Universities
Space Research
Association

USRA

2021 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

Image from the Front Cover

Illustration of a comet from the Oort Cloud as it passes through the inner solar system with dust and gas evaporating into its tail. SOFIA's observations of Comet Catalina reveal that it's carbon-rich, suggesting that comets delivered carbon to the terrestrial planets like Earth and Mars as they formed in the early solar system. Image Courtesy: NASA/SOFIA/Lynette Cook

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

Jeffrey A. Isaacson
President and
Chief Executive Officer

John A. Montgomery
Chair, Board of Trustees

USRA achieved many noteworthy mission accomplishments in 2021, not the least of which was continued, successful operations in a calendar year replete with pandemic-related challenges and constraints. Despite these, USRA staff continued to innovate and accomplish our nonprofit mission: To advance space- and aeronautics-related sciences and exploration; promote space and aeronautics policy; and operate premier facilities and programs involving universities, governments, and the private sector.

Among our many accomplishments in 2021:

- USRA welcomed the University of Texas at El Paso to membership, the 114th university in our association.
- Across all programs, USRA executed 861 research collaborations involving 268 different universities, along with 565 research collaborations involving 164 other research organizations.
- Our staff published 314 peer-reviewed research products.
- Our programs managed or administered over 2,700 internships, despite the pandemic, including 2,289 NASA Interns and 348 AFRL Scholars.
- Observations using the Stratospheric Observatory for Infrared Astronomy (SOFIA) shed new insights on galactic mergers in the early universe and the effects of magnetic fields on galactic evolution.
- USRA established a new partnership on heliophysics with The Catholic University of America; the University of Maryland, Baltimore County; the University of Maryland, College Park; Howard University; and NASA's Goddard Space Flight Center.
- USRA's lunar and planetary scientists contributed to many facets of NASA's solar system exploration program, including scientific support to the Mars 2020 Perseverance Rover, team support to the design of a future probe that will analyze the atmosphere of Venus, and the development of a "Lunar South Pole Atlas" that will aid mission planning for NASA's program to return astronauts to the lunar surface (Artemis).
- USRA was admitted to the United Nations Framework Convention on Climate Change as an Observer Non-Governmental Organization.
- USRA researchers supported the fifth phase of NASA experiments in low Earth orbit that investigate how fires propagate in microgravity and how different materials react to fires in space. This work furthers our understanding of how to design and engineer crewed vehicles for space exploration.
- USRA interns furthered our long-standing work on the design of nuclear thermal propulsion systems by analyzing optimum flow rates for hydrogen propellant during thermal transients.
- Technology developed under NASA's Airspace Technology Demonstration project, with the support of USRA engineers, is now slated to be integrated with FAA systems at 27 airport hubs over the next decade. USRA played a crucial role in the demonstration of this technology at Charlotte Douglas International Airport, where significant reductions in delays, fuel consumption, and aircraft emissions were realized.
- In collaboration with Rigetti Computing and NASA, USRA quantum scientists received a Phase II award to continue the development of new quantum processors under DARPA's Optimization with Noisy, Intermediate-Scale Quantum devices program.

In addition, USRA's Diversity, Equity, and Inclusion (DE&I) Committee continued its efforts to improve DE&I at USRA, bringing three recommendations for change to corporate leadership in 2021, all of which were adopted.

Finally, USRA was a proud recipient of a *2021 Top Non-Profit Workplace Award* by Energage, LLC, an organization that maintains the industry's most robust workplace culture benchmarks. USRA's award was based on employee feedback evaluated against these benchmarks, which encompass data from some 23 million employee surveys gathered from 70,000 organizations over 14 years.

These short highlights, and the more detailed descriptions that follow, can't possibly tell the story of all USRA accomplishments in 2021, nor those of our remarkable staff. They do illustrate, however, our unbridled passion for and relevance to science, technology, and education. This passion remains one of our core values, as it has been since USRA's founding in 1969.

Jeffrey A. Isaacson
President and Chief Executive Officer

John A. Montgomery
Chair, Board of Trustees

Astronomy and Astrophysics

Episodic Accretion in Massive Star Formation

Theory has long suggested that the mass growth of protostars occurs stochastically in a series of episodic accretion events from the surrounding disk. During an accretion event, the luminosity of the protostar increases rapidly due to the conversion of gravitational energy to thermal radiation. A detailed study of massive young stellar objects is hindered by the large quantity of surrounding gas and dust, but infrared observations can penetrate these dense envelopes.

Using the Far Infrared Imaging-Line Spectrometer instrument, SOFIA observations of the massive young star called 6358 were obtained following a report of maser flaring.

The infrared data obtained by SOFIA were crucial in deriving fundamental parameters of the accretion burst such as the mass accreted during the event and the total energy released by the burst.

The new observations provide strong evidence of episodic accretion in young massive stars. Since the matter distribution in the accretion disk appears to be clumpy rather than continuous, disk fragments are occasionally ingested onto the growing star, causing eruptions. These new findings confirm that the formation of high-mass stars can be considered a scaled-up version of the process by which low-mass stars like our Sun are born.

Artist's impression of a stochastic accretion event as a massive fragment of the clumpy accretion disk spirals onto the protostar. Image Courtesy: Lynette Cook

Galactic Merger Warps Magnetic Field

The understanding of the origin, amplification, and morphology of the magnetic fields is crucial for a complete picture of galaxy evolution. The recent observations made with NASA's airborne Stratospheric Observatory for Infrared Astronomy, SOFIA, provide new insights into how the early universe may have been shaped by galactic mergers under the influence of their supercharged magnetic fields.

Centaurus A is the remnant of a merger between an elliptical and a spiral galaxy that took place about 160 million years ago. SOFIA recently observed the warped molecular disk of Centaurus A with the High-resolution Airborne Wideband Camera-plus (HAWC+). These observations show that the magnetic field orientation is tightly aligned with the disk. Since the dust lane is a remnant of the spiral galaxy, a large-scale regular field should be present, but results show a high level of dispersion in orientations of the magnetic field across the warped disk. This must be produced by another mechanism.

This result implies that turbulent gas at scales smaller than the angular resolution of the observations are distorting the original large-scale regular magnetic field from the spiral galaxy. The interpretation is that the small-scale turbulent fields are relatively more important across the warped disk than large-scale regular fields.

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, the origin of gravitational waves and high-energy cosmic rays, and the creation of the universe itself.

Cold Quasars and the Evolution of Galaxies

The early universe is filled with galaxies with an average star formation rate hundreds of times that of today. Star formation may have been shut down over time through many routes, one of which relies on the supermassive black hole in the heart of massive galaxies. The energetic output from the black hole's material accretion around the black hole has a tremendous effect on the host galaxy, heating and expelling the gas, and shutting down star formation. This crucial transition process is difficult to investigate, as the hot material surrounding the black hole outshines the host galaxy at nearly all wavelengths of interest. The one exception is the far infrared.

SOFIA's HAWC+ observations targeted a special cold quasar, a galaxy caught in that astronomically brief transition phase when the supermassive black hole is actively accreting but a significant amount of the infrared-luminous gas remains and star formation is still high, with star formation rates hundreds of times more active than our own Milky Way Galaxy.

Combined with optical data, SOFIA determined the star formation rate and black hole accretion rate in cold quasar CQ4479. Overall, the results indicate that the stellar population and black hole mass in CQ4479 are growing at the same rate, which is surprising since theory predicts that black hole growth follows stellar growth. The active black hole and stellar population could continue to grow for another 500 million years, tripling the mass of each before the black hole halts star birth.

SOFIA's Studies of Comet Catalina

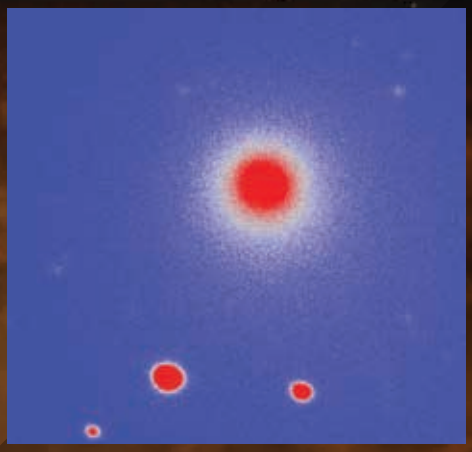
SOFIA discovered that some comets are carbon rich and may be the source of carbon on planets like Earth and Mars. The observations of Comet Catalina, as it made its first pass through the solar system and was briefly visible to stargazers, offers new clues about how this essential ingredient for life came to rocky planets in the Sun's inhabitable zone.

Comets like Catalina could have been an essential source of carbon on planets like Earth and Mars during the early formation of the solar system. New results from SOFIA, a joint project of NASA and the German Aerospace Center, were published recently in the Planetary Science Journal, February 2021.

Originating from the Oort Cloud at the farthest reaches of our solar system, Comet Catalina and others of its type have such long orbits that they arrive on our celestial doorstep relatively unaltered. This makes them effectively frozen in time, offering researchers rare opportunities to learn about the early solar system from which they come.

SOFIA's infrared observations were able to capture the composition of the dust and gas as it evaporated off the comet, forming its tail. The observations showed that Comet Catalina is carbon-rich, suggesting that it formed in the outer regions of the primordial solar system, which held a large reservoir of carbon that could have been important for seeding life.

Researchers think that a slight change in Jupiter's orbit allowed small, early precursors



I-band image of Comet C2013 US10 Catalina as part of a combined infrared and Visual observation. The comet's coma is nicely visible in comparison to the more compact stars toward the bottom of the image. Image Courtesy: C.E. Woodward et al

of comets to mix carbon from the outer regions into the inner regions, where it was incorporated into planets like Earth and Mars. Comet Catalina's carbon-rich composition helps explain how planets that formed in the hot, carbon-poor regions of the early solar system evolved into planets with the life-supporting element.

"All terrestrial worlds are subject to impacts by comets and other small bodies, which carry carbon and other elements," said Charles Woodward, from University of Minnesota and lead author of the paper. "We are getting closer to understanding exactly how these impacts on early planets may have catalyzed life.

X-ray Astronomy/Magnetars

Dr. Oliver Roberts (Science and Technology Institute) was part of a large international effort that published results on an intriguing high-energy transient called GRB200415A, which was detected by several interplanetary X-ray and gamma-ray satellites on April 15, 2020.

Giant flares are a rare, cataclysmic explosion from magnetars: city-sized objects with the mass of the Sun, spinning once on its axis every few seconds with a magnetic field 10 trillion times more powerful than a strong refrigerator magnet. Only three galactic Magnetar Giant Flares (MGFs) have been observed in modern-day astronomy, each time overwhelming the capability of previous instruments to take good data due to their brilliance. Consequently, little is known of the mechanism that creates them. However, due to the increased distance of extragalactic MGFs from existing instrumentation, new discoveries are being made that previously eluded scientists (Roberts et al., 2021 and Burns et al., 2021), opening the door to many new searches of these elusive events. (Dr. Roberts was recently awarded a two-year Fermi Gamma-ray Burst Monitor Guest Investigator project as Co-Investigator to search for more extragalactic MGFs).

MGFs have long been thought to masquerade as Gamma-ray Bursts and with this work, Dr. Roberts and his colleagues have finally unmasked magnetars as a unique, third class of GRBs.

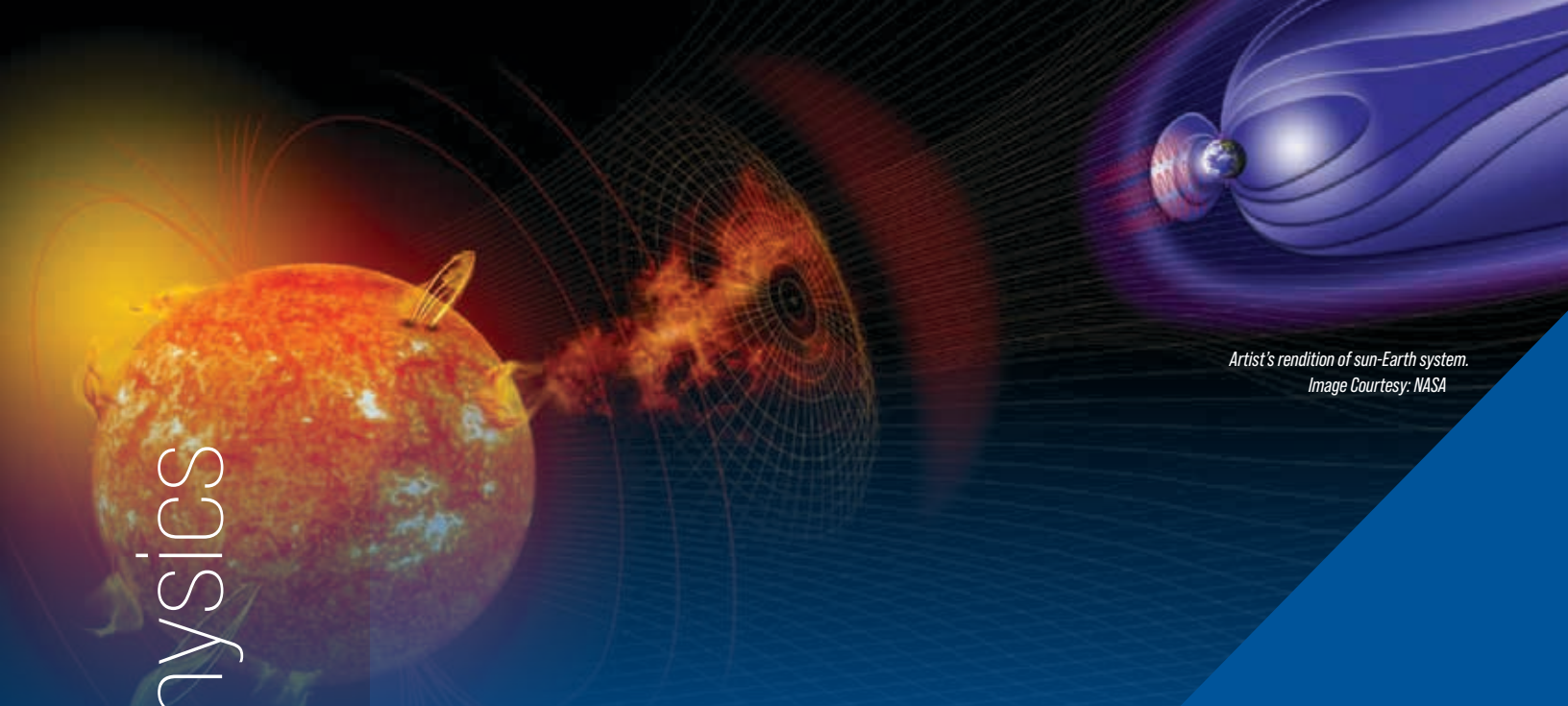
Artist's rendition of magnetar eruptions. Image Courtesy: NASA Goddard/Scott Wiessinger

Astronomy and Astrophysics

USRA's Stratospheric Observatory for Infrared Astronomy (SOFIA) team completed numerous impactful science promotion activities throughout the year. To engage targeted scientific communities, SOFIA has held two virtual scientific workshops: "Rock, Dust, and Ice: Interpreting Planetary Data" in March 2021 and "Magnetic Fields and the Structure of the Filamentary Interstellar Medium" in June 2021. The team supported SOFIA's strong presence at astronomy meetings, especially at the American Astronomical Society's annual meetings, where three plenary talks by David Chuss, Enrique Lopez-Rodriguez, and Chris Packham featured SOFIA science. At the winter meeting USRA's SOFIA team organized a special science session on stellar feedback and hosted a Town Hall and two webinars. The team is now organizing an in-person meeting on "the Galactic Ecosystem" to be held in February/March 2022 and has secured the venue, and ALMA North America has agreed to co-sponsor the event.

USRA established a leadership role in developing the SOFIA Instrument Roadmap. For the purposes of the Roadmap, the team organized and held two, three-day virtual workshops in FY 2020, and based on this input, in FY 2021 developed and submitted the draft of the SOFIA Instrument Roadmap to the leaders of the SOFIA project at NASA (Project). The SOFIA team then worked with the Project to edit the final Roadmap for submittal to NASA Headquarters. USRA staff also assisted our German colleagues at Deutsches SOFIA Institut to organize and conduct a workshop for a German SOFIA Instrument Roadmap which will be completed in FY 2022.

Heliophysics



Artist's rendition of sun-Earth system. Image Courtesy: NASA

USRA is actively involved in Heliophysics, Solar Physics, and Space Weather at the Science and Technology Institute in Huntsville, Alabama. Areas of expertise include space plasma, modeling and assessment of charged particle environments and effects in near-Earth and interplanetary space, spacecraft charging, space radiation, solar wind environment testing and operational assessment for missions.

Partnership for Heliophysics and Space Environment Research (PhaSER)

USRA has active efforts in radiation, particle instrument testing, and Space Weather at the Science and Technology Institute (STI) in Huntsville, Alabama. STI houses expertise in several basic and applied research efforts: radiation particle transport modeling, modeling and assessment of charged particle environments and effects in near-Earth and interplanetary space, space weather assessments for NASA missions, space radiation and solar wind environment testing, and operational assessment for missions such as the Chandra X-ray Observatory and the Parker Solar Probe.

USRA's Science and Technology Institute, under the guidance of Dr. Linda Neergaard Parker, is a partner on the newly awarded Partnership for Heliophyics and Space Environment Research (PHaSER).

The Catholic University is the prime for this endeavor, with local partners: University of Maryland Baltimore County, University of Maryland College Park, George Mason University, and Howard University.

The focus of PHaSER is to:

- Sustain and strengthen existing partnerships with civil service researchers in NASA's Heliophysics Science Division
- Nurture early-career scientists by providing a broad range of opportunities for students and newly-minted Ph.D. scientists
- Facilitate collaborations with visiting scientists and the broader research community and
- Strengthen diversity and inclusion through aggressive programs aimed at underrepresented groups, and enable productive integration of PHaSER scientific staff in Heliophysics science planning, technology development, and all phases of mission implementation.

ARSET International Training Program

Dr. Pawan Gupta (Science and Technology Institute) helped organize and presented a tutorial at the recently completed NASA Applied Remote Sensing Training (ARSET) program, an intermediate-level, bilingual, online training titled "Satellite Observations and Tools for Fire Risk, Detection, and Analysis". This six-part training was ARSET's longest-running training in program history. The training covered the use of Earth observations pre-fire (fire types, conditions, and fire danger), during-fire (thermal anomalies and smoke mapping), and post-fire (burned area, landscape changes, and regrowth). The content spanned air quality, disasters, and land applications. Goddard Space Flight Center, Marshall Space Flight Center, Jet Propulsion Laboratory, Ames Research Center, and Goddard Institute of Space Science jointly developed and delivered the training in both English and Spanish. The total attendance was 2,544 participants from 110 countries and 47 U.S. states. Approximately 1,200 unique organizations were represented.

Lunar and Planetary Sciences

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

NASA's Perseverance Mars selfie with the Ingenuity helicopter, seen about 13 feet from the rover. This image was taken April 6, 2021, the 46th Martian day, or sol, of the mission. The arrow indicates the position of TIRS in the mast of Perseverance. Image Courtesy: NASA/JPL/Caltech/Malin Space Science Systems.

USRA Scientists on a Mission to Mars

The Mars 2020 Perseverance rover touched down inside Jezero Crater on February 18, 2021, and USRA scientists are on the Science team for this mission. Carrying innovative scientific instruments, Perseverance is searching for signs of ancient microbial life, which will advance NASA's quest to explore the past habitability of Mars.

USRA's Dr. Germán Martínez at the Lunar and Planetary Institute (LPI) is co-investigator of the Mars Environmental Dynamics Analyzer (MEDA), a meteorological station comprised of six sensors onboard the Mars 2020 Perseverance rover. The Thermal Infrared Sensor (TIRS), one of these sensors, is the first in situ Martian IR radiometer and it provides first-of-a-kind measurements of reflected solar radiation and thermal atmospheric radiation. Dr. Martínez designed the scientific requirements of TIRS and is responsible for scientific analyses of TIRS measurements. These analyses are key to providing ground truth to satellite observations and improving the predictive capabilities of numerical models.

Moreover, TIRS measurements are important to understand the thermal environment and geophysical properties of the shallow subsurface, thus providing environmental context for the rock and regolith samples that are being collected for sample return.

In addition, USRA's Dr. Allan Treiman at the LPI is co-investigator of the Planetary Instrument for X-ray Lithochemistry (PIXL), which sits on the arm of the Mars 2020 Perseverance Rover. PIXL is an X-ray fluorescence sensor, which determines the chemical composition of a sample (mostly rocks) by shooting a beam of X-rays at it and collecting the X-rays it emits back. PIXL creates a map of chemical compositions by scanning its X-ray source and detector across a sample. The compositions of individual spots reveal which minerals are in the sample, and the sum of the spots gives the bulk chemical composition. These data, with those from other instruments on the rover, allow the team to identify the rocks of Jezero Crater, understand their origins, and evaluate their suitability for return to Earth and their potential to retain signs of ancient Martian life. Treiman's primary responsibility with PIXL is in the interpretation of mineral compositions and its chemical maps. Treiman also works as a payload uplink lead, designing and writing commands for PIXL, and is training to be a Return Sample Scientist.

The Rochette rock in the Jezero crater is shown in the lower right of the figure. The larger dark circular spot is one of the two drill holes made by the Perseverance rover. The Planetary Instrument for X-ray Lithochemistry (PIXL) took an X-ray map of an abraded patch near the drill holes; its chemical data show that Rochette is a basalt rock, formed in an ancient lava flow. Image Courtesy: NASA/JPL/Malin Space Science Systems.

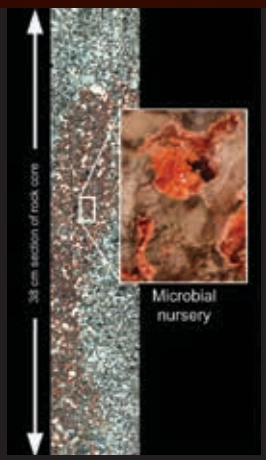
A Subterranean Ecosystem in the Chicxulub Crater

A new USRA-led study reveals that the Chicxulub impact crater, famous for its link to dinosaur extinction, also hosted hydrothermal system with a subterranean ecosystem that could provide a glimpse of Earth's primordial life.

Thousands of craters the size of Chicxulub or larger were produced during a heavy period of impact bombardment more than 3800 million years ago. When life could not exist on the Earth's surface during that bombardment, could it have lurked beneath crater floors in subterranean systems of hydrothermal fluids that streamed through rock fractured by the impact event? A principal author of that concept, USRA's David Kring at the Lunar and Planetary Institute, calls that concept the impact origin of life hypothesis.

To test that hypothesis, Dr. Kring and an international team of scientists drilled into the Chicxulub crater and found it hosted a vast hydrothermal system that persisted for more than a million years.

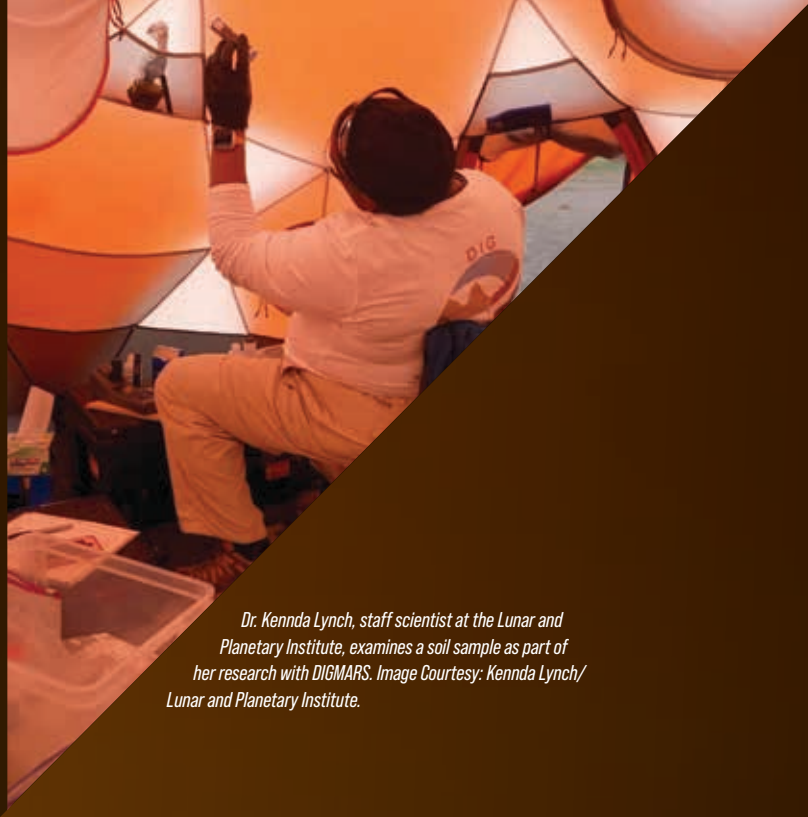
The new finding suggests that impact sites during the dawn of life could have hosted similar hydrothermal systems that provided niches for the early evolution of life on our planet. This research was funded by the National Science Foundation.



The Land of Fire, Ice, and Rovers?

Mars' analog environments on Earth have similar characteristics to Mars, making them the optimal place to test Mars' mission technologies, host mission field trials, and expand our understanding of the geology on both worlds. Iceland is an established Mars' analog as its crust is volcanic with high concentrations of iron and magnesium, much like Mars. Iceland also has glaciers, volcanoes, rivers, lakes, and deserts, environments that existed on Mars at one point in time.

USRA scientists Drs. Kennda Lynch and Candice Bedford at the Lunar and Planetary Institute participated in two NASA-funded Mars analog missions to Iceland this year. The missions, Semi-Autonomous Navigation for Detrital Environments or SAND-E and Digging Iceland Geology for Mars Analog Research Science or DIGMARS, investigated mineralogical and chemical changes in Mars' relevant sedimentary systems. SAND-E also aimed to trial operation scenarios using the new Mars exploration technologies on the Mars 2020 mission.



Dr. Kennda Lynch, staff scientist at the Lunar and Planetary Institute, examines a soil sample as part of her research with DIGMARS. Image Courtesy: Kennda Lynch/ Lunar and Planetary Institute.

USRA Leading the Effort for an Observing System Simulation Experiment (OSSE) Infrastructure for Mars

A USRA-supported effort, part of the USRA's FY 2021 Internal Research and Development (IRAD) Program was led by USRA's Dr. Oreste Reale, involving scientists Dr. Thomas Fauchez, Dr. Manisha Ganeshan, Dr. Samuel Teinturier, Dr. Germán Martínez and several collaborators from Pennsylvania State University, NASA GSFC, NASA AMES and NASA JPL. The project's main goal is to set the foundation of an Observing System Simulation Experiment (OSSE) framework for Mars.

On Earth, OSSEs have been performed for more than 30 years and are required practice to evaluate the impact of any planned future Earth-observing future sensor. On Mars, OSSEs could help NASA estimate the critical mass of instruments necessary to construct an operational weather forecasting capability, and more generally to make informed decisions about the optimal orbit and technical specifics of any future sensor.

The investigations of the team have corroborated the evidence of a fascinating property of the Martian atmosphere, which has been hinted at before but appears to be strongly supported by the findings of this team. Specifically, there appears to be a transfer of energy from diurnal small-scale disturbances originating close to the Equator into larger scale, slower moving systems that propagate poleward and become vast mid latitude systems. This mechanism, absent from the Earth's atmosphere, could play an important role in the development of planetary-scale dust storms.

A composite illustration of the Chicxulub core with the hydrothermal minerals dachiardite (bright orange) and analcime (colorless and transparent) and a closeup image of a portion of core section 0077-63R-2. Image Courtesy: David A. Kring/ Lunar and Planetary Institute.

USRA Scientists to Explore Venus with NASA's DAVINCI Mission

USRA scientists were selected as co-investigators on a team that will analyze Venus' atmosphere to understand how it formed and evolved, and to determine whether Venus ever had an ocean.

As part of NASA Goddard Space Flight Center's Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging (DAVINCI) mission, USRA scientists Drs. Walter Kiefer and Justin Filiberto at the Lunar and Planetary Institute are science co-investigators on the team.

The science impact of DAVINCI will reach even beyond the solar system to Venus-like planets orbiting other stars (exoplanets), which are expected to be common and will represent important targets for NASA's upcoming James Webb Space Telescope. But these planets may be difficult to interpret, especially if they are enveloped in thick Venus-like clouds.

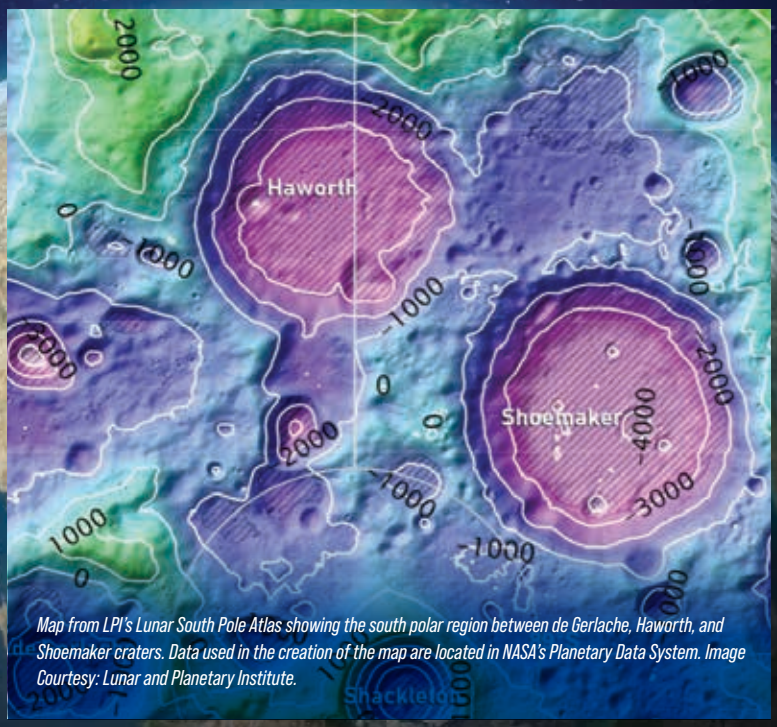
Scientists think that in an earlier time, Venus may have been more like Earth, a world with water oceans that was potentially habitable for life, perhaps for billions of years. They hypothesize something caused a "runaway greenhouse" effect in Venus' atmosphere, cranking up the temperature and vaporizing its oceans. NASA's DAVINCI mission is set to explore Venus to determine if it was habitable and understand how these similar worlds ended up with such different fates.

Launch is targeted for 2029 with two flybys of Venus prior to the probe's descent into and through thick clouds of the Venus atmosphere.

Preparing for a Human Return to the Moon

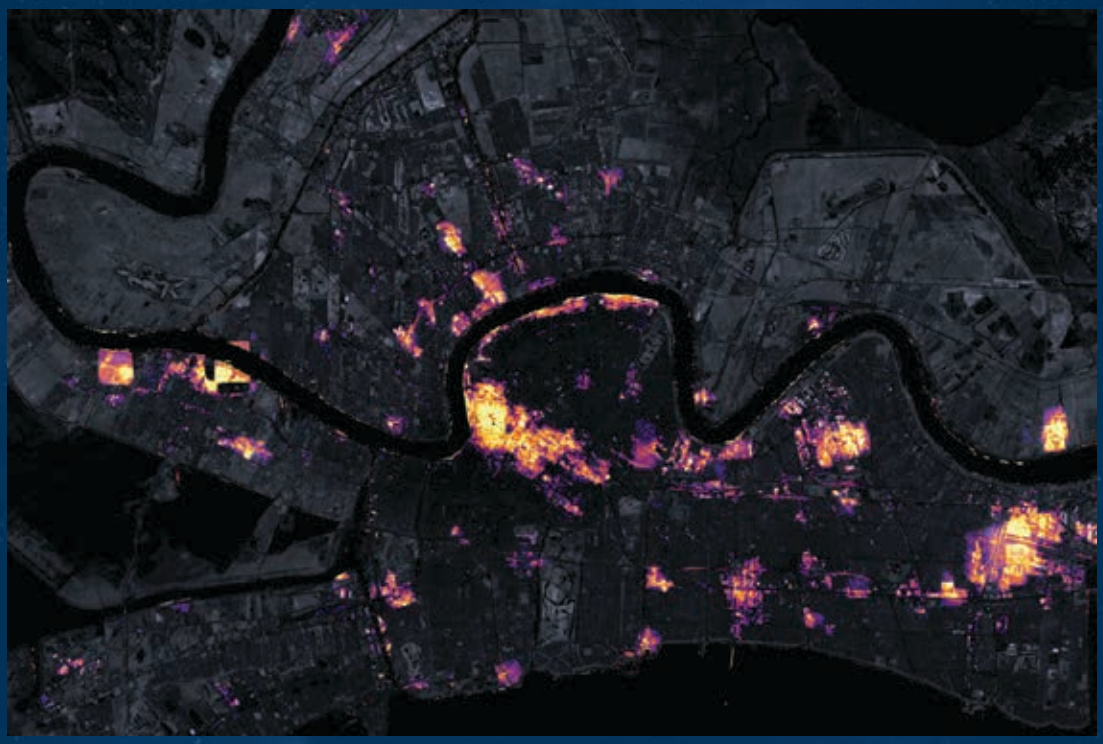
NASA is sending astronauts to the lunar south pole! There is a flurry of ongoing activity related to the Artemis program and the lead up to the first landed mission to carry humans back to the lunar surface. This activity will develop the tools and strategies humans need to live and work in another world. One key effort for planning a human return is to gather and interpret data about the surface and to plan for surface activities. USRA's Drs. David Kring and Julie Stopar at the Lunar and Planetary Institute (LPI) have curated an online collection of graphics and maps in a "Lunar South Pole Atlas" that provides critical context to those planning for south polar missions.

As part of a multidisciplinary team and NASA's Advisory Groups (Lunar Exploration Analysis Group and Mapping and Planetary Spatial Infrastructure Team), Drs. Lisa Gaddis and Julie Stopar of LPI are also working to identify critical data gaps and prioritize actions to fill these needs. LPI scientists are also helping to formulate the science strategy and priorities for the Artemis missions through reporting activities with NASA.



Map from LPI's Lunar South Pole Atlas showing the south polar region between de Gerlache, Haworth, and Shoemaker craters. Data used in the creation of the map are located in NASA's Planetary Data System. Image Courtesy: Lunar and Planetary Institute.

Earth Sciences



NASA Earth Observatory images by Joshua Stevens, using Black Marble data. Image Courtesy: Ranjay Shrestha/ NASA Goddard

Earth From Space Institute (EfSI)

This Institute has been very active in its work on acute recurrent disasters and USRA staff are the recognized leaders in this field. After Hurricane Ida struck, satellite technology, developed by USRA/EfSI/NASA scientists, mapped out the power outage in New Orleans, Louisiana.

A major achievement is that USRA/EfSI was admitted to the United Nations Framework Convention on Climate Change (UNFCCCOP-26), where USRA had a seat at the table, and a USRA staff member was attending.

The Conference of the Parties (COP) is the decision-making body that sets and implements globally agreed-upon climate change goals. The international science community, especially the satellite community, and the atmospheric science/carbon cycle community, has worked hard to make science-based contributions to emission reduction/climate mitigation monitoring. Given that COP is an important meeting that will make key decisions, USRA's presence at the table offers an opportunity to enter into discussions related to using science-based approaches for emission/climate monitoring. This directly responds to the need from the science community and opens the door for a conversation between policy makers and the science community.

USRA scientists strive to understand the Earth's natural processes, their propensity to change, and the linkages between human and natural systems. They also work across sectors and disciplines to apply Earth observations for broad societal benefit.

Monitoring the Reduction of Air Pollution Across the Globe During the COVID-19 Pandemic

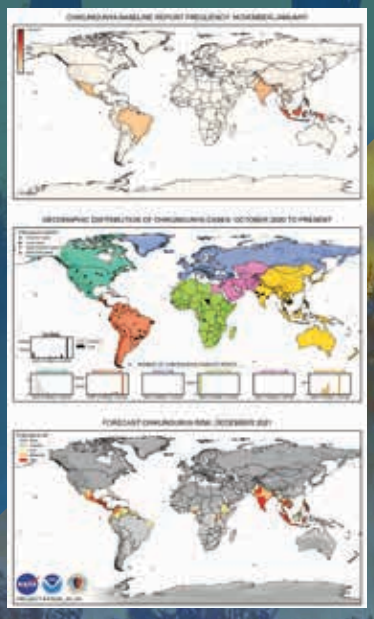
Goddard Earth Science Technology and Research (GESTAR) scientists Dr. Christoph Keller and Dr. Emma Knowland in the NASA Global Modeling and Assimilation Office (GMAO) have continued their remarkable contributions to the development of new applications within the Earth modeling and data assimilation framework known as the Goddard Earth Observing System (GEOS). Reduced human activities in the wake of the COVID-19 pandemic led to sharp reductions in surface nitrogen dioxide (NO_2), an important air pollutant formed during the combustion of fossil fuels. These declines correlate well with reported year-over-year changes in quarterly Gross Domestic Product, highlighting the close relationship between NO_2 concentration and economic activity. NO_2 concentrations rebounded significantly in the second half of 2020, coinciding with reopening measures, but they remained at 5-10 percent below pre-pandemic levels throughout the first half of 2021.

Differences between surface observations and near-real-time NASA computer simulations of nitrogen dioxide, highlighting the decline of surface air pollution during the COVID-19 pandemic. Image Courtesy: Christoph Keller and NASA's Scientific Visualization Studio (SVS), https://www.nasa.gov/feature/goddard/2020/nasa-model-reveals-how-much-covid-related-pollution-levels-deviated-from-the-norm

Global Chikungunya Mapping, Monitoring and Forecasting (CHIKRisk) Dashboard

Chikungunya is a virus disease transmitted by mosquitoes common in the global tropical regions of Asia, Africa, the Caribbean Islands, Central and South America. The Global Chikungunya Mapping, Monitoring and Forecasting (CHIKRisk) dashboard (https://vbd.usra.edu), developed by a team led by USRA's Dr. Assaf Anyamba, is a machine-learning- enabled platform that subsumes various NASA and NOAA Earth Observations and climate forecast anomalies (rainfall, temperature, soil moisture) combined with locations of chikungunya vectors, historical outbreak locations, and human population density data, to map current and forecast areas at risk to chikungunya globally.

In 2021, this application continued to operationally support the Department of Defense/Defense Health Agency's Armed Forces Health Surveillance Division - Global Emerging Infections Surveillance Branch, to improve infectious disease surveillance, prevention, and response worldwide. This dashboard is used to produce relevant and actionable products to inform global combatant commands about ongoing chikungunya disease threats for pre-and-post deployment planning and Force Health Protection decisions. It also supports public-health surveillance by the Pan-American Health Organization. The products include quarterly baseline risk information, tracking chikungunya outbreaks and forecasts of chikungunya risk (see Figure). Over the last year, USRA's Dr. Assaf Anyamba and his team updated and modernized the user interface of the CHIKRisk dashboard. This work is now being carried out as part of NASA's Science Mission Directorate Applied Sciences– Health and Air Quality Program.



Baseline risk chikungunya risk map (top) - for the period July – September based on historical outbreak data (middle) - distribution of global chikungunya activity since October 2020 and temporal distribution by combatant command region, (bottom) - forecast of chikungunya risk for August 2021. Image Courtesy: A. Anyamba/USRA.

Next Generation Nightlights Measurements

Earth from Space Institute (EfSI) scientists are leading the way on innovating new ways to procure next generation nightlights measurements. The institution led the effort to publish a letter in Science, entitled "Retired satellites: A chance to shed light," which makes the case for earlier nighttime observations. Satellites normally stay in one orbit their whole lives, but the the author team, which is made of members from EfSI, ESA, DLR, NOAA and NASA, advocates for retired Joint Polar Satellite System satellites to be reprogrammed and moved to a morning/early nighttime orbit after they are retired. This move might require additional planning and investment but would provide crucial data for disaster monitoring while advancing the climate, land, urban, and Earth at Night science. The team hopes the letter will spark additional discussions with NASA leadership and the broader scientific community on the potential of such a move.

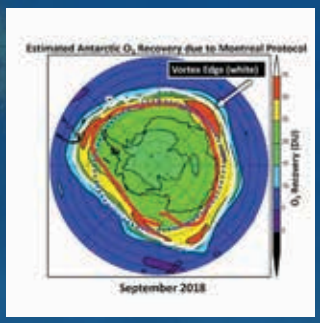
EXPORTS

An aerial view of the R/V Sarmiento de Gamboa (foreground), positioned close to the RRS James Cook (middle) and RRS Discovery (back) at a meet up point in the northeast Atlantic. Image Courtesy: Marley Parker

In May 2021, several USRA scientists were directly involved in the EXport Processes in the Ocean from Remote Sensing (EXPORTS) field campaign, a large NASA and NSF field campaign involving over 150 researchers from more than 30 institutions. EXPORTS was led by USRA's Dr. Ivona Cetinić,who served as Project Scientist. Data from this campaign will provide invaluable information on how carbon cycles through the oceans and how to derive additional information from upcoming satellite missions. As the RRS Discovery and the RRS James Cook sailed the North Atlantic Ocean, researchers deployed instruments, including ocean gliders and autonomous platforms, to sample the waters to characterize the oceanographic conditions and to collect precious measurements to fulfill their goals. Alongside those scientists, fellow colleagues, among them GESTAR's Inia Soto-Ramos, EXPORTS data manager, were on 'shore duty' to provide satellite data that informed the changes in conditions as well as to track all the instruments that had been deployed. In the upcoming months, the scientists will continue to process the data collected during this field campaign, which will provide new insight into the export and fate of primary production in the oceans. This data also will be crucial for further development of global ocean biogeochemical models, such as the one utilized by USRA's Dr. Cecile Rousseaux.

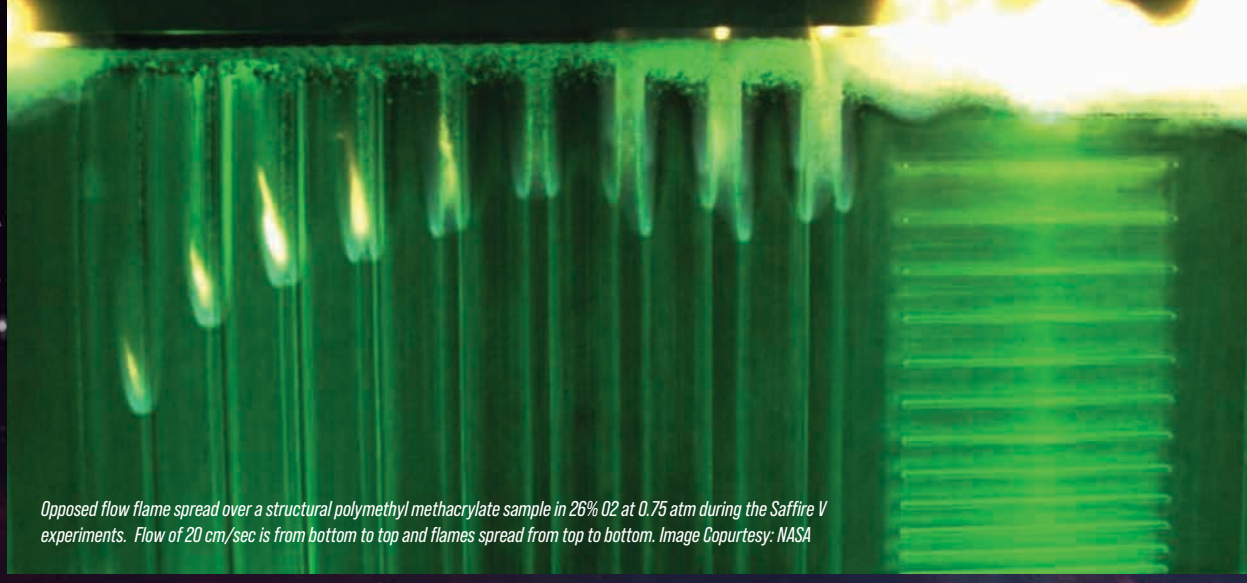
Stratospheric Ozone Recovery

Over the past decade, GESTAR's Dr. Susan Strahan and her collaborators published observational evidence showing that the ozone hole is healing. This research was challenging, as Chloroflurocarbons (CFCs) linger in the atmosphere for decades, making it difficult to identify clear signs of ozone recovery. By using model simulations and measurements of the chemical composition of the ozone hole over the past three decades, Dr. Strahan and co-workers demonstrated how the reduction in chlorine levels (released from CFCs) correlated with the extent to which ozone was recovering. This confirmed that the Montreal Protocol has been a success.



This model shows the estimated increase in September 2018 Antarctic column ozone due to the decrease in CFC levels since their peak in the late 1990s (in Dobson units). The vortex edge (white) is the meteorological boundary for the region of ozone depletion. The red line shows the observed edge of the traditionally-defined ozone hole, i.e., the 220 Dobson Unit(s) contour. The regions of greatest recovery are just inside the vortex edge and outside of the 220 DU hole boundary. The blue line is 63 degrees south latitude. Image Courtesy: Strahan et al. ,USRA/ NASA

Low-Gravity Sciences



Opposed flow flame spread over a structural polymethyl methacrylate sample in 26% 02 at 0.75 atm during the Saffire V experiments. Flow of 20 cm/sec is from bottom to top and flames spread from top to bottom. Image Copurtesy: NASA

Hardware Failure Enables Discoveries Related to Burning on Saffire V

Several USRA scientists along with their NASA collaborators contributed to the success of the Spacecraft Fire Safety (Saffire) V experiments that continued to investigate how fires grow and spread in space. Just as in Saffires I, II, III and IV, the Saffire-V experiments were ignited in a NG-14 Cygnus cargo vehicle after it had completed its primary International Space Station (ISS) supply mission, departed the station, and before its planned destructive reentry to Earth.

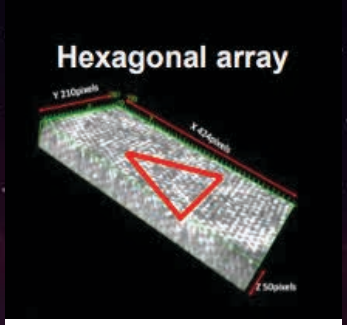
An unintended igniter circuit failure led to what may be the most enlightening of all the Saffire project experiments to date. The failure fortuitously left a pristine sample that showed flame spread propagating toward the air flow. This surprising result is contrary to results on Earth and has provided valuable information on local flame spread rate.

Understanding how fire behaves in microgravity, and how different materials propagate flames in space is immensely important for the development of future crewed spacecraft.

As members of the NASA/Glenn Research Center microgravity science team, USRA scientists support the goals of the Science Mission Directorate's Biological and Physical Sciences (BPS) Division through the use of the International Space Station (ISS) as an experimental platform to understand the physical effects of microgravity on physical and biological systems. These investigations into how these systems respond to the effects of reduced gravity and radiation may someday lead to new discoveries that might reduce risks of prolonged space exploration and eventually benefit life on Earth.

Preparing for Presence on the Moon: Suborbital Investigations on Dust and Fire

USRA scientists will serve as Principal Investigators for two NASA Flight Opportunity Program awards, which will allow them to participate in Blue Origin New Shepard suborbital lunar gravity simulation flights. The first addresses the problem of large amounts of lunar dust expected to adhere to spacesuit fabrics and likely to infiltrate habitable spaces upon return from extra-vehicular activities. It is called "Low-g Transport of Dust Liberated from Spacesuit Fabric" experiment, led by Dr. Benjamin Sumlin (USRA) and Dr. Marit Meyer (NASA Glenn). The second ("Fire in Lunar and Martian Gravity") will be led by Dr. Paul Ferkul (USRA) and will burn representative solid materials in simulated lunar and Martian gravity to assess their flammability compared to Earth. As we fast approach the day when there is a long-term human presence on other worlds, it is crucial that we understand the impacts of lunar dust and material flammability and its impact on the safety of spacecraft and habitats that will land there.



Details of a large colloidal crystal grown in microgravity with no obvious defects during the recent ACE-T11 flight experiment. Image Courtesy: Boris Khusid and Qian Lei (NJIT); Paul Chaikin and Andrew D. Hollingsworth (NYU); and William V. Meyer (USRA at NASA GRC).

Advanced Colloids Experiments (ACE) Proves Fundamental Theory for the First Time

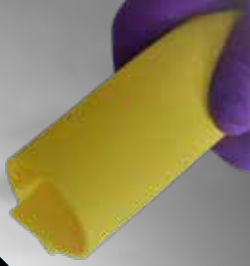
USRA's Dr. William Meyer is the Project Scientist for the Advanced Colloids Experiments (ACE) family of investigations on the ISS that provide a deeper understanding of colloidal behaviors, which are possible to observe when they are not masked by the effects of sedimentation and gravitational jamming seen on Earth. In FY 2021, eight unique ACE investigations were completed using the Light Microscopy Module housed in the Fluids and Combustion Facility onboard the ISS.

During the ACE Temperature Control (ACE-T11) [Hard spheres], the "theory for the simplest, most common, most fundamental Crystallization Transition from Liquid to Face Center to Cubic Crystal" was proven for the first time. Enabled by microgravity conditions, this event offers tremendous promise as scientists can confidently extend theoretical models to better understand complex phenomena. Extending these microgravity discoveries will lead to better materials for ceramics, paints, photonics, and pastes for additive manufacturing on Earth and for space exploration.

Optimizing Polyimide Aerogels for Aircraft Conformal Antennas

A research team that includes USRA scientists is designing flexible polymer materials that can be used for lightweight, low-drag antennas that conform along the surface of an aircraft.

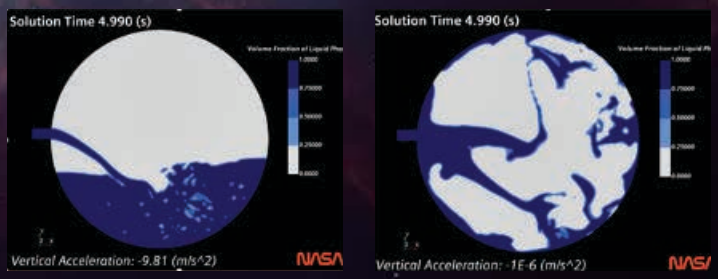
The design of lightweight aircraft that can travel over greater distances is of particular interest for unmanned aircraft. One area for improvement is the antenna, which can be heavy and bulky, and extends far above the surface of the vehicle, creating added drag. A phased array antenna, installed conformally along the curved surface of a wing or fuselage, is an attractive alternative. However, a flexible, lightweight substrate material is needed that will conform to the shape of the aircraft, while providing a low dielectric constant and low loss. The team developed optimized flexible polyimide aerogel substrates with 2 mm thickness for just this purpose. The team also showed the resulting materials have both the mechanical and electrical properties that are needed to manufacture lightweight, high-performing conformal antennas for more efficient unmanned aircraft.



Cool Technology Ensures Space Missions Don't Run Out of "Gas"

Cryogenic propellants are fluids chilled to extremely cold temperatures and condensed to form liquids. Fluids such as liquid hydrogen, liquid oxygen and liquid methane at their ideal operating temperatures can be used to provide high-energy propulsion solutions critical to present and future human missions. Propellant quantity gauging is also critical for space vehicles, yet becomes challenging in low-gravity environments. These difficulties are overcome with the low-gravity propellant gauging technology, Radio Frequency Mass Gauge (RFMG), which was developed at NASA Glenn. The RFMG technology measures the electromagnetic eigenmodes, or natural resonant frequencies, of a tank containing a cryogenic fluid. This information is passed to a pattern-matching algorithm, which compares the measured eigenmode frequencies with a database of simulations at various fill levels. The gauged fill level is the best match between the simulated and measured frequency.

USRA is actively supporting NASA Glenn in applying RFMG to various space missions. In FY 2021, the USRA team provided support to several commercial entities for both the NASA Human Landing System and the Commercial Lunar Payload Services programs, which will carry the next two American astronauts, and deliver science and technology to the lunar surface, respectively. Support was also provided to industry as part of NASA's Tipping Point program, which will help mature cryogenic fluid management technologies via in-space demonstrations as soon as FY 2022.



Computational fluid dynamic simulations comparing the fill behavior of liquid hydrogen in the presence of Earth's gravity (left) and microgravity (right). Simulations were performed by USRA's Bruce Ciccotosto to demonstrate the challenge of gauging propellant quantities in microgravity. Image Courtesy: NASA

Communications to Gateway: Critical to NASA's Artemis program

Gateway, a critical part of NASA's Artemis program, is an orbiting lunar outpost, which will provide vital support for sustainable, long-term human and robotic exploration. The Power and Propulsion Element (PPE) is a solar electric ion propulsion module being developed by Maxar Technologies and is one of Gateway's major components. The PPE provides a communications relay capability for Gateway, enabling it to serve as a mobile command and service module for human and robotic expeditions to the lunar surface. As part of the Glenn Engineering Research and Support contract, USRA is supporting the PPE communication subsystem engineering team. The Gateway concept, with the PPE as its first element, is an important part of NASA's strategy for establishing and maintaining human presence in the lunar vicinity and ultimately to the Martian surface and other deep space destinations.

Space Biosciences

USRA Scientists Discover Prions (Protein-based Genetic Elements) in Domain Archaea

Protein-based genetic elements – prions – have long fascinated biologists because they overturn the central dogma which explains the flow of genetic information through DNA to RNA to make a functional product, a protein. Although they were originally discovered in mammals, it has now become clear that prions and prion-like proteins can also be found throughout Eukarya, from animals to fungi to plants.

USRA scientists have advanced the field of prion research by establishing that amyloid-forming, prion-like domains exist in Archaea and are capable of vertically transmitting their prion phenotype – allowing them to function as protein-based elements of inheritance. These observations, coupled with prior discoveries in Eukarya and Bacteria, suggest that prion-based self-assembly was possibly present in life's last universal common ancestor, and therefore may be one of the most ancient epigenetic mechanisms in nature.

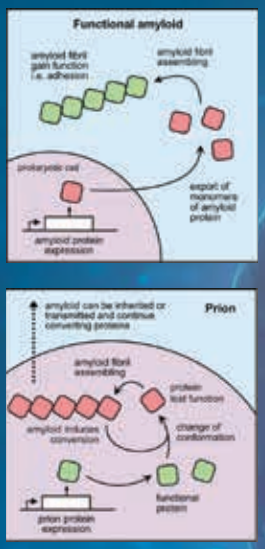
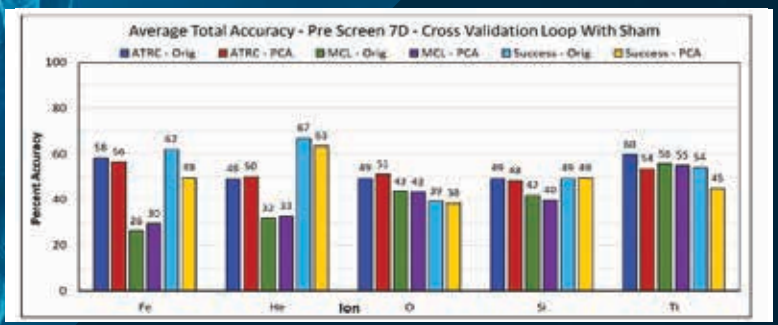


Diagram explaining the difference between functional amyloid and prion as it is observed in prokaryotes. Image Courtesy: Tomasz Zajkowski

Machine Learning Models Help Assess Radiation Risks to Astronauts

USRA's Dr. Raj Prabhu supports the Cross-Cutting Computational Modeling Project (CCMP) to investigate human physiological responses to space stressors and provides modeling and simulation-based support to mitigate Human Research Program (HRP)-related risks.

During FY 2021, scientists working on this project developed machine learning (ML) algorithms to predict Galactic Cosmic Radiation (GCR) doses and cognitive performance deficits using experimental rodent data procured from Dr. Britten's lab at the Eastern Virginia Medical Laboratory. These ML models also predicted a GCR dose-dependent performance impairment for 28Si or 56Fe (ranging from 1 – 10 mGy). These findings are critical while planning for Mars crewed space missions, as astronaut exposure to GRC can be significant outside the Van Allen radiation belt. Further investigations could lead to task-based cognitive performance deficits in astronauts exposed to galatic cosmic radiation.



Example of application of GRC CCMP ML algorithm for classifying rodent cognitive performance. Image Courtesy: NASA

Developing Deep-Learning Algorithm for Astronaut Health

USRA staff support multiple projects to help enable human exploration of space, in particular, lending their expertise in the realm of astronaut health monitoring. In this past year our team worked on CO_2 sensors, cortisol sensors, and deep learning-enabled automation of astronaut health monitoring. The work on automation of astronaut health management is currently focused on developing quantifiable methods to measure how well the autonomous system can be trusted. This work is critical to deep-space exploration where control and monitoring from Earth will be limited due to signal transmission delay.

Flight Experiments

Spaceflight poses significant risk to the central nervous system (CNS) and with the upcoming missions to the Moon and Mars, it is imperative to understand the neurological changes. Scientists recently flew fruit flies on the Multi-use Variable-gravity Platform-Fly01 mission to the International Space Station and evaluated the changes in CNS in response to microgravity and artificially simulated Earth gravity via an inflight centrifugation as a countermeasure.

Results suggest that artificial gravity provides partial protection to the adverse physiological effects of spaceflight on CNS. This work is currently under review in Cell Press. We were also recently awarded the E.12 Space Biology spaceflight grant titled "Integrated physiological responses of CNS and muscle in Drosophila and C.elegans along a gravity continuum". This work will allow us to identify common targets across species that can be further exploited to mitigate negative health effects of space habitation and aid in identifying therapies to combat neurodegeneration and muscle wasting on Earth.

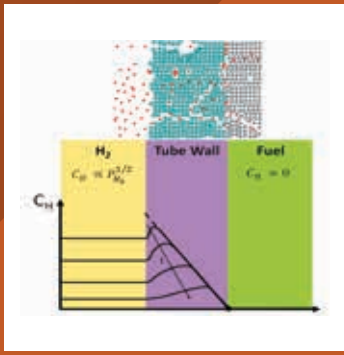
USRA scientists, in collaboration with the Space Biosciences Division at Ames, perform biological research and develop technology needed to enable NASA's long-term human exploration mission. In addition to designing and conducting ground and spaceflight experiments and developing spaceflight-relevant omic datasets and information sharing portals, we help to develop advanced research portals and platforms for the ISS to enable the broader scientific community to conduct life-science experiments in microgravity.

Advanced Technologies for Space Exploration – Nuclear Thermal Propulsion

Nuclear Thermal Propulsion (NTP) conceptual design. Image Courtesy: NASA

Future human exploration of Mars and the outer solar system will require the use of nuclear energy to reduce travel time and thus the exposure of the crew to energetic radiation (i.e., solar and galactic cosmic rays). Such a reduction in travel time cannot be achieved using conventional rockets because of the lower exhaust velocities of the combustion gasses. There are several concepts for attaining higher exhaust velocities (i.e., higher specific impulse) through the use of nuclear energy.

The propulsion concept that has been most developed is Nuclear Thermal Propulsion (NTP), consisting of a very high temperature reactor through which hydrogen flows and is heated from 20 K to about 2700 K in several thousand tungsten tubes of 2 mm diameter before exiting through a nozzle at about 10 km/s. The high velocity and low molecular mass of the hydrogen results in a specific impulse of approximately 900 s, nearly double that of conventional rockets. The



A schematic view of the shutdown transients is shown in the figure above. This view shows the Hydrogen Propellant, Tube Wall, and Fuel in an NTP Reactor. Image Courtesy: USRA/CSNR

NTP is most-efficiently used for short "burns" of about 30 minutes each. A 300-day mission from Earth to Mars and back requires four burns totaling 100 minutes.

Preventing reactor damage during the startup and shutdown transients is very important. The rapid cooling of the flow tubes during shutdown of the reactor causes corresponding decreases in the hydrogen solubility and diffusivity in the tube wall. The result is that hydrogen will be trapped in voids and along grain boundaries in the thin metallic tube walls. This trapped hydrogen has caused fractures of similar components in earlier tests.

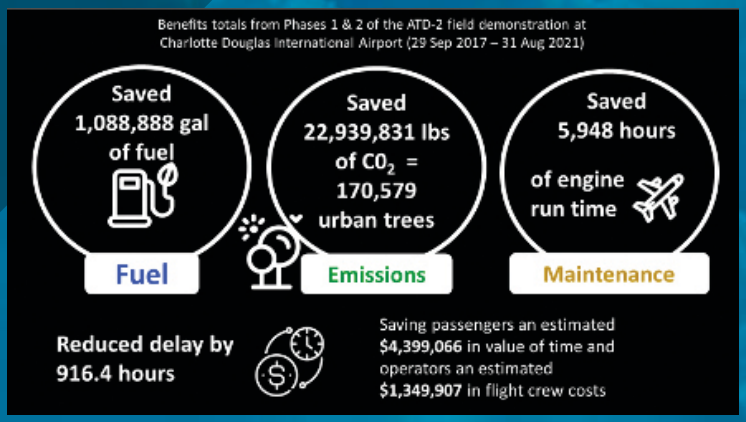
A team of 2021 CSNR Summer Fellows addressed flow tube failure modes due to thermal transients. Their numerical models of the interactions of the flow tubes and the surrounding fuel will provide guidelines for controlling the flow of hydrogen through the reactor during the reactor shutdown. If the hydrogen flow is stopped too abruptly, residual heat due to delayed fission and decay of fission products will not be removed and the fuel will melt. If the hydrogen flow is maintained at the full operational level, the wall temperatures will drop precipitously, and the hydrogen trapped along grain boundaries will cause fracturing of the flow tube material. The models devised by the Summer Fellows will indicate the optimum hydrogen flow as a function of time for achieving successful, non-damaging, shutdowns of the NTP reactor.

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 development of advanced propulsion.

Aeronautics Research and Development

Sustainable and Safe Airspace Operations

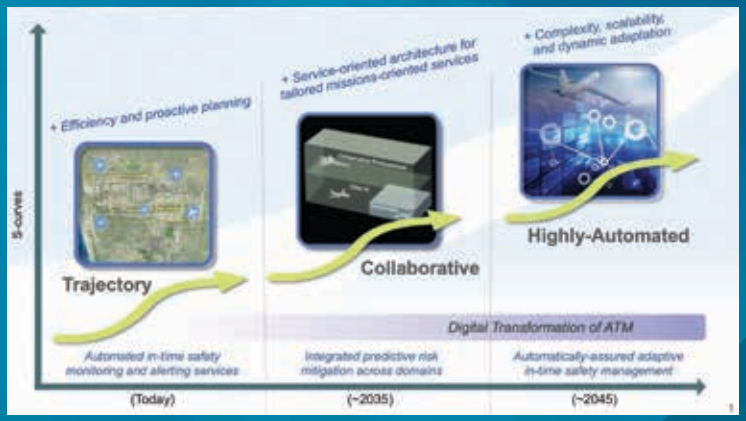
Engineers in USRA's NASA Academic Mission Services (NAMS) team collaborate with NASA's Ames Research Center, small business partners, universities, and other organizations to develop Next Generation Air Transportation System technologies. The purpose is to reduce air travel times and delays, to ensure greater safety in all weather conditions, and to reduce environmental impacts of aviation. This work supports goals of the U.S. Federal Aviation Administration (FAA). During the past year, the FAA Administrator announced that the Integrated Arrival/Departure/Surface (IADS) technology developed as part of the NASA Airspace Technology Demonstration (ATD) project will be integrated with FAA systems and deployed for production use at 27 hub airports over the next decade. This followed the completion of the ATD project after nearly four years of demonstrated use at the Charlotte Douglas International Airport by American Airlines and the FAA, which demonstrated significant reductions in delays on taxiways and runways, use of aviation fuel, and aircraft emissions.



ATD Benefits Measured at Charlotte Douglas International Airport (September 2017 – August 2021) Image Courtesy: NASA

Digital Information Platform

Engineers in USRA's NAMS team collaborate with NASA's Ames Research Center to develop a Digital Information Platform for advanced, data-driven, digital services for flight operators to promote efficient aviation operations in all airspaces, including high-altitude, and for autonomous vehicle operations, including passenger and cargo transport. This builds upon the success of the ATD projects and the latest in cloud-based infrastructures and artificial intelligence technologies to realize the FAA and NASA vision for the digital transformation of Air Traffic Management from trajectory-based to collaborative and highly automated.



Roadmap for Digital Transformation of Air Traffic Management Image Courtesy: NASA

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 Airspace System. USRA's NASA Academic Mission Services team help to make these improvements possible by working closely with NASA, the FAA, the aviation industry and universities to develop and test future capabilities.

Advanced Air Mobility

The NAMS team is supporting NASA's Advanced Air Mobility (AAM) program to accelerate the realization of a safe and scalable AAM capabilities through the development of transformative airspace-operations technologies and through integrated demonstrations of candidate operational concepts and scenarios. This effort involves collaboration with the growing industry that is producing advanced air vehicles, including electric Vertical Takeoff and Landing aircraft, high-altitude long endurance aircraft, and autonomous drones. The work also supports various missions including transporting people and cargo between places previously underserved by aviation and for remote sensing for disaster preparedness, response, and recovery.

The NAMS team is continuing to build upon the award-winning UAS Traffic Management (UTM) system, as well as other software tools, including an Airspace Operations Management (AOM) component to enable comprehensive situational awareness and improve coordinated decision making. This past year the NAMS team collaborated with NASA on AAM simulations and flight tests where these tools were exercised during flight tests involving a Bell OH-58C Kiowa helicopter. These tests involved data integration of real-time automatic dependent surveillance-broadcast inputs, a GPS system, and other flight instrumentation that could be onboard a future vehicle. Also included were simulated instrument-flight rule approaches to heliports and vertiports, terminal area hover tasks, and other maneuvers such as diverting in case of flight changes, avoiding buildings, and other flight maneuvers under various conditions.

Advanced Air Mobility Vision. Image Courtesy: NASA

Joby Aviation's all-electric vertical takeoff and landing (eVTOL) aircraft. Image Courtesy: NASA

Urban Air Mobility (UAM)

The NAMS team collaborates with NASA's Ames Research Center, the FAA, and airspace service providers from industry to develop an airspace management system for Unmanned Aircraft Systems vehicles in urban areas.

During the past year, the NAMS team supported two weeks of tests with Joby Aviation's prototype aircraft near Big Sur, California. For these tests, the Joby aircraft flew planned test scenarios, and the NAMS team supported NASA in processing of information about how the vehicle moved, how the vehicle sounded, and how the vehicle communicated with controllers. A goal of these tests was to collect vehicle performance and acoustic data for use in modeling and simulation of future airspace concepts. Another goal was to analyze the resulting data that are being used to help identify gaps in current Federal Aviation Administration regulations and policies to help incorporate Advanced Air Mobility aircraft into the National Airspace System.

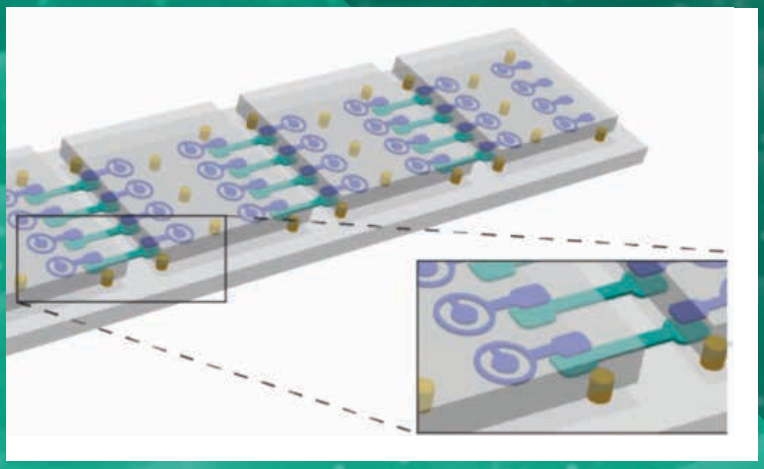
Quantum Artificial Intelligence Laboratory (QuAIL)

USRA's Research Institute for Advanced Computer Science (RIACS) conducts a portfolio of quantum information science research as part of the Quantum Artificial Intelligence Lab at NASA's Ames Research Center. This research supports NASA's missions and involves significant collaboration with two Department of Energy (DOE) National Quantum Initiative Centers: the Superconducting Quantum Materials and Systems Center and the Co-design Center for Quantum Advantage. It also involves collaborations with other federal programs including two Defense Advanced Research Projects (DARPA) Office Programs: the Reversible Quantum Machine Learning and Simulation Program and the Quantum Annealing Feasibility Study.

During the past year, the team continued to make significant progress on the theory of noise impact in Quantum Approximate Optimization Algorithm methods and the design of quantum algorithms for fault-tolerant quantum computers. One paper produced by the group received the Algorithm Best Paper Award from the Multidisciplinary Digital Publishing Institute "for advancing the frontiers of quantum computing through foundational research in algorithms and software that influences the development of commercial quantum computers."

DARPA and NSF Research Programs

The RIACS Quantum Team also collaborates with academia and industry in projects funded by the National Science Foundation (NSF) Spectrum Efficiency, Energy Efficiency, and Security and Expeditions Programs, as well as the DARPA Optimization with Noisy Intermediate-Scale Quantum (ONISQ) Program among others. NSF projects are done in collaboration with Stanford University, Princeton University, Caltech, Cornell University, NTT and others. The group is investigating the power of optical coherent Ising machines and the applications of quantum computing for wireless networks. During the past year, the RIACS team successfully completed Phase I of a project with Rigetti Computing and NASA and was awarded the Phase II option to continue to develop new quantum processors using the Quantum Approximate Optimization Algorithm (QAOA) method to solve real-world scheduling and asset-allocation problems that can be implemented as combinatorial optimization problems and benchmarked against classical computers to determine quantum advantage.



Modular superconducting qubit devices being developed with Rigetti Computing under DARPA ONISQ program. Image Courtesy: Rigetti Computing

Feynman Quantum Academy Internship Program

USRA founded the Feynman Quantum Academy to help train the next generation of quantum information scientists. Interns focus on research in noisy intermediate scale quantum computing within the areas of theory, optimization, machine learning and benchmarking. The students receive hands-on training and undertake individualized research projects utilizing a wide array of quantum architectures including:

- Compilation methods for quantum annealing
- Quantum machine learning algorithms
- Analysis on the impact of noise in QAOA
- Software tools for quantum optimization and machine learning

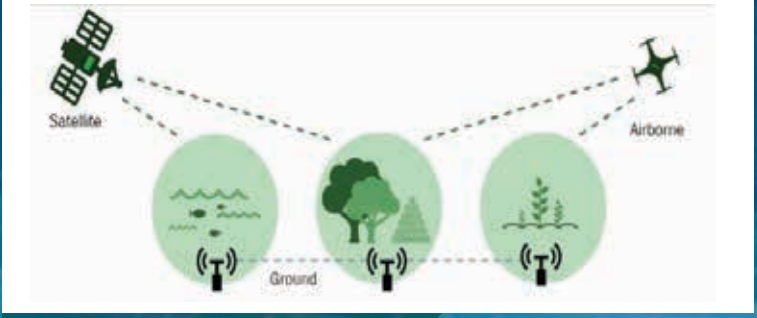
Since launching in 2016 the Feynman Quantum Academy has hosted over 40 students from top international universities. In 2021, the USRA Feynman Quantum Academy had another excellent cohort of student interns, with research topics that included analysis and extensions of QAOA; error correction methods, hardware-efficient quantum algorithms; algorithm-specific benchmarking and error mitigation techniques; benchmarking and analysis of coherent Ising machines.

Artificial Intelligence and Data Sciences

Artificial Intelligence for Natural Hazards

RIACS' scientists are collaborating with United States Geological Survey (USGS), NASA's Ames Research Center and other organizations to develop machine-learning approaches for various applications. The goal is to model and predict natural hazards and their effects for rapid flood mapping, earthquake early warning, landslide risk monitoring, hurricane forecasting and wildfire preparedness, response and recovery and help reduce the impact of such hazards on the lives and livelihoods of people. This research builds upon the decades of research in artificial intelligence that has been done in RIACS since its founding in 1983.

As one example, RIACS scientists collaborated with the USGS Water Mission Area, the NASA Ames Intelligent Systems Division, and other agencies on the DELTA-IRONFIST project. The project utilized neural networks with satellite imagery and other data, to classify whether an area is flooded. Topography-based predictions are incorporated where there are high error rates. The resulting model is in the process of being deployed for operational use.

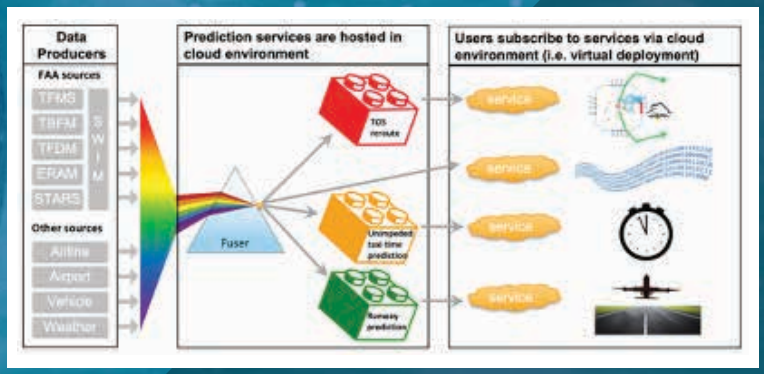


Machine-learning modeling and analysis with ground, airborne and satellite data. Image Courtesy: United Nations

Artificial Intelligence for Sustainable Aviation

Scientists in USRA's Research Institute for Advanced Computer Science (RIACS) are collaborating with NASA's Ames Research Center, small business partners, and other organizations to develop machine learning approaches to model and predict aircraft movements on the surface of airports and in the national airspace system managed by the Federal Aviation Administration (FAA). This work supports the United Nations' International Civil Aviation Organization (ICAO) member state resolution to strive to achieve a goal of keeping the global net carbon emissions from international aviation from 2020 at the same level by enabling reduced fuel use and emissions.

During this past year, RIACS scientists supporting the NAMS program collaborated with NASA and small business partners to develop six machine-learning models. This included models to predict arrival and departure runways, surface taxi times to and from the gate to the runway, and arrival and departure times at the gate. All six machine-learning models demonstrated comparable or better predictive capability than the traditional models.



Real-time machine learning using System Wide Information Management (SWIM) Data. Image Courtesy: NASA

Artificial Intelligence for Advanced Air Mobility

RIACS scientists are collaborating with NASA's Ames Research Center and other organizations including the Civil Air Patrol as part of the NASA Academic Mission Services program to develop a Data and Reasoning Fabric (DRF) for Advanced Air Mobility. The DRF enables integrating streams of data from multiple sources (e.g., satellite and ground data), analyzing data using machine learning algorithms for prioritizing allocation of airborne resources, developing optimal flight plans for autonomous air vehicles, and presenting analysis of airborne remote sensing data to decision makers. The digital marketplace enabled by DRF is being developed to serve the demands for new services that support applications requiring airborne remote sensing and air transportation that utilizes advanced air mobility vehicles, including electric Vertical and Takeoff and Landing aircraft.

Data Sciences using machine learning is enabling computers and other automated systems to perform tasks that have historically required human cognition and human decision-making abilities, USRA scientists and engineers have made significant contributions through use-inspired research and collaborative education projects in application domains that include Aviation Data Sciences and Environmental Data Sciences among others.

Science Facility Management and Operations

Stratospheric Observatory for Infrared Astronomy

USRA's SOFIA team successfully carried out science and mission operations in FY 2021 despite the ongoing pandemic, hired a new Associate Director for Program Management and Integration, developed new bold initiatives with NASA's input, updated the SOFIA Users Group charter and membership, and successfully expanded the SOFIA science community while preparing for the NASA Senior Review expected in the coming fiscal year. We also successfully recruited a record number of postdoctoral fellows to enhance SOFIA science productivity and impact.

SOFIA has expanded its engagement with the science community by organizing and conducting two successful virtual scientific workshops. The team also hosted a webinar at the annual meeting of the Division for Planetary Sciences and sponsored a special session on planetary far-infrared astronomy at the meeting of the American Geophysical Union in San Francisco. We also supported the annual meetings of the American Astronomical Society, where three plenary talks featured SOFIA science. At the winter meeting the SOFIA Science Mission Operations (SMO) staff organized sessions on stellar feedback and hosted a Town Hall and two webinars. We have implemented a highly successful joint ALMA/SOFIA Summer Seminar Series, as well as sponsored weekly colloquia (held virtually this past year) and helped to support the SOFIA Teletalk series held roughly twice a month. The team also launched NASA's new SOFIA blog with five new web articles on SOFIA discoveries. SOFIA science images were also featured online as "Astronomy Picture of the Day" (January 20, 2021, and April 21, 2021). SOFIA papers include 50 published as of September 10, 2021, with projections of 5 additional papers by the end of fiscal year. SOFIA SMO staff co-authored 51 refereed papers, of which 12 are first author. For the Cycle 9 selection process, we held a virtual Time Allocation Committee meeting in October 2021, implementing Dual Anonymous Review for the first time and before it was required by NASA. Additionally, the SOFIA Archival Research Program was offered as a stand-alone Call for Proposals for the first time in FY 2021. The SMO received 42 proposals that oversubscribed the available funding by a factor of 3.9. To promote participation by junior investigators, the SMO offered both Regular and Small proposal categories. Seventeen small proposals were received. The SOFIA SMO continues to advertise its archival datasets on a redesigned webpage featuring promising archival data sets.

Aeronautics R&D Testbed for Airspace Operations

Engineers in USRA's NAMS team are developing and operating an aeronautics R&D Testbed for airspace operations with engineers at NASA's Ames Research Center. The core purpose of the Testbed is to enable realistic simulations of current and proposed future air traffic concepts, for use by government, industry, and academia. The USRA team was involved with key simulations such as origin-to-destination, trajectory-based operations, widespread integration of novel vehicles and operations such as unmanned vehicles, and real-time safety assurance technologies to enable autonomous operations. As part of this work, the team supports industry partners, who provide real-world use cases and challenges to the team. During this past year, NAMS personnel supported a connectivity test of the Aviation Systems Testbed capability with the Independent and Configurable Architecture for Reliable Operations of Unmanned Systems (ICAROUS). The successful test now enables ICAROUS to participate in future Urban Air Mobility experiments that leverage Testbed. The connectivity test consisted of ICAROUS connected via Testbed to three other systems, an air-taxi-vehicle simulator ("Flyer"), a traffic simulator and mission planner, and a web-based visualization platform.

Testbed use for ICAROUS detect-and-avoid algorithm enabling re-routing via Flyer. Image Courtesy: NASA

USRA manages various facilities including the Science Mission Operations for the Stratospheric Observatory for Infrared Astronomy (SOFIA). Summarized on the right are the other facilities it operates.

Artificial Intelligence R&D Testbed

USRA's RIACS developed a new computational testbed for Artificial Intelligence R&D in collaboration with the University of California, San Diego. The testbed provides access to the high-performance Graphic Processing Unit (GPU) and storage nodes for select university research projects aligned with USRA activities. The testbed was used with Jupyter Labs to support a new 12-week Environmental Data Sciences course that a RIACS staff member taught this year for USRA, NASA and USGS personnel.

NTX Research Station

Engineers in USRA's NAMS Team develop and operate the North Texas (NTX) Research Station in collaboration with NASA's Ames Research Center. NTX is a 5000 square-foot purpose built, dedicated, air traffic management research facility. NTX has a dedicated radio tower and a reconfigurable computer lab, with access to live data including Air Route Traffic Control Center and Terminal Radar Approach Control Facilities data from Dallas/Fort Worth and Dallas Love Field airports. The NTX team collaborates with the airline operation centers for American Airlines, Southwest Airlines, and Envoy Airlines. During the past year, benefits of the NASA Airspace Technology Demonstration project were extended through tests at Dallas/Fort Worth and Dallas Love Field airports with American Airlines, Southwest Airlines, and Envoy Airlines.

The final testing of the portable Automatic Dependent Surveillance – Broadcast package at Dallas-Fort Worth International Airport. Image Courtesy: NASA

STEM Workforce Development

NASA Internships

USRA continues to create strategies that target a diverse population of students and brings awareness of opportunities within NASA. We attend events that focus on students from minority-serving institutions (MSIs), identify barriers that preclude these students from applying for an internship, connect with them using Handshake and LinkedIn, and support them through the application process.

With inclusion as one of its core values, USRA seeks talented interns to strengthen tomorrow's science, technology, engineering, and mathematics (STEM) workforce—both on-site and virtually. Virtual internships have continued to provide valuable work-based learning experiences to students across the United States in the wake of the COVID-19 pandemic. In FY 2021, USRA partnered with NASA to enhance the virtual internship experience while implementing steps to ensure broad intern diversity regardless of internship format.

Summer Interns (clockwise from top left): Hannah Falls (Kennedy Space Center), Faizan Darsot (Ames Research Center), Diana Gutierrez (Goddard Space Flight Center (GSFC), Tonye Hale (Kennedy Space Center), Karen Mae Baldonado (Langley Research Center). Image Courtesy: NASA

Our commitment to reach diverse and inclusive student populations allowed over 2,200 students to accept internships in FY 2021. Students were offered fully remote internship experiences coupled with greater flexibility in work hours. Mentors continued to develop project opportunities requiring new skills to allow for quality learning experiences and continued connection to NASA missions.

USRA partnered with NASA to improve interns' access to technological resources and overcome the challenges of engaging interns in a digital world. Together, USRA and NASA will continue to reach and unify students by breaking down barriers that inhibit participation in STEM learning opportunities and NASA's future workforce.

Student R&D Programs

The NASA Academic Mission Services (NAMS) Student R&D Program engages a diverse set of students from national and international universities, including minority institutions. Internship projects focus on artificial intelligence, quantum information science, autonomous air vehicles, nanotechnology, and high-performance computing. This program serves as a workforce pipeline, with approximately ten percent of interns converting to full-time staff to support technical projects with federal sponsors.

As one highlight from this past year, USRA collaborated with NASA and San Jose State University to co-mentor students to develop a schematic design of a high density vertical vertiplex that would decrease surface footprint without jeopardizing the operational efficiency and meet safety critical requirements. The interns' design received first place and top honors in the national Airport Cooperative Research Program design competition under the Airport Operation Maintenance Challenge.

At the Science and Technology Institute, Pawan Gupta mentored two interns in 2021. Paul Lin, who has since joined STI as a software engineer for SERVIR, and Keerthi Gudipudi, who just started last month. Both internships have been virtual, and the students have been working on processing and visualization of air quality data, including machine-learning algorithms.

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

NASA Postdoctoral Program (NPP)

The NASA Postdoctoral Program (NPP) provides early-career and more senior scientists the opportunity to share in NASA's mission. Fellows work on one- to three-year assignments with NASA scientists and engineers at NASA centers and institutes to advance NASA's missions in earth science, heliophysics, planetary science, astrophysics, space bioscience, aeronautics, engineering, human exploration and space operations, astrobiology, and science management. NPP fellows contribute to our national scientific exploration, confirm NASA's leadership in fundamental research, and complement the efforts of NASA's partners in the national science community.

USRA continues to operate NPP, providing recruitment of applicants and review of science proposals for over 2,700 potential fellows since USRA began operations in 2016. USRA also administers the program on behalf of NASA for an average of about 200 fellows at any time. It has hosted recruiting, networking, and career development events for current and prospective fellows. The NPP Town Hall, site visits, and annual meeting were virtual because of COVID-19.

USRA is also focused on diversity in the recruitment of applicants and executes targeted efforts to focus on recruiting from underrepresented groups in multiple STEM areas.

USRA completed Contract Year 5 of the NPP effort in FY 2021 and was awarded a six month extension through July 14, 2021. USRA has been given another contract extension for a period of up to six months through January 31, 2022. USRA provides candidate recruitment and proposal reviews for all NPP applicants. Over the three FY 2020 review cycles, NPP had 485 submissions and over 100 selections, resulting in 89 fellows receiving an NPP award.

Foothill-DeAnza Community College District STEM Internship Program

In September 2021, USRA/ NAMS started a new joint STEM Internship Program with the Foothill-DeAnza Community College District, with priority given to students who demonstrate financial need, are aiming to transfer, and are first-time degree earners. The program is jointly funded to provide internships for five college students in the areas of aeronautics, data science, machine learning, high performance computing, and/or quantum computing in the fall, winter and spring quarters. The first three students started with data science and advanced air mobility projects.

Public Engagement

USRA co-sponsored the 38th annual conference of the American Association for Aerosol Research. A USRA RIACS scientist initiated and organized a special symposium (Satellite Data and Environmental Health Applications) at the conference that focused on research using remote sensing aerosol data for environmental health applications.

USRA co-sponsored co-organized the Quantum 2 Business Conference with QC-Ware, with funding through a grant USRA-RIACS received from the Air Force Office of Scientific Research.

As a service to the quantum computing community, USRA continued to publish a monthly newsletter on noisy intermediate-scale quantum computing, which includes a curated digest of the latest preprints that are impacting the field of near-term quantum computing.

Lunar and Planetary Institute (LPI) Education and Public Engagement

The LPI collaborates with partners and the planetary science community to serve all learners, informing and inspiring diverse audiences to enhance their interest in and understanding of planetary science and exploration.

The LPI's Sharing Planetary Science seminars support scientists' efforts to engage the public in planetary science. The LPI also conducts scientist engagement activities at conferences, such as the 2020 Society for Advancement of Chicanos/Hispanics and Native Americans in Science conference and the 2021 Lunar and Planetary Science Conference, at which LPI conducted a week-long Early Career Presenters Help Desk, to enable early-career scientists to receive feedback from senior scientists before finalizing their posters and presentations.

The LPI Virtual Exploration Experiences with Planetary Scientists (VEEPS) series features planetary scientists and an online demonstration or activity for family audiences. The 2020–2021 topics included NASA's return to the Moon with Artemis, Mars 2020 Perseverance, Asteroid Day, Venus, and more. The Cosmic Explorations Speaker Series 2020–2021 topic was "To the Moon, Asteroids and Beyond," which featured a series of virtual adult presentations. Over the summer, LPI held LPI Intern Stories, highlighting intern panels who shared their interests and experiences. To date, approximately 11,500 people attended these programs or watched the recordings on LPI's YouTube channel. LPI conducted additional public events such as the March 2021 webinar series, Live from LPSC, and virtual programs for libraries, Girl Scouts, and other partners.

Public Engagement Lead Sha'Rell Webb demonstrates how to make a Mars helicopter. Image Courtesy: USRA/ Lunar and Planetary Institute.

AFRL Future Scholars and STEM Workforce Development Programs: Strengthening the STEM Pipeline

USRA has managed the Air Force Research Laboratory (AFRL) Scholars Program since 2013 and continues to expand the success of the program by supporting two new Technical Directorates (TDs) in FY 2021. In total, USRA now oversees placement of students, postdoctoral fellows, and K-12 STEM professional educators at seven TDs across six AFRL locations. USRA supported more than 340 scholars through year-round internships during FY 2021 and successfully administered stipend distribution for the Wright Scholar Research Assistant Program. Additionally, during FY 2021, USRA was awarded a new cooperative agreement entitled "AFRL Future Scholars and STEM Workforce Development Programs" to administer the AFRL Scholars Program, AFRL Scholars Professionals, and the University Research Engagement Program (UREP). Notable achievements during FY 2021 included the placement of the first scholar at the Pentagon to support the Joint Staff Directorate and the placement of the first cohort of Research Assistants at Kirtland Air Force Base. Furthermore, USRA awarded two sub agreements as part of the first UREP funding opportunity.

This year's program success is undoubtedly attributable to USRA's team of highly experienced Intern Program Coordinators. In response to the ongoing COVID-19 pandemic, the team successfully implemented a hybrid summer program offering both virtual and on-site internships. Coordinators also executed 25 virtual enrichment activities including keynote presentations from Dr. Alan Stern and General Lester L. Lyles, USAF (Ret.).

Photo collage featuring the summer 2021 Eglin AFB scholar cohort. Image Courtesy: USRA

The three-pronged portfolio of programs aims to increase the scientific preparedness of the next generation of STEM workers, with an emphasis on the recruitment of students underrepresented in STEM. USRA will continue to work in close collaboration with AFRL to encourage the pursuit of STEM-related disciplines and help prepare future professionals for entry into the high-tech workforce pipeline.

USRA STEM Education Center: Cultivating a New Generation of Scientists, Engineers, and Astronauts

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.

To ignite interest among a new generation of the future scientists, engineers, and astronauts, the USRA STEM Education Center continued to offer unique and engaging learning opportunities during FY 2021 for underserved and underrepresented students, despite the global COVID-19 pandemic. The STEM Education Center team developed an aggressive strategy to ensure students received continued access to unique STEM programming virtually.

American Museum of Natural History's host Dr. Carter Emmart and former astronauts Mary Cleave, Paul Richards, and Alvin Drew. Image Courtesy: USRA

With the Lunar and Planetary Institute (LPI), USRA's STEM Education Center supported an exciting series of interactive virtual workshops to celebrate the landing of Perseverance. The program called "Making Our Way to Mars" included an interactive webinar for elementary and middle school students focused on the mission, an educator workshop, a virtual panel consisting of subject matter experts supporting the mission, and a special event for the public featuring a panel of former astronauts. The "Making Our Way to Mars" culminating event was held the day prior to landing of Perseverance on February 18, 2021, in partnership with the

Workforce Development Programs

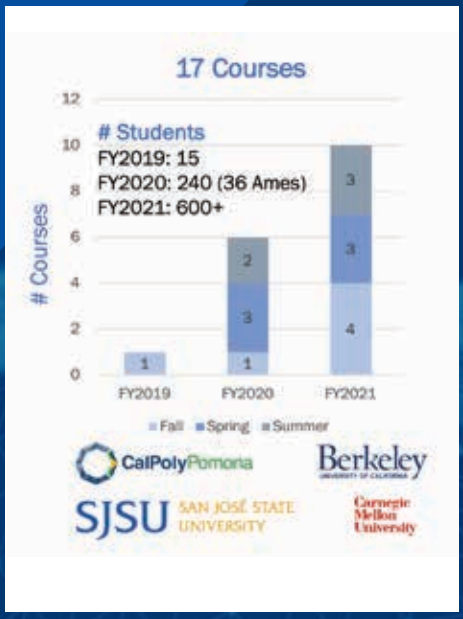
American Museum of Natural History (AMNH). Approximately 3000 teachers, students, and families participated in this series of events, which were funded through a sponsorship with Lockheed Martin.

In addition, the USRA STEM Education Center supported the continuation of a virtual ACT Preparatory Course, in collaboration with The Princeton Review. More than 30 program participants were competitively selected for participation in this course during FY 2021, which was offered free of charge to upper level students from Howard County Public School System as well as to students from other school systems.

In future, the USRA STEM Education Center will extend its reach to other high-needs counties and ensure that underserved and underrepresented students receive immersive opportunities in STEM.

USRA scientists and engineers supporting the NASA Academic Mission Services (NAMS) program collaboratively develop curriculum to help train current workforces and the next generation through university curriculum. This includes courses and other learning materials in the areas of Aviation Data Science, Environmental Data Science, Quantum Information Science, and Flight Control Engineering. Seventeen courses have been developed to date with hundreds of participants. Courses have been taught by RIACS personnel and faculty at a number of universities, including Cal Poly Pomona, UC Berkeley, San Jose State University, and Carnegie-Mellon University. Topics this year included data sciences with focus on machine learning (5 courses), quantum information science (3 courses), and aerospace (2 courses).

As one highlight, USRA collaborated with the University of Maryland, College Park and staff at the National Institute of Standards and Technology to develop and teach a three-week summer bootcamp on the fundamentals of quantum computing. The bootcamp was designed to provide foundational knowledge of quantum computing and quantum machine learning to working professionals and recent graduates with backgrounds in mathematics, physics, engineering and computer science. Over 20 students from across the U.S. and serving in a variety of government, academic and commercial roles participated in the bootcamp.

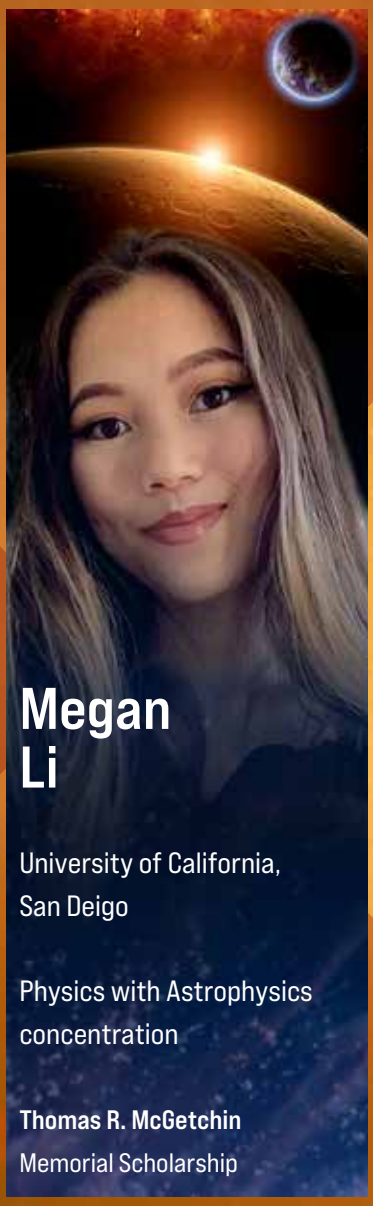


Over 50 lectures on quantum information sciences are now available for students and staff through the RIACS website.

2021 Distinguished Undergraduate Awards

In keeping with its goal to recognize and develop promising future scientists in space-related disciplines, USRA bestows these awards to honor outstanding undergraduate students in a variety of majors through a competitive process. These awards are granted to students who tackle challenging problems in aerospace engineering and space science research, demonstrate leadership, and are poised to make significant contributions to their fields.

The following students were the winners of the USRA 2021 Distinguished Undergraduate Awards:



Megan Li

University of California, San Deigo

Physics with Astrophysics concentration

Thomas R. McGetchin Memorial Scholarship

Joheen Chakraborty

Columbia University

Astrophysics and Computer Science

James B. Willett Education Memorial Scholarship

Sarah Ketchersid

Embry-Riddle Aeronautical University

Aerospace Engineering

Frederick A. Tarantino Memorial Scholarship

Established to honor the service and memory of individuals who made significant contributions to their fields and to USRA, these awards are made possible by financial contributions, including those made by USRA employees.

" The 2021 Distinguished Undergraduate Award winners represent the very best of tomorrow's space scientists and engineers. Despite the COVID-19 challenges, they pressed on with their coursework and individual research, and this award is a testament to their achievements thus far and their potential for future success. In time, I am confident these students will be making new discoveries and tackling our most challenging problems in space-related science and technology."

Dr. Jeffrey A. Isaacson, President and CEO, Universities Space Research Association

Aniket Sanghi

University of Texas at Austin

Astronomy & Physics

Thomas R. McGetchin
Memorial Scholarship

Lindsey Jacobson

North Carolina State University

Aerospace Engineering

John. R. Sevier
Memorial Scholarship

The following students received Honorable Mention:

Rocky An

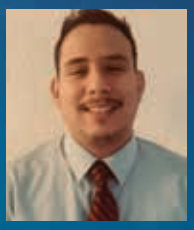
Cornell University

Mechanical Engineering & Biological Engineering

Evan Imata

University of California, Berkeley

Astrophysics



Pedro Salazar Garcia

Iowa State University

Aerospace Engineering

Allison Liu

University of Colorado Boulder

Applied Mathematics

Asher Hancock

University of Pittsburgh

Mechanical Engineering

Emma Rogers

Purdue University

Geology & Geophysics/ Planetary Science

Partnerships

UNIVERSITY PARTNERSHIPS

USRA partners with universities on programs and projects that address national priorities for science and technology research and workforce development, including artificial intelligence and quantum information science, as well as decadal goals in Earth and Space Sciences.

Partnerships for Artificial Intelligence, Quantum Computing, and Advanced Air Mobility Technology

USRA's Research Institute for Advanced Computer Science (RIACS) collaborates with universities on artificial intelligence, quantum information science, and advanced air mobility. Current projects include the USRA-led five-year $190M+ NASA Academic Mission Services (NAMS) contract that involves partnership with the California State University System as well as collaborations with more than 50 colleges and universities and other agencies including NSF and DARPA.

Partnerships for Earth and Space Sciences

USRA's Science and Technology Institute (STI) and SOFIA programs collaborate with universities on space sciences including heliophysics and astronomy. Current projects include a five-year $64M+ cooperative agreement supporting the scientific and technical program of NASA Goddard Space Flight Center's Heliophysics Science Division (HSD) led by The Catholic University, as well as the University of Maryland Baltimore County (UMBC), University of Maryland College Park (UMCP), George Mason University (GMU), and Howard University (HU).

INDUSTRY PARTNERSHIPS

USRA also partners with industry to advance research and enable accelerated scaling of the benefits through partnership with startups and larger firms.

USRA's Research Institute for Advanced Computer Science (RIACS) partners with industrial organizations for quantum computing, artificial intelligence, and nanotechnology. This includes partnership with Rigetti Computing on a $10M+ DARPA project to develop new quantum processors, and with Standard Chartered Bank who invested $1M to grow the ecosystem for quantum computing. This also includes partnership with Space Foundry, to commercialize USRA's patented technology for plasma-based 3D printing.

SOFIA Partnerships, Cooperative agreements, and International Agreements

USRA partners with Deutsches SOFIA Institut to operate, under contract with NASA and DLR (German space agency), for science and mission operations for the SOFIA observatory. In order to keep SOFIA's science instruments at operating temperatures, USRA partnered with international vendors to supply the needed cryogens at our deployment sites in Germany and French Polynesia. Our most recent deployment to French Polynesia required cryogens that came through a partnership with a company in Dubai, UAE. We also partnered with local vendors for export control services for these deployments.

USRA was established in 1969 by the National Academy of Sciences at the request of NASA, with a purpose to "provide a means through which universities and other research organizations may cooperate with one another, with the Government of the United States and with other organizations." The fulfillment of this purpose is enabled through partnerships, both big and small, with academia and industry, in support of government initiatives to advance science and technology through research and workforce development initiatives.

University Engagement

USRA engages with the university research community through its institutes and programs, individual collaborations among USRA scientists and university researchers, and with our member universities. In FY 2021, USRA scientists were involved with 1426 Research Collaborations at 432 organizations.

Regional Meetings

USRA holds regular Regional meetings with its member universities. These meetings offer an opportunity for the members to describe their research programs to USRA and their member colleagues. Members also discuss issues of concern on their campuses. The Regional meetings were suspended during the pandemic, but we were pleased to restart the meetings by holding a meeting of the Region IX members at the University of Alaska, Fairbanks in September 2021.

The COI Region IX Meeting held in the age of COVID-19. Image Courtesy: USRA

USRA's university engagement includes engagement with member and non-member universities in research collaborations; maintaining the active involvement of universities in our governance and oversight; and advocating, in Washington DC, on key issues identified by our members as important to university space-related research and education.

Universities Space Research Association Board of Trustees 2021 – 2022

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USRA is an association of 114 doctoral degree-granting universities engaged in space- and aeronautics-related research and education. University membership ensures broad public oversight of the organization, as it engages in activities to fulfill its nonprofit purpose of "development and application of space-related science, technology, and engineering."

The university members comprise a Council of Institutions. Because of the ongoing pandemic, the 2021 Annual Meeting of the Council was held virtually. Nonetheless, the USRA President and Chief Executive Officer, and the Chair of the Board of Trustees reported on USRA activities. The Council voted to approve the membership of University of Texas at El Paso.

The members elect a Board of Trustees, which governs USRA and appoints the USRA President and CEO.

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Auburn University
Baylor University
Boston College
Boston University
Brandeis University
Brown University
California Institute of Technology
Case Western Reserve University
College of William & Mary
Colorado School of Mines
Columbia University
Cornell University
École Polytechnique Fédérale de Lausanne
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University of Texas at Austin
University of Texas at Dallas
University of Texas at El Paso
University of Texas Medical Branch at Galveston
University of Toronto
University of Virginia
University of Washington
University of Wisconsin - Madison
Utah State University
Vanderbilt University
Virginia Polytechnic Institute & State University
Washington University in St. Louis
Yale University

Public Policy Advocacy

Capitol building, Washington DC. Image Courtesy: Architect of the Capitol

The IPC met virtually with U.S. Congressman Don Beyer (D-VA), Chairman of the House subcommittee on Space and Aeronautics, on Monday, March 1, 2021. Image Courtesy: J. Lochner/USRA

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.

In January 2021, the USRA Issues and Program Committee sent a letter to the Biden transition team advocating for:

- Increased funding for universities for grant and contract augmentations
- Maximum flexibility to modify university contracts and grants to mitigate the effects of the pandemic
- Upholding the study of the Earth as a fundamental part of NASA's mission
- University small satellite missions.

In March 2021, the IPC visited Capitol Hill in Washington D.C. to advocate for space research at our nation's universities. IPC members thanked Members of Congress and their staffs for their support and reported on the status of university-based space research. The committee met with seven key congressional offices, including Rep. Don Beyer (D-VA), Rep. Ed Perlmutter (D-CO), Rep. Brian Babin (R-TX), Rep. Matt Cartwright (D-PA), Sen. Kyrsten Sinema (D-AZ), and Rep. Harold Rogers (R-TX).

For the third consecutive year, Congress has decided to include language in annual appropriations legislation encouraging the funding of 'University Small Missions.' The IPC successfully advocated for the inclusion of $30 million in the House-passed NASA FY 2022 Commerce, Justice, Science appropriations bill 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.

Ethics and Compliance

Rochelle Ford
Vice President,
Corporate Affairs and
Governance
Chief Ethics and
Compliance Officer

In keeping with USRA's values of Passion, Partnerships, and Professionalism, USRA expects all personnel, consultants, and vendors to conduct USRA's affairs with integrity, not merely within the letter but also the spirit of the law. They are also expected and encouraged to report any conduct or circumstances that they believe may violate USRA's values, policies, or applicable laws and regulations.

Program Developments

In December 2020, USRA's Executive Compliance Committee (ECC) held an inaugural meeting, consistent with USRA's strategic plan, to enhance management's oversight of USRA's ethics and compliance functions. The ECC met an additional six times in FY 2021 to assess and monitor ethics and compliance-related policies, procedures, and programs, timely address issues, and consider methods to cultivate and sustain an ethical and compliant organizational culture at USRA.

In May 2021, Rochelle Ford was appointed by the USRA President and CEO with the concurrence of the Audit and Finance Committee of the Board to serve as the Vice President of Corporate Affairs and Governance and Chief Ethics and Compliance Officer (CECO). The CECO reports to the CEO, provides guidance on matters related to the ethics and compliance, and informs the Board of Trustees on ethics and compliance-related risks, incidents, and initiatives.

As in previous years, USRA requires that all personnel complete ethics and compliance training, in eight different areas, to fully inform all of their ethical duties and obligation to comply with laws and regulations applicable to a federal contractor. In FY 2021, at least 94% of USRA's employees timely completed required online ethics and compliance trainings.

Diversity, Equity, and Inclusion

As USRA strives to become a STEM organization that looks like America, we also remember to celebrate our Diversity, Equity, and Inclusion (DEI) accomplishments. USRA's DEI Committee works to promote awareness, understanding, and appreciation throughout the organization

At the corporate level, a USRA success story is embodied in "Equal Pay Day". The "Equal Pay Day" is the number of days that must pass so that the average cumulative pay from the beginning of the year for a USRA woman is equal to the average daily pay for a USRA man in the prior year. USRA undertook a major structural reform in 2018 to revise position titles and pay structures to best match the external market. Assuming employees work an average of 1860 hours per year, data show that USRA women had to work only 1.16 days in January 2021 to earn what USRA men earned the previous year—a gap significantly lower than the US average. This result highlights USRA's commitment to equal pay for equal work, regardless of gender.

On the diversity front, the USRA Leadership Team is as diverse as the workforce, unlike most US STEM organizations. Demographics data indicate that USRA is meeting its diversity goals, with staff percentages higher than the candidate pool in almost every labor category. On race and ethnicity, USRA fared better than the STEM community across the country; approximately 40 percent of the workforce is non-white, equal to the US population, but the balance between over- and under-represented minorities is a work in progress. On gender, women are underrepresented at USRA both overall and in the STEM workforce, similar to the demographics of US STEM.

During the last year, the USRA Diversity committee introduced several other initiatives as well, including a pilot mentoring program for underrepresented minority college students and a DEI Speakers' series to engage and educate the workforce.

At the Institutes and Programs of USRA, DEI continues to play an important role. The Lunar and Planetary Institute's (LPI) inclusion, diversity, equity and accessibility (IDEA) initiative began in FY 2021 and it is now moving forward. In addition to working with USRA Information Technology Systems to make improvements to the USRA Meeting Portal to support inclusion, diversity, equity and accessibility, LPI created an IDEA Advisory Committee. That committee will provide input on aspects of LPI operations (meetings, public engagement, intern programs, etc.) beginning in January 2022.

LPI also recently announced a new, weeklong workshop, "Advancing IDEA in Planetary Science," in April 2022. The goal of this workshop is to bring together the planetary, astrobiological, and social science communities to (1) lean into lessons on IDEA topics learned to date, (2) identify opportunities for improvement by listening to those most impacted in our community, and (3) make recommendations for actionable and tangible. measures for advancing IDEA principles within planetary science.

In the Education Programs, USRA partnered with NASA to increase diversity in the applicant pool for Internships. Some of the activities involved:

- Connecting with students on Handshake and Linked In
- Collaborative partnerships with Pathway and NASA's Office of Diversity, Equity and Opportunity
- Collaborative partnerships with employee resource groups
- Collaborative partnerships with external organizations and
- Targeted Social Media campaigns as a recruitment tool.

Members of the USRA DEI Committee


Joan Schmelz
Chair of DEI


Elena Einstein


Bill Reach


Eric Hammond


Rosa Padilla


Falguni Patadia


Kennda Lynch


Sha'Rell Webb


Carlene Campbell


Assaf Anyamba


Davide Venturelli


Angie Quaranta


Fred Lipschultz


Zaheer Ali


Edgard Rivera Valentin

Jing Li, inventor of NASA's E-Nose device, inspects sensor array chips inside the device for COVID-19 detection. Image Courtesy: NASA

Intelligence Systems: Electronic Nose That Can "Smell" COVID-19 Being Developed at NASA's Ames Research Center

The ability to quickly and cost-effectively screen people for COVID-19 is an essential part of addressing the ongoing pandemic. Adwait Sahasrabhojanee, an Associate Scientist at USRA, is working on the machine learning algorithm to enhance the "E-Nose" device developed by Jing Li, Ph.D., at NASA's Ames Research Center. The team is using patented nano-sensors and nano-sensor array technologies for COVID-19 detection. The E-Nose was originally designed to help monitor air quality on the International Space Station, and is now being adapted to detect COVID-19 by "smelling" a person's breath. The E-Nose could help mitigate community spread of the virus in a manner similar to how temperature checks are used to screen individuals before entering shared indoor spaces, such as a local grocery store or restaurants.

USRA scientists are contributing to the E-Nose project by conducting analyses for sensing material selection and developing a predictive model algorithm. The project is currently in the material selection phase, where the sensitivities and specificities of different nanomaterials to gas biomarkers are being tested. Meanwhile, the team has also started collecting breath samples from healthy as well as COVID-19 -infected subjects for testing.

E-Nose device and app. Image Courtesy: NASA

The pandemic offered more opportunities for research. USRA scientists developed the COVID dashboard (Black Marble), and several researchers studied impacts on socio- economic topics.

Monitoring COVID-19 Impacts on the Economic Sector and Reductions in Surface Nitrogen Oxide

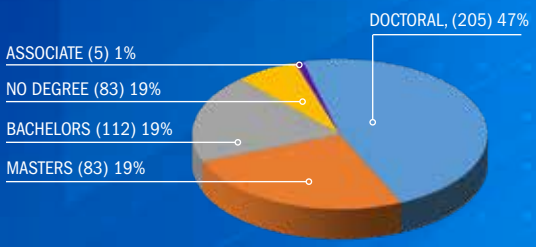
Reduced human activity as seen by reduced lights in the street image (right) of Wuhan, China, after outbreak of COVID-19 (February 2020) compared to higher activity in January 2020 reflected in the image on the left. Image Courtesy: USRA (M. Román/NASA Goddard (R. Shrestha)//NASA Earth Observatory (J. Stevens)

Supporting NASA'a New Earth Systems Observatory that will guide efforts related to climate change , disaster mitigation, and understanding acute disasters such as Category 4 and 5 hurricanes, USRA's Miguel Román and his team at Earth from Space Institute are contributing original research on recurrent acute disasters that can advance the science of disaster reduction and related areas of emergency management and policy.

In addition, USRA scientists continued to develop new applications within the Earth modeling and data assimilation framework known as the Goddard Earth Observing System (GEOS). Reduced human activities in the wake of the COVID-19 pandemic led to sharp reductions in surface nitrogen dioxide (NO_2), an important air pollutant formed during the combustion of fossil fuel.

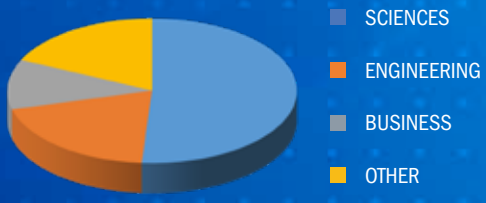
USRA's Diversified Workforce

Employee Distribution by Degree



Approximately 47 percent of USRA's workforce hold Doctoral degrees, and another 19 percent hold Masters.

Employee Distribution by Areas of Study



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

Financial Highlights

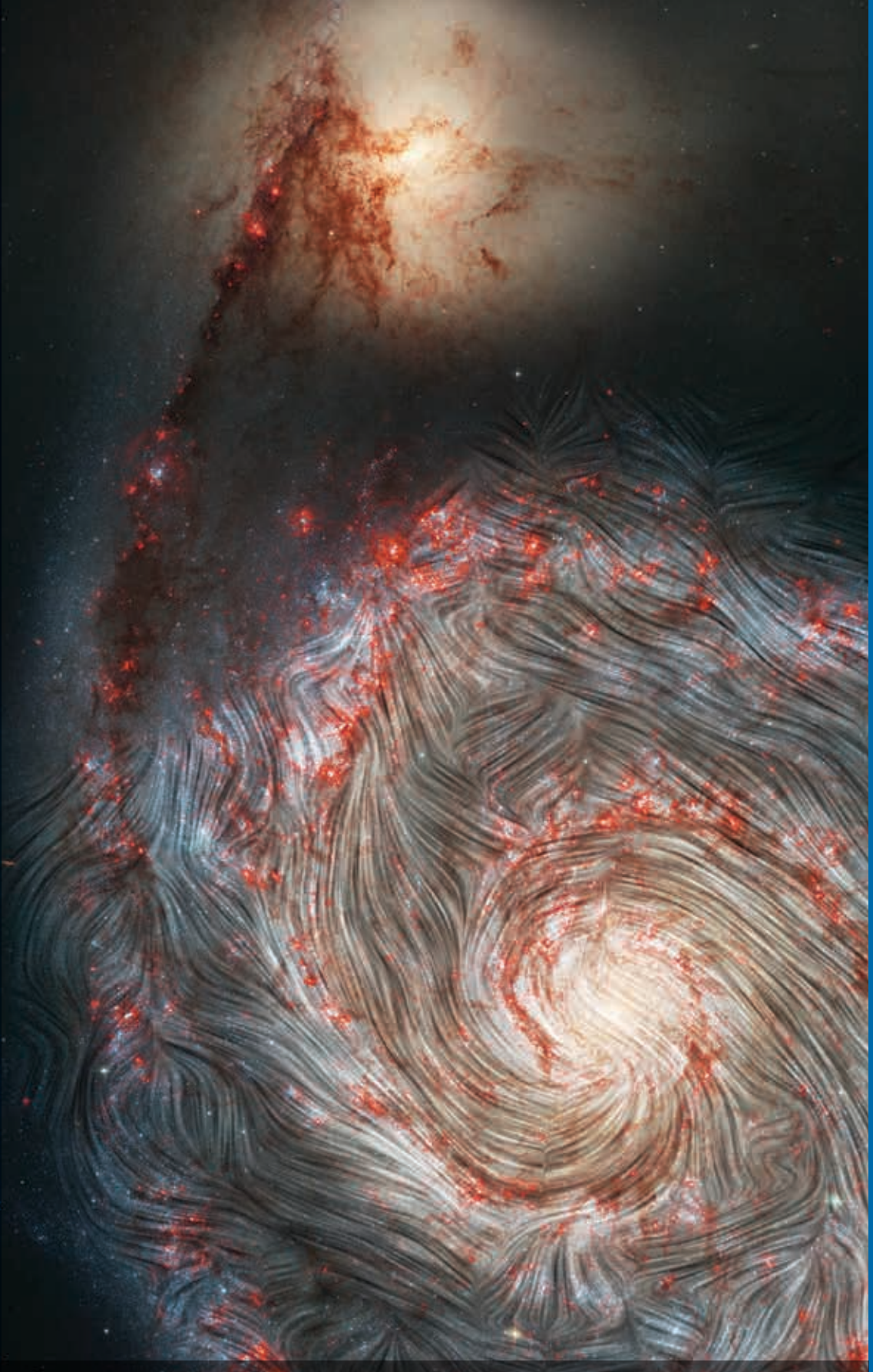
FY 2017-2021 Revenue in Millions

For FY 2021, USRA's annual revenue was $147.7 million. USRA's portfolio of programs weathered COVID-19 with modest impact to revenue.

FY 2017-2021 Total Assets and Net Assets in Millions

USRA's Total Assets for FY 2021 were $65.8 million and Net Assets were $37.3 million.

Net assets are defined as total assets minus liabilities.



Magnetic field streamlines detected by SOFIA are shown over an image of the Whirlpool galaxy, M51, from NASA's Hubble Space Telescope. For the first time, SOFIA's infrared view shows that the magnetic fields in the outer arms do not follow the galaxy's spiral shape and are instead distorted. The intense star formation activity in these regions, shown in red, may be causing the chaos, along with the forces from the yellow neighboring galaxy, NGC 5195, tugging on one of the spiral arms. Image Courtesy: NASA, the SOFIA science team, A. Borlaff; NASA, ESA, S. Beckwith (STScI) and the Hubble Heritage Team (STScI/AURA)

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SEND CORRESPONDENCE AND QUESTIONS TO:

Suraiya Farukhi, Director,
External Communications USRA
7178 Columbia Gateway Drive
Columbia, MD 21046
Or email: sfarukhi@usra.edu

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. 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

www.usra.edu

Composite image of Nebula RCW120. SOFIA measured the glowing gas to study the nebula's expansion speed and determine its age. Image Courtesy: NASA/JPL-Caltech/SOFIA.