



Science Innovation Fund

AWARD

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Science Innovation Fund
Award Report 2012–2016
Office of the Chief Scientist

Science Innovation Fund (SIF) Award

The Science Innovation Fund invested in innovative, exploratory, and high-risk/high-return research activities that aligned with the Agency's strategic goals and objectives.

The Science Innovation Fund provided small amounts of funding to NASA Centers to invest in strategic new scientific research that enhanced the Agency's scientific innovation, ability to meet future missions, ability to forge new collaborations, and retention of scientists.

Major objectives of the SIF were to promote science innovation and breakthroughs across the Agency; enable strategic planning in and across Centers; enable collaborations across disciplines and organizations; allow for flexibility for Centers to recruit and foster new talent; and foster creativity across NASA science workforce. At the same time, the intent of the fund was to discourage the use of Science Innovation Funds for other purposes (e.g., facilities construction, etc.).

The purpose of the Science Innovation Fund was twofold:

- 1 Promote the conduct of highly innovative, exploratory and high-risk/high-return scientific research in support of the strategic direction of the NASA Centers and the Agency.
- 2 Promote the vitality of the NASA Centers through strategic investments in scientific research, capabilities, and people.

✦ *SIF Review at Goddard Space Flight Center (2016), with NASA Chief Scientist Dr. Ellen Stofan*





✦ *Brian Glass, Principal Investigator of the Atacama Rover Astrobiology Drilling Studies (ARADS) project at NASA's Ames Research Center in Silicon Valley and SIF Award recipient*

Management of the SIF

SIF funding activities directly supported advancing the strategic direction of the NASA Centers and the Agency, and were solicited by each participating Center through an open internal call for proposals. SIF awards were selected by the Centers through a transparent internal review process, and the NASA Chief Scientist

approved selected projects to ensure that they directly supported Agency strategy and goals. Individual projects were limited in duration and funding (typically from 1 year up to 18 months and less than \$150,000 total per project). The Centers delivered progress reports to the Chief Scientist on an annual basis. The Chief Scientist then tracked the projects to determine how many SIF awards resulted in successful competitively selected proposals, as well as the number of multidisciplinary, collaborative proposals. The use of NASA Headquarters oversight acted to ensure that (1) funds were used according to program principles, (2) monitoring and tracking of projects occurred on schedule, and (3) programmatic continuity was provided.

The Science Innovation Fund was managed at each individual Center, with oversight by the Office of the Chief Scientist.

Benchmarks of Success

Success for Individual SIF Award

There were many indicators of success for an individual SIF award. A prime indicator of success was that the PI was able to mature the research and successfully receive an award from a conventional, competitively selected source of funding (e.g., Research Opportunities in Earth and Space Science [ROSES]). Other equally important indicators of success involved technology or information transfer, such as through the receipt of patents, publication of research results in a peer-reviewed journal, or utilization of the research in other NASA missions or projects. Broader impact through publicity and outreach—via Web sites, media interviews, and articles—as well as public engagement were also signs of a successful SIF.

Success for SIF Program

Since the SIF was designed to foster highly innovative, exploratory, and high-risk/high-return scientific research, a metric of success involved ensuring that the correct amount of risk was borne by the program. If the ratio of successful SIF awards to those which did not yield promising results was greater than 50:50—a ratio commonly encountered in Department of Defense, Department of Energy, and industry programs¹—then a case could be made that the SIF award was not fostering truly innovative research. Furthermore, since the SIF award acted to promote the vitality of the NASA Centers through strategic investments in scientific research, capabilities, and people, SIFs that fostered cross-disciplinary collaboration, as well as SIFs that encouraged early career and underrepresented individuals to participate were also signs of success.

¹ See, for examples, DOE's LDRD Program, DOE Order DOE O 413.2B; DOD's IR&D Program at <http://www.defenseinnovationmarketplace.mil>; and the report, *Information on DOE's Laboratory-Directed R&D Program* (<http://www.gao.gov/products/GAO-04-489>), which describes not only the DOE program, but those of other governmental programs, including JPL's.

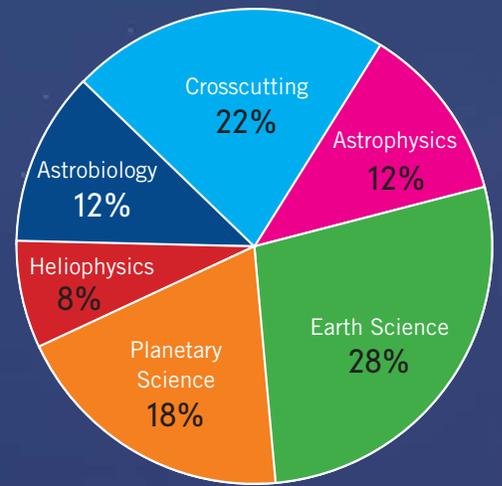


✦ Yolanda Shea (née Roberts), NASA Physical Research Scientist and SIF recipient at Langley Research Center

SIF Award Strategic Research Areas

NASA conventionally divides its science research into the following categories: astrophysics, Earth sciences, planetary sciences, heliophysics, and astrobiology. The term “crosscutting research” is used for any topic that addresses at least two of these areas. SIF awards encouraged the development of new investigations that stress the innovative, exploratory, and/or the interdisciplinary nature of the proposed work. Furthermore, SIF awards were not targeted at work that could be funded under other program resources (including mission directorate programs), formal solicitations such as Stand Alone Missions of Opportunity Notices (SALMON) or ROSES, or other internal funds.

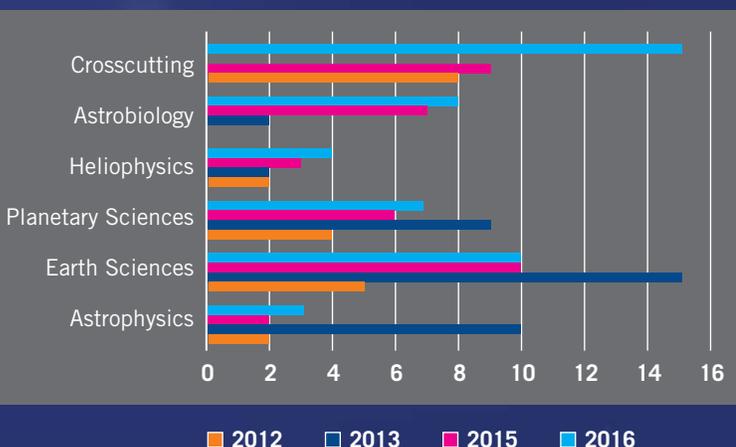
Cumulative Totals for Research Area Allocations (2012–2016)



Distribution of SIF Awards by Year Across Areas

	Astrophysics	Earth Sciences	Planetary Sciences	Heliophysics	Astrobiology	Crosscutting	Totals
2012	2	5	4	2	0	8	21
2013	10	15	9	2	2	9	47
2015	2	10	6	3	7	0	28
2016	3	10	7	4	8	15	47
TOTALS	17	40	26	11	17	32	143

SIF Awards by Area 2012–2016



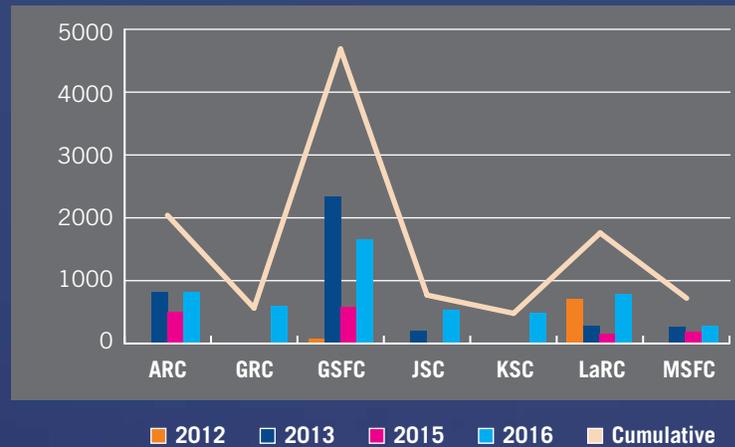
This requirement for non-conventional research led to a dramatic growth of SIF awards being made in crosscutting areas, as seen in the 2016 SIF cycle. An initial emphasis of SIF awards being made in the Planetary and Earth Sciences (2012–2013) was linked to the staged rollout of the SIF award across Centers. An increase in SIF awards made in the Astrobiology area, for example, was linked to the addition of Ames Research Center to the SIF portfolio in 2013.

Breakdown of SIF Awards across NASA Centers

SIF awards were managed at each Center, with oversight coming from the Office of the Chief Scientist. SIF awardees were distributed across 7 NASA Centers: Ames Research Center (ARC), Glenn Research Center (GRC), Goddard Space Flight Center (GSFC), Johnson Space Center (JSC), Kennedy Space Center (KSC), Langley Research Center (LaRC), and Marshall Space Flight Center (MSFC). The allocation of SIF funds to a Center was roughly proportional to the amount of science activity at that Center.

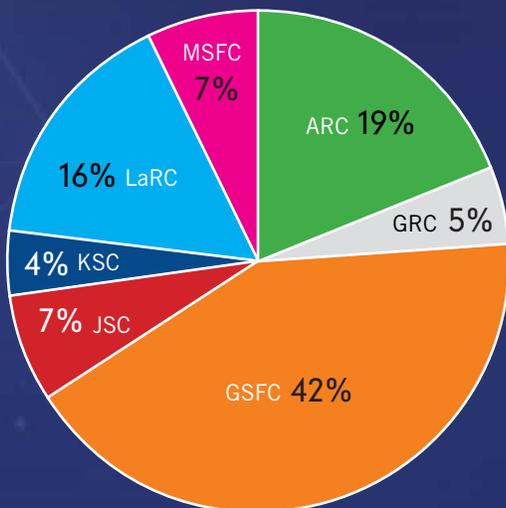
Due to the fact that the SIF program was piloted at Goddard and Langley in 2012, there is a higher cumulative total of SIF awards at those Centers. Additionally, Goddard, Langley, and Ames have a high concentration of SIF PIs due to a traditional or emerging focus on fundamental science areas targeted at innovative frontiers. SIF awards involved co-PIs from

SIF Award Amounts by Center (in thousands of dollars)



multiple Centers; awards of this nature were often able to leverage synergies, thereby creating investigative opportunities for cutting-edge research that would not have existed under traditional NASA funding profiles.

SIF Funding Spread by Center



As of 2017, there are 44 SIF awards still in progress, with 143 SIF awards having been completed since the award's inception in 2012. PIs have been able to leverage known collaborators and facilities, both inter- and intra-Center, in order to ramp up efforts quickly once a SIF was awarded. Since most SIF awards are capped at \$150,000, the highly exploratory nature of the award means that any synergies leveraged act as a strong multiplier for the utility of the final work. Of the 143 SIFs awarded from 2012 to 2016, more than 23 awards involved collaborations with more than one Center, with 4 awards involving 3 Centers.

SIF HIGHLIGHT

Development of the Optimal Estimation Algorithm for Deriving Microphysical Aerosol Properties from Polarimeter (2015), and Microphysical Aerosol Properties from Polarimetry (MAPP): Studying the Earth's Aerosols and Oceans Using Polarized Light and LIDAR Measurements (2016), with PI Dr. Snorre Stamnes (*Langley Research Center*)



✦ *The NASA C-130 aircraft readies to fly and take samples of sea salt aerosols.*

Dr. Stamnes, an early career researcher, has designed an innovative polarimeter aerosol retrieval algorithm based on optimal estimation theory, called Microphysical Aerosol Properties from Polarimetry (MAPP), in order to study Earth's aerosols and oceans using polarized light and Lidar measurements. His research dovetails with the goals of the Aerosols-Clouds-Ecosystems (ACE) decadal survey mission, which places strict accuracy requirements on aerosol characterization in order to quantify the impact of aerosols on Earth's climate, which will require improved satellite instruments and retrieval algorithms. MAPP was designed for the ACE mission, tested on simulated data, and then applied to real Research Scanning Polarimeter (RSP) data.

The project benefited significantly from close collaboration between the NASA Goddard Institute for Space Studies (GISS) Research Scanning Polarimeter (RSP) and the NASA Langley High Spectral Resolution Lidar (HSRL) teams on the aerosol/cloud microphysics and ocean color retrievals. Dr. Stamnes, a Research Physical Scientist in the Atmospheric Composition Branch at NASA Langley Research Center, had always wanted to collaborate with his colleagues at GISS. Dr. Stamnes reflected on his personal growth through his 2015 and 2016 SIF awards, "This SIF award gave me the freedom to work on MAPP, to continue working in collaboration with the NASA GISS RSP team and to visit NASA GISS to meet with the RSP PI and team." He cites key collaborators B. Cairns, A. Wasilewski, J. Chowdhary, and W. Martin at NASA GISS, as well as fellow NASA Langley collaborators C. Hostetler, R. Ferrare, S. Burton, X. Liu, J. Hair, and Y. Hu as enabling his work.

"This SIF award gave me the freedom to work on MAPP, to continue working in collaboration with the NASA GISS RSP team and to visit NASA GISS to meet with the RSP PI and team."

MAPP is one of the algorithms now being used for a funded ROSES Remote Sensing Theory grant. The MAPP algorithm is featured in a proposal to the upcoming ROSES Remote Sensing of Water Quality solicitation. A publication is in progress on the Aerosols Above Oceans ocean color retrievals from the Two-Column Aerosol Project (TCAP) and Ship-Aircraft Bio-Optical Research (SABOR). The microphysical aerosol and ocean color products produced by MAPP for TCAP and SABOR will be archived and made publicly available simultaneously with the publication of the paper.

Diversity and Inclusion in the SIF Award

The provision of seed money for innovative/strategic research has long been considered essential in industry, research universities, and Government institutions to achieve their missions. Under SIF, NASA made a small investment and provided Centers with agile funding opportunities for early stage scientific research activities that aligned with the Agency's strategic goals and objectives. The SIF worked to incubate new ideas that are high-risk/high-reward in nature, with a low technology readiness level (TRL), giving them a chance to mature. An open call at each NASA Center was used to enable NASA scientists to bring forward their most creative ideas for consideration.

The SIF award was especially successful in attracting a wide pool of applicants, which resulted in a diverse pool of awardee PIs. In 2012, the inaugural SIF awards were presented, with 21 awards being made out of 81 proposals submitted. In that first year, approximately 37 percent of the PIs were either women and/

or minorities, which is well above the national average for programs of a similar nature. Additionally, in the 2012 SIF, close to 31 percent of the proposals were won by "early career" scientists, that is, scientists within the first 5 years of their employment at NASA. In 2013, 114 proposals were submitted, with



✦ SIF Review held at Goddard Space Flight Center

47 awards being made. Of these awards, 33 percent of the winning SIF PIs were women, with 14 percent of SIFs being led by minorities, showing the potential of the SIF award to grow its base of underrepresented participants. Similarly, about 42 percent of 2013 SIF awardees were early career scientists, demonstrating the ability of the SIF to encourage individuals early in their career to cultivate their own lines of research outside of traditional NASA funding programs, thereby enhancing innovation in the NASA environment.

Due to budget issues, there was no SIF program in 2014, but in 2015, 27 proposals were funded at four Centers. While 2015 was an abbreviated program, with a duration of approximately 5 months, important results were still achieved: 27 awards were made, with over 40 percent going to PIs from underserved groups. In 2016, 47 SIFs were awarded, with 36 percent having PIs who were either women and/or minorities, and 32 percent were awarded to early career recipients.

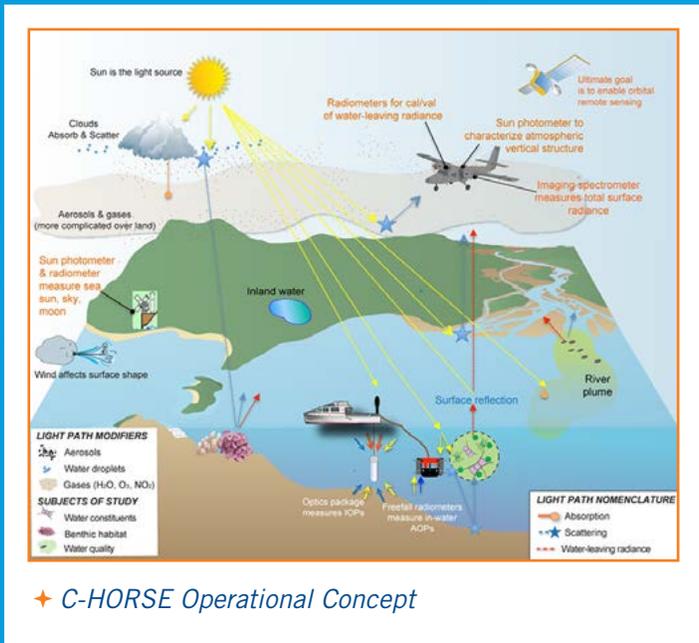
Since its inception, SIF has funded 143 research projects with over a third going to early career PIs, and 38 percent going to PIs from underrepresented groups.



✦ Lauren Fahey and Dr. Liane Guild with SIF Project C-HORSE hardware

SIF HIGHLIGHT

Coastal High-resolution Observations and Remote Sensing of Ecosystems (C-HORSE), with PI Dr. Liane Guild (*Ames Research Center*)



Dr. Liane Guild’s research, under her SIF award, sought to answer the question “Can the unique spectral features of coastal ecosystems (e.g., corals, submerged aquatic vegetation, sand, mixed bottom types, and phytoplankton) be resolved with airborne remote sensing?” She worked on integrating a portable sensor suite into a research aircraft, configured to assess the biological properties of coastal ecosystems and water quality. Dr. Guild has field-tested the instrument suite by collecting bio-optical data simulating a range of water conditions from the clear waters of Lake Tahoe to the turbid waters of Pinto Lake, as well as the Santa Cruz Wharf. Her algorithms then utilize these atmospheric measurements to determine whether the relevant coastal features can be identified, thereby increasing cost effectiveness for rapid response to coastal events impacting water quality and ecosystems.

In 2016, Dr. Guild submitted a ROSES Airborne Instrument Technology Transition proposal, which was based on work done during her SIF. This proposal was funded and has enabled her to continue her flight test and sensor integration efforts; she will be gathering further data in subsequent flights over Lake Tahoe, Pinto Lake, and Santa Cruz Wharf. She is currently in the process of submitting a ROSES Earth Venture Suborbital proposal, to integrate her work with current Earth-observing satellite efforts. She has given a presentation regarding her work done on the SIF at the International Coral Reef Symposium and currently has a manuscript in progress for the special issue of *Frontiers in Marine Science*. She firmly believes that the high-quality bio-optical measurements enabled by the C-HORSE distributed sensor solution linking in- and above-water, air, and satellite data will greatly advance the science of coastal water quality and coastal ecosystems.



✦ *Field setup of C-HORSE hardware. Left to right: Henry Housekeeper and Juan Torres-Perez*

SIF Awards and Public Engagement

The SIF award was targeted at new investigations that stress innovation, exploration, and/or the interdisciplinary nature of the proposed work. Projects that encourage members of the public to participate in the scientific process in unique and innovative ways are highly valued. This public engagement, through the SIF awards acted to enhance the vitality of the NASA Centers through public awareness of research being performed, and helped to promote strategic investments in scientific research, capabilities, and people.

Public engagement in science is vital to a vibrant scientific community, as well as to growing a capable workforce. The SIF award prized PIs who were capable of communicating with public audiences, working for the public good, and, most importantly, generating knowledge with public participation.

Many SIF awards involved public education components that included carrying out live presentations, performing demonstrations, and hosting exhibits that engage the participation of a wide swath of individuals of all ages. SIF PIs have spoken at forums targeted at K–12, secondary, and post-secondary audiences, as well as engaged audiences at museums, libraries, community centers, science fairs, and sporting events. SIF research has been featured in multiple media, including radio, television, magazines, and newsprint.

One of the means by which SIF award winners engaged the broader community was through



✦ Exhibit at Cleveland Natural History Museum of SIF Awardee Dr. Rafat Ansari's Research on Algal Blooms

citizen science. Citizen science can mean anything from ordinary citizens observing natural events and characteristics of the world and universe around them, to a closely coupled collaboration in which a citizen and a scientist partner to answer real-world questions. Many SIF awardees have a strong presence on the Internet and have created immersive apps, as well as interactive Web sites, which encouraged public participation and engagement in their work. SIF PIs have created Web-based projects that have enabled the general public to interact with scientific data and aid in the necessary scientific analysis to enable significant discoveries.

SIF HIGHLIGHTS

Habitats for Planets: A Project to Discover Debris Discs in the WISE Database (2013), and PlanetX.org (2016), with PI Dr. Marc Kuchner (*Goddard Space Flight Center*)



✦ *Star surrounded by a debris disk, which possibly indicates a forming planetary system*

Dr. Kuchner is an avid proponent of citizen science. He is a driving force behind the Disk Detective and Backyard Worlds: Planet 9 initiatives, which are an ongoing effort that encourages members of the public to engage in sifting through data in order to identify forming planets or undiscovered worlds in the outer reaches of our solar system. Both of these projects utilize data collected from NASA's Wide-field Infrared Survey Explorer (WISE) mission, as well as from telescopes around the world.

Disk Detective, which went live on January 28, 2014, is an addition to the successful Zooniverse network of Citizen Science Alliance projects. The Disk Detective Web site has received traffic of over 200,000 unique individuals and is available in 14 languages, thanks to citizen scientist translators. Over 2 million classifications have been made so far by roughly 30,000 participants. Thousands of new "Objects of Interest" have been found, and participants help choose targets for follow-up campaigns on telescopes in California, Arizona, Hawaii, New Mexico, and Argentina. Thirty-seven disk candidates have been published so far. Furthermore, Disk Detectives discovered the first debris disk around a star with a white dwarf companion. Eight citizen scientists are coauthors on a paper that appeared in the prestigious *Astronomical Journal* regarding the debris disk around this binary star system.

Dr. Kuchner's second SIF led to the creation of a new Web site called Backyard Worlds: Planet 9. The site uses data to search for unknown objects in and beyond our own solar system by having citizen scientists perform a systematic search of moving objects in WISE images. "Backyard Worlds: Planet 9 has the potential to unlock once-in-a-century discoveries, and it's exciting to think they could be spotted first by a citizen scientist," said

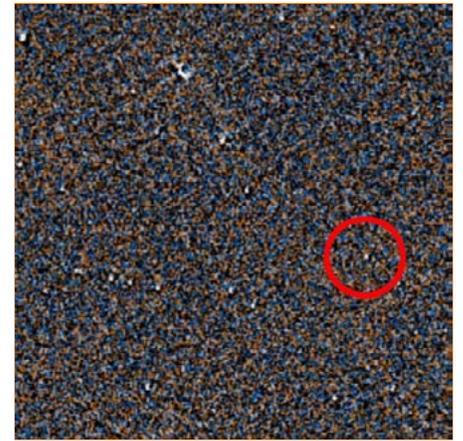
"Backyard Worlds: Planet 9 has the potential to unlock once-in-a-century discoveries, and it's exciting to think they could be spotted first by a citizen scientist."

SIF HIGHLIGHTS (CONTINUED)

team member Aaron Meisner, a postdoctoral researcher at the University of California, Berkeley, who specializes in analyzing WISE images. Backyard Worlds currently has approximately 40,000 citizen scientists participating in classification efforts.

More information on these projects can be found at <https://www.diskdetective.org>, <https://www.BackyardWorlds.org>, <https://blog.diskdetective.org>, or on Twitter at @diskdetective and @diskdetectiveES.

✦ The newly discovered brown dwarf appears as a moving dot (indicated by the circle). (Click image to play movie.)



A General Aviation Citizen Science Study of Harmful Algal Blooms, with PI Dr. Rafat Ansari (*Glenn Research Center*)

Harmful Algal Blooms (HABs)—tiny plants with a toxic punch—are a worldwide ecological problem, and they were cited as such in the Earth Science Decadal Survey of 2007–2017. Almost every state in the United States is affected by HABs, and Dr. Ansari’s research is focused on developing an early warning system to alert communities of ensuing algal bloom. He wants to provide

free, near real-time data access to anyone interested in water quality, such as community members and water quality managers.



✦ Cleveland Natural History Museum volunteers demonstrating hands-on *Environscope*

The approach taken in this SIF award involved leveraging the nearly 600,000 private pilots and over 200,000 general aviation (GA) aircraft in the United States to study land and aquatic systems. Sensors attached to low-flying GA aircraft can provide images with higher spatial and temporal resolution than satellites or commercial jet aircraft. Dr. Ansari worked on developing a pilot network, and his initial call for

pilots yielded approximately 100 volunteers across the United States, along with a few from Australia, Greece, Israel, and Ireland. For this proof-of-concept study, only pilots from OH, MI, MN, CA, TX, and GA were included. These pilots affixed a 3-ounce remotely controlled camera sensor, capable of RGB and near-infrared imaging, to the bellies of their aircraft, which were able to take images in the nadir position every 5 seconds, as well as continuous forward video. The cameras were equipped with a geolocation (geotagging) function that enabled accurate geo-referencing for the early warning system to alert communities of impending HABs. Before the onset of an algal bloom, the images were able to provide insight into the response of the three major indices (mPRI, nVARI, and NDRB) to a strong cyanophyte bloom.

This work has been the feature of a video documentary series for the International Joint Commission for the Great Lakes Water Quality Agreement. It was also a part of a special exhibit at the Cleveland Natural History Museum's Citizen Science Display

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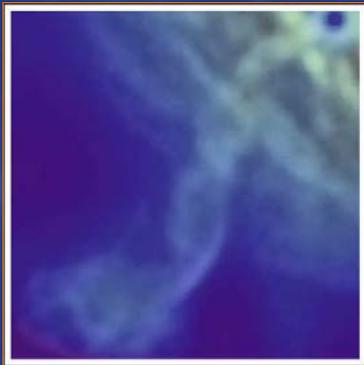


★ *Dr. Ansari's SIF collaborator from North Eastern University (Sophie) educating students on Cartoscope*

from March to June 2017 and had an interactive demonstration (Environscope) on June 4, 2017, which showed how water run-off affects drinking and recreational water. This effort has involved collaboration with Northeastern University, including the development of the mobile app Cartoscope, which engages the public in learning about water quality through hands-on data analysis. A movie can be viewed at <https://drive.google.com/file/d/OB0sbfWDme3q-bWV5QzVyWjhRS1E/view?usp=sharing>.

Innovation and the SIF Award

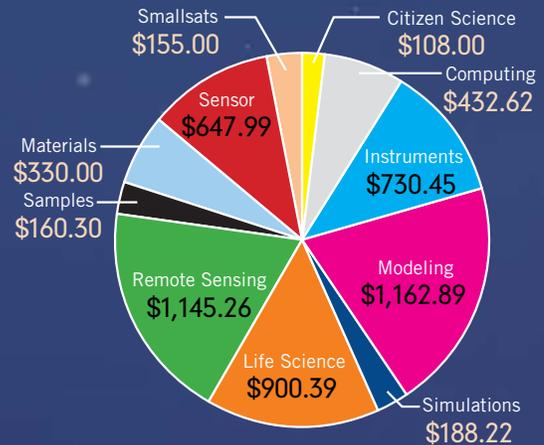
An innovation-driven economy requires the discovery and development of new ideas to solve old problems, as well as the seizing of new opportunities with technology and ingenuity to produce great strides forward in current state of the art processes, practices, and research paradigms. The SIF award was targeted at new investigations that stress innovation, exploration, and/or the interdisciplinary nature of the proposed work. Projects that encouraged members of the public to participate in the scientific process in unique and innovative ways were highly valued. This process acted to enhance the vitality of the NASA Centers through strategic investments in scientific research, capabilities, and people.



★ *Singular Value Decomposition analysis of Chandra X-ray data of the Crab Nebula. (Click image to play movie.)*

The SIF award embraced many topics that are at the vanguard of scientific and technological frontiers, such as novel instruments and sensors; innovative software and simulation modeling techniques; as well as multiple aspects of computing. Awarded research encompassed the areas of quantum computing, data mining, artificial intelligence, and machine learning, along with novel hardware and processor design. Many SIF awards leveraged developments in emerging

SIF Investments 2016
(in thousands of dollars)



technology platforms, such as small satellites' mission design and deployment and remote sensing, in order to enable breakthrough scientific techniques and discoveries.

Furthermore, progressive techniques for biology and astrobiology as well as life sciences, along with cutting-edge work in material properties and sample studies (including biological materials) have allowed for the advancement of our understanding of the nature of life both here on our planet and in the greater universe. Synergies with public interest led to several SIF awards leveraging crowdsourcing opportunities, thereby engaging the citizen science community. For example, in 2016, over \$108,000 was spent on SIF awards that benefited from citizen science inputs.

The focus on innovation created a diverse portfolio of SIF award topics, which may traditionally not have been enabled under NASA's conventional research programs. This environment acted as an incubator for future NASA projects, which are pre-aligned with NASA's strategic goals.

SIF HIGHLIGHT

Meteorologically Driven Dengue, Chikungunya, and Zika Forecasts, with PI Dr. Dale A. Quattrochi (*Marshall Space Flight Center*)

Each year, dengue fever (DF), caused by infection with the dengue virus (DENV), affects 96 million people worldwide; the Chikungunya virus (CHIKV), a virus similar to DENV, has been recently introduced into the Caribbean and the southern United States. Prior to the initiation of this project, there was no effective way to predict the transmission of DENV, CHIKV, and ZIKAV or assess the potential risk of the presence of the *Aedes aegypti* mosquito that is the vector for these viruses.

NASA scientists at Marshall Space Flight Center have created a map to better target future search-and-destroy missions for one of the deadliest creatures on the planet, the female *Aedes aegypti* mosquito. The bloodsucking females are responsible for the spread of dangerous diseases such as yellow and dengue fevers, Chikungunya, and now Zika.

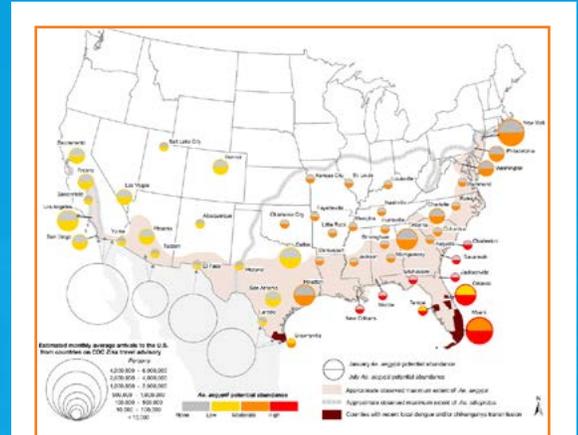
The researchers focused their analysis on 50 cities within or near the currently known range of the *Aedes aegypti* in the United States. The resulting map, newly released in the journal *PLOS Currents*, applies factors such as temperature, amount of rainfall, poverty levels, and travel to the United States from Zika-affected areas of the world. Furthermore, the researchers analyzed the risk for each month in the year.

“This information can help public health officials effectively target resources to fight disease (Zika) and control its spread,” said Dale Quattrochi, NASA senior research scientist at MSFC in Huntsville, AL.

While most of the model seems in line with expectations of the spread of Zika, “there were some surprises,” said Cory Morin, a NASA postdoctoral program fellow with MSFC’s Earth Science Office. One such surprise was just how far north the *Aedes aegypti* might spread during the summer months.

“This suggests that the mosquito can potentially survive in these locations if introduced during certain seasons, even if it hasn’t or can’t become fully established,” Morin said. This project has developed risk forecasts for DENV, CHIKV, and ZIKAV that use a coupled entomological-epidemiological model in conjunction with a real-time weather prediction model to forecast the risk of transmission of these viruses.

This work has led to multiple presentations, media exposure, and a peer-refereed journal publication.



✦ Risk assessment map of presence of *Aedes aegypti* and potential existence of ZIKAV based on airport arrival data

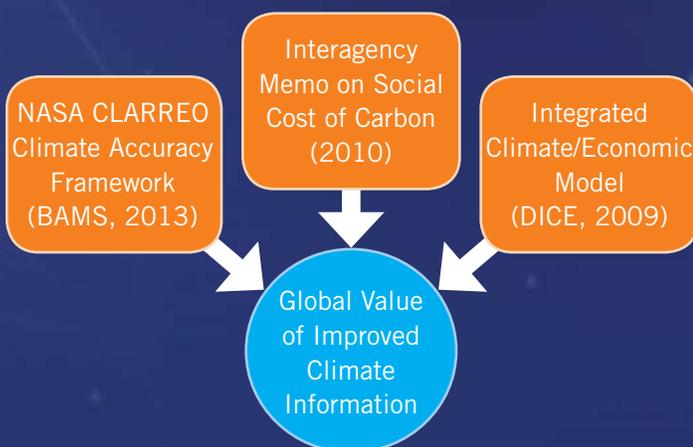
SIF Research Transition and Broader Impacts

The SIF awards have produced over 75 peer-reviewed journal papers (in print or under review), with an additional 18 papers currently under preparation.

The SIF awards supported two of NASA's research-aligned strategic goals: (1) to expand the frontiers of knowledge, capability and opportunity in space, and (2) to advance understanding of Earth and develop technologies to improve the quality of life on our home planet. The SIF also directly reinforced NASA's goal to serve the American public and accomplish NASA's mission by effectively managing people, technical capabilities and infrastructure. Specifically, the SIF dovetailed with NASA's strategic objective to

attract and advance a highly skilled, competent, and diverse workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions. The SIF award's ability to foster innovation acted to attract and maintain an invigorated science workforce and led to the furtherance of fundamental research breakthroughs in our understanding of our planet, solar system, and the greater universe.

SIF awards have produced patents, software and mobile applications, prototype hardware, sensors, experimental platforms, datasets, complex models, and simulations that help further a broader scientific understanding of the cosmos.



SIF awards touched on topics ranging from understanding the fundamental nature of the universe, to the practical design of flight hardware. Issues ranging from environmental and climate modeling, economic systems analysis, life detection techniques, massive dataset collection, processing, dissemination, and curation (e.g., for lunar data) were addressed through SIFs: all of these topics are directly applicable to real world concerns, reach beyond traditional borders in science, aid in engaging a wide public audience, and act to improve society by tackling relevant challenges.

✦ *Economic Model for Global Value of Climate, co-developed by SIF awardee Bruce A. Wielicki*

The SIF awards have produced over 75 peer-reviewed journal papers (in print or under review), with an additional 18 papers currently under preparation. SIF awardees have given more than 23 talks regarding their research at conferences, universities, and in other public forums such as museums, schools, libraries, and fairs or festivals. SIF awards have produced patents, software and mobile applications, prototype hardware, sensors, experimental platforms, datasets, complex models, and simulations that help further a broader scientific understanding of the cosmos.

SIF awardees have been successful in growing their research into mainstream projects. Approximately 37 percent of SIFs have received follow-on funding, of which about 30 percent was composed of further NASA funding. Of that 30 percent, half of the awards received ROSES funding, while the remaining half received other NASA funding (SALMON, Explorers Program, Center Innovation Fund (CIF), Internal Research

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and Development projects (IRAD) etc.). Other sources of follow-on funding included funding from other government agencies (e.g., National Science Foundation, Defense Advanced Research Projects Agency, Department of Defense etc.), funding from industry, or through partnerships with academia.



★ NASA Glenn's Dr. Rafat Ansari (right) and pilot Terry Schubert use their aircraft to monitor algal blooms on Lake Erie as part of a citizen science initiative.

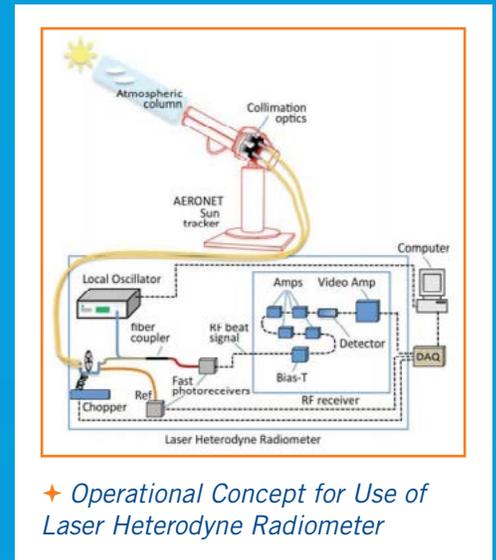
SIF HIGHLIGHTS

A Global Network for Monitoring Greenhouse Gases in the Atmospheric Column: Column Greenhouse Network, with PI Dr. Emily Wilson (*Goddard Space Flight Center*)

During her SIF, Dr. Wilson worked on developing a low-cost global surface instrument network for monitoring key greenhouse gases. Her research focused on carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), and nitrous oxide (N_2O), as well as oxygen (O_2) for determining atmospheric pressure. This work has led to the invention of a new instrument that can operate in tandem with the passive aerosol sensor currently used in AERONET (a well-established network of more than 450 ground aerosol monitoring instruments worldwide), and thus can be rapidly deployed into this established global network.

In the course of this award, and by leveraging prior IRAD funding, Dr. Wilson designed and fabricated the low-cost, miniaturized laser heterodyne radiometer (mini-LHR). The mini-LHR uses a technique based on a radio receiver that amplifies weak signals from a radio antenna by mixing them with a strong local oscillator. Consequently, she is able to measure the concentration of trace gases in the atmosphere by measuring their absorption of sunlight in the infrared spectrum. In her invention, sunlight that has undergone absorption by the relevant gasses in the atmosphere is collected and mixed with continuous wave laser light at a near-by frequency (e.g., 1,573.6 nm for CO_2) in a fast photoreceiver. The resulting beat signal is sensitive to changes in absorption and located at an easier-to-process frequency. Scanning the laser through an absorption feature in the infrared results in a scanned beat signal in the radio frequency. Deconvolution of this signal through the retrieval algorithm allows for the extraction of altitude contributions to the column signal.

Dr. Wilson's work on the mini-LHR has led to multiple journal articles as well as conference papers, presentations, and invited talks. The retrieval algorithm used to analyze the data provided was developed in conjunction with a research effort led out of George Washington University, and strong collaborations with academia arose throughout the work. Furthermore, the mini-LHR has been submitted as a patent application and has led to multiple follow on funding awards from NASA programs, including ROSES and Explorer.



✦ *Operational Concept for Use of Laser Heterodyne Radiometer*



✦ *Mini-LHR (as add-on to an AERONET Sun photometer), enables simultaneous monitoring of aerosols and carbon cycle gases.*

Advanced Bio-Detection Sensors for Icy World Exploration, with PI Dr. Jessica Koehne (Ames Research Center)

Biological molecules involved in electron transfer serve critical roles to life as we know it. In January 2016, Congress directed NASA to “create an Ocean World Exploration Program whose primary goal is to discover extant life.” The Announcement of Opportunity for the New Frontiers Program specifically focuses on ocean worlds, including the search for life as a key target. Dr. Koehne’s work involved developing new sensor-based technologies to enable bio-exploration and life detection during future missions to our solar system’s icy worlds. In the course of her work on this SIF, she sought to identify key molecular targets to enable a scientifically justified search for biomarkers on Europa, as well as to constrain the likely physical and chemical state of those target molecules on Europa, thus allowing for in situ life detection.



Electrochemical sensor arrays can provide high sensitivity with limited power, mass, and volume requirements making them a logical choice for small payload implementation and an attractive alternative to traditional analytical instrument approaches. In this proof of concept study, Dr. Koehne characterized and optimized a number of electrochemical sensors with varied surface chemistries and nanoarchitectures, to a variety of targets of interest that might be found in the oceans of Europa and Enceladus, both icy moons of Jupiter and Saturn, respectively. She examined a variety of electrode materials to distinguish the differences between similar redox active molecules, and she developed a sensor that searches for evidence of the protease trypsin.



✦ *Scanning electron and light microscope images of carbon nanoelectrode array. Left and center: Array of carbon nanotube electrodes. Right: Sensor device with gold working electrode.*

This research has resulted in multiple avenues of follow-on funding, including two NASA Center Innovation Fund awards, as well as a NASA ROSES Concepts for Ocean worlds Life Detection Technology (COLDTech)

award. Dr. Koehne has additionally applied for a NASA Game Changing Development Newstart award, and her work played a key role in an Ames/Applied Physics Lab (APL) submission for a mission proposal to the NASA New Frontiers program, targeting the icy worlds of Europa and Enceladus. Additionally, the results of this study have been published in a peer-refereed journal, with an additional manuscript for a journal under review.

Summary

The Science Innovation Fund enabled NASA to promote science innovation and breakthroughs across the Agency. Furthermore, the SIF facilitated strategic planning in and across Centers, supported collaborations across disciplines and organizations, empowered Centers to recruit and encourage new talent, and fostered creativity across the NASA science workforce. The SIF awards cultivated an environment where innovative, exploratory, and high-risk scientific research could be funded and successfully conducted in a rapid timeframe, leading to potentially high rewards.

The return on investment for the SIF awards has been remarkable. From 2012 to 2016, the SIF employed a lean budget of \$12.5 million over 143 awards across 7 Centers. The yield on these agile, \$150,000 awards has been phenomenal. Approximately 37 percent of SIF awards have received some form of follow-on funding, with 15 percent of awards receiving ROSES funding, 15 percent receiving other NASA funding (SALMON, Explorer, CIF, IRAD, etc.), and the remaining 7 percent receiving funding from external sources (e.g., Department of Defense, Department of Energy, other academic institutions, etc.).

The SIF awards have produced research of the highest caliber, leading to the publication of over 75 journal articles and numerous talks at conferences, academic institutions, and public forums. The SIF awards have produced a patent application, as well as collaborative Web sites for members of the public to participate in research projects, resulting in citizen scientist

SIF Return on Investment Statistics

- ✦ 37% of SIF awards received follow-on funding (including 15% which received ROSES funding)
- ✦ 75+ peer-reviewed journal publications (in-print or in-review)
- ✦ Media exposure through multiple TV, radio, and print documentaries, interviews, and articles
- ✦ 40,000+ user base for citizen science SIFs
- ✦ More than 33% early career SIF PIs
- ✦ Over 38% underrepresented SIF PIs (women & minorities)
- ✦ Approximately 22% interdisciplinary SIF awards
- ✦ Over 16% multi-Center SIF awards

coauthorship in prestigious journal papers. SIF citizen science projects have public user bases numbering over 40,000 participants. The SIF awards have led to the development of mobile applications that raise science awareness in the public consciousness and have dovetailed with interactive demonstrations and talks at museums, public schools, universities, and community centers. Multiple SIF PIs have been interviewed in both print and visual media regarding their research, and several PIs have participated in making televised documentaries.

The SIF awards have also been successful in cultivating a diverse base of principal investigators, as well as funding an interdisciplinary range of research. Well over 33 percent of SIF PIs were early career awardees, and over 38 percent of SIF PIs were either women or minorities. Approximately 22 percent of SIF awards went to interdisciplinary research, spanning two or more of NASA's traditional scientific areas. Over 16 percent of SIF awards involved investigators spanning two or more NASA Centers, with many more involving collaborations with external partners such as academic institutions.

Overall, the SIF can be hailed as a successful effort, in that it promoted innovative, collaborative research across disciplines and Centers; provided a force multiplier for the public impact of NASA's research portfolio through publication and media exposure; and fostered a diverse, creative workforce at NASA via the engagement of early career and underserved PIs.



✦ *Aki Roberge, NASA Research Astrophysicist and SIF recipient at Goddard Space Flight Center*

Credits

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SIF Awardees 2012–2016

Mitzi Adams

Marshall Space Flight Center

Rafat Ansari

Glenn Research Center

Spiro Antiochos

Goddard Space Flight Center

Ricardo Arevalo

Goddard Space Flight Center

John Baker

Goddard Space Flight Center

Anum Barki

Langley Research Center

Richard Barry

Goddard Space Flight Center

Natalie Batalha

Ames Research Center

Brad Bebout

Ames Research Center

Leslie Bebout

Ames Research Center

Kristopher Bedka

Langley Research Center

Bilal Bomani

Glenn Research Center

Jason Burks

Marshall Space Flight Center

Aaron Burton

Johnson Space Center

Anne Caraccio

Kennedy Space Center

Sarah Castro

Johnson Space Center

Winston Chao

Goddard Space Flight Center

Eric Christian

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David Chuss

Goddard Space Flight Center

Mark Cintala

Johnson Space Center

Barbara Cohen

Goddard Space Flight Center

Peter Colarco

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George Cooper

Ames Research Center

Carl DeVore

Goddard Space Flight Center

Josh DiGangi

Langley Research Center

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Ames Research Center

Shawn Domagal-Goldman

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John Dorelli

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Richard Elphic

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Cynthia Evans

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T. Duncan Fairlie

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James Foster

Goddard Space Flight Center

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Stephanie Getty

Goddard Space Flight Center

Brian Glass

Ames Research Center

Thomas Greene

Ames Research Center

Liane Guild

Ames Research Center

Theodore Gull

Goddard Space Flight Center

Alice Harding

Goddard Space Flight Center

Jennifer Heldmann

Ames Research Center

Paul Hintze

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Ames Research Center

Michael Hogue

Kennedy Space Center

Terry Hurford

Goddard Space Flight Center

Laura Iraci

Ames Research Center

Syed Ismail

Langley Research Center

Linda Jahnke

Ames Research Center

Gary Jedlovec

Marshall Space Flight Center

Natasha Johnson

Goddard Space Flight Center



✦ *Members of the Ames algae crew include (from left to right) Angela Detweiler, Erich Fleming, Brad Bebout, and Lee Bebout*

Jennifer Jordan

Glenn Research Center

Virginia Kalb

Goddard Space Flight Center

Demosthenes Kazanas

Goddard Space Flight Center

James Klimchuk

Goddard Space Flight Center

Kirk Knobelspiesse

Goddard Space Flight Center

Jessica Koehne

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Lora Koenig

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William Koshak

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Michael Kraniak

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Maxim Markevitch

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Stefanie Milam

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Richard Moore

Langley Research Center

Douglas Morton

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Samuel Moseley

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Murali Natarajan

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Craig Nickol

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Noah Petro

Goddard Space Flight Center

Dale Quattrochi

Marshall Space Flight Center

Kenneth Ranson

Goddard Space Flight Center

Aki Roberge

Goddard Space Flight Center

Yolanda Roberts

Langley Research Center



✦ *Dr. Laura Iraci, a research scientist in the Earth Science Division at NASA Ames Research Center, studies Earth's atmosphere.*

Miguel Roman

Goddard Space Flight Center

Jeremy Schnittman

Goddard Space Flight Center

Christopher Schultz

Marshall Space Flight Center

David Sibeck

Goddard Space Flight Center

Justin Simon

Johnson Space Center

Snorre Stamnes

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Deirdre Wendel

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Bruce Wielicki

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Emily Wilson

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Diane Wooden

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