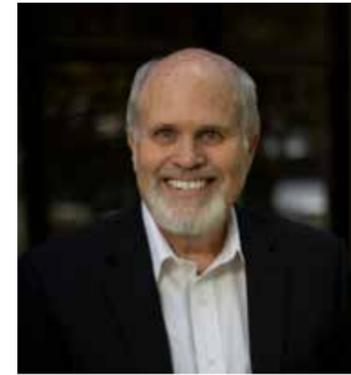
Administrative Assistant Jennifer Hampton and a volunteer assembled the Take & Make Kits at SSI Headquarters using COVID-19 safety protocols.
Credit: SSI/NCIL



Take and Make activity in Georgia as part of NASA@ My Library.
Credit: Gwinnett County Public Library, Georgia

“People respond very positively to something like this simply being available in the community – it changes their perception of what kind of town we are and what opportunities are out there for their kids.”

~Library staff



Virtual Dream, Build, Create Events and Lessons Learned for the Future

Dr. Paul Dusenbery,
SSI/NCIL Boulder Office

With many libraries across the country closing their doors to in-person programming because of the COVID-19 pandemic, there was a need for virtual programming to take its place. A similar need was also felt by schools and caregivers searching for quality online resources to engage youth.



Through the NSF-funded *Project BUILD*, the American Society of Civil Engineers and NCIL developed a new initiative entitled *Dream, Build, Create* aimed at youth in grades 4 and up. Through this virtual program, *Project BUILD* was able to offer the award-winning documentary, *Dream Big: Engineering Our World* (available in both Spanish and English), to libraries and to the broader network of outreach connections established by ASCE, which included schools and after-school centers. Many public libraries also connected with their local schools and school districts to promote the program. Currently available on Netflix and to rent/own through Vimeo and Amazon, the film was available for free on certain dates in November 2020. In addition, six panels of young engineers (“Dream Teams”) were recruited, prepared, and met online to share their engaging stories of what it means to be an engineer. In total, *Dream Big: Engineering Our World* was screened over 1,000 times and Dream Team Panel videos have been viewed more than 900 times.



Diverse engineers were recruited through ASCE's large membership and connections. Individuals with a strong interest in pre-college outreach were invited to be a part of engaging online engineer panels and give youth an opportunity to meet engineers who would share their experiences and answer questions. Engineers for Dream Team panels were chosen by ASCE staff, members of the Society of Hispanic Professional Engineers, and faculty/alumni networks from Historically Black Colleges and Universities. Panelists were selected because they possessed expertise in the topic, had an engaging personality, and were diverse; half of the panelists were female, 28% were Latinx, and 33% were Black.

Project evaluators (from Education Development Center) surveyed library staff, teachers, and caregivers who registered for the *Dream, Build, Create* program and also spoke with a sample of library staff and teachers. In total, 151 surveys were completed and 10 individuals (eight library staff and two teachers) participated in virtual focus groups. Results suggest that *Dream, Build, Create* provided an opportunity that has value beyond the COVID-19 pandemic. Library staff, especially those from rural areas, felt this program was highly valuable and important because they and their patrons do not always have access to engineers in their local community. Teachers also noted that they could face challenges providing students with in-person opportunities to engage with engineers. In fact, only about one-third or fewer of library staff, teachers, and caregivers indicated that they had

opportunities to provide youth with access to programs featuring real engineers (i.e., in-person or virtual talks, screenings of engineering-related films). While in-person activities will certainly return as a staple for libraries in the future, it was also noted that virtual programs such as this have a life beyond the pandemic because of their ability to provide a connection to people and resources that individuals may not otherwise have access to.

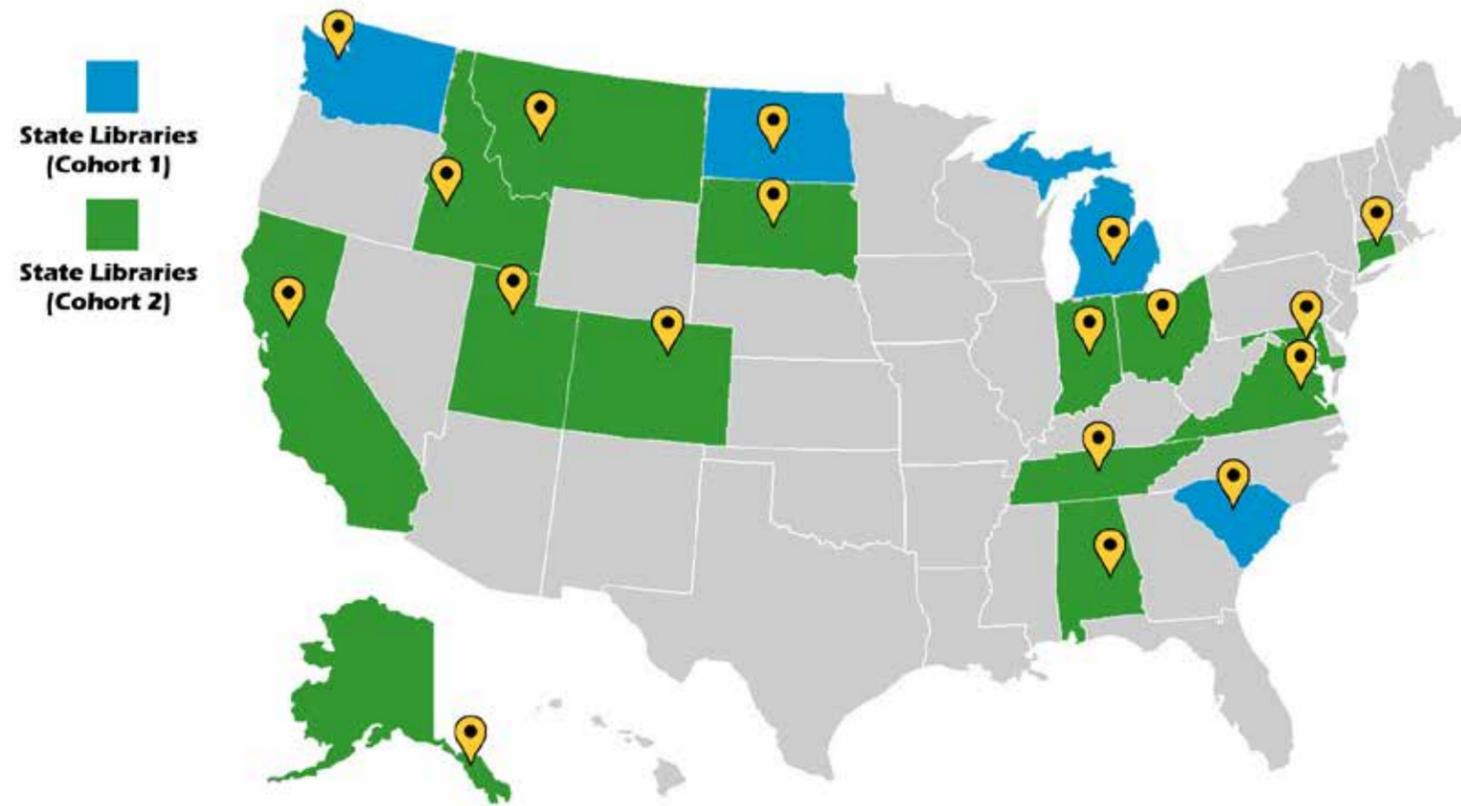
State Library Agencies Circulate NASA STEM Kits to Public Libraries

Dr. Paul Dusenbery, SSI/NCIL Boulder Office

"One of the hallmarks of success for a State Library Agency (SLA) is provision of effective support and leadership. The ways in which this is demonstrated vary by at least 54, the current number of states and territories that comprise the membership of the Chief Officers of State Library Agencies (COSLA). SLAs provide unparalleled reach into communities through access to virtually every public library in the United States. SLA staff are influential leaders, practiced at working collegially to share practices, successes, and challenges. The agencies and the staff are trusted partners, working at the intersection of local libraries and state, even national, organizations." (Tim Cherubini, Executive Director, COSLA)

Between 2018 and 2020, COSLA collaborated with the *NASA@ My Library* project team to help engage, select and monitor the progress of eighteen SLAs in this national earth and space science education initiative. NCIL and Cornerstones of Science led this effort. In 2018, four SLAs were selected to participate as pilot sites in a one-year program to test a new model of public library engagement (Cohort 1). In December 2018, after assessing the pilot results and modifying our approach, the *NASA@ My Library* Team and COSLA chose an additional fourteen SLAs through a competitive process (Cohort 2). \$5,000 was offered to each state to defray their costs of participation. States primarily used their funds to make duplicate copies of STEM kits, pay shipping costs for libraries to use the kits, and to customize the kits to better serve unique audiences in their states. The SLA Partner locations are shown on the following page.

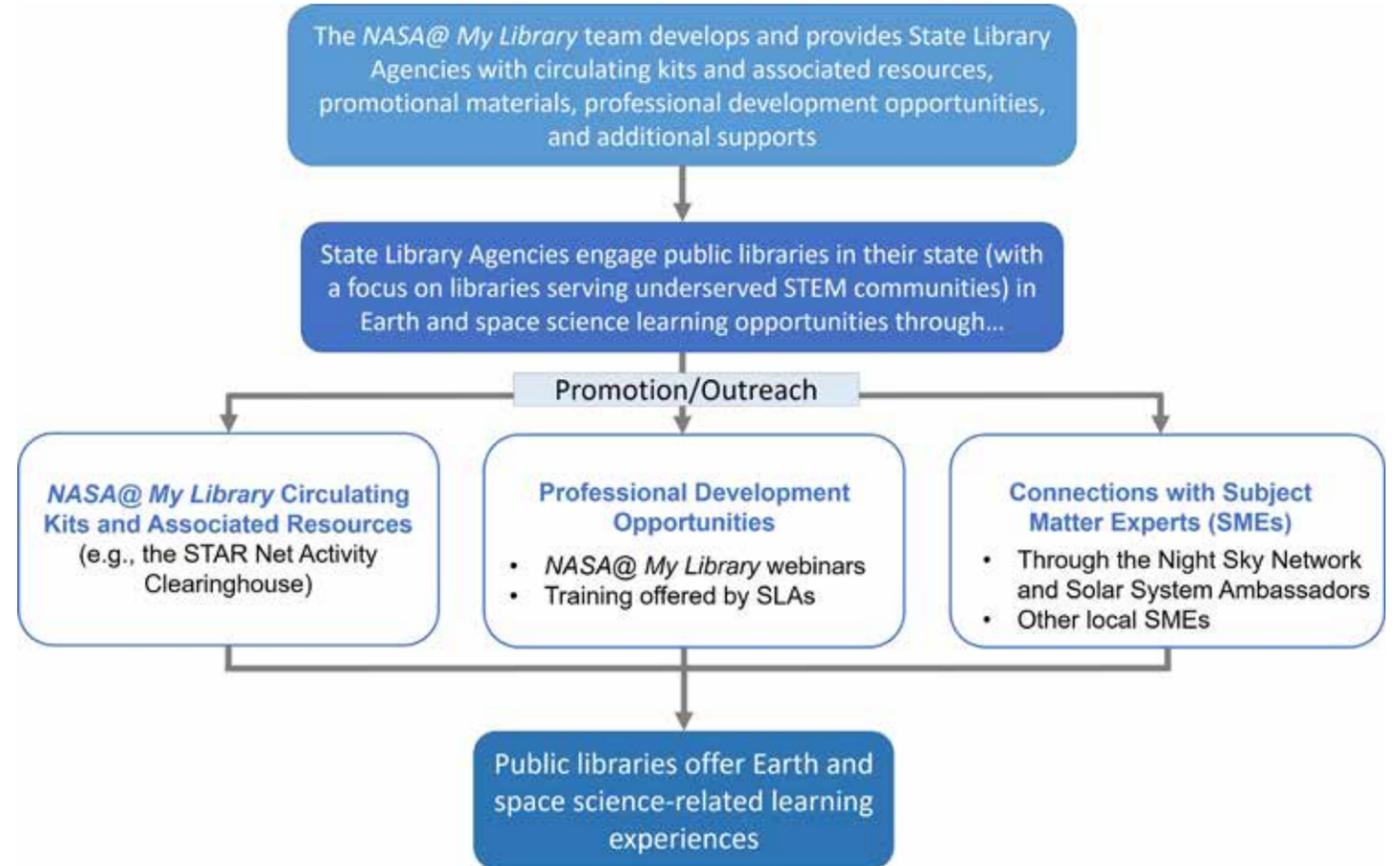
(cont'd)



The principal reasons *NASA@ My Library* partnered with state libraries on a STEM kit program included the following: (1) state libraries can build on their efforts to share resources and best practices statewide by distributing materials to public libraries; (2) public libraries want a self-contained kit that contains easy to use materials to implement a quality STEM program for their patrons; and (3) it is most economical to create loanable kits that can be used by many public libraries.

Participating SLAs performed four key roles (see Figure below):

1. Circulated multiple STEM Kits to public libraries in their state;
2. Participated in professional development for State Library staff and offered training to public library staff;
3. Built relations with NASA and other space science organizations through connections with subject matter experts; and
4. Served as *NASA@ My Library* advisors to offer advice, share insights, and lessons learned with other state libraries.



"I think the library offers a chance for kids to explore STEM without having to worry about grades or coming up with the 'right' answers. Also, they can pick and choose what programs interest them. We also help patrons find resources so that they can continue their exploring at home."
 ~ STAR Net Librarian

The diversity of the participating SLAs was significant and proved to be a project asset. Examples of this diversity included agency size (e.g., number of staff and total operating budget), state size and number of public libraries served and previous experience with circulating loanable science kits, the extent of existing relationships with external science organizations to draw on, and expertise working with underserved STEM audiences and the extent of these audiences in each state. Other factors included: in-kind resources contributed; services provided to public libraries; and if staff offered direct public programming to people who visit their facility. Given this considerable diversity, State Library Partners learned from each other and developed approaches that best suited their needs and situations.



Maryland State Library hosted a NASA workshop.
Credit: Maryland State Library

With considerable help from the SLA Partners, the *NASA@ My Library* team created a [Guide](#) (Keeley et al., 2020) that all state libraries can use when implementing a circulating STEM kit program in their state. While *NASA@ My Library* focused on Earth and space science, the lessons learned apply to all STEM content areas. It is organized into four sections: 1. Managing a STEM Kit Program; 2. Training Library Staff; 3. Engaging Underserved Audiences; and 4. Working with Subject Matter Experts. Each section has “Best Practices”, “Tips” and vignettes from the State Library Partners along with relevant evaluation results from EDC.



Project BUILD activity. Credit: Free Library of Philadelphia

Financial Summary

Space Science Institute • Summary Statement of Financial Position
as of December 31, 2020 and 2019

ASSETS	2020	2019
Assets		
Cash and cash equivalents	700,842	453,797
Accounts receivable	818,805	1,311,013
Prepaid expenses and deposits	130,376	120,144
Net furniture, equipment, and property	205,638	237,839
Total assets	\$ 1,855,661	\$ 2,122,793
LIABILITIES AND NET ASSETS		
Liabilities		
Accounts payable and accrued liabilities	678,258	743,760
Deferred revenues	321,924	317,758
Line of credit	300,000	475,000
Note Payable	101,401	115,842
Total liabilities	\$ 1,401,583	\$ 1,643,360
Net assets		
Without donor restrictions	451,573	473,688
With donor restrictions	2,505	5,745
Total net assets	\$ 454,078	\$ 479,433
Total liabilities and net assets	\$ 1,855,661	\$ 2,122,793

Summary Statement of Activities
for the years ended December 31, 2020 and 2019

SUPPORT AND REVENUE	2020	2019
Grants, contracts, and cooperative agreements	7,853,354	8,339,015
Contributions	26,986	30,611
Exhibit and workshop income	150	6,643
Interest income	155	335
Total support and revenue	\$ 7,880,645	\$ 8,376,604
EXPENSES		
Science research programs	3,866,515	4,276,955
Science education programs	2,108,293	1,991,029
Fundraising	6,197	6,526
General and administrative	1,924,995	1,861,742
Total expenses	\$ 7,906,000	\$ 8,136,252
Change in net assets	(25,355)	240,352
Net assets, beginning of year	479,433	239,081
Net assets, end of year	\$ 454,078	\$ 479,433

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, 2019 and 2018, from which the summarized information was derived. A copy is available upon request.



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