U.S. Geological Survey National Strong-Motion Project Strategic Plan, 2017–22

By Brad Aagaard, Mehmet Celebi, Lind Gee, Robert Graves, Kishor Jaiswal, Erol Kalkan, Keith Knudsen, Nico Luco, James Smith, Jamison Steidl, and Christopher Stephens

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Abbreviations

ANSS	U.S. Geological Survey Advanced National Seismic System
AQMS	ANSS Quake Monitoring System
CESMD	Center for Earthquake Strong-Motion Data
CGS	California Geological Survey
CISN	California Integrated Seismic Network
COSMOS	Consortium of Organizations for Strong Motion Observation Systems
COSMOS VDC	COSMOS Virtual Data Center
FDSN	International Federation of Digital Seismograph Networks
NSMP	U.S. Geological Survey National Strong-Motion Project
PRISM	Processing and Review Interface for Strong Motion Data
USGS	U.S. Geological Survey

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Mission

The mission[3] of the National Strong-Motion Project is to provide measurements of how the ground and built environment behave during earthquake shaking to the earthquake engineering community, the scientific community, emergency managers, public agencies, industry, media, and other users for the following purposes:

- Improving engineering evaluations and design methods for facilities and systems;
- Providing timely information for earthquake early warning, damage assessment, and emergency response action; and
- Contributing to a greater understanding of the mechanics of earthquake rupture, ground-motion characteristics, and earthquake effects.

National Strong-Motion Project

The National Strong-Motion Project (NSMP) is part of the U.S. Geological Survey (USGS) Advanced National Seismic System (ANSS). The NSMP is the primary operator of seismic instrumentation used by engineering seismologists, earthquake engineers, emergency managers, and public agencies. The NSMP manages seismic instrumentation (International Federation of Digital Seismograph Networks network code NP) installed on and near facilities, such as buildings, bridges, dams, and pipelines, and free-field sites, with a focus of capturing the range of motions from the very strongest down to moderate, and even weak, levels. Specifically, the NSMP is directly responsible for installation and maintenance of the instrumentation hardware and software, as well as acquiring, processing, archiving, and disseminating the resulting data. The NSMP network (fig. 1) includes stations owned by the USGS as well as those owned by other Federal and State agencies but maintained by the USGS. The NSMP operates the seismic network in close collaboration with the ANSS regional seismic networks. The NSMP processes, archives, and disseminates relevant ground-motion data for moderate and large earthquakes from many of the ANSS regional seismic networks (fig. 1 and tables 1, 2), and several of the ANSS regional seismic networks provide routine maintenance for some of the NSMP stations. The various pathways for collecting ground-motion data from these multiple sources into the Center for Engineering Strong Motion Data are summarized in figure 2. The

[1] U.S. Geological Survey
[2] University of California, Santa Barbara
[3] Modified from Committee for the Future of the U.S. National Strong-Motion Program (1997).

NSMP staff is part of the USGS Earthquake Science Center and works closely with engineering seismology and earthquake engineering research staff from across the USGS Earthquake Hazards Program. The NSMP Working Group serves as a formal mechanism for maintaining strong connections between the NSMP staff and USGS scientists using NSMP data in their research. The NSMP Working Group also works with the ANSS Structural Response Monitoring Working Group on issues related to structural instrumentation through the ANSS coordinator and overlap in membership.

Table 1. Number of structural monitoring and geotechnical array stations and channels within the United States in the Advanced National Seismic System (ANSS) seismic networks. The National Strong-Motion Project (NSMP) network contains the second largest number of structural monitoring and geotechnical array stations.

[FDSN, International Federation of Digital Seismograph Networks]

Network	FDSN network code	Station category	Number of stations	Number of channels
National Strong-Motion Project	NP	Buildings	91	2,119
		Dams	52	653
		Bridges	13	281
		Geotechnical arrays	11	117
		Other	3	33
		Subtotal	170	3,203
California Strong Motion Instrumentation Program	CE	Buildings	237	3,402
		Dams	27	228
		Bridges	70	1,406
		Geotechnical arrays	39	455
		Other	19	222
		Subtotal	392	5,713
Southern California Seismic Network	CI	Buildings	1	12
		Geotechnical arrays	7	42
		Subtotal	8	54
Northern California Seismic Network	NC	Dams	3	45
		Geotechnical arrays	1	9
		Subtotal	4	54
Cooperative New Madrid Seismic Network	NM	Geotechnical arrays	3	18
Pacific Northwest Seismic Network	UW	Geotechnical arrays	5	36
California Division of Water Resources	WR	Dams	1	6
		Total	583	9,084

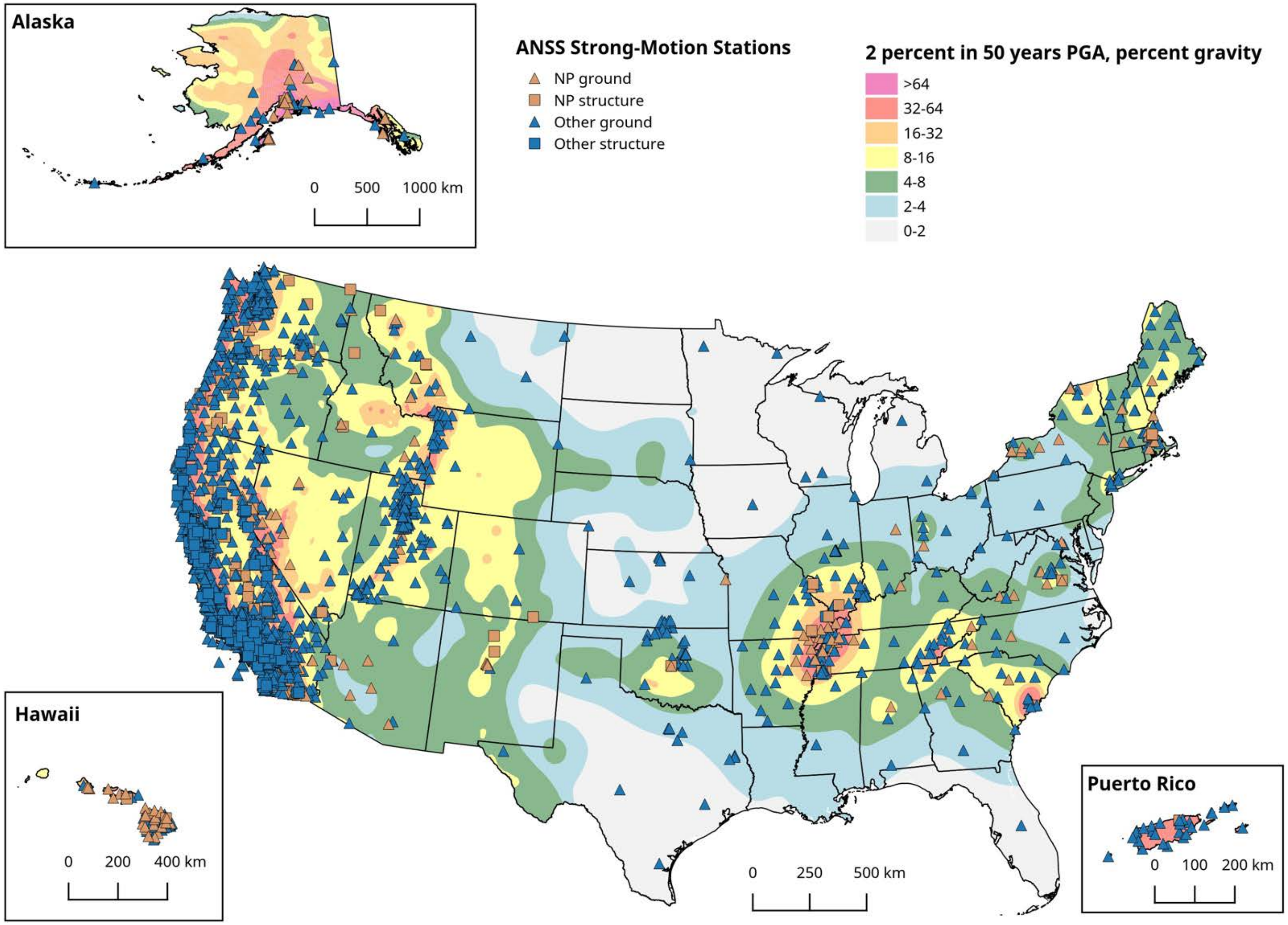

Figure 1. Map of strong-motion stations in the U.S. Geological Survey (USGS) Advanced National Seismic System (ANSS) and partner seismic networks. Orange symbols identify the USGS National Strong-Motion Project (NSMP) seismic network stations (International Federation of Digital Seismograph Networks network code NP) and dark blue symbols identify the stations in other ANSS networks; triangles denote the ground stations and squares denote structures and geotechnical arrays. Background shading shows the USGS National Seismic Hazard Model in percent of gravity (2 percent in 50 years probability of exceeding a given peak ground acceleration (PGA); Petersen and others, 2014). In addition to operating the NP network, the NSMP processes most of the strong-motion data recorded outside of California.

Table 2. Number of ground strong-motion stations and channels within the United States in the Advanced National Seismic Systems (ANSS) and partner seismic networks. The National Strong-Motion Project (NSMP) network contains the second largest number of strong-motion stations.

[CERI, Center for Earthquake Research and Information; FDSN, International Federation of Digital Seismograph Networks; IDA, International Deployment of Accelerometers; IRIS, Incorporated Research Institutions for Seismology; USGS, U.S. Geological Survey]

Network	FDSN network code	Number of stations	Number of channels
National Strong-Motion Project	NP	528	1,587
Arkansas Seismic Network	AG	9	27
Alaska Regional Network	AK	11	33
Arkansas Seismic Observatory	AO	1	3
Anza Regional Network	AZ	25	75
Berkeley Digital Seismograph Network	BK	53	158
California Strong Motion Instrumentation Program	CE	837	2,511
Southern California Seismic Network	CI	398	1,194
South Carolina Seismic Network	CO	6	21
CERI Southern Appalachian Seismic Network	ET	8	24
U.S. Geological Survey Networks	GS	148	447
Hawaiian Volcano Observatory Network	HV	37	111
Global Seismograph Network (IRIS/IDA)	II	2	6
Global Seismograph Network (IRIS/USGS)	IU	17	51
Intermountain West Seismic Network	IW	10	30
Lamont-Doherty Cooperative Seismographic Network	LD	14	42
Montana Regional Seismic Network	MB	6	18
Central and Eastern US Network	N4	41	123
Northern California Seismic Network	NC	289	1,054
New England Seismic Network	NE	19	57
Cooperative New Madrid Seismic Network	NM	63	189
Nevada Seismic Network	NN	60	180
NetQuakes	NQ	36	108
Central Coast Seismic Network	PG	15	45
Puerto Rico Seismic Network	PR	31	93
USArray Transportable Array	TA	13	39
University of Oregon Regional Network	UO	23	69
United States National Seismic Network	US	61	183
University of Utah Regional Network	UU	155	465
Pacific Northwest Seismic Network	UW	265	795
California Division of Water Resources	WR	17	51
Yellowstone Wyoming Seismic Network	WY	10	30
	Total	3,208	9,819

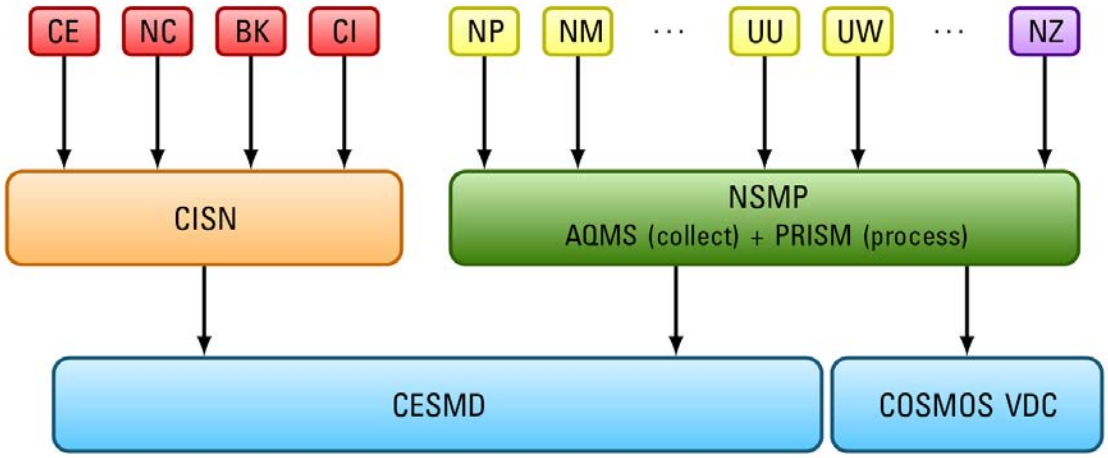

Figure 2. Diagram showing where the National Strong-Motion Project (NSMP) fits within the flow of waveform data to the Center for Engineering Strong Motion Data (CESMD) and the Consortium of Strong Motion Observation Systems Virtual Data Center (COSMOS VDC). Data from the California Integrated Seismic Network (CISN) is collected and processed by the individual regional seismic networks (CE, California Geological Survey; NC, Northern California Seismic Network; BK, UC Berkeley Seismic Network; CI, Southern California Seismic Network). The NSMP uses the Advanced National Seismic System (ANSS) Quake Monitoring System (AQMS) to collect strong motion data from its network of stations (NP) and all ANSS regional networks outside of California (for example, the Cooperative New Madrid Seismic Network, NM; the University of Utah Regional Network, UU, and the Pacific Northwest Seismic network, UW). The NSMP is transitioning towards using the new Processing and Review Interface for Strong Motion Data (PRISM) to process the data. The NSMP also posts waveform data from foreign seismic networks (for example, the New Zealand GeoNet seismic network, NZ) to the COSMOS VDC.

Strategic Plan Objectives

This strategic plan, developed by the NSMP Working Group, will be used to guide the activities of the NSMP staff and the NSMP Working Group for the next 5 years. It will also facilitate long-term planning efforts by the USGS Earthquake Hazards Program and Earthquake Science Center. In developing this strategic plan, we assume the fiscal environment will remain about the same with nearly flat appropriated funding, and thus, we focus on solidifying our current capabilities rather than greatly expanding them. Nevertheless, many of the strategic actions discussed are readily expanded and (or) provide the foundation for subsequent actions should additional resources become available. For example, there are clear avenues for directing funding that targets the ANSS priorities identified in USGS Circular 1429, Advanced National Seismic System: Current Status, Development Opportunities, and Priorities for 2017–2027 (U.S. Geological Survey, 2017), to the corresponding strategic actions identified later in this document. This strategic plan also informs external partners of the directions and opportunities the NSMP intends to pursue, including identifying opportunities for collaboration and engagement.

Vision

The NSMP aims to be an international leader in acquiring, processing, archiving, and disseminating earthquake strong-motion and structural response data, thereby contributing to increased public safety, reduced property damage, and increased resilience.

Achieving this vision involves commitment to maintaining the network, leveraging technological advances to increase efficiency, delivering the seismic data in a timely manner, and sustaining effective leadership across the NSMP staff and USGS Earthquake Hazards Program management.

Core Values

Forged through a long history of capturing important scientific records of how the ground and built environment behave during strong earthquake shaking, the NSMP staff and its community value the following:

- Diligence in maintaining free-field and structural monitoring instrumentation and disseminating the acquired data;
- High-quality data products generated using accepted standards;
- Open access to data products and data processing tools and procedures;
- Innovation in development and implementation of new technologies;
- Effective partnerships with other Federal, State, and local agencies, and other organizations;
- Stewardship in archiving and preserving data;
- Strong public service ethics, teamwork, and accountability; and
- Effective use of available resources.

Strategies, Actions, and Outcomes

Over the next five years (2017–22), the NSMP will pursue the following four strategies to strengthen its abilities to achieve its mission and realize its vision:

1. Improve the efficiency and sustainability of NSMP network operations;
2. Modernize procedures for collecting, processing, archiving, and disseminating NSMP data;
3. Enhance the utility of NSMP data through further integration with USGS/ANSS data products; and
4. Expand and strengthen external partnerships.

These strategies support several ANSS priorities identified in USGS Circular 1429 (U.S. Geological Survey, 2017), including the following:

- Ensuring readiness in an earthquake crisis [*A*],
- Developing earthquake early warning systems [*B.1*],
- Developing high-resolution damage and impact assessment for urban areas [*B.2*],
- Developing high-resolution damage and impact assessments for critical facilities and lifelines [*B.3*],
- Monitoring data for determining the seismic response of structures and lifelines [*C.1*],
- Improving coverage in the Central and Eastern United States [*C.4*], and
- Expanding coverage in areas of high seismic hazard [*C.5*].

In describing the planned actions for each of the four strategies, we highlight these ANSS priorities supported by each action using the labels in square brackets.

Strategy 1. Improve the Efficiency and Sustainability of NSMP Network Operations

The strong-motion and structural monitoring instrumentation owned and operated by the USGS forms the core of the NSMP. Ensuring that the instrumentation captures shaking from large, damaging earthquakes and is delivered to users in a timely manner is a cornerstone of the NSMP mission. This strategy focuses on ensuring that NSMP can deliver on its mission through careful, consistent, long-term investment in maintaining the instrumentation, frequent assessment of observation gaps and needs, and development of a workforce commensurate with rapidly advancing technology.

Actions supporting this strategy to improve the efficiency and sustainability of the NSMP instrumentation include the following:

- **Develop an upgrade plan and amortization schedule for NSMP instrumentation** [*A*]. This information will allow NSMP and the USGS Earthquake Hazards Program to assess the resources needed to maintain the existing NSMP network and to scale growth and (or) contractions accordingly. In addition, agencies that provide data streams to the NSMP can establish long-term budget targets based on the guidelines in the upgrade plan and amortization schedule.
- **Leverage advances in technology to reduce installation and maintenance costs** [*A, B.2, B.3, C.1*].
    - Continue to expand the use of information technology to monitor the state-of-health of instrumentation and perform remote administration to minimize site visits. This effort builds on the success of applying these techniques to many free-field sites and a small number of sites with structural instrumentation.
    - Build on the success of the NetQuakes instruments by continuing development and adoption of lower cost sensors with sufficient fidelity to capture ground motions within urban environments. This is especially important for achieving target station densities in the Central and Eastern United States, where current instrumentation is very sparse.
    - Conduct full-scale testing of new and alternative structural instrumentation designs, including sensors, data loggers, and telecommunications technology. The testing should leverage shake table experiments and existing structures that are easily accessible to NSMP field staff and have high-quality instrumentation to allow benchmark tests of new or alternative designs.
- **Establish guidelines for prioritizing instrumentation of new sites** [*C.1, C.4, C.5*].
    - Identify gaps in the observational database in accordance with research needs and seismic risk assessments, including the National Seismic Hazard Models and short-term hazard changes (for example, induced seismicity). Some examples include identifying the types of structures and facilities that should be instrumented, assessing the density of instrumentation relative to research needs and engineering analyses, and identifying sites that would help fill in gaps in the earthquake magnitude/distance distribution. These guidelines will update those developed by Whittaker and others (2005) for engineered civil systems.
    - Leverage free-field stations serving multiple uses, such as earthquake detection and location, earthquake early warning, and ground-motion characterization to increase

the density of strong-motion stations. Multiple-use stations generally reduce the cost per channel, which can free resources to add new instrumentation at high-priority sites.

- **Develop a staffing plan and seek broad support for its implementation to ensure NSMP staffing levels and expertise meet required needs** [*A*].
    - Match staffing levels with network maintenance and operational demands.
    - Train and retain new NSMP staff that have both information technology and instrumentation skills commensurate with today's evolving technologies.
    - Optimize the geographic distribution of field staff to minimize travel and allow employees to live in regions with lower costs of living.
- **Develop, implement, and test continuity of operations plans for collecting, processing, archiving, and disseminating strong-motion and structural response data in the event of a large earthquake** [*A*]. Most of the NSMP infrastructure is at the USGS Menlo Park office, making collection of NSMP data potentially vulnerable to a large earthquake that disrupts telecommunications and transportation to or from the USGS Menlo Park office.

Opportunities with Increased Funding

A substantial increase in funding would allow the NSMP to adopt a much more aggressive upgrade strategy, add new sites to fill important observational gaps, harden the operations infrastructure to ensure redundancy in data collection and processing, and hire sufficient staff for proactive maintenance and operations. Achieving the station density and coverage targets for ANSS across the entire United States will require substantial capital investment as well as a long-term commitment to provide sufficient resources for maintenance and upgrades.

Strategy 2. Modernize Procedures for Collecting, Processing, Archiving, and Disseminating NSMP Data

Advances in information technology have transformed the way scientific data is collected and shared. The NSMP needs to be proactive and agile in leveraging these advances to improve management of its data and provide user-friendly and efficient interfaces to a wide variety of data products.

Actions in support of modernizing procedures for collecting, processing, archiving, and disseminating NSMP data include the following:

- **Collecting** [*A, C.1*]
    - Improve centralized access to all strong-motion and structural response data recorded by the NSMP network and regional seismic networks by completing current efforts to automate gathering of these data across the ANSS into the Center for Earthquake Strong-Motion Data (CESMD).
    - Implement regular, automated collection of ambient motion in instrumented structures to establish baseline structural response characteristics.
    - Ensure completeness and accuracy of metadata for all waveforms collected by the NSMP.
    - Develop and maintain one or more portable structural monitoring systems for rapid post-earthquake deployments, complementing existing portable free-field systems.

- **Processing** [*A*, *C.1*]. Complete current efforts to implement automated preliminary processing of all waveforms via PRISM (Jones and others, 2017). Update thresholds for manual review.
- **Archiving** [*A*, *C.1*]. Expand the range of ground motions included in the CESMD by developing and implementing procedures for archiving NP network recordings for small and moderate earthquakes with good signal-to-noise ratio that are not already archived by the regional seismic networks.
- **Disseminating** [*A*, *C.1*] In collaboration with the California Geological Survey (CGS), expand the capabilities of the CESMD. The CESMD, operated jointly by the CGS and USGS, currently serves as the archive for all CGS and USGS strong-motion and structural response data.
    - Build on standards used throughout the scientific community, such as web services and self-describing binary formats to provide unified, programmatic/scriptable (for example, via web services) and user-friendly interfaces (for example, graphical user interface to web services) to all data archived in the CESMD and the Consortium of Organizations for Strong Motion Observation System (COSMOS) Worldwide Strong-Motion Virtual Data Center.
    - Provide training sessions at meetings (for example, COSMOS Technical Session, Pacific Earthquake Engineering Research Center Annual Meeting, Earthquake Engineering Research Institute Annual Meeting, and Seismological Society of America Annual Meeting) for accessing data and using the recently developed waveform processing software, PRISM, outside of the USGS.

Opportunities with Increased Funding

Transforming the CESMD into a state-of-the-art repository for strong-motion data will require significant investment from the USGS in addition to that provided by the CGS. Increased funding can be used to accelerate this transformation; advance data collection, management, and processing techniques; and expand training opportunities.

Strategy 3. Enhance the Utility of NSMP Data through Further Integration with USGS/ANSS Data Products

Tighter integration with USGS/ANSS data products provides the opportunity to increase the value of the data generated by the NSMP. Additionally, development of new products directed towards the general public can increase the visibility of the NSMP to a broader audience. Increasing the value and visibility of NSMP data will lead to new opportunities for directing resources towards supporting the broader mission of the ANSS, including achieving its targets for the coverage and density of free-field and structural monitoring sites.

Actions supporting enhancing the utility of NSMP data through further integration with USGS/ANSS data products include the following:

- **Encourage development of quantitative analysis of uncertainties in the National Seismic Hazard Models to identify new instrumentation sites that would have the largest impact on reducing uncertainty in seismic hazard assessments** [*B.2, C.4*].
- **Expand the integration of strong-motion data with ShakeCast through the use of private and public free-field and structural monitoring near critical facilities and structures** [*B.2, B.3, C.4*]. Provide ShakeCast with free-field shaking parameters via

ShakeMap and analogous structural response data. This will allow ShakeCast enhancements that use site-specific ground motions and structural response data, where available, to reduce uncertainties in structural performance assessments.

- **Continue increasing the number of free-field stations providing low-latency data for earthquake early warning (ShakeAlert)** [*B.1*]. Reducing the time required to transmit information from instruments to central processing facilities is critical for providing earthquake early warning to areas subjected to the strongest shaking. Many NSMP stations are in the urban environment, so providing low-latency data is critical for early warning in these populated areas.
- **Reduce latency in collecting and processing structural response data to facilitate its use in emergency response and structural performance assessment** [*A, B.2, B.3*].
- **Increase the visibility of NSMP structural response data by developing visualization products that illustrate important structural response concepts**.
- **Provide opportunities for NSMP field technicians to learn about the research needs associated with instrumentation projects** [*A*]. Field technicians can address the most relevant technical details and unique aspects of sites, especially structural monitoring sites, if they are kept informed of the research needs.

These actions expand existing, broader efforts to enhance the utility of NSMP data. For example, both the USGS Geologic Hazards Science Center and the USGS Earthquake Science Center have groups focused on characterizing the site conditions at instrumented sites, which facilitates the use of the data in ground-motion models that are critical for the National Seismic Hazard Models.

Opportunities with Increased Funding

Expansion of seismic and structural monitoring networks often go hand-in-hand with development of new data products. An increase in structural monitoring instrumentation will increase the demand for incorporating structural response data into ShakeCast. Furthermore, implementation of earthquake early warning will lead to new requests for integrating NSMP data into earthquake early warning related products, especially automated systems. These new demands will require investment in research and operations in order to improve data products, such as ShakeCast and ShakeAlert.

Strategy 4. Expand and Strengthen External Partnerships

Finding resources to achieve the goals for the density of strong-motion and structural response instrumentation of the ANSS will likely require strengthening existing partnerships with other Federal and State agencies and establishing new ones. The NSMP should seek a proactive leadership role to engage stakeholders so that they readily identify the benefits of collaborating on new free-field sites and instrumenting additional structures and facilities.

Actions in support of expanding and strengthening external partnerships include the following:

- **Engage owners of structures and facilities on the benefits of seismic instrumentation and ShakeCast in order to expand structural monitoring via reimbursable contracts and memorandums of understanding** [*C.4, C.5*]. Owners are more likely to fund installation and maintenance of seismic instrumentation if they can easily identify the direct benefits, such as increased situational awareness following significant earthquakes.

- **Explore partnerships for leveraging structural instrumentation that is primarily intended for purposes other than seismic monitoring** [*C.4*, *C.5*]. Multipurpose instrumentation used on a much more frequent basis than recording strong motions from earthquakes (for example, instrumentation for occupancy tracking in building energy/space efficiency, marketing research, security, and healthcare applications) provides additional incentives for instrumenting structures beyond seismic monitoring.
- **Engage the engineering seismology and earthquake engineering communities through workshops and programs, such as the external USGS grants, to demonstrate and evaluate the utility of NSMP data** [*C.1*]. Encourage earthquake engineers to analyze facilities instrumented by the NSMP and to facilitate discussions of how to improve structural monitoring. Expand participation in Pacific Earthquake Engineering Research Center research activities to increase collaboration with the engineering seismology and earthquake engineering communities on ground-motion and structural monitoring research issues.
- **Pursue a higher level of engagement with international data providers via the COSMOS** [*C.1*]. Promote open-data policies, cross-sharing data and improving standards for instrumenting structures, processing strong-motion data, and interfaces and file formats for disseminating data.
- **Engage external partners (for example, utilities, building owners, and other private entities) on the benefits of open-data policies** [*B.2*, *B.3*, *C.1*, *C.4*, *C.5*]. Open-data policies expand the data available for situational awareness, thereby allowing emergency managers to respond more effectively.
- **Expand NSMP capabilities to ingest very large datasets** [*B.2*, *B.3*]. Low-cost accelerometers, such as those in cell phones and smart gas meters, are resulting in efforts to deploy several thousand and even hundreds of thousands of sensors across a region. The NSMP can provide leadership by developing procedures for processing, archiving, and disseminating these very large datasets.

Opportunities with Increased Funding

External partnerships could be greatly expanded and strengthened with increased funding. A prime target would be aggressively engaging partners in deploying vast numbers of sensors across the built environment to capture earthquake shaking and its effects at unprecedented resolution. This would dramatically enhance situational awareness during earthquake response and provide new pathways for risk assessment and mitigation. Additionally, the USGS could use increased funding to direct more external USGS grants toward promising research areas related to assessing and mitigating seismic risk.

Outcomes

Taking the actions outlined above in pursuit of the four strategies will direct the NSMP toward the following outcomes:

- Strong-motion data products from the NSMP, which are disseminated by the CESMD, are used by structural and geotechnical engineers to increase the earthquake resistance of facilities and systems through retrofits and improved seismic designs. The data also lead to advancing the USGS National Seismic Hazard Models and research in characterizing earthquake ruptures, ground motions, soil/structure interaction, and structural response.

- The NSMP rapidly collects, processes, archives, and disseminates strong-motion and structural response data with a return rate greater than 95 percent for all damaging earthquakes in the United States.
- The NSMP lowers maintenance and upgrade costs, thereby allowing instrumentation of new sites and structures to fill in gaps in the observational database and response capabilities.
- Data from the NSMP serve a growing number of users from across the seismology and earthquake engineering communities, including the academic community, public agencies, design engineers, emergency managers, and the media.
- The NSMP expands its data streams through reimbursable and data acquisition agreements with public agencies and private entities based on their use of USGS/ANSS products, such as ShakeAlert, ShakeMap, and ShakeCast.
- The NSMP shares, archives, and disseminates data from a growing number of international data providers, thereby providing the United States and international communities with important datasets from damaging earthquakes.

These outcomes will help the NSMP achieve its vision of being an international leader in acquiring, processing, archiving, and disseminating earthquake strong-motion and structural response data, thereby contributing to increased public safety, reduced property damage, and increased resilience.

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References Cited

Committee for the Future of the US National Strong-Motion Program [R.D. Borcherdt, Chair], 1997, Vision for the future of the US National Strong-Motion Program: U.S. Geological Survey Open-File Report 97–530–B, 46 p., https://pubs.usgs.gov/of/1997/of97-530/b/.

Jones, J., Kalkan, E., and Stephens, C., 2017, Processing and review interface for strong motion data (PRISM) software, version 1.0.0—Methodology and automated processing: U.S. Geological Survey Open-File Report 2017–1008, 81 p., https://doi.org/10.3133/ofr20171008.

Petersen, M.D., Moschetti, M.P., Powers, P.M., Mueller, C.S., Haller, K.M., Frankel, A.D., Zeng, Yuehua, Rezaeian, Sanaz, Harmsen, S.C., Boyd, O.S., Field, Ned, Chen, Rui, Rukstales, K.S., Luco, Nico, Wheeler, R.L., Williams, R.A., and Olsen, A.H., 2014, Documentation for the 2014 update of the United States national seismic hazard maps: U.S. Geological Survey Open-File Report 2014–1091, 243 p., https://doi.org/10.3133/ofr20141091.

U.S. Geological Survey, 2017, Advanced National Seismic System—Current status, development opportunities, and priorities for 2017–2027 (ver.1.1, July 2017): U.S. Geological Survey Circular 1429, 32 p., https://doi.org/10.3133/cir1429.

Whittaker, A.S., Aho, J.L., Crouse, C.B., Frosch, Robert, Kelly, D.J., Lizundia, Bret, Lowes, L.N., Miranda, Eduardo, Nigbor, R.L., Sanders, D.H., and Stewart, Jonathan, 2005, Guideline for ANSS seismic monitoring of engineered civil systems—Version 1.0: U.S. Geological Survey Open File Report 2005–1039, 59 p., https://pubs.er.usgs.gov/publication/ofr20051039.

Appendix 1. NSMP within the USGS Earthquake Hazards Program

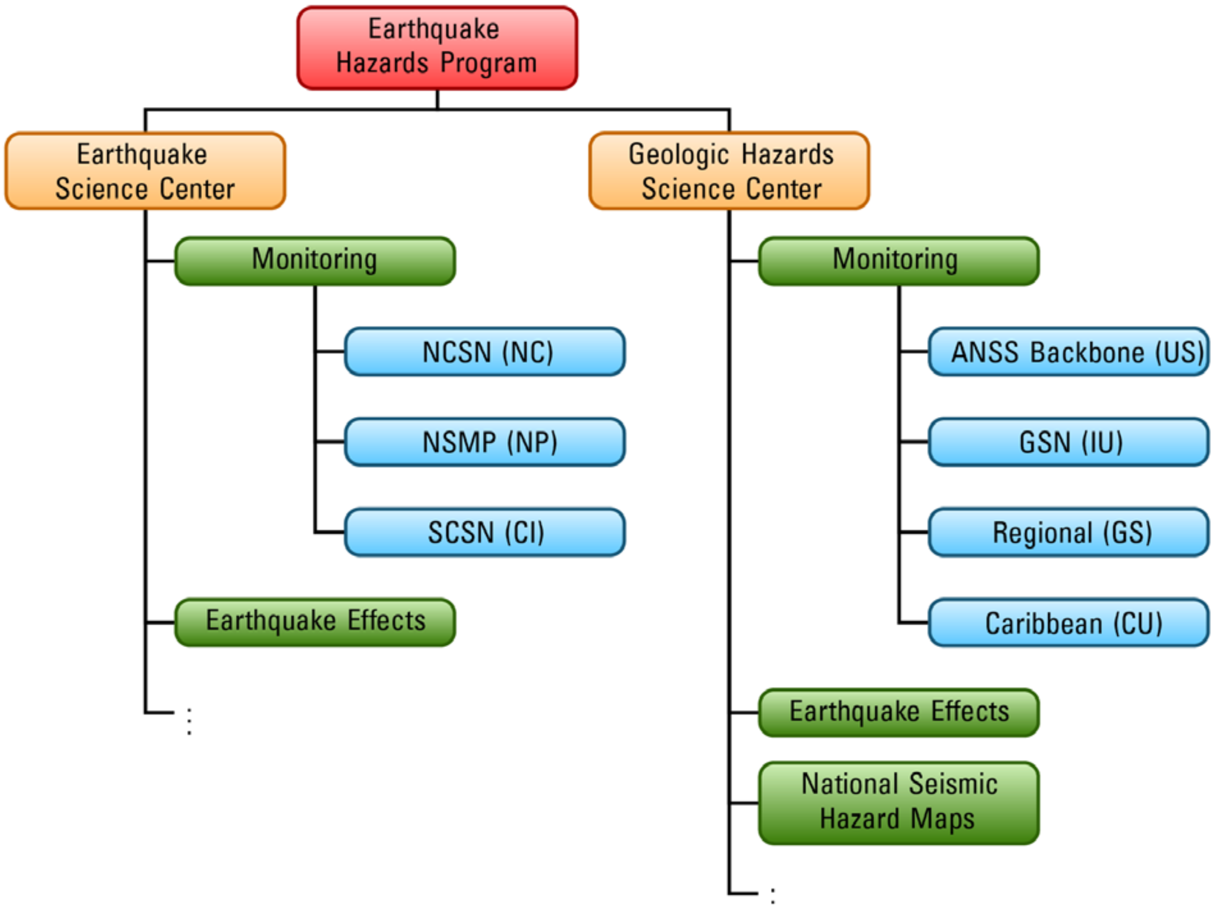

Figure 1.1. Excerpt from the organizational chart of the U.S. Geological Survey Earthquake Hazards Program. The Earthquake Hazards Program is composed of primarily the Earthquake Science Center headquartered in Menlo Park, Calif., with field offices in Pasadena, Calif., and Seattle, Wash., and the Geologic Hazards Science Center headquartered in Golden, Colo., with a field office in Albuquerque, N. Mex. Earthquake monitoring within the Earthquake Science Center includes the Northern California Seismic Network (NCSN), the National Strong-Motion Project (NSMP), and the Southern California Seismic Network (SCSN) run cooperatively with Caltech. Earthquake monitoring within the Geological Hazards Science Center includes the Advanced National Seismic Systems (ANSS) backbone network, the Global Seismic Network (GSN), the Caribbean U.S. Geological Survey network (CU), and several regional deployments (GS; primarily in the intermontane Western United States, Oklahoma, Kansas, Illinois, and Virginia). The NSMP staff work closely with engineering seismology and earthquake engineering research staff (Earthquake Effects) in both the Earthquake Science Center and Geologic Hazards Science Center. Abbreviations in parentheses denote the International Federation of Digital Seismograph Networks (FDSN) network code for the seismic network shown.

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