Planetary Science Institute
NEWSLETTER

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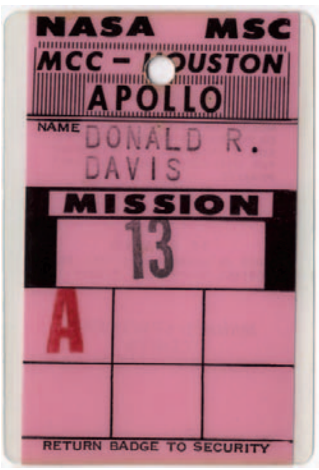
Apollo 13: Forty Years Later

Don Davis recalls his role in the mission



Everyone needed a badge to get into mission control.

By April 1970, even the Apollo program was getting a bit humdrum for many of us who had been involved in NASA's space program for years. Hard to believe, but going to the moon was just routine following the stunning successes of the previous 16 months: Apollo 8, breaking the bonds of Earth gravity with the first human spaceflight, sending astronauts to orbit the moon at Christmastime, 1968; Apollo 10, the dress rehearsal mission; Apollo 11, the first lunar landing, thereby meeting President Kennedy's 1961 challenge to the nation to put a man on the moon; and Apollo 12, struck by a tremendous bolt of lightning at lift-off yet still completed a successful mission. So, everything was going smoothly in the program, and the big worry within the project was the American public's growing disenchantment with space as Vietnam continued to splinter the country.

However, there were seven more missions planned (Apollo 20 was canceled in January, 1970), so NASA continued on, expanding the capabilities of the astronauts on the moon with more stay time, a buggy to drive, and a host of other improvements that led to a scientific treasure trove. As befitting a rational, science-based organization, NASA, of course, would never consider changing the next mission from number 13 — no superstitions here. The gods must have chuckled.

I was working in my office on the evening of April 13 (that number again) when I heard a tapping on my window. Looking outside, I saw my wife who passed the message, "Mission control wants you to contact them ASAP!" NASA had called my home, and my wife had tried to call me, but the switchboard at TRW Systems, where I worked as a contractor on the Apollo program, had shut down for the evening and incoming calls were not accepted. I called in, learned that there had been some type of emergency on Apollo 13, that I should stay in touch and be prepared to come in on short notice.

Some background. I was fortunate to have gotten my PhD in the field of celestial mechanics in 1967 and even more fortunate that celestial mechanicians were in demand for Apollo, so it was relatively easy to find a job then. (Timing is everything when you finish school and enter the workforce. I have always been grateful to Kennedy for launching the space program just in time to open job opportunities for me when I needed one.) My family and I moved to Houston in early 1967 and I

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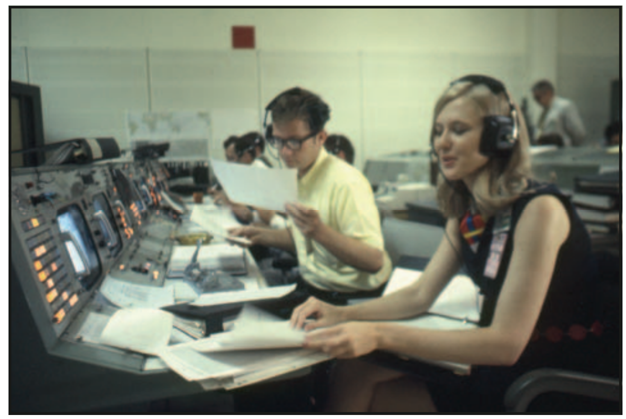


In 1970, Don Davis (center) working at mission control alongside Poppy Northcutt, a member of the software team throughout the project. During Apollo 11, a **Paris Match** ***reporter featured her in an article, dubbing her the "Venus of Apollo."***

Don Davis (center front) at NASA's Mission Control Center.

Inside this issue:

Apollo 13: Forty Years Later *(continued)*

went to work on a project developing computer programs for mission control to compute all maneuvers required to bring spacecraft safely back to Earth. This software was initially termed the "abort" program, a holdover from the days when spaceflight consisted of just orbiting the Earth. However, political correctness, as well as a recognition of the changing nature of the software, led to the new name of "Return-to-Earth" program. There were five dynamicists working on A60.1, the contractual name of the task charged with developing this software. Not being astute in the ways of big projects, I was too slow in finding a reason to say "no," and thus became the task manager of the effort in 1968.

So, what did we do? Mission requirements specified that we develop a number of options for getting the astronauts home under any conceivable circumstance. Normally, we would compute a trajectory to return the spacecraft to a specific spot on the ocean. But what if there was only limited fuel due to some unspecified emergency? Then we computed the trajectory that would get them back to Earth with the minimum expenditure of fuel, regardless of where they landed. Or what if there was a medical emergency and they needed to get back ASAP? Then we computed the minimum trip time trajectory, again regardless of where they would land. One imperative boundary condition absolutely had to be met for all trajectories: hit the entry interface. This was a condition of the speed and direction of the spacecraft when it re-entered Earth's atmosphere. If the spacecraft's re-entry was too shallow, it would skip out of the atmosphere into a long orbit around the Earth, and the astronauts would perish when their life support gave out. Too steep, and the spacecraft would burn up as a magnificent meteor. Hitting this entry interface was all important.

So, we developed the computer code and gave it to IBM who did the implementation of the mission control computers and software (that giant room filled with state-of-the-art computers know as the RTCC, Real Time Computer Center). The team members and I worked in mission control in support of Flight Director Gene Kranz and the other flight controllers to interpret the output of the RTCC, and to be prepared to fix any glitches. The flight controllers had specific areas of responsibility and their call signs reflected these: "fido" (flight dynamics officer), "guido" (guidance officer, pronounced guide-o, not the Italian pronunciation), etc. We were in support of "retro," the flight controller responsible for getting the astronauts in the right orbit to come home. When you watch documentaries or movies about the Apollo program and the flight director polls the individual controllers about a decision, retro is always the first name to be called, reflecting the seating arrangement in mission control (though we liked to argue that it's in order of importance of the controllers).

There were months of "sims," simulations of the upcoming mission that were carried out to prepare not only for the nominal mission, but also for a variety of fiendish problems that the trainers could come up with. Since these simulations were crucial to the success of the program, our team practiced them continually at mission control.

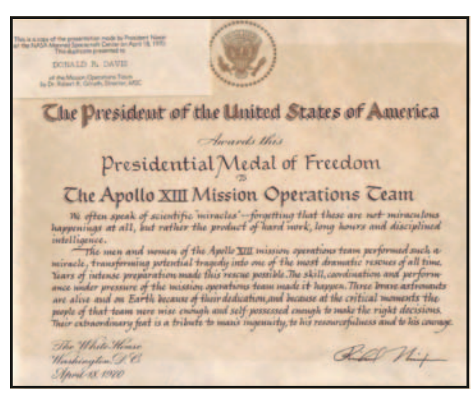
Back to 1970, now 56 hours after the very routine April 11 launch. Still en route to the moon, the Apollo 13 spacecraft suffered serious damage when the number two oxygen tank suddenly ruptured, causing real safety concerns for the crew and forcing cancellation of the lunar landing. After the initial assessment of the disaster, getting the astronauts into the lunar module and safe for the moment, the next decision was how to get them back to Earth as quickly and safely as possible. We computed what were called TCUA (Time Critical, Unspecified Area) trajectories, the minimum return time regardless of landing site and other variables. All solutions were possible with a healthy spacecraft, but no one knew if the engines would be able to execute the necessary long burns to turn the spacecraft around. After all, Apollo 13 was still on its way to the moon on what was termed a non-free return trajectory. As a safety measure, all of the earlier flights were on a free-return trajectory, an orbit which looped around the moon, using lunar gravity to slingshot the spacecraft back to Earth. The problem was, these trajectories limited the potential landing sites on the moon to those near the equator. With the earlier successes and the desire to go to more scientifically interesting sites, Apollo program managers decided to send Apollo 13 on a non-free return trajectory to reach the desired Fra Mauro crater landing site.

Therefore, the choice was to fire up the main engines and hope that they had not been damaged and could still deliver the sufficient thrust (delta-vee, in the vernacular) needed to return directly to Earth. Or, use the smaller engine of the lunar module, which was not thought to have been damaged, to put the spacecraft back on the free return trajectory, let the moon's gravity do the heavy lifting of swinging it back to Earth, then use the lunar module engine to do a burn to speed up the trajectory and get home a day earlier. The latter was the decision made and our good old return-to-Earth software calculated the necessary maneuvers.

For the next four days our team manned our post in mission control 24/7. Like so many events, much of the time passed slowly with little happening. Events were monitored, such as blowoff of the supercritical helium release valve which produced a tiny alteration of the trajectory. Nothing required any action, though. We were all waiting for re-entry, hoping against hope that the command module with its all important heat shield had not been damaged by the explosion. And we were planning to photograph the service module as it was jettisoned, to see for the first time what the damaged area looked like.

Like the rest of the world, we were turning blue waiting for the command module to come out of communication blackout following re-entry. Capcom (Capsule Communicator, the only one speaking directly to the astronauts) wished them a successful spashdown as the radio link was lost. An eternity passed until the predicted time of blackout end, but no voice from the spacecraft. Two more eternities passed as Capcom tried to establish radio contact until finally, four long minutes later, there were the glorious words, "Apollo 13 is here." The feeling of relief was absolutely incredible — they were alive and they were home! The joy was boundless. Let the splashdown parties begin!

Apollo 13 was my last mission. I was already planning to get back into the world of science before this mission and had started looking around. The timing was excellent as I found a position in Tucson working for the Illinois Institute of Technology where I joined Bill Hartmann and others in a group the ultimately became the Planetary Science Institute. The rest is history. ◻


DONALD R. DAVIS

The President of the United States of America

Awards this

Presidential Medal of Freedom

to

The Apollo XIII Mission Operations Team

We often speak of scientific "miracles"—forgetting that these are not miraculous happenings at all, but rather the product of hard work, long hours and disciplined intelligence.

The men and women of the Apollo XIII mission operations team performed such a miracle, transforming potential tragedy into one of the most dramatic rescues of all time. Years of intense preparation made this rescue possible. The skill, coordination and performance under pressure of the mission operations team made it happen. Three brave astronauts are alive and on Earth because of their dedication, and because at the critical moments the people of that team were wise enough and self-possessed enough to make the right decisions. Their extraordinary feat is a tribute to man's ingenuity, to his resourcefulness and to his courage.

The White House
Washington, D.C.
April 18, 1970

PSI Gets *WISER* *by Ed Stiles, Thea Caňizo and Alan Fischer*

PSI has received a $750,000 NASA grant to help improve science education in schools in the Tucson area, Texas, and Wisconsin. *Workshops in Science Education and Resources (WISER): Planetary Perspectives* will fund a series of professional development workshops targeting K-8 teachers. The funding will allow the PSI team to create instructional rock kits for use in workshops and classrooms, generate scientific visualizations and web-based virtual tours of planetary surfaces, and establish the "Ask An Expert" site where students, teachers, and the public can directly interact with PSI scientists.

PSI scientists are collaborating on the project with the Tucson Regional Science Center, a partnership of three independent school districts and several charter schools that is led by the Tucson Unified School District. The RSC supports member districts with nationally recognized curricula and instructional materials. "This collaboration will lead to further opportunities to engage teachers and students in space science, and will increase innovative, effective educational efforts to apply real-life applications to how we learn science," said RSC Coordinator Joan Gilbert.

PSI's Elisabetta Pierazzo advises teachers Joy Swanson (left) and Marilee Flynn how to use a rock kit to identify materials seen in images of Martian craters.

PSI's Larry Lebofsky (right) assists as teachers Carol Lugo and Tom Hawkins practice classifying craters by size and type.

The WISER team will further develop and expand the teacher workshops (www.psi.edu/epo/papt) it has been conducting since September 2008. Tucson science teachers – from about 60 schools who instruct about 5,000 students in grades 1 through 9 – attended nine offerings of three different workshops in the "Planets are Places Too" series: "Moon-Earth System," "Exploring the Terrestrial Planets," and "Impact Cratering!"

Participating teachers have been very enthusiastic; one-third attended more than one of PSI's workshops. In final evaluations, they rate the workshops very highly, highlighting the value of the scientist-teacher interaction. Not only have the teachers been able to tap into the knowledge of our scientists and experience the ways they conduct their research, but PSI scientists have also gained insight into the teachers' work and needs.

Along with principal investigator David Crown, the project team includes PSI educators Larry Lebofsky, Thea Cañizo, Sanlyn Buxner and Steven Croft, as well as PSI scientists Alice Baldridge, Les Bleamaster, Frank Chuang, Steve Kortenkamp, Elisabetta Pierazzo, and Aileen Yingst. Others on the project include Steven Anderson, director of the University of Northern Colorado's Mathematics and Science Teaching Institute, and Christopher Andersen and Bill Schmitt of the Science Center of Inquiry. ▫

Sanlyn Buxner: New Education Specialist at PSI

Sanlyn Buxner joined PSI this winter as an Education Specialist working in Tucson. Sanlyn, who is originally from Denver, CO, attended the University of Colorado in Boulder where she earned a bachelor's degree in molecular, cellular, and developmental biology. While a student at CU, Sanlyn worked at Fiske Planetarium and Sommers-Bausch Observatory running planetarium shows and evening telescope events, and assisting with the production of new shows. After graduation she spent several years working in science education and public outreach including working as a production intern at the Adler Planetarium and Astronomy Museum in Chicago; as an instructor at Astrocamp, a year-round residential science and adventure experiential camp; and as an outreach specialist and planetarium show producer at the University of Colorado.

Sanlyn moved to Tucson in 2004 to pursue a PhD in astronomy education research at the University of Arizona, and she received her master's degree in science education there in 2006. Her dissertation work investigates teachers who participate in summer science research programs and how their experiences are related to changes in their understandings in science, beliefs about science teaching, and shifts in their identity as science teachers. In Tucson, she has worked with teachers in the Tucson Unified School District to assist them in the design and revision of district-wide science assessments for students in grades 1 – 8.

She has also worked as the Education and Public Outreach Specialist for the Mars Odyssey Gamma Ray Spectrometer and NASA's Phoenix Mars Lander. In addition, she has developed and facilitated summer camps for middle and high school students, teacher workshops, and family science events. This past winter, she traveled to the Sultanate of Oman with Peter Smith (PI of the Phoenix Lander), Dana Smith, and Frankie Kolb to participate in the installation of an exhibit of Phoenix and HiRISE images in the Bait Al Baranda Museum in Muscat. During the week, they participated in presentations and hands-on activities for the local community.

In Oman (from left) Sanlyn Buxner, Peter Smith (UA), Sultan bin Hamdoon Al Harthy (Chairman of the Muscat Municipality), Dana Smith (Peter's wife) and Frankie Kolb.

Sanlyn is currently working on several projects at PSI, including making podcasts with Elisabetta Pierazzo, and will help develop and facilitate teacher workshops through Project WISER. In addition to her work at PSI she teaches undergraduate science labs and graduate statistics at the University of Arizona.

Welcome to PSI, Sanlyn!

Ross Irwin Joins PSI

Ross Irwin is a new Research Scientist at PSI, stationed at NASA's Goddard Space Flight Center in Greenbelt, MD. His specialty is the evolution of landscapes, with a particular interest in early Mars. Most of Ross's publications focus on the development of valley networks and paleolakes, which provide the best empirical evidence for a warmer, wetter Martian paleoclimate.

The concept that Martian valley networks developed over a brief period of Earth-like (but more or less arid by our standards) conditions around the Noachian/Hesperian boundary, about 3.7 billion years ago, helps to explain why the valleys are so poorly developed in an environment where precipitation and surface water were available. Estimates of river discharge based on channel dimensions suggest that Mars had Earth-like runoff at times, on the order of a centimeter per day from some watersheds. It did not necessarily rain often, but larger watersheds generated enough runoff to fill and overflow lakes, sometimes producing spectacular canyons. The climate of early Mars before this time seems to have been drier, with weak or intermittent runoff, substantial rock weathering, and frequent impacts by asteroids and comets.

Current research projects include the amount of erosion on early Mars, the annual runoff from Martian watersheds, landscape evolution on Saturn's moon Titan, and three field projects. A field study of box canyons suggests that groundwater sapping does not usually act alone in forming canyons with steep headwalls, and in some locations (particularly layered rocks with a strong cap rock) it can play no significant role at all. Ross and colleagues also proposed the short-listed Holden crater landing site for the upcoming Mars Science Laboratory rover. Geologic mapping projects with colleagues include the Holden crater area and a large section of the Martian highlands.

Ross received his Bachelor of Science (1997) in Geological Sciences from Virginia Tech and MS (2000) and PhD (2005) from the Department of Environmental Sciences at the University of Virginia. Ross worked at the Smithsonian Institution's National Air and Space Museum from 2001 to 2010. Previously, he was a geospatial analyst at SAIC, a large government contractor.

When not working on the solar system, Ross serves as the at-large representative and treasurer on a 364-unit condominium Board of Directors, and he helps to maintain his family farm in Virginia, about 70 miles west of Washington, D.C. Other interests include sailing, diving, backpacking, theater, stand-up comedy shows, and mechanical or home improvement projects.

We're glad you have joined PSI, Ross!

Baby Balme!

The newest member of the extended PSI family, Isobel Sarah Balme, was born to Anne Jay and PSI Research Scientist Matt Balme in England on June 5. She weighed 8 lb. 9 oz., and she is beautiful. Congratulations, Anne and Matt!

Floyd Herbert 1942-2010 *by William K. Hartmann*

On May 12 our long-time colleague and PSI alumnus, Floyd Herbert, a planetary physicist, died in Tucson. Floyd worked briefly at PSI in the 1970s, helping with our experimental program on low-speed rock collisions, between grants at the Lunar and Planetary Laboratory. Floyd studied physics at Caltech, taking courses from Richard Feynman, then came to the University of Arizona and obtained a PhD in physics. He was also an excellent photographer who studied with Ansel Adams, an avid motorcyclist, and an ultralight pilot. He was a high school chum and later college roommate of PSI scientist Chuck Wood.

After early diagnoses of serious respiratory problems (and predictions of possible death by age 40), he took up karate, studied in Japan, and received a black belt. This was followed by marked improvement in his condition, although it was finally responsible for his peaceful death at age 68.

Scientifically, Floyd worked on issues of magnetic fields interacting with asteroids, Io, and extra-solar planets. An innovative example was his 1979 paper in Icarus, with Charles Sonett, then director of the Lunar and Planetary Laboratory at the University of Arizona. Herbert and Sonett analyzed heating of asteroids by strong magnetic fields and solar winds, associated with the "T Tauri" phase of solar system formation. In traditional theories, planetary heating comes from radioactive elements in rock minerals that would melt asteroids from the inside out, with the largest bodies having the most heating. In the Herbert-Sonett mechanism, however, the heating came from electric currents induced in the surface layers by the magnetic effects of the passing early intense solar wind. The heating would occur from the outside in, involving not just size but also distance from the sun and surface composition. The Herbert-Sonett model offered an explanation of why some moderate-sized bodies, like Vesta (2.36 AU semi-major axis), have once-melted igneous surfaces, while larger bodies, like Ceres (2.77 AU axis), seem to have unmelted primitive surfaces.

The subject of asteroid heating has been somewhat dormant in recent years, but tests of Floyd's ideas may come with the Dawn mission, now sailing toward both Vesta and Ceres, with the involvement of PSI Director Mark Sykes.

At age 49, he met and married the light of his life, Maggie Gilman, creating a wonderful domestic partnership that lasted the rest of his life. Floyd will be greatly missed, particularly for his gentle, wonderful sense of humor. ▫

Jade Bond: Another New Face at PSI

Jade Bond joined PSI last fall (2009) as a Postdoctoral Research Scientist working off-site from Lexington, KY. Her research currently focuses on the very broad area of the chemistry of extrasolar planetary systems and its implications for terrestrial planets. More specifically, she is primarily working on determining the elemental composition of simulated extrasolar terrestrial planets. She hopes this will lead to a better understanding of the full range of terrestrial planetary compositions possible within the 350-odd known extrasolar planetary systems.

Originally from Australia, Jade earned her BSc in physics from the University of Sydney where she worked with Prof. Chris Tinney to determine spectroscopic abundances of known planetary host stars observed as part of the Anglo-Australian Planet Search. She also received a Graduate Diploma in science communication from Central Queensland University before moving to Arizona to complete her PhD in planetary science at the University of Arizona. Working with Dr. Dante Lauretta, she focused on the unique chemistry of known extrasolar planetary systems and the potential consequences of these compositions on terrestrial planets. This project was the first time anyone had included detailed chemical models with dynamical simulations of terrestrial planet formation. She also recently completed a Master of Public Administration (Policy) through Flinders University. Yes, she really does have four degrees in four completely different areas!

Jade has a broad range of interests in astronomy and geology. After completing her PhD, she worked for a year at Steward Observatory (UA) on refining and expanding her simulations of terrestrial planet compositions. Currently, she is working with Dr. David O'Brien to determine simulated terrestrial planet compositions for a variety of conditions including giant planet migration. She is also expanding her work to include simulations of ices and clathrates in a variety of systems, along with determining stellar spectroscopic compositions across known stellar clusters.

Jade recently left Tucson and moved to Lexington, KY, when her partner Jason was relocated for work. Although currently landlocked, Jade loves to sail and spend time at the beach when she has time. She also enjoys rugby and stays up late to watch any game she can! Currently she spends her free time volunteering for a variety of organizations, working on a number of quilts she has started or just being outside, exploring the Bluegrass state.

Good to have you aboard, Jade!

Director's Note: *PSI Begins a Development Program*

To raise essential funding for the Institute, PSI has begun a new and much needed professional level development program. These funds will provide working capital for our growing solar system research programs, support public involvement in the Institute, and enable a capital campaign for a permanent corporate headquarters.

I am very pleased to announce that Amy Hartmann-Gordon will be running this program as PSI's first Development Officer. Amy has an MBA from the University of Arizona and was the Director of Finance who ran the successful fundraising campaign for Congresswoman Gabrielle Giffords of Tucson. Prior to that, she was the Associate Director of Marketing for the Arizona-Sonora Desert Museum. Most specially, Amy has a personal tie to PSI as the daughter of founder William K. Hartmann! In a sense, she is coming home to a place whose mission and capabilities she already knows well. We are very fortunate to have her join us, and we look forward to a long and successful relationship.

Building a development program from scratch is not an easy task. Many non-profits start out with either a significant endowment or a large built-in community of supporters. For many years, PSI was part of Science Applications International Corporation (SAIC) before splitting off to become a non-profit in 1995, without such an infrastructure in place. Last summer we finally started planning our development program with Amy by laying out a two-year $70K budget with the goal of making our development program self-sustaining (we are forbidden from using federal funds we receive from NASA for fundraising). Through a number of generous contributions from members of our Board of Trustees — all of whom contributed — as well as further generous contributions from our staff and affiliates, we were able to raise $65.1K, enough to begin operations. Any further donations, which are tax deductible, to help us reach our initial goal will be deeply appreciated!

Development is not just raising money. It is also about building relationships within our communities. Every year PSI funnels millions of dollars into the Tucson community and provides high-paying jobs to highly educated and experienced workers. PSI scientists are engaged in exciting research to better understand our solar system, planets around other stars, and the insights these provide about our home planet, Earth. We are engaged in many ongoing NASA missions. We enjoy sharing our work with students in local area schools and with the public in general at open lectures and before community groups. We are also involved in teacher training and have been able to provide continuing education credits for Tucson area teachers at a time when state programs have been slashed. We have received funding from NASA to expand this program and to see how we might be able to extend it to other communities around the country where our scientists live and work.

Under the leadership of Amy Hartmann-Gordon, we look forward to expanding our connections with our communities and creating more opportunities for everyone to participate in building an exciting future to be shared by all.

Mark V. Sykes
June 2010

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PLANETARY SCIENCE INSTITUTE
Newsletter Published Quarterly
1700 E. Fort Lowell Rd., Suite 106
Tucson, AZ 85719-2395
Phone: 520/622-6300
Fax: 520/622-8060
www.psi.edu