Universities Space Research Association

2018 ANNUAL REPORT

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MISSION

- Advance the space- and aeronautics-related sciences exploration through innovative research, technology, and education programs
- Promote space and aeronautics policy
- Develop and operate premier facilities and programs by involving universities, governments and the private sector for the benefit of humanity

VALUES

- Passion—for science, technology, and education
- Partnerships—with universities, governments, and the private sector
- Professionalism—through excellence, accountability, and respect for others

Cover: Artist's rendering of an image of the moon. Image courtesy: Forge Branding

The Delta IV Heavy rocket carrying Parker Solar Probe is seen in this long exposure photograph taken during launch on Sunday, Aug. 12, 2018 from Launch Complex 37 at Cape Canaveral Air Force Station, Florida. Image courtesy: NASA/ Johns Hopkins APL/Ed Whitman

Message from the President and Chief Executive Officer and the Chair of the Board of Trustees

Jeffrey A. Isaacson
President and
Chief Executive Officer

William Ballhaus, Jr.
Chair, Board
of Trustees

Fifty years ago, at the height of the Apollo program, USRA was founded under the auspices of the National Academy of Sciences at the request of NASA. At the time, NASA sought a new organization with which to work side-by-side, to engage and organize the research community. James Webb, NASA Administrator from 1961-1968, wrote to Academy President Frederick Seitz, "I would like to propose that the Academy take initiative in convening the representatives of a number of appropriate universities to discuss the formation of such a consortium." The resulting chartered purpose, as set by our member universities, is straightforward:

> "To constitute an entity by means of which universities and other research organizations may cooperate with one another, with the governments of the United States and other nations, and with other organizations toward the development and application of space-related science, technology, and engineering."

The first task of the newly formed USRA was operation of the Lunar Science Institute, located in a renovated mansion near the NASA Manned Spacecraft Center in Houston. Today, the Lunar and Planetary Institute (LPI), housed in a modern facility and located near the NASA Johnson Space Center, continues the important job of organizing community activities in support of NASA's exploration of our solar system.

As we approach our 50th anniversary, it is informative to see the evolution, extent, and depth of the activities in which we are now engaged, in fulfillment of our charter. In 2018, the LPI led a team of New Horizons researchers that published the first official global and topographic maps of Charon and Pluto. Scientists were amazed at the towering peaks and deep valleys that were revealed in the data returned from the New Horizons spacecraft in July 2015. The LPI-led team registered all images from the Long Range Reconnaissance Imager and Multispectral Visible Imaging Camera systems and assembled the mosaics.

Another major activity at USRA is the science operations for the Stratospheric Observatory for Infrared Astronomy (SOFIA). This past year, the HAWC+ instrument, developed by Yerkes Observatory at the University of Chicago, and upgraded by Cal Tech's Jet Propulsion Laboratory, provided a dramatic advancement in astronomers' capability to map magnetic fields. HAWC+ is producing outstanding results on the influence of magnetic fields on star formation and galaxy outflows. Publications resulting from SOFIA observations increased more than 50 percent over the previous year, and changes to further increase scientific productivity were implemented.

At NASA's Ames Research Center, USRA is tasked with supporting operations of the Ames Airborne Sensor Facility (ASF). The primary mission of ASF is to support the airborne science research of NASA's Earth Science Division with sensor development, data collection, and instrument engineering services. Two deployments in 2018 utilized a NASA P-3B aircraft in Greenland, Alaska, and Argentina in support of Operation IceBridge. ASF personnel collected and processed over one million frames of imagery this past year, which is being used to document the changing conditions of sea and land ice.

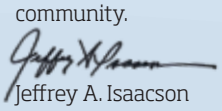
USRA's Research Institute for Advanced Computer Science continued research and development (R&D) efforts in quantum computing for aeronautics and space applications, as part of a jointly operated Quantum Artificial Intelligence Laboratory with NASA's Ames Research Center and Google. This past year included the first summer session of the USRA Feynman Quantum Academy, and our co-organizing the 7th International Adiabatic Quantum Computing Conference.

The United States Air Force turned to USRA to conduct a study on the challenges universities face when doing early stage research. In 2017, Secretary of the Air Force Heather Wilson announced the "S&T Strategy 2030" initiative, with the objective of updating Air Force methods for conducting R&D to meet the projected national security challenges of 2030. For its part, USRA carried out a seven-month effort, surveying over 120 university administrators and professors, culminating in a workshop at the USRA Washington Office with university and Air Force stakeholders present. USRA put forward innovative solutions to expand interactive engagement with the university community.

Within our educational activities, USRA coordinated or supported over 2,000 student interns, from high school to graduate school. We provided awards to undergraduates pursuing degrees in space-science and related engineering fields, owing in part to the service of our university representatives who served on review panels. Students at 55 universities applied, and more than twenty percent were minority students.

Four new universities were admitted to membership in USRA: Montana State University, University of Canterbury, University of Bern, and École Polytechnique Fédérale de Lausanne. This brings membership in the Association to 110 universities, including 13 non-US members. USRA remains financially healthy, with revenue growing by three percent over 2017 to $162.3 million.

A key to USRA's success through the decades has been meeting the new needs of our sponsors and addressing the new challenges faced by the university community we serve. Another key to our success is that we have remained true to our original nonprofit mission, and firmly grounded in governance by the university community. This report captures, if only in the space of these few pages, the range of our nonprofit mission, our commitment to our chartered purpose, and our service to that community.



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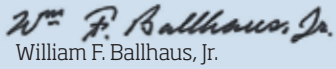
President and Chief Executive Officer



William F. Ballhaus, Jr.
Chair, Board of Trustees

Astronomy and Astrophysics

USRA scientists, in collaboration with scientists around the world, are contributing to our understanding of a wide array of current astrophysical problems, using nearly the full-range of the electromagnetic spectrum. Current work enabled by USRA includes the turbulent youth and explosive death of stars, the largest gravitationally-bound structures in the universe, the behavior of matter under the most extreme conditions and the origin of gravitational waves and high-energy cosmic rays, and the creation of the universe itself.

SOFIA observes magnetic field in the center of the galaxy adding new knowledge to the field

The Stratospheric Observatory for Infrared Astronomy (SOFIA) revealed a unique view of the streams of material close to the black hole in the center of the Milky Way – something that has never been observed before.

Using the newest scientific instrument, the HAWC+, developed by Yerkes Observatory of the University of Chicago and upgraded to its present form by NASA's Jet Propulsion Laboratory at the California Institute of Technology, SOFIA has made a dramatic advance in astronomers' capability to map magnetic fields. These fields permeate the universe and have significant effects on the motions and evolution of interstellar matter. HAWC+ images the intensity and polarization of far-infrared emission from interstellar matter, and the angle at which the polarization is oriented tells us the direction of the magnetic field within that material. SOFIA had previously imaged the so-called "circumnuclear ring" that surrounds the massive black hole at the center of the Galaxy. These observations reveal the distinct temperature of the streams of material and indicate it is likely heated locally by star formation rather than by photons from the black hole itself. The new galactic center image shows this same material but now with the polarization measured at each point.

The studies performed by the HAWC+ instrument on SOFIA are a glimpse into the instrument's potential for using far-infrared polarimetry to decode the physical phenomena of extragalactic regions.

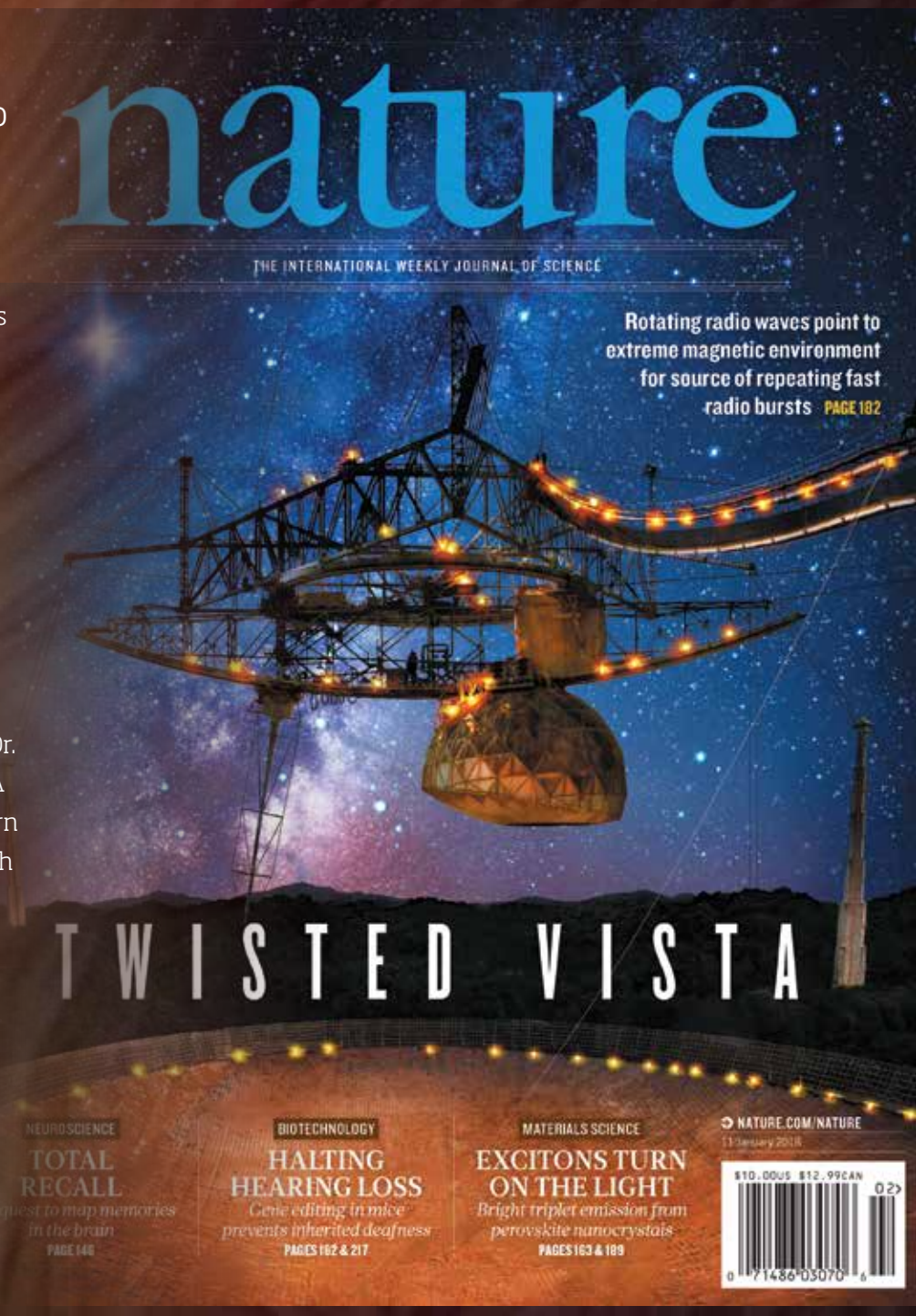
Background image: SOFIA's observservation of the magnetic field in the center of the galaxy. Image courtesy: SOFIA

Rotating radio waves point to extreme magnetic environment for source of repeating fast radio bursts

A team of scientists from Universities Space Research Association (USRA) and other institutions discovered that Fast Radio Bursts (FRB) may be coming from near a giant black hole. This stunning discovery was the cover story on Nature magazine.

Fast Radio Bursts are a strong and very short flash of radio waves first identified in 2007 using archival data obtained in 2001. Interestingly, most of the bursts have not been observed again, with the exception of one. "FRB121102 was found to repeat and is the only known FRB source to do so", noted Dr. Andrew Seymour, an Astronomer with USRA at Arecibo Observatory. "Even then, no pattern to the bursts have been identified, unlike with other radio phenomena, such as pulsars."

Though how FRBs are produced remains a mystery, astronomers last year confirmed that at least one of the bursts, FRB121102, which was first discovered at the Arecibo Observatory, originated from beyond our galaxy at a distance of 3 billion light years from Earth.



Issue of Nature magazine featuring work of USRA scientists and their collaborators. Image courtesy: cover image reprinted with permission from Nature Springer/Customer Service Centre GmbH

Bruno Rossi Award
USRA scientists William Cleveland, Valerie Connaughton, Adam Goldstein, William Paciesas and Oliver Roberts were part of a team that won the Bruno Rossi Award. Bruno Rossi Award is given annually by the High Energy Astrophysics Division of the American Astronomical Society for a significant contribution to High Energy Astrophysics.

Scientists working with SOFIA detect properties of the most pristine comets

SOFIA' s instruments have enabled astronomers to observe various aspects of the solar system. Comets are our most direct link to the earliest stages of the formation and evolution of the solar system. Every few years, a new comet is discovered that is making its first trip toward the Sun from the Oort Cloud, a zone of icy objects beyond the orbit of Pluto. Such opportunities offer astronomers a chance to study a special class of comets.

"Comet C/2012 K1 is a time capsule of the early solar system's composition," said Dr. Charles Woodward of the University of Minnesota, the lead of the observing team. "Every opportunity to study these bodies contributes to our understanding of the general characteristics of comets and the formation of small bodies in our solar system."

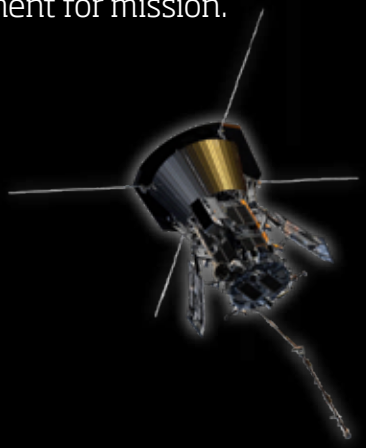
Unexpectedly, these observations revealed weak silicate emission features from the comet, rather than the anticipated strong silicate features found in prior observations of Oort Cloud comets like Hale-Bopp. By analyzing these silicate emissions and comparing them to thermal models, the researchers determined that the coma's dust grains are large and composed predominately of amorphous carbon rather than crystalline silicate. This composition challenges existing theoretical models of how Oort cloud comets form. The strength of Comet C/2012 K1's silicate features observed in mid-infrared with SOFIA have set the stage for what we have proposed for observations using the forthcoming James Webb Space Telescope – to study even fainter more distant comets. Scientists believe there will be a nice synergy between those two missions in target selection and targeted follow up.

Observations conducted by NASA's flying observatory, whose science is managed by the Universities Space Research Association, reveal significant advances being made in the scientific knowledge concerning our solar system.

Artist's impression of properties of most pristine comets. Image courtesy: Lynette Cook

Heliophysics

USRA is actively involved in Heliophysics , Solar Physics, and Space Weather at the Science and Technology Institute in Huntsville, AL. Areas of expertise include particle acceleration in the heliosphere, modeling and assessment of charged particle environments and effects in near-Earth and interplanetary space, space weather assessments for NASA, space radiation, solar wind environment testing and operational assessment for mission.



Parker Solar Probe

USRA's world class investigators are scientific and technical leaders who work collaboratively with science agencies and universities to solve complex problems. Dr. Ken Wright is no exception. His contributions to developing one of the instruments aboard the Parker Solar Probe–NASA's daring historic mission to fly seven times closer to the Sun than any other mission before–are significant.

The Earth is 93 million miles away from the Sun and the Parker Solar Probe will come within 3.85 million miles of the Sun. It will fly into the solar corona and will orbit 24 times between 2018 and 2025. The Parker Solar Probe Mission will revolutionize our Understanding of the Sun resulting from the data gathered.

Data from the instruments aboard the Parker Solar Probe will allow scientists to decipher how the corona gets so hot and to understand more about solar wind and solar flares that can shake the earth's magnetic field and wreak havoc on Earth. Understanding these phenomena will enable us to be better prepared for space events and their impact on Earth. Image courtesy: NASA

Lunar and Planetary Science

USRA works to advance our understanding of the solar system, from its formation, through its evolution, to its current missions.

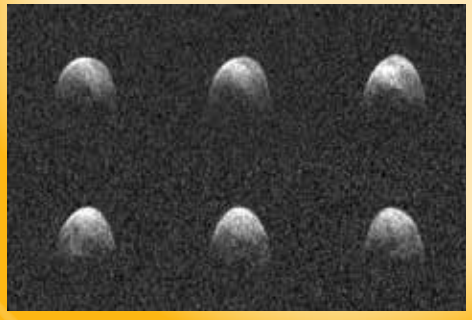
Stunning beauty of new worlds revealed

Perspective view of Pluto's highest mountains along the western margins of Sputnik Planitia. The Tenzing Montes rise 3-6 kilometers above the smooth nitrogen-ice plains in the foreground. Image courtesy: Lunar and Planetary Institute/Paul Schenk

Until 2015, it was not known whether icy Pluto or its largest moon, Charon, had mountains, valleys or even impact craters. After the spectacular success of the New Horizons mission in July 2015, scientists were amazed at the towering peaks and deep valleys that were revealed in the returned data. Now, thanks to the efforts of the New Horizons team, the first officially validated global image mosaic and topographic maps of these two bodies have been published and are available to all. The maps and the process of creating them are described in two new research articles published in the journal Icarus. These new maps from the landmark New Horizons mission reveal in stunning detail some of Pluto and Charon's most prominent features and provide clues to understanding the geological history of these worlds.

Arecibo planetary radar returns to action with images of asteroid Phaethon

After several months of downtime in the aftermath of Hurricane Maria, the Arecibo Observatory Planetary Radar returned to normal operation providing the best images to date of near-Earth asteroid 3200 Phaethon, which is thought to be the parent body for the Geminid meteor shower. The radar images, which are subtle at available resolution, reveal the asteroid is spheroidal in shape and has a large concavity at least several hundred meters in extent near the leading edge and a conspicuous dark, circular feature near one of the poles. Radar images obtained at Arecibo indicate Phaethon has a diameter of about 3.6 miles, roughly 0.6 mile larger than previous estimates. Phaethon is the second largest near-Earth asteroid classified as "Potentially Hazardous." Near-Earth objects are classified as potentially hazardous asteroids (PHAs), based on their size and how closely their orbits approach Earth.



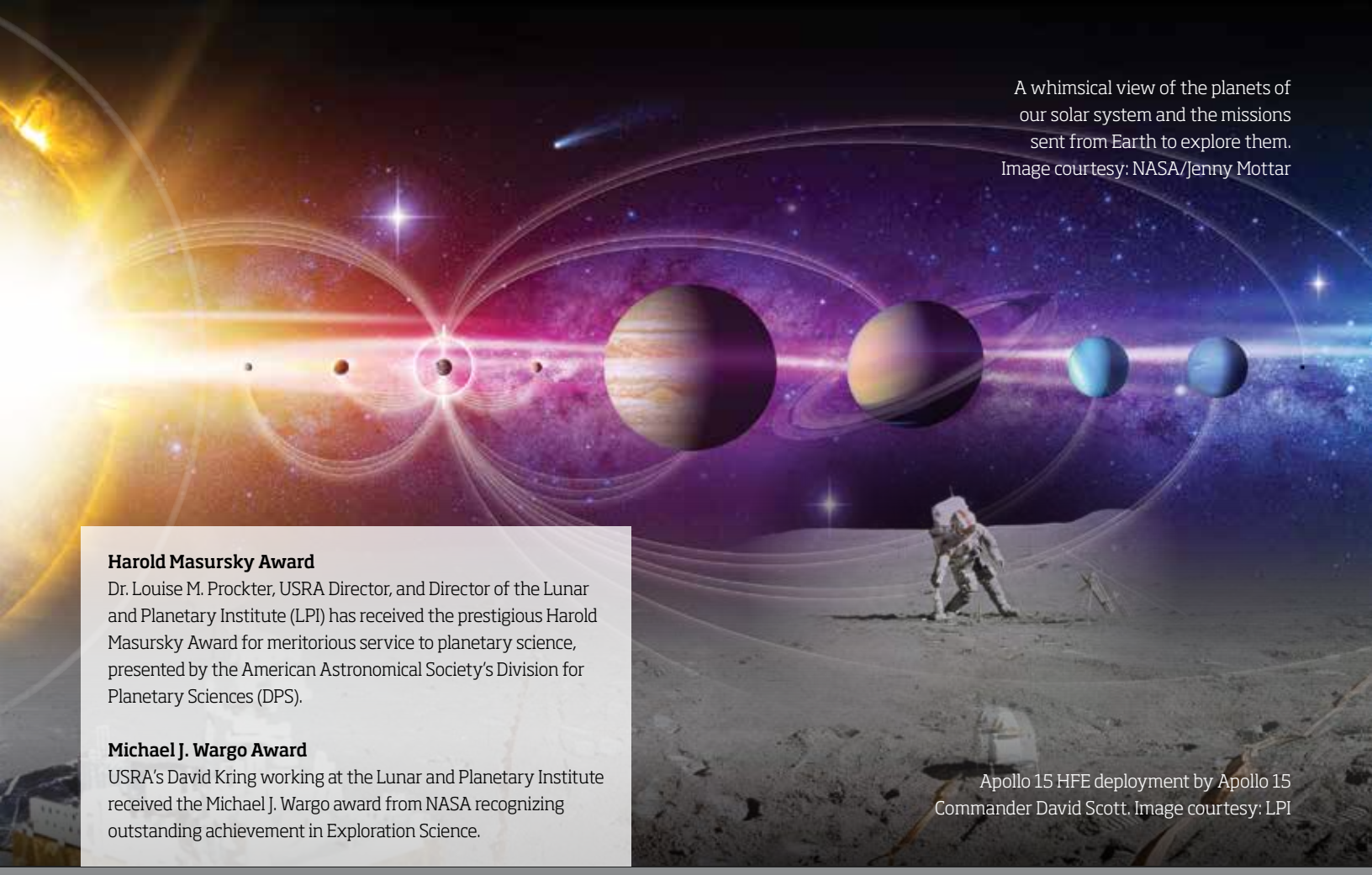
Images of asteroid Phaethon captured by Arecibo. Image courtesy: USRA

Ancient moon once had an atmosphere

A new study, published by USRA scientists in Earth and Planetary Science Letters, shows that an atmosphere was produced around the ancient Moon, 3 to 4 billion years ago, when intense volcanic eruptions spewed gases above the surface faster than they could escape to space. This new result has important implications for future exploration of the Moon and beyond.

When looking up at the Moon, dark surfaces of volcanic basalt can be easily seen to fill large impact basins. Those seas of basalt, known as maria, erupted while the interior of the Moon was still hot and generating magmatic plumes that sometimes breached the lunar surface and flowed for hundreds of kilometers before freezing. Analyses of Apollo samples indicate those magmas carried gas components, such as carbon monoxide, the ingredients for water, sulfur, and other volatile species creating a transient atmosphere.

This atmosphere maybe a source of volatile deposits in regions near the lunar poles and could provide air and fuel for astronauts conducting lunar service operations.



A whimsical view of the planets of our solar system and the missions sent from Earth to explore them. Image courtesy: NASA/Jenny Mottar

Harold Masursky Award
Dr. Louise M. Prockter, USRA Director, and Director of the Lunar and Planetary Institute (LPI) has received the prestigious Harold Masursky Award for meritorious service to planetary science, presented by the American Astronomical Society's Division for Planetary Sciences (DPS).

Michael J. Wargo Award
USRA's David Kring working at the Lunar and Planetary Institute received the Michael J. Wargo award from NASA recognizing outstanding achievement in Exploration Science.

Apollo 15 HFE deployment by Apollo 15 Commander David Scott. Image courtesy: LPI

Scientists solve moon warming mystery

Scientists have wondered what caused the Moon's subsurface temperature to gradually increase soon after the Apollo 15 and Apollo 17 missions in 1971 and 1972. USRA researcher, Dr. Walter Kiefer, working at the Lunar and Planetary Institute (LPI), reveals the cause of lunar heating, the disturbance of the Moon's surface by the astronauts themselves, in a new study published in the Journal of Geophysical Research: Planets. These new findings have implications for future lunar-landing missions and will influence approaches to probe deployment and measurement methodologies.

During the Apollo 15 and 17 missions, astronauts conducted experiments on the Moon as part of the Apollo Lunar Surface Experiments Package (ALSEP). Heat Flow Experiment (HFE) probes were deployed into the lunar surface to measure how much radioactive heating the moon produced and to obtain details about its recent geologic activity. The probes remained long after the astronauts departed and transmitted temperature data back to Earth, where it was recorded on open-reel magnetic tapes.

Once the experiment ended in 1977, only tapes from 1971 to 1974 were archived. In 2010, the research team including Dr. Kiefer recovered and restored some of the unarchived data that included 440 archival tapes at the Washington National Records Center, and ALSEP Performance Summary Reports at the LPI. These reports were weekly logs summarizing the operational status of each of the ALSEP instruments from 1973 to 1977 and included temperature readings from the deepest sensors of all four heat flow probes on the Moon. The newfound data were instrumental to filling in the missing gaps which aided researchers in pinpointing the cause of the warming observed on the lunar surface. They concluded that the astronauts' footprints disturbed the soil and lowered its albedo, allowing it to become a few degrees warmer than the surrounding undisturbed terrain.

Earth Sciences

USRA scientists strive to understand Earth's natural processes and their propensity to change and the linkage between human and natural systems. They also lead efforts to build knowledge and abilities to apply earth observations for societal inputs.

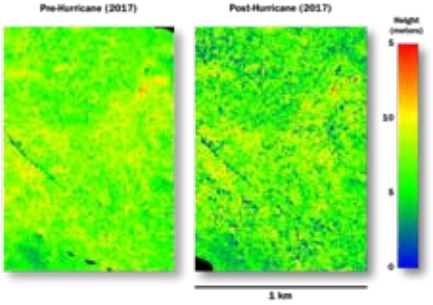
NASA's G-LiHT team reveals Hurricane Maria's destructive impact on Puerto Rico's forests

NASA Goddard's G-LiHT is a portable, airborne imaging system that simultaneously maps the composition, structure, and function of terrestrial ecosystems. The high resolution imaging that this system allows is a capability that did not previously exist.

In 2017 before the destruction wreaked by Hurricane Maria, the G-LiHT team had traveled to Puerto Rico to conduct an airborne survey of forest canopies. At that time, Puerto Rico was very green. Directly after the hurricane, it was almost completely brown as many trees had fallen, and most others had lost all of their leaves. When the G-LiHT team returned in 2018, Puerto Rico was green again, so much so that it looked almost the same as before the hurricane from satellite data. However, it was clear that the story up close from G-LiHT was very different: the structure and composition of many areas of Puerto Rico's forest had changed entirely.

The 2018 canopy survey showed that the forest was riddled with gaps from fallen trees, and in many areas the canopy height was reduced 2-3 meters, the tops of trees having been sheared off. Meanwhile, ground surveys with laser scanners showed that understory plants had flourished in the increased Sunlight reaching the forest floor, accounting for the greenness observed from space.

G-LiHT's high-resolution aerial imagery is capable of picking out individual tree species, and it suggests that opportunistic trees such as the African tulip tree (Spathodea campanulata) may have expanded their range and increased their abundance. Hurricane Maria has undoubtedly reshaped Puerto Rico's forests forever, both in terms of their structure and composition, and it was NASA's G-LiHT team that was able to demonstrate this change.



Local canopy heights for a section of the El Yunque National Forest from the G-LiHT lidar data, before (2017, left) and after hurricane Maria (2018, right). The increased green regions in 2018 show the overall shortening of the canopy from trees, and the blue regions indicate tree falls.

A NASA survey shows how Puerto Rico's forests were impacted by the two category 5 Hurricanes, Maria and Irma. This image is how the forests "look" through G-LiHT, the airborne instrument scientists are using to complete this survey. Image courtesy: NASA/ Matthew Radcliff

USRA scientists along with NASA evaluate new threats to Earth's ozone layer

Image from the International Space Station showing the Earth's atmosphere. Image courtesy: NASA

Scientists are closely monitoring positive signs of recovery of the Earth's stratospheric ozone layer, which is depleted by the use of chemicals called chlorofluorocarbons (CFCs) for a range of industrial and commercial purposes. Even after the landmark Montreal Protocol banned these substances in the late 1980s, threats to the ozone layer persist. USRA scientists at NASA's Goddard Space Flight Center are weighing in on an ongoing debate about the relative impacts of continuing sources of ozone depletion, including short-lived chemicals not banned by the Protocol, the effects of climate change, and banned chemicals that are still being released into the atmosphere. All could potentially delay the recovery of the seasonal ozone hole over Antarctica.

One likely effect of warming climate will be an increase in natural emissions of methyl chloroform (CH_3Cl) and methyl bromide (CH_3 Br) and the brominated VSLSs (very short-lived substances) from oceanic and terrestrial sources. Biomass burning emissions of CH_3Cl and CH_3Br will also likely increase in the future. A climate-induced increase of 0.2 percent per year in atmospheric concentrations of these compounds could lead to a 20-year delay of the Antarctic ozone recovery and a 4 percent reduction in the Antarctic total ozone column.

2018 Cryosphere Early Career Award
Dr. Ludovic Brucker received the prestigious 2018 Cryosphere Early Career Award presented by the American Geophysical Union.

Earth Sciences continued

Developing applications to enable use of NASA satellite data for decision support across the world

The USRA Science and Technology Institute (STI), working with the NASA Marshall Space Flight Center Science Research Office, provides critical information for decision support under the Short-term Prediction Research and Transition Center (SPoRT) and capacity-building efforts under SERVIR. In particular, STI develops uses of remotely sensed data acquired from Earth-observing satellite systems such as MODIS, Landsat, and others. The observational data provide usable information for applications such as (in the case for SERVIR) climate variability in developing regions (e.g., Eastern Africa, Himalayas and Lower Mekong), extreme heat impacts on public health in the US, and public air quality data for use in monitoring air pollution and respiratory health.

In the SPoRT program, applications are developed that can assist "boots-on-the-ground" decision makers in the US by providing current status for disaster affected areas, such as areas affected by a hurricane making landfall. All this has major implications for recovery efforts.

STI researchers developed a dam tool for SERVIR to simulate watersheds and reservoirs. The tool has the functionality to generate the reservoir that would result from constructing a dam at any selected place.

Aeronautics Research

USRA works closely with NASA, universities and industry developing advanced aeronautical technology concepts, for both conventional aircraft and unmanned aircraft systems through development and integration of advanced autonomy and software systems

ATD-3 DRAW tech lead demonstrating NASA's arrival metering in weather capabilities to visitors during the AOSP R&D Workshop in April 2018.

Providing suggestions to air traffic controllers for rerouting aircraft

USRA has been helping NASA make air travel safer and more efficient – especially in bad weather. USRA works with NASA in support of aeronautics research by helping to develop the next-generation air transportation system for both conventional aircraft and unmanned aircraft systems through development and integration of advanced autonomy and software systems. Our team works closely with NASA, the FAA, and the aviation industry to enable development and testing of future capabilities.

The team continues to support development of the Dynamic Routes for Arrivals in Weather (DRAW) system capabilities, which provide suggestions to air traffic controllers for rerouting aircraft in and around weather near the airport. The team completed two simulations over the last year and is now in the process of integrating DRAW into other FAA systems. This will provide additional capabilities for controllers to manage aircraft schedules in and around the terminal area. The first DRAW Tech Transfer to the FAA was completed in June 2018.

Integrated coordination (MAAGIC) software

The MAAGIC system provides the capability for pilots and airline dispatchers to coordinate reroutes around weather patterns by exchanging information and proposed route changes. The team helped NASA reach a milestone with the on-time delivery of the MAAGIC Ground software to Alaska Airlines in Aug 2018. The Ground software will be deployed at Alaska Airlines Headquarters for use alongside operational FAA systems. Additionally, the team implemented a version of the Future ATM Concepts Evaluation Tool (FACET) software for Chinese airspace. This is in support of the collaboration with the Chinese aeronautics research programs.

Computer Science and Information Technology

USRA has continued to advance computer science and information technology in support of a broad range of scientific and engineering application domains of relevance to NASA. Accomplishments this past year have contributed to the revolutionizing of exploration and science through innovation in information technology. Included below are a few highlights of accomplishments from this past year that show examples from multiple USRA programs.

Quantum Computing: An international race for quantum advantage

Using features of quantum physics, such as quantum superposition, tunneling and entanglement, quantum computers offer immense computational advantages over classical computing processors. Such computational advantages have the potential to dramatically improve the capability to optimize plans and schedules for autonomous air and ground vehicles, to optimize image analysis using machine learning techniques, and to secure communications that are free from disruption.

Envisioning the future opportunities of this technology, USRA entered into a long-term agreement (2012-2021) with NASA Ames Research Center and Google to build and operate a Quantum Artificial Intelligence (AI) Lab, with USRA having a primary role of growing the ecosystem for quantum AI by enabling a diversity of research through collaboration with academic institutions and companies, including both domestic and international universities. As part of this, USRA operates the Feynman Quantum Academy at NASA's Ames Research Center, in support of developing the next generation quantum workforce.

USRA's team of quantum physicists and computer scientists work in collaboration with scientists from NASA, Google, universities and other research organizations to conduct research on quantum hardware, algorithms and applications, which include both quantum and hybrid quantum classical approaches as well as experimental and theoretical results. This has involved research on quantum annealing computers, and universal gate-model quantum computers.

The ecosystem for Quantum AI that USRA has enabled with NASA and Google has involved the utilization of a quantum annealer hosted at Ames and used by over 150 users from over 40 organizations with over 75M problems solved to date and ~2M problems solved monthly to date.

USRA is also focusing its resources on workforce development. As the quantum research efforts in the U.S. grow, the need for trained quantum scientists increases. USRA is collaborating with the Air Force Research Laboratory to develop virtual training resources and providing scientists and students hands-on training opportunities to develop a workforce for the growing requirements.

Machine learning

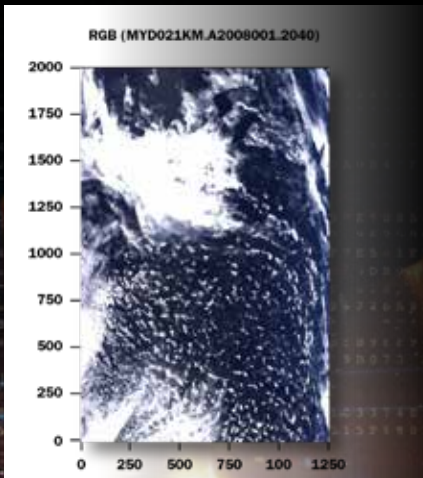


Image courtesy: USRA

Machine learning is a potentially disruptive technology for a cross-cutting range of application areas that include earth and space sciences, life sciences, aeronautics and space exploration. A team of machine learning scientists within USRA/RIACS, working on the NAMS contract have supported the leadership of NASA Ames Research Center. USRA scientists in the GESTAR program are also contributing to this effort.

Scientists in the GESTAR program developed a number of software technologies to support earth science applications. They used machine learning approaches to develop a new cloud phase classification algorithm. The main objective is to provide cloud phase uncertainty quantification, an important missing component in current cloud phase products, based on Gaussian processes. These are a well-known non-parametric learning approach that are being used for classification problems.

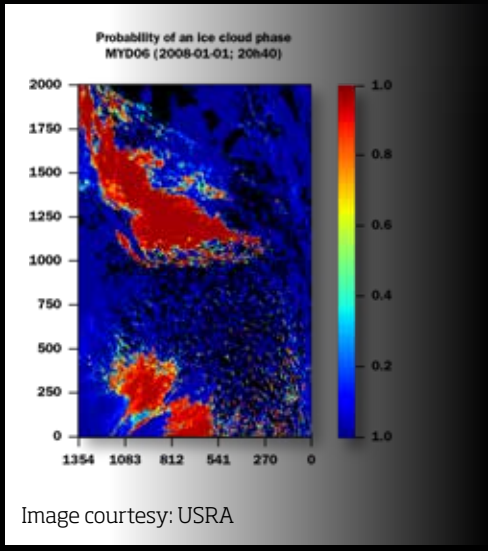


Image courtesy: USRA

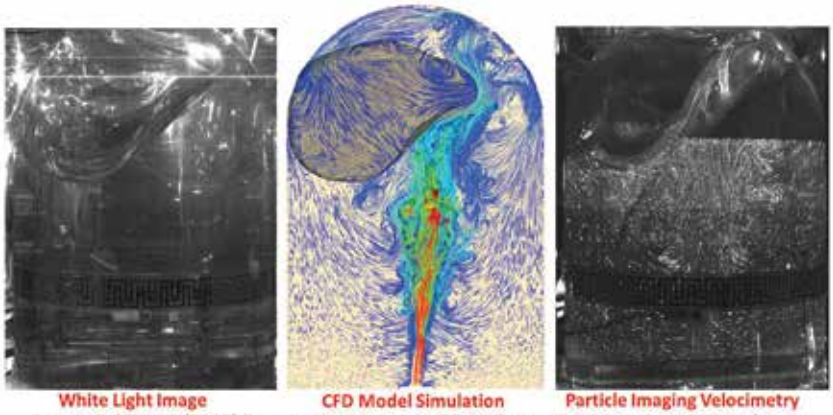

5
USRA
ESTABLISHED 1969

Advancing Space Research and Exploration for 50 years

Microgravity (µg) Sciences

USRA collaborations make key contributions in the areas of Combustion, Fluid Physics, and Complex Fluids. These three areas of research are integral to the future of the exploration and commercialization of space.

Long-term cryogenic fluid storage in space



Zero-Boil-Off Tank (ZBOT) Experiment: Depiction of fluid flow and deformation of Ullage (vapor bubble) by the liquid jet during forced jet mixing pressure control in microgravity

Many spaceflight systems rely on very cold cryogenic fluids for propellant, astronaut life support, and temperature control of sensitive scientific instruments. Heat from the environment around cryogenic tanks can cause unwanted "boil-off" of these valuable cryogenic fluids, affecting the cost and feasibility of long-duration space missions. To combat this, NASA is researching technologies and methods that can minimize, or potentially eliminate, cryogenic fluid boil-off.

The Zero-Boil-Off Tank (ZBOT) flight experiments consist of three small-scale tank pressurization and pressure control experiments on the ISS investigating various fluid flow, heat and mass transport, and phase change phenomena that affect storage tank pressurization and pressure control in µg. ZBOT-1 flight operations ran Oct - Dec 2017 and yielded a significant quantity of valuable flight data that showed strong correlation with the research team's high fidelity Computational Fluid Dynamic (CFD) models. Dr. Mohammad Kassemi (CWRU) serves as the Principal Investigator on the ZBOT experiments, collaborating with USRA and NASA scientists.

The ZBOT-1 data are now being used to revise and improve NASA's CFD models of cryogenic propellant storage in µg. These models are critical to the design and development of long duration spaceflight missions that will use cryogenic propellants. The ZBOT-2 and -3 flight experiments are in the planning stages.

The ACE family of experimen
are conducted on th
International Space Station in th
Light Microscopy Module of th
Fluids and Combustion Facili
Image courtesy: USR

Controlling Flames with Electric Fields

While the discovery of fire occurred more than a million years ago, the study of combustion continues to this day. Scientists at USRA and Case Western Reserve University (CWRU) are studying flames in microgravity to better understand the fundamental physics of combustion in ways that will improve life on Earth.

One of the investigations is the Electric-Field Effects (E-FIELD flame) investigation, led by PI Prof. Derek Dunn-Rankin of University of California – Irvine. The investigation is studying how an electric field can influence flames because of the field's effect on the ions produced by the combustion reactions. The direct ion transport and the induced ion wind can modify the flame shape, alter the soot or flammability limits, direct heat transfer, and reduce pollutant emission.

By better understanding how to use electric fields to control the combustion process, we can improve the performance of nearly every combustion device in use today, and potentially invent new devices with much greater efficiency that create significantly less emissions.

At NASA Glenn Research Center, USRA scientist Dr. Paul Ferkul and Case Western Reserve scientists Dr. Vedha Nayagam and Dr. Uday Hegde play important roles in the combustion research program by serving as the Project Scientists for a range of combustion experiments being performed in the Fluids & Combustion Facility on the International Space Station.

Self-assembling and self-organizing structures

Advances in colloidal engineering could lead to the development and production of a wide range of new and improved materials in the areas of stabilizers for consumer products, large area electrodes for energy storage, micro-machines, and photonic devices to control and manipulate light.

USRA Project Scientist for the Advanced Colloids Experiments (ACE), William Meyer, is supporting a family of investigations that lay the foundation for understanding the physics of colloidal engineering necessary to design new functional materials and structures for use on Earth and in space that are based on micron-scale building blocks. In FY 2018, five unique ACE investigations were conducted in the Fluids & Combustion Facility using the Light Microscopy Module. Each of the five investigations focused on different aspects of self-assembling and self-organizing colloidal structures.

One of the investigations, ACE-T7, was led by Principal Investigator (PI) Prof. Paul Chaikin of New York University - a world-renown expert in the field of condensed matter physics. ACE-T7 observed for the first time the 3-D formations of "super-cubes", which are engineered to self-organize into crystalline structures. Referring to this research in self-organizing functional materials, Prof. Chaikin noted that, "It's really important to work at the forefront of science that will then become the forefront of engineering and production."

Space Technology

USRA performs advanced studies at the Center for Space Nuclear Research (CSNR) that support the development of advanced propulsion and power systems for space exploration.

Nuclear Thermal Propulsion – sending more payload faster

Reducing the transit time on a typical mission from Earth to Mars reduces the exposure of astronauts to cosmic radiation by more than 40 percent due to the shorter time and use of cargo as shielding. USRA scientists are currently engaged in developing Nuclear Thermal Propulsion (NTP) technology to achieve this goal. NTP uses a fission reactor to heat a propellant, usually hydrogen (H_2), to high temperature and pressure after which the gas, which is partially dissociated into hydrogen atoms, is exhausted through a nozzle. With a high specific impulse, which is the ratio of the thrust to the rate at which the propellant is being consumed, less propellant is needed, and thus more cargo can be transported and higher velocities can be attained.

On a typical mission from the Earth to Mars, the mission duration using a chemical rocket with a high specific impulse of 350 seconds (exhaust velocity = 3430 m/s) would be 9 months, while NTP rocket with a high specific impulse of 900 seconds would require only 5-6 months and potentially carry significantly more cargo.

In an effort to develop affordable NTP technology, there is a national need to investigate the use of low-enrichment uranium (LEU, < 20% ^{235}U). The use of LEU, as opposed to Highly Enriched Uranium (HEU) has the potential to greatly reduce the cost of NTP development. Also, LEU reactor systems have less proliferation related concerns and regulatory burden, and therefore can be significantly more affordable to develop. USRA scientists are currently working on computer codes and models with an eye to bring this innovative technology to fruition.

Powering robotic exploration of the solar system

Plutonium-238 is used as a heat source for Radioisotope Thermoelectric Generators (RTGs), which power robotic spacecraft missions when solar power will not suffice.

RTGs have been used in the past to provide heat and electricity to operate the Voyager 1 and 2 probes (which were launched in 1977 and are still operating), the New Horizons probe to Pluto, Charon and the Kuiper belt, the Cassini probe to Saturn, and the Mars Science Laboratory Curiosity rover. The reactors where Plutonium-238 was produced until 1988 are no longer in operation, so DOE test reactors are being considered for irradiating Neptunium-237 targets with neutrons

The Advanced Test Reactor at the Idaho National Laboratory in operation. Image courtesy: INL

to yield Plutonium-238. Currently, there is a paucity of Plutonium-238 to power future missions and new options are needed to increase the rate of production.

In 2018, USRA scientists and Summer Fellows investigated the use of the Advanced Test Reactor (ATR) at the Idaho National Laboratory for the production of Plutonium-238. In their research they discovered that the ATR can produce very pure Plutonuim-238, which can be used to upgrade decayed RTG fuel in the stockpile. The project suggested various target configurations, locations and irradiation schedules to optimize production in the ATR.

Artists' conception of a Kilopower nuclear reactor on Mars, showing the thermal radiators required for reactor cooling . Image courtesy : NASA

Fission reactors can provide heat and power through the long, cold lunar nights

The National Aeronautics and Space Administration (NASA), other international space agencies, industry, and private entrepreneurs plan a wide range of robotic and human activities on lunar, Martian and other planetary surfaces in the next 10-20 years. Performing these activities via public/private partnerships is highly advantageous, offering NASA and industry the opportunity to share both the risks and rewards.

All these robotic and human activities need abundant and reliable electrical power. More capable robotic exploration and sustained human presence will require 10 kWe to 100 kWe that is continuously available throughout the entire day/night cycle. In the case of the Moon, such a power plant would form the basis for commercial electrical service. Such services will jump-start the exploration, resource mapping, commercial exploitation, and colonization of the Moon by a broad mix of public and private users.

A significant difference between USRA's Surface Modular Fission Reactor (SMFR) IRAD project and NASA's Kilopower project is that USRA is focused on developing an SMFR using low enriched uranium (LEU) as its heat source. While highly enriched uranium (HEU) requires a lower nuclear fuel mass, allows the use of a wider range of materials and reduces the need for a moderator, there are significant problems associated with HEU that are insurmountable from a commercial perspective.

HEU has sufficient U-235 concentration to be usable for nuclear weapons. The security and safety costs associated with the production, transportation, storage, and use of HEU make it commercially impractical.

Conversely, LEU is not usable for nuclear weapons and has significantly fewer restrictions associated with its use. The cost and availability of LEU make it a good candidate fuel for SMFRs. The reactor design challenges associated with using LEU fuel will be thoroughly addressed in the USRA concept study. To define that study, USRA's Steve Mackwell, Chris Pestak and Steve Herring wrote a white paper, "Small Modular Fission Reactors for Space Applications," discussing an on-going concept study by USRA.

Science Facility Management and Operations

USRA is recognized for its expertise in managing ground, airborne, and spaceborne research through the operation of laboratories, observatories and other facilities. USRA often draws upon the technical competencies of its member universities and programs to leverage external and internal technical resources to operate facilities.

This specialization in coordinating multi-institutional teams allows USRA to serve government sponsors by coordinating the work of industrial partners and academia. In addition, USRA's robust contract, project and facility management employs industry-standard practices and tools that include business systems using accepted government contracting software.

Science facility management

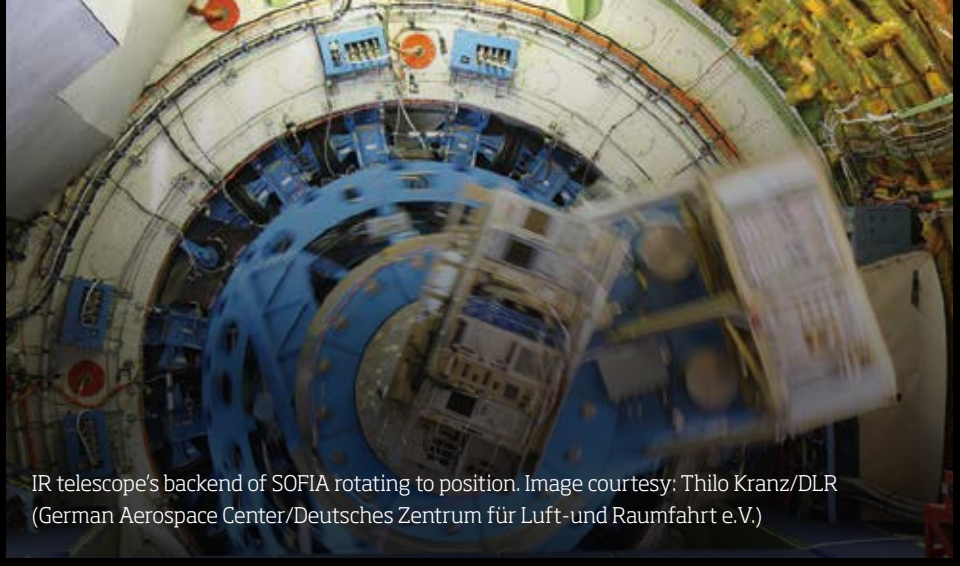
USRA undertakes the management of various facilities, including science operations for the Stratospheric Observatory for Infrared Astronomy (SOFIA), the Quantum Artificial Intelligence Laboratory (QuAIL), the Keck Remote Observation Center, and the Research Institute for Advanced Computer Science.


Sunset before an observing flight: Image courtesy: NASA/SOFIA

SOFIA is a heavily modified Boeing 747 jetliner that carries a 100-inch (2.5-meter) telescope to altitudes up to 45,000 feet, above more than 99% of Earth's atmospheric water vapor. This gives astronomers the ability to study celestial objects at infrared wavelengths that cannot be seen from ground-based observatories. USRA operates the SOFIA Science Operations Center (SOC) for NASA's Ames Research Center and solicits proposals and allocates time and funding to the user community. USRA also undertakes science flight planning and scheduling, and other science operations efforts.

The aircraft is based at NASA's Armstrong Flight Research Center in Palmdale, California. NASA's Ames Research Center in California's Silicon Valley manages SOFIA's science and mission operations, in cooperation with the USRA and the German SOFIA Institute at the University of Stuttgart.

In addition, USRA operates the **Quantum Artificial Intelligence Laboratory** in collaboration with Google and NASA's Ames Research Center. The lab hosts a D-Wave 2000Q Quantum Computing System. The computer offers the promise for solving challenging problems in a variety of applications including machine learning, scheduling,



IR telescope's backend of SOFIA rotating to position. Image courtesy: Thilo Kranz/DLR (German Aerospace Center/Deutsches Zentrum für Luft-und Raumfahrt e.V.)

diagnostics, medicine and biology among others. Residing at the NASA Advanced Supercomputing Facility, the new system has 2031 quantum bits (qubits) in its working graph—nearly double the number of qubits compared to the previous processor. USRA allocates time to the international scientific community on a competitive merit-based proposal process, at no cost to the users. Currently there are 90 registered users of the system –an increase of 25 percent over last year.

The **USRA-Keck Remote Observation Center**, located at the USRA headquarters facility in Columbia, Maryland, provides the capability for astronomers to connect remotely to the Keck telescopes on Mauna Kea in Hawaii and undertake observations, eliminating the need for distant travel. The facility is one of three in the world. USRA undertook the design, development, and construction, and continues operation of the facility as a USRA contribution to the community.

USRA also manages and operates the **Research Institute for Advanced Computer Science** which focuses on interdisciplinary research and challenging applications associated with NASA's mission to develop innovative information systems and other technologies. To implement this approach, research staff undertake collaborative projects with research groups at NASA and elsewhere, integrating computer science with other disciplines to support NASA's mission.

Cockpit of SOFIA. Image courtesy: USRA/SOFIA/NASA

STEM Education Activities

Since 1969, STEM activities have been a critical part of USRA's mission to involve society more broadly in space and aeronautics research and activities. Throughout the past five decades, USRA has offered innovative learning opportunities for students, educators and the general public.

STEM action center

The USRA STEMaction Center had a stellar year moving through the second season as the Maryland Affiliate Partner for the FIRST Tech Challenge (FTC) and FIRST LEGO League Junior (FLL Jr) programs. The FLL Jr program focuses on kindergarten through third grade students, who engage in a science project of discovery through LEGO and their WeDo platform. The FTC is an annual competitive robotics program, where teams of middle and high school students compete with and against each other. In 2018, the USRA STEMaction Center management of the FIRST programs saw stabilization and growth of teams affiliated with their respective programs.

The USRA STEMaction Center also hosted the second annual Maryland Tech Invitational (MTI), the premiere off-season competition for the FIRST Tech Challenge program, at Reservoir High School in Howard County, Maryland. Thirty-two teams from across the nation and the world, competed for grant awards provided by local sponsors. The MTI competition was a two-day event for students, coaches, and volunteers, with several evening events, including a team social hosted by the USRA STEMaction Center that included activities in USRA's Planetarium, which is managed by the Lunar and Planetary Institute.

Over the course of this past fiscal year, the USRA STEMaction Center continued to open its doors for workshops, trainings, and practices for the FIRST programs. Over 800 students from 130 teams utilized the facility during the 2018 competition season. Due in part to the use of the facility and students' hard work, one team that utilized the USRA STEMaction Center was the recipient of the Inspire Award at the FIRST World Championship event.

The USRA STEMaction Center built upon the success of the inaugural 2017 ACT program that provides training for underserved students from the Howard County Public School System. Sixteen high school juniors participated in a ten-week Saturday program held at USRA HQ to prepare for the ACT test. In order to qualify, students submitted an application and were selected based on their GPA plus a written essay, displaying a willingness to pursue STEM fields in a four-year college. USRA covered the cost of the ACT prep program conducted by Princeton Review and the student's parents covered the cost of the ACT test. Over the ten week period, students were administered the ACT test twice. The prep program resulted in most students scoring higher on the second round of ACT testing.

This year, USRA STEMaction Center continued the USRA Headquarters summer internship program by offering four-week internships to college students from University of Maryland to gain firsthand knowledge of USRA Programs and to work with a USRA staff sponsor/mentor. The USRA STEMaction Center plans to extend the internship program so that new interns may participate throughout the year.

LPI education and engagement

USRA's Lunar and Planetary Institute continued its strong program of community education and public engagement in 2018. The education and public engagement (E/PE) team conducted Early Career Presenters Review sessions at two international conferences, along with a mentoring program that paired student attendees with experienced scientists. LPI also invited planetary scientists to use USRA's new portable planetarium to share planetary exploration with a variety of audiences; over 1,600 members of the public attended these sessions in 2018.

Camp conference attendees examine soil for evidence of life. Image courtesy: USRA

In addition, E/PE staff shared resources and SMD content with a variety of informal educators. The E/PE team led multiple sessions and operated a booth to disseminate space science content at the American Camp Association conference, which had an attendance of 1,700. The E/PE team also led a four-day institute on public engagement for 36 Solar System Ambassadors, librarians, and others at the Johns Hopkins Applied Physics Laboratory in Maryland.

In 2018, four Sky Fest events were held at the LPI for approximately 500 visitors, including an event featuring Apollo 17 astronaut Harrison Schmitt. These Sky Fest events engage local families in celestial events and NASA mission milestones.

The LPI is also engaged in the Exploration of the Moon and Asteroids program for high school students. In this program teams of high school students conduct research in lunar or asteroid science. One of the 2016-2017 teams was invited to present their research at the 2018 Intel International Science and Engineering Fair.

Students participating in FIRST Tech Challenge competition. Image courtesy: USRA

Internships, Fellowships and Scholarship Awards

As an association of universities, USRA recognizes a fundamental responsibility to facilitate the education and career development of children and young adults. With its focus on the science and technology of space, USRA is uniquely situated to utilize the pervasive fascination with space exploration to engage young people, attract and retain them in science and technology careers, advancing the Nation's technical prowess. This engagement includes programs that span from elementary and middle school to high school to university and beyond, which are supported by NASA, NSF, DOD and USRA's own corporate resources. A cornerstone of USRA's commitment to developing the STEM workforce of the future resides in support of internship programs, which supported hands-on experiences in 2018 for around 2000 students from high school to graduate school.

NASA internships: building the technical workforce of tomorrow

Marshall Space Flight Center, Summer 2018 Interns. Image courtesy: NASA

USRA oversees the implementation and administration of internships for high school, undergraduate, and graduate students, with placements of students throughout NASA. In 2018, 1,685 interns participated in the NASA Internship program, representing a 21 percent increase in the number of interns placed since the previous year. Since its inception in April 2013, 6,034 interns, representing 787 high schools, colleges, and universities have participated. These internships provide opportunities for America's next generation of science, technology, engineering, and mathematics (STEM) professionals to develop the critical skills necessary to effectively accomplish NASA's mission in the future.

NASA Internships increase the capabilities, diversity, and size of the nation's STEM workforce through participatory immersive educational experiences. Attracting a diverse group of NASA interns continues to be a priority of both NASA and USRA.

AFRL scholars: retaining STEM talent in support of the nation

USRA continues to excel at managing the Air Force Research Laboratory (AFRL) Scholars Program at Eglin Air Force Base (AFB) in Valparaiso, Florida; Kirtland AFB in Albuquerque, New Mexico; and the Air Force Maui Optical and Supercomputing Site in Maui, Hawaii. Additionally, USRA provides more limited support to the AFRL program at Wright-Patterson AFB near Dayton, Ohio. The AFRL Scholars Program seeks to strengthen the high-tech workforce of the future by preparing a new generation of STEM professionals, capable of addressing the nation's defense needs.

During spring and summer 2018, 291 students participated in the AFRL Scholars Program. Since USRA began administering the program in 2013, participants have included more than 1,280 high school, undergraduate, and graduate students nationwide.

An AFRL Scholar at AFWERX Vegas working on a self-designed and 3D printed camera mount. Image courtesy: AFWERX

Research projects for scholars this past year included plasmonic and optical devices, spacecraft navigation systems, autonomous vehicles, space weather instrumentation and modeling, biologically-inspired flight control, and other cutting-edge research opportunities.

USRA supported four interns at AFWERX sites across the country under the Kirtland AFB agreement; AFWERX is the Air Force's latest initiative intended to connect the government with external entrepreneurs to encourage innovation and collaboration. At Eglin AFB, USRA supported four hybrid interns who worked on collaborative projects between AFRL and industry partner Cummings Aerospace.

Internships in other USRA programs and institutes

The Lunar and Planetary Institute (LPI) continues to play a vital role in attracting, training, and nurturing future planetary scientists through the LPI/JSC Summer Intern Program in planetary science, which has been offered since 1977.

The class of the 2018 LPI Summer Intern Program. Image courtesy: USRA

The Center for Lunar Science and Exploration's (CLSE) summer internship program hosted 10 graduate students to explore options for NASA and its international partners in the new era of robotic and human exploration.

The NASA Academic Mission Services (NAMS) Student R&D Program supported 40 student interns from domestic and international universities during the 2018 summer cycle. The unique aspect of this program is that it allows students to collaborate with scientists and engineers onsite at NASA or a hybrid version, where students work on their project at their university with faculty and at NASA Ames with a mentor over several months. The internship projects are designed with emphasis on learning, advancing research, and incorporating the research into their graduate theses. The students are given a full experience of collaborating in a R&D environment by participating in talks within the organization codes, tours of various research areas across NASA Ames, summer seminar series, presentations at the Education Poster session, and possible publication of project results.

2018 student interns from USRA's NASA Academic Mission Services at the NASA Ames wind tunnel. Image courtesy: USRA

The Center for Space Nuclear Research Interns program supported 2 teams of students in the summer of 2018, investigating important questions for the future of space nuclear power and propulsion. One team focused on developing computer codes and models for developing Nuclear Thermal Propulsion technology to enable a significant reduction in travel times for astronauts from Earth to Mars. The other team investigated the use of the Advanced Test Reactor at the Idaho National Laboratory to increase the rate of production of Plutonium-238, the fuel used in Radioisotope Thermoelectric Generators. Such RTGs have been used to power robotic spacecraft sent to places of low solar radiation, such as the outer solar system, and rovers on Mars.

Internships, Fellowships and Scholarship Awards *continued*

NASA postdoctoral program

NPP Director, Dr. Scott Miller leads a discussion with current and potential postdoctoral fellows at the 2017 fall meeting of the American Geophysical Union. Image courtesy: USRA

USRA operates the NASA Postdoctoral Program, providing recruitment of applicants and review of science proposals for over 1400 potential Fellows since USRA began operations in 2016. USRA also administers the program on behalf of NASA for an average of over 200 Fellows at any time, working with NASA Science, Space Technology, and Human Exploration Missions Directorates, as well as other NASA research and technology organizations. USRA is also focused on diversity recruitment of applicants, and executes targeted efforts to focus on recruiting from underrepresented groups in multiple STEM areas.

Other representative career development activities at USRA

USRA'S Research Institute for Advanced Computer Science (RIACS) operates the **Feynman Quantum Academy** at NASA's Ames Research Center. Six participants were selected for the 2018 Summer Cycle from both domestic and international universities.

Feynman Quantum Academy Participants at the 2018 International Conference for Adiabatic Quantum Computing. Image courtesy: USRA

USRA's RIACS organized the 2nd annual **GeneLab for High School (GL4HS)** Summer Training Program during July 2018. This year's 4-week program included 15 High School students who were taught about omics techniques and how to write a research proposal based on a hypothesis and testable aims. As part of the program, students chose a specific GeneLab dataset that they were interested in and worked on analyzing their dataset with bioinformatics tools. A research proposal was generated by each team based on data mining of the dataset from GeneLab. One GL4HS student team was awarded 1st Place in the 2017 ASGSR High School Poster Session.

Scholarship Awards

The USRA Scholarship Awards were established to honor the service and memory of individuals who made significant contributions to their fields and to USRA.

Fredrick A. Tarantino Memorial Scholarship Award
Honors Tartantino's contributions to USRA and his commitment to education

John R. Servier Memorial Scholarship Award
Honors Servier's contributions to aerospace technology

Thomas A. McGetchin Memorial Scholarship Award
Honors McGetchin's contributions to planetary science

James B. Willett Education Memorial Scholarship Award
Honors Willett's contribution to astronomy and astrophysics

2018 Scholarship Award Winners

USRA is pleased to recognize and support the careers of these winners of the 2018 USRA Scholarship Awards. These students have made contributions to the fields of study and have given back to their communities through outreach and education efforts.

The following students were selected for the Scholarship awards :

Mahlet Shiferaw
Harvard University (Tarantino)

Hannah Lyons
University of Florida (Tarantino)

Destiny Fawley
University of Illinois at Urbana-Champaign (Servier)

Connor Tinker
Purdue University (McGetchin)

Bryce Cousins
Indiana University (Willett)

University Engagement

USRA is tied to the university community. The activities of USRA institutes and programs are characterized by engagement with the university community in research collaborations, and providing opportunities for student internships and post-doctoral researchers at Federal laboratories and at USRA sites. In FY18, USRA was involved in 1,038 research engagements at 340 research organizations which included both universities and other research organizations. USRA also serves as a voice in Washington on public policy issues identified by its member universities.

Featured USRA University Engagements in 2018

University survey and workshop for SecAF 2030

USRA brought together university and Air Force stakeholders in a workshop at USRA's Washington Office to examine the challenges universities face in contributing to Air Force research needs.

USRA conducted a three-step study on the challenges universities face in doing early stage research with the United States Air Force. In September 2017, Heather Wilson, Secretary of the Air Force, announced the broader "S&T Strategy 2030" study, with the objective of updating Air Force methods for conducting research and development to meet projected national security challenges of 2030. For its part, USRA carried out a seven-month study that included surveying over 120 university administrators and professors to identify challenges. The study culminated in a workshop at the USRA Washington Office, with university and Air Force Research Laboratory stakeholders present. USRA provided a report proposing innovative solutions to expand interactive engagement with the university community.

University engagement in NASA's microgravity research program

USRA engages with university researchers through NASA's Microgravity Research Program, a portfolio of projects in combustion science, fluid physics, and complex fluids. Flight experiments are performed on the International Space Station and the Cygnus resupply vehicle, while ground-based experiments use the drop tower at NASA's Glenn Research Center or aircraft that fly parabolic trajectories. This past year, USRA, together with Case Western Reserve University, engaged 69 investigators from 39 universities.

Visit by Alabama A&M University to NASA's Ames Research Center

USRA arranged for Alabama A&M University (AAMU), a USRA member institution, to meet with NASA executives and technical leads at NASA's Ames Research Center to identify potential areas for collaboration including aeronautic systems, biological sciences, data mining, quantum computing, and autonomy.

Professor Chance Glenn, center, with faculty from Alabama A&M University discussing possible collaboration opportunities at NASA/ Ames Research Center.

Allocation of time on the Quantum Annealer System at NASA's Ames Research Center

USRA's Research Institute for Advanced Computer Science (RIACS) administered Cycle 3 of the Quantum Artificial Intelligence Lab call for proposals this past year. USRA allocates time on the D-Wave 2000Q quantum annealer system, at no cost to selected awardees. Twelve university proposals and four industry proposals were selected through a peer review process.

Allocation of observing time on SOFIA

USRA issues calls for proposals to the astronomical community to allocate time for use of the observatory. This past year, USRA received 199 proposals for the Cycle 6 call. A Time Allocation Committee of 30 astronomers from universities and government laboratories selected 68 proposals, with other proposals included as "do if time" projects.

Public policy advocacy

USRA provides a voice on public policy issues important to the university community through the Issues and Program Committee (IPC). Composed of representatives from USRA members universities, drawn from nine geographic regions, the IPC formulates public policy positions, meets with members of Congress and their staffs, provides testimony, as requested, and also organizes the program for a symposium held in conjunction with the Annual Meeting of the member universities in Washington.

The IPC has successfully advocated for reform of space-related export control regulations, and for NASA's suborbital program, which allows for the hands-on training of students in NASA-sponsored suborbital flight research projects.

2018 USRA symposium

The topic of the 2018 symposium was "Return to the Moon: A Partnership of Government, Academia and Industry". Acting NASA Administrator Robert Lightfoot gave the keynote address, and Apollo 17 Astronaut and former U.S. Senator Harrison Schmitt spoke on managing the environment for implementing a return to the Moon. The symposium brought together scientists and decision makers from across academia, government agencies, and the commercial sector, both nationally and internationally.

Jeff Isaacson (left), USRA President and Chief Executive Officer, was joined by Robert Lightfoot, Acting NASA Administrator (right), in presenting a limited-edition globe of the Moon to Harrison Schmitt in recognition of his service to the nation.

Governance

USRA governance is grounded in the university community. USRA is an association of 110 universities engaged in space and aeronautical related research and education. All members of the association are PhD-granting, major research institutions. The members comprise a Council of Institutions, which holds an Annual Meeting in Washington, each spring, at which the USRA President and Chief Executive Officer, and the Chair of the Board of Trustees, report on USRA activities. The Council elects new trustees to the Board of Trustees, votes upon admission of new members to the Association, and on changes to the bylaws.

The Board of Trustees is the governing board of USRA. The Board has fifteen members, including nine regional trustees–one for each of nine geographic regional groups of members, four at-large trustees, and the Chair of the Council of Institutions, all of whom are elected by the Council. The Trustees appoint the President and CEO, who serves as a member of the Board, ex-officio. Regional and at-large trustees serve a three-year term, limited to re-election to a second term. The Chair of the Council serves a two-year term.

USRA Board of Trustees: Front row (from left) John Carlstrom, Renu Malhotra, Jeffrey Isaacson, Elizabeth Protas. Back row (from left) Edward Weiler, Patricia Doherty, John Montgomery, Thomas Soifer, Pascale Ehrenfreund, Carolyn Morgan, and Alfred Krabbe. Not pictured above: William Ballhaus, Jr., James Johnson, Louis Lanzerotti, and Daniel Baker.

The broadly-based university membership ensures accountability of USRA in serving its nonprofit purpose: "To develop and manage programs and facilities, and provide other services as required under contract, or otherwise, with the governments of the United States and other nations, and other organizations for space-related education, research, development, and operations."

At its 2018 Annual Meeting, the Council welcomed four new members: University of Bern, University of Canterbury, École Polytechnique Fédérale de Lausanne, and Montana State University.

USRA Member Universities

Alabama A&M University
The University of Alabama in Huntsville
University of Alaska - Fairbanks
The University of Arizona
Arizona State University
University of Arkansas
Auburn University
Baylor University
University of Bern
Boston College
Boston University
Brandeis University
The University of British Columbia
Brown University
University at Buffalo, SUNY
University of California, Berkeley
California Institute of Technology
University of California, Los Angeles
University of California, San Diego
University of California, Santa Barbara
University of Canterbury
Case Western Reserve University
University of Central Florida
University of Chicago
The College of William & Mary
The Chinese University of Hong Kong
University of Cologne
University of Colorado Boulder
Colorado School of Mines
Columbia University
University of Connecticut
Cornell University
University of Delaware
University of Denver
École Polytechnique Fédérale de Lausanne
University of Florida - Gainesville
Florida State University
George Mason University
The George Washington University
Georgetown University
Georgia Institute of Technology
Hampton University
Harvard University
University of Hawaii
University of Houston
Howard University
University of Illinois at Urbana-Champaign
Indiana University
University of Iowa
Iowa State University
Johns Hopkins University
The University of Kansas
Lehigh University
University of Leicester
Louisiana State University
University of Maryland
Massachusetts Institute of Technology
University of Michigan
Michigan Technological University
University of Minnesota
Mississippi State University
Montana State University
University of Nebraska - Lincoln
University of New Hampshire
New Jersey Institute of Technology
The University of New Mexico
New Mexico State University
New York University
North Carolina A&T State University
North Carolina State University
Northwestern University
Ohio University
The Ohio State University
The University of Oklahoma
Oklahoma State University
Old Dominion University
The Pennsylvania State University
University of Pittsburgh
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Rice University
University of Rochester
Rochester Institute of Technology
The Rockefeller University
The University of Sheffield
University of Southern California
Stanford University
Stony Brook University, SUNY
University of Stuttgart
The University of Sydney
Technion - Israel Institute of Technology
Tel Aviv University
University of Tennessee, Knoxville
Texas A&M University
Texas Tech University
University of Texas at Arlington
University of Texas at Austin
University of Texas at Dallas
University of Texas Medical Branch at Galveston
University of Toronto
Tufts University
Utah State University
Vanderbilt University
University of Virginia
Virginia Polytechnic Institute & State University
Washington University in St. Louis
University of Washington
University of Wisconsin - Madison
Yale University

Selected List of Publications*

Astronomy and Astrophysics

- **Connaughton, V.**, et al. (2018) On the Interpretation of the Fermi-GBM Transient Observed in Coincidence with LIGO Gravitational-wave Event GW150914 (2018), Astrophysical Journal, 853, L9.
- **Goldstein, A.**, et al. (2017) An Ordinary Short Gamma-Ray Burst with Extraordinary Implications: Fermi-GBM Detection of GRB 170817A, Astrophysical Journal, 848, L14.
- Lavigne, T., Liu, C., Deierling, W., and **Mach, D.** (2017) Relationship between the global electric circuit and electrified cloud parameters at diurnal, seasonal, and interannual timescales, Journal of Geophysical Research, 122, 8525, DOI:10.1002/2016JD026442.
- Chun, F.K., Tippets, R.D., Strong, D.M., Della-Rose, D.J., Polsgrove, D.E., **Gresham, K.C.**, et al. (2018) A New Global Array of Optical Telescopes: The Falcon Telescope Network, Publications of the Astronomical Society of the Pacific, 130.
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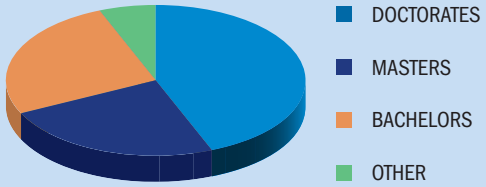
** USRA scientists and engineers published over 300 articles in 2018*

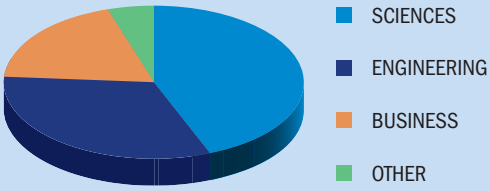
USRA's Workforce: Growing and Diversified

Employee Distribution by Degree



Approximately 42 percent of USRA's workforce hold Doctoral degrees, and another 24 percent hold Masters

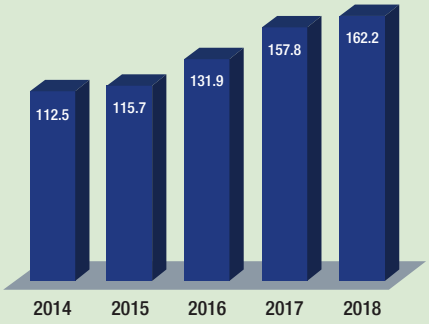
Employee Distribution by Areas of Study



Approximately 64 percent of USRA's workforce comprises physical scientists and engineers

Financial Highlights

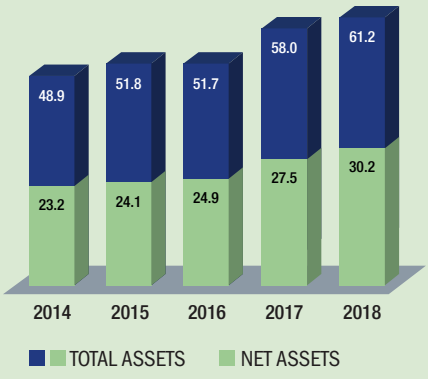
FY2014-2018 Revenue in Millions



For FY2018, USRA's annual revenue from contracts and grants totaled more than $162 million.

Roughly 20 percent of USRA's revenue is devoted to education programs including STEM workforce development that included more than 2,000 internships, and the NASA Postdoctoral Programs.

FY2014-2018 Total Assets & Net Assets in Millions



USRA continues to maintain a healthy ratio of total assets versus liabilities. Net assets are defined as total assets minus liabilities.

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