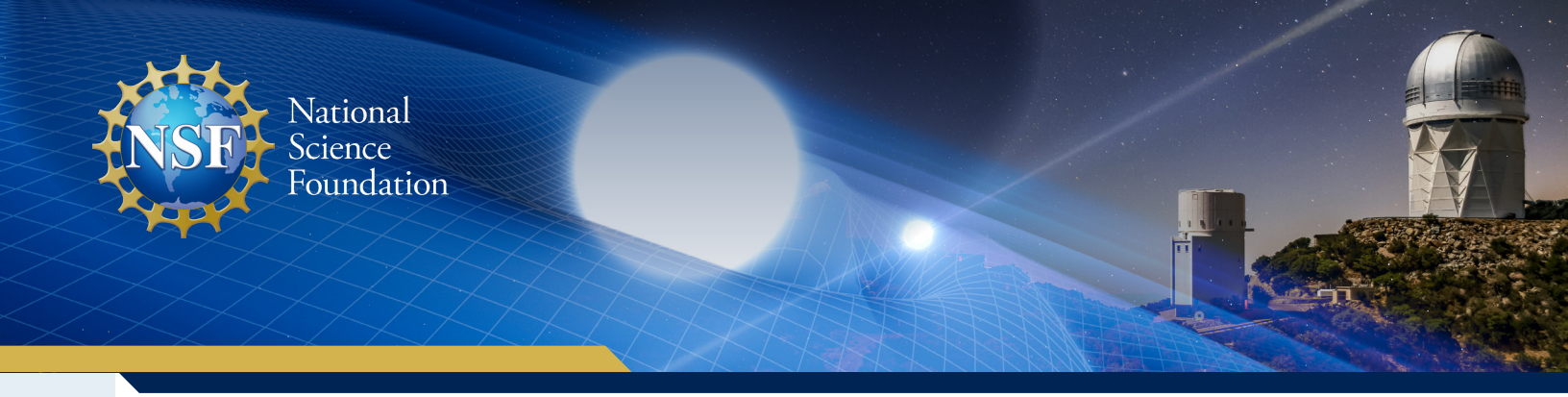
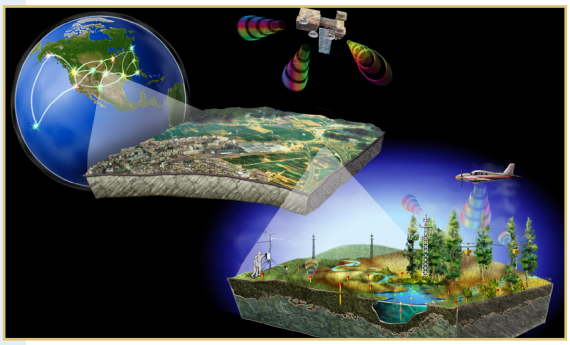


NSF Major Multi-User Facilities

DIRECTORATE FOR BIOLOGICAL SCIENCES:



Credit: Nicolle R. Fuller, National Science Foundation

National Ecological Observatory Network

The National Ecological Observatory Network, NEON, consists of geographically distributed field and lab infrastructure networked into an integrated research platform for regional to continental scale ecological research. Cutting-edge sensor networks, instrumentation, observational sampling, natural history archive facilities and remote sensing will be linked via the internet to computational, analytical and modeling capabilities to create NEON's integrated infrastructure. NEON is the first research platform, and only national facility, specifically designed to collect consistent and standardized sensor and observational measurements across 81 sites nationwide.

NEON enables research on the impacts of climate and land use change, water use, and invasive species on the Nation's living ecosystems at temporal and spatial scales. No other standalone system — federal or private — can provide the scientifically validated suite of data measurements that NEON is delivering.

The managing organization for NEON is Battelle Memorial Institute, Inc., funded under a cooperative agreement. In July 2019, the NSF notified the National Science Board of its intention to exercise the option to provide funding to Battelle for a fourth year. Therefore, the current Operations and Maintenance award to Battelle, which began in November 2017, was scheduled to end in October 2021. Because of delays in the next management competition resulting from COVID-19, which prevented site visits by potential non-incumbent proposers, the award to Battelle has been extended through October 2023. Oversight is provided by the BIO Division of Biological Infrastructure.

- Management competition is underway, although delayed somewhat by COVID-19. The NEON management solicitation has been re-issued, with proposals now due by Jan. 31, 2022.

DIRECTORATE FOR GEOSCIENCES:

Credit: Oregon State University

Academic Research Fleet

The Academic Research Fleet, ARF, included 18 vessels in Calendar Year 2020. ARF ships range in size, endurance and capabilities and serve as the main platform for the collection of data, testing of hypotheses about the structure and dynamics of the ocean, and development and testing of novel oceanographic instrumentation. ARF vessels are owned by NSF, academic institutions or the U.S. Navy.

ARF is financially supported through an interagency partnership, principally with the Office of Naval Research, ONR and the National Oceanic and Atmospheric Administration. Oversight is provided to the ARF by the GEO Division of Ocean Sciences through cooperative agreements with each ship-operating institution and through a separate cooperative agreement with University-National Oceanographic Laboratory System, which schedules ship time for research cruises. NSF is the cognizant agency for ship day-rate negotiations regardless of owner. All cooperative agreements for ship operations were renewed in 2018 and will be competed openly every 10 years.

CY 2019 funding provided support for 1,675 ship operating days, including the entry to the fleet of research vessel Neil Armstrong and R/V Sally Ride, the two new vessels delivered by ONR in 2016. CY 2020 funding supported 1,719 operating days, which was considerably lower than planned. COVID-19 caused a complete stand-down of the fleet from March 2020 into early July 2020, followed by a gradual resumption of voyages with new social distancing and quarantine procedures in place. The ONR-owned R/V Revelle reentered the fleet in CY 2020 after a one-year mid-life refit, and NSF transferred the ownership of R/V Marcus G. Langseth to Columbia University. Columbia continues to operate the ship for marine seismic research with support from NSF.

In CY 2021, ARF was able to safely accomplish approximately 95% (3,059 operational days) of the originally planned work or that deferred from CY 2020. In addition, the ONR-owned R/V Atlantis completed a mid-life refit and returned to service. The overhaul of the deep-submergence vehicle Alvin, including an upgrade to 6,500-meter depth capability, was also conducted under very strict COVID-19 protocols.

- Some vessels will be retired and replaced by the new Regional Class Research Vessels when they come online.

Credit: Architectural design by Glosten Associates Inc.

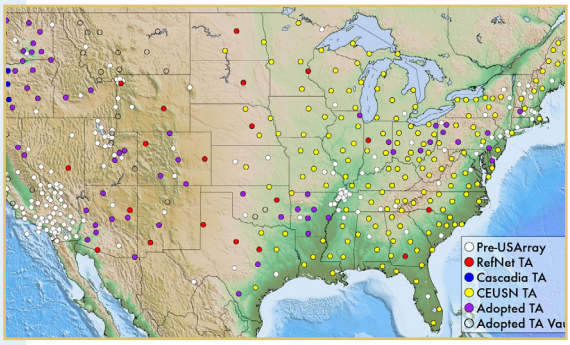
Regional Class Research Vessel

Major Research Equipment and Facilities Construction Account project

The Regional Class Research Vessel, RCRV, project is a major component in the plan for rightsizing and modernizing the U.S. Academic Research Fleet and will provide vessels essential for U.S. coastal ocean research. RCRV is a Major Research Equipment and Facilities Construction Account, MREFC, project.

The RCRV project is funded through a cooperative agreement with Oregon State University to manage the design, construction and commissioning of three RCRVs and the operation of the first RCRV —R/V Taani; "taani," pronounced "tawney," is a word in the Siletz tribal language meaning "offshore." The East Coast Oceanographic Consortium, led by the University of Rhode Island, was selected for operation of the second RCRV, R/V Narragansett Dawn. NSF selected the Gulf-Caribbean Oceanographic Consortium — whose members include the University of Southern Mississippi, the Louisiana University Marine Consortium and 15 associate members — as operator for the third RCRV, R/V Gilbert R. Mason.

Oregon State has contracted with Bollinger Houma Shipyards in Houma, Louisiana, for construction of all RCRVs (Bollinger acquired the shipyard from Gulf Island Shipyards). Oversight is provided by the GEO Division of Ocean Sciences.



Credit: courtesy IRIS

Geodetic Facility for the Advancement of Geoscience

The Geodetic Facility for the Advancement of Geoscience, GAGE, is a distributed, multi-user, national facility that supports fundamental research and discovery on continental deformation, plate boundary processes, the earthquake cycle, the geometry and dynamics of magmatic systems, continental groundwater storage and hydrologic loading.

GAGE is managed and operated for NSF through a cooperative agreement with the University NAVSTAR Consortium, or UNAVCO, which was renewed for a five-year term from October 1, 2018, through September 30, 2023.

UNAVCO is a consortium of 115 U.S. universities and nonprofit institutions with research and teaching programs in geophysics and geodesy, and 108 associate members from foreign institutions. Oversight is provided by the GEO Division of Earth Sciences.

- GEO recently announced that GAGE and the Seismological Facility for the Advancement of Geoscience, or SAGE will be open to competition for management by a single entity beginning in 2025 (start date changed from 2023 to permit input from a decadal survey and interagency discussions).

UNAVCO and the Incorporated Research Institutes for Seismology — the current manager of SAGE — have announced their intention to merge, effective in December 2022.

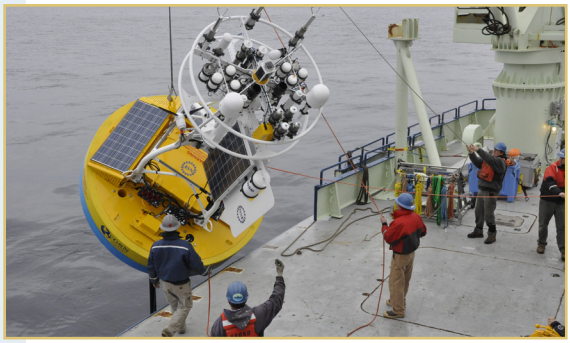
Credit: William Crawford and IODP

International Ocean Discovery Program

The International Ocean Discovery Program, IODP, represents an international partnership of scientists, research institutions and funding organizations from 23 nations to explore the evolution, structure and behavior of Earth as recorded in the ocean basins. Annual operations and maintenance support for operating the JOIDES Resolution, the most-used IODP platform, represents NSF's primary contribution to the program.

NSF provides the JOIDES Resolution as the light IODP drillship through a five-year cooperative agreement with Texas A&M University, renewed Oct. 1, 2019. NSF funding is leveraged by international partners. Oversight of IODP is provided through the GEO Division of Ocean Sciences.

- JOIDES Resolution was damaged during a dry-dock accident in 2018; all necessary repairs have now been completed at no cost to NSF.
- COVID-19 disrupted the drilling expeditions planned for Fiscal Years 2020 and 2021. Under strict mitigation protocols, several engineering cruises were conducted during this period, setting the stage for future scientific expeditions. The first expedition, including a complement of scientists, was conducted in late FY 2021, following quarantine and COVID-19 testing protocols.



Credit: Elizabeth Caporelli, © Woods Hole Oceanographic Institution

Ocean Observatories Initiative

The Ocean Observatories Initiative, OOI, is a networked, ocean-focused research observatory with arrays of instrumental buoys, profilers, gliders and autonomous vehicles operating in different open-ocean and coastal regions and with a cabled array of instrumented platforms and profilers on or above the seafloor over the Juan de Fuca tectonic plate. This networked system enables researchers to study complex, interlinked physical, chemical, biological and geographic processes throughout coastal regions. Some OOI sensors ran out of battery power because servicing was not possible during the COVID-19 peak, but all are now back in service.

Oversight is provided by the GEO Division of Ocean Sciences. OOI is managed and operated under a five-year cooperative agreement with Woods Hole Oceanographic Institution, which began Oct. 1, 2018 and ends on Sept. 30, 2023.

- Operation of OOI's cyberinfrastructure was transferred from Rutgers University to Oregon State University at the end of July 2021.
- A line fault in the Southern Line of the Regional Cabled Array occurred in August 2020. Repairs were effected with the help of a contracted cable ship and the sensors have been brought back online as of August 2021.

Credit: Earthscope

Seismological Facility for the Advancement of Geoscience

The Seismological Facility for the Advancement of Geoscience, SAGE, is a distributed, multi-user, national facility for the development, deployment and operational support of modern digital seismic instrumentation to serve national goals in basic research and education in earth sciences, earthquake research, global real-time earthquake monitoring, and nuclear test ban verification.

SAGE is managed and operated by the Incorporated Research Institutes for Seismology, or IRIS, which is incorporated as a nonprofit consortium representing 125 U.S. universities and nonprofit organizations with research and teaching programs in seismology. See the Geodetic Facility for the Advancement of Geoscience section for information on award status and the next competition. Oversight is provided by the GEO Division of Earth Sciences.

- The Alaska Transportable Array, or ATA, component of SAGE was scheduled for decommissioning in 2020 but was operated for another year in a bare-bones mode because COVID-19 prevented removal of the hardware. Removal of remaining ATA stations was completed in September 2021.
- IRIS and the University NAVSTAR Consortium (the current manager of GAGE) have announced their intention to merge, effective in December 2022.

Credit: © UCAR byCarlye Calvin (CC BY-NC 4.0)

National Center for Atmospheric Research — Boulder, Colorado

Federally Funded Research and Development Center

The National Center for Atmospheric Research, NCAR, is an NSF-sponsored Federally Funded Research and Development Center serving a broad research community, including atmospheric and geospace scientists and researchers in complementary areas of the environmental sciences and geosciences. NCAR provides world-class research programs, services and facilities that enable the research community to advance understanding of the sun-atmosphere system. These facilities include the NCAR-Wyoming Supercomputing Center, the Mauna Loa Solar Observatory, two research aircraft, a transportable ground-based radar system, an atmospheric sounder and other surface sensing systems.

NCAR is managed under a five-year cooperative agreement through Sept. 30, 2023, with the University Corporation for Atmospheric Research. Oversight is provided by the GEO Division of Atmospheric and Geospace Sciences.

- The NCAR aviation infrastructure in Broomfield, near Boulder, Colorado, has been replaced with a new facility, which opened for operation in September 2021.

Credit: Peter Rejcek, National Science Foundation

Antarctic Facilities and Operations

The Office of Polar Programs, OPP, manages Antarctic facilities and operations and provides the infrastructure needed to support U.S. research conducted in Antarctica, including research funded by NSF and by U.S. mission agencies, for year-round work at three U.S. stations, on two research ships and at numerous remote field camps. Through its active and influential presence on the continent, the U.S. Antarctic research program advances science in support of some of the most critical issues of our time, including climate change and its impacts.

OPP has overall responsibility for managing Antarctic facilities under the U.S. Antarctic Program. The Antarctic prime support contract is currently held by Leidos Innovations Corporation, with many separate subcontractors for supplies and technical services. NSF has initiated a competitive procurement process for the follow-on acquisition at the end of the current contract in Fiscal Year 2025.

- COVID-19 and its associated risks and restrictions caused significant delays in science support for the 2020-21 and 2021-22 research seasons. Operational and scientific infrastructure was safely maintained, but a large backlog of science activities resulted from a severe reduction in on-ice deployers. Levels of support will need to surge in future seasons to resume robust science.

Credit: Sven Lidstrom, National Science Foundation

IceCube Neutrino Observatory — South Pole, Antarctica

The IceCube Neutrino Observatory is the world's first high-energy neutrino observatory. It is located deep within the ice cap under the U.S. NSF Amundsen-Scott South Pole Station in Antarctica. The observatory includes a Deep Core Array with tightly spaced digital optical modules to detect lower energy neutrinos. It provides unique data on the engines that power active galactic nuclei, the origin of high-energy cosmic rays, the nature of gamma ray bursts, the activities surrounding supermassive black holes and other violent and energetic astrophysical processes.

IceCube is managed by the University of Wisconsin-Madison under a five year cooperative agreement that began on April 1, 2021. Oversight is the joint responsibility of OPP and the MPS Division of Physics.

- Operations at the South Pole have continued over the southern winter seasons despite the challenges to South Pole access during COVID-19, with remote work by staff in the U.S. sustaining the data flow to the scientific community.

Credit: courtesy OZ Architecture

Antarctic Infrastructure Recapitalization

Formally, Antarctic Infrastructure Modernization for Science project Major Research Equipment and Facilities Construction project

The Antarctic Infrastructure Modernization for Science, AIMS, project will replace major facilities at McMurdo Station, Antarctica, one of three stations that make up the U.S. presence in Antarctica, to meet anticipated science support requirements for the next 35 to 50 years. The project will also support critical scientific research and capabilities such as nuclear test detection, earthquake monitoring and real-time weather data ingestion for global forecasting. McMurdo Station's main purpose is to support both near- and deep-field science in Antarctica, including activities at Amundsen-Scott South Pole Station. AIMS will enable faster, more streamlined logistical and science support. Oversight is provided by the GEO Office of Polar Programs.

At the February 2019 National Science Board, meeting, the NSB authorized NSF to move forward with the AIMS, project. AIMS was planned as a 10-year undertaking to overhaul McMurdo Station into an energy- and operationally efficient platform from which to support world-class science. However, the extreme impact of COVID-19 on access to Antarctica, including lockdowns at the NSF gateway in Christchurch, New Zealand, had a severe impact on AIMS's cost and schedule. Inability to execute AIMS on the original schedule has led to the urgency of other Antarctic infrastructure needs; these needs cannot be deferred until after completion of the original scope of AIMS. Therefore, AIMS has been replanned to include only a portion of the originally envisioned project and will be transitioned to a sustainable Antarctic Infrastructure Recapitalization program.

DIRECTORATE FOR MATHEMATICAL AND PHYSICAL SCIENCES:

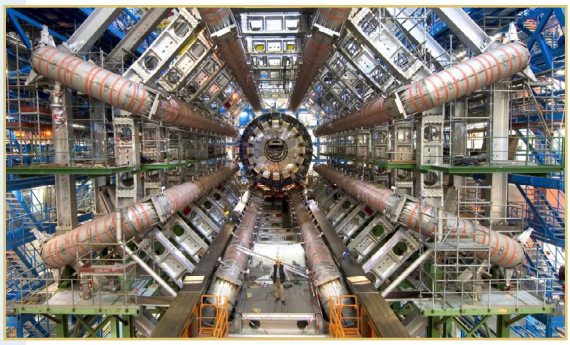
Credit: NAIC Arecibo Observatory, a facility of the NSF

Arecibo Observatory — Arecibo, Puerto Rico (National Astronomy and Ionosphere Center)

Built in 1963, Arecibo Observatory was for decades the site of the world's largest operating single-dish radar/radio telescope, with a 305-meter diameter reflector. Three major areas of research were supported at Arecibo: radio astronomy, solar system radar astronomy and geospace and atmospheric sciences. Arecibo suffered a direct hit by Hurricane Maria in 2017 and a series of major earthquakes from late 2019 into 2020. Following an initial cable failure in August 2020, the receiver platform of the 305-meter telescope suffered a catastrophic collapse on December 1, 2020. Clean-up of the debris from that collapse, which destroyed the upper parts of the support towers and a significant portion of the reflector dish, is nearly complete. Discussions regarding future use of the site are ongoing.

Arecibo is operated by the University of Central Florida; Yang Enterprises, Inc.; and Universidad Ana G. Méndez under a five-year cooperative agreement that began on April 1, 2018.

Arecibo is jointly supported by the MPS Division of Astronomical Sciences and the GEO Division of Atmospheric and Geospace Sciences. Arecibo was also supported by NASA under their Near-Earth Object Observation Program, but that support is ending in FY 2022 because the NASA radar system is not operable without the 305-meter reflector.



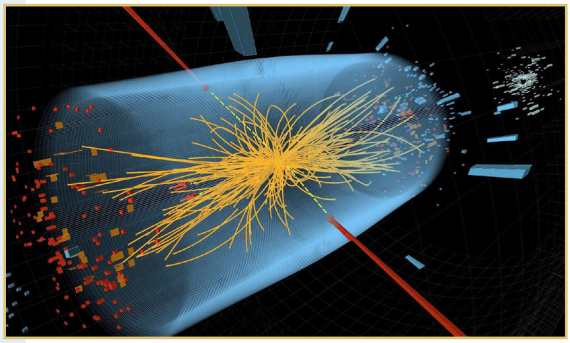
Credit: CERN

Large Hadron Collider — European Organization for Nuclear Research — Geneva, Switzerland

The Large Hadron Collider, LHC, is an international project at the European Organization for Nuclear Research, CERN, laboratory in Geneva, Switzerland. It is the most powerful particle accelerator ever constructed and has the highest energy particle beams ever created, making it the premier facility in the world for research in elementary particle physics. It consists of a superconducting particle accelerator, about 16.5 miles in circumference, providing two counter-rotating proton beams. Four large particle detectors collect the data delivered by the LHC. Researchers use the data to search for new particles and forces.

CERN is responsible for meeting the overall LHC project goals and coordinating international participation. The U.S., through a partnership between NSF and the U.S. Department of Energy, is a major contributor to the construction and operation of two of the largest particle detectors: A Toroidal LHC ApparatuS, ATLAS; and the Compact Muon Solenoid. Oversight is provided by the MPS Division of Physics.

- The LHC is preparing to resume operations in 2022 to collect data for approximately three years. The pandemic has had relatively little impact on detector operation and near-term plans, since NSF's support is concentrated in areas such as computing that can be accomplished remotely.
- The LHC is currently engaged in an upgrade to higher luminosity of the particle beam, described below.



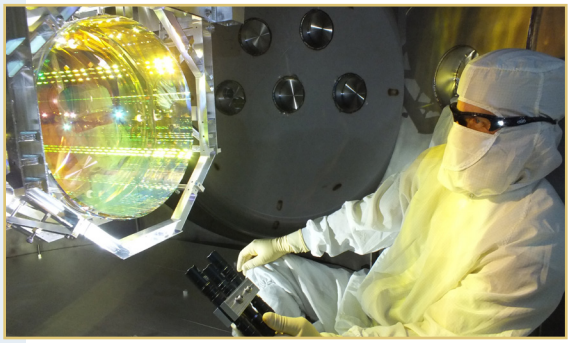
Credit: CERN/CMS collaboration 2011

High Luminosity — Large Hadron Collider Upgrade — Geneva, Switzerland

Major Research Equipment and Facilities Construction project

A major international effort is underway to upgrade the luminosity of the particle beam at the Large Hadron Collider, or LHC (see above), to increase the intensity of the high-energy particle collisions and unleash a torrent of data for research in elementary particle physics. NSF is one of more than 45 funding agencies contributing to this effort. NSF's contributions to the upgrades will enhance the ATLAS and Compact Muon Solenoid detectors at the LHC to enable them to exploit the scientific opportunities that will result from high luminosity operation of the LHC. NSF funding is concentrated in a few key areas such as high granularity sensor and electronic signal readout, where the work it supports can proceed relatively independently from that supported by other agencies; however, the upgrade effort, like LHC operations, is being closely coordinated with the U.S. Department of Energy. Oversight is provided by the MPS Division of Physics.

- FY 2020 was the first year of requested and appropriated construction funds for a five-year project.
- The pandemic has significantly delayed efforts supported by NSF and other funding partners to upgrade the detectors because of restrictions on access to workshops, laboratories and test facilities where the upgraded components are being fabricated and tested.



Credit: Matt Heintze/Caltech/MIT/LIGO Lab

Laser Interferometer Gravitational-wave Observatory — Livingston, Louisiana, and Hanford, Washington

The Laser Interferometer Gravitational-wave Observatory, LIGO, is the most sensitive gravitational-wave detector ever built, with two main facilities: at Livingston, Louisiana, and Hanford, Washington. Each facility has an L-shaped vacuum chamber with two 4-km long arms joined at right angles and each houses an optical interferometer. A passing gravitational wave causes one arm to lengthen and the other to shrink. Einstein's theory of relativity predicts that cataclysmic processes involving extremely dense objects in the universe — for example, the collision of black holes — will produce gravitational radiation. LIGO directly observed gravitational radiation from a black hole merger for the first time in September 2015. The Advanced LIGO upgrade is expected to increase its sensitivity tenfold.

LIGO is operated by the California Institute of Technology through a five-year cooperative agreement that began October 1, 2018. Oversight is provided by the MPS Division of Physics.

- NSF has funded the "A+" upgrade to LIGO, involving improved mirror coatings and quantum light squeezing, in order to increase the detection threshold by a factor of five over Advanced LIGO. That upgrade is going on in parallel with the staged effort to reach the full sensitivity of Advanced LIGO; both have been slowed somewhat by the impacts of COVID-19. The next scientific observing session of LIGO, O4, originally scheduled to begin in early 2022, is now scheduled to begin no sooner than August 2022.

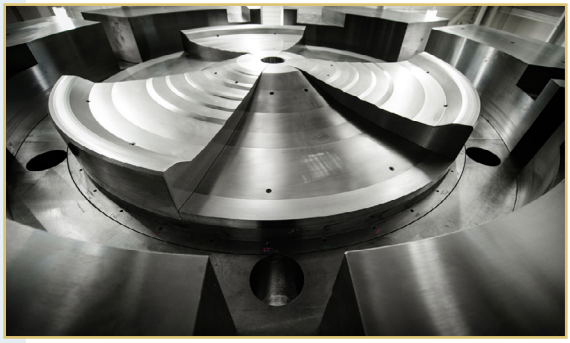
Credit: National MagLab

National High Magnetic Field Laboratory — Tallahassee, Florida

The National High Magnetic Field Laboratory, NHMFL, develops and operates high magnetic field facilities that scientists and engineers use for research in condensed matter and material physics, materials science and engineering, chemistry, biology, biochemistry, neuroscience, energy and the environment. It is the world's premier high magnetic field laboratory. It is an internationally recognized leader in magnet design, development and construction, including the development of new superconducting materials.

NHMFL is operated by a consortium of Florida State University, the University of Florida and Los Alamos National Laboratory under a cooperative agreement covering a five-year period from Jan. 1, 2018, to Dec. 31, 2022. Renewal of that agreement to cover the five-year period beginning in January 2023 is planned. Oversight is provided by the MPS Division of Materials Research, with some oversight by the Division of Chemistry.

- The NHMFL celebrated 25 years in operation in October 2019.
- NSF is currently supporting the design of a new 40-Tesla all-superconducting magnet at the NHMFL through the Mid-scale Research Infrastructure-1 program.



Credit: MSU

National Superconducting Cyclotron Laboratory — Michigan State University

The National Superconducting Cyclotron Laboratory, NSCL, is a national user facility based at Michigan State University. It has two linked superconducting cyclotrons, and it is the leading rare isotope research facility in the U.S. It is a world leader in nuclear physics with the unique capability of producing radioactive beams at energies relevant to nuclear astrophysics. Scientists at NSCL make and study atomic nuclei that cannot be found on Earth and perform experimental research using beams of unstable isotopes to extend our knowledge of new types of nuclei.

Michigan State operates NSCL under a cooperative agreement with NSF. The U.S. Department of Energy, DOE, is currently constructing the new Facility for Rare Isotope Beams, or FRIB, on the NSCL site. After construction is completed, oversight will transfer to DOE. The cooperative agreement for NSCL was originally planned to expire in Fiscal Year 2021 but has been extended through FY 2022 to allow for interleaving of approved experiments and completion of FRIB construction. Oversight is provided by the MPS Division of Physics.

Credit: NRAO/AUI/NSF

Green Bank Observatory — Green Bank, West Virginia

Federally Funded Research and Development Center

Green Bank Observatory, GBO, is a major NSF research facility and a Federally Funded Research and Development Center located in Green Bank, West Virginia. Radio telescopes, including the Robert C. Byrd Green Bank Telescope, or GBT, provide key ground-based radio-wavelength research facilities. The GBT is the world's largest fully steerable single-dish radio telescope and is GBO's flagship research instrument. In conjunction with observations from other types of telescopes, data from GBT address topics from fundamental physics to the discovery and characterization of interstellar organic molecules that provide insight into the organic chemistry of life on Earth and the search for life beyond. GBO is located in the 13,000-square-mile National Radio Quiet Zone.

Formerly part of the National Radio Astronomy Observatory, NRAO, GBO was separated in Fiscal Year 2017 from NRAO but continues to be managed by Associated Universities, Inc., or AUI. In FY 2020, NSF awarded a new five-year cooperative agreement to AUI for operations and maintenance of GBO. Oversight of GBO is provided through the MPS Division of Astronomical Sciences.

- GBO receives support from external partners and other sources, including Breakthrough Listen, the Gordon and Betty Moore Foundation, the NSF-funded NANOGrav Physics Frontier Center, and numerous small contracts, in exchange for observing time on the GBT.

Credit: Andrew Clegg, NSF

National Radio Astronomy Observatory —

Headquartered in Charlottesville, Virginia

Federally Funded Research and Development Center

The National Radio Astronomy Observatory, NRAO, conceives, designs, builds, operates and maintains state-of-the-art radio telescopes used by scientists from around the world. Operating synergistically with optical, infrared, x-ray, particle, and gravitational wave telescopes, NRAO facilities enable discovery over a remarkably broad range of key problems in modern astrophysics that reach from within our solar system to the most distant parts of the universe. NRAO supports facilities in Chile and the U.S. NRAO Telescopes include: the Atacama Large Millimeter/submillimeter Array, ALMA; the Very Large Array, VLA, near Socorro, NM (pictured left); and the Very Long Baseline Array, VLBA.

The managing organization for NRAO is Associated Universities, Inc., which is funded by a cooperative agreement with NSF. Oversight is provided by the MPS Division of Astronomical Sciences.

Credit: Karen Pearce, NSF

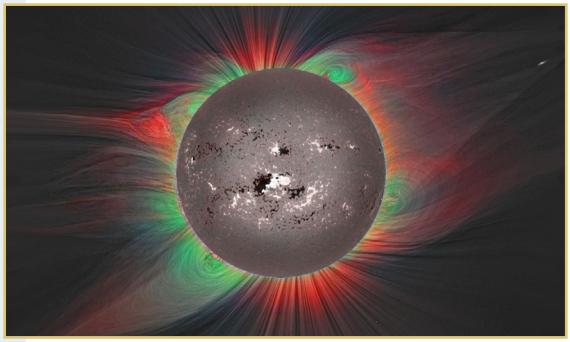
ALMA is an international partnership among a number of organizations, in cooperation with the Republic of Chile: NSF; the European Southern Observatory; the National Institutes of Natural Sciences of Japan; the National Research Council Canada; the National Science Council and the Institute of Astronomy and Astrophysics, Academia Sinica, in Taiwan; and the Korea Astronomy and Space Science Institute in the Republic of Korea. ALMA — the largest astronomical project in existence — is a single telescope of revolutionary design, composed of 66 high-precision antennas located on the Chajnantor plateau, at 5,100 meters altitude in northern Chile. Because of the severe impacts of COVID-19 in Chile and the need for support staff to travel regularly to the remote site, ALMA observations were halted for approximately a year, from March 2020 through March 2021.

Credit: Alex Savello, NRAO

The Very Large Array is one of the world's premier astronomical radio observatories, consisting of 27 radio antennas in a Y-shaped configuration on the Plains of San Agustin, 50 miles west of Socorro, New Mexico. Each antenna is 25 meters (82 feet) in diameter. Science observations at the VLA continued throughout the COVID-19 pandemic period, with only early minor impacts on maintenance and operations.

Credit: NRAO/AUI/NSF

The Very Long Baseline Array is the world's premier radio interferometer, using 10 identical 25-meter radio telescopes located across the U.S., from Hawaii to St. Croix, Virgin Islands. The VLBA provides key insight into the structure and evolution of the Milky Way and helps to determine the fundamental distance scale of the universe. VLBA is also used for fundamental support of the International Celestial Reference Frame, under an agreement with the U.S. Naval Observatory. Like the VLA, the VLBA continued to operate during the COVID-19 pandemic.



Credit: NSO

National Solar Observatory — Boulder, Colorado

Federally Funded Research and Development Center

The National Solar Observatory, NSO, is headquartered on the campus of the University of Colorado Boulder and provides leadership to the solar community through management of the NSO Integrated Synoptic Program, or NISP, and construction of the Daniel K. Inouye Solar Telescope, DKIST. NISP, through the Global Oscillation Network Group, provides a unique 24/7, full-disk data set for both scientific research and operations, including monitoring of solar active regions which can generate extreme space weather events.

The managing organization for NSO is the Association of Universities for Research in Astronomy, Inc., or AURA, which is funded under a 10-year cooperative agreement with NSF. In August 2014, NSB authorized a renewed cooperative agreement with AURA for management and operation of NSO. The renewal award started in June 2015 and will run through September 2024. Oversight is provided by the MPS Division of Astronomical Sciences.

- Scientific operation of the former NSO facility in Sunspot, New Mexico has been transitioned to a university-based consortium led by New Mexico State University (partially funded by NSF), as NSO moves its concentration to DKIST and continued operation of NISP.

Credit: NSO/AURA/NSF

Daniel K. Inouye Solar Telescope — Haleakala, Maui, Hawaii

With completion of construction in November 2021, the Daniel K. Inouye Solar Telescope, DKIST, is now operational. It is the world's most powerful solar observatory. DKIST will investigate the structure and evolution of magnetic structures on the sun on spatial scales of tens of kilometers, the scales of the processes that drive space weather.

NSO will operate and maintain DKIST after construction. Funding for operations and construction are provided by NSF through a cooperative agreement with the Association of Universities for Research in Astronomy, Inc.

NSO and the DKIST construction project are managed through the MPS Division of Astronomical Sciences.

Credit: Munizaga, CTIO/NSF's NOIRLab/AURA/D

NSF's National Optical-Infrared Astronomy Research Laboratory

Federally Funded Research and Development Center

Facilities include the Gemini North and South telescopes in Hawaii and Chile; the Kitt Peak National Observatory, in Arizona; the Cerro Tololo Inter-American Observatory, in Chile; the Community Science and Data Center, in Arizona; and operations of the Vera C. Rubin Observatory in Chile.

At the start of Fiscal Year 2020, NSF launched NSF's National Optical-Infrared Astronomy Research Laboratory, NOIRLab, a Federally Funded Research and Development Center that will be the foundational hub of U.S. ground-based, optical-infrared astronomy in the era of the Vera C. Rubin Observatory, multi-messenger astrophysics, data intensive science, and Extremely Large Telescopes. NOIRLab integrates into a single center the programs and activities that have previously been associated with the National Optical Astronomy Observatory, the Gemini Observatory, and the Rubin Observatory operations (NOIRLab does not encompass the Rubin Observatory construction project).

NOIRLab enables the U.S. research community to pursue a broad range of modern astrophysical challenges, from studying rapidly moving small bodies within the solar system to characterizing the most distant galaxies in the early universe and indirectly observing dark matter and dark energy.

NOIRLab is managed for NSF by the Association of Universities for Research in Astronomy, Inc. , which comprises 47 U.S. institutions and three international affiliates. Oversight is provided by the MPS Division of Astronomical Sciences.

Credit: Gemini Observatory

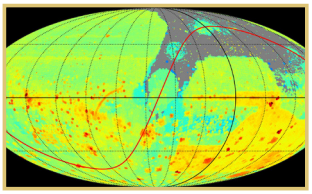
Gemini Observatory consists of twin optical/infrared 8-meter telescopes, one each in the northern and southern hemispheres, thereby providing complete coverage of the sky. Though Gemini is used for all areas of astronomy, topics of particular interest are high-resolution adaptive optics-assisted imaging and follow-up of time-domain and multi-messenger alerts. Other fundamental questions being investigated are the age and rate of expansion of the universe, the origin of dark energy, the nature of nonluminous matter, and the birth of stars and their planetary systems. Gemini is supported by an international partnership among the U.S., Canada, Brazil, Argentina, the Republic of Korea, and Chile.

Credit: P. Marenfeld; NOAO/AURA/NSF NOAO

The Kitt Peak National Observatory, or KPNO, supports the most diverse collection of astronomical observatories on Earth for nighttime optical and infrared astronomy. KPNO operates the Mayall 4-meter Telescope (specializing in dark energy science) and the Wisconsin-Indiana-Yale-NOIRLab, or WIYN, 3.5-meter Telescope (specializing in exoplanet characterization). KPNO also supports operations of 22 other small and mid-sized optical telescopes and two radio telescopes for university groups and various national/international partnerships. The Windows on the Universe Center for Astronomy Outreach is under construction and expected to open in 2022. Kitt Peak is located 56 miles southwest of Tucson, AZ.

Credit: NOAO/NSF/AURA

The Cerro Tololo Inter-American Observatory, or CTIO, operates the Blanco 4-meter Telescope on Cerro Tololo and the 4.2-m Southern Astrophysical Research Telescope, SOAR, on neighboring Cerro Pachón. Blanco excels in survey astronomy and dark energy science, complementing the higher-resolution capabilities of SOAR and Gemini. SOAR, Blanco and Gemini are also being used together as part of NOIRLab's Astronomical Event Observatory Network, responding to multi-messenger alerts from NSF facilities such as LIGO and IceCube Neutrino Observatory. Like KPNO, CTIO also supports operations of over two dozen small and medium-sized telescopes on Cerro Tololo for university consortia and foreign partners.



Credit: NOIRLab

The Community Science and Data Center, or CSDC,provides user support services, software tools and data management services for NOIRLab telescopes and for the entire U.S. community. CSDC maintains a science platform providing high-level tools for discovery, exploration and analysis of large public survey datasets, and is developing infrastructure for time-domain astronomy.

Credit: LSST Project/NSF/AURA

Vera C. Rubin Observatory — Cerro Pachón, Chile

Major Research Equipment and Facilities Construction project

The Vera C. Rubin Observatory, formerly known as LSST, will, once commissioned, be NSF's flagship optical survey instrument. Rubin Observatory will conduct an unprecedented, decade-long survey of the optical sky called the Legacy Survey of Space and Time. Rubin Observatory is a joint undertaking of NSF and the U.S. Department of Energy consisting of an 8-meter class wide-field ground-based telescope, a 3.2-gigapixel camera, an automated data processing system, and a public engagement platform. Rubin Observatory seeks to enable science in four main areas: understanding the nature of dark matter and dark energy, cataloging the Solar System, exploring the changing sky, and probing the Milky Way's structure and formation.

Operations will be part of NSF's National Optical - Infrared Astronomy Research Laboratory, but the construction project is independent of NOIRLab. Rubin Observatory construction is carried out by the Association of Universities for Research in Astronomy, Inc. through a cooperative agreement. Oversight is provided by the MPS Division of Astronomical Sciences.

- Rubin Observatory was approximately 90% complete as of June 2021. Primary remaining activities included integration of the telescope mount, completion of the data management system, and overall system integration and commissioning. COVID-19 has severely limited work on the mountain since March 2020, resulting in schedule delays amounting to 22 months and associated increases to project costs.

credit Sean Whelan-Woods Hole

Mid-scale Research Infrastructure Track 2

Major Research Equipment and Facilities Construction Account — Agency-wide

The Mid-scale Research Infrastructure, or Mid-scale RI for short, program is an NSF-wide effort to meet the research community's needs for modern research infrastructure to support priority science and engineering research. Mid-scale RI-2 covers projects with individual implementation costs between $20 million and $100 million with funding from the Major Research Equipment and Facilities Construction account, or MREFC.

In the 2018 appropriation for NSF, report language from the House of Representatives directed the National Science Board — in collaboration with the National Academies of Science, Engineering, and Medicine — to consider steps to bridge the gap between the NSF's Mid-scale RI program and the agency's MREFC account and to develop appropriate processes to address this matter through the MREFC account within a restricted funding environment.

NSF responded to these recommendations and the American Innovation and Competitiveness Act mandate to develop a strategy with the detailed Mid-scale RI program that is described in the NSF-Wide Investments chapter of the Budget Request. As part of that strategy, funding for the mid-scale projects with implementation costs above $20 million was requested in the MREFC account as Track 2 of an NSF-wide mid-scale program and funding was first appropriated in that account in Fiscal Year 2020. NSF issued its first solicitation for Mid-scale RI-2, NSF 19-542, in December 2018, requesting proposals with total implementation costs ranging between $20 million and $70 million.

Five Mid-scale RI-2 awards were made from the first solicitation:

- "High Magnetic Field Beamline," Cornell University, $32.69 million. This award supports the realization of a mid-scale infrastructure project that exploits cutting edge synchrotron X-ray tools to enable new science at the high magnetic field frontier by building a dedicated High Magnetic Field (HMF) X-ray facility at the Cornell High Energy Synchrotron Source, CHESS. This proposal is a partnership among CHESS, the National High Magnetic Field Laboratory, and the University of Puerto Rico.

- "Global Ocean Biogeochemistry Array," Monterey Bay Aquarium Research Institute, $52.94 million. This project aims to drive a transformative shift in our ability to observe and predict, at the global scale, the effects of climate change on ocean metabolism, carbon uptake, and living marine resource management by implementing an innovative and sustained robotic network of 500 profiling floats carrying chemical and biological sensors that would take measurements from 2000-meters depth to the surface every 10 days for several years.

- "Grid-Connected Testing Infrastructure for Networked Control of Distributed Energy Resources," University of California, San Diego, $39.47 million. DERConnect represents a first-of-its-kind complete integrated grid system, enabling the exploration of joint optimization of grid operations and communications infrastructure in both normal and adversarial operating conditions. The project aligns well with the nation's high-priority goals of clean and efficient energy.
- "Network for Advanced NMR [Nuclear Magnetic Resonance]," University of Connecticut, $39.72 million. This award will support the establishment of the geographically distributed Network for Advanced NMR in the U.S. to provide ultra-high field NMR spectrometers, allowing users to tackle important and diverse scientific problems, and to educate and train the next generation of scientists and engineers. Scientific research areas enabled by these systems cover a wide range of problems in structural biology, dynamics, and function of different biological systems from molecules to whole cells and tissues, as well as complex mixtures, metabolomics and natural products. Non-biological applications include, but are not limited to, amorphous materials, battery components, pharmaceutical ingredients, nanomaterials, surface coatings and catalysts.
- "The Research Data Ecosystem, a National Resource for Reproducible, Robust, and Transparent Social Science Research in the 21st Century," University of Michigan, $38.36 million. This award will support the development of infrastructure to advance social science research, including a suite of software modules and accompanying standards for data and metadata, that will improve the quality, integrity and safety of data while increasing accessibility to users across disciplines.