USRA

Universities Space Research Association

2020 ANNUAL REPORT

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MISSION

Advance the space- and aeronautics-related sciences exploration through innovative research, technology, and education programs

Promote space and aeronautics policy

Develop and operate premier facilities and programs by involving universities, governments and the private sector for the benefit of humanity

VALUES

Passion—for science, technology, and education

Partnerships—with universities, governments, and the private sector

Professionalism—through excellence, accountability, and respect for others

Cover: *SOFIA finding Water on the sunlit surface of the Moon.*

Inside Cover: *This image highlights the Moon's Clavius Crater with an illustration depicting water trapped in the lunar soil there, along with an image of NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) that found sunlit lunar water. Image Courtesy: NASA/Daniel Rutter*

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

Jeffrey A. Isaacson
President and
Chief Executive Officer

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

It is impossible to reflect on 2020 without considering the COVID-19 pandemic and its far-reaching effects. For an organization like USRA, whose mission depends on partnerships and collaboration, the pandemic created terrific challenges as laboratories and offices closed and almost all aspects of work moved into the home. Yet, the people of USRA, working virtually with our government sponsors and university partners, met those challenges head-on and made the year remarkably successful.

USRA has many accomplishments to be proud of this year, not the least of which are 473 peer-reviewed publications by USRA researchers. Here are just a few others:

Research engagement of universities by USRA's institutes and programs increased this past year by 37% to 959 collaborations with 324 universities. USRA also had 342 engagements with 216 international organizations.

USRA administered 1,866 internships for NASA and 367 internships for the Air Force Research Laboratory (AFRL). For NASA, the USRA team invented ways to connect interns virtually, including the development of a mobile app to provide students instant access to speakers and events across NASA. We also provided laptops and VPN access to alleviate connectivity challenges some interns faced at home.

For AFRL, USRA established a virtual internship model during FY20 that administered remote experiences for 93% of originally anticipated summer session participants. Working from different locations, USRA arranged for more than 65 virtual events in a 12-week period, including talks from the AFRL Chief Scientist and researchers from seven AFRL directorates, along with career forums with industry and DOD.

USRA worked alongside NASA to ensure the NASA Postdoctoral Program continued as normally as possible. Eighty-four fellows were selected this past year, with all reviews being conducted virtually, and on schedule. Working with NASA, the program implemented the first-ever paid family and medical leave program for fellows.

SOFIA's Cycle 8 call for proposals attracted 196 responses in the U.S. queue, amounting to 1,986 hours requested for the 228 hours available. In addition, publications stemming from the observatory rose, and a number of important scientific discoveries were announced, including the first-ever detection of water molecules on the sunlit lunar surface.

NAMS researchers made significant progress in advancing data sciences using machine learning. One noteworthy example of university engagement initiated under NAMS was the development of a 12-week course on Aviation Data Science for the workforce at NASA's Ames Research Center, along with a joint seminar series on the same topic with NASA and the University of California, Berkeley.

Although, regrettably, the Lunar and Planetary Science Conference (LPSC) was cancelled, the USRA-operated Lunar and Planetary Institute (LPI) organized 29 conferences and workshops, in-person and later virtually, serving 2,693 attendees from 49 countries.

USRA was awarded a new, 3-year cooperative agreement for continued management of the LPI. USRA has proudly managed the institute, for NASA and the community, since 1969.

In October, prior to pandemic restrictions, USRA's newly established Earth from Space Institute held its inaugural symposium, Making Communities More Resilient to Extreme Flooding, with 160 participants from 95 organizations in attendance. Senator Chris Van Hollen delivered the keynote, with a call for government to embrace the scientific consensus on climate change and fund continued research using Earth observations.

USRA's Research Institute for Advanced Computer Science began a new effort for DARPA on quantum computing, managing a team that includes Rigetti Computing and partners in the NASA Quantum Artificial Intelligence Laboratory.

USRA organized two national conference calls for the university community to hear from and ask questions of senior legislators: Senator Ted Cruz, Chairman of the Senate Subcommittee on Space and Aviation; and Senator Kyrsten Sinema, the Ranking Member of the Subcommittee.

USRA reinvigorated its Diversity, Equity, and Inclusion (DE&I) Committee, which went straight to work, bringing forward recommendations which are already being implemented.

Despite the pandemic, USRA's financial engine remained strong, with revenue exceeding $149 million.

Although more is captured in the pages of this report, it can only give a glimpse into the contributions and achievements of USRA's employees. They care deeply about the institution and its nonprofit mission, and their extraordinary efforts and can-do spirit are praiseworthy. As USRA will undoubtedly face new challenges in the future, we are inspired by the teamwork and dedication exhibited in all corners of the organization today.

Jeffrey A. Isaacson
President and Chief Executive Officer

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

USRA Helping in COVID-19 Response

Claire Fortenberry (USRA), Marit Meyer (NASA GRC), and Rosa Padilla (USRA) during AMBUstat fogger testing. The AMBUstat nozzle, at left, sprays a water mist into the test enclosure. Image Courtesy: USRA

AMBUstat G2—A Decontamination System for Ambulances and Public Spaces

USRA joined the fight against the coronavirus in collaboration with NASA Glenn Research Center and the company Emergency Products and Research to test a fogging system called AMBUstat G2. The system sprays a mist full of disinfectant that kills pathogens floating in the air, such as the coronavirus. The product would be ideal for decontaminating ambulances and other public spaces in under an hour. Currently, the product is being tested within northeast Ohio, and engineers hope to keep the costs down so underserved communities will be able to afford it.

USRA's Claire Fortenberry, Rosa Padilla, and Gordon Berger assisted the team to characterize the droplet size distribution made by the spray from the AMBUstat sterilizing fogger. The distribution of droplet sizes in the sprayed fog are the determining factor in delivering sufficient sterilizing liquid throughout a space and into its tightest corners. Using particle size measurement techniques, the fogging spray was measured to determine settings on the AMBUstat and the evolution of the fog as it progressed through a similarly sized enclosure.

Gordon Berger during N-95 mask testing. Image Courtesy: USRA

Making N-95 Masks Reusable in the Face of PPE Shortages

USRA, NASA's Glenn Research Center (GRC) and University Hospitals (UH) in Cleveland, Ohio, have collaborated to develop new methods and technologies for decontaminating personal protective equipment (PPE) for safeguarding the health of workers caring for patients with coronavirus (COVID-19).

USRA's Gordon Berger assisted a team to test the effect of an N-95 mask sterilization process by atomic oxygen treatment. Pervasive in low-Earth orbit, these single oxygen atoms can remove organic materials that can't easily be cleaned by other methods. However, treatments are often chemically and thermally aggressive, causing damage to masks and their operability. Thus, masks were tested to make sure they continued to be functional filters before the equipment was shared with University Hospital epidemiologists for further testing on their effectiveness against the COVID-19 virus. The group also tested N-95 media samples recharged by corona charging. N-95 masks achieve their high efficiency and breathability by carrying a surface charge to attract and capture the smallest particles. This charge is dissipated over time and with the exposure to particles and moisture. Testing was done to determine whether the charge could be returned to masks that were no longer effective.

Both of these efforts were done in an effort to make N-95 masks reusable in the face of PPE shortages during the early stages of the COVID-19 pandemic.

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

Astronomy & Astrophysics

SOFIA Reveals New View of Milky Way's Center

The Stratospheric Observatory for Infrared Astronomy, SOFIA, captured a crisp infrared image of the center of our Milky Way galaxy, completing its first Legacy Program. The panorama reveals previously hidden details in the dense swirls of dust and gas, opening the door to future research into how massive stars are forming and what's powering the black hole at our galaxy's core.

Background photo is a composite infrared image of the center of our Milky Way Galaxy. It spans 600+ light years across and is helping scientists learn how many massive stars are forming in our galaxy's center. Galactic Center from combined SOFIA/FORCAST 25 and 37 μm images a Spitzer/MIPS 24 μm images, and Herschel 70 μm images. Image Courtesy: NASA/SOFIA/JPL-Caltech/ESA/Herschel

The Milky Way's central regions have significantly more material, as well as ideal conditions, to create new stars compared to other parts of the galaxy. However, 10 times fewer massive stars are born here than expected. Understanding why this discrepancy exists has been difficult due to obscuring dust between Earth and the galactic core — but infrared light can pierce through this dusty veil.

SOFIA's camera, the Faint Object Infrared Camera for the SOFIA Telescope (FORCAST), observed warm, galactic material emitting at infrared wavelengths of light that other telescopes could not detect. This material glows brightly in infrared light and was highly saturated in data from the Spitzer Space Telescope. SOFIA's new perspective gives scientists a more complete picture of our Galactic Center and is available to the broader community. An overview paper was published in the *Astrophysical Journal.*

Astronomy & Astrophysics continued

SOFIA Finds Magnetic Rivers Feed Young Stars

Stars like our Sun form when clouds of gas and dust collapse under gravity. But scientists are still discovering how material gets from interstellar space into these clouds and how magnetic fields, gravity and turbulent gas motions contribute to the creation of new stars.

Narrow, spindle-like structures, called filaments, act like rivers channeling material from interstellar space into the Serpens South star cluster. SOFIA discovered magnetic fields in the region can further fuel star formation. The fields, shown as streamlines, have been dragged by gravity to align with the narrow, dark filament on the lower left — helping material flow down it — and allowing gravitational collapse and cluster formation to occur even in the presence of relatively strong magnetic fields

Understanding the role of celestial magnetic fields is challenging because they are invisible to most telescopes and are about 10,000 times weaker than Earth's magnetic field. SOFIA's HAWC+ infrared instrument can observe dust grains as they align perpendicular to the fields, allowing scientists to infer the strength and direction of the magnetic field. Additional observations are needed to fully understand the complex relationships among the forces responsible for creating new stars. The results are published in *Nature Astronomy.*

Composite image of the Serpens South Cluster. Magnetic field lines measured by HAWC+/SOFIA are shown as streamlines over an image from the Spitzer Space Telescope. Image Courtesy: NASA/SOFIA/T. Pillai, NASA/JPL-CalTech/L. Allen

Proposed LEAP Mission to Study Cosmic Explosions

Concept of the LEAP instrument observing polarized gamma-rays. The mounting site on the ISS is to be determined. Image Courtesy: Mark McConnell on behalf of the LEAP Collaboration

The LargE Area burst Polarimeter (LEAP), was selected for a nine-month mission concept study by the NASA Science Mission Directorate. It is one of two Astrophysics Mission-of-Opportunity proposals to be selected for additional study. The LEAP instrument would be mounted as an external payload to the International Space Station, and its primary mission would be to study the polarization of gamma-rays from gamma-ray bursts (GRBs). An instrument capable of measuring the polarization of the GRB radiation has been long desired in the community, since it could answer several open questions about the jet physics and the underlying processes that produce the jets. Specifically, measuring the polarization could tell us about the magnetic field strengths present in these systems during core collapse or collision; it could tell us if the jet itself mostly contains matter moving at very near the speed of light or contains a lot of radiation; and it could also indicate how the matter in the jet is converted to the gamma-rays that we observe.

The LEAP instrument is composed of gamma-ray scintillators coupled to photo-multiplier tubes, together creating detectors that owe heritage to both the current Fermi Gamma-ray Burst Monitor (GBM) and the previous Burst and Transient Source Experiment (BATSE) onboard the Compton Gamma-ray Observatory. Different from GBM and BATSE, however, is the unique arrangement of the detectors that will allow LEAP to measure the polarization of the gamma-rays that neither of the previous instruments could. Additionally, it's very large observing area, several times that of GBM, will make it sensitive to detecting many GRBs, so GRB polarization could be measured for potentially hundreds of GRBs, allowing for a population analysis.

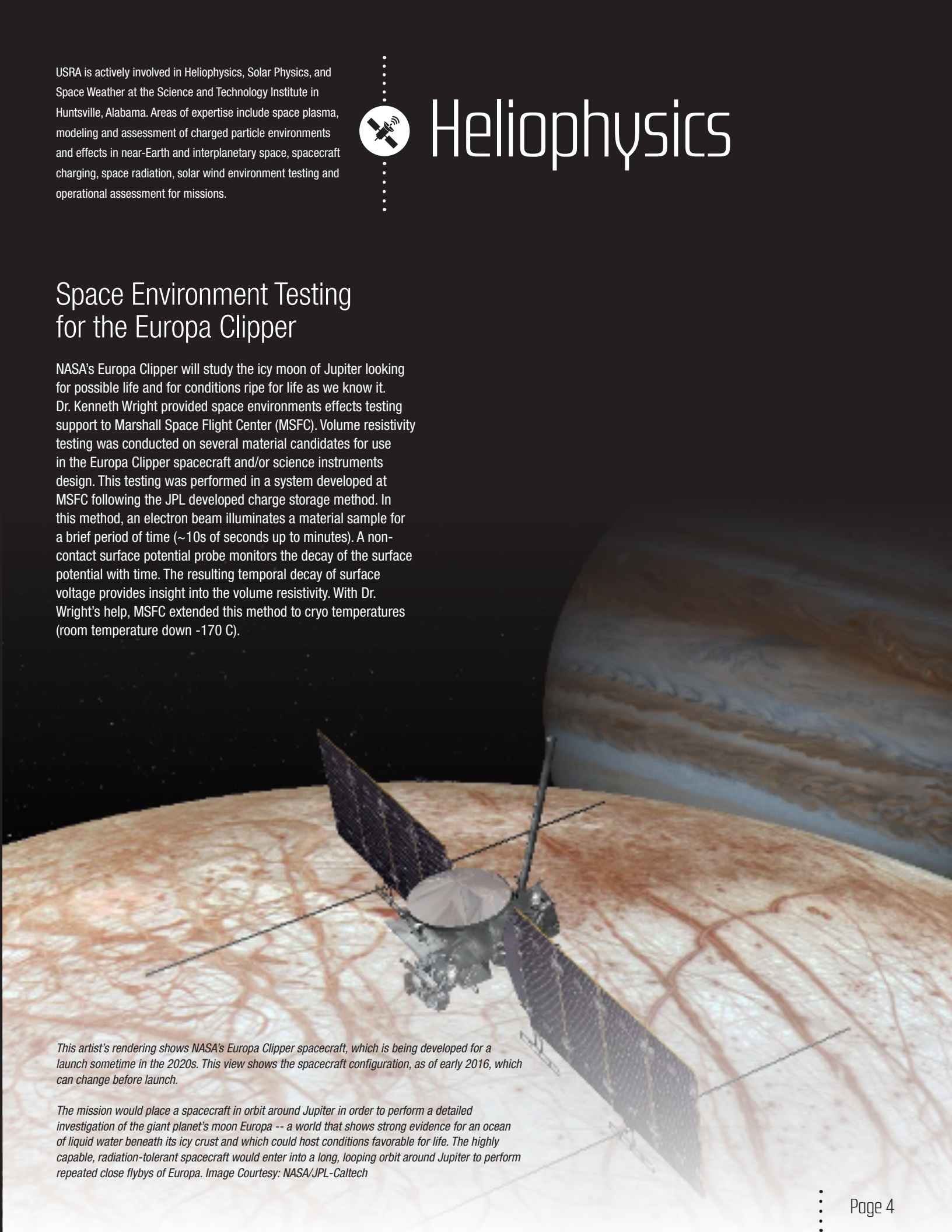
LEAP is led by PI Mark McConnell at the University of New Hampshire, and the concept study is being managed by NASA Marshall Space Flight Center (MSFC). USRA, in partnership with MSFC, will participate in the concept study to produce a final report on the ability of LEAP to achieve its proposed science.

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.

Heliophysics

Space Environment Testing for the Europa Clipper

NASA's Europa Clipper will study the icy moon of Jupiter looking for possible life and for conditions ripe for life as we know it. Dr. Kenneth Wright provided space environments effects testing support to Marshall Space Flight Center (MSFC). Volume resistivity testing was conducted on several material candidates for use in the Europa Clipper spacecraft and/or science instruments design. This testing was performed in a system developed at MSFC following the JPL developed charge storage method. In this method, an electron beam illuminates a material sample for a brief period of time (~10s of seconds up to minutes). A non-contact surface potential probe monitors the decay of the surface potential with time. The resulting temporal decay of surface voltage provides insight into the volume resistivity. With Dr. Wright's help, MSFC extended this method to cryo temperatures (room temperature down -170 C).

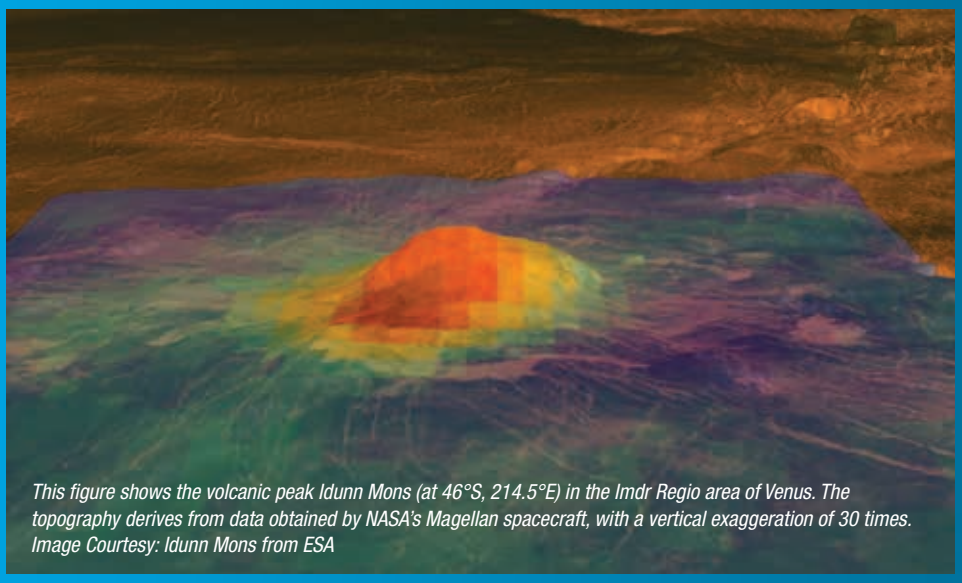


This artist's rendering shows NASA's Europa Clipper spacecraft, which is being developed for a launch sometime in the 2020s. This view shows the spacecraft configuration, as of early 2016, which can change before launch.

The mission would place a spacecraft in orbit around Jupiter in order to perform a detailed investigation of the giant planet's moon Europa -- a world that shows strong evidence for an ocean of liquid water beneath its icy crust and which could host conditions favorable for life. The highly capable, radiation-tolerant spacecraft would enter into a long, looping orbit around Jupiter to perform repeated close flybys of Europa. Image Courtesy: NASA/JPL-Caltech

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

Lunar & Planetary Sciences

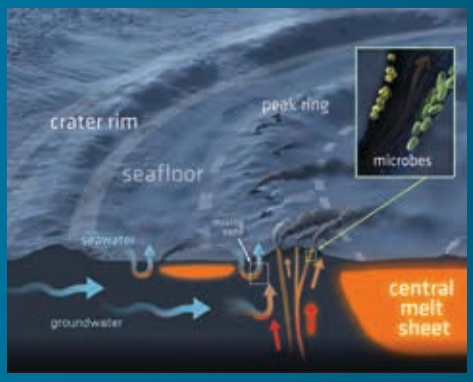


This figure shows the volcanic peak Idunn Mons (at 46°S, 214.5°E) in the Imdr Regio area of Venus. The topography derives from data obtained by NASA's Magellan spacecraft, with a vertical exaggeration of 30 times. Image Courtesy: Idunn Mons from ESA

Scientists Find Evidence that Venus may have Active Volcanoes

Radar imaging from NASA's Magellan spacecraft in the early 1990s revealed Venus, our neighboring planet, to be a world of volcanoes with extensive lava flows. New research by USRA/LPI scientists Drs. Justin Filiberto and Allan Treiman, and LPI summer intern Kyra Cutler has shown that these Venusian lava flows may be only a few years old, suggesting that Venus is volcanically active today. This would make it the only planet in our solar system, other than Earth and Jupiter's moon Io, with recent eruptions. In their work, published in *Science Advances*, the team recreated Venus's hot caustic atmosphere in the laboratory to investigate how lava rocks would react and change over time. Their experimental results, paired with spacecraft data, indicate that some lava flows on Venus are very young, which would imply that Venus does indeed have active volcanoes. Future missions, such as Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging (DAVINCI+), of which USRA/LPI scientists Drs. Justin Filiberto and Walter Kiefer are Co-Investigators, should be able to image these flows; if their surfaces have changed since earlier spacecraft mission, this would provide concrete evidence of current volcanic eruptions.

A Steaming Cauldron Follows the Dinosaurs' Demise



A three-dimensional cross-section of the hydrothermal system in the Chicxulub impact crater and its seafloor vents. The system has the potential for harboring microbial life. Image Courtesy: Victor O. Leshyk for the Lunar and Planetary Institute

With support from the International Ocean Discovery Program, International Continental Scientific Drilling Program, and National Science Foundation, scientists drilled 1,335 meters below the sea floor and analyzed rock core from the heart of the Chicxulub impact crater, famously linked to the demise of dinosaurs. In this study, published in *Science Advances*, a team led by USRA/LPI scientist Dr. David Kring found the crater hosted an extensive hydrothermal system that chemically and mineralogically modified more than 100,000 cubic kilometers of Earth's crust. Thousands of impact craters like Chicxulub were formed on Earth more than 3.8 billion years ago, and each one likely created a hydrothermal system like that at Chicxulub. The abundance and longevity of these hydrothermal systems suggest that they may have provided ideal environments for the development of life – niches with abundant hot water and consistent supplies of materials suitable for thermophilic organisms. The study provides support for the 'impact-origin-of-life' hypothesis, which postulates life may have evolved in an impact crater. The international team studying the core involved nearly 40 scientists from 19 universities and several additional research institutes.

Perspective view of domes and pits formed by groundwater movement in the floor of Ceres's Occator Crater. Image Courtesy: NASA/JPL-Caltech/UCLA/MPS/ DLR/IDA/USRA-LPI

Bright Hydrothermal Deposits on Dwarf Planet Ceres Have a Style All Their Own

Data from NASA's recent Dawn mission show that salty groundwaters in Occator Crater on Ceres were driven to the surface by impact heat and formed low mounds and pits, as well as thin sheets of sodium-carbonate minerals from multitudes of small hot-spring seeps. Such systems, which are strong candidates for habitable environments on early Earth, are thus of astrobiological importance.

Using images and detailed topographic maps derived from Dawn observations, USRA/LPI scientist Dr. Paul Schenk and other members of the Dawn science team have mapped the distribution, dimensions, and structures of these water-related features in Occator, and deduced their origins. Their findings, published in *Nature Communications*, confirm that hydrothermal-related features are common on the floor of Occator. These deposits were formed by effusion of warm brine solutions at hundreds or even thousands of individual sites, where dissolved carbonates and other minerals rapidly came out of solution and crystallized on the surface as the waters evaporated.

However, the deposits are very different from those seen on Mars by other spacecraft. Schenk and colleagues found numerous low mounds and pits with bright deposits on the floor of Occator, but they do not resemble the densely packed, large, deep pits found on martian craters. This difference in morphology is likely related to the more water-rich composition of Ceres's crust.

High-resolution color image of the haze layers in Pluto's atmosphere, acquired by the New Horizons spacecraft on July 14, 2015. Image Courtesy: NASA/JHUAPL/SwRI

Pluto's Atmosphere: New Findings based on SOFIA's Observations

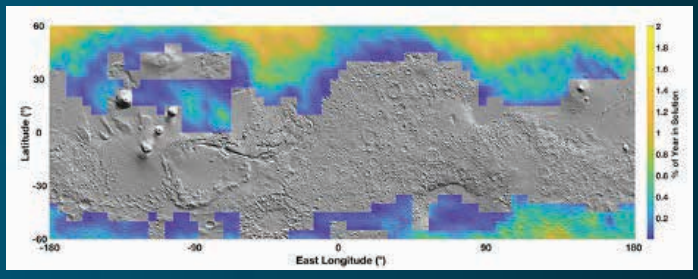
The Stratospheric Observatory for Infrared Astronomy (SOFIA) studied Pluto two weeks before the New Horizon spacecraft's flyby in July 2015, as Pluto cast a faint shadow on Earth's surface during an eclipse-like event called an "occultation". Though the data were obtained in 2015, the results were published in 2020 in the journal *Icarus*, causing scientists to reevaluate their predictions about Pluto's atmosphere.

SOFIA observed the middle layers of Pluto's atmosphere at infrared and visible light wavelengths, while New Horizons probed the upper and lower layers using radio waves and ultraviolet light. These combined observations, taken so close in time, provided the most complete picture yet of Pluto's atmosphere.

New Horizons found evidence of haze particles when it sent back images of a blue-tinted atmosphere. SOFIA's data fills in more details by showing that the particles are extremely small, just 0.06-0.10 microns thick, or about 1,000 times smaller than a human hair.

With these new insights, scientists are reevaluating their predictions on the fate of Pluto's atmosphere. Many forecasts indicated that as the dwarf planet moved away from the Sun in its orbit, fewer atmospheric gases would be created while losses to space continued — eventually leading to atmospheric collapse. But the hazy atmosphere appears to change on a short, cyclical pattern. The researchers suggest that Pluto's unusual orbit is driving these changes and therefore may be more important in regulating the atmosphere than its distance from the Sun.

Salty Liquids on Mars — Present, but not habitable?



Distribution of brines on Mars, with colors showing the percent of the year that briny water could exist near the surface. Image Courtesy: Rivera-Valentín, et al.

Over the past decades, several observations have hinted that Mars may harbor liquid water. Because liquid water is one of the requirements for life as we know it, knowing when, where, and for how long it could exist on Mars is important to understand its present-day habitability. In a new paper in *Nature Astronomy*, USRA/LPI scientists Drs. Edgard G. Rivera-Valentín and Germán Martínez (and others) used experimental results, spacecraft data, and climate modeling to constrain the distribution of liquid water on Mars. Their results showed that stable liquids on Mars would be salty (i.e., brines) and could be present (depending on the available salts) over nearly half of the Martian surface, but only for a small fraction of each year. Those brines, though, would form and persist at temperatures far too cold to be tolerated by known terrestrial organisms. Their work has shown that, on a planetary scale, the Martian surface and shallow subsurface may not be suitable for known life. Further understanding of Martian brines – their chemistry, physics, and biologic potential – will help refine our estimates of Mars's habitability. To that end, the LPI is launching a topical conference initiative to investigate brines across the solar system.

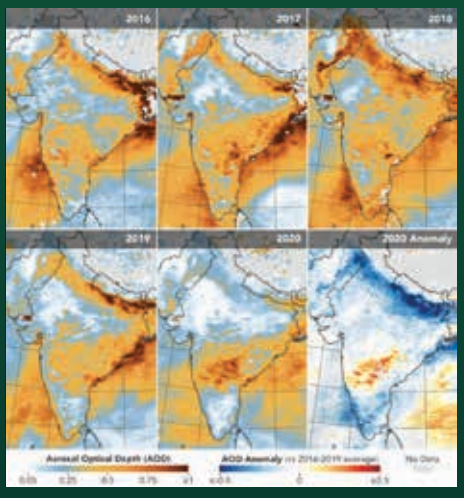
USRA scientists strive to understand the Earth's natural processes, their propensity to change, and the linkages between human and natural systems. They also work across sectors and disciplines to apply Earth observations for broad societal benefit.

Earth Science

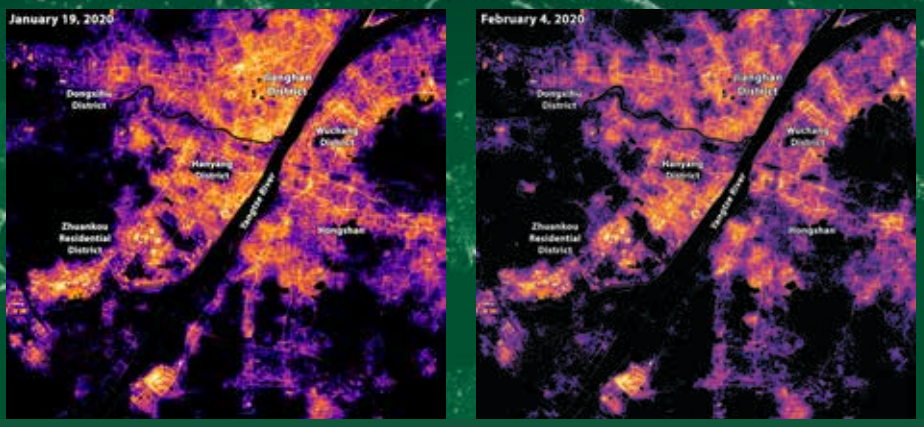
Decreasing Pollution in India During COVID-19

STI's Dr. Pawan Gupta's research is instrumental in showing how data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite is revealing that aerosol levels in Northern India are decreasing during the country's COVID-19 lockdown.

The mean aerosol levels have decreased in the northern regions by more than 50 percent as compared to the climatological mean during the first two weeks of the lockdown, which began on March 25. In many places, satellite observations show the lowest aerosol loading in two decades of data records. It is important to note that the favorable weather conditions, along with the shutdown of emission sources, played a role in observed lower values. The decrease in atmospheric aerosols loading indicates improved air quality, which is confirmed by ground monitoring network across Indian cities.



Satellite observations of air pollution in India during COVID-19 Lockdown. The large negative values in 2020 anomaly map (last map) illustrate the decrease in aerosol levels indicating improved air quality. Image Courtesy: NASA Earth Observatory, Joshua Stevens, using Terra MODIS data; courtesy of Pawan Gupta, USRA



Lighting changes between January 19 and February 4 2020 in Jianghan District, a commercial area of Wuhan, China, as retrieved by the Visible Infrared Imaging Radiometer Suite (VIIRS) using NASA's Black Marble product suite: https://blackmarble.gsfc.nasa.gov/. Image Courtesy: NASA

New Nighttime Lights Data Show COVID-19 Response and Recovery

The frequency and brightness of the lights humans use at night tell us about the daily patterns of human life. They also tell us about the events that disrupt these patterns —the disasters, conflicts, transitions, and celebrations—that shape our societies in new ways. The "Black Marble" product suite, a daily satellite-derived dataset of nighttime lights covering the entire globe was released this year by the Universities Space Research Association's Earth from Space Institute team, under the leadership of Dr. Miguel Román and Dr. Eleanor Stokes. The data are available to download freely for anyone to use.

As city governments began to employ preventative measures against the spread of COVID-19, human activity changed dramatically. The human response to these measures has shown up in the satellite record. Nighttime lights associated with businesses, traffic, and even some transportation corridors dimmed and shifted to residential areas, and emergency facilities. When compared with previous years, 2020 records showed dramatic plunges in city lights, corresponding to the dates that curfews and physical distancing restrictions were enacted. Even traditional annual events—like the religious holiday of Ramadan—were celebrated differently this year and evidence of this can be found in the Black Marble dataset.

To help others understand nighttime lights data in the context of the COVID-19 pandemic, and to provide tools for assessing the impact of the pandemic on cities, the Black Marble data were integrated into NASA's COVID-19 online dashboard, which received NASA's Group Achievement Award. Along with continuing to monitor the economic recovery in a post-COVID-19 world, Black Marble data will be used to study other short-and long-term changes within and across human settlements, providing information to guide sustainable urbanization and equitable development, as well as to support disaster risk-reduction efforts.

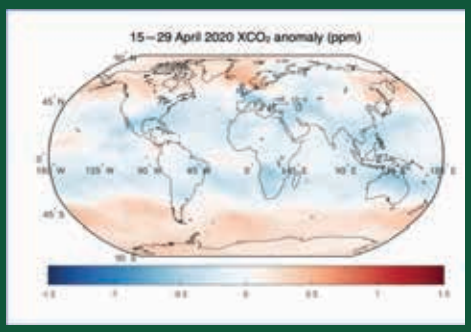
Modelling Capabilities Enable Tracking of CO_2 Emissions

USRA Scientists at GESTAR continue to be major contributors to the development of modeling capabilities within the NASA Global Modeling and Assimilation Office (GMAO). In 2020, their work on the global distribution of greenhouse gases, particularly carbon dioxide (CO_2), using spaceborne observations and incorporating them in the Goddard Earth Observing System (GEOS) framework, was significant.

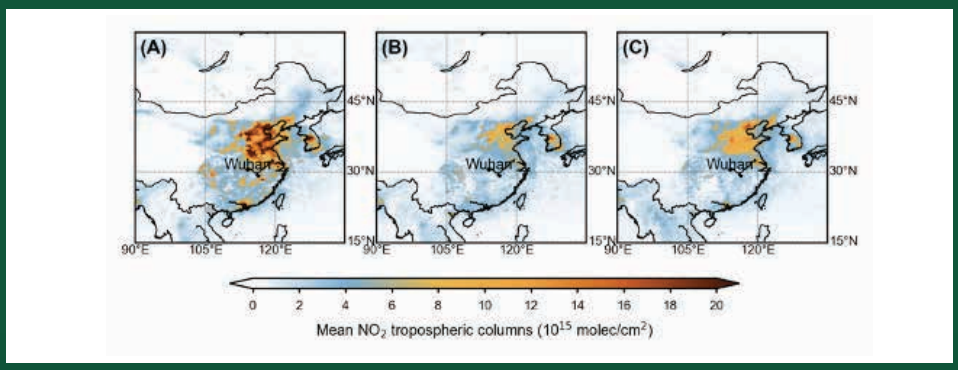
USRA's Brad Weir led the development and testing of a special version of the GEOS to attempt ingesting the vertical column-averaged carbon dioxide observations from NASA's Satellite—the Orbiting Carbon Observatory 2. The purpose of this effort was to investigate whether CO_2 emission changes, consequent to the setback in economic activity initiated in early 2020 due to the Coronavirus Disease 2019 (COVID-19), were measurable. The results show a 0.2-0.4 parts per million (ppm) reduction in emissions from February through May 2020 over the world's industrialized countries *(top left)*, with subsequent rebound coinciding with changes in country-level activity due to COVID-19.

The ability to observe and analyze such small changes, orders of magnitude smaller and shorter than the ~415 ppm background of CO_2, is an enormous advance for present-day sensors and data-assimilation capabilities. With planned increases in observational coverage from NASA's future missions, space-based monitoring systems will help decision making based on the actual responses of CO_2 to different mitigation efforts.

Another COVID-related study was performed by Fei Liu, a GESTAR scientist in the NASA Atmospheric Chemistry and Dynamics Laboratory. Dr. Liu led a multi-institutional study using data from NASA's Aura satellite and the European Copernicus Sentinel-5, showcasing a 48 percent reduction of nitrogen dioxide, a noxious gas emitted by burning fossil fuels, over China, consequent to the implementation of COVID-19 policies.



Spatial maps of changes in column-averaged carbon dioxide growth from GEOS/OCO_2 for 15–29 April 2020 show significant reductions (blue) over much of the World's largest economies. The United States, Western Europe, and Australia are roughly 0.3 ppm lower in 2020 than business-as-usual growth. Increases in the polar regions are likely due to the response of the terrestrial biosphere to climate variability, such as the record high temperatures in Australia in 2019 and over Siberia and much of the Arctic in 2020. Image Courtesy: Brad Weir, USRA/NASA GMAO and the OCO_2 Mission Team, JPL



Average tropospheric NO_2 vertical column densities over China in 2020. (A) -20 to -1, (B) 0 to 19, and (C) 20 to 39 days relative to the January 25, 2020 Lunar New Year. Abrupt decline in tropospheric nitrogen dioxide over China after the outbreak of COVID-19. Science Advances 6, eabc2992 (2020). The study received widespread media attention. Image Courtesy: Fei Liu, USRA/GSFC and the OMI NO_2 Team, NASA, GSFC

Understanding the Ocean's Role in Climate

The Research Vessel used for the EXPORTS field campaign in the North Pacific in 2019 (left), picture of the PACE satellite set to launch in 2023 (top right) and Dr. Cetinic working with Dr. Werdell (NASA) on the Glider instruments used during the EXPORTS field campaign (bottom right). Image Courtesy: NASA

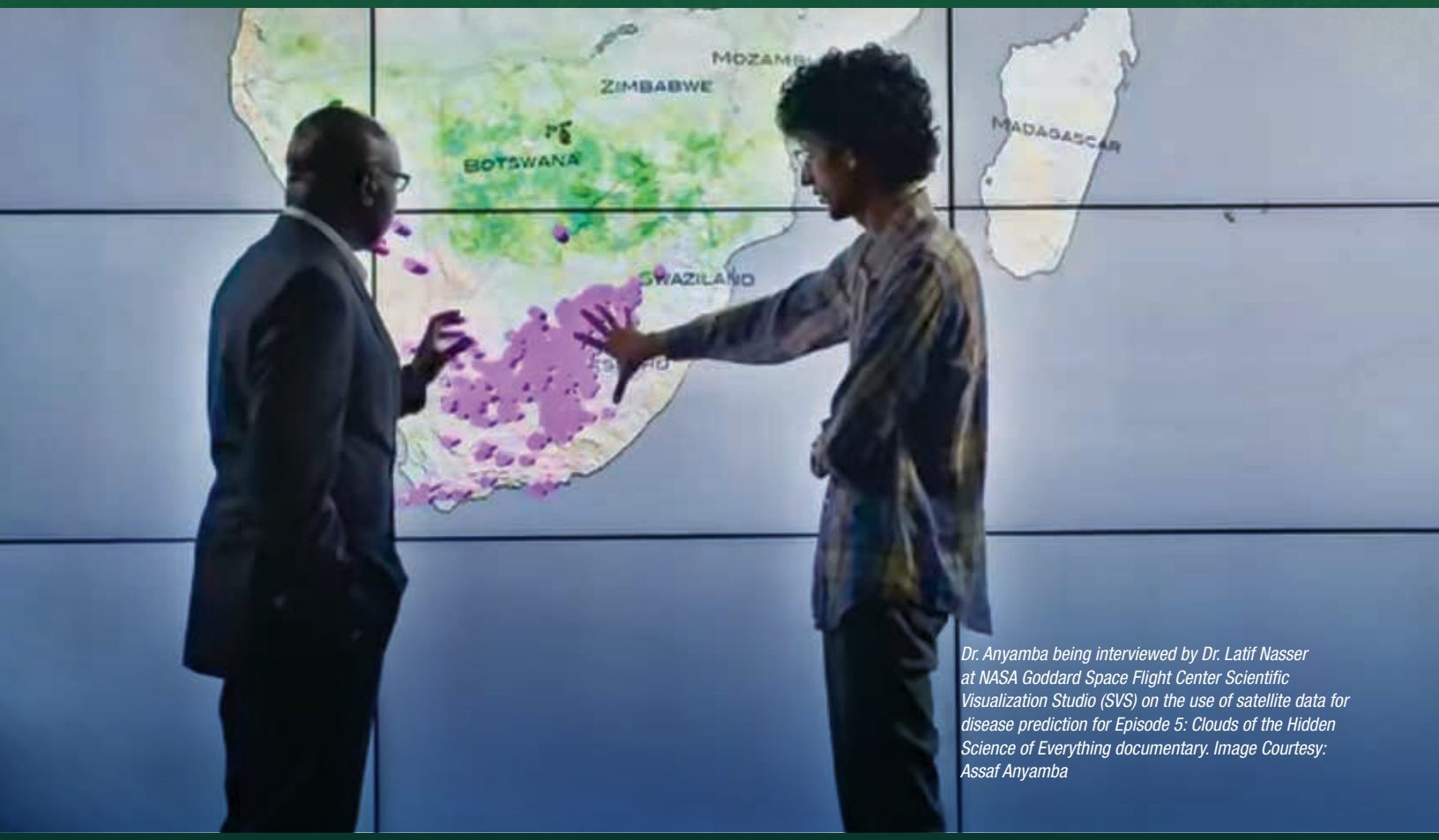
GESTAR scientists working in the NASA Ocean Ecology Laboratory played a pivotal role in two major NASA missions, which focused on studying ocean biogeochemistry and improving the understanding of the oceans' role on climate: the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Mission and the EXport Processes in the Ocean from Remote Sensing (EXPORTS) field campaigns. PACE, currently one of the largest upcoming missions for NASA Goddard, is set to launch in 2023 to monitor the world's ocean's health as well as atmospheric quantities associated with air quality and Earth's climate. The PACE team, inclusive of eight GESTAR scientists (Andrea Andrew, Andy Sayer, Bridget Seegers, Dirk Aurin, Inia Soto Ramos, Ivona Cetinic, Susanne Craig, and Violeta Sanjuan Calzado,) whose leadership role in algorithm and data processing development was recognized, was selected for the prestigious NASA Robert H. Goddard Honor Award. In addition, GESTAR Scientist Ivona Cetinic was assigned the role of Project Scientist for the EXPORTS field campaigns, which aims to develop a predictive understanding of the future of global ocean primary production and its implications for the Earth's carbon cycle. Dr. Cetinic has led the project office that supports a team of ~180 NASA- and NSF-funded scientists, and has promoted the science of EXPORTS in the media. The first field campaign was successfully completed in 2018 in the North Pacific, and the EXPORTS Team is now preparing for a second field campaign in 2021 in the North Atlantic.

Earth Science continued

Mosquito Vector Data and Cloud Computing Technology Forecasts Areas of Risk for Disease Outbreak

Research and applications led by Dr. Assaf Anyamba on monitoring, mapping and forecasting vector-borne disease were broadcasted in Episode 5 of the recently released Netflix documentary series "Connected - The Hidden Science of Everything." The segment illustrates how NASA and NOAA satellite-derived climate data, disease data from a variety of sources, and in situ mosquito vector data are combined using cloud computing technology and machine learning methods to map and forecast areas at potential risk for disease outbreaks. This work is also featured in an Earth Observatory story to showcase the application of NASA Earth Science Data and Models: *Of Mosquitoes and Models: Tracking Disease by Satellite* https://earthobservatory.nasa.gov/features/disease-vector. In addition, Dr. Anyamba was invited to be of part of The Brookings Institution and The Rockefeller Foundation 17 Rooms initiative. He contributes to the Room 3 Initiative on Transforming National and Global Epidemic Intelligence Systems aimed at determining systems, methodologies and infrastructures that will better prepare us for future outbreaks and pandemics.

NASA Earth Science Data and Models: "Of Mosquitoes and Models: Tracking Disease by Satellite". https://earthobservatory.nasa.gov/features/disease-vector. Image Courtesy: Assaf Anyamba



Dr. Anyamba being interviewed by Dr. Latif Nasser at NASA Goddard Space Flight Center Scientific Visualization Studio (SVS) on the use of satellite data for disease prediction for Episode 5: Clouds of the Hidden Science of Everything documentary. Image Courtesy: Assaf Anyamba

Ob river (summer) from Landsat satellite. Image Courtesy: NASA.

Applied Earth Sciences

Airborne Sciences

USRA's NASA Academic Mission Services program operates the Airborne Sensor Facility (ASF) at NASA's Ames Research Center. Data acquired by the ASF are used by a variety of scientific programs to study ecosystem processes, assess global environmental change, and respond to natural disasters.

This year, the ASF supported a dozen flights for field experiments and engineering test flights for the newest facility instrument – the Push-broom Imager for Cloud and Aerosol R&D (PICARD) imaging spectrometer. PICARD is expected to become a heavily used facility instrument for cloud and aerosol R&D. It combines advanced radar, lidar, and microwave radiometer remote sensing instruments.

AFS was also involved in the FIREX-AQ experiment with a joint NASA/NOAA effort involving collaboration with several universities and other organizations. The key goal of this experiment was to conduct large-scale assessments of air-quality impact and the efficacy of satellite detections for estimating fire emissions. The role of the USRA/NAMS team was to operate two infrared imaging devices to pin-point the sources of smoke emissions, and to estimate the radiative power of the fires.

Environmental Analytics

USRA/NAMs Environmental Analytics led by Dr. Sorek-Hamer conducted research on air quality and health impact models, atmospheric sciences and aerosol sciences in Earth and Space environments. The group also developed new approaches for studying various hazards and natural disasters (e.g., flood modeling). A novel aspect of the group's research is to explore hybrid machine learning and physics-based approaches for deriving useful science products from fusing commercial and NASA satellite images and other environmental data.

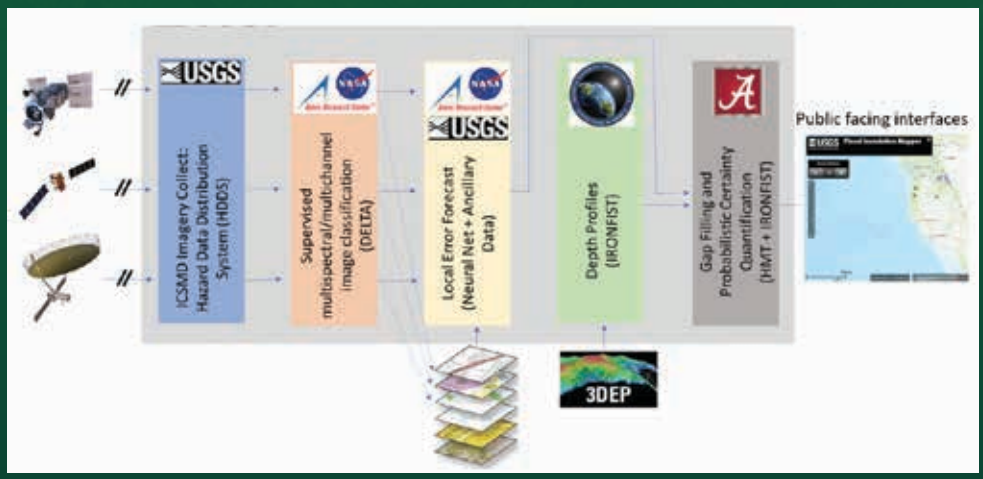
USGS Project

USRA's cooperative research agreement with the U.S. Geological Survey (USGS) is a vehicle to provide support for collaborative research, development, and education to advance science and technology in areas of common interest. USRA works across multiple technical areas and collaborates with Geology Minerals, Energy and Geophysics Science Center (GMEGSC), the USGS National Innovation Center (NIC), USGS Programs, or other USGS sources as needed

This year, USRA scientists conducted research with USGS scientists on floods. This hazard is one of the most devastating natural calamities, affecting millions of people and causing damage all around the globe. In this project, machine learning algorithms were leveraged to automate flood mapping algorithms so that information from large streams of data could be extracted in near-real time. Near-real time flood mapping from such an algorithm can be extremely important and useful for disaster response.

Also, USRA scientists worked on a collaborative project, Deep Earth Learning, Tools, and Analysis (DELTA), which is an automated machine learning algorithm designed for Earth Science application. DELTA was developed by the Intelligent Robotics Group at NASA Ames Research Center, in collaboration with the USGS, National Geospatial Intelligence Agency, National Center for Supercomputing Applications and the University of Alabama. DELTA is used for mapping flood extents using multiple sources of satellite imagery, including World View, Sentinnel-1 and Landstat.

The Flood Inundation Surface Topology (FIST) model being developed will use USGS's 3D Elevation Program DEM to predict flood water depths in flooded regions. A Hidden Markov Tree (HMT) model will be used as a probabilistic predictor of surface water extent based on inundation and elevation status of nearby pixels. The final IRONFIST flood prediction map will be produced by using these three algorithms: DELTA, FIST and HMT.



USRA scientists worked on a collaborative project DELTA – a machine learning tool designed for Earth Science applications. This image illustrates the DELTA-IRONFIST workflow showing various components. Image Courtesy: Liz Carter

As members of the NASA/Glenn Research Center low gravity 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.

Low Gravity Sciences

Saffire Continues the Flame of Discovery in Space

Front views of polymethyl methacrylate (PMMA) burn during the Saffire IV experiment (sample width 40 cm). The burn was ignited in a Cygnus Cargo vehicle after it had completed its primary International Space Station Supply mission, departed the station, and before its planned destructive reentry to Earth. Image Courtesy: NASA, GRC

Several USRA scientists along with their NASA collaborators contributed to the success of the Spacecraft Fire Safety (Saffire) IV experiments in May 2020 that continued to investigate how fires grow and spread in space. Just as in Saffires I, II and III, the Saffire-IV experiments were ignited in a Cygnus cargo vehicle after it had completed its primary ISS supply mission, departed the station, and before its planned destructive reentry to Earth. The success of the program is largely due to the efforts of USRA's Jay Owens, Paul Ferkul, Rosa Padilla, Dan Gotti, Gordon Berger and Claire Fortenberry along with John Easton from Case Western Reserve University. Support included mission operations including pre-operations planning and training, experiment run phase, daily data download and processing and subsequent data dissemination to the Science Team.

Understanding how fire behaves in microgravity, and how different materials propagate flames in space is immensely important for the development of future crew spacecraft. It also helps inform operational protocols for dealing with fire emergencies, particularly when astronauts do not have the ability to exit a spacecraft or quickly return to Earth. One of the unique features of Saffire-IV, is that after two material burns, a carbon dioxide scrubber and smoke eater were used to remove particulate and carbon monoxide. The instrument to monitor combustion gases and the smoke-eater filter are prototypes of what will be used on the Orion spacecraft. Two additional Saffire experiments are scheduled for October 2020 and March of 2021, as NASA continues to develop safer ways to operate future crewed exploration missions.

StarLab Free Flyer Design Concept for Commercial Destination Development in LEO

USRA supported Nanoracks in a virtual briefing to Congressional Staffers and other NASA senior officials entitled Skylab to StarLab: A New Era of Low-Earth Orbit Commercialization. In partnership with USRA, Lockheed Martin Space, Ohio State University, and University of Arizona, Nanoracks submitted an unsolicited proposal to study development of StarLab Outposts in a unique and vibrant public-private partnership (PPP) with NASA and the United States Government as a whole, in cooperation with the private sector. The StarLab Outposts will be a constellation of orbiting autonomous laboratories that will push the frontier of the human-robot interface (HRI), buttressed by the commercial marketplace of customers: government, private sector and non-US. Three StarLabs are envisioned by 2030, located in different low-earth orbiting (LEO) locations and with differing commercial, civil and strategic objectives. The initial proposed platform StarLab One will be co-located in the vicinity of the International Space Station. The station will be fully autonomous but will permit short-term visits by astronauts and researchers relying on the visiting vehicle's life-support systems.

Based on USRA's expertise in both microgravity science and science-facility management and operations, USRA was invited to serve on the team as the Star Lab Free Flyer Science Facilitator for LEO research and development. Representing USRA, Dr. William Meyer participated in the briefing and described why such a free flyer is complementary to the International Space Station and the potential science missions enabled by it.

Potential science missions enabled by a StarLab Free Flyer presented by Dr. William Meyer (USRA) in the August 2020 briefing to congressional staffers and NASA senior officials. Image Courtesy: USRA

Fabrication of 1 meter long full-scale bus bar prototype employing the newly invented MMEI system targeting 10-20 MW at 20-40 kV, 400 – 4000 Hz, and rated to 260 °C via vacuum-bagging and autoclave heat fuse-bonding process. Image Courtesy: USRA

Adding Materials Expertise to USRA's Portfolio

In addition to microgravity sciences, Glenn Engineering and Research Support Services now supports the Material and Structure Division at NASA Glenn. Six materials researchers joined USRA in 2020.

USRA's materials' expertise spans a broad spectrum of activities –from aerogels, to support of Radioisotope Power Systems to advanced multifunctional materials for Electric Aircraft Propulsion and Advanced Air Transport Technologies.

Over the past year, extensive efforts were made to improve/optimize, scale up and commercialize the newly invented high voltage, lightweight micro-multilayer multifunctional electrical insulation (MMEI) system that can be a disruptive technology for future large passenger electrified aircraft development. In-service performance characterizations of MMEI were conducted in collaboration with the Ohio State University and University of Arizona.

Other areas of expertise are development of novel polymer electrolytes and cathodes for batteries for Urban Air Mobility (UAM) and all electric aero-vehicles; Advanced Air Transport Technology (AATT) involving an extrusion of different flexible polymer composites to study their properties applicable for wire coating, slot liners and high voltage separators; and the development and modification of new and current materials for power cable improvements for the Transformational Tool and Technologies (TTT) project.

USRA's Dr. Baochau Nguyen (middle), extruding polyphenylsulfone-hBN composite films with Dr. Tiffany Williams (NASA, front) and Dr. Marisabel Kelly (NASA, back). Image Courtesy: USRA

Tiny Colloid Particles Yield Big Results

Thanks to years of colloids research aboard the ISS, we have enjoyed the benefits of improvements to things like toothpaste, 3D printing, and pharmaceuticals. Colloids are mixtures of tiny particles suspended in a liquid that include natural mixtures such as milk and muddy water as well as a range of manufactured products from shampoo to medicine to salad dressing. Some colloids contain unique particles that form crystals that assemble into new materials.

The ACE-T9 Mission Simulation Test (MST) with Dr. Ramona Mhanna (right) of the Colorado School of Mines preparing for a future ISS flight opportunity. Dr. William Meyer (left), USRA NASA Project Scientist for the ACE experiments, and Louis Chestney (middle), ZIN Technologies Light Microscopy Module operator and senior programmer for the Light Microscopy Module Image, are also supporting the Mission Simulation test. Image Courtesy: USRA

Space study of colloids is important because microgravity takes away the complication of the Earth's gravity, which masks colloid behavior with the effects of sedimentation and gravitational jamming. The list of colloid experiments on the space station is long and includes the ongoing Advanced Colloid Experiments (ACE), with more than a dozen investigations to date.

USRA's Dr. William Meyer serves as Project Scientist for the ACE family of investigations. In that role, he has contributed to a deeper understanding of colloidal behaviors. This work could lead to the development of a wide range of new and improved materials and technologies in the areas of stabilizers for consumer products, large area electrodes for energy storage, micro-machines, photonic materials to control and manipulate light, and tougher inks for 3D printers. In FY 2020, three unique ACE investigations were completed using the Light Microscopy Module (LMM) housed in the Fluids and Combustion Facility (FCF) onboard the ISS. In parallel, future ACE experiments were undergoing Mission Simulation Tests on Earth to optimize their science return and to enhance the scripts that control the LMM that is run from the Telescience Support Center (TSC) at NASA Glenn Research Center.

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.

Space Biosciences

GeneLab: Providing Spaceflight Datasets for Scientific Collaboration

USRA supports the GeneLab project at NASA's Ames Research Center, which provides spaceflight relevant omics datasets and tools for science collaboration. In 2020, USRA was involved in the design and development of an advanced data submission portal for GeneLab that leverages sophisticated knowledge resources known as ontologies. Ontologies define a consensus for how scientific entities relate to one another. Through these resources, scientists will be able to discover and compare GeneLab and other data more accurately, leading to new scientific knowledge about the basic mechanisms by which biological organisms adapt to the spaceflight environment.

In 2020, syntheses of data from the GeneLab database have been used to generate at least 6 scientific publications. The work from Genelab in the past year has been published in leading journals and conferences, such as the International Journal of Molecular Sciences, and Proceedings of the 12th International Conference on Bioinformatics and Computational Biology.

SPACE RADIATION

Photo of the Advanced Neutron Spectrometer on the International Space Station. Image Courtesy: M. Sabra /USRA/STI/NASA MSFC

In 2020, several activities in space radiation were supported by USRA. This included Space Radiation analysis by Dr. Linda Parker for the Chandra when needed. She also conducted a study that can effectively reduce space radiation risks for crewed and robotic operations in the inner heliosphere in orbits about Earth, cislunar space and Mars.

Dr. Mohammad Sabra, from USRA's Science and Technology Institute also performed calculations of integral flux and ambient dose equivalent using the Fast Neutron Spectrometer (FNS) detector on the International Space Station for the year 2019-2020. He also conducted a comparison of ambient dose equivalent calculations between FNS and the Radiation Assessment Detector (JSC team) for the period September 2019 – January 2020. In the Lunar Radiation area, Geant4 simulations of Advanced Neutron Spectrometer Lunar detector were conducted to study detector response and neutron-energy spectra.

Mitigating Effects of Long-Term Space Exposure on Humans

As NASA plans long-duration missions to the Moon and Mars, understanding the impacts of space exposure on humans and how to mitigate them become increasingly more important. USRA's Dr. Raj Prabhu serves as the Deputy Project Scientist of the Human Research programs Cross-Cutting Computational Modeling Project (CCMP). CCMP focuses on using various computational modeling and simulation techniques to provide NASA researchers with the means to understand integrative effects of space missions on human physiology. Additionally, studies include characterization of mission health and performance risk as a means of establishing effective countermeasure methods.

Screening for COVID-19 by Electronic-Nose Technology

The COVID-10 Pandemic has caused millions of cases globally, resulting in millions of deaths worldwide. In the US alone to date over 300,000 plus deaths have been recorded with numbers projected to grow by the time the epidemic ceases. Rapid and effective testing for COVID-19 is a critical need to help the world recover.

USRA scientists working with the Center for Nanotechnology at the NASA Ames Research Center are developing novel biosensors that use artificial intelligence and nanotechnology to measure volatile organic compounds (i.e., scents or odors) in people's breath, and correlate the relative compound concentrations with those associated with Sars-Cov-2 infection. These novel biosensors have the potential to serve as "breathalizers" that provide a portable approach for community monitoring of COVID-19. The electrochemical sensors being developed will be validated with human clinical studies at Stanford University. These novel sensors build upon nearly twenty years of research on nanosensor technology at the NASA Ames Research Center and nearly ten years of research on nanosensor technology at USRA's Research Institute for Advanced Computer Science (RIACS).

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.

Advanced Technologies for Space Exploration

Nuclear Thermal Propulsion for Travel to Mars and Beyond

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 protons (i.e., galactic and solar cosmic rays) in space. 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.

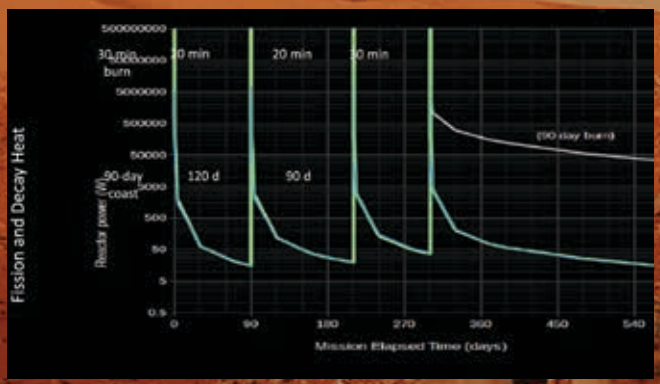
The most developed propulsion concept is nuclear thermal propulsion (NTP), that uses a very high temperature reactor in which hydrogen is heated from 20 K to about 2500 K before exiting through a nozzle at about 10 km/s, producing a specific impulse of approximately 900 s, nearly double that of conventional rockets.

Because NTP provides twice the specific impulse of chemical rockets, it enables faster trips and more payload in missions to Mars and beyond. Rapid startup and shutdown thermal transients are required for an NTP rocket to use the hydrogen propellant most efficiently.

During the summer of 2020 Summer Fellows at the Center for Space Nuclear Research focused on the phenomena of rapid shutdown. During operation, the hydrogen propellant/coolant diffused into the tungsten-rhenium tubes. When the reactor was shut down at the end of its required burn, the fuel cooled rapidly. Experiments on nuclear fuels have shown that overly-rapid cooling causes hydrogen to collect along the grain boundaries, resulting in decohesion failure. The goal will be to determine the maximum cooling rate and to balance the heat losses by convection and radiation with the decay heat of the fission products to prevent fuel failure.

Three of the CSNR Summer Fellows modeled the performance of a nuclear thermal rocket, using 20 percent enriched uranium, during a Martian mission. The fission and decay heat of the reactor for the four burns and three coasting periods shown below in the figure on the right. These complex calculations determined the heat given off by the reactor after the burns and cooling profiles of the tungsten-rhenium tubes.

Nuclear Thermal Rockets (NTRs) for Propulsion to Mars. Image Courtesy: NASA



Fission and Decay Power during a Martian Mission. Image Courtesy: Zane Emery, Cornell University, Teyen Widdicombe, University of Idaho and Avery Grieve, University of Michigan

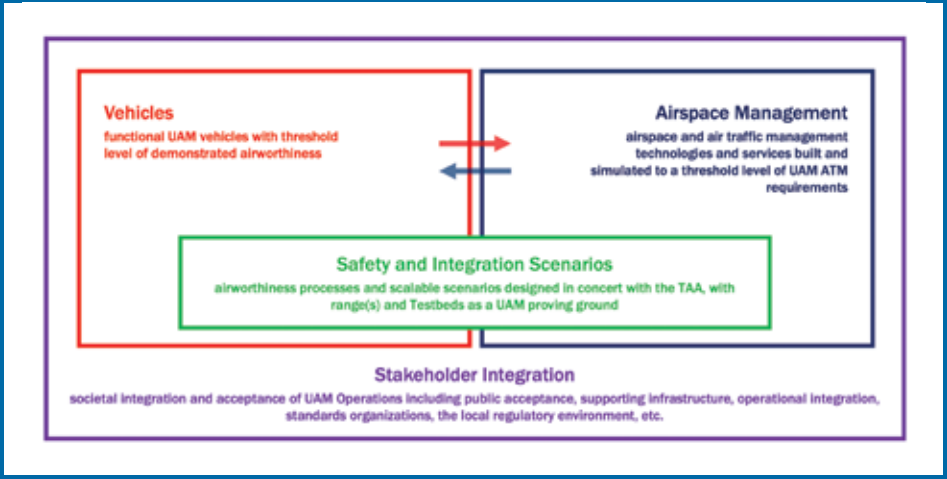
USRA's Air Traffic Management technologies continue to evolve to improve safety, reliability and efficiency for the benefit of passengers and airline operators and prepare for the coming of autonomous vehicle operation in the National Airspace System (NAS). USRA's NASA Academic Mission Services (NAMS)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

Aeronautics Research and Development

Aeronautics Research

USRA teams are working in close cooperation with NASA aviation, aeronautics and aeromechanics experts to help forge future generations of manned and unmanned air transportation systems. USRA's scientists, investigators, students, faculty and subject matter experts are researching and developing mission-critical systems with their NASA colleagues, supported by best-practice program governance and leadership. USRA's (NAMS) team remains at the center of advances in autonomous electric and hybrid aircraft systems through collaboration with the NASA Aviation Systems Division, the NASA Aeronautics Research Institute (NARI), the Federal Aviation Administration (FAA) and the broader aviation industry, A significant example of this aeronautics research teamwork is the Regional Modelling and Simulation (RMS) project, a vertical airport (vertiport) location-planning application that enables urban architects to visualize cityscapes and identify accurate building locations as they design the airports of the future.

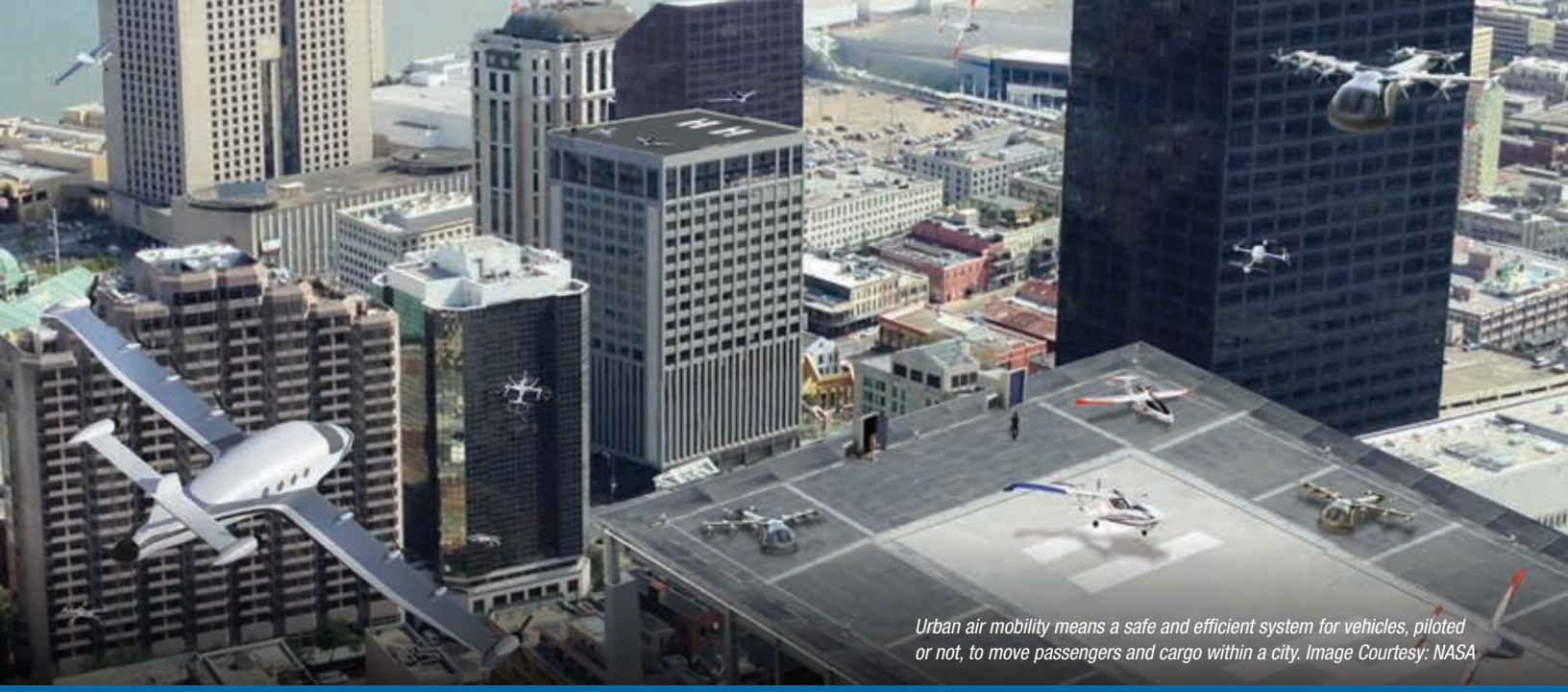
Advanced Aerial Mobility (AAM)



USRA focuses on three elements of research –Vehicles, Airspace Management and Safety, and Integration Scenarios to enable a safe an effective future for Advanced Aerial Mobility. Image Courtesy: David Bell/Peter Kim, USRA

USRA is collaborating with NASA's Ames Research Center, academia and industry to pioneer new technologies that will enable a safe and effective future for advanced aerial mobility. This will allow autonomously operation electric aircraft to operate in urban, suburban and rural environments to support a variety of uses including package delivery and autonomous air taxis. In addition, the USRA-managed NASA Academic Mission Services Program is concentrating its efforts on enabling rapid development and scenario-based flight testing of Advanced Aerial Mobility (AAM) vehicles, starting with operations that have strong societal benefits such as emergency medical services, search and rescue, and disaster relief.

Through the USRA managed NASA Academic Mission Services (NAMS) program, USRA is focused on three main elements of research, development and education as highlighted in the figure above: 1) Vehicles – with focus on AI-Enabled Autonomy Software and the AAM Supply Chain, 2) Airspace Management – with focus on autonomous air traffic management, and 3) Safety and Integration Scenarios – with focus on virtual and physical testbeds for AAM. Following the 2020 AAM Consensus Study of the National Academies, the NAMS team is focusing on enabling rapid development and scenario-based flight testing of AAM vehicles.



Urban air mobility means a safe and efficient system for vehicles, piloted or not, to move passengers and cargo within a city. Image Courtesy: NASA

Unmanned Aircraft Systems

USRA recently supported development and testing of a novel approach for Unmanned Aircraft Systems Traffic Management (UTM), developing international standards for "detect and avoid" procedures, modeling and simulating various UTM concepts, and conducting UTM flight tests. This work has involved 35 partner organizations and was awarded the 2019 NASA Software of the Year Award. The UTM approach is now being extended to support urban air mobility in the national airspace, in collaboration with Uber Air and other partners. USRA is also conducting research on the AAM Supply Chain, to mitigate AAM cybersecurity risks throughout the supply chain.

Some of the UTM team members, including USRA and Crown staff, in the UTM Flight Test Command Center located at NASA Ames Research Center who were awarded the Software Award of the Year. Image Courtesy: NASA

Urban Air Mobility (UAM)

The UAM project is developing concepts for integrating Urban Air Taxis into the National Airspace System — the next revolution in air traffic management. The UAM team developed increasingly autonomous airspace services such as airspace constraint identification (noise, weather), route planning, resource scheduling and trajectory management. The software capabilities supported NASA with running Human-in-the-Loop (HITL) simulations. The HITLs initially simulated the concepts for the management of highly autonomous small Vertical Takeoff and Landing (VTOL) aircraft using helicopters in urban environments.

This portfolio of advanced aerial mobility research projects is of national importance. These projects are helping enable a transformation of air transportation with new entrants in the United States such as Uber Air, Amazon Air, and Wing Aviation. They are also enabling evolution of U.S. industry focused on Unmanned Aircraft Systems (UAS) for civil applications, with dual support to enable domestic production capability for small UAS in the U.S. This has been deemed essential to national defense.

The Urban Air Mobility project built upon the success of UTM, and successfully completed many milestones this past year, building towards the goals of the NASA Advanced Aerial Mobility (AAM) National Campaign series.

Aeronautics for National Security - US Army R&D

In addition to supporting NASA's aeronautics research missions at Ames Research Center, USRA also provides software development and research support in the areas of aircraft flight control and human-systems interface for the U.S. Army Technology Development Directorate at Ames, which is part of the overall U.S. Army Combat Capabilities Development Command Aviation and Missile Center. The team works closely with the Army researchers to develop advanced flight control methodologies and associated software tools, as well as supporting the research and development in the area of human/machine interface and human/autonomy interaction for helicopter aviators and unmanned aerial systems ground-control station operators.

During FY 2020, the USRA team has continued to make exceptional contributions in supporting the Army 's research and development activities in the flight control and human-systems Interface technical areas.

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 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.

Quantum Information Sciences

Aviation Data Sciences

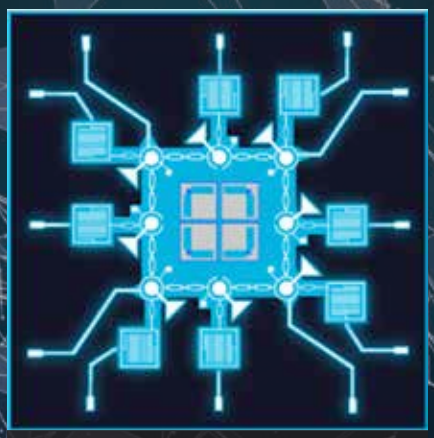
In Spring 2020, USRA staff participated in an ad hoc FAA-NASA led focus group on Aviation Data Analytics. These groups applied data sciences to different analysis tasks including traffic-based flow management, and worked with open datasets and open algorithms. USRA scientists conducted research for a portfolio of related projects.

Environmental Data Sciences

USRA/NAMs conducted research on air quality and health impact models, atmospheric sciences and aerosol sciences in Earth and Space environments, and developed new approaches for studying various hazards and natural disasters (e.g., flood modeling).

DOE/National Quantum Institute

NASA's QuAIL team of researchers, including several from USRA, are part of the new Superconducting Quantum Materials and Systems Center (SQMS), led by Femilab's Dr. Anna Grassellino. Dr. Eleanor Rieffel, NASA's QuAIL team lead, is the Chief Scientist for the national center. Fermilab hosts the SQMS, and, in addition to NASA Ames, core partners include the Rigetti Computing company, Northwestern University and the Ames Laboratory of the U.S. Department of Energy. Other university contributors are the University of Colorado Boulder, Stanford University, the Colorado School of Mines, the Johns Hopkins University, Temple University, the University of Arizona, the Illinois Institute of Technology, the University of Padua and the University of Illinois Urbana-Champaign. SQMS researchers are developing long-coherence-time quantum bits, or qubits, based on Rigetti Computing's state of the art quantum processors. At the heart of SQMS research, the interdisciplinary team will be solving one of the most pressing problems in quantum information science - the length of time that a qubit, the basic element of a quantum computer, can maintain information - also called quantum coherence. Understanding and mitigating sources of decoherence that limit performance of quantum devices is critical to engineering the next generation of quantum computers and sensors.



Rigetti Processor qubit. Image Courtesy: Rigetti

NASA Quantum AI Laboratory

USRA supports NASA's Quantum Artificial Intelligence Laboratory (QuAIL) with staff scientists and management of a D-Wave 2000Q Quantum Computing System hosted at the NASA Ames research center. The team supports a wide range of activities within Quantum Theory, Compilation and Optimization, and Benchmarking and Analysis, with over a dozen research papers published in peer-reviewed journals and international conferences this past year. The QuAIL group continues to be funded by external sources such as the Army Research Office and DARPA, as well as two of five recently announced DOE National Quantum Initiative centers.

DARPA, AFRL and NSF Programs

In addition to NASA QuAIL programs, the USRA quantum team has awards from several other U.S. government agencies including DARPA, NSF and AFRL. USRA is the prime contractor in the DARPA Optimization with Noisy-Intermediate-Scale-Quantum devices (ONISQ) program and has been awarded two NSF programs: Expeditions in Computing program and Spectrum Efficiency, Energy Efficiency, and Security on wireless networks. USRA also has been working on an AFRL workforce development program in the quantum information sciences, involving over 30 hours of training and lectures, a six-week course in quantum optimization and a monthly applied Noisy Intermediate Scale Quantum computing (NISQ) newsletter with over 600 subscribers.

Feynman Academy: Academic Engagement

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 (NISQ) within the areas of theory, optimization, machine learning and benchmarking. The students receive hands-on training and undertake individualized research projects in advanced computing including:

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

Since launching in 2016 the Feynman Quantum Academy has hosted 28 students from top international universities. Students have performed research across a wide array of quantum architectures. The program operates within the Quantum Artificial Intelligence Laboratory (QuAIL) and the NAMS R&D Student Program at NASA Ames, with several students being co-sponsored between NASA, DLR, NSF, AFRL and DARPA. Students work collaboratively with staff, with projects often resulting in opportunities for publication or conference presentations.

Private Sector Engagement

USRA partnered with Standard Chartered Bank (SCB), an international banking group, to advance quantum annealing research. SCB funded hosting and utilization of the D-Wave machine at NASA Ames until the end of 2020 and helped launch a competition open to U.S. universities, providing free access to the quantum computer.

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

SCIENCE & FACILITY MANAGEMENT

Stratospheric Observatory for Infrared Astronomy (SOFIA)

SOFIA is a significantly modified Boeing 747 jetliner that carries a 110-inch (2.5 meter telescope to altitudes up to 45,000 feet above more than 99 percent of Earth's atmospheric water vapor. This gives astronomers the ability to study celestial objects at infrared wavelengths that cannot be seen from ground-based observatories.

USRA manages the SOFIA Science Mission Operations for NASA's Ames Research Center. It is also involved in the development and operation of the instruments for SOFIA and deploys the instruments on board based on the requirements of the observing cycle.

For example, the SOFIA instrument called the High Resolution Airborne Wideband Camera Plus (HAWC+), reveals the magnetic field structure in star-forming molecular clouds and on a wide-scale in nearby galaxies. It forces astronomers to take into account this important physics of the interstellar medium.

SOFIA's Instrument, the High Resolution Airborne Wideband Camera Plus (HAWC +). Image Courtesy: NASA

QuAIL

USRA operates the Quantum Artificial intelligence Laboratory (QuAIL) in collaboration with Google and NASA's Ames Research Center. It is staffed by 10 scientists (including subject matter expert consultants as appropriate) on three technical actions detailed in the Task plan: Theory, Compilation and Optimization, and Benchmarking and Analysis. Our workforce represents the majority of the full-time personnel in the group.

USRA allocates time to the international scientific community on a competitive merit-based proposal process at no cost to the users. The QuAIL group continues to be funded also by external sources such as the Army Research Office and DARPA, and USRA contributes to the writing of the competitive proposals and reports that sustain the groups funding.

Airborne Science Facility

USRA's NASA Academic Mission Services (NAMS) program operates the Airborne Sensor Facility (ASF) at NASA's Ames Research Center. The ASF maintains and operates a suite of remote sensing systems used on many of the NASA Airborne Science Program field campaigns. Data acquired by the ASF are used by a variety of scientific programs to study ecosystem processes, assess global environmental change, and respond to natural disasters. The ASF has laboratories for sensor engineering and development at both the Ames and Armstrong research centers and sensor calibration and data processing facilities at Ames.

The ASF is staffed by USRA and includes capabilities for sensor engineering, optical and infrared sensor calibration and data processing.

Facility Sensor Systems

Facility Sensor Systems includes the development and operation of remote sensing systems for satellite calibration/validation, algorithm development and basic Earth Science research.

Airborne Sensor Network Development

Airborne Sensor Network Development includes the design, fabrication and operation of real-time payload communication and control systems, to increase the productivity of the core NASA science aircraft.

Payload Integration Engineering

Payload Integration Engineering includes cross-center airborne instrument integration support with mechanical, electrical and software engineering services. This group also provides services in flight planning, mission coordination, Investigator Liaison, post-flight data evaluation and data process.

Optical and Infrared Calibration Laboratory

The Optical and Infrared Calibration Laboratory provides NIST-traceable characterizations of airborne imaging devices (supervised by the EOS Calibration Scientist).

GeneLab Data Platform

GeneLab is an interactive, open-access resource where scientists can upload, download, store, search, share, transfer and analyze omics data from spaceflight and corresponding analogue experiments.

GeneLab is funded by NASA's Division of Biological and Physical Sciences (BPS) in the Science Mission Directotate. The BPS focuses on using the spaceflight environment to enable space exploration and benefit life on Earth.

USRA operates some of the data systems and partially staffs GeneLab (4-5 FTE). The consumers of GeneLab data and systems are the space biology science community, both within NASA and at large.

GeneLab promises to facilitate and improve information sharing, foster innovation and increase the pace of scientific discovery from extremely rare and valuable space biology experiments. Discoveries made using GeneLab have begun and will continue to deepen our

understanding of biology, advance the field of genomics and help to discover cures for diseases, create better diagnostic tools and ultimately allow astronauts to better withstand the rigors of long-duration spaceflight.

GeneLab helps scientists understand how the fundamental building blocks of life itself – DNA, RNA, proteins and metabolites – change from exposure to microgravity, radiation and other aspects of the space environment. By carefully curating and implementing best practices for data standards, users can combine individual GeneLab datasets to gain new, comprehensive insights about the effects of spaceflight on biology. In this way, GeneLab extends the scientific knowledge gained from each biological experiment conducted in space, allowing scientists from around the world to make novel discoveries and develop new hypotheses from these priceless data.

Keck Remote Observation Center

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

The Planetary Radar Investigation, Demonstration, and Exploration (PRIDE) Laboratory at the LPI

Ground- and space-based radar measurements have provided significant insight into the composition of planetary surfaces, including the location of hidden water ice in support of in-situ resource utilization and invaluable characterization of the diversity of small Solar System bodies in support of planetary defense. The LPI's in-development PRIDE Lab is aimed at enhancing the scientific return of both ground- and space-based radar assets. PRIDE Lab experiments will investigate how radar interacts with planetary analog materials, such as meteorite samples and regolith simulants, in a controlled setting, demonstrate the efficacy of radar modeling and analytical techniques and further explore scattering phenomena encountered in radar observations of Solar System bodies. The PRIDE Lab is supported by USRA strategic investment funds and by a grant from NASA through the Early Career Award program awarded to LPI scientist Edgard G. Rivera-Valentín.

NASA-USRA Science and Technology Innovation Laboratories

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

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

Nanoelectronics and Nanodevices for Space Exploration

Advances in nanotechnology continue to push the boundaries of devices and electronics into more compact footprints that operate at faster speeds with low-power consumption. In addition, nanotechnology lends itself to new, low-cost fabrication techniques. USRA scientists work with NASA on this endeavor to develop nanodevices that provide astronaut protection from the deleterious space environment. One application was the development of ultraviolet (UV) photodetectors that have applications in medical and healthcare, space, military and scientific instruments. Commercially available photodetetors are fabricated on semiconductor wafers using conventional microfabrication methods. USRA researchers have developed an inexpensive alternative by printing the layers of the photodetector, including the substrate using zinc oxide (ZnO) as the active sensing layer. The bandgap of ZnO matches well with UV wavelength, and, thus, they have been able to obtain performance comparable to commercial UV sensors. The team has been working on developing printable sensors and detectors for various space radiations including gamma-rays. This work was published in the journal *ACS Sensors*. Other publications that applied this printing process of nanodevices included demonstrations of thermotherapy pad and supercapacitor.

Top image shows the device under bending status. Image in inset (top) shows a view of the fabricated electrode. The bottom left image is the photodetector concept with photo response to UV on/off (bottom right). Image Courtesy: J.W. Han et al, USRA

Stock photo Image Courtesy: Forge Branding

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

STEM Workforce Development

USRA's STEMaction Center: Fulfilling the National Need to Strengthen the High-Tech Workforce Pipeline

USRA's STEMaction Center presents a unique opportunity to provide immersive and innovative learning opportunities for K-12 students. Throughout FY 2020, USRA supported an array of robotics programming through a partnership with a nonprofit organization *For Inspiration and Recognition of Science and Technology* (FIRST), intended to heighten interest among students in pursuing STEM degrees, and careers within the high-tech workforce of the future. FIRST robotics not only reinforces fundamental and advanced STEM concepts, but emphasizes the importance of experiential learning.

Weekly, more than one thousand students leveraged resources available through the STEMaction Center to build robotic prototypes in collaboration with their teammates, with the guidance and encouragement from a seasoned mentor. Following the development and vetting of robotic prototypes, students competed in 12 qualifying events at numerous regional venues. USRA strategically coordinated all logistics for these large-scale events to ensure a successful execution. Subsequent to a competitive down-select, FIRST Tech Challenge (FTC) Teams advanced to the culminating championship event, held this year at the Carroll County Agricultural Center in Westminster, MD. An estimated two thousand FTC participants, parents, mentors, supporters and sponsors attended this highly visible event, managed entirely by USRA.

In addition, realizing the importance of cultivating young learners, USRA supported FIRST Lego League (FLL) Junior activities during the FY 2020 season. Exactly 221 FLL Teams consisting of approximately one thousand students participated in practices at the STEMaction Center. FLL student participants also engaged in competitions in an effort to stimulate STEM interest, and provide preparation for FTC.

USRA's expansive 18,000 sq. ft. STEMaction Center facility will continue to serve as a critical community resource in future. During FY 2021, the USRA STEMaction Center will harness the knowledge acquired through the partnership established with FIRST to develop and implement a new portfolio of STEM programming. These programs will be developed in alignment with NASA's on-going and future missions to attract the next generation of STEM career professionals and reinforce the high-tech workforce pipeline of the future.

FTC Championships. Image Courtesy: USRA

First Tech Challenge Championships. All photos taken March 1, 2020 prior to COVID-19 Lockdown. Image Courtesy: USRA

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.

Internships, Fellowships, Scholarships

NASA Postdoctoral Program

USRA continues to operate the NASA Postdoctoral Program (NPP), providing recruitment of applicants and review of science proposals for over 2,400 potential fellows since it began operations in 2016. It also administers the program on behalf of NASA for an average of about 200 fellows at any time. USRA worked with NASA to implement a paid family and medical leave program for fellows in 2019. It has hosted recruiting, networking and career development events for current and prospective fellows. Additionally it has focused on diversity recruitment of applicants and executes targeting efforts to focus on recruiting from underrepresented groups in multiple STEM areas.

The NASA Post doctoral Program provides early career scientists as well as 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.

Last year, NPP had more than 500 submissions and 100 selections, resulting in 84 fellows receiving an NPP award. Regarding demographics of selected applicants, 36 percent were female which is higher than the 28 percent of total applicants that were female. The selection percentages by ethnicity are consistent with application percentages: seven percent Hispanic selected compared to seven percent Hispanic applications.

NASA Interns Are Virtually Everywhere

The COVID-19 pandemic shifted the landscape of today's workforce, and internships were no exception. Students hoping to contribute to NASA's mission through hands-on experiences were impacted by agency-wide mandatory telework. Propelled by challenge, NASA proposed a structural re-design of the Internship Program that would allow interns to support NASA's mission in virtual environments across the United States.

USRA's highly capable Internship Team quickly assimilated plans, developed digital resources and facilitated enriching "Intern Engagement Events" to support a completely virtual program. Internship Program Coordinators worked diligently with spring 2020 mentors to convert nearly 400 onsite projects to virtual

To maximize the experience and to ensure continued productivity, NASA Interns were consistently supported by the USRA NASA Internship Team. Image Courtesy: USRA

research experiences that made impactful contributions to NASA. Internship Program Coordinators exceeded the expectations of NASA management by selecting and placing 1,179 virtual interns for the summer 2020 session (the initial goal was 500).

Undoubtedly, the success of NASA Internships during FY 2020 is attributable to USRA's team of Internship Program Coordinators. The team's efforts led to the impressive placement of 1,866 interns during FY 2020. Furthermore, the team is on track to place a record-setting cohort of interns for the fall 2020 session. NASA's determination to reach the Moon and Mars is dependent on the Artemis generation. USRA will continue to work in close collaboration with NASA to provide the foundation for this generation to continue contributing to the agency's overarching mission, regardless of the physical location of students.

Internships, Fellowships, Scholarships continued

AFRL scholars: Exemplifying "Excellence In All We Do"

USRA continues to "aim high" in the management of the Air Force Research Laboratory (AFRL) Scholars Program, administering technical internship experiences that meet a critical need in the recruitment of the next-generation scientific workforce. In FY 2020, the AFRL Scholars Program supported more than 360 scholars across seven AFRL technical directorates, also demonstrating notable lateral expansion into additional Air Force directorates. Amidst unprecedented challenges presented by COVID-19, USRA successfully adapted the traditional internship model to deliver a unique cross-site virtual experience for participating interns. From their respective remote locations, interns participated in virtual engagement events (collaboratively hosted by multiple AFRL sites) and accomplished technical research in hypersonics, machine learning and artificial intelligence, spacecraft guidance and navigation, additive manufacturing and other critical technologies. USRA's response to an AFRL funding opportunity announcement in July 2020 proposed expansion of the AFRL Scholars Program, including continuation of virtual internships, hybrid internships with industry partners, research assistantships and anticipated growth in year-round sessions. Also included were two new endeavors: AFRL Scholars Professionals is a gateway program for recent STEM graduates to attain work experience in a range of research focus areas that align with AFRL's objectives to meet current scientific and technical needs, and the University Research and Engagement Program (UREP) is designed to leverage university-based research to meet research focus areas identified by AFRL and to secure long-term, productive partnerships.
In the coming year, USRA will continue to reinforce and strengthen the STEM workforce pipeline at AFRL by executing intensive research-based programs that will further influence the educational and career paths for the next generation of STEM professionals.

AFRL scholar Yao Sedzro poses outside his home during his remote internship, sporting his AFRL gear. Image Courtesy: Y. Sedzro

AFRL Scholar Mark Noftz remotely supporting the Aerospace Systems directorate at Arnold AFB in Tennessee, working near the Purdue Mach 6 Quiet Tunnel with the HIFiRE 6 model, exercising appropriate social distancing and adhering to the mask wearing requirement during the COVID-!9 pandemic. Image Courtesy: M. Noftz

Exploration Science Summer Intern Program

The Center for Lunar Science and Exploration's (CLSE) summer intern program, led by LPI's Dr. David Kring, is designed to host 5 to 10 graduate students who have a keen interest in assisting NASA and its international partners examine options for a new era of robotic and human exploration using the Orion crew vehicle and other assets being developed for missions beyond low-Earth orbit. The Exploration Science Summer Intern program is open to graduate students in geology, planetary science, planetary astronomy and related programs. The intern program has been recently motivated by Space Policy Directive – 1, which directs NASA to deliver humans to the Moon for long-term exploration and resource utilization. In response, NASA has developed the Artemis Program and plans for a human landing in 2024. This year's Exploration Science Summer Intern program was designed to study two potential landing sites identified in NASA's Plan for Sustained Lunar Exploration and Development.

This summer, four students worked virtually with Dr. Kring on detailed descriptions of potential landing sites on the rim of de Gerlache crater near the south pole and an unnamed mountain summit near Shackleton crater at the south pole. The students utilized data produced by the Lunar Reconnaissance Orbiter and integrated that data with geologic products from older missions. The students briefed their results to the LPI and Johnson Space Center communities in early August 2020. Their results were incorporated into a report, delivered to NASA in September, about extravehicular activity (EVA) options available to Artemis III astronauts.

LPI Education and Public Engagement

The LPI's Education and Public Engagement team conducts exciting events to increase scientific literacy and convey the excitement of planetary science. To help address the challenges of engaging public audiences, the team conducts seminars and workshops for planetary scientists, including its "Sharing Planetary Science" seminars on topics such as Using Social Media, Presenting to Culturally Diverse Audiences, and Engaging Audiences Virtually.

The LPI staff hosts public Sky Fest events to engage families, participates in Houston area public and education events, and providing virtual tours of the solar system in its portable planetarium. LPI has begun monthly Virtual Exploration Experiences with Planetary Scientists (VEEPS) for families, and has moved its Cosmic Explorations Speaker Series to entirely online presentations. Altogether, the LPI conducted or participated in 25 public events in FY 2020, reaching approximately 2,500 participants.

The LPI continues to share resources and content from NASA's Science Mission Directorate with formal and informal educators. The LPI's library exhibits, portable StarLab planetarium and ALTA® spectrometer kits were loaned to institutions across the United States.

Children recovering from cancer enjoy a virtual trip through our solar system in the Lunar and Planetary Institute's planetarium. LPI used the planetarium in a variety of public engagement programs up to March 2020, then shifted to virtual public programs. Image Courtesy: Periwinkle Foundation

Lunar and Planetary Institute Summer Intern Program in Planetary Science

Since 1977, the LPI has played a vital role in training and mentoring future planetary scientists through a 10-week summer intern program for undergraduate students. The selected 2020 class included 14 undergraduate students from universities in the United States, Canada, and Europe, who were competitively selected from 79 qualified applicants (i.e., 18 percent selection rate). Two additional students were also planned for the LPI's PRIDE (Planetary Radar Investigation, Demonstration, and Exploration) laboratory and the LPI's Planetary Radar Astronomy group. Each intern would have worked one-on-one with an individual scientific mentor, either at the LPI or at NASA Johnson Space Center in Houston, carrying out a complete, end-to-end research project. Unfortunately, after careful deliberation and in light of the ongoing pandemic, the summer internship program this year was cancelled. In lieu of the internships, students were offered virtual networking opportunities, scientific talks, and professional development seminars. The topical scientific seminars included nine one-hour talks on a variety of planetary science topics, designed to provide an overview of the field. The professional development seminars included interactive workshops on ethics in science, best practices in presenting research, diversity and inclusion and graduate school preparation.

LPI Summer Professional Development Seminar, Topic: Preparing for Graduate School. Top left to right: LPI panel speakers Drs. Edgard G. Rivera-Valentín and Prajkta Mane. Bottom left to right: Drs. Germán Martínez, Justin Filiberto, and Julie D. Stopar. Image Courtesy: LPI

Summer Undergraduate Program for Planetary Research

The Summer Undergraduate Program for Planetary Research (SUPPR) is an eight-week internship program that runs from June to August. SUPPR interns were competitively selected from over 107 qualified college undergraduate applicants. This year's eleven interns were paired up to work virtually one-on-one with NASA-sponsored planetary science investigators from various scientific institutions. In addition to their virtual individual projects, the interns participated in virtual seminars, given by LPI scientists. The virtual 2020 SUPPR program culminated with several interns giving remote presentations about their summer research to a team of science advisors and the LPI Interim Director. In addition, many of the 2020 SUPPR interns have already indicated that they plan to present their SUPPR research at an upcoming national conference.

Virtual presentation given by the 2020 Summer Undergraduate Program for Planetary Research interns. Image Courtesy: LPI

CSNR Fellows

The Center for Space Nuclear Research has hosted more than 200 Summer Fellows for a 10-week summer program in Idaho Falls, Idaho since 2006. Many of the Fellows have gone on to lead innovative applications of nuclear power in space in NASA and the U.S. aerospace industry. The Summer Fellows work on two to four projects each summer, including the optimization of Plutonium-238 production for future missions to the outer solar system, radioisotope powered cubesat power supplies, alternative materials for radioisotope thermoelectric generators and reactors for nuclear thermal propulsion.

The USRA Scholarship program was established in 2000, and since then USRA has awarded scholarships to 70 undergraduate students.

USRA Distinguished Undergraduate Awards

The USRA Distinguished Undergraduate Awards program recognizes undergraduate juniors and seniors who excel in fields of space science and aerospace engineering, and show leadership promise in their careers. 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.

Faculty from USRA Member Universities review the applications for the Award. Through a rigorous process, four review committees—two for science applicants and two for engineering applicants—review the students' dossiers. They evaluate the students based on stated career goals and accomplishments, leadership qualities, outreach to their communities, and strengths such as initiative, creativity and perseverance. Recommendation letters from their professors and intern advisors play an important role in the review. In 2020, the reviewers took into consideration the impact of COVID-19 on the applicants' academic and research activities.

Each year, three to four finalists are selected by each of the four review committees. From a pool of 12-16 finalists, who are evaluated by all reviewers, the winners of the award are chosen. The USRA President and CEO makes the final selection. Finalists not selected as winners receive an Honorable Mention.

In 2020, USRA received 126 eligible applications from 61 different universities (including 39 member universities) and nearly 23 percent of the applicants were underrepresented students.

The 2020 USRA Distinguished Undergraduate Award Winners

Zoe de Beurs

University of Texas at Austin, Physics & Astronomy

Thomas R. McGetchin Memorial Scholarship Award

Andrea de Fonseca

Illinois Institute of Technology, Aerospace Engineering

Frederick A. Tarantino Memorial Scholarship Award

Maryam Hussaini

University of Texas at Austin, Astronomy & Physics

James B. Willett Memorial Scholarship Award

Wilbert Ruperto-Heránndez

University of Puerto Rico – Mayagüez, Mechanical Engineering

John R. Servier Memorial Scholarship Award

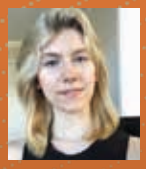
Honorable Mentions

Tanisha Bowman, Texas State University, Computer Science

Delondrae Carter, Arizona State University, Astrophysics

Joheen Chakraborty, Columbia University, Astrophysics and Computer Science

Asher Hancock, University of Pittsburgh, Mechanical Engineering



Alina Kochocki, University of California, Los Angeles, Physics

Megan Li, University of California, San Diego, Physics with Astrophysics Specialization

Dillan McDonald, University of Texas at Austin, Aerospace Engineering

Lorin Nugent, Purdue University, Aeronautical and Astronautical Engineering

Michael O'Neill, Georgia Institute of Technology, Materials Science & Engineering

Emma Rogers, Purdue University, Geology & Geophysics/Planetary Science

Ryan Udell, Rice University, Mechanical Engineering

Governance & Member Universities

Universities Space Research Association Board of Trustees 2020-2021

USRA is an association of 113 doctoral degree-granting universities engaged in space and aeronautics related research and education. University membership ensures broad public oversight of the corporation, as it engages in activities to fulfill its nonprofit purpose of "development and application of space-related science, technology, and engineering. The members elect a Board of Trustees, which govern USRA and appoint the USRA President and CEO.

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Ms. Natalie W. Crawford, RAND Corporation
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Ms. Kim P. Williams, Lawrence Berkeley National Laboratory (ret.)

Member Universities and Regions

USRA'S 113 MEMBER INSTITUTIONS THROUGHOUT THE U.S. AND AROUND THE WORLD

Region V
University of Bern
The University of British Columbia
University of Canterbury
The Chinese University of Hong Kong
University of Cologne
École Polytechnique Fédérale de Lausanne
Korea Advanced Institute of Science and Technology
University of Leicester
Seoul National University
The University of Sheffield
University of Stuttgart
The University of Sydney
Technion - Israel Institute of Technology
Tel Aviv University
University of Toronto

Region IX
University of Alaska Fairbanks
University of California - Berkeley
California Institute of Technology
University of California, Los Angeles
University of California, San Diego
University of California, Santa Barbara
University of Hawai'i
University of Southern California
Stanford University
University of Washington

Region VI
The University of Chicago
University of Illinois at Urbana-Champaign
Indiana University
The University of Iowa
Iowa State University
University of Michigan
Michigan Technological University
University of Minnesota
Montana State University
The University of Nebraska-Lincoln
Northwestern University
Purdue University
University of Wisconsin - Madison

Region I
Boston College
Boston University
Brandeis University
Brown University
University of Connecticut
Harvard University
Massachusetts Institute of Technology
University of New Hampshire
Tufts University
Yale University

Region II
University at Buffalo, SUNY
Columbia University
Cornell University
Lehigh University
New Jersey Institute of Technology
New York University
The Pennsylvania State University
Princeton University
Rensselaer Polytechnic Institute
University of Rochester
Rochester Institute of Technology
The Rockefeller University
Stony Brook University, SUNY
University of Pittsburgh

Region VIII
The University of Arizona
Arizona State University
University of Arkansas
University of Colorado Boulder
Colorado School of Mines
University of Denver
The University of Kansas
The University of New Mexico
New Mexico State University
The University of Oklahoma
Oklahoma State University
Utah State University
Washington University in St. Louis

Region VII
Alabama A&M University
The University of Alabama in Huntsville
Auburn University
Baylor University
University of Houston
Louisiana State University
Mississippi State University
Rice University
Texas A&M University
Texas Tech University
University of Texas at Arlington
University of Texas at Austin
University of Texas at Dallas
University of Texas Medical Branch at Galveston

Region IV
University of Central Florida
The College of William & Mary
University of Florida
Florida Institute of Technology
Florida State University
Georgia Institute of Technology
Hampton University
North Carolina A&T State University
North Carolina State University
Old Dominion University
University of Tennessee, Knoxville
Vanderbilt University

Region III
Case Western Reserve University
University of Delaware
George Mason University
The George Washington University
Georgetown University
Howard University
Johns Hopkins University
University of Maryland
Ohio University
The Ohio State University
University of Virginia
Virginia Polytechnic Institute & State University

Public Policy Advocacy

IPC members on the balcony of the Speaker of the House during a visit to congressional offices on February 11, 2020

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

The IPC successfully advocated for the inclusion of $30 million in the House-passed NASA FY 2020-21 Commerce, Justice, Science appropriations bill for university-led small satellite missions. This is an increase of $5 million for university small missions over the FY 2020 enacted amount, building on the IPC advocacy effort from last year. Such SmallSat and CubeSat missions provide research opportunities for universities, and training for the next generation of scientists and engineers.

In response to the deleterious effect of the COVID-19 pandemic on universities, Dr. Jeffrey A. Isaacson, USRA President and CEO, was invited by Senate Commerce, Science and Transportation Chairman Roger Wicker (R-MS), to submit written testimony on behalf of the university community on May 13, 2020. Dr. Isaacson's testimony conveyed from USRA's member universities the effects of the COVID-19 pandemic on their campuses. Dr. Isaacson requested that an additional appropriation be provided to the NASA Science Mission Directorate for augmentations to university grants and contracts to enable graduate students and postdoctoral researchers to complete their research obligations.

Diversity, Equity and Inclusion

Diversity is a fundamental element of USRA's culture and practice. We embrace the richness of diversity as an important asset, and value both the similarities and differences of every member of the USRA team. USRA recognizes that diversity builds a stronger organization as it undergirds and exemplifies our Core Values of Passion, Partnerships, and Professionalism.

Scientific discovery is blind to race, color, religion and so many other human characteristics that comprise the diversity and commonality of all people. Science and research must be as free from bias as possible to ensure our staff, systems and solutions – which impact so many areas of space research and technology – do not create additional barriers.

Our mission is to serve the scientific community and the common good. USRA continues to enter into partnerships with historically black colleges and universities (HBCUs) to broaden the impact of space related science through partnerships, seminars, internships, mentoring and research collaborations.

We have made progress – the Leadership Team was 79 percent white male in 2014; today it is 38 percent. We've also increased female representation from 16 percent to 38 percent, and minority representation from 16 percent to 31 percent. In the last five years the diversity of our program directors has more than doubled; and more than 80 percent of our leadership team has been educated to overcome unconscious bias in their hiring practices. And we have woven the tenets of diversity, equity and inclusion into the fabric of our culture by reaffirming our commitment to diversity and inclusion, and re-energized a newly constituted Diversity, Equity and Inclusion Committee (DE&I).

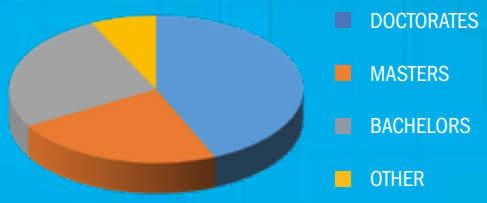
Yet, there is more to do. The opportunities for our DEI committee to weigh in are many, and we continue to roll out initiatives which positively impact our workforce.

We move quickly to address areas of persistent inequity. USRA CEO, Jeff Isaacson, addressed this issue in USRA's Statement Denouncing Racism, declaring USRA's stand in solidarity with the Black community as an ally in the fight against systemic racism, racial injustice and discrimination in all its forms.

USRA strives to create a workplace where everyone feels empowered to bring their full, authentic selves to work, and with the help of our scientific and research communities — our employees, customers, partners, we will create opportunities for each of us to better understand our own beliefs, values and cultures to fully experience new ideas, perspectives and traditions.

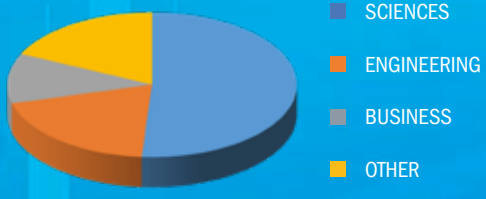
USRA's Workforce: Growing and Diversified

Employee Distribution by Degree



Approximately 44 percent of USRA's workforce hold Doctoral degrees, and another 24 percent hold Masters

Employee Distribution by Areas of Study



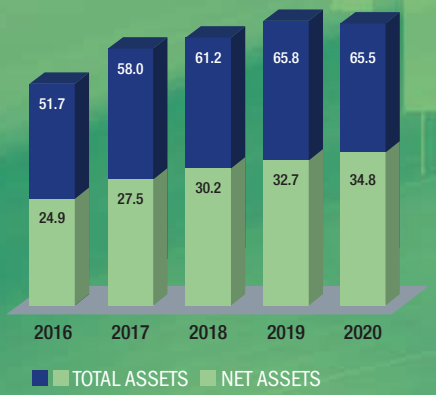
Approximately 70 percent of USRA's workforce comprises scientists and engineers

Financial Highlights

FY 2016-2020 Revenue in Millions

For FY 2020, USRA's annual revenue was $149.3 million. USRA's portfolio of programs weathered COVID-19 with modest impact to revenue. Despite the dip in revenue across programs, the 2020 portfolio was stable.

FY 2016-2020 Total Assets and Net Assets in Millions



USRA's Total Assets for FY 2020 were $65.5 million and Net Assets were $34.8 million. The FY 2020 increase in Net Assets of $2.2 million extends a three year stretch of annual increase in Net Assets of greater than $2 million.

This artist's concept illustrates a catastrophic collision between two rocky exoplanets in the planetary system BD +20 307, turning both into dusty debris. Ten years ago, scientists speculated that the warm dust in this system was a result of a planet-to-planet collision. Now, NASA's SOFIA mission found even more warm dust, further supporting that two rocky exoplanets collided. This helps build a more complete picture of our own solar system's history. Such a collision could be similar to the type of catastrophic event that ultimately created our Moon.
Image Courtesy: NASA/SOFIA/Lynette Cook

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

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