

**SEISMOLOGICAL FACILITY FOR THE ADVANCEMENT
OF GEOSCIENCE (SAGE)**

**\$21,870,000
+\$20,000 / 0.1%**

**Seismological Facility for the Advancement of
Geosciences Funding
(Dollars in Millions)**

FY 2020 Actual	FY 2021 Estimate	FY 2022 Request	Change over	
			FY 2021 Estimate Amount	Percent
\$21.50	\$21.85	\$21.87	\$0.02	0.1%

Brief Description

SAGE is a distributed, multi-user facility that enables a diverse PI community to make advances in understanding Earth processes that would otherwise not be possible, through broad access to seismic instrumentation, field training and support, and data services. SAGE provides the development, deployment and operation of modern digital seismic instrumentation and related geophysical instrumentation, including magnetotellurics and infrasound. The facility operates a global network of seismic stations; provides field and technical resources; supports data archiving, quality control, and distribution; and provides education and outreach activities that serve a wide range of audiences. SAGE deploys geophysical instruments globally—on the land, including in polar regions, and under the oceans.

Scientific Purpose

SAGE data and services advance fundamental studies in earthquake and fault processes, Earth structure and evolution, volcanoes and magmatic systems, glacier and ice sheet dynamics, and near-surface Earth processes, like landslides, hydrology, and sedimentation. Data from SAGE are also used for studies of solid earth geohazards research, as well as monitoring of natural and anthropogenic hazards, such as global real-time earthquake monitoring, and nuclear test ban verification.

Status of the Facility

SAGE is currently in year three of a five-year award, and the current capabilities provided by the facility have evolved based on input from a series of community engagement activities held in 2015, including a NSF-sponsored workshop entitled “Future Seismic and Geodetic Facility Needs in the Geosciences”.¹ The Division of Earth Sciences (EAR) in the Directorate for Geosciences is deliberating the path forward for evolving NSF’s geophysical facilities to best enable emerging research directions. In 2018, EAR commissioned a National Academies of Science, Engineering, and Medicine-led decadal survey that identified the top research priorities for the Earth sciences for the next decade. Released in July 2020, *A Vision for NSF Earth Sciences 2020-2030: Earth in Time*² reaffirmed the importance of NSF’s seismic and geodetic facilities in advancing Earth science research over the next decade.

As part of the decadal survey process, a workshop entitled *Management Models for Future Seismological and Geodetic Facilities and Capabilities* was held to review the strengths and weaknesses of different management models for NSF geophysical facilities.³ Following the release of the workshop report EAR announced that, at the time of the next competition for their management and operation, the current SAGE and Geodetic Facility for the Advancement of GEoscience (GAGE) facilities would be consolidated into a

¹ www.iris.edu/hq/files/workshops/2015/05/fusg/reports/futures_report_high.pdf

² www.nap.edu/catalog/25761/a-vision-for-nsf-earth-sciences-2020-2030-earth-in

³ www.nap.edu/catalog/25536/management-models-for-future-seismological-and-geodetic-facilities-and-capabilities

Major Facilities

single facility with a single operator.⁴

To further inform its planning for the future geophysical facility, the Directorate for Geosciences commissioned from a subcommittee of its Advisory Committee a portfolio review of possible geophysical instrumentation and sensor networks that a new facility might support to address the science priorities highlighted in the decadal survey. The portfolio review highlights the capabilities that a new facility should support in order to best enable the community to address the science priorities in the 2020 decadal survey. Additionally, the portfolio review report emphasizes the importance of developing partnerships in support of elements of SAGE and GAGE that are mission critical for other Federal agencies. EAR is now strategizing to define the best path forward for a future facility and undertaking efforts to expand existing federal partnerships.

COVID-19 impacts: SAGE has continued to operate remotely during the COVID-19 pandemic, with most staff teleworking and data continuing to flow. Restrictions on travel and social distancing precluded decommissioning and removal of the Alaska Transportable Array (ATA) as had been planned during 2020. Instead, ATA continues “bare-bones” operations and data delivery, with removal now planned for 2021.

Meeting Intellectual Community Needs

SAGE users include scientists who perform research using instruments and/or data provided via SAGE; educators who make use of teaching materials and training made available via SAGE; other Federal agencies and international groups that make use of resources and/or data provided via SAGE for multiple operational purposes; and interested members of the public and private sector.

SAGE users can access data and many educational products via the internet at no cost. Scientists making use of equipment, training, and other resources provided by SAGE typically are funded via awards from NSF, the U.S. Geological Survey (USGS), and other agencies. The Geophysics, GeoPRISMS, Tectonics, and Frontier Research in Earth Sciences in EAR; the GeoPRISMS and Marine Geology and Geophysics programs in the Division of Ocean Sciences (OCE); and the Earth Science and Glaciology programs in the Office of Polar Programs (OPP) provide most of the funds for the NSF-sponsored research making use of SAGE.

Demands remain high for data, equipment, and other resources provided via SAGE. In the first three quarters of fiscal year 2020:

- The total amount of data downloaded from the SAGE Data Management Center increased by a factor of 1/3 compared to the same period in FY 2019;
- At least 70 field experiments used equipment and support provided via SAGE worldwide; and
- More than 150,000 classroom activities were downloaded by K-16 educational projects.

Governance Structure and Partnerships

NSF Governance Structure

SAGE, together with GAGE, is overseen by a single Integrated Project Team (IPT) whose charge is to: 1) establish a collaborative team with a broad spectrum of expertise and perspective to help address current facility challenges and identify potential barriers to project success; 2) ensure effective and timely communications regarding facility activities and issues across NSF organizations by sharing knowledge and information on a regular and recurring basis; and 3) provide a formal mechanism to coordinate agency-wide oversight, take effective action, and remain accountable in support of program activities.

⁴ www.nsf.gov/pubs/2020/nsf20037/nsf20037.jsp

The IPT membership includes a core group consisting of the SAGE and GAGE managing Program Officer (PO), a representative from the Division of Acquisition and Cost Support, and an LFO official. The GAGE and SAGE PO serves as chair of the IPT. The IPT will remain active through the planned five-year duration of the GAGE and SAGE awards. The IPT chair is responsible for uploading all IPT documentation into the official electronic records for the GAGE and SAGE awards. The IPT may periodically be assisted by other NSF staff as expertise is needed (e.g., OGC staff, OD staff).

External Governance Structure

SAGE is managed and operated by the Incorporated Research Institutions for Seismology (IRIS), which is incorporated as a non-profit consortium representing 125 U.S. universities and non-profit organizations with research and teaching programs in seismology. Each voting member institution of the consortium appoints a member representative, who collectively elect the nine members of the IRIS Board of Directors. Board members, who serve three-year terms, vet all internal program decisions associated with SAGE management and operation, through consultation with IRIS staff and SAGE advisory committees (one for each major SAGE component and additional *ad hoc* working groups appointed for special tasks). The Board of Directors appoints a president of IRIS to a renewable two-year term. The president is responsible for IRIS operations, all of which are managed through the IRIS Corporate Office located in Washington, DC.

Partnerships and Other Funding Sources

The core SAGE facility is managed for NSF by IRIS, under a single award overseen by NSF’s EAR. IRIS has received funding under the SAGE award for additional activities, including support for specific PI-driven research in Antarctica, organization of relevant workshops, and operation of regional seismic networks. One regional seismic network—ATA—continues to operate under the old SAGE award. This array will be decommissioned in 2021.

Besides its role in providing the observational data essential for basic Earth science research, SAGE also plays a significant role providing real-time seismic data to USGS and the National Oceanic and Atmospheric Administration (NOAA) for global earthquake, volcano, and tsunami monitoring, and international seismic monitoring of compliance with the Comprehensive Test Ban Treaty. The Global Seismographic Network (GSN) component of SAGE is managed as a partnership among USGS, NSF, and IRIS.

SAGE is heavily involved in partnership activities, many international in nature. Installation and operations of the GSN have put IRIS in contact with scientists, as well as government and non-government organizations, around the world. Many international GSN stations are designated as the official stations for nuclear test ban treaty monitoring in their host countries. SAGE also provides multi-use resources for other government agencies that have responsibilities for development of a nuclear test ban monitoring capability and for monitoring global seismicity. For these purposes, agencies in partnership with NSF have provided substantial support for accelerated development of the GSN, shared operation and maintenance of the GSN, and accelerated development of the Portable Seismology Instrument pool.

Funding

Total Obligations for SAGE

(Dollars in Millions)

	FY 2020	FY 2021	FY 2022	ESTIMATES ¹				
	Actual	Estimate	Request	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027
Operations & Maintenance	\$21.50	\$21.85	\$21.87	\$23.37	\$23.37	\$23.37	\$23.37	\$23.37

¹ Outyear estimates are for planning purposes only. The current cooperative agreement ends September 2023.

Major Facilities

The Earth's interior remains a major scientific frontier holding the key to understanding the origin of the planet. Recent developments in seismic sensor design and the acquisition, transmission, and storage of data have resulted in dramatic improvements in the resolving power of seismic imaging of the interior of the Earth. To serve the research needs of the broad Earth science community, SAGE is organized under three primary service areas:

Instrumentation Services

- The GSN consists of over 150 permanently installed broadband digital seismic stations, most of which have real-time data access. GSN stations provide critical data for a range of global Earth science research and support key national security needs such as nuclear test-ban treaty verification and natural hazards warning and response. GSN is operated in partnership with the USGS.
- Portable Seismology includes a pool of over 5,200 portable seismometers that are made available to the Earth science research community for a wide range of principal investigator-driven experiments largely funded through the NSF merit review process to study a wide range of Earth processes.
- Polar Support Services supports the development of specialized seismic equipment for use in harsh environments and provides instrumentation, training, and field support for experiments in the polar regions.
- The Transportable Array (TA) was a continental-scale seismic observatory designed to provide a foundation for multi-scale integrated studies of continental lithosphere and deep Earth structure. After operating 1,700 stations in the lower 48 states between 2004 and 2015, the full 280-station TA network is now deployed in Alaska and western Canada. This regional seismic network continues to operate under the old SAGE award and NSF is in the process of transferring adopted stations to other Federal agencies for long-term operations and maintenance. Stations that are not adopted will be decommissioned in FY 2021.
- The Magnetotelluric component exploits the natural variations in Earth's magnetic and electric fields to provide information on the distribution and composition of fluids in Earth's crust and upper mantle, which gives constraints on Earth's structure that are complementary to those resulting from seismology.
- Instrumentation Services-Coordinated Activities include efforts to develop the next generation of seismic instrumentation for large-scale scientific experiments; global-scale geophysical networks; and training courses to distribute best practices to partners worldwide.

Data Services

SAGE Data Services manages an archive of over 540 terabytes of seismic, magnetotelluric, and other data from all SAGE components, the EarthScope program⁵, and numerous affiliated networks; operates automated and manual systems to ensure the quality of all data stored in the archive; and provides systems to give the national and international research community timely access to these data. In FY 2020, more than 19,000 unique users downloaded data from the SAGE archive. These data are used for a wide range of applications, including research and education.

Education and Public Outreach

The SAGE Education and Public Outreach program enables audiences beyond seismologists to access and use seismological data and research, including student internships, and programs for under-resourced educational institutions.

In addition to the three services mentioned, program plans to implement recommendations from the 2019 and 2020 management reviews. These include innovating SAGE's portable sensor pool to include additional nodal instruments for studies of processes in Earth's near surface, moving data services for the Facility to the cloud and recapitalization of aging instrumentation. A pilot cloud service program was

⁵ EarthScope was an MREFC-funded experimental facility focused on understanding the structure and evolution of the North American continent and the processes that cause earthquakes and volcanic eruptions.

initiated in 2020 in partnership with GAGE and the program plans to expand this capability over the existing award period. The program is evaluating different strategies and scales of aging instrumentation and plans to phase in recapitalization over the existing award period.

Reviews

NSF externally reviews components of the SAGE facility on an annual basis. NSF reviewed the SAGE instrumentation services programs in late June 2020 and the data services programs in September 2019. Both reviews noted the outstanding management and the critical services these programs provide to the research community. As per the reviews' recommendations, EAR, in collaboration with SAGE, GAGE and the NSF Office of Advanced Cyberinfrastructure, is implementing a pilot program to move facility data services to the cloud.

NSF will conduct a full management review of the facility in FY 2021.

Renewal/Recompetition/Termination

The previous SAGE award is in a no-cost extension period to complete activities associated with ATA. The divestment of ATA began in FY 2020 and is scheduled to be completed by the end of FY 2021. NSF personnel are working with other federal agency partners to take over operations of some of the stations.

The current SAGE award will fund the facility until the end of FY 2023. NSF is considering the recommendations contained in the *Earth in Time* decadal survey as well as the interagency context in which the facility operates in formulating a strategy for continued support of this important community research resource.