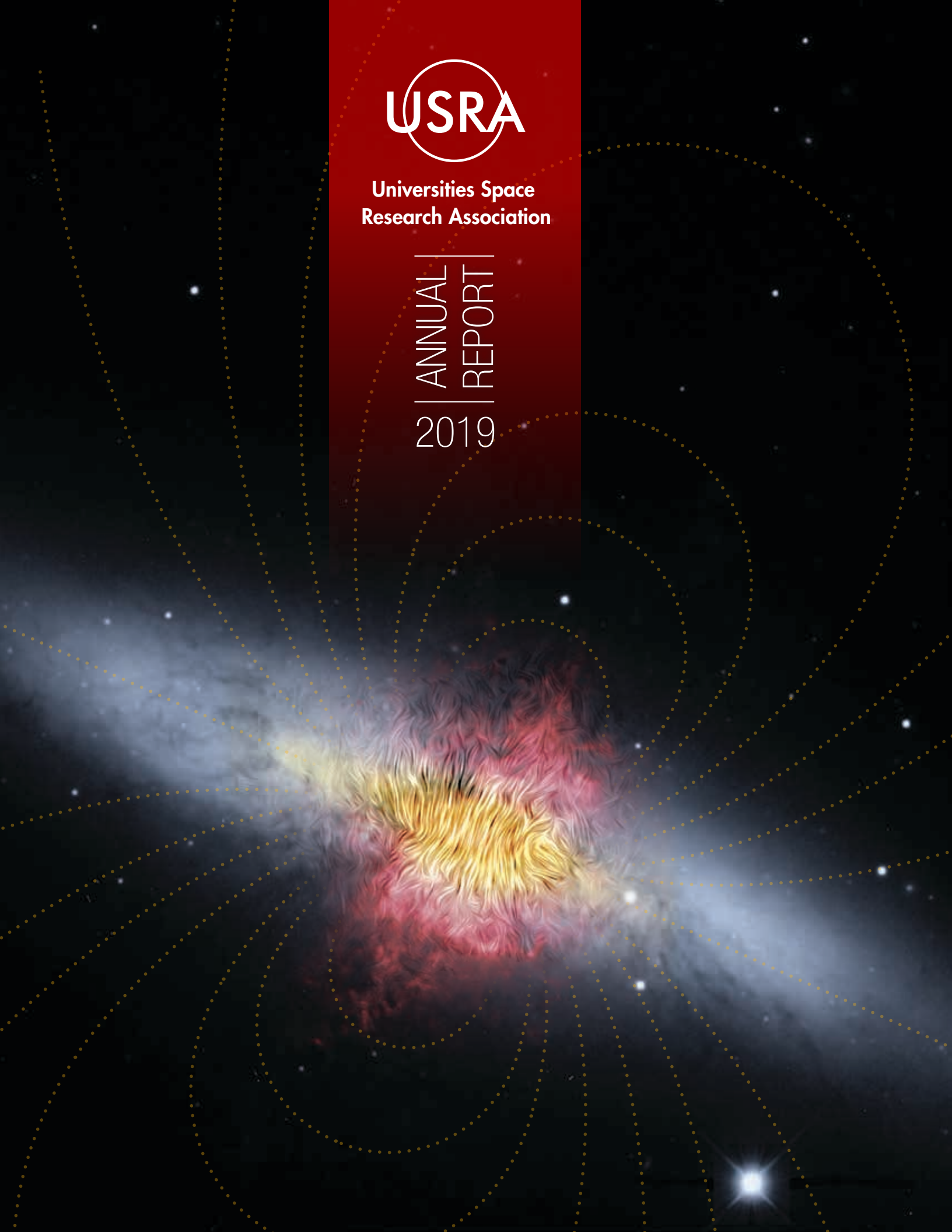

USRA

Universities Space Research Association

2019 ANNUAL REPORT

TABLE OF CONTENTS

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

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COVER IMAGE: THE CIGAR GALAXY'S MAGNETIC FIELD

A composite image of the Cigar Galaxy (also called M82), a starburst galaxy about 12 million light-years away in the constellation Ursa Major. The magnetic field detected by the High-resolution Airborne Wideband Camera-Plus instrument (known as HAWC+) on SOFIA (the Stratospheric Observatory for Infrared Astronomy), shown as streamlines, appears to follow the bipolar outflows (red) generated by the intense nuclear starburst. The image combines visible starlight (gray) and a tracing of hydrogen gas (red) observed from the Kitt Peak Observatory, with near-infrared and mid-infrared starlight and dust (yellow) observed by SOFIA and the Spitzer Space Telescope. Image Courtesy: NASA

INSIDE COVER IMAGE: LOST-IN-SPACE GALAXY

Most galaxies are clumped together in groups or clusters. A neighboring galaxy is never far away. But this galaxy, known as NGC 6503, has found itself in a lonely position, at the edge of a strangely empty patch of space called the Local Void. The Local Void is a huge stretch of space that is at least 150 million light-years across. It seems completely empty of stars or galaxies. The galaxy's odd location on the edge of this never-land led stargazer Stephen James O'Meara to dub it the "Lost-In-Space galaxy" in his 2007 book, Hidden Treasures. NGC 6503 is 18 million light-years away from us in the northern circumpolar constellation of Draco. NGC 6503 spans some 30,000 light-years, about a third of the size of the Milky Way. Image Courtesy: NASA, ESA, D. Calzetti (University of Massachusetts), H. Ford (Johns Hopkins University), and the Hubble Heritage Team

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

The year 2019 was a period in which USRA maintained current operations while focusing on long-term objectives to fulfill our nonprofit purpose. Several of USRA's programs and institutes experienced new growth, while, across all of our activities, USRA continued its fundamental role of serving the university and broader research communities. Here are a few highlights:

One major activity for which USRA is responsible is the science operations for the Stratospheric Observatory for Infrared Astronomy (SOFIA). This past year, USRA supported 89 science flights, with 713 research hours and 10 science instrument changes. This included a nine-week, southern-hemisphere deployment to New Zealand. The year 2019 was the most scientifically productive period of the observatory to date, including two *Nature* papers based on SOFIA observations, one of which documented the extra-terrestrial discovery of Helium Hydride, the first molecule formed in the early universe. We also issued the 8th Call for Observing Proposals, which had a strong turnout and oversubscription rate, indicating SOFIA remains in demand and USRA outreach has been effective at recruiting new observers.

USRA is also responsible for operation of the Lunar and Planetary Institute, which carries the important job of organizing community activities in support of NASA's exploration of our solar system. Last year, the Institute organized 16 conferences and workshops, including the 50th annual Lunar and Planetary Science Conference, which had a record 2,095 attendees from 38 countries, and student participation at more than 30 percent. Originally called the "Lunar Science Institute" 50 years ago, the Institute today is housed in a modern USRA facility near the NASA Johnson Space Center.

Within our educational activities, USRA managed a record 2,300 internships for high school, undergraduate, and graduate students in laboratories nationwide, through both the NASA Internships Program and the Air Force Research Laboratory (AFRL) Scholars Program. USRA worked closely with AFRL this past year to extend the Scholars Program to additional AFRL sites and directorates, and also expand it from a summer program to an activity providing students with internship opportunities in the fall and spring semesters.

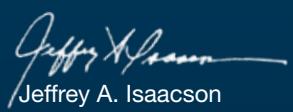
The activity of the Issues and Program Committee of USRA's Council of Institutions was raised to a whole new level. The Committee was established, over a decade ago, to provide a voice in Washington, D.C. to the university community engaged in space-related research and education. This past year, the Committee hosted a congressional briefing on "University Small Satellite Programs: Furthering the Economy, Securing the National Defense, and Training the Next Generation of Space Professionals." The briefing featured talks from faculty and students from three universities, and Chairwoman Eddie Bernice Johnson of the House Science, Space and Technology Committee provided keynote remarks. Over 65 members of the congressional staff attended, as well as officials from NASA and NSF.

The Council of Institutions annual symposium celebrated USRA's 50th anniversary, with the theme, *Space Exploration: Achievements of the Past 50 Years and Ambitions for the Future*. Held at the National Academy of Sciences historic building, the celebration featured remarks from distinguished speakers, including Christine Darden, the former NASA aeronautical engineer portrayed in the book *Hidden Figures*. Dr. Darden was awarded the Congressional Gold Medal, one of the country's highest civilian awards, later in the year.

The Florida Institute of Technology was admitted to membership in USRA, bringing the Association to 111 universities, including 13 non-U.S. members.

Our financial engine remained strong. USRA had revenue of $161M, less than one percent behind 2018, reflecting the government shutdown.

As our 50th anniversary year comes to a close, it is informative to look at the extent and depth of our activities. We are always changing to address the new needs and challenges of our sponsors and the communities we serve. At the same time, we have remained true to our original nonprofit mission and firmly grounded in governance by our member universities. The highlights presented in this annual report convey our partnership with the university community, the trust of our long-standing sponsors, and the dedication of our professional staff.



Jeffrey A. Isaacson
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 Detects Helium Hydride: The Universe's First Molecule Found at Last

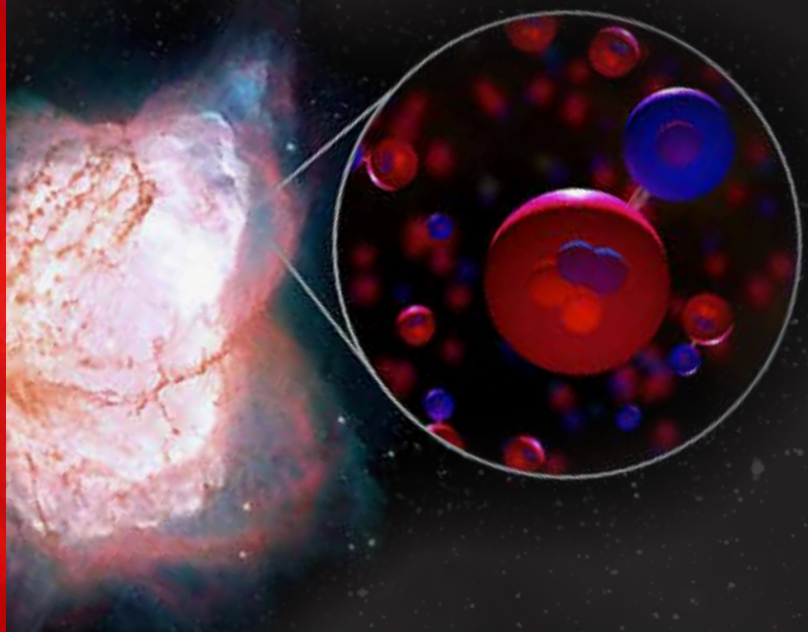


Illustration of planetary nebula NGC 7027 and helium hydride molecules. In this planetary nebula, SOFIA detected helium hydride, a combination of helium (red) and hydrogen (blue), which was the first type of molecule to ever form in the early universe. This is the first time helium hydride has been found in the modern universe. Image courtesy: NASA/SOFIA/L. Proudfit/D.Rutter

For the first time, after decades of searching, scientists have detected the first type of molecule that ever formed in the Universe. This molecule, called helium hydride, was detected using the Stratospheric Observatory for Infrared Astronomy (SOFIA), managed by Universities Space Research Association (USRA) for NASA.

Scientists believe that around 100,000 years after the big bang, helium and hydrogen combined to make a molecule called helium hydride for the first time. Helium hydride should be present in some parts of the modern universe, but it has never been detected in space — until now.

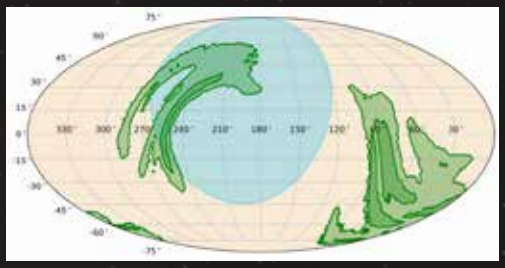
SOFIA found modern helium hydride in a planetary nebula, a remnant of what was once a Sun-like star. Located 3,000 light-years away near the constellation Cygnus, this planetary nebula, called NGC 7027, has conditions that allow this mystery molecule to form. The SOFIA observers, using the GREAT instrument discovered the signature of HeH^+ in the envelope of a dying star, where conditions for its existence were predicted to be optimal. "This molecule was lurking out there, but we needed the right instruments making observations in the right position — and SOFIA was able to do that perfectly," said Harold Yorke, USRA's director of the SOFIA Science Center, at NASA Ames Research Center.

"The lack of evidence of the very existence of helium hydride in interstellar space was a dilemma for astronomy for decades," said Rolf Guesten of the Max Planck Institute for Radio Astronomy, in Bonn, Germany, and lead author of the paper. The discovery was made possible by a recent upgrade to one of SOFIA 's science instrument (GREAT), led by Dr. Guesten, that added the specific channel for helium hydride that previous telescopes did not have.

The discovery serves as proof that helium hydride can, in fact, exist in space. This confirms a key part of our basic understanding of the chemistry of the early universe and how it evolved over billions of years into the complex chemistry of today. The results were published in *Nature*.

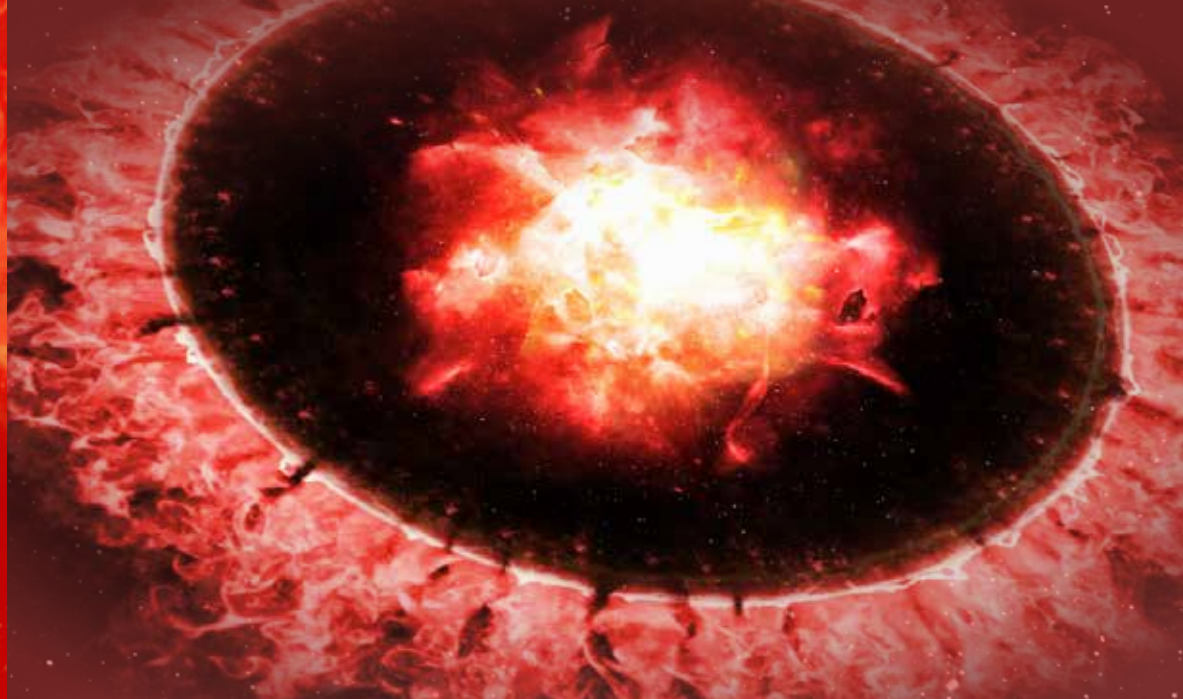
Fermi GBM: An Instrument for Multi-messenger Astronomy

The Fermi Gamma-ray Burst Monitor (GBM), operating in low-Earth orbit, continuously observes two-thirds of the sky in gamma rays, regularly detects cosmological gamma-ray bursts (GRBs) and disseminates rapid alerts to telescopes all over the world. Over the last year, USRA scientists and collaborators made many improvements to operations to better serve the broad interests of the community. GBM now produces continuous data faster for the public, provides more accurate localizations of GRBs on the sky, and the GBM Team has improved the sensitivity of its sub-threshold searches, looking for weak GRB signals once the data has been downlinked to the ground. The GBM Team, through a special data-sharing agreement with LIGO and Virgo, utilizes these improved sub-threshold searches to look for signals in GBM data that correspond to weak signals in the gravitational-wave data. The sub-threshold searches are also used to search for counterparts to astrophysical neutrinos, fast radio bursts, and very high energy transient alerts produced by other telescopes. These improvements, and GBM's critical role in multi-messenger astronomy, were partly responsible for a successful and positive 2019 NASA Senior Review for the Fermi observatory.



Sky map of the localization (green) for a binary neutron star alert from LIGO/ Virgo in April 2019. The blue circle is the region of the sky occulted by the Earth for Fermi. Fermi GBM is unique in that it can observe ~2/3 of the sky instantaneously in gamma rays. Image Courtesy:Adam Goldstein.

In addition to GBM operational improvements, a new set of spectral analysis tools was released to support external community analysis of GBM-detected GRBs. A python-based toolkit, the GBM Data Tools, is being developed to enable easy and open access to the vast amount of continuous data that GBM produces. Using these tools, scientists external to the GBM Team will be able to search GBM data and analyze interesting events or perform correlative analysis with events detected in other instruments.



Artist's concept illustrating Supernova 1987A as the powerful blast wave passes through its outer ring and destroys most of its dust, before the dust re-forms or grows rapidly. SOFIA observations reveal that this dust — a building block of stars and planets — can re-form or grow immediately after the catastrophic damage caused by the supernova's blast wave. Image courtesy: NASA/SOFIA/Symbolic Pictures/The Casadonte Group

SOFIA Shows that Supernovae May Have Created the Earliest Dust

Cosmic dust, a building block of stars and planets can form in the wake of a violent stellar explosion called supernova, according to a new study using the Stratospheric Observatory for Infrared Astronomy (SOFIA). These findings provide clues to an astronomical mystery surrounding cosmic dust.

Dust particles form as dying red giant stars throw off material and become part of interstellar clouds of various sizes, densities and temperatures. The cosmic dust is then destroyed by supernova blast waves.

Supernova explosions are among the most powerful events in the universe, with peak brightness equivalent to the light from billions of individual stars. The explosion also produces a blast wave that destroys almost everything in its path, including dust surrounding the interstellar medium, the space between the stars.

Current theories predict that when a supernova blast sweeps through a region of space, much of the dust would be destroyed, so there is very little dust left. Observations from SOFIA however, tell a different story –revealing more than 10 times the dust expected. This suggests that dust is much more abundant in the wake of a blast wave than theoretical estimates, and it survives the harsh supernova environment.

The dust detected by SOFIA could result from either significant growth of the existing dust particles or the formation of a new dust population. These new observations compel astronomers to consider the possibility that the post-blast environment might be ready to form or re-form dust immediately after the blast wave passes—a new clue that may be pivotal in resolving the discrepancy between dust destruction estimates from models and observations.

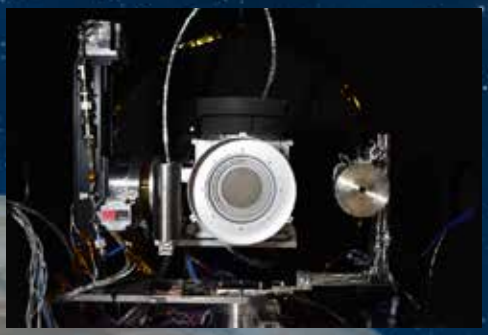
HELIOPHYSICS

USRA is actively involved in Heliophysics, Solar Physics, and Space Weather at the Science and Technology Institute in Huntsville, Alabama. 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.

Plasma Instrument for Magnetic Sounding to Measure Jupiter's Magnetosphere

USRA's Dr. Ken Wright tested space environment effects on several hardware items of NASA's upcoming Europa Clipper mission, led by the Jet Propulsion Laboratory in partnership with the John Hopkins University Applied Physics Laboratory.

To verify instrument design (e.g., energy range and angle range) for the Plasma Instrument for Magnetic Sounding (PIMS), the NASA/MSFC Solar Wind Facility (SWF) was used. PIMS role on Europa Clipper is to measure the plasma currents in Jupiter's magnetosphere. Since Jupiter, located about 5 AU from the Sun, receives only 4% of the light intensity as compared to Earth and possesses a much more intense radiation environment, spacecraft materials and instruments must be carefully selected and designed to survive this cold and severe radiation environment. Various candidate spacecraft thermal control coatings and cable designs were tested at cold temperatures against electrostatic discharge susceptibility using various electron sources. The information from this test campaign contributed toward successful completion of the mission critical Design Review.



PIMS installed in the Solar Wind Facility on a two-axis rotation system. PIMS contains two heads mounted at 90 degrees to each other on a central box containing the electronics. Image courtesy: Todd Schneider/NASA.

LUNAR & PLANETARY SCIENCE

USRA's mission is to advance our understanding of the solar system, from its formation, through its evolution, to its current state.

Earth's Oldest Rock Found on the Moon?

Scientists have discovered what may be Earth's oldest rock in a lunar sample returned by the Apollo 14 astronauts. The research about this possible relic from the Hadean Earth contains traces of minerals with a chemical composition common to Earth and very unusual for the Moon.

Artistic rendering of the Hadean Earth when the rock fragment was formed. Image courtesy: Simone Marchi

An international team of scientists, which included Drs. Katherine Robinson and David Kring of Universities Space Research Association at the Lunar and Planetary Institute, found evidence that the rock was launched from Earth by a large impacting asteroid or comet. This impact jettisoned material through Earth's primitive atmosphere into space, where it collided with the surface of the Moon (which was three times closer to Earth than it is now) about 4 billion years ago.

The sample is, therefore, a relic of an intense period of bombardment that shaped the solar system during its first billion years. After that period, the Moon was affected by smaller and less frequent impact events. The final impact event to affect this sample occurred about 26 million years ago, when an impacting asteroid hit the Moon, excavating the sample back onto the lunar surface where Apollo 14 astronauts collected it and returned it to Earth almost 50 years ago.

New Maps of the Moon's South Pole Released

USRA staff scientist, Julie Stopar, at the Lunar and Planetary Institute, has studied the permanently shadowed regions of the Moon's poles which hold clues to the origin of the solar system, water and other volatile elements. More importantly, her maps of the Moon's polar region, which is not visible from Earth, provide a deeper understanding of the lunar surface that is essential since NASA is planning to send astronauts to the lunar south pole by 2024.

Little is currently known about the form and location of the Moon's water-ice reserves. Maps of the illumination conditions, terrain, and the permanently shadowed regions of the Moon help to identify the best places on the Moon for human exploration.

Dr. Stopar used the Lunar Reconnaissance Orbiter data to generate a set of 14 topographic maps that can be used to visualize the terrain near the south pole. This series of maps, images and illustrations are compiled into a new atlas that provides context and reference for future human exploration by NASA and commercial space companies.

Darkness surrounds illuminated peaks between Shackleton crater (at right) and de Gerlache crater (out of scene left). Image courtesy: NASA/GSFC/Arizona State University

Are Comets Source of Earth's Oceans?

The origin of the Earth's water has been a subject of heated scientific debate in recent decades, with competing ideas that the water could have been delivered by comets, asteroids, or volcanic eruptions on the young Earth.

To identify the original sources of the Earth's oceans, scientists compared isotopes of the hydrogen found in the planet's water to isotopes of hydrogen seen in extraterrestrial bodies such as comets. All isotopes of an element have the same number of protons, but each has a different number of neutrons — for instance, regular hydrogen has no neutrons, while the hydrogen isotope known as deuterium has one neutron. Adding a neutron to one of the hydrogen atoms makes it Deuterium, which is twice as heavy as hydrogen.

Scientists, using SOFIA, measured the amount of heavy water (HDO) when comet Wirtanen passed close to the Earth in December 2018. The results showed that the ratio of Deuterium to Hydrogen was similar to the Earth's oceans. However, this is only the second comet whose isotope ratio matches the Earth's oceans. Many other comets do not match, in particular, comet Churyumov-Gerasimenko.

Comparing the properties of the two comets that match the Earth's oceans with those that do not, SOFIA observers concluded that only the "hyperactive" comets that have a very high production rate of water, match the isotopes of the Earth's oceans. These new results, only made possible by new SOFIA observations, suggest that comets are indeed plausible sources of the Earth's oceans—not just any comet throughout its life—but the hyperactive ones that generate water from solid particles that break from the nucleus.

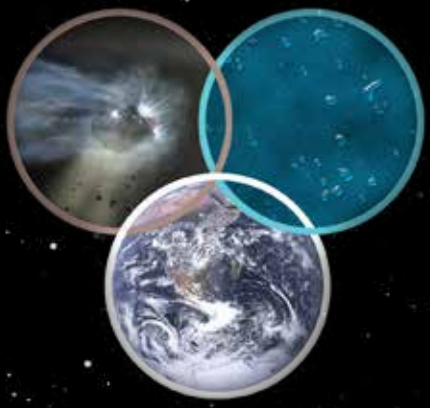


Illustration of a comet, ice grains and Earth's oceans. SOFIA found clues in Comet Wirtanen's ice grains that suggest water in comets and Earth's oceans may share a common origin. Image courtesy: NASA/SOFIA/L. Cook/L. Proudfit

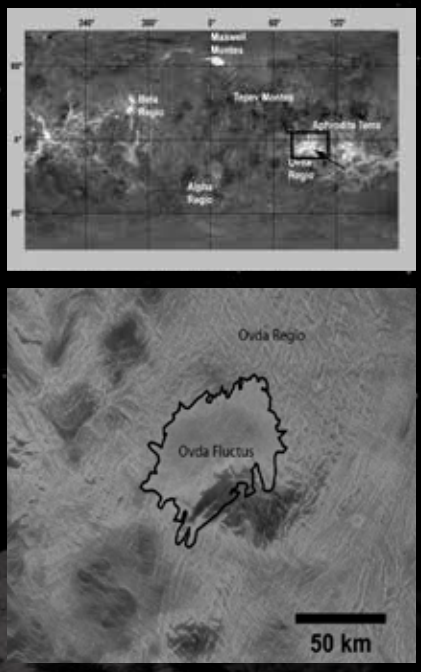
Was Venus Once Warm and Wet? New Study of Lava Flow Suggests Not!

USRA scientists working at the Lunar and Planetary Institute (LPI), and undergraduate student intern Frank Wroblewski from Northland College, found that the Ovda Fluctus lava flow on Venus is composed of basaltic lava, reversing the idea that the planet might once have been Earth-like with an ancient ocean of liquid water.

Previous studies suggested that early Venus was once warm and wet. This idea came from the chemistry of its atmosphere and the presence of highlands which were thought to be granitic, like Earth's continents, requiring oceans of water to form.

The LPI team re-mapped the Ovda Fluctus lava flow using radar data. They discovered that the flow is not granitic, but is more likely made up of basalt rock which can form with or without water. The result has potentially significant implications for the evolutionary history of Venus. The new map and results are published in the *Journal of Geophysical Research: Planets.*

USRA's Dr. Allan Treiman, Associate Director of Science, at the LPI suggests that the Ovda Regio highlands, where this particular lava flow is located, were squeezed up to their current heights by internal forces, possibly like mountains which result from plate tectonics on Earth.



The top image shows the Magellan Radar mosaic of Venus; the Ovda Fluctus lava flow at the arrow's point. The bottom image is a close-up of the lava flow – dark line shows its margin. Image courtesy: NASA.

EARTH SCIENCE

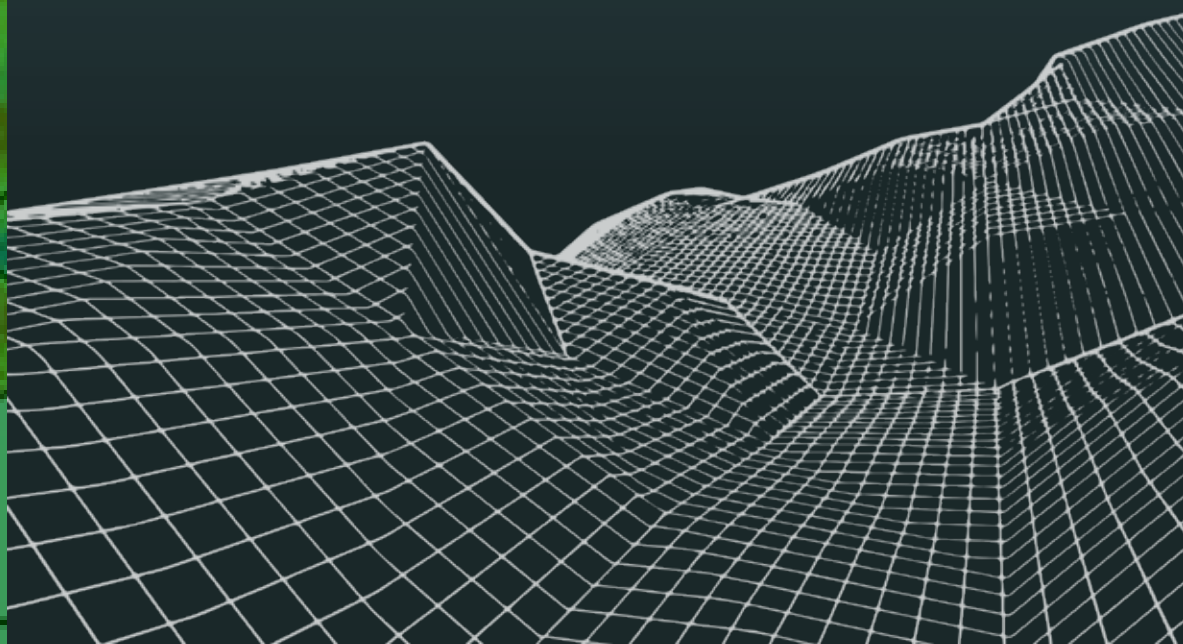
USRA scientists strive to understand Earth's natural processes and their propensity to change and the linkage between human and natural systems. They also lead efforts to build knowledge and abilities to apply earth observations for societal benefits.

Improving Land Surface Modeling Using NASA Observations

Simulated and observed radar reflectivity. (Left) WRF 24-h forecast from control run; (center) WRF 24-h forecast with SMAP data assimilation; (right) observed NEXRAD radar reflectivity. The SMAP run (center image) more accurately depicted the shape and timing of precipitation. Image courtesy: USRA/NASA

USRA'S Clay Blankenship leads an effort for the NASA Short-term Prediction Research and Transition (SPoRT) center to improve a land surface model by data assimilation of soil moisture from the NASA Soil Moisture Active Passive (SMAP) satellite mission. The SMAP observations are assimilated into the Noah land surface model within the NASA Land Information System. A new non-localized bias correction has been developed which allows the satellite observations to influence the model climatology of soil moisture, making it possible to correct errors in soil moisture fields due to biases in the forcing precipitation data. Over the continental US, validation against soil moisture probes shows improvement in correlations over the eastern US, but degradation over much of the southwestern US and west coast.

Additionally, impact of SMAP observations on weather prediction is being evaluated using a combination of observations and the weather research forecasting model in data assimilation mode. Individual test cases demonstrate that SMAP can improve the timing and structure of certain severe storm events. A more systematic assessment is ongoing to evaluate the impact of SMAP daily forecasts over the summer months for different regions of the US.



SERVIR – Promoting Sustainable Development

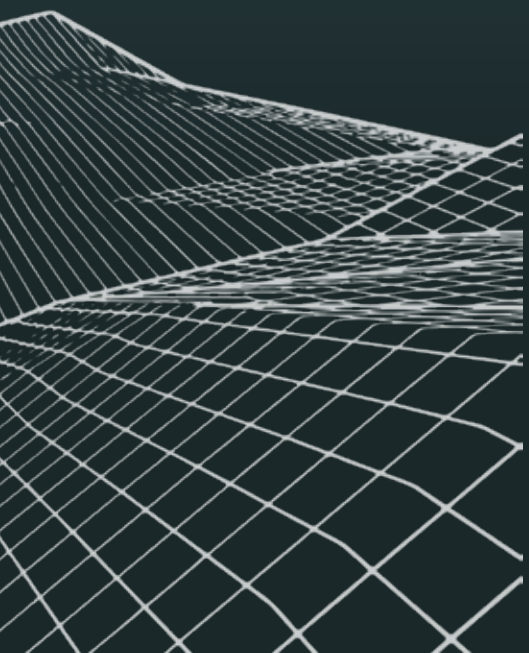
SERVIR, a joint development initiative of NASA and USAID, is present in over 50 countries. It is served by 5 hubs hosted by leading regional organizations applying Earth science data and tools to promote sustainable development. Image Courtesy: SERVIR

The purpose of the SERVIR project, a joint effort between NASA and the US Agency for International Development (USAID) is to build capacity in developing regions to use Earth observation data and models to help in several thematic areas relies on effective methods and applications to process large volumes of data and deliver results to users in ways they can easily incorporate in decision-making processes. USRA scientists contribute to SERVIR by leading the Geospatial Information Technology (GIT) community of practice across the global SERVIR network. Software engineers based at USRA/STI in Huntsville, participate as members of SERVIR's Science Coordination Office (SCO), to co-develop software solutions along with scientists and engineers from the regional SERVIR hubs, and from several research centers throughout the USA and with global partners such as the United Nations' Food and Agriculture Organization (UN/FAO).

The USRA team is responsible for:

- Co-development of Collect Earth Online (https://collect.earth), an application to crowdsource land use/land cover data across the globe (in coordination with UN/FAO);
- ClimateSERV (https://climateserv.servirglobal.net), a system to allow users to run zonal statistics on a series of key datasets over large time series. It also allows the extraction of small chunks of data from those data sets which would otherwise be extremely challenging to do in regions with internet bandwidth problems;
- Operating SOCRATES, a shared cluster that allows the hubs to run complex models and processing tasks that require much larger computing capacity than what is available at their premises.

The team also promotes the adoption of development technologies and platforms that allow the hubs to deliver applications faster and more effectively to their user communities. This includes leading the adoption of cloud computing and engaging potential technological partners from the private sector. USRA's GIT Team is also responsible for knowledge management on GIT topics through the entire SERVIR network.



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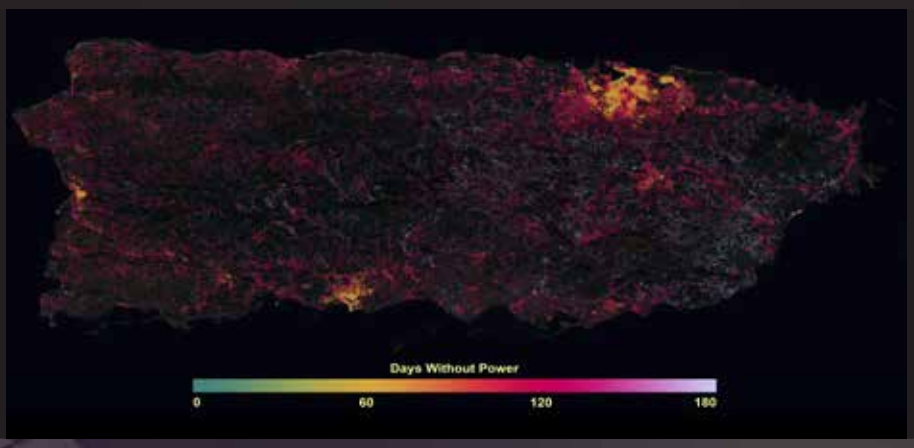


Novel Satellite-based Technology Monitors Power Outages from Space in Real Time

Severe weather events frequently result in large-scale power failures, affecting millions of people for extended durations. Such power failures affect the health, well-being and productivity of people and businesses. When power is not restored quickly, catastrophic consequences may ensue. For the first time, the Black Marble visualization product developed by USRA and NASA, enables real-time monitoring of power outages and restoration of electricity services, both within cities and in remote and isolated areas.

The impact of Maria which struck Puerto Rico in 2017 devastated the island resulting in loss of lives and in the longest power outage within a US territory. Immediately after the hurricane, approximately 1.5 million customers across the island suffered from long duration power failures. Little information was available from PREPA, Puerto Rico's sole power utility, due to disruption in monitoring systems.

To map areas that were hit hardest and to track the recovery of the grid, USRA and NASA scientists used the Black Marble Product Suite, to measure changes in night lighting before the storm, and during days post-Maria. The maps created from Black Marble over Puerto Rico showed an 80% decrease in lights, in total, immediately after Hurricane Maria for the entirety of Puerto Rico which in turn indicated areas that needed the most help.

USRA and NASA scientists worked with emergency response groups such as FEMA and the National Guard so they could use the data to target their resources and efforts efficiently to minimize long-term impacts on residents. When applied during disasters, the Black Marble Product Suite can support humanitarian decision-making via real-time estimations of persons affected, the coordination of rapid response teams and thus potentially save lives.

USRA's Miguel Roman and his colleagues at NASA published a paper describing in details the electricity restoration efforts after Hurricane Maria.

Román MO, Stokes EC, Shrestha R, Wang Z, Schultz L, et al. (2019) "Satellite-based assessment of electricity restoration efforts in Puerto Rico after Hurricane Maria." PLOS ONE 14(6): e0218883. https://doi.org/10.1371/journal.pone.0218883

This image shows surface concentrations of tropospheric ozone (O_3) simulated by GEOS-CF (GEOS-Composition Forecast) for July 22, 2018 at 1500 UTC. At the surface, ozone is harmful to humans and vegetation. It is produced chemically from other air pollutants under the presence of sunlight. Highest concentrations of surface ozone can be found during daytime close to urban areas and in the vicinity of forest fires (e.g., South America, Africa). Image courtesy: Christoph Keller, in collaboration with the NASA Scientific Visualization Studio/USRA

Contribution to the Goddard Earth Observing System (GEOS)

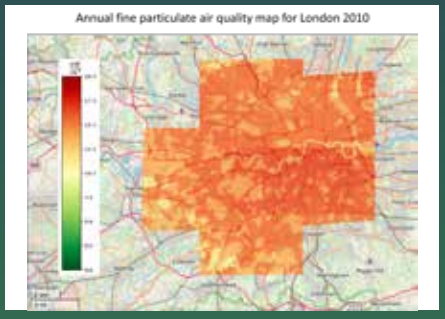
Current global models of the Earth System have reached an extraordinary level of detail and complexity. The resolution, which grants the ability of detecting phenomena at exceedingly smaller scales, continues to grow; more importantly, the amount of physical, chemical and biological processes actually represented has increased enormously. The Goddard Earth Observing System (GEOS) global model and data assimilation has reached one of the greatest levels of sophistication in the world.

The main advantage of the GEOS system is its modular structure, i.e., the capability of studying processes separately from the main model, and then plugging or unplugging these processes according to the needs of the research. Outstanding features of the GEOS range from the ability to produce real-time air quality forecasts globally at the Earth surface, to the treatment of stratospheric chemistry and the extensive work performed on atmospheric aerosols from state-of-the art representation of convection, to the advances in the radiative transfer. Top contributors to the GEOS development are USRA scientists Drs. Virginie Buchard-Marchant, Saulo Freitas, Christoph Keller, Emma Knowland, Peter Norris and Brad Weir, among others.

Developing Virtual Sensors for Air Quality Measurements in Urban Systems

USRA's Environmental Analytics group is engaged in the research, development, and improvement of air quality and health impact models. It also focuses on atmospheric sciences, and aerosol sciences in Earth and space environments. Led by Dr. Meytar Sorek-Hamer, the team is working in collaboration with NASA Artificial Intelligence researchers and University of British Columbia to develop a deep learning model to map exposure to fine particulate matter (PM2.5) with high resolution satellite images in developed and developing cities. The team obtained over 40,000 commercial high resolution images (0.3m-4m) at no cost through the NASA Private Sector Small Constellation Satellite Data Product Pilot program. The data have been pre-processed and a deep-learning approach has been applied to estimate air pollution over urban environments. The novel hybrid model which integrates physics with an image analysis approach revealed good results with a prediction error (RMSE) below 1 microgram/cubic meter PM2.5.

While current air quality modeling uses statistical models at coarse spatial resolution, USRA scientists can produce air quality maps at the meter scale, including high resolution satellite images, which will increase current knowledge and forecast capabilities for developing cities that are lacking any information or characterization of their environmental status in general, and air quality specifically.



Satellite imagery of London, England, was processed using a hybrid deep-learning model to derive the concentration of atmospheric particulate matter with a size less than 2.5 microns (PM2.5). Model results agree well with target data. Image courtesy: USRA

MICROGRAVITY 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 exploration and commercialization of space.

Liquid Crystal Facility

The Liquid Crystal Facility (LFC) is a multi-user facility that will be used to conduct investigations aimed at identifying new physical phenomena related to the formation of liquid crystals with the ultimate objective of improving liquid crystal displays and electro-optic devices. LCF will provide a unique capability to study the natural two-dimensional structures and dynamics of freely suspended liquid crystal films as thin as six nanometers. USRA's Dr. Padetha Tin is the Project Scientist for the LFC that is currently in development. The LCF is rapidly progressing towards first use on the International Space Station in 2021. The first three experiments using the LCF will be:

1) "Interaction and Dynamics of Ferromagnetic Inclusions on 2D Smectic Films in Microgravity", with Prof. Noel Clark from the University of Colorado as the Principal Investigator.

2) "Structure and Dynamics of Monodispersed Liquid Crystal Domains Created on Freely-suspended, Molecularly-thin Smectic Films using Sub-femtoliter Inkjet Technology", with Prof. Hiroshi Yokoyama from the Liquid Crystal Institute at Kent State University as Principal Investigator

3) "Microgravity Studies of Nanoparticles and Topological Defects in Liquid Crystal Thin Films", with Prof. Charles Rosenblatt from Case Western Reserve University as Principal Investigator

USRA's Dr. Padetha Tin, in collaboration with Prof. Hiroshi Yokoyama of Kent State University, developed a unique sub-femtoliter droplet dispenser that will be used in the LCF on board the ISS. Their novel device makes use of electrostatic force where the individual droplets can be dispensed in a highly controlled manner. This new invention can dispense sub-femtoliter droplets of high-viscous fluids and electronic materials. Image courtesy: USRA

Upcoming Saffire Experiments Study Fire Hazards and Interaction of Fire Byproducts Health Hazards

A composite image from the Saffire-1 experiment that shows how the flame front propagated in microgravity. Image Courtesy: NASA

USRA's Dr. Paul Ferkul and Dr. Rosa Padilla, who are key members of Spacecraft Fire Safety Experiments (Saffire) team at NASA GRC, have analyzed data from the first three Saffire flights and are preparing for the next set of flights that are scheduled to start early in FY 2020. Saffire is flown in the Cygnus cargo vehicle to investigate large-scale fire growth and limits of material flammability.

Dr. Padilla performed detailed testing and analysis of the fire hazards associated with lithium-ion batteries in a spacecraft environment. In June 2019 she was a key participant in a series of tests where laptops and tablets containing lithium-ion batteries were burned in a combustion chamber at NASA's White Sands Test Facility that simulated the atmosphere inside the Orion Crew Module. Upcoming Saffire investigations will also include testing to better understand the transportation and interaction of fire byproduct health hazards such as hydrogen chloride, carbon dioxide, and particulates.

USRA's Gordon Berger and John Easton (CWRU) are key members of a team that designed, developed, and built a new ground-based laboratory to determine how to best measure these hazardous byproducts.

USRA's Dr. Rosa Padilla, a key member of the Saffire team, has analyzed data from the previous Saffire flights. Image courtesy: USRA

Fluid Physics and Complex Fluids Research Advanced Collioids Experiment

The Advanced Colloids Experiments (ACE) family of investigations 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. Advances in colloidal engineering could lead to the development of a wide range of new and improved technologies in the areas of stabilizers for consumer products, large area electrodes for energy storage, micro-machines, and photonic materials to control and manipulate light.

USRA's Dr. William Meyer, the Project Scientist for the Advanced Colloidial Expereiments, conducted three unique ACE investigations using the Light Microscopy Module. Each of the three investigations focused on different aspects of self-assembling and self-organizing colloidal structures. One of the flight experiments was ACE-T12, a microgravity colloids study being led by Professors Stuart Williams and Gerold Willing, both of the University of Louisville. ACE-T12 is testing the theory that underlies particle "haloing," where smaller particles halo (shroud) larger particles and help control attractions between particles. Understanding particle haloing is important for advancing self-assembly and colloidal engineering. The goal of ACE-T12 is to increase the number of charge carriers in a colloidal gel system which holds open the possibility for a significant increase in solar cell efficiency.

SPACE TECHNOLOGY

USRA performs advanced studies at the Center for Space Nuclear Research (CSNR) in Idaho Falls. These studies support radioisotope and fission power systems for space exploration and the development of advanced propulsion.

Reestablishing the Production Capability for Plutonium 238

The Radioisotope Thermoelectric Generator (RTG) has been an enabling technology for more than 40 years on NASA missions such as the New Horizons mission (to Pluto, Charon and the Kuiper Belt), Cassini (to Saturn) and the Curiosity Rover on Mars. The RGT uses the heat of long-lived isotopes to produce 100 to 300 W of electricity and heat necessary to keep electronics and mechanical joints functional. The Mars 2020 Rover will also have an RTG. Earlier RTGs continue to power the Voyager 1 and 2 spacecraft more than 42 years after launch.

Since the US has not produced Plutonium-238 (Pu-238) since1988, new sources to power future space missions are essential. And USRA researchers are working hard to optimize the production of Pu-238. These engineers used neutron transport simulations to determine the feasibility of using little-used B- and I-locations in the beryllium reflector.

Additional irradiation sites in a beryllium reflector for the enhanced production of Pu-238. Image courtesy: Idaho National Laboratory and CSNR 2019 Summer Fellows

Seal Technology Developed for New Docking System for Space Missions

A team of researchers from the University of Akron and the University of Toledo is working with NASA Glenn to develop a new docking system for future missions to the International Space Station (ISS) and other destinations beyond low Earth orbit. A key component of this docking system is the seal at the main docking interface on the top of the docking system tunnel. The seal is relatively large and is compressed during the docking process to seal the interface between the top of the docking system tunnel and the mating surface on the vehicle to which it is docking. After docking, the seal must exhibit extremely low leak rates to ensure that astronauts have sufficient breathable air for extended missions. This novel seal technology, developed by the research team at NASA Glenn, was awarded a US patent in June 2019.

This artist illustration shows the SpaceX Crew Dragon spacecraft docking to the International Space Station. Image courtesy: NASA

LIFE SCIENCE RESEARCH

In support of human exploration missions for the Moon and beyond, USRA's NASA Academic Mission Services program conducts research and development in the space biosciences, synthetic biology and bioinformatics. Research in microgravity and space radiation is offering countermeasures to minimize deleterious effects on the human body such as bone loss, cancer and nervous system impairment, caused by microgravity and space radiation. Additionally, USRA supports the technology development of data system protytypes that are providing the Gateway missions with requirements to facilitate autonomous medical care operations.

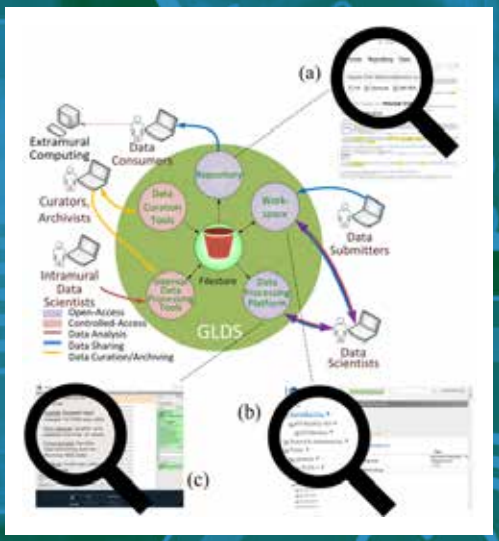
Medical System for Space Exploration

For manned space exploration missions, the risk of crew members experiencing a medical condition increases as the duration in the space environment increases. Limitations in mass, volume and power prevent the ability to bring all necessary medical equipment to diagnose and treat all possible medical conditions. However, technology continues to provide improved computational capability. Hence, a medical system that manages and analyzes data would augment decision support in future missions. As a first step towards realizing clinical decision support in a space medical system, USRA supports the Exploration Medical Capability in the development of a medical data management system under the Human Research Program. Developed through the Medical Data Architecture project, this medical system integrates with biomedical devices and other relevant medical data sources to seamlessly collect, load and store data. To demonstrate functionality, this system was deployed and operated in Gateway prototype habitats. Demonstration of automated data management has provided a platform for the next phase of development where analytical tools that use artificial intelligence or machine learning may be applied to help diagnose, treat or prevent medical conditions from occurring.

USRA's Michael Krihak, Project Manager for the Medical Data Architecture project, is shown operating the medical system software during a Gateway habitat prototype test at Johnson Space Center. Image courtesy: USRA

Research Space Biomolecular Database

USRA supports the GeneLab project at NASA's Ames Research Center, which provides spaceflight relevant omics datasets and tools to support science collaboration through Analysis Working Groups (AWGs) in the following domains: Plants, Multi-Omics/System Biology, Microbes, Animals – Mammals, and Animals – Non-mammals. In 2019, USRA was tasked to take over GeneLab Data Services to engage the broad non-federal user community. The new data services will provide improved support for all of the GeneLab AWGs, which work to optimize the processing of raw omics data from the GeneLab repository. This will allow the generation of new scientific knowledge related to understanding basic mechanisms by which biological organisms adapt to the spaceflight environment.



The graphic depicts the single platform for omics data archiving, sharing, and analysis provided by the GeneLab Data Systems (GDLS). Image courtesy: NASA

AERONAUTICS RESEARCH

USRA's Air Traffic Management technologies continue to evolve to improve safety, reliability and efficiency for the benefit of passengers and airline operators and prepare for the coming of autonomous vehicle operation in the National Air Space (NAS). USRA's NASA Academic Mission Services (NAMS) team researchers help to make these improvements possible by working closely with NASA, the FAA, the aviation industry, and universities to develop and test future capabilities.

NASA's field tests of UTM technologies in urban environments under a variety of weather and traffic conditions. Image Courtesy: NASA / Dominic Hart

Support for Aeronautics

USRA is developing prototype software systems in support of Airspace Technology Demonstration-2 (ATD-2) that serve as a precursor to FAA systems currently under development. NAMS-supported field demonstrations of integrated arrival, departure and surface (IADS) operations give stakeholders and users the ability to exercise some of the new capabilities now, which helps to inform FAA investment decisions. Benefits analyses of the field demonstration data suggest the system saves fuel, reduces emissions and congestion on taxiways, and improves compliance with scheduled takeoff times for managing overhead stream insertion.

The images above show the ATD-2 IADS systems in use at the Charlotte-Douglas International Airport. Image Courtesy: NASA/E.M. Wang

Advancing capabilities for Unmanned Aircraft System (UAS) Traffic Management (UTM)

USRA engineers are helping usher in an era of autonomous package delivery and passenger air services. The NAMS team supports development of novel, innovative and award-winning UTM software that enables small UASs to access low-altitude airspace in a safe, efficient, and fair manner. Traditional Air Traffic Management relies on a central body (like the FAA) to manage and control the airspace. UTM allows for distributed management of the airspace wherein private companies collaborate to maintain a safe and accessible environment. Successful demonstrations of this capability involved flying small drones near and around downtown skyscrapers to test effects of rapidly changing wind flows, communication via cellular networks, backup location detection, detecting and avoiding obstacles in the flight path, and the ability to land safely in an emergency.

Urban Air Mobility

In support of Urban Air Mobility (UAM), USRA's activities at NAMS have been testing the integration and interconnectivity of the NASA UTM System and NASA's Air Traffic Management Exploration project. NAMS work has included the joint development and modeling of operational airspace volumes, integrating a Vertical Takeoff and Landing (VTOL) model with common UAM vehicle flight models, and adding functionality to the UAM system and expanding it to provide a software simulation testbed for analyzing future concepts of operations for UAM integration into the NAS.

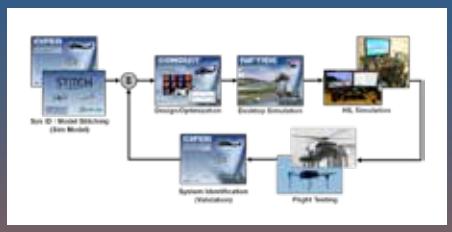
Artist's concept depicting multiple unmanned aircraft flying in an urban environment, which will be the scenario for NASA's last in a series of demonstrations of a system that safely manages drone flight. Image courtesy: NASA Aeronautics Research Mission Directorate

USRA Develops and Deploys Software Tools to Aid in Aircraft Control Systems Design

The USRA Flight Control System Software Development team, under the NAMS Aeroflightdynamics Technical Area, continues to make significant improvements to the flight control design software suite jointly developed with the U.S. Army Aviation Development Directorate at Ames (ADD-A). In FY2019, the team worked closely with the ADD-A researchers to develop STITCH, an important new addition to the flight control design software suite. Based on many years of research in physics-based modelling and simulation, the STITCH software allows researchers to "stitch together" a full-flight envelope simulation model of any aircraft configuration, including rotorcraft, fixed-wing, and multi-copter UAS, for application in a software- or hardware-in-the-loop simulation environment.

Another significant accomplishment by the USRA team in FY2019 was the release of version 6.0 of CONDUIT® -- one of the flagship tools of the flight control design software suite. CONDUIT® is an aircraft flight control design and optimization tool that allows engineers and researchers to rapidly evaluate and optimize their designs against relevant performance specifications and design criteria. Over the years, CONDUIT® and the associated design methodologies have been successfully applied to many rotorcraft, fixed-wing aircraft, and UAS programs.

These flight control design software tools are developed not only for supporting ADD-A's research and development missions, but have also been deployed to and widely-used by engineers and scientists in many aerospace companies, academia, and government agencies world-wide, through the USRA/NAMS-managed Software Transfer Agreement (STA) distribution program.



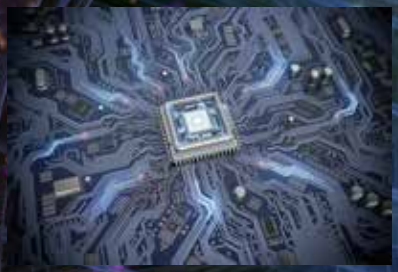
A collage of the new STITCH software, featuring the CONDUIT® 6.0 environment: the Integrated Flight Control Design, Simulation, and Validation Workflow. Image courtesy: Kenny Cheung and Jonathan Soong, USRA

COMPUTER SCIENCE & INFORMATION TECHNOLOGY

USRA's R&D support is focused primarily on discovering new algorithms and applications of quantum computers for national needs, including aeronautics, exploration, and science applications.

USRA's Research and Development Activities

This includes research on both Quantum annealing and emerging universal gate model quantum computing architectures. This research has resulted in numerous papers co-authored by USRA and NASA scientists, including seminal research on new quantum algorithms, the application of quantum computing to a number of NASA challenges, and research associated with benchmarking quantum computers against classical computers. During the past year the USRA team contributed to more than ten quantum-related publications in peer-review venues, six of which were led by USRA researchers. USRA staff also support major projects that include the IARPA Quantum Enhanced Optimization Program, which tests and evaluates different quantum computing hardware platforms, and a NASA Convergent Aeronautics Solutions (CAS) project led by NASA Ames focused on using quantum computing to build a secure and jam-free network capable of accommodating hundreds of thousands of drones flying each day.



USRA Joins Quantum Economic Development Consortium

In 2019, USRA joined the Quantum Economic Development Consortium (QED-C) established by SRI for NIST to support the emerging quantum industry as part of the National Quantum Initiative signed into law last December. The purpose of the QED-C is to support enabling technology R&D, facilitate industry coordination and interaction with government agencies, and provide the government with a collective industry voice in guiding R&D investment priorities and quantum workforce issues. The QED-C is working to determine workforce needs, provide efficient public-private sector coordination, identify technology solutions for filling gaps in research and infrastructure, and foster sharing of intellectual property, efficient supply chains, technology forecasting and quantum literacy.

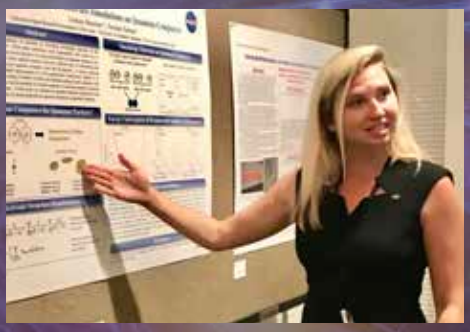
USRA's participation in QED-C will enable the organization to further its not-for-profit mission of bringing together government agencies, industry, and universities to work on quantum related science problems. Additionally, much of the R&D work in the emerging field of quantum is still very early stage research done in a large part by university faculty.

The plenary meeting of the QED-C, which focused on quantum sensing, was attended by over 160 scientists, technologists, and entrepreneurs and provided a current state of quantum sensing technology, including sensors

USRA Feynman Quantum Academy Students at NASA's Ames Research Center

USRA recognizes that quantum science is complex, and advances require a broad range of expertise including mathematics, physics, chemistry, engineering and material science. Quantum science needs to build a multidisciplinary community of professionals who can translate basic university research into operational environments, build prototypes and drive technology development. To help meet these needs, USRA founded the Feynman Quantum Academy to help train the next generation of quantum information scientists.

Quantum students presenting posters at the Ames Summer poster session. Image courtesy: USRA



A Quantum Academy was piloted with a couple of students in the summer of 2016, and renamed the Feynman Quantum Academy the following year, with permission from Professor Feynman's Estate. Since that time, the Academy has grown in 2019 to 8 students from top universities, working on a variety of NASA challenges in advanced computing, aeronautics, and other space-related optimization problems. The students have direct access to a 2048 superconducting qubit processor in the D Wave quantum annealer.

Operating within the Quantum Artificial Intelligence Laboratory (QuAIL) and the NAMS R&D Student Program at NASA Ames, the program supports participants from domestic and international universities. The students receive hands-on training and undertake individualized research projects in advanced computing including applied work on quantum annealing, numerical simulation of quantum circuits, and software development for quantum algorithms. The small size of the program ensures that each student receives engaged scientific mentoring, resulting in opportunities for publication or conference presentations.

that measure temperature, gravity, timing, and magnetic fields. The new technologies not only offer greater sensitivity but also eliminate the need for regular recalibration resulting in cost savings particularly for agencies like the DOD that field large fleets of vehicles, including aircraft, destroyers, aircraft carriers, helicopters, etc. with an untold number of sensors. As artificial intelligence technology advances and computers take on driving our cars and making other consequential choices, it is critical to have accurate, reliable sensors to inform those decisions. The quantum sensing field will be a key part of that evolution.

SCIENCE FACILITY MANAGEMENT & 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 manages various facilities including the science operations for the Stratospheric Observatory for Infrared Astronomy (SOFIA), the Airborne Science Facility, the Quantum Artificial Intelligence Laboratory (QuAIL), the Innovation Laboratory, the Gene lab, the Keck Remote Observation Center and the Research Institute for Advanced Computer Science.

SOFIA

SOFIA is a significantly 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 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 under sponsorship of NASA's science mission directorate.

QuAIL

In addition, USRA operates the Quantum Artificial Intelligence Laboratory (QuAIL) 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, 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.

Keck Remote Observation Center

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.

Research Institute for Advanced Computer Science

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 undertakes collaborative projects with research groups at NASA and elsewhere, integrating computer science with other disciplines to support NASA's mission.

NASA's Airborne Science Facility

The Airborne Sensor Facility (ASF) at Ames supports a variety of airborne research activities for the NASA Earth Science Division. It conducts engineering development of remote sensing instrumentation and real-time payload communications systems, and supports their operational use on science field campaigns. The ASF maintains a suite of facility instruments that are made

Scientists working on SOFIA's telescope. Image Courtesy : NASA

available for use by NASA-approved research projects, with all resulting data being made available free of charge through public archives. These data are typically used for fundamental earth science process studies, satellite calibration and validation, development of retrieval algorithms, and disaster response. The sat-com based payload communications systems are deployed on most of the NASA science aircraft, and are a key element of the larger NASA Airborne Sensor Network, which allows scientists to view data from multiple instruments in real time during science campaigns.

The ASF is staffed by the Universities Space Research Association under the NASA Academic Mission Services contract. It includes elements for sensor engineering, optical and infrared sensor calibration, and data processing.

NASA-USRA Science and Technology Innovation Laboratories

The Science & Technology Innovation Laboratories (Innovation Labs) Program supports collaborative scientific research and STEM workforce development through the operation of multidisciplinary analytical instruments for shared use by multiple organizations. The Innovation Labs are jointly managed by USRA and NASA. Users from government, industry, and academia become Affiliates to engage in the shared use of the Innovation Labs in support of collaborative research and STEM workforce development.

The premiere resource of Innovation Labs is the Materials Characterization Lab (MCL), an advanced microscopy and materials analysis facility that provides flexible and powerful instruments and analytical tools for advanced materials, nanotechnology, bioengineering, and space bioscience research applications. The MCL offers sample processing and characterization capabilities necessary to conduct advanced materials research and analysis. The MCL provides training and access to state-of-the-art instruments including electron microscopes and complementary equipment to support research at NASA Ames and the Silicon Valley academic and industrial community. USRA oversees lab safety, operations, maintenance, and hands-on training for independent lab instrumentation operation.

GeneLab Data Platform

This program has the goal of teaching high school students the importance of 'omics studies and space biology, as well as teaching them how to analyze datasets using the NASA GeneLab Data Platform. This program was led by USRA Scientist, Dr. Elizabeth Blaber, and was implemented successfully for two years. During the program, students were taught about NASA, biological research in space, model organisms and molecular biology, 'omics techniques and how to write a research proposal based on a hypothesis and testable aims. The end goal of the program was the generation of a research proposal that each team of students developed based on data mining of the dataset from GeneLab. One student group was selected to return to NASA ARC and conduct their research proposal in collaboration with a NASA mentor. The results of this experiment are expected to be published in a scientific journal, such as Nature Microgravity.

Capabilities and Services

Facility Sensor Systems

Development and operation of remote sensing systems for satellite calibration/validation, algorithm development, and basic Earth Science research.

Airborne Sensor Network Development

Design, fabrication, and operation of real-time payload communication and control systems, to increase the productivity of the core NASA science aircraft.

Payload Integration Engineering

Cross-center airborne instrument integration support with mechanical, electrical, and software engineering services. This group also provide services in flight planning, mission coordination, Investigator Liaison, post-flight data evaluation, and data process.

Optical and Infrared Calibration Laboratory

NIST-traceable characterizations of airborne imaging devices (supervised by the EOS Calibration Scientist).

INTERNSHIPS, FELLOWSHIPS & SCHOLARSHIPS

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, thereby advancing the Nation's technical prowess. This engagement includes programs that span from elementary and middle school to university and beyond, which are supported by NASA, DOD, and USRA's own corporate resources.

AFRL SCHOLARS: Enhancing the Intern Experience

Eglin scholars met with Maj. Gen. William T. Cooley, AFRL Commander, to talk about how AFRL Scholars will impact their future STEM careers. Image courtesy: AFRL.

USRA continues to exceed Air Force expectations in management of the Air Force Research Laboratory (AFRL) Scholars Program, supporting hands-on internship experiences that seek to strengthen the high-tech workforce of the future. In FY19, the program expanded into a year-round internship program at multiple AFRL sites and experienced a record-setting year with 351 students participating in technical research projects in high-speed aero-optics, artificial intelligence and machine learning, multi-material additive manufacturing systems, and other cutting-edge technologies.

Eglin scholar networking with industry-leading employers at the Career Expo event in July 2019. Image courtesy: USRA.

Since its inception in 2013, more than 1,656 high school, undergraduate, and graduate students have participated in the AFRL Scholars Program. USRA manages the AFRL Scholars Program at Eglin AFB, Florida; Kirtland AFB, New Mexico; the Air Force Maui Optical and Supercomputing Site, Hawaii; and multiple AFWERX sites. It also administers scholar stipends at Wright-Patterson AFB, near Dayton Ohio. Under USRA's management, the program experienced multiple first-time accomplishments during FY19: the successful launch of the AFRL Scholars Program at Rome Laboratory, New York; implementation of a pilot Educators Program at Kirtland AFB; and administrative support for five scholars, funded by the Air Force Office of Scientific Research, at three AFRL sites.

Through the implementation of these events, USRA continues to greatly amplify the Scholar experience, reinforce career paths for the next generation of STEM professionals, and thereby address the nation's defense needs.

USRA Distinguished Undergraduate Awards

Formerly the USRA Scholarship Awards, the renamed USRA Distinguished Undergraduate Awards continue to recognize undergraduate juniors and seniors who excel in space science and aerospace pursuits and show promise for leadership in their fields. The awards are made possible by financial contributions, including those made by USRA employees through payroll deductions. Applications are reviewed by representatives from the USRA Council of Institutions, who make award recommendations to the USRA President.

In 2019, 85 eligible applications were received from students at 43 different universities. Nearly 17% of the applicants were minority students and under represented students.

USRA is pleased to recognize and support the careers of these winners of the 2019 Awards: The awards were established to honor the service and memory of individuals who made significant contributions to their fields and to USRA.

2019 SCHOLARSHIP AWARD WINNERS

NASA Interns: Contributing to the Advancement of NASA's Mission

The NASA Internship Program provides innovative opportunities in support of NASA's mission that inspire the next generation of explorers. Since its inception in 2013, over 7,400 students from across the nation have participated in the program. In FY19, 1,416 high school, undergraduate, and graduate interns were placed across all NASA Centers and facilities. These internship opportunities immerse students in meaningful and challenging projects that help develop the critical skills necessary to contribute to NASA's future missions.

USRA continues to successfully implement and administer the NASA Internships program on behalf of NASA. In FY19, USRA expanded its team of highly skilled Intern Program Coordinators to provide support at NASA Headquarters in Washington, D.C. and NASA's Stennis Space Center in Mississippi – increasing USRA's presence to eight NASA Centers. Additionally, the program's social media platforms saw a significant growth in followers this year, with Instagram reaching more than 82,000 users.

Increasing the capabilities, diversity, and size of the nation's STEM workforce continues to be a high priority for both NASA and USRA. To support this goal, Intern Program Coordinators facilitate professional development workshops, networking events with NASA professionals, and culminating poster session events, designed to provide interns the opportunity to showcase their contributions to NASA's missions.

NASA Armstrong Flight Research Center interns pose in front of the X-IE static aircraft for their first official group photo to kick off the start of their summer internship programs. Image courtesy: NASA.

CONTINUED

NAMS R&D Student Program

Student R&D Interns at NASA Ames Research Center. Image Courtesy: USRA

NASA Academic Mission Services (NAMS) Research & Development (R&D) Student Program supports current and future research by encouraging students to continue education in Science, Technology, Engineering and Mathematics (STEM). The Student R&D Program supports the overall mission of NAMS. The key technology areas include: Aeronautics, Earth Science, Intelligent Systems and Bio-Sciences and the goal of the program is to advance the research being performed under the NAMS tasks orders and provide students with research projects that align with their education goals in STEM fields. The unique aspect of this program is for the student to work collectively with the NAMS PI and academic professor to ensure a successful outcome of the project milestones and their educational thesis requirements are met. One hundred students have successfully completed their internships through this program over three years.

Lunar and Planetary Institute Summer Intern Program

This program continues to play a vital role in attracting, training and nurturing future planetary scientists through the Lunar and Planetary Institute LPI/ Johnson Space Center JSC Summer Intern Program in planetary sciences which has been offered since 1977. In 2019, the annual ten-week program coordinated by Claudia Bellard and Drs. Edgard G. Rivera-Valentín and Julie D. Stopar hosted students from the United States as well as students from the United Kingdom, Australia, and Argentina.

Two additional students participated in the program; one from SUPPR (Summer Undergraduate Program for Planetary Research) and one for USRA's PRIDE (Planetary Radar Investigation, Demonstration, and Exploration) laboratory. Each intern worked one-on-one with an individual scientific advisor, either at the LPI or at NASA JSC, carrying out a complete, end-to- end research project. In addition to their individual projects, the interns participated in special activities, including scientific visits to NASA's Johnson Space Center's Lunar and Meteorite curatorial facilities, a weekly Brown Bag seminar designed to acquaint the interns with the breadth of planetary science and its application to NASA missions, and a Professional Development Seminar series, which included workshops on scientific writing, presentation skills, and graduate school preparation.

The Center for Space Nuclear Research Interns Program

CSNR supported 2 teams of students in the summer of 2019, 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. Such a reduction can reduce cosmic radiation exposure by as much as 40%. 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. These 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 such as Curiosity and Mars 2020.

The Feynman Quantum Academy Internship Program

In 2019 this program onboarded eight more students from six different universities: Princeton, Michigan State University, Technical University of Munich, University of Southern California, University of Milan, and Carnegie Mellon University. Several students were mentored by the USRA team on highly impactful research projects, including applied work on quantum annealing, numerical simulation of quantum circuits, software development for quantum algorithms.

NASA Postdoctoral Program

USRA continues to operate the NASA Postdoctoral Program (NPP), providing recruitment of applicants and review of science proposals for over 1,900 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's Science, Space Technology, and Human Exploration and Operations Mission directorates, as well as other NASA research and technology organizations.

In FY 2018, NASA worked with USRA to implement increases in the base stipend and travel allowance levels for all fellows and geographic areas, resulting in a nine percent increase in stipends and 25 percent increase in travel budget for these researchers. USRA has hosted recruiting, networking, and career development events for current and prospective fellows. USRA is also focused on diversity recruitment of applicants and executes targeted efforts to focus on recruiting from underrepresented groups in multiple STEM areas.

The Center for Lunar Science and Exploration's Summer Internship Program

LPI interns presented their presentation at the 35th Annual Summer Intern Conference on August 8, 2019." Image Courtesy: Lunar and Planetary Institute.

CLSE hosted 10 graduate students to explore options for NASA and its international partners in the new era of robotic and human exploration. One team evaluated the physical properties and trafficability of two types of lunar surface terrains, pyroclastic deposits and permanently shaded regions, both of which are high priority targets for scientific exploration and the development of in-situ resources on the lunar surface. The other team evaluated a landing site and potential robotic traverse in the Schrödinger basin on the lunar farside. The students presented their research results to LPI science staff, Johnson Space Center rover engineering staff, NASA Headquarters staff, and a representative of the Lockheed Orion team.

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 Education Activities

Throughout FY 2019, USRA operated an array of internships, fellowships, and scholarships intended to incite interest in STEM careers, and reinforce the workforce pipeline of the future. Through immersion in these programs, young scientists have the opportunity to cultivate the skills needed to excel in their chosen STEM field and contribute to high-tech scientific advancements, publications, and patents. To better prepare the workforce of the future, USRA also seeks to address underrepresentation in STEM fields among underserved students. During FY 2019, USRA managed over 2,300 internships for high school, undergraduate, and graduate students in laboratories nationwide.

In addition, k-12 activities conducted by USRA offered enriching STEM educational opportunities to broadly convey the excitement of STEM to students, teachers, informal science educators, and the general public.

USRA's STEMaction Center: Igniting Interest in a New Generation

The USRA STEMaction Center provides k-12 and community programming that works to strengthen the STEM workforce of the future. Since USRA's acquisition of the STEMaction non-profit in 2017, this mission has been fulfilled mostly through the Center's role as a regional partner for FIRST robotics programs. During FY19, the STEMaction Center's operations have expanded to include a growing array of regular programs and partnerships. USRA's STEMaction Center continued to promote experiential learning activities through programs like FIRST, FIRST LEGO League, and FIRST LEGO League Junior. The USRA StemAction Center Team hosted the Maryland DC FIRST Tech Challenge Regional Championship. More than 17,000 students between the age of 6 and 18 representing 37 countries participated in the FIRST Robotics World Championship in Detroit in April 2019.

ACT Prep continues its successful preparation of local students. Thirty-five students from Howard County participated in the course this spring. In addition to the comprehensive test preparation, USRA provided these students transportation to and from USRA and an opportunity to engage with USRA leadership on the program's final day. In 2019 the Center's flagship FIRST robotics programs and free practice space engaged over 5,600 k-12 students in Maryland and Washington, D.C. through competitions, robotics trainings, and visits to USRA for events.

New programming in the Center delivers one-time and drop-in occurrences to engage students, teachers, and the general public. Monthly events and workshops revolving around engineering (with LEGO bricks), 3-D printing and CAD, have attracted dozens of new STEM enthusiasts of all ages. A partnership with iDoodle Learning provided 35 students the opportunity to fly experiments during the summer through the Cubes in Space program. In FY19, USRA also established an exciting new partnership with a local nonprofit, TechChangers, which brought free physical computing and programming courses to the Center.

Ishaan Oberoi, a FIRST Tech Challenge Participant, regular volunteer, and subject matter expert for STEMaction coding and electrical configuration workshop, accepts the coveted "Dean's List" award at the Maryland/DC FIRST Tech Challenge Championship in March. Image courtesy: Rockville Robotics.

UNIVERSITY ENGAGEMENT

USRA is intimately 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 postdoctoral researchers at Federal laboratories and at USRA sites. In FY19, USRA scientists were involved in 857 research collaborations at 292 organizations, including both universities and other research organizations.

Featured USRA University Engagements in 2019

Symposiums in celebration of 50th anniversary of Apollo 11

At the behest of the JKF Library Foundation, USRA sought out member universities to host symposiums to celebrate the Golden anniversary of Apollo 11 and look forward to important advances in space exploration and other significant technology areas in today's world. Working with university partners, USRA arranged symposiums at Rice University in September 2019, Florida Institute of Technology in November 2019, and Case Western Reserve University in February 2020. In each, prominent leaders gave their insights into the past and their view for the future.

Development of Planetary Radar System with Puerto Rico students

USRA's Lunar and Planetary Institute is collaborating with the University of Puerto Rico Mayaguez (UPRM) to develop ground-based radar to carry out post-discovery characterization of near-Earth objects. The instrumentation is being developed by undergraduates from UPRM working with LPI personnel as part of a senior capstone engineering design class. Students gain valuable research experience as well as an introduction to planetary science.

University engagement in NASA's microgravity research program

USRA has extensive engagement with university researchers through our role in NASA's Microgravity Research Program. This program is comprised of a robust portfolio of fundamental, applied, and translational research projects in the areas of combustion science, fluid physics, and complex fluids that address the current and future science and technology needs of NASA and the nation. Flight experiments are performed on the ISS or the Cygnus resupply vehicle, while ground-based experiments utilize the 5.2-second drop tower at NASA Glenn Research Center. This past year, USRA, together with Case Western Reserve University, engaged 65 investigators from 37 universities.

Public Policy Advocacy

USRA provides a voice on public policy issues important to the university community through the Issues and Program Committee (IPC). Comprised of representatives from USRA member universities in nine geographic regions, the IPC formulates public policy positions, meets with members of Congress and their staffs, provides testimony as requested, and 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 the inclusion of $25 million in the NASA FY 2020 science budget for university-led small satellite missions. Such SmallSat and CubeSat missions provide research opportunities for universities, and training for the next generation of scientists and engineers.

2019 USRA 50th Anniversary Symposium

USRA celebrated its 50th Anniversary with a special symposium held at the National Academy of Science. The theme was "Space Exploration: Achievements of the Past 50 Years and Ambitions for the Future". The program featured Marcia McNutt, President of the National Academy of Sciences; Scott Pace, the Executive Secretary of the National Space Council; Jan Wörner, Director General of the European Space Agency; and Christine Darden, NASA Mathematician and Aeronautical Engineer. The symposium brought together scientists and decision makers from across academia, government agencies, and the commercial sector, both nationally and internationally.

Christine Darden, retired NASA mathematician and aeronautical engineer, addresses the USRA 50th Anniversary Symposium on her time as a "hidden figure" in NASA's early history. Image courtesy: Aaron Clamage

Universities Space Research Association Board of Trustees 2019-2020

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USRA governance is grounded in the university community. USRA is an association of 111 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 Intuitions, 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.

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 2019 Annual Meeting, the Council welcomed one new member: Florida Institute of Technology.

Background image courtesy: 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

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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

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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

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École Polytechnique Fédérale de Lausanne

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Florida Institute of Technology

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The University of New Mexico

New Mexico State University

New York University

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North Carolina State University

Northwestern University

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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

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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

USRA's Workforce: Growing and Diversified

Employee Distribution by Degree

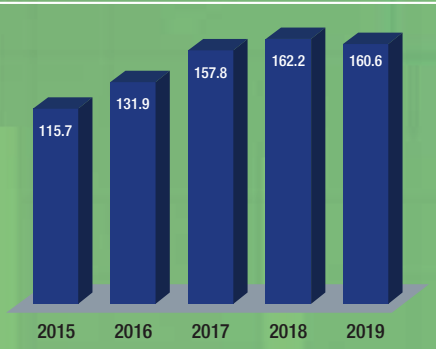
Approximately 43 percent of USRA's workforce hold Doctoral degrees, and another 24 percent hold Masters

Employee Distribution by Areas of Study

Approximately 70 percent of USRA's workforce comprises physical scientists and engineers

Financial Highlights

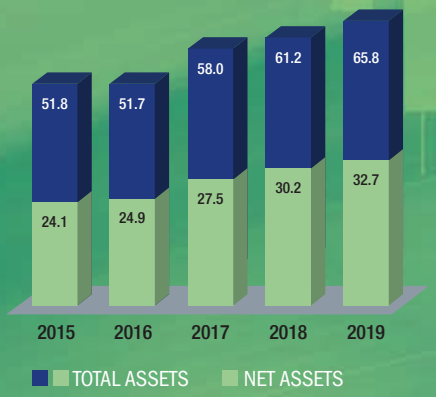
FY2015-2019 Revenue in Millions



For FY2019, USRA's annual revenue from contracts and grants totaled more than $160 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.

FY2015-2019 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.

The tail assembly of SOFIA just before take off.
Image courtesy: NASA

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About USRA
Founded in 1969, under the auspices of the National Academy of Sciences at the request of the U.S. Government, the Universities Space Research Association (USRA) is a nonprofit corporation chartered to advance space-related science, technology and engineering. USRA operates scientific institutes and facilities, and conducts other major research and educational programs, under Federal funding. USRA engages the university community and employs in-house scientific leadership, innovative research and development, and project management expertise. More information about USRA is available at www.usra.edu.

Universities Space Research Association

USRA CORPORATE OFFICES

Headquarters
7178 Columbia Gateway Drive
Columbia, MD 21046
410-730-2656

425 3rd Street SW, Suite 605
Washington, DC 20024

3600 Bay Area Boulevard
Houston, TX 77058

320 Sparkman Drive
Huntsville, AL 35805

615 National Avenue, Suite 220
Mountain View, CA 94043

www.usra.edu