Advanced National Seismic Systems

Performance Standards

The Earthquake Hazards Reduction Act (P.L. 95–124 as amended) gives the USGS the Federal responsibility for providing notifications of earthquakes and its reauthorization in 2000 established the ANSS to modernize and expand the Nation's seismic monitoring infrastructure to provide accurate and timely data and information products for seismic events, including their effects on buildings and structures, employing modern monitoring methods and technologies.

This document establishes the standards for performance related to seismic monitoring, product generation, and data availability for the U.S. Geological Survey's (USGS) Earthquake Hazards Program (EHP) and governing the operation of the Advanced National Seismic System (ANSS). These standards are intended to assure quality and consistent performance within ANSS for all participants related to monitoring and evaluation of significant earthquakes nationwide. The standards and related metrics are, in some cases, aspirational, i.e., ANSS infrastructure and data processing capabilities may need to be improved for some ANSS participants. Aspirational standards include all metrics that are not specific to earthquakes at and larger than the articulated response magnitudes.

All ANSS participants are required to follow these standards and procedures as well as all ANSS policies and the derivative standards, procedures, and specifications as they pertain to each participant's scope of operations and authority.

Performance Areas

Performance standards of ANSS address expected performance in the following areas:

- **Seismic Monitoring/Strong Earthquake Shaking.** Collect accurate information on the occurrence of earthquakes and archive the appropriate data for seismic hazards and earthquake research. Accurately record large-amplitude earthquake ground motions that may cause damage to engineered structures or affect land use by causing liquefaction or other type of ground deformation.

- **Real-Time/Automated Product Generation.** When an earthquake occurs, rapidly and authoritatively compute earthquake source parameters and ground shaking maps (where appropriate), and distribute this information to emergency responders, the media, and the public.

- **Preparation of Seismologist-Reviewed Products for Significant Earthquakes.** Conduct seismologist review of earthquakes that may have seismic hazards or other societal implications. Provide useful, accurate, and timely release of products to communities most at risk from earthquakes likely to cause damage.

- **Data Exchange between ANSS Networks.** Exchange real-time waveforms, amplitudes, picks, and other raw data products between network centers, to improve quality and timeliness of data products.

- **Data Archiving and Public Distribution.** Archive all relevant data and data products generated by ANSS, including regional and global seismic networks at designated datacenter(s).

Geographic and magnitude divisions

Based on ANSS requirements, USGS mission responsibilities, and the occurrence of commonly significant earthquakes, Performance Standards are geographically defined by the following criteria:

- **Metro areas:** 34 metropolitan statistical areas identified by scaling 2018 population with the 10% probability of exceeding 12% g in 50 years, as defined by the 2023 National Seismic Hazard Model. The list or metropolitan areas is provided at the end of this document.

- **Moderate-to-High Hazard areas:** Areas within ANSS authoritative monitoring regions that have an earthquake hazard of 10% probability of exceeding 8% g in 50 years, as defined by the 2023 National Seismic Hazard Model.

- **National areas:** Areas within ANSS authoritative monitoring regions that exclude designated Metro monitoring regions, international land, and waters outside of the U.S. Territorial Waters (approximately 22 km from U.S. shorelines).

- **Global areas:** All regions outside of the U.S. Territorial Waters (approximately 22 km from U.S. shorelines), the U.S. Aleutian Islands, and U.S. territories excluding Puerto Rico and the U.S. Virgin Islands.

- **Response Magnitude (M_r)**: The earthquake magnitude at and above which ANSS Performance Standards require the articulated performance for rapid and accurate earthquake analysis of potentially significant earthquakes. M_r is defined regionally as:
  - **M_r3.5:** Conterminous United States and adjacent U.S. Territorial Waters (approximately 22 km from U.S. shorelines).
  - **M_r4.0:** Mainlands of Alaska, Hawaii, Puerto Rico and U.S. Virgin Islands, and their adjacent U.S. Territorial Waters (approximately 22 km from U.S. shorelines).
  - **M_r5.0:** International regions, Aleutian Island chain, U.S. regions outside of U.S. Territorial Waters (approximately 22 km from U.S. shorelines) and U.S. Territories excluding Puerto Rico and the U.S. Virgin Islands.

Metric (unit)	**Mag Range**	**Metro: Median (98th percentile)**	**Mod-High Hazard: Median (98th percentile)**	**National: Median (98th percentile)**	**Global: Median (98th percentile**
ComCat Completeness Magnitude	All	2.5	3.0 (WUS, PR), 2.5 (CEUS)	3.0 (WUS, PR), 2.5 (CEUS)	4.5
Time to first automatic origin (min)	All	6 (15)	6 (15)	6 (15)	10 (30)
Time to first reviewed origin (min)	$M<M_r$	60 (10080)	60 (10080)	60 (10080)	-
	$M \geq M_r$	15 (35)	15 (35)	15 (35)	20 (30)
Time to stable magnitude (min)	$M \geq M_r$	20 (35)	20 (35)	20 (35)	30 (45)
Magnitude variation (dM)	$M \geq M_r$	+/- 0.3 (0.75)	+/- 0.3 (0.75)	+/- 0.3 (0.75)	+/- 0.3 (1.0)
Magnitude Quality Metric (MQM)	$M \geq M_r$	1 (1.5)	1 (1.5)	1 (1.5)	1 (1.5)
Time to first reviewed ShakeMap release (min)	M< 4.5	60 (10080)	60 (10080)	60 (10080)	-
	M≥4.5	20 (40)	20 (40)	20 (40)	30 (60)
Time to first moment tensor/focal mechanism release (min)	M<4.5	60 (10080)	60 (10080)	60 (10080)	-
	M≥ 4.5 (≥M6 global)	30 (60)	30 (60)	30 (60)	45 (90)
% of events with a ShakeMap (%)	M≥ 4.5	98 (95)	98 (95)	98 (95)	-
% of events with a moment tensor/focal mechanism (%)	M≥ 4.5	98 (95)	98 (95)	98 (95)	-
Epicenter uncertainty, first automatic (km)	All	10 (20)	10 (20)	10 (40)	25 (45)
Epicenter uncertainty, first reviewed (km)	All	4 (10)	4 (10)	4 (20)	15 (35)
Depth uncertainty, first automatic (km)	All	15 (25)	15 (25)	15 (45)	25 (45)
Depth uncertainty, first reviewed (km)	All	5 (15)	5 (15)	5 (25)	15 (45)
Time to event deletion (min)	$M< M_r$	60 (10080)	60 (10080)	60 (10080)	-
	$M \geq M_r$	30 (60)	30 (60)	30 (60)	30 (60)
Time to product finalization (weeks)	All	5	5	5	5

Table 1: Performance standards for earthquake product and catalog production. Values given are median and 98th percentile performance values for earthquakes sampled over a given time period within the authoritative region of a given network. Values for M_r (respone magnitude) are given in the details above. 10080 minutes = 7 days. All metrics in Table 1 are tracked via information available in ComCat. WUS: U.S. regions west of 104°W. CEUS: U.S. regions east of 104°W. PR: Puerto Rico and U.S. Virgin Islands. In each instance, performance for a given earthquake is measured relative to the finalized authoritative origin.

Metric	Performance Standard
Phase delivery after origin submission (min)	0.5
Origins with associated phase data (%)	99
Network average uptime (%)	80
Realtime waveform availability to ANSS users (min)	0.5
Archived waveform availability to external users (min)	60
Metadata availability in SIS (%)	95
Reviewed COSMOS V0-V3 Products Post Time (days)	7
Triggered strong motion data sampling rate (samples per second, sps)	200

Table 2: Performance standards for data and metadata availability.

Explanation of Metrics

1. **Magnitude of Completeness** – Minimum magnitude above which all (or nearly all) earthquakes within the designated region can be routinely detected and cataloged. The magnitude is estimated by a standard procedure for analyzing earthquake catalogs.
2. **Time to first automatic origin** – The time, in minutes, between the authoritative origin time of an earthquake and when the first automatically-derived origin is submitted to the Product Distribution Layer (PDL).
3. **Time to first reviewed origin** - The time, in minutes, between the authoritative origin time of an earthquake and when the first human-reviewed origin is submitted to PDL.
4. **Magnitude variation** – The variation, in magnitude units, of any magnitude submitted to PDL measured relative to the authoritative magnitude.
5. **Time to stable magnitude** – The time, in minutes, between the authoritative origin time of an earthquake and when the submitted magnitudes stabilize. An event magnitude is considered stabilized when all subsequent submitted origin magnitudes vary by no more than 0.2 magnitude units.
6. **Magnitude Quality Metric (MQM)**– A unitless metric that measures the weighted quality of magnitudes submitted to PDL by a network for a single event. MQM weights time to stable magnitude (50%), magnitude variation (20%), and the number of times the submitted magnitude has a large variation (0.3 magnitude units or larger) from the authoritative magnitude (30%). MQM includes a correction for instances where a switch to a moment-based magnitude (i.e., M_w, M_{ww}, M_{wb}) causes magnitude variations or large magnitude variations. MQM is calculated for a single event as follows:

$$0.5x(\text{Time to stable mag} / 20) + 0.2x((\text{Magnitude Range} - 0.2 \times \text{MwFlag})/0.3) + 0.3x(\text{Number of large magnitude swings} - \text{MwFlag})$$

7. **Time to first reviewed ShakeMap** – The time, in minutes, between the authoritative origin time of an earthquake and the first submission to PDL of a ShakeMap derived from a reviewed origin.
8. **Time to first moment tensor and/or focal mechanism** – The time, in minutes, between the authoritative origin time of an earthquake and when the first moment tensor and/or focal mechanism is submitted to PDL.

9. **% of events with a ShakeMap** – The percentage of earthquakes above a stipulated magnitude that have an associated ShakeMap.
10. **% of events with a moment tensor and/or focal mechanism** – The percentage of earthquakes above a stipulated magnitude that have an associated moment tensor and/or focal mechanism.
11. **Epicenter uncertainty, first automatic** – The formal reported location uncertainty, in kilometers, of the first automatic origin submitted to PDL.
12. **Epicenter uncertainty, first reviewed** – The formal reported location uncertainty, in kilometers, of the first reviewed origin submitted to PDL.
13. **Depth uncertainty, first automatic** – The formal reported depth uncertainty, in kilometers, of the first automatic origin submitted to PDL.
14. **Depth uncertainty, first reviewed** – The formal reported depth uncertainty, in kilometers, of the first reviewed origin submitted to PDL.
15. **Time to event deletion** – The time, in minutes, between the computed origin time of a spurious event and when it is deleted from ComCat.
16. **Time to product finalization** – The time, in weeks, between the authoritative origin time of an earthquake when associated products are marked as finalized for PDE review.
17. **Phase delivery after origin submission** – The time, in minutes, between when an origin is submitted to PDL and when associated phase data is delivered to PDL.
18. **Origins with associated phase data** – The percentage of all origins submitted to PDL that have associated phase data submitted to PDL.
19. **Network average uptime** – The time, reflected as a percent, that a network's seismic stations are recording and providing continuous waveforms. This metric considers archived waveforms held in an authorized public waveform repository.
20. **Real time waveform availability to ANSS users** – The time, in minutes, between when a measurement is made in the field (a sample), and when the measurement is available to other ANSS networks.
21. **Archived waveform availability to external users** – The time, in minutes, between when a measurement is made in the field (a sample), and when the measurement is delivered to an authorized public waveform database.
22. **Metadata availability in SIS** – The percentage of active ANSS stations with metadata available in the Seismic Information System (SIS).
23. **Reviewed COSMOS V0-V3 products post time** – The time, in days, between the authoritative origin time of an earthquake and when reviewed COSMOS products are posted to the CESMD.
24. **Triggered strong motion data sampling rate** – The sampling rate, in samples per second (sps), of triggered strong motion data.

Designated Metro Regions and authoritative network:

- Los Angeles, Long Beach, Anaheim (CI)
- San Francisco, Oakland, Berkeley (NC)
- Riverside, San Bernardino, Ontario (CI)
- Seattle, Tacoma, Bellevue (UW)
- San Jose, Sunnyvale, Santa Clara (NC)
- San Diego, Chula Vista, Carlsbad (CI)
- New York City, Newark, Jersey City (US)
- San Juan, PR (PR)
- Portland, Vancouver (UW)
- Oxnard, Thousand Oaks, Ventura (CI)
- Sacramento, Roseville, Folsom (NC)
- Salt Lake City (UU)
- St Louis (NM)
- Memphis (NM/SE)
- Santa Rosa, Petaluma (NC)
- Atlanta, Sandy Springs, Alpharetta (NM/SE)
- Boston, Cambridge, Newton (US)
- Chicago, Naperville, Elgin (US)
- Las Vegas, Henderson, Paradise (NN)
- Charleston, North Charleston (NM/SE)
- Bakersfield (CI)
- Philadelphia, Camden, Wilmington (US)
- Anchorage (AK)
- Reno (NN)
- Washington, Arlington, Alexandria (US)
- Dallas, Ft Worth, Arlington (TX)
- Phoenix, Mesa, Chandler (US)
- Ogden, Clearfield (UU)
- Fresno (NC)
- Stockton (NC)
- Provo, Orem (UU)
- Honolulu (HV)
- Knoxville (NM/SE)
- Denver, Aurora, Lakewood (US)

A note on Education and Outreach

The end users of products from ANSS seismic network include large communities of emergency responders, earthquake engineers, decision makers, education community, media, and public. While the ANSS initiative does not include a focus on 'Education and Outreach" per se, in order to provide reliable, useful, accurate, and timely release of products to these and other target communities, education will need to be provided either directly or through partnerships with organizations that do E&O. The principal goals of this education are to minimize product misuse, to maximize the use of monitoring products, and to generate feedback for long-term product improvement. Specific minimum standards on dissemination goals and product/data use are difficult, if not impossible, to quantify. Determination and implementation of appropriate metrics will require expertise external to existing ANSS operations and management.

History of this document

This document is based heavily on ANSS priorities established by the National Earthquake Hazard Reduction Plan legislation and strategic plan, the ANSS Strategic Plan and ANSS Management Plan, and the USGS Earthquake Hazards Strategic Plan, with significant input from the ANSS Performance Standards Working Group, chaired by Natalia Rupert of the Alaska Earthquake Center at the University of Alaska, Fairbanks. This document is developed on the foundation of previous versions of the ANSS Performance Standards that were informed by the draft report of Working Group A (Performance Standards) of the ANSS Technical Implementation Committee, chaired by Mitch Withers of the Center for Earthquake Information of the University of Memphis, which compiled its report in 2004-2005.

This document is reviewed and revised as needed by the ANSS Coordinator, ANSS Integrated Products Teams, and the ANSS National Implementation Committee.

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