

GEODETI FACILITY FOR THE ADVANCEMENT OF GEOSCIENCE (GAGE)

\$12,050,000
+\$5,130,000 / 74.2%

Geodetic Facility for the Advancement of Geoscience Funding
(Dollars in Millions)

FY 2019 ¹	FY 2020	FY 2021	Change over	
Actual	(TBD)	Request	FY 2019 Actual	Percent
\$6.92	-	\$12.05	\$5.13	74.2%

¹ FY 2019 Actual obligations reflect part of an operating year as funding for these continuing agreements was re-phased for continuity into

GAGE comprises a distributed, multi-user, national facility for the development, deployment, and operational support of modern geodetic instrumentation to serve national goals in basic research and education in the Earth sciences. GAGE focuses on studies of Earth's surface deformation at many scales with unprecedented temporal and spatial resolution. GAGE facilities support 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 by UNAVCO, a consortium of 119 U.S. universities and non-profit institutions with research and teaching programs in geophysics and geodesy and 111 associate members from foreign institutions. GAGE was formed in late FY 2013 from the geodetic component of the EarthScope facility and related geodetic facilities previously managed by UNAVCO. The FY 2021 Request will enable GAGE to continue to provide key services for the geoscience research community, including global and regional observing networks, field and technical support for experiments worldwide, data management and distribution systems, and other related activities.

Over the last three decades, the Earth science research community has greatly refined our ability to determine the position and motion of points on Earth's surface using space geodetic techniques, enabling high-resolution studies of Earth processes in a wide range of fields. Space geodesy applications are extremely broad and expanding to include important societal research on earthquake and tsunami hazards, volcanic eruptions, hurricanes, coastal subsidence, wetlands health, soil moisture, groundwater distribution, and space weather. Applications of geodetic techniques to understand the complex interplay between climate dynamics, continental ice sheet and mountain glacier dynamics, crustal isostatic adjustments, and sea level change are of foremost relevance to current global issues confronting humanity.

Total Obligations for GAGE
(Dollars in Millions)

	FY 2019	FY 2020	FY 2021	ESTIMATES ²				
	Actual ¹	(TBD)	Request	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026
Operations & Maintenance	\$6.92	-	\$12.05	\$12.64	\$12.64	\$12.00	\$12.00	\$12.00

¹ FY 2019 Actual obligations reflect part of an operating year as funding for the continuing agreement was re-phased for continuity of operations into FY 2020.

² Outyear estimates are for planning purposes only. The current cooperative agreement ends September 2023.

For information on continuity of operations funding, see the opening narrative of this chapter.

To serve the research needs of the broad Earth science community, GAGE is organized under three primary service areas:

Geodetic Infrastructure

- Currently, the Network of the Americas (NOTA) includes 1,257 continuous Global Positioning System (GPS) and Global Navigation Satellite System (GNSS) stations (more than 800 of which transmit data in real-time with sub-second latency) distributed across the U.S., Mexico, and the Caribbean, with focus on the active plate boundaries. The FY 2021 Request includes funds to support a network that includes about 1,100 stations.
- The GAGE facility also provides operational and maintenance support for a network of 87 borehole strainmeters and 79 borehole seismometers deployed along the San Andreas Fault and above the Cascadia subduction zone and volcanic arc. Tiltmeters (26) and pore pressure sensors (23) are also collocated with the other borehole instruments. Together, data collected by these instruments enable scientists to study the full range of deformation in the solid Earth, from the rapid shaking associated with earthquakes, through more gradual motions related to slow slip events on faults and to Earth's evolving water cycles, up to long-term plate tectonics.
- Global geodetic arrays outside of the NOTA footprint are supported by GAGE in partnership with investigators. Eight hundred continuous GPS stations from over 60 networks around the world are now maintained and monitored, and have their data compiled into the GAGE data system. In addition, GAGE provides operational and maintenance support for 58 National Aeronautics and Space Administration (NASA)-supported stations, and the GNSS network that supports satellite orbit and clock corrections and the refinement of the International Terrestrial Reference Frame (ITRF). The ITRF is the foundation for high-precision global Earth science and other applications of geodesy such as land surveying.
- Community GPS/GNSS receiver and geodetic technology pool consists of over 700 GPS and GNSS receivers, ancillary equipment, and six terrestrial laser scanners, which can be used by investigators for short- and long-term deployments on research projects supported via multiple EAR and OPP science programs funded by NSF.
- GAGE supports the polar GPS network in Antarctica (ANET) and development of specialized GPS monumentation, power, and telemetry solutions for use in harsh environments. GAGE also provides portable campaign deployment geodetic instrumentation, training, and field support for experiments in the polar regions.
- Investigator Project Support includes project management, field engineering, and technical support services to plan and execute GPS surveys and permanent station installations. GAGE also maintains a staff focused on geodetic technology equipment testing services to evaluate new geodetic technologies and improve performance for science applications.

Geodetic Data Services

- Geodetic Data Services manages an archive of over 300 terabytes of data from GPS, terrestrial and airborne laser scanning, Synthetic Aperture Radar (SAR), and borehole geophysical instruments from all GAGE components including NOTA, global continuous geodetic networks, and campaign GPS observations; 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.
- The archive of SAR imagery maintained and distributed by GAGE to support interferometric SAR imagery of continuous surface deformation at scales of 100 km to 1,000 km is complementary to discrete GPS measurement of displacement. UNAVCO, as the manager of GAGE, brokers for cost-effective community access to the SAR imagery acquired by foreign SAR satellite systems.
- In FY 2019, more than 15,000 unique users downloaded data from the GAGE archive. These data are used for a wide range of applications, including research, commerce, and education.

Education and Community Engagement

- The GAGE Education and Community Engagement program enables audiences beyond geodesists to access and use geodetic data and research for educational purposes, including technical short courses, student internships, web-based materials, and programs for strengthening workforce development and improving diversity in the geosciences.
- Scientific community activities include scientific and technical workshops that bring together the international geodetic community and publications designed to communicate GAGE activities and results to the community.
- External affairs maintain outreach efforts to policymakers and planning for coordination with the international geodesy community.

In addition to its role in providing observational data essential for basic Earth science research, GAGE also plays a significant role providing geodetic infrastructure support to NASA investigators and the international community by maintaining the Global GNSS Network (GGN). GGN supports the refinement of the ITRF and corrections to satellite orbits and clocks, all contributing to the capability for millimeter-level geodetic positioning, subtle observations of Earth's time-varying gravity field, and detection of millimeter-level changes in sea level. These capabilities, particularly precise geodetic positioning, have become essential tools for civil and commercial activity. Commercial surveyors and engineering firms download GAGE real-time GPS data daily to support precision positioning which is now a mainstay of their industry. GPS is also used extensively for terrestrial and marine navigation both commercially and by the general public.

Management and Oversight

- NSF Structure: The Division of Earth Sciences in GEO, through its Instrumentation and Facilities program, provides general oversight of GAGE to assure effective performance and administration. The program also facilitates coordination of GAGE programs and projects with other NSF-supported facilities and projects, and with other federal agencies, and evaluates and reviews the performance of UNAVCO in managing and operating GAGE. In addition, an Integrated Project Team consisting of representatives from EAR, Division of Acquisition and Cooperative Support, and the Large Facilities Office work with the cognizant program officer in addressing challenges and identifying potential barriers for success. The EAR Division Director and Integrated Activities Section Head provide other internal oversight.
- External Structure: GAGE is managed and operated by UNAVCO, which is incorporated as a non-profit consortium representing 119 U.S. universities and non-profit organizations with research and teaching programs that rely on geodetic technologies for Earth Science research. Each voting member institution of the Consortium appoints a member representative, and these member representatives elect the nine members of the UNAVCO Board of Directors, seven of which are drawn from member institutions, and two directors-at-large. The board members, who serve two-year terms, vet all internal program decisions associated with GAGE management and operation, through consultation with UNAVCO staff and GAGE advisory committees (one for each major GAGE component and additional *ad hoc* working groups appointed for special tasks). The Board of Directors appoints a president of UNAVCO to a renewable two-year term. The president is responsible for UNAVCO operations, all of which are managed through the UNAVCO Corporate Headquarters in Boulder, Colorado.
- Reviews: In FY 2019, EAR conducted a joint review of the data services activities of GAGE and its seismic facility counterpart Seismological Facility for the Advancement of GEoscience (SAGE).

Renewal/Recompetition/Termination

A successful NSF merit review of the proposal for the GAGE facility took place in 2017 and 2018, and funding for the current GAGE cooperative agreement began in FY 2019 and it will end in FY 2023. In preparation for the next recompetition that will begin in FY 2022, NSF is gathering input through several mechanisms. First, NSF requested the National Academy of Science, Engineering, and Medicine to explore different models to manage geophysical capabilities to serve the Earth Sciences community as one component of the decadal study “*Catalyzing Opportunities for Research in Earth Sciences*”¹. The report from the workshop that explored different models can be found at <https://www.nap.edu/catalog/25536>. Second, NSF is convening an interagency working group to identify the needs other agencies have for the capabilities currently provided by SAGE and GAGE. Lastly, NSF will use internal processes to assess facility capabilities. The information from these activities will be used to draft the solicitation requesting proposals to support geophysical capabilities for Earth Sciences research and education.

¹ www8.nationalacademies.org/pa/projectview.aspx?key=51287