

GEODESY ADVANCING GEOSCIENCES AND EARTHSOPE (GAGE) \$12,190,000
-\$91,000 / -6.9%

Geodesy Advancing Geosciences and Earthscope Funding
(Dollars in Millions)

FY 2017 Actual	FY 2018 (TBD)	FY 2019 Request	Change over FY 2017 Actual	
			Amount	Percent
\$13.10	-	\$12.19	-\$0.91	-6.9%

Geodesy Advancing Geosciences and EarthScope 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 with a focus 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 115 U.S. universities and non-profit institutions with research and teaching programs in geophysics and geodesy and 108 associate members from foreign institutions. GAGE was formed in late FY 2013 from the geodetic component of the EarthScope facility and related geodetic facilities previous managed by UNAVCO. The FY 2019 Budget Request will enable GAGE 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 understanding the complex interplay between climate dynamics, continental ice sheet and mountain glacier dynamics, crustal isostatic adjustments, and sea level change is of foremost relevance to current global issues confronting humanity.

Total Obligations for GAGE
(Dollars in Millions)

	FY 2017	FY 2018	FY 2019	ESTIMATES				
	Actual	(TBD)	Request	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Operations & Maintenance	\$13.10	-	\$12.19	\$12.19	\$12.19	\$12.19	\$12.19	\$12.19

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

Geodetic Infrastructure

- The EarthScope Plate Boundary Observatory (PBO) includes more than 1,100 continuous Global Positioning System (GPS) stations (more than 720 of which transmit data in real-time with sub-second latency) distributed across the U.S., with focus on the active plate boundaries in the western contiguous U.S. and southern Alaska. Data recovery for the PBO GPS network typically exceeds 90 percent. PBO also includes 76 borehole strainmeters and 79 borehole seismometers deployed along the San Andreas Fault and above the Cascadia subduction zone and volcanic arc. Tiltmeters (25) 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 PBO footprint are supported by GAGE in partnership with investigators. Nearly 900 continuous GPS stations from around the world are now maintained, monitored, and data compiled into the GAGE data system. GAGE supports 58 of the over 250 GPS sites in the National Aeronautics and Space Administration (NASA)-supported Global Navigation Satellite System (GNSS) array 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. GAGE is also supporting the development of data distribution systems for a Caribbean region GPS and meteorological sensor network (COCONet) of more than 100 stations that support tectonic, volcano, tropical storm, and sea level change investigations.
- Community GPS receiver and geodetic technology pool includes a pool of over 680 GPS and Global Navigational Satellite System (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 Earth science programs funded by NSF.
- Polar Networks supports GAGE's polar GPS networks in Antarctica (ANET) and Greenland (GNET) 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 282 terabytes of data from GPS, laser scanning, Synthetic Aperture Radar (SAR), and borehole geophysical instruments from all GAGE components including EarthScope PBO, 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. These data enable the wide range of Earth science studies described above.

Education and Community Engagement

The GAGE Education and Community Engagement (ECE) 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.

Special Emphasis Areas

- 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 maintains outreach efforts to policymakers and planning for coordination with the international geodesy community.

Beside 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 through activities in maintaining a subset of 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.

Commercial surveyors and engineering firms download GAGE facility real-time GPS data daily to support precision positioning. The economic impact of this service to the commercial sector has not been quantified, but is likely substantial.

Management and Oversight

- **NSF Structure:** The Division of Earth Sciences (EAR) in the Directorate for Geosciences, through its Instrumentation & Facilities program (IF), provides general oversight of GAGE to help 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. 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 115 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:** All major ongoing geoscience facilities routinely undergo reviews of their management, in addition to peer review of proposals for new or continued support. The formal NSF merit review of the five-year proposal for the GAGE facility took place in 2012 and 2013 and was also the most recent review of UNAVCO. Although the *ad hoc* reviewers and two independent review panels had a number of specific recommendations at the working level for GAGE, overall the review found that GAGE was a critical facility for U.S. and international earth sciences. Furthermore, the reviewers found that UNAVCO is a well-managed and effective organization that has, through its commitment to the collection and open dissemination of the highest quality geodetic data, transformed the discipline of geodesy and its geoscience applications.

Renewal/Recompetition/Termination

The GAGE cooperative agreement began October 1, 2013, and will expire September 30, 2018. In FY 2016, in keeping with the phased integration and recompetition plan presented to the National Science Board in December 2009, NSF solicited proposals to manage and operate one or more components of a new facility to support the Earth sciences research and education community. These components are currently supported by GAGE and the related Seismological Facilities for the Advancement of Geoscience and EarthScope (SAGE). The new distributed, multi-user, national facility would support the development, deployment, management, and operational support of modern geodetic, seismic, and related geophysical instrumentation and provide services to serve national goals in basic research and education in the Earth sciences. NSF is currently reviewing proposals received in response to this facility solicitation. As part of a robust re-competition and cost review process, various NSF oversight activities have been completed and others are underway, such as an independent cost assessments to inform NSF's cost analysis for a potential award.