



Testimony of

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and
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“The Great American Eclipse: To Totality and Beyond”

Chairwoman Comstock, Ranking Member Lipinski, Chairman Babin, Ranking Member Bera, and Members of the Subcommittees, I am Dr. James Ulvestad, Assistant Director (Acting) for the Mathematical and Physical Sciences Directorate at the National Science Foundation (NSF). Thank you for the opportunity to testify before you today to discuss the recent solar eclipse and NSF’s solar research, education and outreach efforts. August 21st was indeed an exciting day for our citizens and scientists alike, as our nation was center stage for the 2017 solar eclipse. We welcomed scientists and spectators from around the world who gathered across the country to witness this extraordinary event.

Introduction

More than a million planets the size of Earth could fit inside the sun, yet our sun is only considered a "yellow dwarf." The Sun is larger than most stars, but considered a dwarf because it is nowhere near the size of many of the bright stars in the night sky, such as Rigel and Betelgeuse in the constellation Orion. Even though the sun appears to be a rather ordinary star, one cannot overstate the sun’s significance to life on earth as we presently know it. Solar energy fuels life on Earth. Solar winds spark the Aurora Borealis and Aurora Australis in Earth's atmosphere. The sun's magnetic fields and atmosphere—specifically its corona—fuel space weather that affects Earth's power grids and communications systems. Moreover, the sun's undeniable power has increasingly become a source of renewable energy for our advanced

civilization. It's because of these connections and more that NSF sponsors a broad array of research related to the sun.

On August 21, 2017, the U.S. was treated to its own solar eclipse, a total solar eclipse that made its way from Oregon to South Carolina, illuminating a 70-mile-wide path across 14 states. While only those in that direct path could see the total eclipse—when daylight was extinguished for over two minutes while the moon completely covered the sun—the rest of the continental U.S. experienced some percentage of a partial solar eclipse. The eclipse traversed the continental U.S. in about 90 minutes.

Solar science

The total solar eclipse provided researchers a unique opportunity to study the sun's corona, the upper level of the sun's atmosphere. The corona is the launching point into space for the solar storms that create the space weather we experience on earth. This year's eclipse path, mostly over land, set up particularly good conditions for gathering data about this solar corona.

The recent total solar eclipse, the first in the continental U.S. since 1979, afforded extraordinary opportunities for scientific research. For example, the High Altitude Observatory (HAO) of NSF's National Center for Atmospheric Research (NCAR) in Boulder, Colorado, in partnership with the Harvard-Smithsonian Center for Astrophysics, designed, developed and flew an instrument called the Airborne Infrared Spectrometer (AIR-Spec) onboard NSF/NCAR's Gulfstream V research aircraft. AIR-Spec collected infrared data from the sun's corona during the eclipse, without needing to contend with clouds or compensate for the atmospheric distortion that affects ground-based telescopes. AIR-Spec was able to probe the complex magnetic environment of the sun's corona.

NSF also supports scientists who track the development of sunspots, flares and coronal mass ejections (giant clouds of solar plasma that are blown away from the sun during strong solar flares). These researchers, often using data from NSF's National Solar Observatory, are working to better understand how and when these phenomena are associated with the sun's magnetic field. That magnetic field is the apparent source of the energetic space weather events that can wreak havoc on Earth's power grids, satellites and communications systems. Space weather has the potential to interfere with everything from satellite communications to electrical power. Atmospheric scientists and geospace researchers are studying the behavior of the sun to develop warnings of solar storms that may be coming toward Earth. The National Solar Observatory's Global Oscillations Network Group (GONG) of six solar monitoring telescopes sited worldwide provides full-time monitoring of the sun and is a critical element of the models used to forecast solar storms and space weather.

Prior to the solar eclipse, a research team from Predictive Science Inc. (PSI) used the NSF-funded Stampede2 supercomputer at The University of Texas at Austin's Texas Advanced Computing Center (TACC) and Comet at the San Diego Supercomputer Center (SDSC) to forecast the corona of the sun during the upcoming eclipse. Similarly, the National Solar Observatory made a forecast of the magnetic field and the shape of the corona 25 days in advance of the eclipse, based on data from GONG and other sources. The findings shed light on

what the eclipse of the sun might look like. The opportunity provided researchers with a chance to compare projections with the actual event. This kind of predictive computer modeling improves the accuracy of space weather forecasting, which could have important practical ramifications. If a powerful solar storm such as the 1859 Carrington Event— which led to auroras being visible as far south as the Caribbean and caused telegraphs to short and catch fire—were to hit Earth today, it would cause more than \$2 trillion in damages, according to a 2008 [National Academy of Sciences](#) workshop report.

Predicting the arrival of such a solar storm in advance would allow officials to take the most critical electronic infrastructure offline and limit the storm’s impact. But doing so requires understanding how the visible surface of the sun (the photosphere) relates to the mass ejections of plasma from the corona, ultimately causing the space weather that we experience here on earth. The importance of this increased understanding was recognized by the 2013 National Academies decadal committee report in Solar and Space Physics. The first Key Science Goal in that report was to “Determine the origins of the Sun’s activity and predict the variations in the space environment.”

One of the sun's biggest mysteries is why its corona is so hot. The sun's core is a searing ~27 million degrees Fahrenheit (F), but by the time that heat reaches the sun's surface, it cools off to a mere ~10,000 degrees F, only to again heat up to several million degrees F in the corona, above the surface. This isn't just about understanding the sun, though. The corona is made of plasma, and many believe the answer has to do with the physics of how these plasmas work. NSF-funded researchers are investigating this issue and many other plasma physics issues that surround our sun.

Our sun emits trillions of times as much energy as the total electrical energy produced by all the Earth's power generators. Harnessing the power of the sun is a challenge that many scientists and engineers continue to work toward to solve more effectively. NSF-funded material scientists, engineers, physicists, mathematicians and computer scientists all play a role in moving this technology forward so that solar power can flourish and most effectively augment other energy sources in the future.

Outreach and education efforts

The NSF National Solar Observatory organized a citizen science project, [Citizen CATE](#) (Continental-America Telescopic Eclipse), an experiment that included a network of 68 identical telescopes, placed along the 2,500-mile path of totality and operated by citizen scientists, high school groups and universities. I’m sure you’ll hear more about this project from Dr. Matt Penn of the National Solar Observatory. Citizen CATE was a joint project involving volunteers from more than 20 high schools, 20 universities, informal education groups, astronomy clubs across the country, 5 national science research labs and 5 corporate sponsors. The academic partners involved in the Citizen CATE project were drawn from a geographically and demographically varied set of institutions. These diverse partners connected with even broader audiences in different settings—from small, rural events to international broadcasts viewed by thousands.

The goal of Citizen CATE was to produce a scientifically unique data set of high-resolution, rapid-cadence images of the inner corona for 90 minutes. The full, high-resolution dataset captured consists of more than 4,000 highly processed images spanning the entire path of totality. The dataset continues to be assembled and will include the production of a continuous video of the eclipse as it passed over our country. NSF Director Dr. France Córdova was pleased to be in Glendo, Wyoming to experience the solar eclipse with scientists from the National Solar Observatory.

Another NSF-funded citizen outreach-focused project was the American Astronomical Society's program called, [Solar Eclipse Across America](#). This project included an eclipse project manager, a centralized website of resources, and a mini-grants program to coordinate and facilitate local and national activities to educate the public about the science of the event. The program funded 31 projects in 21 states, leveraging curiosity about the eclipse to engage as many people as possible in the endeavor of science.

Lessons learned are now being collated in a publicly available formal report that will lay the groundwork for a strategic plan to fully capitalize on the next U.S.-based total solar eclipse in 2024. Because this project aligns well with the objectives of multiple NSF directorates, this award is co-funded by the Division of Undergraduate Education and the Division of Research on Learning in the Directorate for Education and Human Resources; the Division of Astronomical Sciences in the Directorate for Mathematical and Physical Sciences; and the Division of Atmospheric and Geospace Sciences in the Directorate for Geosciences.

Public participation in scientific research projects such as these are instrumental in educating K-12 learners and beyond because they provide hands-on experiences that can be followed through to results. These kinds of STEM (Science, Technology, Engineering, and Mathematics) education activities serve to inspire and train the next generation of scientists and engineers.

Future

Two more major solar eclipses are coming to the U.S. in the not-too-distant future. On Saturday, October 14, 2023, an annular ("ring of fire") eclipse sweeps from Oregon to Texas in a 125-mile-wide path. Just six months later, on Monday, April 8, 2024, a total solar eclipse darkens a 115-mile-wide swath from Texas to Maine. In both cases, all of North America will have at least a partial solar eclipse.

By early 2020, NSF won't need to wait for an eclipse to study the sun's corona in great detail. NSF's Daniel K. Inouye Solar Telescope (DKIST), which will be the new centerpiece of the National Solar Observatory, is now nearing completion on the summit of Haleakalā on Maui, Hawaii. DKIST, at a total project cost of \$344 million, will be the largest, most powerful solar telescope in the world, located at an optimal site for solar research. Research conducted with DKIST is expected to lead to a better understanding of the sun. Such understanding has the potential to reduce significantly the impact from a Carrington event by enabling an increased warning time for such an event.

The primary mirror for DKIST—the heart of this sophisticated instrument—was successfully delivered to its destination atop Haleakalā on August 2. The safe delivery marks a major milestone for the DKIST project. The 4-meter (13-foot) mirror is an engineering marvel, polished to a surface roughness of only 2 nanometers (2 billionths of a meter), the scale of single molecules. The mirror will be supported by 142 electromechanical actuators that will adjust the structure, compensating for the pull of gravity as it tilts throughout the day, from sunrise to sunset. A fast, adaptive optics system also will compensate for atmospheric distortions to provide views of solar phenomena on scales as small as 20 kilometers (roughly 10 miles) on the sun.

DKIST will be the most sensitive instrument available for studying the various layers of the sun, including the corona. Specifically, DKIST will include a coronagraph, which allows researchers to create an artificial eclipse blocking the bright light of the sun. This will permit researchers an unprecedented, close-up view of the solar corona, which is nearly 1 million times dimmer than the light from the sun itself. The summit of Haleakalā is one of the few places on Earth with "coronal skies," meaning solar astronomers can view the sun's corona relatively free from the hazy scattering of light caused by the Earth's atmosphere.

Summary

The recent solar eclipse was a great opportunity for scientific research and for citizen engagement in an event that brought a sense of wonder, curiosity, and awe to scientists and citizens alike. It helped highlight all that we still have to learn about the sun and its impacts on earth. The basic research to be conducted with NSF's Daniel K. Inouye Solar Telescope will revolutionize our understanding of the sun, and our ability to mitigate future extreme space weather events. The combination of grass-roots citizen engagement and leading-edge scientific research exemplify the role of the National Science Foundation for our society, and we are pleased to enjoy the support of the committee and the public in fulfilling this role.