# Strategies for Long-Term Operation of Geotechnical Strong-Motion Arrays

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## INTRODUCTION

Past studies have recognized that successful implementation and long-term operation and maintenance of strong-motion instrumentation programs involve special problems for management and funding [1]. In significant part the problems relate to the potentially long time period that a given installation must be maintained before significant data are obtained.

This imposes in addition to the requirements for long-term maintenance of instrument installations, resources for changing out or upgrading instrument over time. The problems are similar, but may be amplified, for long-term operation and maintenance of strong-motion array test sites. Additional problems arise for these installations, particularly when the array installation has a narrow research goal, which can limit broad ongoing experimentation that could serve as a continuing stimulus for sustained operational funding.

In the United States, a number of public and private organizations operate strong-motion instrumentation programs. Most have focused missions to assure earthquake safety of specific critical facilities that they operate. The two major strong-motion instrumentation programs in the United States, the Advanced National Seismic System National Strong-Motion Program (ANSS/NSMP) and the California Strong-Motion Instrumentation Program (CSMIP) in contrast, have broad missions to provide data for research and practice, to advance public safety in earthquakes, and to support response and recovery following significant damaging earthquakes. A working mission statement for U.S. Strong-Motion Programs, which was developed in a workshop in 1993 sponsored by the National Science Foundation, emphasizes this broad public safety focus [2].

*"The Mission of U. S. Strong-motion Program is to increase public safety by providing users of earthquake strong-motion information, i.e.,*

- *Engineering and Scientific Community*
- *Public Agencies*
- *Industry*
- *Media*
- *Other users*

*with data and analyses on strong earthquake shaking for the purpose of:*

- *Improving engineering evaluations and design methods for facilities and systems.*
- *Providing timely information for post-earthquake alerting and assessment.*
- *Contributing to a greater understanding of the mechanics of earthquake generation and ground motion characteristics."*

A well-prioritized mix of strong-motion arrays single instrument installations is needed to fully respond to this broad mission statement for publicly supported string-motion instrumentation programs Effective implementation of such programs involves making sound choices about the appropriate mix of strong-motion arrays and single station instrument installations over time, which necessarily must involve effective ongoing feedback and oversight by the community of strong-motion information users.

Both the ANSS/NSMP and the CSMIP programs have strategic plans that respond to the agencies' specific missions, include structured management and oversight components, and have long time horizons, twenty years or more. Resources for long-term maintenance and upgrading of these instrument installations are part of the base line funding programs of the two agencies. Both programs incorporate dense strong-motion arrays as part of their long-term strong-motion installation mix (e.g., [3] [4]). But, in reality these two important strong-motion instrumentation programs are not able to muster the funding levels' that would be required to install within a reasonable time frame the number of strong-motion arrays that are needed to address the broad range of recognized scientific and engineering needs and to sustain maintenance and upgrading of the instrumentation for the required long operational time periods.

A very productive workshop lead by Professor Iwan comprehensively addressed requirements for implementation and long-term maintenance of strong-motion arrays [5]. The insightful recommendations of the workshop have guided much of subsequent strong-motion array development. The Iwan report emphasized the importance of international corporation, coordination, and collaboration, which is succinctly captured in the stated overarching objective of the workshop implementation recommendations.

> "*The intention is to develop a program that is controlled by the participating scientists, and this constraint excludes an organization that is tied to existing international inter-governmental organizations."*

This insightful perception of a major key for successful implementation and long-term operation of strong-motion arrays lead directly to the formation of the IASPEI-IAEE Joint Working Group on Effects of Surface Geology (JWG-ESG) on Seismic Motion in 1986 [6]. The stated goal of the JWG-ESG is to provide leadership for understanding the effects of local geology on strong ground motion. The JWG-ESG encourages the establishment of site response strong-motion array test sites, holds workshops and symposia to coordinate assessment of prediction results, coordinates evaluations of ongoing developments in site response prediction methods, and stimulates exchanges of new ideas, and serves as a forum for the exchange of information about newly implemented strong-motion arrays [6]. The Ashigara Valley, Japan site response strong-motion array and blind prediction experiment, which was organized by the Japanese National Working Group on ESG, was an early accomplishment under the coordination of the JWG-ESG [7]. The Turkey Flat site effects test array, which was organized and implemented by CSMIP in 1986, successfully recorded the M6.0 Parkfield earthquake of September 28, 2004, almost twenty years following installation of the array, is a particularly illustrative example of successful long-term operation and maintenance of a strong-motion array test site. One key to this important achievement was well-coordinated ongoing active engagement of the scientific community through a series of prediction exercises and active participation of an oversight committee [8] [9] [10] [11] [12] [13] [14]. The JWG-SEG continues as a forum for exchange of information about strong-motion array sites, among them the EUROSEISTEST [15] and the Borrego Valley and Garner Valley arrays [16]. ESG 2006, the 3rd International Symposium on The Effects of Geology on Seismic Motion, will be held from August 29 through September 1, 2006 (http://esg2006.obs.ujf-grenoble.fr).

The recommendations of the important Iwan [4] workshop remain current in their basic content and continue to provide important guidance for installation and management of strong-motion arrays, that is useful for development of strategies for long-term operation of geotechnical strong-motion arrays. The remainder of this summary paper focuses on identifying key requirements for successful long-term operation, which may serve as points for the Session 2 Round Table Discussion.

## SUCCESSFUL LONG-TERM OPERATION: PERSPECTIVE FROM EXPERIENCE

Experience shows that a strong management structure and adequate funding sources for maintaining and upgrading instrument installation over the long time intervals normally required to obtain significant data for a given location are primary requirements for successful long-term operation of strong-motion arrays. For most arrays, obtaining sufficient funding for long-term operation is the most difficult problem. But experience also shows that the potential for funding long-term operation of individual arrays can be enhanced through high levels of coordination, cooperation, and collaboration at the basic science and engineering levels as well as at institutional levels. Similarly, experience shows that successful implementation of uniform formatting, uniform processing and an infrastructure for effective dissemination of metadata and of the acquired recordings can be more effectively managed through active coordination, cooperation, and collaboration.

### *Coordination*

Coordination is highly productive at basic science and engineering levels and at the same time provides an ongoing stimulus for expanded institutional corporation and collaboration. The JWG-ESG serves as a forum primarily for coordination focusing on prediction the effects of near-surface geology on strong-ground motion. The stated functions of the JWG-ESG [7] are as follows:

*"1. Develop a plan for an International Experiment to test and compare methods of estimating the effects of surface geology on seismic motion.*

*2. Select test sites for participation in the International Experiment by:*

- *Establishing guidelines for participation in the International Experiments*
- *Encouraging participation in the International Experiment*
- *Reviewing and approving the plan for Test Sites using the established guidelines*

*3. Provide technical assistance to participate and to organizations wishing to become participants.*

*4. Provide for distribution of ground motion data and geotechnical data.*

*5. Convene Special Workshops to:*
- *Compare predictions and observations of site response following 'significant' earthquakes.*
- *Discuss weak motion data and procedural issues.*

*6. Hold Informational Workshops to:*
- *Keep research community aware of needs and progress in field*
- *Promote interest in this activity among scientists, engineers, and public policy makers*

*7. Assist in raising funds from both international and national sources to support the goals of the International Experiment."*

Since its formation in 1986, the JWG-ESG has very productively performed its stated functions [6]. In particular, the JWG has performed the important function of providing a framework and international sponsorship of site-response blind prediction experiments: the Ashigara Valley blind prediction experiment, which was organized and managed by the Japanese National Working Group on ESG [7] and the Turkey Flat blind site response prediction experiment, which was organized and is managed by the CSMIP [14]. Of critical importance the JWG provides ongoing coordination leadership for communicating prediction results through international symposia and special theme sessions at international conferences.

These ongoing coordination activities proactively advance scientific understanding by stimulating ongoing development of products, emphasizing the importance of providing long-term funding for operation and maintenance. The successes of the Ashigara Valley and Turkey Flat strong-motion array test sites indicates that significant benefit could be gained through the formation of international working groups patterned after the JWG-ESG, each involving representation of engaged scientists and engineers as well as strong-motion instrumentation programs, to provide forums for coordination of strong-motion arrays addressing soil-structure interaction, liquefaction, and other earthquake engineering problems.

## Cooperation

Many public and private organizations have individual mission requirements particular facilities that they own that include strong-motion instrumentation. The two major strong-motion instrumentation programs in the United States, the ANSS/NSMP and the CSMIP operate strong-motion instrument installations including strong-motion arrays under cooperative agreements with other public and private organizations. CSMIP provides management for installation and long-term maintenance of some twenty downhole arrays that have been instrumented in cooperation with other organizations, the primary one being the California Department of Transportation [3]. Currently, approximately 30% of the ANSS/NSMP strong-motion installations involve corporative agreements with other public and private organizations ([4]; http://nsmp.wr.usgs.gov/about_nsmp.html). The experience of these cooperative strong-motion instrumentation activities is that individual organizations that may have narrow missions involving strong-motion instrumentation as well as the two major strong-motion instrumentation programs that have broad missions can substantially benefit through cooperation, especially with respect to providing resources for long-term operation and maintenance of the systems.

The recently implemented California Integrated Seismic Network (CISN) elevates long-term cooperative storng-motion activities to a new level and is an important example of the enhanced effectiveness and economies that can be realized through well-structured cooperation among individual strong-motion instrumentation programs (http://www.cisn.org). The CISN is a cooperative partnership among the California Geological Survey, Caltech Seismological Laboratory, U.C. Berkeley Seismological Laboratory, USGS/ANSS, and the California Governor's Office of Emergency Services, which integrates management of the strong-motion instrumentation activities of the partner organizations. A particularly important aspect of the CISN is that it integrates strong-motion instrumentation programs, research, archiving and dissemination of information for public earthquake safety, emergency response and recovery, and earthquake loss mitigation. An Advisory Committee constituted of representatives of strong-motion information user organizations guides CISN projects, which also are actively coordinated with a number of other universities as well as with other federal, state, private organizations. The establishment of the CISN represents a major advancement in the effectiveness of strong-motion instrumentation programs in California region and serves first implementation model for implementation of ANSS/NSMP cooperative instrumentation programs in other regions of the United States.

### *Collaboration*

Operations of both the EUROSEISTEST and the Corinth Soft Soil Array (CORSSA) strong-motion array test sites [15] involve high levels of collaboration within a broader scope of research and seismic hazard activities. The EUROSEISTEST test site functions as a large experimental laboratory infrastructure within the framework of the EUROSEIS-RISK Project. The EUROSEIS-RISK project provides a framework for experimental and theoretical research collaboration across disciplines ranging from applied geophysics to geotechnical and structural engineering. Collaboration includes a broad scope of research related to earthquake hazard assessment and earthquake design of structures, currently involving ten academic institutions. The CORSSA strong-motion array is operated as part of the Corinth Seismicity project (CORSEIS) of the Corinth Rift Laboratory (http://corinth.dt.insu.cnrs.fr/index_en.html). The Corinth Rift Laboratory, which is designed as an in-situ testing laboratory, is the result of collaboration among twenty-one European academic and private laboratories and private sector companies to implement a broad-scope test laboratory for evolving methodologies and tools for integrated seismic hazard assessment. Currently about seventy individuals constituted of academic scientists and engineers and practitioners are participating on the collaboration. The participants are engaged in coordinated work packages ranging from investigations of the mechanical behavior of faults to development of data management and dissemination infrastructure.

These two important collaborative efforts share a number of operating characteristics that promote long-term operation in common with other successful long-term strong-motion

(1) They involve a broad scope of monitoring and experimental testing.

(2) They have strategic plans for long-term operation and ongoing sharing of experimental testing results through work package coordination meetings and workshops.

(3) They deliver a continuous stream of test results and products.

(4) They have a strong management structure including:

- an overall coordinator
- oversight by a steering committee
- an outreach network constituted of scientists and engineers who share common

research interests or are users of the results

- frequent workshops for communicating results and setting future directions for the work

These dynamic management characteristics and active collaboration promote successful long-term operation and should be viewed as keys for successful long-term operation of strong-motion array sites independently of whether the site serves as an independently operated experimental test facility or is part of the mix larger broad-scope permanent strong-motion instrumentation networks.

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