Dedicated to Solar System exploration,
PSI scientists are involved in NASA and international missions, fieldwork around the world, education, and public outreach.

The Planetary Science Institute is a private, nonprofit 501(c)(3) corporation dedicated to Solar System exploration. It is headquartered in Tucson, Arizona, where it was founded in 1972.

PSI scientists are involved in NASA and international missions, the study of Mars and other planets, the Moon, asteroids, comets, interplanetary dust, impact physics, the origin of the Solar System, extra-solar planet formation, dynamic evolution of planetary systems, the rise of life, and other areas of research. They conduct fieldwork on all continents around the world. They are also actively involved in science education and public outreach through school programs, children’s books, popular science books and art.

PSI scientists and educators are based in 30 states and the District of Columbia, and work from various international locations.

ON THE COVER:
“Landscape on Pluto: Where the Plains Meet the Mountains”
Acrylic painting by PSI co-founder and Senior Scientist Emeritus, William K. Hartmann

This painting was inspired by photos from the New Horizons spacecraft’s flyby of Pluto, which show regions of brighter plains – possible ice-rich materials – with darker toned mountain regions that are somewhat more brown in tone based on spectroscopic observations. The sky is not completely black because of Pluto’s thin atmosphere. In the sky are Charon, Pluto’s largest satellite, and the Sun, hardly more than a very bright star at this distance, which is about 40 times the distance of the Earth from the Sun.
2020 brought us the COVID-19 pandemic, which by March was shutting down businesses and schools around the country with people isolating in their homes and not venturing out. Toilet paper and various seemingly random foods and supplies were suddenly in short supply. Hospitals were filling up and deaths were relentlessly on the rise.

PSI WAS RELATIVELY PREPARED FOR THE WORKING ENVIRONMENT CHALLENGES IMPOSED BY THE PANDEMIC.

The great majority of our scientists were already working remotely in home offices across 30 states and various international locations. NASA missions kept flying, the agency kept functioning, and so did we. A few people lost access to needed laboratory facilities, but most had access to the data and computational resources they needed to conduct their research, and multiple projects could be juggled as needed.

The biggest impact was on those scientists and admin staff who suddenly had to care for their children during the days they would otherwise be at school or in daycare. Some of our employees got COVID, and some continued to suffer from long hauler syndrome associated with the disease. Some of us lost friends and family members. We are thankful that no one at the Institute died.

DURING THE PANDEMIC, COMMUNICATION IS KEY.

PSI had been conducting monthly staff meetings for more than 15 years online, using tools like Webex and GoToMeeting. We were recognized by Nature magazine as a pioneer in using the internet for knitting together our distributed employees, so PSI employees were quite used to online communications. However, now the need was greater and there were new tools that made things even easier for groups to interact online: Slack and Zoom.

In March, with our offices closed in Tucson and Lakewood, Colorado, we commenced daily admin meetings on Zoom and nine “PSI Connects” on Zoom at different times during the workweek so people could share news and strategies for dealing with child care and other situations. New collaborations were also created. The diversity in times also accommodated the wide-ranging time zones in which our scientists are located. It was fun to see the children and pets that insisted on participating!

FAIRLY SOON AFTER CLOSING OUR OFFICES, WE HAD TO MAKE A DECISION ABOUT OUR ANNUAL PSI RETREAT.

In August we arrange for all our employees from around the country and world to gather in Tucson for several days, hear presentations on the state of the Institute and research, and celebrate milestones and accomplishments. Most of the retreat is scheduled for planned and spontaneous breakout sessions where people can discuss existing projects and chart new projects or just sit around and have informal conversations. Families are welcome. Outside the meeting rooms it is common to see packs of children cavorting with their new best friends.

We decided to cancel the face-to-face retreat and created a virtual event using Zoom. We had recorded 10-minute new hire talks with live Q&A and recorded one-minute lightning talks. We had numerous breakout sessions in parallel that worked seamlessly, including a cooking lesson by Nick Castle and his wife! The retreat ended with a virtual mixer that was scheduled for an hour, but went on for almost five! All in all, it was a remarkably successful event that preserved some of the spontaneity of our face-to-face retreat.

EARLY ON IN THE PANDEMIC THERE WAS A SHORTAGE OF EMERGENCY MEDICAL EQUIPMENT IN TUCSON.

So PSI started fabricating face-mask holders and “ear savers” using its 3-D printers, overseen by Gavin Nelson who then delivered them to fire stations and medical centers around the city. We are all in it together as an institution and as members of communities everywhere. We look forward to things returning to “normal,” but appreciate that “normal” may have significant differences from the past.

— Mark V. Sykes
Ryan Watkins Receives NASA SSERVI’s Niebur Early Career Achievement Award

Research Scientist Ryan Watkins has been honored by NASA’s Solar System Exploration Research Virtual Institute with the Susan Mahan Niebur Early Career Award.

The Niebur award goes to a researcher who is within 10 years of receiving their Ph.D., and who has made significant contributions to the science and/or exploration communities. The prize is presented, along with an invited lecture, at the annual Exploration Science Forum held each July at NASA Ames Research Center.

“It’s a true honor to be given an award in the name of Susan Niebur. While I didn’t know her personally, her passion for and commitment to advocating for early career scientists, women in science, and parents in science made her a true leader and catalyst for change in our community,” Watkins said. “I have been an active advocate for early career scientists and for mothers in science for several years, and I plan to proudly carry the torch that Susan lit as I advance through my career.

“I have had many great opportunities to merge my passion for lunar exploration with my research on understanding the physical and compositional properties of the lunar surface, and I am incredibly grateful to Susan and others who have continually supported early career scientists,” she said.

“Dr. Watkins’ research focuses on integrating remote sensing data sets to characterize the physical and compositional properties of airless bodies, with particular emphasis on the lunar surface. She specializes in using photometry to understand physical and compositional properties of the lunar surface, and in integrating planetary data sets to assess landing site safety hazards for future missions,” SSERVI said in a press release.

“Dr. Watkins is actively engaged in service and leadership within the planetary science community. She serves on the Organizing Committee for the Next Generation Lunar Scientists and Engineers (NextGen) group, on the Executive Committee for the Lunar Exploration Analysis Group (LEAG), on the Steering Committee for the Equity, Diversity, and Inclusion (EDI) Working Group, and on Blue Origin’s Science Advisory Board for their Blue Moon lander project,” SSERVI’s release said. “In addition to research and planetary community service, Dr. Watkins regularly participates in Education and Public Outreach in her local community, and with the Solar System Exploration Virtual Institute (SSERVI) Toolbox for Research and Exploration (TREX) team. SSERVI is very pleased to present the Susan Niebur award to Dr. Ryan Watkins.”

Sykes and Villas Named AAS Legacy Fellows

Mark Sykes and Faith Vilas were made Legacy Fellows of the American Astronomical Society. The AAS Fellows program was established to recognize AAS members for the contributions toward the Society’s mission of enhancing and sharing humanity’s scientific understanding of the universe. Fellows may be cited for original research and publication, innovative contributions to astronomical techniques or instrumentation, significant contributions to education and public outreach, and noteworthy service to astronomy and to the Society itself.
MASSIVE MUD DOWNPOURS MIGHT HAVE FORMED SOME OF THE MOST ANCIENT HIGHLANDS ON MARS

Independent research by Senior Scientist Alexis Rodriguez shows that muddy rains produced by giant impacts into a primordial glaciated Mars may have played a crucial role in the emplacement of kilometers-thick mudstones on Mars. These mudstones comprise the Solar System’s oldest known sedimentary rocks.

Mars preserves the Solar System’s oldest water-modified landscapes. Rivers and glaciers are known to have extensively excavated the planet’s earliest highlands, which date back to about 4 billion years ago.

Rodriguez and colleagues found that impact craters and adjoining fluvially emplaced sediments in these ancient highlands were excavated by wind to enormous depths, in some cases more than a kilometer. Wind on Mars can only move sand- and silt-sized sediments and finer, so very fine-grained sediments must largely make up these parts of the highlands.

PSI scientists Eldar Noe Dobrea, Jeffrey S. Kargel, David A. Crown, Kevin D. Webster, and Daniel C. Berman participated in this work.

When wind moves large amounts of sand, it produces dunes, but dunes are absent in these wind-sculpted terrains, suggesting that they are made mainly of silt, and perhaps clay. The wind erosion of these surfaces took place recently and might still be happening.

So, what happened about 4 billion years ago that led to the formation of these highlands? The current state of knowledge suggests that the planet’s flowing water and glacial record that overprints these highlands postdates their formation by up to several hundred million years.

However, something unique happened on Mars during this early phase in its history – most of the planet’s impact basins formed. The formation of these gigantic structures, hundreds to 2,000 kilometers in diameter, would have produced extremely powerful winds and would have also most likely triggered transient climate change conducive to rainfall.

The winds could have dislodged from the surface vast volumes of dust that existed when the impacts occurred, resulting in dust-laden atmospheric conditions. Rodriguez and colleagues suggest that when rainfalls happened, large amounts of the dust were removed from suspension to be redeposited as thick sedimentary units. An interesting implication of the muddy rain hypothesis is that this process could have emplaced enormous volumes of wet sediments over the planet’s extremely cold surface environments. In the likely presence of salts, the water-soaked mud might have produced immense aquifers with low-temperature freezing brines.

NASA’s Mars 2020 Perseverance rover will land nearby some of the study regions located in very similar terrains. Perseverance might sample fine-grained highlands dating from the time when life could have emerged on Earth and when heavy impact bombardment by asteroids was delivering organics to Mars and Earth, potentially resulting in life-forming hydrothermal systems.

These results were published in Nature Scientific Reports (https://www.nature.com/articles/s41598-020-64676-z).
Senior Scientist Jeffrey Morgenthaler used PSI’s Io Input/Output facility (IoIO) to observe the bright comet C/2020 F3 (NEOWISE) on July 8, 2020, revealing its extended sodium tail.

Comets are “icy dirtballs” and their tails are made of dust, gas and plasma (ionized gas). As comets approach the Sun on their highly elliptical orbits, heat from sunlight causes the ice to turn into gas (sublime) which drags material (generically called “dust”) from the surfaces of the comet as it escapes in various directions. As sunlight reflects off of tiny particles of dust, they get a kick of momentum away from the Sun as they drift away from the nucleus. Heavier bits of dust are harder to push and drift more slowly. These forces affect the shape of the dust tail, very similar to the appearance of the comet to the naked eye, shown in the image on the left. Atomic sodium responds to sunlight in a similar way to cometary dust, but its momentum kick comes from a very particular wavelength of yellow light – the same color seen in sodium vapor street lamps – a results in a narrower, long tail pointing directly away from the Sun as seen in the image on the right.

Since the push on sodium atoms is stronger than on the dust and other gas that comes off of comets, it provides a different perspective on conditions close to the comet’s surface. Sodium tails have only been observed in very bright comets, such as Hale-Bopp and the sungrazer ISON. While the element has been found in spectra of comets near the Sun, images of the emission are relatively rare, since the glare of the Sun makes this a challenging observation.

In early July 2020, Comet NEOWISE approached the Sun for the first time in nearly 4,500 years. For observers in the northern hemisphere, it was faintly visible just before dawn, and later became visible at dusk as well. Although it grew fainter, when viewed through binoculars its showy tail continued to dazzle through July 22, when it passed a mere 100 million kilometers from Earth. The team, including Carl Schmidt of Boston University, used Monte-Carlo computer models to simulate the comet’s sodium tail in order to understand the outgassing rates and speeds.

IoIO was built with the support of an NSF grant to PSI to study the effect of Io’s volcanic material on Jupiter’s magnetosphere (https://www.psi.edu/news/iosodium). The observatory has also observed Mercury’s sodium tail (https://www.psi.edu/news/cover-pages/2018/mercurys-sodium-tail).
The discovery of Martian dune fields largely preserved in the rock record for up to a billion years offers new insights on past climatic conditions on Mars.

Mapping of extensive sedimentary rock deposits in the Valles Marineris region of Mars by Research Scientist Matthew Chojnacki shows clear evidence for preserved lithification and burial of dune fields.

While modern sand dunes and other wind-formed features are common on the surface of Mars and other terrestrial planets, typically most of the deposits are worn away by erosion.

Extensive dune fields in the canyons of Valles Marineris were identified and mapped, showing clear evidence for lithification and burial. This level of preservation is rare for terrestrial sand dunes due to ongoing erosion and tectonics. Based on the dune deposit's relationships to other geologic units and modern erosion rates, Chojnacki and his colleagues estimated these to be roughly a billion years old. Because of the duneforms' size and spatial arrangements, which are not that much different to modern equivalents, they suggest that the climate and atmospheric pressure to have been similar to that of contemporary Mars.

Surface erosion and landscape evolution are greatly different on Earth and Mars. Water and tectonics that constantly reshape the surface of Earth are not currently a factor on Mars, thus there is an opportunity to learn from the geologic record of the Red Planet. The ancient dune fields found within Valles Marineris, with their complex variety of landform shapes, degree of preservation, and context, reveal the richness of regional geology. This demonstrates that wind-driven sand transport, deposition, and lithification have occurred throughout much of Mars' recent history and illustrate how landscape evolution there greatly differs compared to that of Earth.

Data was collected using instruments on NASA's Mars Reconnaissance Orbiter and Mars Odyssey spacecraft. Chojnacki's research was funded by a grant from NASA Mars Data Analysis Program. These results were published in Journal of Geophysical Research: Planets (https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020JE006510).

"...Wind-driven sand transport, deposition, and lithification have occurred throughout much of Mars’ recent history and illustrate how landscape evolution there greatly differs compared to that of Earth."
Glacial lakes have grown by almost 50 percent since 1990 due to climate change and melting glaciers. These growing glacial lakes are often dammed by unstable glacial sediment or ice that can burst, causing sometimes deadly flooding downstream. These are the conclusions of a worldwide study conducted by Senior Scientist Jeffrey Kargel, Dan Shugar (University of Calgary) and others.

The authors calculated the role of glacial lakes in temporarily storing glacial meltwater that otherwise would drain straight into the sea. However, that stabilizing effect on sea level rise is small. “The issue is for many parts of the world where people live down-stream from these hazardous lakes, mostly in the Andes and in places like Bhutan and Nepal, where glacial lake outburst floods can be devastating,” Shugar said. “Fortunately, organizations like the United Nations are doing or facilitating a lot of monitoring work and some mitigation work where they’re lowering the lakes to try and decrease the risks.”

Kargel, who has led expeditions in the Himalaya to assess glacial lake hazards and to prepare for mitigation, agreed: “The widespread expansion of unstable glacial lakes represents a threat to communities and ecosystems.”

Researchers ran their software in Google Earth Engine to analyze historic and recent images from NASA satellites to detect, map, and measure areas of all the glacial lakes on Earth, except for in Antarctica, between 1990 and 2018.

More than a quarter million Landsat images were used to map glacial lakes and track their growth – or shrinkage – from the 1990s to the 2010s. Lake areas were measured, and then their volume was estimated using the average relationship between lake area and volume. The number of lakes and the lakes’ distribution and changes both globally and region by region were determined. There was about a 48 percent increase in the lakes’ total volume.

Another issue is fresh water availability. Melting of glaciers and mountain snowpack is a part of the shifting global impacts of climate change on the loss of fresh water and altered behavior of rivers. For example, the mighty glacier-fed rivers of the Himalayan region, such as the Ganges and Indus and their tributaries, will gradually lose their glacier sources during this and next century. Some of the rivers in Asia will behave more like the Colorado River does today, where almost all the Ice Age glaciers have melted already and runoff is now mainly from melting snowpack and rainfall. The Colorado River in recent historical times dried to a trickle in the dry seasons. Scientists, water managers, and policy makers around the world are increasingly focused on these impacts of climate change on melting glaciers and snowpack because they affect millions of people’s health, safety, and livelihoods.

Visit https://www.youtube.com/watch?v=rvRCKgw2B8k to see a video showing glacial lake growth due to glacier melt.

These results were published in Nature Climate Change (https://www.nature.com/articles/s41558-020-0855-4) with lead author D. Shugar. J. Kargel is the principal investigator of the NASA Earth Science Division-funded project supporting this work.
COLLAPSED TERRAINS ON MERCURY MIGHT BE WINDOWS INTO ANCIENT – POSSIBLY HABITABLE – MATERIALS

Chaotic terrains on Mercury opposite the large Caloris impact basin are landscapes produced by the removal of vast volumes of upper crustal volatiles, a team led by the Senior Scientist Alexis Rodriguez concludes. This team includes PSI scientists Jeff Kargel, Deborah Domingue, Daniel Berman, Maria Banks, Kevin Webster, and Mark Sykes.

The finding means that Mercury had a thick volatile-rich – possibly but not necessarily water-rich – crust in this location. Mercury’s surface temperature reaches a scorching 430 degrees Celsius during the daytime, and in the absence of an atmosphere, it plummets to -180 degrees Celsius at night. So, its surface environments have rightfully been out of scientific consideration as a possible host of life. However, the new research raises the possibility that some parts of Mercury’s subsurface, and those of similar planets in the galaxy, once could have been capable of fostering prebiotic chemistry, and perhaps, even simple life forms.

The deep valleys and enormous mountains that now characterize the chaotic terrains were once part of volatile-rich geologic deposits a few kilometers deep, and do not consist of ancient cratered surfaces that were seismically disturbed due to the formation of Mercury’s Caloris impact basin on the opposite side of the planet, as some scientists had speculated.

A key to the discovery was the finding that the development of the chaotic terrains persisted until approximately 1.8 billion years ago, 2 billion years after the Caloris basin formed.

Investigation also shows that there are also numerous extensive chaotic terrains in other regions of the planet, which have latitudinal distributions ranging from equatorial to subpolar. Hence, Mercury’s volatile-rich crust appears to be greater than regional, perhaps global, in extent, and it is most likely made up of compositionally diverse volatile compounds.

Evidence of surficial devolatilization, probably caused by solar heating, provides an opportunity to infer the range of Mercury’s volatile properties and compositions. A possibility is that Mercury’s volatile-rich crust was delivered via impacts from the frigid confines of the outer Solar System or the main asteroid belt. Alternatively, volatiles were outgassed from the interior. While not all volatiles make for habitability, water ice can if temperatures are right. Even if habitable conditions existed only briefly, relics of prebiotic chemistry or rudimentary life still might exist in the chaotic terrains.

If these results are confirmed, this and other similar areas of collapse on Mercury could be important considerations for future landing sites to investigate the origin of the planet’s volatile-rich crust and, perhaps, even its astrobiological potential.

This work was supported in part by the NASA Solar System Workings program. These results were published in Nature Scientific Reports (https://www.nature.com/articles/s41598-020-59885-5).

VAST CHAOTIC TERRAIN ON MARS
Left: Extent of a vast chaotic terrain (white outline) at the antipode of the Caloris basin (~5 x 10^5 km^2).
Right: Zoom in showing variable magnitudes of collapse, which includes a relatively unmodified rim section that is smooth but not broken into knobs (arrow 1). This area adjoins another part of the rim that has been almost entirely removed (arrow 2). The adjacent intercrater regions also exhibit deep and abrupt relief losses (arrows 3 & 4).
THANK YOU TO OUR 2020 BENEFactors

With deep appreciation the Planetary Science Institute acknowledges the following individual and organizational benefactors who made contributions between Jan. 1, 2020 and Dec. 31, 2020.

$2,000 and up
Mr. and Mrs. Maurizio and Tina Balistreri
Conoco Phillips
Mr. and Mrs. William and Gayle Hartmann
Dr. and Mrs. Tim and Carol Hunter
Dr. Mark V. Sykes and Ms. Marilyn Guengerich

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Mr. and Ms. David and Kelly Yoder

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Dr. Thea L. Canizo
Dr. Christopher Chyba
Mr. Avery Davis and Ms. Debbi Golden-Davis
Mr. and Mrs. Bruce and Lynne Dusenberry
Mr. William Elliott
Mr. David Fales and Ms. Sara Hammond
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Dr. Andrew Wheeler
PSI had revenues totaling $15 million for the fiscal year ended September 30, 2020. During the fiscal year, PSI was actively involved in 113 prime awards issued directly from federal agencies and 149 subawards/contracts issued through other institutions. 95% of all funding originated from NASA.

**REVENUES**

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<td>Contributions</td>
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<td>Other</td>
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<td><strong>Total Revenues</strong></td>
<td><strong>$15,029,779</strong></td>
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</table>

PSI had revenues totaling $15 million for the fiscal year ended September 30, 2020. During the fiscal year, PSI was actively involved in 113 prime awards issued directly from federal agencies and 149 subawards/contracts issued through other institutions. 95% of all funding originated from NASA.

**EXPENSES**

<table>
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<th>Description</th>
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<td><strong>Total Expenses</strong></td>
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</table>

Salaries and related fringe benefits represent 71% of PSI’s total expenses. Operating expenses include $2.7 million paid on subawards to other institutions whose scientists are included on PSI prime awards. Program Services expenses were 90% of total expenses.

**ACTIVE PROJECTS BY PRIME AWARDING AGENCY**

<table>
<thead>
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<th>Agency</th>
<th>Number</th>
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<td>NASA</td>
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<td>NSF</td>
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<tr>
<td>Non-Federal</td>
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<td><strong>Total Projects</strong></td>
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**EXPENSES BY FUNCTION**

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<td>Management &amp; General</td>
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<td>Fundraising</td>
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PSI’s financial records are audited annually by independent auditors. A condensed Statement of Financial Position from PSI’s audit report as of September 30, 2020 is reflected below.

<table>
<thead>
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<th>Description</th>
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<td><strong>Total Liabilities &amp; Net Assets</strong></td>
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**PSI Education and Public Outreach**

**Education and Public Outreach Continues Through Worldwide Pandemic**

Despite changing global conditions, PSI continues to support many science education and public engagement projects that have a national and international reach. Currently, our scientists, education specialists, and staff are based in 30 states, the District of Columbia, and several international locations. In 2020, PSI continued the program that supported Education and Public Outreach (EPO) through funding the “Friends of PSI” program (see www.psi/support/friends for more info).

Programming in 2020 led by scientists and education and communication outreach specialists ranged from large public talks, classroom and camp visits, and public outreach events across the US. As the pandemic stretched across the world and closed schools, camps, and businesses, many activities pivoted to being conducted virtually or in smaller socially distanced ways.

*Here are a few of the EPO highlights of a busy year for PSI scientists, educators, and communicators:*

**In-Person Events**

Prior to March 2020, there were several in-person events including two large public events in Tucson and in Albuquerque. On February 28, 2020, Senior Scientist Tom Prettyman presented at the Look Across the Mountain IV, a STEAM conference for Native American communities held in Albuquerque, NM. The event was attended by parents, students, and teachers from rural communities throughout the Western U.S.

Senior Scientist and Education and Communication Specialist Sanlyn Buxner, along with Research Assistant Maya Bakerman and volunteer Mark Morris shared meteorites, hands-on activities, and talked about lunar landing sites with visitors at SciFest at Children’s Museum Tucson on February 15, 2020, an event that had 1,830 visitors (Image above right). Additionally, Senior Scientist Candice Hansen-Koharcheck gave a talk to 40 visitors who were socially distanced at the Kayenta Art Foundation about JunoCam in August 2020.

**Virtual Events**

Although the worldwide shutdown altered the kinds of events that could be held, many scientists and educators were able to take advantage of virtual presentations to expand the reach of audiences around the world. Collectively, scientists and educators provided dozens of virtual presentations to astronomy clubs, museums, K12 and university classrooms, camps, and large public events. Those involved included Catherine Johnson, Than Putzig, Amanda Hendrix, Tom Prettyman, Beatrice Mueller, Rebecca Williams, David Grinspoon, Grace Wolf-Chase, Nalin Samarasinha, Eric Palmer, JA Grier, Liz Jensen, Deborah Domingue, Eldar Noe Dobrea, Jamie Molaro, Shawn Wright, Larry Lebofsky, Ryan Watkins, George Kramer, Pamela Gay, Sanlyn Buxner, Faith Vilas, Becky Ghent, and Luke Sollitt.

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Luke Sollitt was interviewed for the National Air and Space Museum for “Stem in 30.” He discussed an exoplanet video he helped produce with other researchers.
The Planetary Science Institute (PSI) is a nonprofit science research organization that secures its primary source of funding through competing for grants from NASA, the National Science Foundation, and other similar entities. Because this grant funding is somewhat unpredictable (and subject to government budget adjustments), PSI also pursues other sources of revenue throughout the year to contribute to the smooth operation of the organization.

In particular, we reach out to businesses and individuals (local, national, and international) to sustain the Institute’s far-reaching education and public outreach efforts (EPO) that are led by PSI scientists across the country. These efforts include conducting science presentations at schools and other venues (farmers’ markets, churches, clubs) and serving as judges at science fairs. The Institute provides scientists with the use of customized Rock Kits (durable cases that contain samples of meteorites and other rocks) to provide a powerful “show and tell” experience to a diverse audience. Due to COVID-19 concerns and restrictions, PSI’s education and public outreach efforts were placed on hold during 2020.

**Typically throughout the year, PSI conducts a few different fundraising events and initiatives:**

### Annual Dinner

The PSI Annual Fundraising Dinner is the organization’s main live and in-person fundraising activity. In 2020 the traditional dinner was transformed into a “virtual” event to comply with the suggested COVID-19 safety guidelines for gatherings.

This was PSI’s first-ever such fundraising event – a meeting of people from all over the country using the Zoom platform. The innovative evening consisted of:

- Five Pre-event Live Science Chat Rooms hosted by PSI Scientists: *Where to Look for Life on Mars, Comet Making Demo, Colonizing Titan, Alien Techno-Signatures, and Solar System 101*
- Main event/Keynote and Q & A with speaker Doug Loverro, space policy expert
- Post-event private chat room with Doug (for Sponsors only)
- Live Online Auction

With navigating so many new elements and trying to connect to our donors in the pandemic environment, we could not predict the outcome of this important fundraiser. Ultimately, we were gratified to see an unprecedented level of support from donors that resulted in our most successful Annual Fundraising Dinner ever.

### Challenge Match Campaign

In 2020 the Institute faced numerous scheduling challenges due to COVID. The PSI Annual Dinner had to be postponed from its typical April/May timeframe and was pushed into September. That timing also affected the Challenge campaign. Normally the Challenge is launched on October 1st but adhering to that timetable meant that it would start just three weeks after the annual fundraising dinner. There was concern about the viability of having two PSI fundraisers so close together. Therefore it was decided to move the launch date to Nov. 1 – shortening the duration of the campaign by four weeks.

The campaign was launched after collecting some initial “seed money” pledges. Typically the seed money is donated by PSI Board members, PSI scientists and staff, and a few key donors. That sum then becomes the financial goal for the campaign. The 2020 Challenge Match Campaign was launched with $6,750.

In spite of the delayed start and the shortened time frame, we met the targeted goal and exceeded it by more than 200%. The 2020 Challenge Match Campaign raised more than $21,000 in unrestricted funds for the Institute.

**“Friends of PSI” Program**

The Institute has a core group of supporters who form the “Friends of PSI” program. This group of individuals makes an annual, tax-deductible membership donation of $40. A “Friend of PSI” receives the PSI Weekly Briefing (a digital newsletter), a selection of PSI logo merchandise, a discount on tickets to the Annual Dinner, breaking news press release announcements, and alerts about interviews with PSI’s scientists.

All revenue from this program is designated to support the Institute’s nationwide education and public outreach (EPO) activities. PSI scientists volunteer their time within their own communities to conduct STEM-related activities for children and adults and serve as judges at science fairs.

**Betty Pierazzo Fund**

Created to honor the late Dr. Elizabeth Pierazzo, a PSI senior scientist, this program enables early-career scientists to attend a scientific conference of their choice. Two students are selected each year – one studying in the U.S., one studying outside the U.S. – and each receives a check of $2,000 to defray travel cost related to attending a scientific conference. These travel awards were suspended in 2020 due to the pandemic.

**Belton Fund**

Created by Dr. Michael and Mrs. Anna Don Belton, this fund supports a biennial symposium on Comets. The inaugural event is planned for 2022.

### Grants and Business Sponsorships

Additional funding efforts include submitting grant applications and talking to Tucson-area businesses about supporting PSI’s research and/or EPO efforts.

### Other

PSI continues to partner with Amazon through the AmazonSmile program and a “PSI Gift Shop” is available on the PSI website. With a new website design to be unveiled sometime in late 2021 or early 2022 the gift shop will be revamped with a new look and additional merchandise selections.
PSI Continues To Expand in 2020

As it has been for more than 45 years, PSI’s strength and advantage continue to be in its people. Our culture of openness and high level of mutual support distinguishes us as an organization. In 2020 PSI continued to grow, adding 19 new research and administrative staff members.

NEW PSI RESEARCH GRANTS

Amy Barr Mlinar. The role of cryovolcanism in creating habitable niches on exoplanets beyond the snow line. NASA Habitable Worlds program.


Matthew Chojnacki. Characterizing the dynamic activity of Martian mega-ripples and transverse aeolian ridges. NASA Mars Data Analysis program.

Matthew Chojnacki. Investigating the source(s) of dark sand in the western medusae fossae formation: Testing the volcaniclastic hypothesis. NASA Mars Data Analysis program, Northern Arizona University subaward.


Deborah Domingue Lorin. Understanding radiation processing and alteration of icy regoliths. NASA Cassini Data Analysis program.


David Horvath. The hydrology and climate of past and present Titan. NASA Solar System Workings program.


Catherine Johnson. Structure of Mercury's core and lithospheric magnetic fields from MESSENGER data. NASA Discovery Data Analysis program, University of Alabama subaward.

Jeffrey Kargel. ISRO ASAR investigation of supraglacial materials and melting relevant to glacier dynamics. NASA-ISRO Synthetic Aperture Radar program, University of Dayton subaward.

Jeffrey Kargel. Single source-continuing studies of glaciers and glacier hydrology in high mountain Asia. NASA Cryosphere program.


Lucille Le Corre. Janus: Reconnaissance missions to binary asteroids.

NASA Small Innovative Missions for Planetary Exploration, University of Colorado subcontract.


Jamie Molaro. Project ESPRESSO accessible exploration initiative. NASA Solar System Exploration Research Virtual Institute, Southwest Research Institute subaward.

Alexander Morgan. Linking alluvial fan morphology and sedimentology with formation processes via Martian analog studies in the Atacama Desert, Chile. NASA Solar System Workings program.

Gareth Morgan. Analysis of Mars surface roughness, dielectric losses, and polar layering from multi-band SHARAD data processing. NASA Mars Data Analysis program, Smithsonian Institution subaward.


Jeffrey Morgenthaler. Juno observations of temporal variability in Jupiter's magnetosphere. NASA New Frontiers Data Analysis program, Boston University subaward.


Alex Patthoff. Tectonic history, thermal evolution, and interior structure of the Uranian satellites Miranda and Ariel. NASA Solar System Workings program, Propulsion Laboratory subcontract.


Thomas Prettyman. Elemental constraints on Ceres' hydrothermal evolution and crustal processes from data acquired by Dawn's Gamma Ray. NASA Discovery Data Analysis program.


Katie Primm. Deliquescence of Martian salts in regolith monitored by in-situ electrical property measurements. NASA Solar System Workings program, Southwest Research Institute subaward.

Katie Primm. Seasonality and surface properties of slopes streaks. NASA Mars Data Analysis program.

Katie Primm. Testing dry and wet recurring slope lineae (RSL) formation mechanisms using machine learning with high-resolution digital terrain maps. NASA Mars Data Analysis program, Southwest Research Institute subaward.

Than Putzig. 3D subsurface imaging and analysis of the Martian polar regions with MARSIS data. NASA Mars Data Analysis program, Freestyle Analytical & Quantitative Services subaward.

Than Putzig. Deciphering the martian surface and near-surface with radar
statistics. NASA Mars Data Analysis program, University of Texas at Austin subaward.

Than Putzig. Determining the radar loss properties of the south polar layered deposits on Mars. NASA Mars Data Analysis program, Tulane University subaward.

Than Putzig. Geophysical sounding services for Mars in situ resource. NASA Solar System Workings program, Bay Area Environmental Research Institute subaward.


Matthew Siegler. Thermal and dielectric properties from the Chang’E 2 microwave radiometer. NASA Lunar Data Analysis program.

Hanna Sizemore. High-resolution geologic mapping of Urvara Crater, Ceres. NASA Discovery Data Analysis program.


Golish, D.R., N. DellaGiustina, J.-Y. Li, B.E. Clark, X.-D. Zou, P.H. Smith, J. Rizos, P.H. Hasselmann, C.A. Bennett, S. Fornasier R.-L. Ballouz, C. Drouet d'Aubigny, B. Rizk, M.G. Daly, O.S. Barnouin, L. Philpott, M. Al Asad, J.A. seabrook, C.L. Johnson, D.S. Laurenta (2020). Disk-resolved photometric modeling and properties of asteroid (101955) Bennu. Icarus 357, 113724. DOI:10.1016/j.icar.2020.113724.


