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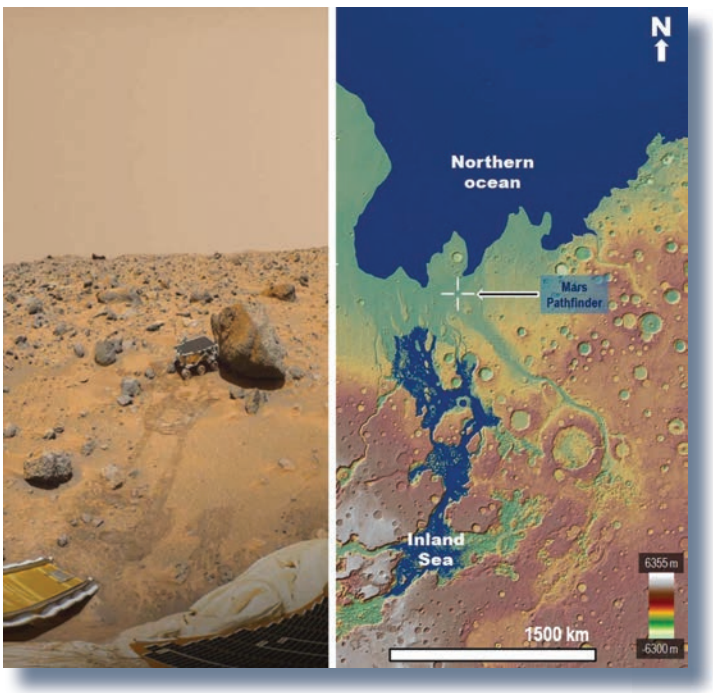
Spacecraft in '97 May Have Explored Edges of Early Martian Sea *by Alan Fischer*

NASA's first rover mission to Mars, Pathfinder, captured images of a marine spillover landscape 22 years ago, according to a new paper by PSI Senior Scientist Alexis Rodriguez.

Pathfinder landed on the spillway of an ancient sea that experienced catastrophic floods released from the planet's subsurface. This could potentially yield evidence of Martian habitability, said Alexis, lead author on "The 1997 Mars Pathfinder Spacecraft Landing Site: Spillover Deposits from an Early Mars Inland Sea," which appeared in Nature Scientific Reports.

In 1971 the Mariner 9 spacecraft returned images of some of the largest channels in the Solar System. Orbital observations of the gigantic channels suggested they were formed approximately 3.4 billion years ago by cataclysmic floods, much larger than any known to have occurred on Earth. The prospect that abundant flowing water once sculpted the Martian landscape ignited renewed interest in the possibility that life once thrived on the planet.



Left: View from the NASA spacecraft lander of Sojourner rover, near the large boulder, driving over possible fluvial sediments. *Credit :* NASA/JPL

Right: This panel shows an ancient geographic reconstruction of the circum-Chryse region, which at that time included the flood-produced inland sea and part of the northern plains ocean. Pathfinder's landing site (crosshair symbol) is located on an enormous spillway that connected the inland sea and the northern ocean. MOLA Science Team, MSS, JPL, NASA.

To test the Martian mega-flood hypothesis, NASA deployed its first Martian robotic rover, Sojourner, sending it to the red planet on board the 1997 Mars Pathfinder spacecraft. NASA spent a total of $280 million on the mission, including the launch vehicle and mission operations. The terrain within the rover's view included potential fluvial features suggestive of regionally extensive flooding. However, those features suggested floods that were less than one-tenth the depth of those estimated using images obtained from orbit. Hence, the mission was not able to rule out still disputed views sustaining that debris or lava flows could have, in fact, dominated the channels' formation without significant water discharges.

"Our paper shows a basin, with roughly the surface area of California, that separates most of the gigantic Martian channels from Pathfinder's landing site. Debris or lava flows would have filled the basin before reaching Pathfinder's landing site. The very existence of the basin requires cataclysmic floods as the channels' primary formational mechanism," said Alexis.

"The basin is covered by sedimentary deposits with a distribution that precisely matches the extent of inundation from potential catastrophic floods, which would have formed an inland sea," Alexis said. "This sea is approximately 250 kilometers upstream from Pathfinder's landing site, an observation that reframes its paleogeographic setting as part of a marine spillway, which formed a land barrier separating the inland sea and a northern ocean."

"Our simulation shows that the presence of the sea would have reduced cataclysmic floods, leading to shallow spillovers that reached the Pathfinder landing site and produced the bedforms detected by the spacecraft," Alexis said.

The team's results indicate marine spillover deposits contributed to the landscape that the spacecraft detected nearly 22 years

Continued on page 3

Inside this issue:

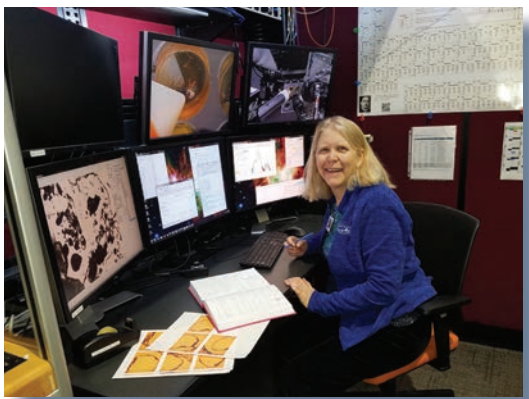
DYAR TO STUDY UNTOUCHED LUNAR MATERIAL	2
WATKINS ON LUNAR MISSION ADVISORY BOARD	2
STEPHEN E. WOOD JOINS PSI	3
DRAGONFLY MISSION TO STUDY TITAN	4
NEW HIGH-RES IMAGES, VIDEO OF LUNAR LANDINGS	4
PAMELA GAY WINS ISAAC ASMINOV AWARD	6

Dyar to Study Untouched Lunar Material

by Alan Fischer

M. Darby Dyar has been selected by NASA to lead a team in the study of pristine lunar samples returned to Earth by NASA's Apollo spacecraft almost 50 years ago.

"This project brings massive state-of-the-art synchrotron and infrared analysis to bear on tiny lunar samples to unlock the secrets of the lunar interior," said Dyar, a Senior Scientist at PSI and Principal Investigator for the Spectroscopy Consortium Addressing Redox Acquired by Beads (SCARAB) project selected for funding by NASA. Dyar's team includes Steve Sutton and Antonio Lanzarotti at the University of Chicago, Molly McCanta at the University of Tennessee, and Sheila Seaman at the University of Massachusetts in Amherst.



PSI Senior Scientist M. Darby Dyar

"SCARAB will use tiny glass beads found in the lunar soil to turn the Moon inside out," Dyar said. "We will study the interior processes that lead to volcanism on the lunar surface. We will use state-of-the-art synchrotron technology and a mapping Fourier-transom infrared (FTIR) spectrometer to measure gradients of volatiles – hydrogen and oxygen – preserved in lunar glass beads.

"The beads are formed by rapid cooling of droplets from explosive lunar fire fountains, like those seen in Hawaii," she said. "We will map changes from core to rim that reveal hydrogen and oxygen pressures in the lunar interior before, during, and after eruption."

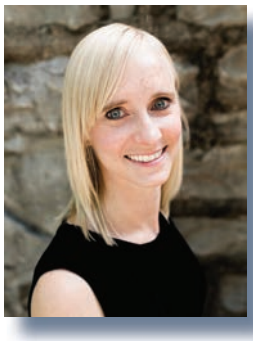
The team will study pristine lunar volcanic glass beads in specially curated materials from Apollo 15, 16, and 17 that will be released by the Apollo Next Generation Sample Analysis (ANGSA) program. These samples have been locked up untouched since they were returned to Earth in 1971-72.

Results will be compared to previously studied samples, some of which have been exposed to air in the time since the 1970s, which will be analyzed using the same methods. Results will determine if chemical changes have taken place under terrestrial conditions despite our most careful curation procedures.

"I first studied lunar glasses as part of my Ph.D. thesis 40 years ago," said Dyar. "It's so exciting to return to this problem with new technologies I could never have imagined then. I'm thrilled and honored to be part of this new effort to analyze these specially curated samples."

Watkins on Lunar Mission Advisory Board

by Alan Fischer



PSI Research Scientist Ryan Watkins

PSI Research Scientist Ryan Watkins has been named a member of the Science Advisory Board for the Blue Origin lunar transportation service, Blue Moon.

"My role has been to provide feedback regarding the Blue Moon lander design and landing site selection. The Board members provide feedback on their subsystem designs and payload capabilities," Watkins said. "My expertise has mainly been on landing site selection and some general feedback related to plume effects during landing – but at this stage we are all providing any kind of input we can regarding what we think is feasible and reasonable for their design concepts, from a science perspective."

Science Advisory Board members are consultants to Blue Origin, not full-time employees.

Blue Origin's Blue Moon project is a scalable lunar transportation service that is designed to be able to land anywhere on the surface of the Moon. For more information on Blue Moon, visit www.blueorigin.com.

"It is an honor for me to be selected to serve on the Board, especially since I am serving alongside several prominent lunar and planetary scientists, including the only geologist who has walked on the Moon, Harrison "Jack" Schmitt, who flew on Apollo 17. I am acting as an early career representative and feel that it is imperative that Blue Origin and other spacefaring entities continue to keep the next generation involved with the future of lunar exploration," Watkins said. "The early career generation not only has a passion and vision for lunar science and exploration, but we are the future workforce for NASA, academia, and industry. As such, I am honored that Blue Origin values my input and expertise as they move forward in their plans to return the U.S. to the lunar surface."

Blue Origin's announcement took place May 9 at the Walter E. Washington Convention Center in Washington, D.C.

Frontpage masthead: NASA's Juno spacecraft flew by Jupiter in December 2018 capturing this image of its turbulent southern hemisphere and its Great Red Spot. Citizen scientists Gerald Eichstädt and Seán Doran created this image using data from the JunoCam imager.

Credit: NASA /JPL-Caltech/SwRI/MSSS/ Gerald Eichstädt and Seán Doran

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Chris Holmberg, Editor and Writer
Alan Fischer, Writer and Photographer
Special thanks to Dianne Janis, Carol Neese, and Elaine Owens

Stephen E. Wood Joins PSI *by Chris Holmberg*

Steve Wood hiking in the Cascades with his daughter, Cameron. *Credit: Steve Wood*

Stephen E. Wood joined PSI in September 2018 as a Senior Scientist. Before that he was at the University of Washington in Seattle where as a Research Assistant Professor he taught remote sensing and planetary geology to upper level and graduate students and conducted his science research for 19 enjoyable years. He will continue doing research from his Seattle office, traveling to Tucson periodically.

Steve holds a Bachelor of Science in Physics from the University of North Carolina at Chapel Hill, and a Ph.D. from UCLA in Geophysics and Space Physics.

When he was young, Steve was a serious animal and nature lover – capturing and studying snakes was a specialty – so it was natural that he would study biology in high school. In fact, he was on a genetics/physics track in college until a visiting professor caused him to alter his course. In the late 1980s at Chapel Hill, Steve, then a physics major, took a geology elective for fun and heard Brown University Professor Jim Head lecture on planetary geology, specifically about Venus. That changed everything! The inspiration was discovering that space could be studied by methods other than exclusively peering through a telescope: There were spacecraft missions exploring new worlds.

Carl Sagan's groundbreaking 1980s television show, *The Cosmos*, had a huge impact on Steve, as did science fiction works by Isaac Asimov and Larry Niven, and *Star Trek* and *Star Wars* films.

Steve's father was a civil engineer; for several years when Steve was young he and his family lived in Saudi Arabia. He also spent some time in Mogadishu, Somalia, helping his father with engineering projects. Thus he speaks from experience when he describes planetary geology as "where engineering meets physics."

Currently, Steve studies the environment on other planetary bodies in our Solar System, from the permanently-shadowed polar regions of the Moon and Mercury where billion-year-old ice persists, to the lower latitudes of Mars where we see evidence for present-day flows of liquid water and glacial ice, and "fossilized" remains of ancient river valleys and lakes.

His research seeks to understand the relationships between the properties of planetary regolith (aka "soil") and the behavior of "volatile" compounds such as water and CO_2 (gas, liquid, or solid) as they evolve through time. In other words, he studies the climate systems of other worlds. One motivation for this work is that other planets provide valuable natural laboratories for testing models that are used to study Earth's climate system under a wider range of conditions but with fewer complicating factors (such as oceans or pervasive biology).

Steve is also interested in determining if conditions suitable for life, as we know it, could exist elsewhere in the Solar System, either now or in the past. And from a practical perspective, his work helps us learn about the conditions and resources that are available in places where humans are likely to visit in the not-too-distant future.

Steve's research methods include theoretical modeling, laboratory experiments, and analysis of data from spacecraft missions. In collaboration with other UW faculty, he has built an environmental simulation chamber that can recreate conditions at the surface of Mars (temperature, atmospheric pressure, humidity, solar and IR radiation) in order to test model predictions regarding the properties and behavior of ice in an analog soil sample.

He has also worked on a number of planetary spacecraft missions, including the Phoenix Mars Lander mission which landed near the north polar cap of Mars in May 2008 and operated throughout the long Martian summer, making the first direct observations of atmospheric humidity, subsurface ice, and precipitating snow.

In his free time, Steve enjoys hiking in the Cascade mountains with his wife and two daughters (ages 10 and 6).

PSI extends the warmest of welcomes to Steve!

Edges of Early Martian Sea *(cont'd from front page)*

ago, and reconcile the mission's i*n situ* geologic observations and decades of remote-sensing outflow channel investigations.

The sea bears an uncanny resemblance to the Aral Sea on Earth in that both lack distinct shoreline terraces. Its rapid regression over shallow submerged slopes resulted in rates of shoreline front retreat too fast for the terraces to form. The same process could partly account for the long-recognized lack of northern plains shorelines on Mars.

"Unlike on Earth, this sea was likely fed by groundwater. If the ancient source aquifers hosted life, the proposed marine sedimentary materials at the Pathfinder landing site might contain a record of that life, a location easily accessible by future missions," Alexis said.

"An exciting observation is that the inland sea and the previously proposed northern plains ocean share a maximum paleoshoreline elevation, implying a subsurface connection, perhaps through conduits, between the two marine bodies soon after they formed. This elevation match forms a new powerful observation that strongly favors the northern ocean hypothesis," said PSI Senior Scientist Dan Berman, a co-author in the paper.

PSI Senior Scientists Mark Sykes, Maria E. Banks and Jeff Kargel are co-authors on the paper.

Dragonfly Mission to Study Titan *by Alan Fischer*

In July, NASA announced funding for the Dragonfly mission, featuring a drone-like rotorcraft lander that would explore the chemistry and habitability of dozens of sites on Saturn's moon Titan. It is slated to launch in 2026 and reach Titan in 2034.

The Dragonfly mission, part of NASA's New Frontiers program, will sample materials and determine surface composition to investigate Titan's organic chemistry and habitability, monitor atmospheric and surface conditions, image landforms to investigate geological processes, and perform seismic studies.

PSI Senior Scientists R. Aileen Yingst and Catherine Neish will be Co-Investigators on the Dragonfly mission.

Catherine will study Titan's geology, with a particular focus on impact cratering, volcanism, and aqueous surface chemistry. Aileen will research what geologic processes have been – and currently are – active on Titan.

"Unlike other worlds we've landed on, Titan really has an otherworldly feel," Aileen said. "For a geologist, being able to study and remotely move around on the surface of a planet where water ice is as hard as rock, and liquid water would be considered a lava, is tremendously challenging and exciting."

"My Ph.D. dissertation investigated the creation of biological molecules on Titan's surface. Titan is a natural laboratory for the study of prebiotic molecules," Catherine said. "I am thrilled to have the opportunity to 'collect the results' of these natural experiments as a part of the Dragonfly team."

Dragonfly is a dual-quadcopter, Martian-rover sized lander that would take advantage of the environment on Titan to fly to multiple locations, some hundreds of miles apart.

Credit:NASA/Johns Hopkins Applied Physics Laboratory

Titan features water ice, methane, carbon-based molecules and energy needed for life. Dragonfly will investigate organic chemistry, habitability, and the presence of past or current life.

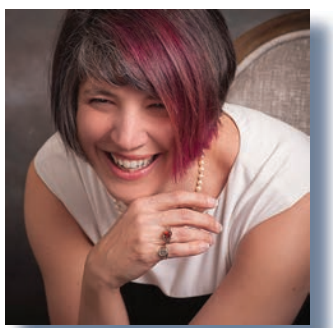
Elizabeth Turtle, lead investigator on Dragonfly, worked at PSI from 2002-2006 and is now at the Johns Hopkins Applied Physics Laboratory, which manages the mission for NASA.

New Frontiers is NASA's largest program of competitively selected planetary science missions. The program calls for a mission cost limit of $850 million for development, excluding launch and operation costs.

New System to Offer High-Res Images, Video of Lunar Landings *by Alan Fischer*

A new spacecraft-mounted camera system funded by NASA is poised to return the first high-resolution video of a landing plume as it lands on the Moon.

The Heimdall camera system project, headed by PSI Senior Scientist R. Aileen Yingst, consists of four color cameras and a DVR to store images until they can be uplinked to Earth.



PSI Senior Scientist R. Aileen Yingst is the head of the Heimdall camera system project and is also a Co-Investigator on the Dragonfly mission (see article above).

"The camera system will return the highest resolution images of the undisturbed lunar surface yet obtained, which is important for understanding regolith properties," Aileen said. "We will be able to essentially video the landing in high resolution for the first time, so we can understand how the plume behaves, how far it spreads, how long particles are lofted. This information is crucial for the safety of future landings.

"Like its namesake in Norse mythology – Heimdall, the watchman of the gods – the Heimdall camera system has broad vision: It is designed to image a lunar landing site from above the horizon to the ground directly below the lander," said Aileen, Principal Investigator on the project. "Also like its namesake, it is a shapeshifter; the system has flexible mounting options adaptable to a range of payload or mission goals."

Heimdall includes a wide-angle descent imager positioned to capture near-video-speed images of the interactions of the exhaust plume with the lunar regolith, and a narrow-angle regolith imager positioned looking down, to image the surface at approximately 35 µm/pixel (less than the width of a human hair). Two wide-angle panoramic imagers will be positioned to look outward at the landscape.

PSI Research Scientist Ryan Watkins is part of the Heimdall team. She will be studying the interaction of rocket exhaust plumes with the surface of the Moon, and will create digital terrain models.

Funding for the project is $2.3 million over two years. The camera is funded as part of NASA's partnership with commercial entities to send scientifically robust payloads to the Moon. Heimdall is part of NASA's Lunar Surface Instrument and Technology Payloads program.

Director's Note: *Testifying before Congressional Subcommittee on Space*

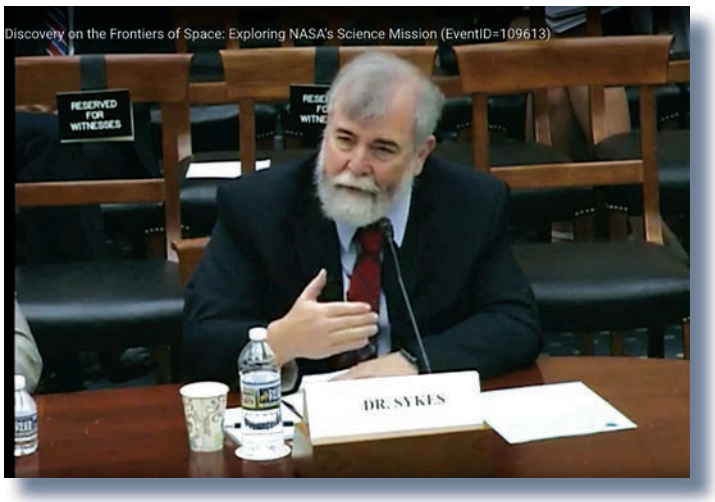
It's always an honor to testify before Congress and present one's views on a variety of topics. In June, I was before the House Subcommittee on Space and Aeronautics along with several others, and we talked about the effort to land Americans on the Moon again by 2024, the importance of the Near-Earth Object (NEO) Camera mission, maximizing the bang for the buck from research programs and missions, and China.

I argued for a dedicated science team for any human exploration activity to the Moon or elsewhere, to assist in planning and provide support – after all, we are the pathfinders.

I described NEOCam as essential to understanding the population of NEOs that threaten the Earth. At one point I was explaining at length about the kind of subpopulations it might reveal interior to the Earth's orbit that could explain an excess of Chelyabinsk-type explosions in the atmosphere, when *I* asked the Member who had asked me a question to cut me off, since I could talk forever. Another member said "never apologize for being enthusiastic" to the chuckles of the committee.

I described the consequences of NASA being the only agency to withhold cost information from proposal reviewers – I have something of a reputation for talking about fiscal responsibility and maximizing science return on investment. Finally, I called for the relaxation or removal of the ban against NASA funds supporting bilateral activities with China.

China is a greatly expanding and successful player in Solar System exploration, and we already have a lot of regulation in place to effectively deal with security issues. I look forward to PSI partnering with them on future initiatives.



In June 2019, PSI CEO and Director Mark Sykes testified before Congress, sharing his views on a variety of space topics.

(Credit: Screenshot from the Congressional hearing video by Alan Fischer)

Since testifying, I have answered additional queries and had discussions with staff on both the House and Senate side. I have been interacting with people on the Hill for more than 20 years. When I meet with staff, it generally ends up being a bipartisan group – everyone finds what we do in exploring the Solar System to be very interesting! I think the biggest challenge, however, continues to be to find a long-term, open-ended vision to motivate human space activity that goes beyond a target on a particular timescale.

Mark V. Sykes
August 2019

PSI Staff News

PSI Research Scientist **Ryan Watkins** and her husband Matt welcomed their second daughter this spring. Claire Abigail Watkins was born on April 6, weighing 6 lbs 15 oz, and measuring 20 inches long.

Claire is doing very well, considering she had to be resuscitated just after she was born. And now Alexis (age 2), after making the shocking transition from only child to older sibling, adores her little baby sister.

PSI Research Scientist **Eva Lilly** and her husband Clayton added another new person to their family this summer. Their second child arrived early on June 20. Samuel Edward Lilly made a "nice and loud entry with 8 lbs 7oz of cuteness," Eva said.

Mother and son are doing very well. While newly crowned 'big sister' Elizabeth (age 3) is very excited to have a little brother.

Congratulations, scientists!

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Pamela Gay Wins Isaac Asimov Award *by Alan Fischer*

In March, the American Humanist Association bestowed its 2019 Isaac Asimov Science Award to Pamela Gay for her work in astronomy and technology, and for playing an important role in creating a more informed and progressive society by communicating science to the public.

Pamela, a Senior Scientist and Senior Education and Communication Specialist at PSI, is an astronomer, writer, and podcaster focused on using new media to engage people in science and technology.

"To receive an award named after Isaac Asimov is a particular honor. My own love of science originated in a love of science fiction and a desire to learn what science in that fiction could be made possible," Pamela said. "Today I hope to find ways to inspire future writers to write new stories using modern science. It is through these future histories that we so often learn how science can potentially corrupt, but also advance and liberate our society."

Pamela is co-host of the Astronomy Cast podcast and one of the streamers for the CosmoQuestX Twitch channel, which are now programs at PSI. She leverages these platforms to educate people and invite them to do science on CosmoQuest.org. This website allows everyday people to map out other worlds and find the safe places to land a spacecraft and the scientifically interesting places to explore.

John Hooper, of the American Humanist Association, presented PSI Senior Scientist Pamela Gay with the 2019 Isaac Asimov Science Award for her work in astronomy and technology, and communicating science to the public.

Credit: Roy Speckhardt, American Humanist Association

"Humans are one people sharing one sky, and there is simply too much universe for scientists to try and understand without help," she said. "As a scientist, I work to communicate science to the public, making the world my classroom. Then I invite those people to help us explore the universe with me through citizen science."

Pamela received the award at the American Humanist Association's 78th Annual Conference June 7 at Carnegie Mellon University in Pittsburgh, Pennsylvania.