Draft ANSS Performance Standards

Background

Within the National Earthquake Hazards Reduction Program, a key objective of the USGS Earthquake Hazards Program is to operate, maintain and improve comprehensive earthquake monitoring in the United States. To achieve that objective, the USGS is implementing the Advanced National Seismic System (ANSS), designed to upgrade national and regional seismic networks and with a major focus on "real-time" systems in at-risk urban areas. ANSS is a national initiative to improve all aspects of earthquake monitoring and reporting in the US.

The ANSS initiative provides an opportunity for infrastructure upgrades of the US seismic networks that will lead to improvements in routine operations. For instance, additional strong motion stations, new software, and computer upgrades may allow a seismic network to start generating *ShakeMaps* for emergency response. As these improvements are being made, the ANSS constituent seismic networks are being brought up to a performance level that will allow them to meet the ANSS performance standards. These standards will also allow the ANSS management to track how the goals and objectives of ANSS are being met.

ANSS Performance Standards

The ANSS performance standards set specific goals and requirements for the operation of ANSS participating seismic networks. These standards are intended to improve the response of the ANSS as a system to significant earthquakes nation wide. In most cases the standards imply that the infrastructure, operational efficiency, and data processing needs of each seismic network need to be improved. Further, the product availability needs to be standardized and brought up to the standards of the best performing networks within the ANSS.

Draft performance standards are provided for:

Seismic Monitoring
Strong Earthquake Shaking
Rapid Notification
Data Exchange
Data Archiving
External Product Dissemination

Seismic Monitoring

Earthquakes occur throughout the US with varying frequency and are recorded by both regional networks and the national seismic network. In addition, US seismic networks record other seismic events, including explosions, quarry blasts, volcanic tremors, and teleseisms.

Goal: To monitor seismic activity throughout the US to catalog the occurrence of earthquakes and archive the appropriate data for seismic hazards and earthquake research.

Key Components: The standard for seismic activity involves both operations of seismic networks and generation of data products. Seismic networks operate remote seismic stations with dedicated telemetry and data acquisition systems 24/7. The data are pre-processed using automated algorithms. Most networks also post-process the data with human input to refine data quality before archiving.

The completeness level measures the minimum earthquake magnitude above which the network detects all earthquakes. If significant equipment failures occur, it may not be possible to meet this standard for a few days or, possibly, weeks. The average location and magnitude uncertainties capture the overall network performance in terms of being able to produce a high quality catalog. The "magnitude "capability" describes the range, types, and uncertainties of magnitudes which the ANSS should be able to routinely calculate. The "waveforms saved" standard tracks possible station or communication outages that results in loss of seismic waveform data. The "metadata availability" ensures the availability of station instrumentation responses needed for all products based on amplitude information. The performance standard sets the following minimum requirements for parameters needed to catalog all earthquakes that are recorded:

Region	**Performance Standard:** **Completeness level/ % of time reached**	**Performance Standard:** **Average location uncertainty**	**Performance Standard:** **Magnitude capability**	**Performance Standard:** **Waveforms saved**	**Performance Standard** **Metadata availability**
Densely instrumented regions of the US	M1.5/ 99%	1.0 km hor./2.0 km vert.	1.5<Md<4.5±0.2 3.0<ML<6.0±0.2 4.5<Mw±0.1	95%	Complete instr. resp. 100%
Sparsely instrument regions of the US	M3.0/ 99%	5.0 km hor./10.0 km vert.	3.0<ML<6.0±0.2 4.0<Mb<6.5±0.2 4.5<Mw±0.1	90%	Complete instr. resp. 100%
Non-US	M4.0/ 95%	25.0 km hor./50 km vert.	4.8<Mb<6.5±0.2 5.0<Ms<8.0±0.2 6.0<Mw±0.1	90%	Nominal instr. resp. 100%

Comments:

The completeness level is difficult to determine, and most networks have not carried out rigorous analysis of their catalog to determine the spatial and temporal variability of M. It is recommended that ANSS establish standards for determining M and request that network operators do basic analysis of M spatial-temporal variability within their network.

The uncertainties in location and magnitude may be method dependent. It is recommended that ANSS adapt a standard for determining these parameters.

Maintenance of metadata is a resource-consuming task for most seismic networks. It is recommended that ANSS establish standards and tools for this task.

Consider adding fault modeling specification for M>6.5 continental U.S. earthquakes and M>7.0 global earthquakes.

Justification

1. Completeness levels and location uncertainty are determined to provide sufficient data for identification of active faults, improved hazard estimates, recurrence intervals, etc. A threshold lower than the "felt limit" is necessary, particularly in less seismically active areas of the country and where station density permits, in order to build sufficiently large catalogs in a reasonable amount of time. The stated thresholds are reasonable estimates that can be met by the ANSS as outlined in circular 1188.
2. Magnitude capability includes types and errors that balance best practice for the CISN with a reasonable estimate of the capability of a completed ANSS.
3. Percentage of waveforms saved balances the desire to have 100% availability with an experienced-based estimate of network performance.

Strong Earthquake Shaking

Large earthquakes have finite source dimensions that may extend from a few kilometers to 100s of kilometers. When such a fault rupture takes place, strong-motion acceleration recorders at free-field or reference sites record the potential violent and damaging shaking of the ground. Such data are used to infer the finite properties of the earthquake source and to establish attenuation relationships and site effects.

Goal: To capture large amplitude ground motions from earthquakes, which may cause damage to engineered structures or affect land use by causing liquefaction or other type of ground deformation.

Key Components: The standard for ground motion involves operation of dense and sparse networks of strong-motion stations. Some stations may not have communications, but most will use dial-up telephone lines or dedicated real-time communications. Stations are located in urban areas as well as along major fault lines. The most important data are recorded within a few km distance of the earthquake rupture or adjacent to a significant engineered structure that sustained damage due to shaking.

Strong motion data are essential for applications such as ShakeMap, and the value of the information can be enhanced through higher station density. The "instrument spacing" standard is meant to meet the needs of ShakeMap and the need for data from strong motion reference stations in the built environment. Table 3 in USGS Circular 1188 provides additional recommendations on the regional distribution of stations. The strong motion stations without continuous telemetry typically have a high triggering threshold and thus only record data for accelerations exceeding 0.1g. This low data rate makes station maintenance a challenge and the "data return rate" for most strong motion networks is in the range of 90%. The standards for "Peak ground motion, sampling rate, and absolute timing" are desirable recording characteristics. The "data processing" standard refers to carrying out minimum processing of the data to make them useful for the end user. The strong earthquake shaking performance standards set the following expectations:

Region	Performance Standard: Instr. Spacing in urban areas	Performance Standard: Waveform Data return rate	Performance Standard: Peak ground motion on scale/ sps/abs timing	Performance Standard: Data Processing
Urban regions of the US with-high risk	10 km	90%	2g/ 100sps/yes	**Archive raw data/ Calc. Spectra Correct acc/vel/disp**
Non-urban regions of the US with high hazard	20 km	90%	2 g/ 100sps/yes	**Archive raw data/ Calc. Spectra Correct acc/vel/disp**
Non-urban regions of the US with low hazard	300 km	80%	2 g/ 100sps/yes	**Archive raw data/ Calc. Spectra Correct acc/vel/disp**

Comments:

As of the date of this report, the ANSS has deployed ~500 new strong motion instruments in urban areas to make ShakeMap generation possible. It is recommended that ANSS evaluate if the new and existing stations provide an adequate coverage of urban areas at highest risk for the needs of ShakeMap and structural response monitoring.

Strong motion records from instruments placed in the near-field of fault zones are quite rare and essential for seismological and engineering research. It is recommended that ANSS establish goals and standards for active fault zone strong motion monitoring to ensure that those valuable data will be collected.

Justification

1. Instrument spacing is primarily designed to provide sufficient resolution for the purposes of Shakemap in areas with elevated hazard. For the purposes of emergency response, there may be a greater tolerance for lower resolution maps in non-urban areas with high hazard.
2. The waveform return rate reflects the operational likelihood that some stations will be triggered and may not trigger for a given event.
3. The peak ground motion strikes a balance between a high probability of remaining on scale and useful signal to noise ratios for mid-size events. Likewise, the sample rate strikes a balance between data rates that operators can reliably and easily record in real-time and the sample rates needed for engineering applications.
4. Both the engineering and seismological communities will benefit from preprocessed archived spectra of standard units.

Rapid Notification

When a significant earthquake occurs, there is need for immediate information to facilitate emergency response and to provide information to decision makers, the media and the public. Federal, state, and local governments are responsible for responding to a significant earthquake. To facilitate efficient response, the seismic networks must provide rapid, consistent, high quality information about the earthquake.

Goal: Automatically and rapidly broadcast accurate information to emergency responders, the media, and the public when a significant earthquake occurs.

Key Components: Seismic networks process earthquake data 24/7 to automatically generate and distribute a variety of products. In general, the products are less accurate just after the earthquake, but their accuracy improves as more data are included and models are refined. Human review, reprocessing, and updating of information follow the automated distribution of information. The products are distributed via short messages (pager and cell phone), email, and the Web.

The performance standards for rapid notification involve timeliness and consistency of initial product delivery. The time delays that contribute to late delivery of products are, for instance, the time it takes seismic waves to traverse the whole seismic network, packetizing delays for waveform data, processing delays, and product delivery delays. Seismic networks may have unforeseen outages and product delivery will not be possible during that time. We have established performance standards for the most common products of seismic networks:

Real-time Automated Product Generation

Region	**Performance Standard:** **Hypocenter Lapse time/ % of time**	**Performance Standard:** **Magnitude Lapse time/ % of time**	**Performance Standard:** **Moment Tensor Lapse time/ % of time/threshold**	**Performance Standard:** **ShakeMaps Lapse time/ % of time/threshold**	**Performance Standard:** **Aftershock Probabilities Lapse time/ % of time/threshold**
Densely instrumented regions of the US	2 min./99%	3 min./99%	8 min./95%/M4.5	5 min./99%/M3.5	10 min./99%/M5.0
Sparsely instrument regions of the US	3 min./99%	4 min./99%	10 min./90%/M4.5	6 min./99%/M4.0	15 min./99%/M5.0
Non-US	12 min. 98%	12 min./98%	60 min./90%/M6.0	14 min./90%/M6.0	60 min/50%/M6.0

Justification

1. In order to meet the needs of the rapid response community and others, automated products should be produced as quickly as possible while maintaining a reasonable level of product quality.
2. Automated product generation standards are based on experience from existing operations such as the CISN.

Post-Processing Product Generation for Major Earthquakes

Region	**Performance Standard:** **Human Review Hypocenter Lapse time/ % of time /Threshold**	**Performance Standard:** **Human Review Magnitude Lapse time/ % of time/Threshold**	**Performance Standard:** **Human Review Moment Tensor Lapse time/ % of time/Threshold**	**Performance Standard:** **Human Review ShakeMaps Lapse time/ % of time/Threshold**
Densely instrumented regions of the US	15min./99%/M3.5	15 min./99%/M3.5	30 min./95%/M4.5	15 min./99%/M3.5
Sparsely instrument regions of the US	30 min./99%/M3.5	30 min./99%/M3.5	45 min./90%/M4.5	30 min./99%/M3.5
Non-US	30 min. 99%/M6.0	30 min./99%/M6.0	60 min./90%/M6.0	60 min./90%/M6.0

Justification

1. In order to meet the needs of the rapid response community and others, reviewed products should be produced as quickly as possible while maintaining a reasonable level of product quality.
2. Reviewed product generation standards are based on experience from existing operations such as the CISN.

Data Exchange

The operational efficiency of seismic networks can be greatly improved through real-time data exchange. Data recorded at stations operated by a neighboring network can provide important information about significant earthquakes, particularly when it occurs near the border region of the two networks or where the spatial extents of network operations overlap.

Goal: Share real-time waveforms, amplitudes, picks and other raw data products amongst regional and national networks to improve quality and timeliness of data products.

Key Components: Unprocessed waveforms are the most basic seismic data that can be continuously exchanged and provide the ability for networks to compute all seismological products. However, the bandwidth can be considerable, so it may be necessary to exchange derived products such as amplitudes (acceleration, velocity, displacement, spectral ordinates, etc.) for calculation of magnitude and ShakeMaps, arrival times and polarity of seismic waves for computing locations, origin times, and first-motion mechanisms, or "snippets" of waveforms when earthquakes occur for computing moment tensors and analyst review. The "Dataless" SEED and V0 are files formats that contain necessary instrument calibration for seismic waveform data exchanged between networks. The data sharing performance standards are summarized below:

Region	**Performance Standard:** **Waveforms: Timeliness/ Completeness**	**Performance Standard:** **Amplitudes Timeliness/ Completeness**	**Performance Standard:** **Phase Picks Timeliness/ Completeness**	**Performance Standard:** **Dataless SEED/V0 Availability**
Densely instrumented regions of the US	30 sec/95%	30 sec/95%	30 sec/95%	100%
Sparsely instrument regions of the US	30 sec/90%	30 sec/90%	30 sec/90%	100%
Non-US	60 sec/90%	60 sec/90%	60 sec/90%	100%

Justification

1. Exchange standards represent minimums required for automated product generation, likely packetization size, and anticipated communications bandwidth and availability.

2. Standards are based on existing experience with data exchange throughout the U.S.
3. Note that current U.S. backbone packet size is about 50 s of data. A higher sampling rate and wider VSAT bandwidth would be required to meet the 30 s waveform specification.

Data Archiving

Seismic networks generate data continuously as they monitor seismicity. When an event is detected, the respective window of waveforms is typically stored for later archiving. Similarly, at the onset of detection, products such as phase arrival times, amplitudes, hypocenters, magnitudes, mechanisms, ShakeMaps, and slip distributions may be generated. In some cases, seismic networks record continuous data from broadband data.

Goal: Archive all relevant data and data products generated by ANSS, including the regional and global seismic networks at public datacenters.

Key Components: The datacenters must balance the archiving of data from the seismic networks against the speed at which they serve data to the users. Data archiving occurs on a regular basis, whereas user requests for data may be episodic. Consequently, during a major earthquake sequence a data archive will need to be able to deal with increased data volume (input) as well as an exponential increase in user requests (output).

Some data archives presently provide data to users via command-line scripts, while most use Web pages and ftp as transfer mechanisms. In the future all data archives should provide data via the former mechanisms, as well as via simple subroutine calls. Similarly, data formats are evolving from legacy binary or ASCII formats to XML. One of the challenges facing datacenters is to import decades of legacy date into modern database structures to be able to serve up the data in a variety of ways as dictated by user needs.

The data archiving performance standards address several aspects of the datacenter operations. First, the datacenter needs to import data in a timely fashion. Products such as waveforms and parametric data should automatically be made available to users with minimal delay. The datacenters need to be able to serve a large number of users during periods of high demand. Metadata must be provided that describe station characteristics and instrument responses. The standards of data archiving are summarized below:

Region	**Performance Standard:** **Import of data to the archive: Timeliness/ completeness**	**Performance Standard:** **Availability of Waveforms: Timeliness/ completeness**	**Performance Standard:** **Availability of Parametric data Timeliness/ completeness**	**Performance Standard:** **User data retrieval Speed/# of users**	**Performance Standard:** **Metadata availability**
Densely instrumented regions of the U.S.	10 min./95%	30 min/95%	30 min/95%	56KB per sec/30	99%
Sparsely instrumented	10 min/95%	30 min/95%	30 min/95%	56KB per sec/30	99%

regions of the U.S.					
non-U.S.	24 hrs/95%	36 hrs/95%	36 hrs/95%	56KB per sec/30	99%

Justification

1. Standards for data import into the archive provide a reasonable balance between the desires of the user and the abilities of the system.
2. Availability of the data provides sufficient time for archive construction and processing.
3. Retrieval rates provide a reasonable balance between expected number of users, speed, and likely bandwidth.

External Product Dissemination

The end users of the products from the seismic network include large communities of emergency responders, earthquake engineers, decision makers, education community, media, and public.

Goal: Provide reliable, useful, accurate, and timely release of products to target communities.

The ANSS mission does not include Education and Outreach *per se*. In order to meet the above goal however, education will need to be provided either directly or through partnerships with organizations that do perform E&O. The principal goals of this education are to minimize product misuse and to maximize feedback for long-term product improvement. Specific standards on dissemination goals and use are difficult, if not impossible to quantify. Determination and implementation of appropriate metrics will require expertise external to existing ANSS operations and management.