

## ***Transmittal Letter***



# PROPOSAL COVER PAGE

(Date : Nov 19, 2002)

**REASON-0156-0039**

**Name of Submitting Institution:** Jet Propulsion Laboratory

**Congressional District:** 27

**Certification of Compliance with Applicable Executive Orders and U.S. Code**

By submitting the proposal identified in this Cover Sheet/Proposal Summary in response to this Research Announcement, the Authorizing Official of the proposing institution (or the individual proposer if there is no proposing institution) as identified below:

- certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;
- agrees to accept the obligations to comply with NASA award terms and conditions if an award is made as a result of this proposal; and
- confirms compliance with all provisions, rules, and stipulations set forth in the two Certifications contained in this NRA [namely, (i) Assurance of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs, and (ii) Certifications, Disclosures, And Assurances Regarding Lobbying and Debarment & Suspension]. Willful provision of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).

**NASA PROCEDURE FOR HANDLING PROPOSALS**

This proposal shall be used and disclosed for evaluation purposes only, and a copy of this Government notice shall be applied to any reproduction or abstract thereof. Any authorized restrictive notices that the submitter places on this proposal shall also be strictly complied with. Disclosure of this proposal for any reason outside the Government evaluation purposes shall be made only to the extent authorized by the Government.

**[1] ... PI Information**

<b>Name:</b>	Webb, Frank H	<b>Email:</b>	fhw@jpl.nasa.gov
<b>Organization:</b>	Jet Propulsion Laboratory	<b>Department:</b>	
<b>Mail Stop:</b>	Mail Stop 301-125	<b>Telephone:</b>	818/354-4670 Ext:
<b>Address:</b>	4800 Oak Grove Drive	<b>Fax:</b>	818/393-4965
<b>City, State, Zip:</b>	Pasadena, CA 91109 - 8001	<b>Country:</b>	USA

PI Signature and Date:

---

<b>Authorizing Official:</b>		<b>Email:</b>	
<b>Title:</b>		<b>Phone:</b>	
<b>Institution:</b>			
<b>Address:</b>			

AO Signature and Date:

---

**[2] ... Team Member**

Role	Name	Organization	Email Address	Telephone
COI	Anderson, Greg	US Geological Survey	ganderson@usgs.gov	626 583 6799
COI	Bock, Yehuda	University of California San Diego	ybock@ucsd.edu	858/534-5292

<b>COI</b>	Dong, Danan	Jet Propulsion Laboratory	danan.dong@jpl.nasa.gov	818-393-1827
<b>COI</b>	Heflin, Michael	Jet Propulsion Laboratory	mbh@cobra.jpl.nasa.gov	818/354-2823
<b>COI</b>	Kedar, Sharon	Jet Propulsion Laboratory	Sharon.Kedar@jpl.nasa.gov	(818) 393-6808
<b>COI</b>	King, Nancy	US Geological Survey	nking@usgs.gov	626-583-7815

**[3] ... Proposal Title (Short and/or Full)**

<b>Short Title:</b>	GPS Data Products for Solid Earth Science
<b>Full Title:</b>	

**[4] ... Proposed Start/End Date**

<b>Start Date:</b>	02/01/2003
<b>End Date:</b>	12/31/2007

**[5] ... Science Areas**

Applications/Type I Research SEEDS Open Source
--

**[6] ... Summary**

Over the past decade, regional and global networks of continuously operating GPS ground stations have been deployed to monitor Solid Earth deformation , and to support Earth Science Enterprise (ESE) priorities and flight projects. At the forefront, and the focus of this project, is the 250-station Southern California Integrated GPS Network (SCIGN), a multi-agency effort jointly sponsored by NASA, NSF, USGS, and the W.M. Keck Foundation, under the umbrella of the Southern California Earthquake Center (SCEC). Over the next five years, SCIGN will become an integral part of the multi-agency, multi-disciplinary Plate Boundary Observatory (PBO), an observatory of high-precision geodetic instruments spanning western North America. This project is intended to solidify NASA's participation in PBO and the larger NSF-lead EarthScope initiative while concurrently meeting objectives of NASA's ESE.

Currently, SCIGN provides GPS data and metadata and only low-level data products. We propose to enhance delivery of these products using modern IT methodology, and to produce and disseminate an entirely new set of higher-level data products to a larger community, including scientists, government agencies (Federal, State, and Local), surveyors, and GIS mappers. This project will build on current capabilities within SCIGN for data archiving, information systems, and data analysis to disseminate the following products: geodetic position time series, crustal motion models, strain rate maps, geologic fault models, near-real-time earthquake response information, geodetics reference systems for precise GIS and surveying, and aquifer recharge monitoring.

To provide these data and data products in a highly available, highly integrated system numerous improvements in archiving, end-user interfaces, delivery mechanisms and data modeling will be developed. As part of the development of these advanced information systems components we propose an optional open source project based on a redundant, multi-tiered "Virtual Archive" for GPS applications.

**[7] ... Budget**

Type	Year 1	Year 2	Year 3	Year 4	Year 5	Total
<b>Direct Labor</b>	\$188.00	\$269.00	\$260.00	\$305.00	\$273.00	\$1,295.00
<b>Other Direct Costs - Subcontracts</b>	\$725.00	\$725.00	\$704.00	\$709.00	\$719.00	\$3,582.00

<b>Other Direct Costs - Consultants</b>	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
<b>Other Direct Costs - Equipment</b>	\$4.00	\$1.00	\$3.00	\$0.00	\$0.00	\$8.00
<b>Other Direct Costs - Supplies</b>	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
<b>Other Direct Costs - Travel</b>	\$10.00	\$10.00	\$10.00	\$10.00	\$7.00	\$47.00
<b>Other Direct Costs - Other</b>	\$105.00	\$142.00	\$136.00	\$157.00	\$141.00	\$681.00
<b>Indirect Costs</b>	\$74.00	\$86.00	\$85.00	\$93.00	\$90.00	\$428.00
<b>Other Applicable Costs</b>	\$16.00	\$17.00	\$16.00	\$17.00	\$16.00	\$82.00
<b>Subtotal - Estimated Costs:</b>	\$1,122.00	\$1,250.00	\$1,214.00	\$1,291.00	\$1,246.00	\$6,123.00
<b>Less: Proposed Cost Sharing - Cost Sharing:</b>	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
<b>Budget Total</b>	<b>\$1,122.00</b>	<b>\$1,250.00</b>	<b>\$1,214.00</b>	<b>\$1,291.00</b>	<b>\$1,246.00</b>	<b>\$6,123.00</b>

Continue

Edit Proposal Information

## Table of Contents

<i>TRANSMITTAL LETTER</i> .....	1
PROPOSAL COVER PAGE .....	2
TABLE OF CONTENTS .....	I
1.0 ABSTRACT .....	1
2.0 PROJECT DESCRIPTION .....	2-1
2.1 Relevance of Data or Services.....	2-4
2.2 Approaches for Data Production, Distribution, and User Support .....	2-6
2.2.1 Data Production .....	2-6
2.2.1.1 Summary of Current Status .....	2-6
2.2.1.2 Objectives.....	2-6
2.2.2 Data Distribution and User Support .....	2-7
2.2.2.3 Adaptive Seamless Archive System.....	2-8
2.2.2.4 GPS Explorer.....	2-9
2.2.2.5 Spatial Services .....	2-10
2.3 Earth System Science User Support .....	2-10
2.4 SEEDS Guiding Principles.....	2-10
2.5 Level of Participation in SEEDS Working Group.....	2-11
2.5.1 <i>Data Format and Content</i> .....	2-11
2.5.2 <i>Interface Standards</i> .....	2-12
2.5.3 Software Reuse .....	2-12
2.5.4 Evolution .....	2-12
2.5.5 Technology Utilization.....	2-12
2.5.6 Levels of Service.....	2-12
2.5.7 Metrics .....	2-13
2.6 <i>Compliance with REASoN Project Requirements</i> .....	2-13
2.7 <i>Additional Research REASoN Project Elements</i> .....	2-13
2.7.1 <i>Archiving</i> .....	2-13
2.7.2 <i>Distribution of End Products</i> .....	2-13
2.8 <i>Additional Application REASoN Project Elements</i> .....	2-14
2.8.1 <i>Description of Application</i> .....	2-14
2.8.2 <i>Utilization of NASA Data, and/or Science Results, and/or Technology Products in the Project/Application</i> .....	2-14
2.8.3 <i>Current State of the Application</i> .....	2-14
2.8.3.1 <i>Expected End State of the Application</i> .....	2-15
2.8.4 <i>End Users of the Application</i> .....	2-15
2.8.5 <i>Milestones to Evaluate the Application’s Readiness</i> .....	2-15
2.8.6 <i>Post-Cooperative Agreement Intent/plan</i> .....	2-15
3.0 OPEN SOURCE .....	3-15

4.0 PREFERENCES FOR PARTICIPATION IN THE FEDERATION AND SEEDS WORKING GROUP(S).....	4-17
5.0 METRICS.....	5-17
5.1 <i>Inputs</i> .....	5-18
5.2 <i>Outputs</i> .....	5-18
5.3 <i>Outcome</i> .....	5-18
5.4 <i>Impact</i> .....	5-19
6.0 MANAGEMENT APPROACH.....	6-19
6.1 Management Approach.....	6-19
6.2 <i>Coordination Between Participants</i> .....	6-19
6.3 Statement of Work.....	6-2
6.4 <i>Key Personnel</i> .....	6-4
7.0 PERSONNEL.....	7-1
8.0 REFERENCES.....	8-9
9.0 PROPOSED COSTS.....	9-1
9.1 <i>Budget Breakdown by Fiscal Year</i> .....	9-1
10.0 FACILITIES AND EQUIPMENT.....	10-2
10.1 Computing Equipment.....	10-2
10.2 Mass Store.....	10-3
10.3 GIS Laboratory.....	10-3
10.4 Experimental Facilities.....	10-3
10.5 Software.....	10-5
11.0 COOPERATIVE AGREEMENT PAYMENT SCHEDULE.....	11-1
12.0 CURRENT AND PENDING SUPPORT.....	12-1
13.0 SPECIAL MATTERS.....	13-1
14.0 LETTERS OF SUPPORT.....	14-1

## **1.0 ABSTRACT**

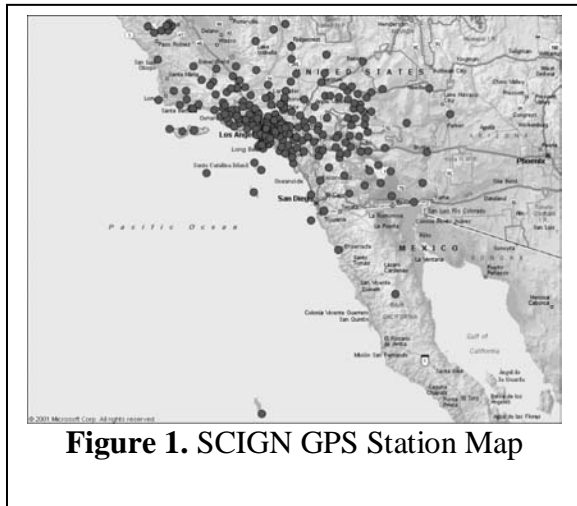
Over the past decade, regional and global networks of continuously operating GPS ground stations have been deployed to monitor Solid Earth deformation, and to support Earth Science Enterprise (ESE) priorities and flight projects. At the forefront, and the focus of this project, is the 250-station Southern California Integrated GPS Network (SCIGN), a multi-agency effort jointly sponsored by NASA, NSF, USGS, and the W.M. Keck Foundation, under the umbrella of the Southern California Earthquake Center (SCEC). Over the next five years, SCIGN will become an integral part of the multi-agency, multi-disciplinary Plate Boundary Observatory (PBO), an observatory of high-precision geodetic instruments spanning western North America. This project is intended to solidify NASA's participation in PBO and the larger NSF-lead EarthScope initiative while concurrently meeting objectives of NASA's ESE.

Currently, SCIGN provides GPS data and metadata and only low-level data products. We propose to enhance delivery of these products using modern IT methodology, and to produce and disseminate an entirely new set of higher-level data products to a larger community, including scientists, government agencies (Federal, State, and Local), surveyors, and GIS mappers. This project will build on current capabilities within SCIGN for data archiving, information systems, and data analysis to disseminate the following products: geodetic position time series, crustal motion models, strain rate maps, geologic fault models, near-real-time earthquake response information, geodetics reference systems for precise GIS and surveying, and aquifer recharge monitoring.

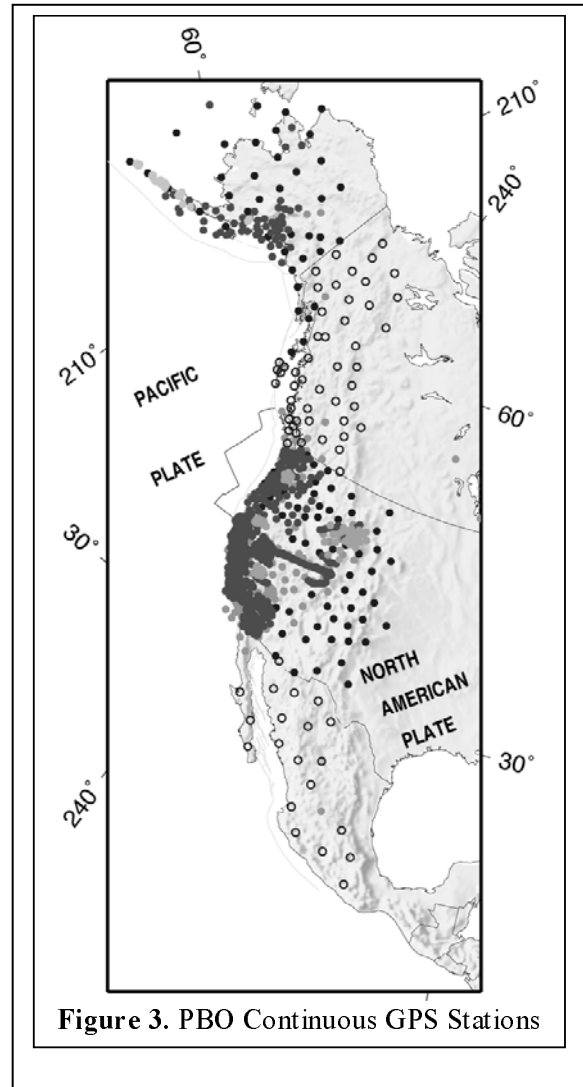
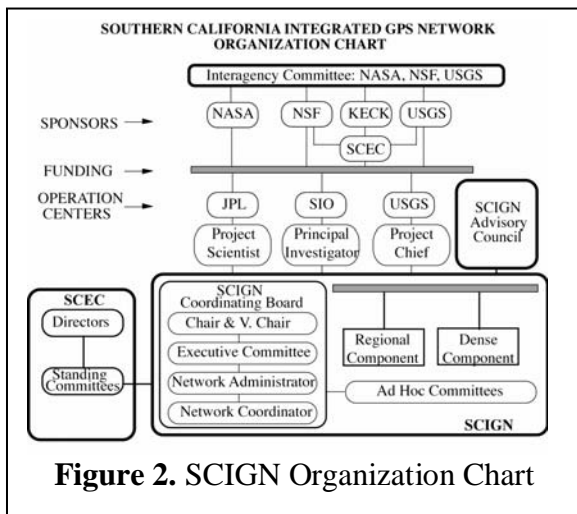
To provide these data and data products in a highly available, highly integrated system numerous improvements in archiving, end-user interfaces, delivery mechanisms and data modeling will be developed. As part of the development of these advanced information systems components we propose an optional open source project based on a redundant, multi-tiered "Virtual Archive" for GPS applications.

## 2.0 PROJECT DESCRIPTION

The utility and justification for continuously operating GPS networks has been well documented in numerous recommendations and reports, and through community use of the data, science advancement, and the growth in scientific, civil, and commercial applications, around these networks [e.g., *SESWG*, 2002, *PBO White Paper*, 1999].



A cornerstone of this growth has been the Southern California Integrated GPS Network (SCIGN), a 250-station network of continuously operating GPS receivers (Fig. 1). SCIGN is jointly sponsored by NASA, NSF, USGS, and W.M. Keck Foundation and operates under the auspices of the Southern California Earthquake Center (SCEC). A multi-agency and multi-organization coordinating board (Fig. 2) consisting of



project members, universities, local, state, and federal government officials, and scientific community members govern SCIGN. An independent science Advisory Council (AC) provides critical input on its operations, goals, and responsiveness to the community. A website (<http://www.scign.org/>) is maintained that documents the project, including annual reports, and project status. Level-0 GPS data are provided to users via the SCIGN archive (<http://sopac.ucsd.edu/>).

When SCIGN was first proposed, there was only a 10-station continuous GPS network in southern California that was dedicated to monitoring crustal strain [*Bock et al.*, 1997]. Following the valuable contribution from these stations to both the 1992 Landers



[Hudnut *et al.*, 1994; Shen *et al.*, 1994; Wdowinski *et al.*, 1997], and 1994 Northridge [Heflin *et al.*, 1998; Donnellan and Lyzenga, 1998; Deng *et al.*, 1999] earthquakes, SCIGN was proposed as a 7-year experiment into both the utility of applying GPS network technology to studying the Earth and the understanding of the processes driving tectonics in southern California.

One of the primary concerns at that time was the ability of the community to retrieve, distribute, and process the observations from such a large network. Since its inception, SCIGN has demonstrated that these obstacles can be overcome, resulting in the development of other regional GPS networks (including the 1200-site Japanese national network) and the initiation of the largest integrated strain network in history, the Plate Boundary Observatory (PBO) (Fig. 3). The PBO, which SCIGN will become an integral part of, enjoys wide community support and is progressing through the National Science Foundation as part of the EarthScope initiative (<http://www.earthscope.org>).

EarthScope is a multi-pronged initiative to apply modern observational, analytical and telecommunications technologies to investigate the structure and evolution of the North American continent and the physical processes controlling earthquakes and volcanic eruptions. The major components are ground based deformation instruments, seismic arrays, deep crustal observatories, and a space-based InSAR. EarthScope will provide a foundation for fundamental and applied research throughout the United States that will contribute to the mitigation of risks from geological hazards, the development of natural resources, and the public's understanding of the dynamic Earth. Successful completion of the proposed project under this CAN will allow NASA Solid Earth Science to play a key role in the success of EarthScope beyond its envisioned InSAR role. In fact, the leveraging of NASA's investment in GPS network technology into EarthScope has been a recommendation of NASA's Solid Earth Science Working Group (SESWG) and is a key NASA contribution to EarthScope.

At its inception, SCIGN was perceived narrowly as an important resource for the geophysics community and has clearly met its original objectives [King *et al.*, 2002; SCIGN 2001-2002 Accomplishments, 2002; SCIGN Analysis Committee Report, 2001]. In the scientific community, GPS technology and applications have grown [e.g., Bock *et al.*, 2000; Nikolaidis *et al.*, 2001], further than originally imagined. Furthermore, over the last 7 years, GPS technology has become pervasive in civilian life, in addition to its contributions to the nation's security. An excellent example of the spinoffs of GPS technology into the public and government sectors is the California Spatial Reference Center (<http://csrc.ucsd.edu/>), a SCIGN outreach success story.

SCIGN was originally conceived as an observatory, providing Level-0 data products from the networks to users who would then process them for geophysical parameters. The value of the observations has been recognized by the community in a number of ways such as through publications [SCIGN Publication List, 2002] and new projects and feedback from the SCIGN science Advisory Council (AC). Growth in community interest in the information contained in the data from SCIGN has led the AC to recommend to SCIGN that it provides higher level data products and that these data products be provided with lower latency. This is a testament to the success of the project and represents a new phase of operations and an unsupported requirement on the network to increase the value of the data.

We propose to provide high-level (Level-1C to Level-3) data products to the community of geophysicists studying earthquake processes, crustal evolution, and magmatic systems. These data products will be at the level just below interpretation. In addition we will also provide rapid geophysical parameters in response to earthquakes and volcanic events within the GPS networks that will give emergency managers, policy makers, and service providers key information to respond to such events [See *Letters of Support*].

Table 1. Data products, relevance, and users. Research (yellow); Applications (orange)

Data Product	Product Level	Format	Data Product Description	Accessibility	Relevance of Data Services & Primary Users	Production
GPS Observables and Metadata	0	Raw receiver files, RINEX, IGS site logs (update to XML format this proposal)	RINEX files organized by year and day of year, Metadata through Site Information Manager ( <a href="http://sopac.ucsd.edu/scripts/SIMpl_launch.cgi">http://sopac.ucsd.edu/scripts/SIMpl_launch.cgi</a> ).	GSAC and SCIGN archive at <a href="ftp://garner.ucsd.edu">ftp://garner.ucsd.edu</a> <a href="http://garner.ucsd.edu">http://garner.ucsd.edu</a> <a href="http://gsac.ucsd.edu">http://gsac.ucsd.edu</a>	Raw GPS observables used by scientists, surveyors, and others for calculating geodetic coordinates and their time history.	Funded through SCIGN project and UNAVCO
Geodetic Time Series	1, 1C	XML based format under development by SCIGN.	Automated daily update of time series from each SCIGN/PBO site based on the combined solutions from the analysis centers.	SCIGN web-site at <a href="http://www.scign.org/">http://www.scign.org/</a> as machine readable observations and graphical displays.	Forms the basis for all high-level products. Lower latency and SCIGN combined product recommended by SCIGN Advisory Council (SAC)	Independent processing using GIPSY and GAMIT (Level 1), followed by combination into an official SCIGN time series.
Crustal Motion Model	2	TBD through negotiations with user communities	Automated update of the crustal motion field of SCIGN at intervals as needed by users (e.g. daily).	SCIGN web-site at <a href="http://www.scign.org/">http://www.scign.org/</a> as machine readable observations and graphical displays	Long-term, high-resolution monitoring of changes in Earth's surface addressing ESE goals in SES. Recommended by SAC & SESWG.	Existing software for strain estimation will be extended to produce automated crustal motion maps from the SCIGN time series.
Strain and Strain Rate Field	3	TBD	Automated update of strain and strain rate fields as required	SCIGN web-site at <a href="http://www.scign.org/">http://www.scign.org/</a> as machine readable observations and graphical displays	Directly called for and addresses recommendations of SESWG, EarthScope, and NASA ES research strategy goals in surface stress and deformation, with special focus on active earthquake and volcanic regions.	Existing software for strain estimation will be extended to strain differentials and rates, fault slip rates, aquifer undulation, and pre-, co- and post-seismic fault slip rates using the methodology of a spatial-temporal (S-T) filter.
Aquifer undulations	3	TBD	Aquifer discharge and recharge rates provided for water resource management with tectonic signal removed	SCIGN web-site at <a href="http://www.scign.org/">http://www.scign.org/</a> as machine readable observations and graphical displays.		Independent near real time analysis systems will be implemented.
Earthquake Fault Parameters	3	TBD	Fault slip rates derived from the SCIGN crustal motion maps will be provided on a long term, and event driven basis.	SCIGN web-site at <a href="http://www.scign.org/">http://www.scign.org/</a> as machine readable observations		
Co-Seismic and Post-Seismic Deformation	3	TBD	Co-seismic and rapid post-seismic displacements within 1 hour of an event	SCIGN web-site at <a href="http://www.scign.org/">http://www.scign.org/</a> as machine-readable observations and graphical displays, and California Integrated Seismic Network (CISN)	Office of emergency services, local authorities, utilities, transportation and media outlets will be the primary users of this product.	
Public and commercial sector products	1	RTCM (other real-time data formats) Near-real-time CGPS positions.	This community is interested in real-time access to high-rate CGPS data, site positions, and network correction for enhanced accuracy.	CSRC at <a href="http://csrc.ucsd.edu/">http://csrc.ucsd.edu/</a> as well as real-time internet access through wired and wireless communications.	Surveyors, GIS mappers, transportation departments, emergency services, aviation, bridge and dam deformation, agriculture, etc.	Funded through CSRC and other grants.

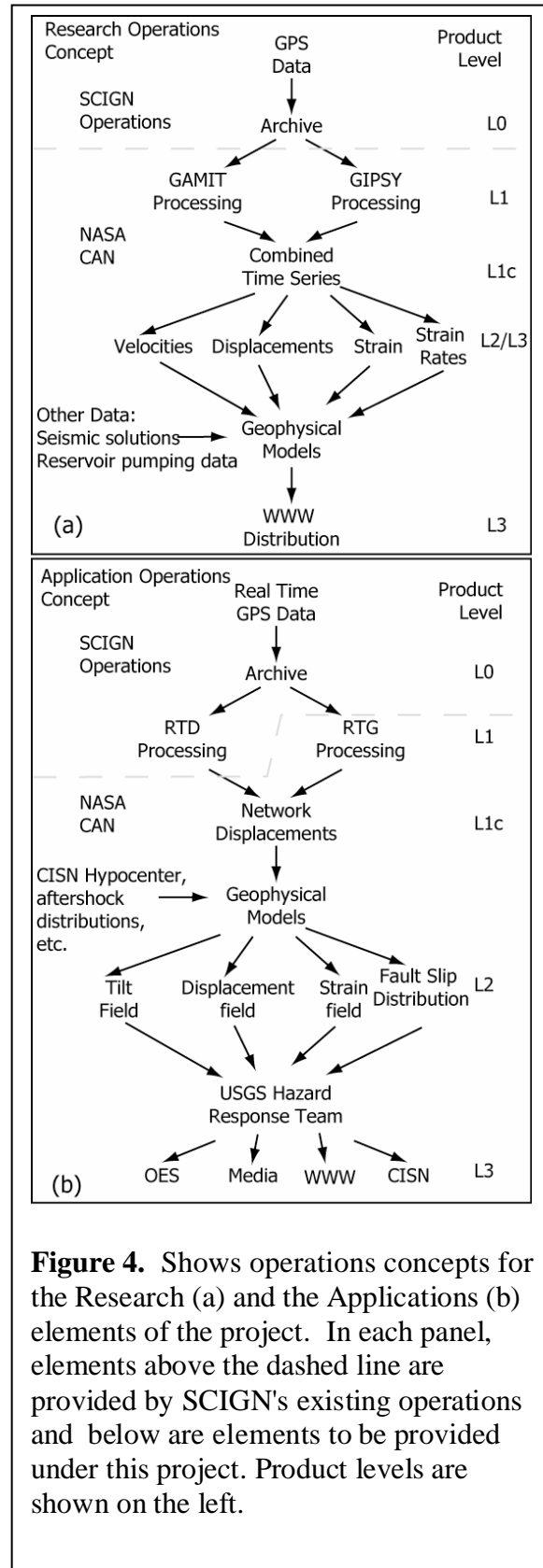
The specific products and target user communities are summarized in Table 1. Currently, SCIGN produces Level-0 data from the GPS receivers in the network and preliminary geodetic time-series (Level-1) which are byproducts of the verification and validation of the network health. The new proposed data products in Table 1 are products that have been requested by the community of science users through the AC, and the local government users through their participation on the SCIGN Coordinating Board and through the California Spatial Reference Center (CSRC). We plan for these data products to be derived from the SCIGN network initially, and as SCIGN transitions to the multi-agency EarthScope project in the next few years, the scope and basis of data products will be derived from the larger Plate Boundary Observatory (PBO).

The data products are targeted at both research users and government officials and agencies, which provide services and emergency management support. The target research community is the Solid Earth science community and the target products and service for them are derived from NASA's ESE strategic plan, SESWG report, NSF recommendations, and other community input to the SCIGN project via the EarthScope initiative, and the SCIGN Advisory Council.

This project will leverage its existing depth in the science and commercial community in developing standards for GPS networks, data formats, metadata, and archiving to apply principles from the Strategy for the Evolution of ESE Data Systems (SEEDS). With this depth, this project will support ongoing SEEDS efforts through participation in Working Groups for Standards and Interfaces, and Metrics Planning and Reporting.

**2.1 Relevance of Data or Services**

The primary data products to be produced by the project, their relevance, users, and how they relate to the existing efforts are shown in the operational concept in Figure 1 and summarized in Table 1.



**Figure 4.** Shows operations concepts for the Research (a) and the Applications (b) elements of the project. In each panel, elements above the dashed line are provided by SCIGN's existing operations and below are elements to be provided under this project. Product levels are shown on the left.

The SCIGN Advisory Council (AC), which represents the solid earth science community has recommended that SCIGN provide high-level data products and low latency data products from that network that will allow geophysical users to make use of the network without the need to process the raw data.

We will follow and expand the AC recommendations and those of NASA's Solid Earth Science Working Group (SESWG) by generating these high level data products through an integrated effort within the project in which estimates from the processing groups within SCIGN are compared and then combined to provide the following official SCIGN products: Daily time series; Daily positions and velocities; Differential strain and strain-rate maps; Fault slip rates; Aquifer discharge and recharge rates; and an event-driven rapid post-seismic deformation. The products will be archived and made available to the scientific community via a web interface.

### 2.1.1 Level 1-2 Products: Time Series and Velocity Fields

The main motivation for providing official SCIGN geodetic time series and velocity maps is to provide scientists with the most basic scientifically useful data set, while relieving them of the need for tedious, costly and redundant data processing. Generating weeks, months, and years of GPS geodetic time series requires a substantial commitment of resources to the time-consuming and delicate data processing effort.

Reference frame consistency as well as other important issues concerning antenna height offsets, editing of outliers, the number of position breaks due to co-seismic displacement or undocumented equipment changes, ambiguity resolution, tropospheric modeling, regional filtering, and non-linear effects such as seasonal aquifer variations and post-seismic relaxation, all have to be taken into account. SCIGN (and PBO)'s provision of these products will facilitate Earth scientists' ability to focus their limited resources on science, rather than on data

processing. At the same time, in accordance with SCIGN philosophy, interested parties will still find the raw GPS observables in the SCIGN public archive.

### 2.1.2 Level 3 Products: Strain, Fault Slips, Aquifer Undulation, Co-seismic & Post-Seismic Deformations

Strain rates and fault slip rates are the most robust measurable physical parameters related to earthquake generation on inter-seismic time scales [Wood and Gutenberg, 1936; Thatcher, 1975; Harris, 1998; Hardebeck *et al.*, 1998; Stein, 1999; Peltzer *et al.*, 2001]. Strain differentials and rates, fault slip rates, the rise and fall of the ground above aquifers (aquifer undulation), and co-seismic and post-seismic fault slip rates will be calculated using the methodology of a spatial-temporal (S-T) filter [Segall and Matthews, 1997, Leduc 1997] through the calculation mechanism of the JPL developed Quasi-Observation Combination Analysis software (QOCA) [Dong *et al.*, 1998; <http://gipsy.jpl.nasa.gov/qoca>]. QOCA is an open structure software, which can assimilate a variety of measurements (SAR, EDM, VLBI, SLR) with the GPS station position estimates. QOCA is used all over the world for strain and deformation analysis [e. g., Svarc *et al.*, 2002; Dong *et al.*, 2002; Gan *et al.*, 2001; Savage *et al.*, 2001; Hager *et al.*, 1999], and is one of the primary tools used by the USGS.

The implementation of an S-T filter would be an extension of the QOCA software to estimate the amplitudes of various Green's functions directly, and as a result perform time-dependent inversion directly. Currently, a basic protocol of the S-T filter has been established that implements the 4-D (time-space) Kalman filtering and dynamic memory allocation, and can easily combine more than 1500 sites simultaneously, which will be necessary for PBO implementation. In addition, the flexibility of the S-T filter approach enables user-defined requests for a deformation map in a specified region for co-seismic or post seismic displacement field.

Once a SCIGN velocity map is obtained, calculation of strain rates is a straightforward

process. Strain rate maps with and without cyclic signals (such as from aquifers [Bawden *et al.*, 2001; Watson *et al.*, 2002]) will be derived from the SCIGN combined velocity maps. SCIGN strain analysis will integrate direct strain measurements from the SCIGN laser strainmeter, and the USGS borehole strainmeters within the array. The integration of regional strain inference from GPS measurements with pin-pointed precise direct strain measurement is at the core of PBO.

## 2.2 Approaches for Data Production, Distribution, and User Support

### 2.2.1 Data Production

#### 2.2.1.1 Summary of Current Status

The production of level-0 data (raw and RINEX files) is managed by the SCIGN collection centers (USGS and SIO) in close coordination with the data archive (SIO). All raw data are deposited at SIO, where RINEX and RINEX-compressed files are created, quality-controlled and forwarded to archive and for dissemination by means of ftp and http. This is an extremely successful system and the SCIGN archive distributes about 1M level-0 files a months to about 2500 users (see statistics at <http://sopac.ucsd.edu/>). The Site Information Manager (SIM) maintained by SIO is the gateway for all site metadata, and is available to registered network operators through a convenient Web-based data portal. The SIM and all archiving functions are fully integrated with SOPAC's Oracle 9i RDBMS.

Once the level-0 data are archived, SCIGN's two analysis centers (JPL and SIO) access these data and perform two independent analyses to produce site positions (latitude, longitude and height) on a daily basis. From its inception, SCIGN has operated these two independent analysis centers to provide validation for its level-1 products (raw position time series). Each center uses the same input data but different processing software and analysis strategies. The Gps Inferred Positioning SYstem (GIPSY) software is used by JPL while the Gps At MIT (GAMIT) software and associated GLOBK software are used by SIO.

The daily positions produced at the analysis centers provide two independent geodetic time

series that contain, embedded within, the deformation signals. These are accessible through links on the SCIGN Web Page that redirect the user to the respective analysis center. Both centers also produce "modeled" time series, estimating geophysical signals, such as site velocities, co-seismic and post-seismic deformation, meteorological signals including atmospheric water vapor, hydrological signals including aquifer recharge, and "nuisance" parameters such as apparent position offsets due to GPS equipment changes and seasonal terms due to a variety of non-tectonic processes. Currently, the raw and modeled time series remain uncoordinated between the two analysis centers, and therefore a source of some confusion for potential users of these data products.

The JPL analysis is not yet tightly coupled with the metadata produced and archived at SOPAC. This has resulted in unnecessary differences between the two analysis centers and wasted effort by the analysts and Analysis Coordinator to resolve these discrepancies [SCIGN Analysis Committee Report, 2000, 2001, 2002]. Nevertheless, the SCIGN Executive Committee has concluded in 2002 that the independent SIO and JPL solutions agree to satisfactory levels.

#### 2.2.1.2 Objectives

The primary objective of this proposal is the production of higher-level research and application data products listed in Table 1, according to the production scheme outlined in Figure 4. In order to achieve these objectives, it is essential to improve the analysis process by automating the use of identical metadata by the two analysis centers. This issue will be addressed in the section on data distribution and user support.

Once the data have been gathered, archived, and processed by the two analysis centers, the position time series will be delivered in an agreed upon XML format to the SCIGN Solution Center (SSC), to be funded under the REASoN CAN. The SSC will combine the two independent solutions into a single SCIGN position time series. Quality control

will detect any remaining anomalies and/or differences in the solutions and feedback this information to the analysis centers. Once a consistent time series is generated, a long-term (years) and short-term (weeks-months) crustal motion model will be calculated. As described earlier, derivatives of the time series will be combined to produce corresponding dilatation and shear-strain maps, and other higher-level products. The scientific community representative within SCIGN, the Science Advisory Council, will be periodically consulted during the development and implementation stages of the higher-level products to make sure that the communities' needs are being met.

Currently, the analysis results and model output are stored in distinct flat-file structures. The array of parameters output by the processing software and estimated by the model, multiplied by several hundred sites, results in a large volume and complexity of data. This necessitates the integration of a relational database approach to efficiently manage and store these data.

We propose to augment SOPAC's Oracle 9i Relational Database Management System (RDBMS) with a comprehensive cataloging of non-modeled (raw) and modeled GPS position time series. This database integration will enable us to provide two significant deliverables:

- (1) Inclusion of the above data types as integrable services in the **GPS Explorer** described in the next section. This is essential for the production of level-2 and above products.
- (2) An additional service of the **GPS Explorer** that provides users with the ability to calculate epoch-specific coordinates for any GPS site, using sophisticated time series models. This is of particular use to surveyors and GIS professionals.

The raw and modeled time series will be provided as XML Web Services and integrated into the functioning of **GPS Explorer**.

Our approach also enables the development of an automated offset detection system, a perennial pitfall in the analysis of GPS data. Offsets in coordinates generated by processing

software packages may be due to equipment changes, earthquakes, and other reasons, including the software itself. Determination of these offsets is critical in guaranteeing high-quality time series. Processing software-generated coordinates, calculated daily, can be compared to their expected positions as stated by the model. Any coordinates falling outside the expected range of positions can immediately be identified to the software operator for analysis. Also, the modeled time series may be used to generate a-priori values in the processing software packages to automate the updating of these values. This reduces the magnitude of the resulting software-calculated adjustments.

Further, the epoch-specific coordinates utility can also be realized as a component of the Explorer. The GPS Explorer's use of web-based XML utilities utilizing the Soap XML server (see below), and SOPAC-developed graphical user interfaces will deliver these services to users in an efficient, straightforward manner.

An added layer of validation will be provided by comparison and assimilation with other geophysical data sets, such as seismic and strainmeter data, which are important data elements of the EarthScope project. For example, researchers at all three centers (JPL, SIO USGS) are working on various approaches to integrating GPS and seismic data. In an event of a large earthquake we plan to be equipped to compare to our deformation model to fault plane solutions (moment tensor solutions) from seismic networks (e.g., CISN), and even combine these data into a single solution of total (static and dynamic) site displacements [Nikolaidis *et al.*, 2001].

### 2.2.2 Data Distribution and User Support

Data distribution and user support will be addressed in a series of three related projects including:

- (1) Adaptive Seamless Archive System - XML Web Services for GPS Data Discovery, Exchange and Storage
- (2) GPS Explorer - An Integrated Data/Metadata Discovery and Research Tool

- (3) Spatial Services - Providing Contextual Layers for GIS users

### 2.2.2.3 Adaptive Seamless Archive System

We will develop an adaptive, modular Seamless Archive System to support an integrated, dynamic, and multi-discipline information exchange system involving GPS-related data products and information, not unlike many e-commerce applications. The proposed system would include the following: an XML-based Web Services protocol to support client-server communication, retailer server middleware to provide any developed XML Web Services, XML schemas/DTDs for GPS-related data products and related strategies, and software interfaces (Control Panels) to administer the Web Services. It will utilize existing infrastructure (such as UNAVCO's GSAC and the constellation of existing US-based GPS data centers) as a primary source for GPS data "discovery" but build, in parallel, a more advanced and adaptive XML-based system for interested agencies to manage and share data and information in a way that is self-describing, completely dynamic, easily adaptable to new data products and fully customizable on a agency-by-agency basis. The same system will also allow the two analysis centers (JPL and SIO) and the coordination center (USGS) to tightly couple their production of data products.

With SIO/SOPAC's extensive experience in the development and maintenance of a seamless archive system we are uniquely suited to this component of our SEEDS proposal. The GSAC software/system developed by SOPAC for UNAVCO uses a variety of web-based software components, a custom communication language, and relies on relational databases at each retailer. This experience lends itself to rapid development of more advanced, integrative, seamless archive features built on Web Services technology. As an international GPS data portal service the GSAC has enormous potential to attract further participation from additional GPS-related agencies/individuals in the United States and abroad. Our development of Web Services for the

integration of GPS-related data products into applications with GSAC access, as well as those without, will offer SEEDS a standardized conduit for the GPS world into the broader expanse of Earth sciences applications and decision support systems.

As an example, through an interface a user could arrive at the time series parameters matching their current interests, save their "session" as a "ticket" for later use and/or sharing with other colleagues, and then use that ticket to fetch data from the seamless archive at a later time. The ticket would be self-describing (XML), provide the seamless archive service all of the information it needs to fulfill the request, and be immune to limits on the length of URLs, peculiarities of HTTP in character translation, or minor changes/versions of the service itself.

This XML document could then be shared by different individuals, e-mailed to colleagues, posted as a "canned example" on a website for users, and "cut and pasted" as input into client applications or used in an automated system to identify a GPS dataset. In essence the XML document would be a sort of "ticket" to the Seamless Archive for a set of data/information pertaining to time series in the ticket itself. This ticket could be used and reused any number of times by any number of individuals/applications to fetch the same data set - taking GPS data exploration and sharing to a whole new level. Furthermore, this XML Web Service for Seamless Archive communications could be designed in such a way as to be utilized by other, non-GPS, data centers.

Besides the "ticket" use of XML to describe a user's request for an ad-hoc dataset, there are many GPS-related products and/or information that could be exchanged among individuals and agencies alike, using an XML data format. This same data could then be made available over an additional XML Web Service for which applications such as the GPS Explorer (described next) could easily utilize. Such services would open the doors for users to request subsets of data files, or just certain pieces of information rather than be burdened by files, formats, and compressions they might be unfamiliar with or unable to deal with on their local machine. In particular, we foresee the immediate need to

develop XML schemas/DTDs for the hierarchy of product levels described earlier (see Table 1).

#### 2.2.2.4 *GPS Explorer*

Building on the existing GPS site information management infrastructure at SOPAC (see Site Information Manager (SIM) <http://sopac.ucsd.edu/cgi-bin/SIMpl.cgi>) we plan to create an all-inclusive, publicly-available (through WWW) GPS site/network “GPS Explorer” (or wizard) that will aid users in the GPS community ( and beyond) in the location, selection, metadata acquisition, research-oriented analysis and acquisition of GPS site/network-related data, metadata and analytical products This CGI-based tool will allow users to interact with dynamic geodetic content in a variety of contexts, including: mapping interfaces, graphical charts and reports, time series, movies and a myriad of nominal/attribute information about all GPS sites/networks registered in the SOPAC database.

Built to support a large portion of the Southern California Integrated GPS Network (SCIGN) information system, maintained in an Oracle 9i database at SOPAC, the Site Information Manager has served SCIGN staff in their GPS site-related metadata management since early 1999. This CGI-based web application has undergone several revisions since it’s creation, with extensive input from the GPS user community. As the SIM continues to evolve it has developed into a tool utilized by more than just SCIGN. Today the SIM helps numerous agencies “register” GPS sites in a central database, providing the best means in the GPS community with which to avoid GPS site naming conflicts, among other things. SCIGN will continue to depend on the SIM for centralized management of nearly ALL information directly related to SCIGN sites, which now number more than 260 in all.

At the outset of the project, the GPS Explorer will simply be an adapted version of the current SIM, It will be then be upgraded in order to focus on browsing, metadata collection and research-oriented interests in the GPS community - as opposed to site information management, it’s current

objective. It is anticipated that the GPS Explorer will evolve rapidly over time to incorporate numerous additional GPS-related research tools, products and information. Included in this aspect of our proposal are adaptations to support GPS site velocities, offsets, time series, data life-cycle, data quality, and other future metrics for analyzing GPS-related data. The primary goal is, to provide an integrative environment for GPS-related data and metadata discovery, selection and acquisition, per site, per network or in user-defined assemblies of either or both.

As part of our overall approach to participate in SEEDS we envision this application to incorporate extensive use of XML-based services and protocols developed for the Seamless Archive System. In large part, this application will adopt the services described above as a primary means of communicating information to the user via a dynamic, interactive, and integrative experience. Therefore, this application, GPS Explorer, naturally follows the development and testing of the preceding project.

The underlying technology of this application ranges from storage of the metadata (an Oracle or Postgres DBMS), to knowledge/use of the seamless archive SOAP service (XML – see section 2.4), to open-source mapping tools such as the University of Minnesota’s MapServer, to basic HTTP/CGI client-server technologies. As a great deal of the general design and architecture of the SIM already exists and has been proven in the SCIGN project since 1999 there is a significant head-start involved in this aspect of our proposal. Depending on time constraints, it is also plausible that this architecture could be solidified into a schema and general overall strategy for other (non-GPS) related data contexts.

Furthermore, we hope to go beyond the GPS world with this application to incorporate scientific data contexts provided by other participants of SEEDS offering data services of immediate utility to this application’s mapping contexts and other integrable functionalities.

For users of hand-help devices like PDAs, cell phones and tablets, we envision offering a vastly simplified version of GPS Explorer to



the user community through a publicly available, XML-based interface. This will extend what is already a wide array of platforms and architectures able to act as the display vehicle for what is currently the SIM.

From secondary school children, to college undergraduates, graduate students, scientists and commercial entities (surveyors, consulting firms, airborne remote sensing services, civil engineers, etc) we believe the GPS Explorer will provide a suite of services whose value cannot be equaled anywhere in the existing international GPS community.

#### 2.2.2.5 *Spatial Services*

Given the widespread use of Geographic Information Systems throughout numerous spheres of education, government, commerce and research in the United States alone, we propose to make available to the public numerous services with direct application and compatibility with prevalent GIS software packages such as ESRI's ArcView, Internet Map Server, ArcGIS, and other competing GIS software vendors. With an existing spatially enabled database already in place to support many of the above-described activities we will offer automated services to the public which take this information and provide spatial services of immediate use to their needs and applications.

For example, we will provide, among other things, an ESRI Internet Map Server (IMS) service registered with ESRI's Geography Network. This service will then be immediately available for use in ArcView, ArcGIS or other applications supporting this technology. Furthermore, we can offer automated selection, packaging and delivery of other spatial data file formats such as ESRI's popular "Shapefile" format.

Although a subset of these spatial services may be made available through the GPS Explorer, there will be some which cannot, and will therefore be offered separately to the public - like the IMS service described above.

In any case, we expect these "layers" will be widely used in any number of Earth systems applications through a GIS context as specialized "control" layers due to their high-precision, dynamic update/availability and the

suite of supporting Web Services providing metadata directly relatable to individual entities contained in one of these "layers".

### 2.3 **Earth System Science User Support**

The project will support Earth System Science users by providing the validated high-level data products listed in Table 1 at the SCIGN web site, <http://www.scign.org/>. In addition, project members will work with and participate in forums, workshops, and committees in the community of Solid Earth Science users. The groups that we will work with include: SCEC, UNAVCO, PBO, IGS, SCIGN, CSRC. We have budgeted for travel to the appropriate meetings for these organizations.

### 2.4 **SEEDS Guiding Principles**

This project will leverage its existing depth in the science, civil, and commercial communities in developing standards for GPS networks, data formats, metadata, and archiving to apply principles from SEEDS. The project members have a long history of engaging the community in defining products and services for GPS geodesy through their participation in the leadership and governance of the major GPS geodesy organizations: International GPS Service (IGS), University NAVSTAR Consortium (UNAVCO), GPS Seamless Archive (GSAC), California Spatial Reference Center (CSRC), Southern California Earthquake Center (SCEC), SCIGN, and PBO.

Through these organizations, we have developed and implemented solutions for storage, access, distribution, and long term archive of GPS data and defined and implemented standard interfaces and data formats for exchanging data with other GPS archives, in particular NASA's CDDIS and the community based GPS Seamless Archive (GSAC).

With this depth, this project will support ongoing SEEDS efforts through participation in Working Groups for Standards and Interfaces and Metrics Planning and Reporting.

## 2.5 Level of Participation in SEEDS Working Group

The project will participate on the SEEDS Standard and Interfaces Work Group. Given our depth in developing standards and interfaces for the community as discussed in the preceding section, SIO through its archive activities at SOPAC (<http://sopac.ucsd.edu/>) will lead the SEEDS participation.

The SCIGN archive at SOPAC currently participates as an archive for the IGS, SCIGN, and GSAC. SOPAC maintains an Oracle 9i RDBMS that unifies collection, archive, analysis and dissemination of Level-0 data and metadata on GPS stations. The higher level data products generated under this project will be added to the database for access by users.

Currently, automatic access to the RDBMS is through ftp and web-based applications that allow users to the information. GIS functionality that adds spatial awareness to the products. Level-0 data is also available through the GPS Seamless Archive (GSAC). This archive allows users to access several data archives with common interface. SOPAC is a lead organization in the establishment and development of the GPS Seamless Archive (GSAC). Access is primarily through <http://sopac.ucsd.edu> and the database tools there, such as the Site Information Manager ([http://sopac.ucsd.edu/scripts/SIMpl\\_launch.cgi](http://sopac.ucsd.edu/scripts/SIMpl_launch.cgi)). The experience from these programs and the community driven development of the standards and interfaces will be valuable contributions to the SEEDS.

The project members, lead by SOPAC, have been involved in the UNAVCO community for over five years now in the development and implementation of the Seamless Archive, designed to permit user-friendly, single-point access to GPS data in a common format from multiple GPS data centers. Basic capability went into in place in early 2002 with implementation of a retail interface tool that provides a simple graphical interface to the combined archive holdings, along with a data request mechanism.

One of the most important steps in the development of the seamless archive

architecture was the definition of the Data Holding Records (DHR) which are designed to describe not only data holdings in the form of GPS standard Receiver Independent Exchange (RINEX) format and raw GPS data files but also data products such as the Solution Independent Exchange format (SINEX) files that contain results from the analysis of the GPS data. The definition of the DHR's is sufficiently flexible to allow other types of information from GPS networks to be incorporated in the future.

Several GPS data archives have been designated as retail and/or wholesale data centers, depending on whether they provide data community-wide holdings or just holdings to other data centers that serve as retailers. The Seamless Archive project forms a foundation for the more capable network and data management system envisioned for this project based on the data formats, data access tools, and institutional synergies developed over the period of the project.

The data management system for this project will not only include handling, dissemination and archiving of the data collected for PBO but will also cover the dissemination of the analysis results. SIO (<http://sopac.ucsd.edu>) and JPL (<http://mihouse.jpl.nasa.gov>) provide access to GPS position time series and velocity results. For this project, these product centers will be coordinated with the aim of generating results that can be directly interpreted and used in further analyses to build geophysical models the deformation process in the plate boundary. These developments will also include near-real-time production of results that can be used for geophysical studies and emergency response.

### 2.5.1 Data Format and Content

There are many different types of data that already exist. Some of the data formats are de facto standards, such as RINEX and SINEX. RINEX is widely accepted as a standardized exchange format for GPS data observations and is actively maintained and adapted by the GPS community. Likewise, SINEX is widely accepted as a standardized user exchange format. Different groups are developing other data types; such as the XML-based site information logs for GPS metadata by SIO

(level-0) and GPS time series by JPL (level-1).

GPS-related data are archived at varying temporal resolution and intervals. This includes raw GPS data and RINEX GPS data in real time, near-real time, daily, and archival timeframe contexts. The goal is to transition old products and to store new solutions in XML format.

### 2.5.2 Interface Standards

The interfaces for the Seamless Archive project will be based on HTTP and SOAP. HTTP is a standardized Internet specification with many tools available. SOAP is a lightweight protocol for exchange of information in a decentralized, distributed environment. SOAP is based on XML, which is a standardized markup language. Many large software vendors are supporting SOAP (Microsoft, Oracle, IBM, Sun). Because the use of SOAP is growing, it has been selected as the primary communication interface.

### 2.5.3 Software Reuse

Many of the projects will be using the Apache HTTP server along with Axis as the SOAP server. Apache was chosen for its wide use and because it is Open Source. Axis has been chosen because it is Open Source, has been written in Java, and has a strong user base. Java and Perl are being used as the programming languages. Both languages can use existing libraries, facilitating software reuse. We will be using both the Oracle [9i](#) RDBMS database server and the Open-Source PostgreSQL database server in our projects. A spatial component can be added to PostgreSQL to provide spatial functions. We will also be reusing existing Perl libraries to communicate with the database and maintain system configuration. Perl modules and source-code from the Comprehensive Perl Archive Network (CPAN) may be used to support development of the Seamless Archive System, GPS Analysis Database Integration, and the GPS Data Explorer. Most of the modules and components used in our projects will be available to others in support of research.

### 2.5.4 Evolution

Software is being written in a modular fashion, which allows libraries to be shared across applications. Communication between the different applications will be through XML and SOAP. During development, great consideration will be given to expandability and evolution of the different applications. By using a modular development approach, and using XML messages for communication, the software will be capable of being upgraded in smaller components over time. Documentation of the individual modules and the interfaces will make it easier to reuse in future applications.

### 2.5.5 Technology Utilization

Web Services is a technology that integrates XML, SOAP, and HTTP along with UDDI, WSDL. This is an evolving area of the Internet infrastructure. Similar to modularized software, Web Services allow different applications to remotely access data using a standardized interface. Once a Web Service has been deployed, future applications can take advantage of the service. We believe Web Services will help different scientific disciplines share data, and supports the development of a more cohesive and integrated information network. The Seamless Archive System and GPS Explorer will provide an Internet-based GPS data/metadata "service" that other disciplines can take advantage of to promote better modeling, solutions, and knowledge of our planet.

### 2.5.6 Levels of Service

The Seamless Archive System will support data discovery, identification, and selection of archive data. Translation, ordering, and delivery of archive data would be performed by a command-line or client interface.

There exists a partnering arrangement in the GPS community including GPS data archives that provide data over the Internet. The Seamless Archive would continue to utilize this cooperation and expand upon the existing GSAC partners.

### 2.5.7 Metrics

A component of the Seamless Archive involves publishing data quality statistics. Additionally, statistics would be gathered and displayed. For example, in the GPS Explorer, a geographic map of the United States could display the amount of data available in different regions based on color. A user could instantly understand which areas have more GPS data available, and could be used to identify where to install new GPS sites. The Data Delivery Service will include features to record and track data quality.

## 2.6 Compliance with REASoN Project Requirements

The project will maintain a WWW-compliant presence at <http://www.scign.org/>. This web site will be enhanced over its current capabilities to provide high level data and information to the users via the Internet. It will contain descriptions of all products and services. These descriptions will be provided to the NASA GCMD. In addition, the products will contain and be searchable via FGDC compliant metadata. The SCIGN EC is currently moving forward with applying for membership to the existing Federation.

## 2.7 Additional Research REASoN Project Elements

SCIGN has pioneered and championed the adoption of an open data policy for GPS and other geodetic data. Under this project, we will continue this policy and extend it to include the higher level data products. The policy can be found at <http://www.scign.org/DataPolicy.html>.

The fundamental tenants of the policy are that data from all SCIGN stations are available on-line as soon as they can be physically moved from the site to the archive. In SCIGN's current operational mode, that occurs usually within a few hours. Additionally, higher level data products such as daily coordinate solutions, periodic velocity solutions, and plots of resulting positions or position differences are available promptly to the scientific community. SCIGN requires that users of these data products acknowledge SCIGN and its sponsoring organizations,

(W.M. Keck Foundation, NASA, NSF, USGS, SCEC) as the source of the data and that other permanent networks cooperating with SCIGN and receiving benefits from SCIGN (hardware, software, logistic support, etc.) are required to adhere to the same data distribution policy.

Under this project, we will continue this policy and extend it to include all data products produced and have budgeted for the resources necessary to accomplish.

### 2.7.1 Archiving

As described earlier, this proposal relies on the existing archive at SOPAC, and its lead role in the development of the community-wide GPS Seamless Archive (GSAC), under the auspices of UNAVCO, Inc. This effort has successfully coordinated seamless data dissemination to users from other geodetic archives in the U.S., including NOAA's National Geodetic Survey, Southern California Earthquake Center (SCEC), UNAVCO's Boulder Facility, NASA's Crustal Dynamics Data Information System (CDDIS), and the Northern California Earthquake Data Center (NCEDC). Efforts are already underway to solicit international participation, in particular from facilities under the umbrella of the International GPS Service (IGS). Finally, SOPAC also maintains the archive for the California Spatial Reference Center. Thus, we feel that archiving needs will be adequately met. Our proposal also includes the streamlining of existing level-0 data and metadata using modern IT methods, as well as the incorporation of the higher-level products into the archive. We have a proven record from the GSAC archive in providing comprehensive, clear, and concise documentation and setup scripts for GSAC Retailers, Wholesalers, and users. Our efforts in the CSRC gives us considerable experience in serving specialists and non-specialists alike.

### 2.7.2 Distribution of End Products

SCIGN has a proven track record of distribution of raw data, metadata, and level-1 products to the user community, although this project will significantly enhance these capabilities with modern IT methods. The

archive in question (SOPAC) is part of the proposal and adequate funds have been budgeted for the smooth distribution of the higher-level products, including complete documentation, applicable metadata and supporting peer-reviewed articles.

## **2.8 Additional Application REASoN Project Elements**

### **2.8.1 Description of Application**

The USGS Earthquake Hazards Program is responsible for scientific earthquake response and for communicating results to researchers, the media, and emergency responders. Under this project, we will develop and implement a system based on the research system described above that will determine the co-seismic and rapid post-seismic displacements within 1 hour of an event, and generate rapidly the other high level data products described above for the research user. These high level data products will be used by the USGS Earthquake Hazards Program as part of its response to seismic events in southern California and will be integrated into the California Integrated Seismic Network (CISN) response system (see letter of support).

This is a Type 1 application using NASA data products to support decisions made for Disaster Management (National Application #7, Appendix 7) in that it supports the USGS in providing reliable information about earthquake location, magnitude, rupture zone, shaking intensity, and co-seismic deformation. Precise geodetic data products are co-seismic and post-seismic displacement, strain, and tilt, and estimates of the stress change on nearby faults. Combined geodetic and seismological data provide high-quality earthquake fault parameters. These data products will be developed as a dynamically updated interactive Web service.

The production of these earthquake response data products will differ from that for the research data products in that the emphasis will be on low latency solutions from a subset of the network that was affected by the earthquake. Rapid and real-time processing techniques and software will be used to

analyze the raw GPS observables and generate the displacements (Level-1 data products). These data products will then be processed with the code developed in the research part of this project to produce strain maps and displacement fields that are integrated with observations from other available sensors and systems, including hypocenter locations generated by CISN.

### **2.8.2 Utilization of NASA Data, and/or Science Results, and/or Technology Products in the Project/Application**

The role of NASA data and technology investment includes: A key sponsor of SCIGN responsible for the implementation and construction of the network; sponsor of the development and maintenance of GIPSY; a contributing sponsor for Real-Time GIPSY (RTG) for sub-daily analysis; sponsor of applications research into the integration of GPS and seismic data; sponsor of the technology, development, and maintenance of the Global GPS Network which supports the generation of precise GPS orbits and clocks.

### **2.8.3 Current State of the Application**

USGS processes data daily to be ready for earthquake response. Each day USGS downloads the data from the previous day and processes it with the ultra-rapid orbit from the International GPS Service (IGS). This preliminary result is sufficient for timely response to an earthquake, should one occur. Better solutions are produced 12 days later using the highest quality precise orbits.

The USGS Web page at <http://pasadena.wr.usgs.gov/scign/Analysis/> (which can be reached from <http://www.scign.org/>) provides several interactive tools. MapSurfer, developed at USGS, shows SCIGN stations on a map of California. Users can zoom in and out, obtain basic information about stations, and choose whether to display recent earthquakes, major faults, and geographical and cultural features. Co-seismic displacements are available, in both digital and mapped vector form, for the M 7.1 Hector Mine earthquake of October

1999. Automatically generated displacement vectors between the last two daily solutions can be displayed; these are usually used for quality control, but are estimates of co-seismic deformation when an earthquake of M 6 or larger occurs. Interactive time series tools allow users to plot or download time series.

### *2.8.3.1 Expected End State of the Application*

The anticipated end state of the application is the operation of a demonstration system at the USGS that will use sub-daily and real-time solutions and high quality orbits in near real-time to automatically generate strain and tilt fields. These fields will then be integrated with seismic solutions and used to automatically generate estimates of stress changes on nearby faults. The results will be provided on the web and to the USGS.

### *2.8.4 End Users of the Application*

As the primary end user and as a Project Member, the USGS is committed to incorporate these products into its emergency response to earthquakes in Southern California. Currently, following a significant earthquake, the USGS responds via its Southern California Earthquake Hazards Program Web page at <http://pasadena.wr.usgs.gov/> providing information on the location, size, and magnitude of the event. If the event results in significant effects, the USGS conducts briefings with state and local governments and the media. The products developed under this project will allow the USGS to provide timely data to the public on the effects of an earthquake (Table 1). The secondary end users are the scientific community, the media, and agencies involved in earthquake response (FEMA, the California Office of Emergency Services, the California Department of Transportation, local governments, and operators of lifeline services).

### *2.8.5 Milestones to Evaluate the Application's Readiness*

See section 5.3 and Table 3 for a description of each milestone and success criteria.

### *2.8.6 Post-Cooperative Agreement Intent/plan*

The project intends to continue the applications activities pending successful demonstration of the application to the USGS and the availability of funds to operate the system. If the application is successful, SCIGN will seek through its USGS partner funds from the CISEN, USGS, OES, and/or SCEC to continue the operation of the rapid earthquake response part of the project.

## **3.0 OPEN SOURCE**

This proposal includes the option to build an Open-Source prototype for the purpose of demonstrating software reuse and identifying resources available from the Open-Source community. SCIGN has pioneered the open access of GPS data, to scientists, government agencies, and the civil community. Furthermore, SCIGN has exported software components to other organizations for integration into their own operations, and worked collaboratively with other groups to develop software. Many of the tools developed over the years have utilized Open-Source resources such as programming languages and software libraries.

In addition to the Research, Application, and SEEDS components of this proposal we are also interested in developing an Open-Source prototype as an option to our overall participation in ESE. This prototype would be focused on the delivery of Earth Systems Enterprises data files through a **Virtual Archive** application. Consider the Virtual Archive application as a replacement for FTP, which provides end-users with a fixed view of a physical file system. To the outside user the Virtual Archive can be configured in such a way as to provide the style/organizational layout of their preference for the implementing agency. The central idea is that an application controls access to the actual files at a given data center, providing a valuable layer of insulation between the end user and the archive. In the way delivery of the actual data files can: a) be optimized for periods of increased demand by distributing access to data files with multiple copies across multiple servers, b) elegantly handle servers

that are temporarily unavailable, c) avoid file systems with stale links or NFS mounts.

In a traditional public data archive (WWW/FTP) users access data files through URLs that lead directly to the actual physical location of the file(s). This strategy, though successful in the GPS community for well over a decade, is prone to failure in numerous stages in the overall data discovery and delivery process. By insulating the provision of data through a “front-door” application, the **Virtual Archive**, we offer a means of avoiding these traditional traps for agencies with a limited budget but enough data (and demand for that data) that merit an improved strategy over traditional FTP/HTTP data services.

The **Virtual Archive** (VA) will communicate, internally, with a SOAP server via XML. This SOAP server will act as the **Data Delivery Service** (DDS) and will have direct access to a relational database with a relatively simple, and configurable, schema containing information about the archive. Requests made by the VA to the DDS will take place via XML-packaged messages in a SOAP context. These messages, for which an appropriate XML schema or DTD will be developed, will describe a request for information based on what that particular archive DDS can offer. In turn, the DDS will decode the message, lookup data files in the local database that match the request, compose URLs associated with those files, and return the results (URLs included) in a response message to the VA. The VA can then decode the message and present the end user with a “virtual” representation of the “folder” they are currently browsing. The user can configure the folder to be organized in various fashions supported by the VA.

For example, many GPS data centers organize their data collections in hierarchical trees based on traditional file systems starting with data type, then year or GPS week, then serial day of year. When users access an archive through FTP they are actually walking through the file system. Server load can be adversely affected depending on the number

of files in each directory, and the number of users traveling through the file system. The VA, communicating with the DDS, could offer this traditional scheme to the user, but it could also provide, for example, an upside down scheme starting with year, then serial day of year, and finally data type. Or, it could start with GPS site, then data type, then year, then serial day of year. The options are vast and, we hope, can be adapted to suit data center contexts beyond those specializing in GPS.

As the sampling rate for GPS data acquisition increases, archives need to deal with larger files more frequently. A single system will have difficulty keeping up with the demand. Rather than store a single copy of a data file, it makes sense to store multiple copies in order to protect the data from a disk failure, provide data redundancy, and to support load balancing. The Data Delivery Service will be designed to track multiple copies of data. With multiple copies of data, if a system is unavailable, the DDS can deliver a copy from a secondary copy.

The actual open-source components of this optional project component include:

1. The **Virtual Archive** (VA) CGI application, complete with the ability to be configured by the local data center agency.
2. The SOAP server **Data Delivery Service** (DDS).
3. The XML schema or DTD describing the XML messaging communication between the VA and the DDS.
4. The generic relational database schema (conceptual) applicable to serving a data center with Earth Systems-related data sets.
5. A utility to add, delete, and update data through the DDS.

SIO/SOPAC has experience developing software in a public environment with multiple stakeholders. Open-Source projects are often more free-flowing than development performed in software corporations, evolving over time depending on the interests and demands of the developers involved with the project. We believe that this project has a

high potential for software reuse both as a component of future projects and as the basis for customized versions of the software supporting different types of data archives. We also believe that this project represents sufficient technical merit along with being general enough to be a good prototype for demonstrating reusable asset deployment using Open-Source methods and resources.

In contribution to the SEEDS Architecture and Reuse study goals, we will track the level of support available in the Open-Source community, track individuals that participate in the project, and identify software reuse that results from work brought from other Open-Source projects. Information flow will be monitored in order to identify which method of communication (mail, newsgroups, chat, phone) appears to work best. Project difficulties and “branches” of the project will be documented. Considering that the project will be designed to suite different groups of people, we will document the requirements of taking the project and implementing it into our operations, along with maintaining synchronization with the project as it evolves. As a result of the project, we will provide the SEEDS Architecture and Reuse study with best and worst case aspects of software development in the Open-Source community, and our recommendations for utilizing this community in NASA projects.

#### **4.0 PREFERENCES FOR PARTICIPATION IN THE FEDERATION AND SEEDS WORKING GROUP(S)**

This project will leverage its existing depth in the science, civil, and commercial communities in developing standards for GPS networks, data formats, metadata, and archiving to apply principles from SEEDS. The project members have a long history of engaging the community in defining products and services for GPS geodesy through their participation in the leadership and governance of the major GPS geodesy organizations: International GPS Service (IGS), University Navstar Consortium (UNAVCO), GPS Seamless Archive (GSAC), California Spatial Reference Center (CSRC), Southern

California Earth Quake Center (SCEC), SCIGN, and PBO.

Through these organizations, we have developed and implemented solutions for storage, access, distribution, and long term archive of GPS data and defined and implemented standard interfaces and data formats for exchanging data with other GPS archives, in particular NASA’s CDDIS and the community based GSAC. Given the depth and experience of SCIGN in the above areas, participation in the SEEDS Working Groups for Standards and Interfaces and alternatively, Metrics Planning and Reporting, are obvious choices for this project.

The participation of this project in the ESIP Federation is also natural. As a provider of satellite and ground-based high-level data products, it will become a Research (Type 2) ESIP in the Federation. SCIGN is already a well-interfaced contributor to the Earth Science community. Once a Federation member, this project will be a part of the GIS Services Cluster, and contribute to the Hydrology cluster. In addition, we will explore with other ESIPs the formation of Earthquake & Volcano Monitoring cluster to consolidate and disseminate national and global near-real-time data of seismically and volcanically hazardous regions.

All project data will conform to the requirements of the CAN and ESE Guidelines for internet-based data delivery systems, dynamic database update capability, support of NASA’s Global Change Master Directory (GCMD) conformance to the objectives and requirements of the National Spatial Data Infrastructure (NSDI) of the Federal Geographic Data Committee (FGDC) to develop and maintain on-line data and information systems consistent with the Administration’s “Geo-Spatial One-Stop” (e-government) initiative.

#### **5.0 METRICS**

The PI and SCIGN are familiar with working with our program managers defining and



reporting metrics to NASA in accordance with the Government Performance Results Act (GPRA). These were provided to Code-Y for the installation of the SCIGN network. In addition, SCIGN currently maintains and tracks metrics that it reports at least twice a year to its sponsors including NASA, WM Keck Foundation, NSF, and SCEC. Some of these reports can be found at [www.scign.org](http://www.scign.org). The metrics include number of downloads of data from the archive, the number of papers and presentations published, students supported, budget status, participating users and organizations, impact on the our understanding of the earthquakes and tectonics, sharing of experiences with other networks, training users and builders of networks.

Under this project, we will work with NASA, the Federation, and our collaborators to establish and define metrics appropriate to their needs and provide these metrics to NASA and the Federation as required. For additional information, see Section 2.5 and Section 6.2.

### 5.1 *Inputs*

Input metrics involved in this proposal are numerous and varied. Ranging from raw GPS data in a variety of real-time, near real-time and daily file/transmission formats, to conceptual database management system data models (SCIGN metadata), to XML-formatted GPS analysis results (velocity fields, time series, strain, etc) the input to one component of this proposal may be the output of another. Direct end-user “knowledge” and community feedback may also provide significant direction for a number of the sub-projects in this proposal as integrative science is a pervasive objective throughout.

Furthermore, information gleaned from external (non-SCIGN) sources pertaining to ancillary data types and other scientific disciplines are also anticipated and welcome. For example, various parties involved in the IGS and the GSAC continue to provide SCIGN and other projects related to those stated herein with useful and timely data

products, services and information. We fully expect these sources to continue, and be utilized in this project wherever needed.

### 5.2 *Outputs*

Anticipated deliverables of this project include: a) a variety of XML DTDs/schemas pertaining to high-level GPS data product modeling, storage and exchange, b) XML DTDs/schemas for GPS site metadata and entry-level data discovery, exchange and management, c) advanced Web Services for the provision of information and data products derived from components of this project, d) an integrative, one-stop, interface for GPS data, metadata and data products discovery, analysis and collection (GPS Explorer), e) GIS contextual data services, f) a Virtual Archive open-source suite of software facilitating high-capacity, high-availability, distributed access to an Earth Sciences data archive.

### 5.3 *Outcome*

Among the various results anticipated from this project, we hope to achieve a complete integration and synthesis of GPS-related data, metadata, analysis and peer resources through a cooperative effort on the part of JPL, SIO, and USGS participants, building upon over a decade of experience with projects like SCIGN, PBO, CSRC, SCEC, and GSAC. Through this collaborative effort we hope to offer the GPS community, and beyond, a synthesized portal for discovering, acquiring and analyzing information from the GPS world. These services, all of which will be publicly accessible and prominent on the WWW, we hope, will demonstrate the level of integration and sophistication needed to apply GPS-based tools and knowledge into other Earth Systems spheres in an automated and fully open manner.

As the lifespan of this project draws to a close we would expect our products and services to have become an integral part of the GPS community as well as the larger Earth Systems community as a whole. Evidence of this, we anticipate, could be measured in increases in the magnitude of: a) file transfers from SCIGN, b) WWW log “hits” at websites of

participants, c) literature references to products and/or services stated herein, d) frequency and breadth of communication with external users in the GPS community and beyond. Such metrics can and will be easy to distinguish from other overlapping measurables via ftp/http logs, email records, academic publications, etc.

#### 5.4 Impact

4) *Impact: The consequences of the program, including intended benefits and utility and socio-economic benefit to the end users/customers. Impact addresses questions such as: "Why were the results of the projects useful?" "How were they useful?" "How were the end results (i.e., applications and data products developed) used in decision-making?" "What kind of significant economic or policy consequence resulted from the project?" Most important, it answers the question, "So what?" and includes assessments such as new knowledge shared, cost saved, new applications or functions that were done that were not possible before. How did or would the results impact the public good or expanded commercialization of value-added Earth Science data?*

*Respondents may propose additional metrics for measuring the performance of the REASoN project and state how the project intends to provide these metrics*

## 6.0 MANAGEMENT APPROACH

### 6.1 Management Approach

The management of this project is modeled after the successful coordination among the three lead institutions in the implementation of the SCIGN network. The PI will have overall responsibility for the project to NASA and will work with the Co-PI's at the partner institutions to implement the tasks. The Co-Investigators from SIO and the USGS will be directly responsible for the work efforts at their institutions, as well as share in the responsibilities for the overall success of the project.

The management of the project will be integrated with the existing SCIGN governing structure. SCIGN is governed by a set of bylaws <http://www.scign.org/bylaws.html> and by a Coordinating Board that operates as a standing committee of the Southern California Earthquake Center (SCEC) (Fig. 2). The coordinating board consists of representatives from SCEC, the United States Geological Survey (USGS), the Jet Propulsion Laboratory, Scripps Institution of Oceanography of the University of California, San Diego (SIO), NASA, the National Geodetic Survey (NGS), the California Department of Transportation (Caltrans), the California Committee on Reference Stations (CORS) and the Center Director and Science Director of the Southern California Earthquake Center, who are members ex-officio. An Executive Committee (EC) of the CB composed of one member from each of the three lead institutions (SIO, JPL, and USGS), plus one other member of the board, manage the day-to-day operations of the network. The PI and two Co-Investigators are permanent members of the SCIGN EC and therefore the coordination with the overall SCIGN project is assured. A board member who is elected by the CB at the annual meeting chairs the EC and CB. Interagency funding issues are resolved by an interagency steering committee composed of member representatives from the NSF, USGS, and NASA, ensuring coordination among the different agencies.

### 6.2 Coordination Between Participants

Coordination of the participants will be through the weekly EC telecons. At these telecons, the Principal Investigators will discuss progress, resolve issues, develop plans, and coordinate work among the project members. Reports, including financial statements, will be made to the sponsors as required and as needed. The Coordinating Board and the Advisory Council will convene at least twice per year. At these meetings the EC will provide to the CB status reports on progress, issues, and plans and will seek the advice and consent of the SCIGN coordinating board and the advice of the AC.

Table 2. Roles and responsibilities of project partners. **Currently performed tasks**

Task		Roles and Responsibilities		
		JPL	SIO	USGS
Project management		Principal Investigator	Co-Principal Investigator	Co-Principal Investigator
Data Retrieval			Secondary data retrieval	Primary data retrieval
Daily Data Processing		Process network data with GIPSY	Process network data with GAMIT/GLOBK	
Near Real Time Data Processing		Process network data with RTG software	Process network data with RTD software	
Verification and Validation		Participation on SCIGN Analysis Committee	Participation on SCIGN Analysis Committee	Lead SCIGN Analysis Committee
Solution Combination		Participation on SCIGN Analysis Committee	Participation on SCIGN Analysis Committee	Lead SCIGN Solution Combination effort
Product Generation	Geodetic Time series	Generation of GIPSY time series	Generation of GAMIT/GLOBK time series	Generation of combined time series
	Crustal Motion	Support generation of combined model	Support generation of combined model	Generation of combined crustal motion model
	Strain and Strain Rate Field	<b>Modify existing software for spatial and temporal filtering</b>	Modify existing software for spatial and temporal filtering strategies	Consult on spatial and temporal filtering strategies
	Fault Models	<b>Implementation of faults parameter estimation into existing software</b>	Support modeling efforts	<b>Calculation of fault slip rates + assimilation with seismic data</b>
	Aquifer Models	<b>Implementation of aquifer parameter estimation into existing software</b>	Generalization of Orange County work to other aquifers	
	Earthquake response	<b>Implementation Near Real Time deformation field and strain rate calculation</b>	<b>Integrate seismic and GPS data in a tightly coupled system (NASA funded)</b>	<b>Assimilation of geodetic and seismic data + interface with authorities / utilities/ media</b>
Archive		Support project participation in SEEDS	<b>SEEDS Technology Infusion Work Group participation</b>	Support project participation in SEEDS
SEEDS			<b>SEEDS compliant SCIGN archive development</b>	
Product Delivery / User support		Product and user support	<b>Development and maintenance of www.scign.org</b>	Product and user support
Open Source / Software reuse			<b>Development and implementation</b>	

### 6.3 Statement of Work

The following are concise statements of work and success criteria for each major milestone shown in Table 3.

#### 1. *System Requirements Definition and Design*

Work with users including the SCIGN CB and AC, CSRC, CISON, and PBO, to develop and document the system requirements, develop the system design, and generate a detailed project schedule. *Success criteria:* documented requirements and schedule with documented approval by the SCIGN CB.

#### 2. *Level 1 Product Development - Combined Geodetic Time Series*

Define input and output formats for Level-1 data products; define combination strategy and reference frame; develop and implement a software solution for combination; work with SEEDS on standard; solicit user community feedback at the SCEC annual meeting. *Success Criteria:* prototype operation of combination software.

#### 3. *Automation of Level 1 Data Products*

Solicit user community feedback at the SCIGN and UNAVCO annual meetings; implement combined time-series production; automate daily and sub-daily data processing and develop performance metrics; enhance SCIGN web page to deliver products based on input from SEEDS Standards and Metrics working groups. *Success criteria:* Combined SCIGN time series available on the SCIGN web page.

#### 4. *Level 2 Product Development - Velocity Field*

Define strategy for velocity field derivation from time series; define strategies for removing outliers and non-linearities; define output formats for Level-2 data product; develop and implement a software solution for velocity field derivation. Work with SEEDS on Standards; solicit user community feedback at the SCEC annual meeting. *Success*

*Criteria:* prototype operation of velocity field derivation software.

#### 5. *Automation of Level 2 Data Products*

Solicit user community feedback at the SCIGN and UNAVCO annual meetings; implement velocity field production; automate daily and sub-daily data processing and develop performance metrics; enhance SCIGN web page to deliver products based on input from SEEDS Standards and Metrics working groups. *Success criteria:* SCIGN velocity field available on the SCIGN web page.

#### 6. *Level 3 Product Development - Geophysical Parameters*

Implement S-T filter algorithm and develop software; define input and output formats and user interface; validate strain rate, aquifer undulations and fault slip rates with independent data sets; integrate into QOCA; participation in SEEDS Standards working groups; solicit user community feedback at the SCEC annual meeting. *Success criteria:* prototype operation of S-T filter software; validated geophysical parameters.

#### 7. *Automation of Level 3 Data Products*

Solicit user community feedback at the SCIGN and UNAVCO annual meetings; Implement geophysical parameters production; automate daily and sub-daily data processing and develop performance metrics; enhance SCIGN web page to deliver products based on input from SEEDS Standards and Metrics working groups. *Success criteria:* SCIGN strain-rates, aquifer undulation, and fault slip-rates available on the SCIGN web page.

#### 8. *Integrate with Independent data Products*

Work with PBO community and SEEDS to develop standards and interfaces for incorporating strainmeter and seismic solutions into Level-3 product generation, and develop and implement web interface; solicit user community feedback at the SCEC annual meeting. *Success criteria:* Prototype combination demonstrated.

### 9. *Incorporate PBO data into products*

Incorporate PBO GPS into time series production and solution combination, and incorporate PBO strainmeter data into Level-3 product generation, and deliver products on the web. *Success criteria:* Generating and delivering combined Level-3 products.

### 10. *Adaptive Seamless Archive System*

Investigate and install infrastructure to support Web Services. Configure Web Services software to support development of the Seamless Archive. Identify reusable software components that can be pulled from existing software. Design database schema to support a multitude of data types. Develop XML DTD to support communication protocol between retailers and wholesalers. Develop server middleware to interface with database. Integrate components of the GSAC. Develop control panels to assist with administration of the seamless archive. Develop XML DTD's to support GPS data such as time series and solicit feedback from the community. Work with JPL and/or USGS to remotely test Web Services, such as parameters for time series. Improve middleware to support GPS XML data requests using XML "tickets". Publish documentation on the public Web Services interface to enable other groups to remotely use the GPS Web Service. Work with other archives to install and use the Adaptive Seamless Archive. *Success Criteria:* The ability for a remote application to communicate with the Seamless Archive using Web Services and return the desired result. Integration of the Web Services with other applications.

### 11. *GPS Explorer*

Design database schema to support additional information beyond site metadata, such as GPS time series, velocities, offsets, and data quality metrics. Develop software to use the database thus replacing older flat file versions and enabling more dynamic use of the information. Use the existing SIM as a base for the GPS Explorer. Upgrade the software to utilize Web Services and communicate with the Adaptive Seamless Archive. Design the

GPS Explorer as an integrated environment to assist users in the location, selection, and acquisition of GPS site metadata and GPS Analysis products. Once the web-based version of the GPS explorer is complete, demonstrate the ability of a hand held device to utilize Web Services to retrieve GPS Explorer information. *Success Criteria:* A web-based application that integrates many different GPS-related tools and information into a single comprehensive application that allows users to interact with dynamic geodetic content. Access to similar information would be available to hand held PDA's using Web Services.

### 12. *Spatial Services*

Investigate equipment to support GIS Spatial Services. Purchase server and install software. Install and configure ESRI Internet Map Server to support the ESRI Geography Network. Add mapping tools to the GPS Explorer utilizing Spatial layers. Develop software to support the automated selection, packaging, and delivery of spatial data in various formats. *Success Criteria:* A GPS layer served to the ESRI Geographic Network and a utility that provides access to GIS related data.

### 13. *Open-Source Virtual Archive*

Define project goals and requirements. Advertise the project to the Open-Source community. Inform other GPS archives of project and get feedback. Identify existing Open-Source resources such as SourceForge. Create a project web site and solicit feedback. Identify existing Open-Source projects and software that can be reused in support of the Virtual Archive. Begin development of the Virtual Archive in cooperation with potential users. Maintain source code in a publicly accessible software repository. Maintain a mailing list in support of the project. Regularly post releases of the software to the web site. Seek out parties that will assist with software testing and development. Demonstrate integration of software by potential users. *Success Criteria:* Successful demonstration of software reuse. A working prototype of a successful Open-Source project. Software that places a layer between

the user and the actual data, supporting redundancy, and providing access to GPS data files through Web Services.

stress change estimates and displacement, velocity, and strain fields. Mr. Stark will develop, improve, and maintain systems to automate production of data products and transfer them to the SCIGN web page.

#### **6.4 Key Personnel**

Dr. Frank Webb, a permanent member of the SCIGN EC and Chair of the PBO Standing Committee, is the Principal Investigator (PI) with direct responsibility to NASA for the project and within SCIGN. He is supported at JPL by Dr. Sharon Kedar, Dr. Michael Heflin, and Dr. Danan Dong. Dr. Kedar will lead the product generation at JPL and coordinate with counter parts at the USGS and SIO. He supported by Dr. Heflin who will lead the production of the Level-1 data products. Dr. Dong will lead the development implementation at JPL of the S-T filter and the geophysical model development

#### **Table 3. Milestone Schedule**

Dr. Yehuda Bock is a permanent member of the SCIGN EC, Director of the Scripps Orbit and Permanent Array Center (SOPAC), and Director of the California Spatial Reference Center (CSRC). He is the SIO Project Member (PM) with direct responsibility to the project for the tasks at SIO. He also is responsible for the coordination of project activities with the surveying/GIS community represented by the CSRC. An experienced and talented archive/IT team, including Brent Gilmore, Michael Scharber, Paul Jamason, and David Malveaux, and analysis team including Dr. Peng Fang and Dr. Linette Prawirodirdjo support him.

Dr. Nancy King is a permanent member of the SCIGN EC, chair of the SCIGN Analysis Committee, and the USGS lead for operation of SCIGN. She is the USGS Project Member with direct responsibility for the implementation of USGS activities leading the coordination of the generation of project products. She is also responsible for the interface between the project's emergency response products and their users. She will also implement the SCIGN combined solution and oversee the implementation of other high-level data products. She is supported by Dr. Greg Anderson and Mr. Keith Stark. Dr. Anderson will implement techniques used to produce higher-level data products such as

## **7.0 PERSONNEL**

The biographical sketches and publication lists for the PI and each PM can be found at the end of this section. The following are biographical summaries for other key project members:

Mr. Stark holds a B.A. in cognitive science (1992) and an MBA (2000). He has more than 10 years of experience in system administration and programming in Perl, Java, C, C++, and other languages. He developed the automated systems used at USGS to download GPS data, supports a complex Perl system to automatically process data, and is now developing a system to collect data in real time. He works for SCIGN as a contractor (Stark Consulting) and, as SCIGN Network Coordinator, is responsible for operation and data flow.

Mr. Paul Jamason holds a B.S. in Atmospheric Science (1993) and an M.S. in Physical Geography (1996). He has worked as a research associate and programmer at SOPAC/ CSRC for over 5 years, and also oversees field operations for the SOPAC component t of the SCIGN GPS network. He is the developer and webmaster of the SOPAC/CSRC web sites, which utilize Perl CGI scripts and Apache modules. He assists in the download and archiving of continuous GPS data, and is responsible for the daily and weekly GPS analysis operations performed at SOPAC. He also develops software to provide analysis products to SOPAC/CSRC users.

Dr. Linette Prawirodirdjo received her Ph.D. in Earth Sciences from the University of California, San Diego in 2000, where she did her thesis work on geodetic studies of plate kinematics and crustal deformation in Indonesia. As a Postdoctoral Researcher at the Scripps Institution of Oceanography, UCSD, she continues her research in crustal deformation through analysis and modeling of GPS data from California and is currently completing a deformation study of the California Borderlands.

FRANK H. WEBB, JET PROPULSION LABORATORY

EDUCATION

PH.D Division of Geological and Planetary Sciences, California Institute of Technology, June 1990, Geodetic Measurement of Deformation in the Offshore of southern California.

M.S., Geology, California Institute of Technology, June 1989.

B.A. Geology, University of California, Santa Barbara, Mar. 1984. Summa cum laude, Phi Beta Kappa, Exxon outstanding senior. Planetary Geology Undergraduate Research Program, NASA, participant, Spring 1984.

RESEARCH, RESPONSIBILITIES, AND EXPERIENCE:

09/01-07/02 Proposal Manger for the Earth Change and Hazard Observatory (ECHO)

02/00-Present Group Supervisor for the Satellite Geodesy and Geodynamics Systems Group, JPL

06/99-Present JPL Program Element Manager for the Southern California Integrated GPS Network

10/96-05/99 Senior Member of the Technical Staff, JPL

03/90-09/96 Member of the Technical Staff, JPL

DUTIES:

Group Supervisor of the Satellite Geodesy and Geodynamics Systems Group, JPL

Chair of the Plate Boundary Observatory Standing Committee (2002-present)

Executive Committee Chairman and JPL board member for the Southern California Integrated GPS Network (SCIGN) (1998-1999);

Executive Committee Member and JPL board member for the Southern California Integrated GPS Network (SCIGN) (1999- present)

NASA GPS:

GPS System Development, Task Manager

GPS Data Analysis, Task Manager

GPS User Support, Task Manager

SELECTED PAPERS AND PUBLICATIONS

Preseismic transient slip during the 2001  $M_w=8.4$  Peru earthquake sequence from continuous GPS, Melbourne, T. I. And F. H. Webb, *Geophys. Res. Lett.*, in press, 2002.

Estimating the motion of atmospheric water vapor using the Global Positioning System, Emardson, T. R., and F.H. Webb, *GPS Solutions*, in press, 2002.

Neutral atmospheric delay in interferometric synthetic aperture radar applications: Statistical description and mitigation, Emardson, T. R., M. Simons, F. H. Webb, *JGR*, in press, 2002

Broadband moment release in subduction zones, Melbourne, T. I., F. H. Webb, J. Stock, C. Reigber, *Journ. Geophys. Res.*, in press, 2002.

Co-seismic slip from the July 30, 1995,  $M_w$  8.1 Antofagasta, Chile, earthquake as constrained by radar interferometry and other geodetic measurements, Pritchard, M. E., M. Simons, P. A. Rosen, S. Hensley, F. H. Webb, *Geophys. J. Int.*, **150**, 362-376, 2002

AWARDS AND HONORS

2000 – NASA Honor Award for SCIGN Team

2000 – NASA Cert. of Recog. for AODA Team for Shuttle Radar Topography Mission

1999 – NASA Group Achievement Award

1996 – JPL Award for Excellence for Exceptional Quality in GPS

1992 – NASA Group Achievement Award OASIS/GIPSY Development Team



**Greg Anderson**

Dr. Anderson is a Mendenhall Postdoctoral Fellow at the US Geological Survey in Pasadena. He received his Ph.D. in Earth Sciences from the University of California, San Diego (UCSD) in 1999, where he specialized in GPS and tiltmeter studies of crustal deformation and statistical studies of earthquake stress transfer. As a graduate student and postdoctoral researcher at UCSD, he led several field GPS surveys in southern California, including co-coordinating several large surveys following the 1999 Hector Mine earthquake, and was part of a team that designed a novel long-baseline tiltmeter for submarine volcano deformation monitoring. Since coming to the USGS in December 2001, he has developed software for rapid estimation of strain fields from SCIGN data, has studied crustal deformation in the Salton Trough from survey-mode GPS and trilateration, and is developing techniques for estimation of earthquake probabilities from geodetic data.

**EDUCATION**

Nov 1999      Ph.D., Earth Sciences, University of California, San Diego  
Dec 1990      A.B., Geophysics, University of California, Berkeley

**PROFESSIONAL EXPERIENCE**

Dec 2001-present Mendenhall Postdoctoral Fellow, US Geological Survey, Pasadena  
Jan-Dec 2001      Postdoctoral Fellow, Southern California Earthquake Center  
Nov 1999-Dec 2000 Postgraduate Research Geophysicist, UC San Diego  
Aug 1993-Nov 1999 Graduate Student Researcher, UC San Diego  
Jan 1991-June 1993 Staff Research Associate, Berkeley Seismological Laboratory

**RELEVANT PUBLICATIONS**

- Anderson, G., D.C. Agnew, and H.O. Johnson, 30 years of Salton Trough regional deformation estimated from combined trilateration and survey-mode GPS data, in preparation for submission to *Bull. Seismol. Soc. Am.*, 2002.
- Agnew, D.C., S. Owen, Z.-K. Shen, G. Anderson, J. Svarc, H. Johnson, K.E. Austin, and R. Reilinger, Coseismic displacement from the Hector Mine, California, earthquake: Results from survey-mode Global Positioning System measurements, *Bull. Seismol. Soc. Am.*, 92, 1355-1364, 2002.
- Owen, S., G. Anderson, D. C. Agnew, H. Johnson, K. Hurst, R. Reilinger, Z.-K. Shen, J. Svarc, and T. Baker, Early postseismic deformation from the 16 October 1999 Mw 7.1 Hector Mine, California, earthquake as measured by survey-mode GPS, *Bull. Seismol. Soc. Am.*, 92, 1423-1432, 2002.
- Tolstoy, M., S. Constable, J. Orcutt, H. Staudigel, F.K. Wyatt, and G. Anderson, Short and long baseline tiltmeter measurements on Axial Seamount, Juan de Fuca Ridge, *Phys. Earth Planet. Int.*, 108, 131-143, 1998.
- Anderson, G., S. Constable, H. Staudigel, and F.K. Wyatt, A seafloor long-baseline tiltmeter, *J. Geophys. Res.*, 102, 20,269-20,285, 1997.

**YEHUDA BOCK**

Research Geodesist and Senior Lecturer (1993- present)

Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics

Scripps Institution of Oceanography · University of California, San Diego·

**Research Interests**

Space Geodesy (GPS and InSAR)

Crustal Deformation, Plate Motion, Earthquake Hazards

GPS Meteorology and Climatology

Real-Time Positioning of Dynamic Platforms with GPS

Geographic Information Systems (GIS)

**Education**

Ph.D., 1982; M.S., 1980, Geodetic Science, The Ohio State University

B.Sc., 1977, Geodetic Engineering, Technion-Israel Inst. of Technology, *with honors*

B.A., 1971, Mathematics, New York University, *Dean's list*

**Academic Experience**

Research Geodesist and Senior Lecturer, Scripps Institution of Oceanography, UCSD, 1993- ;

Assoc. Adjunct Professor and Assoc. Research Geophysicist 1989-1993

Visiting Scientist, Technion, Israel Institute of Technology, Haifa, Israel, 1996

Visiting Scientist, Tel Aviv Univ., Israel, 1995

Staff Scientist, Jet Propulsion Laboratory, Pasadena, California, 1989-1992

Research Scientist, Massachusetts Institute of Technology, 1984-1989; Lecturer, 1986

Visiting Associate Professor, Gadjah Mada Univ., Yogyakarta, Indonesia, 1987

Geophysics Research Scholar, Air Force Geophysics Laboratory, 1982-1984

Graduate Research Associate, The Ohio State University, 1977-1982

**Administrative Posts**

Director, Scripps Orbit and Permanent Array Center (SOPAC), 1993 to present,

<http://sopac.ucsd.edu/>; Permanent GPS Geodetic Array (PGGA), 1993- , UNAVCO Orbit

Facility, 1992-1997, IGS Global Data Center and Global Analysis Center, 1992-

Director, California Spatial Reference Center (CSRC), 1999 to present, <http://csrc.ucsd.edu/>;

Member, Southern California Integrated GPS Network (SCIGN) Executive Committee and

Coordinating Board, 1995 to present (Chair, 1997-1998; Vice-Chair, 1999-present),

<http://www.scign.org/>

**Awards**

Certificate of Appreciation for Outstanding Service, International GPS Service, 1999

Certificate of Appreciation, International GPS Service for Geodynamics, 1994

Fellow, International Association of Geodesy, 1991

The Karrina and Weikko A. Heiskanen Award, Department of Geodetic Science and Surveying,

The Ohio State University, Columbus, 1989

**Field and Laboratory Experience**

Co-developer (with Robert King) of GAMIT GPS software package, 1985-

Co-founder (with Shimon Wdowinski) of continuous GPS array in Israel and Jordan, 1997-2002

GPS projects in Indonesia, Italy (Venice), Japan, southern California, 1989-

**Professional Activities**

Western North America Plate Boundary Observatory Steering Committee, 1999-2002

SCEC Crustal Deformation Working Group, 1991- 2001

IGS Steering Committee and Governing Board, 1991-1999

IAG Executive Committee, 1995-1999

Lecturer, International GPS School, Delft, the Netherlands, 1995, 1997

Editorial Board, Manuscripta Geodaetica, 1992-1995; Editorial Board, Journal of Geodesy,

1996-1998; Associate Editor, Journal of Geophysical Research, 1998-

**Danan Dong**

*Jet Propulsion Laboratory · 4800 Oak Grove Drive , Pasadena, CA 91109*

**Education:**

1988 - 1993 Ph.D. in Geodynamics and Geodesy, MIT  
1982 - 1984 M.S. in Geodynamics, Shanghai Observatory, Academia Sinica  
1979 - 1982 B.S. in Geophysics, Dept. of Geophysics, Peking University

**Work Experience:**

1998 - Senior Technical Staff, JPL  
1993 - 1998 Technical Staff, JPL  
Summer-1992 Visiting Scientist, Ashtech Inc.  
1988 - 1993 Research Assistant, Dept. of EAPS, MIT  
1987 - 1988 Visiting Scientist, Dept. of EAPS, MIT  
1984 - 1987 Research Associate, Shanghai Observatory

**Professional Activities:**

Member of American Geophysical Union since 1987

**Awards:**

NASA group award for SCIGN network analysis (2000)  
NASA award for the creative work on software QOCA (1999)  
The Second Science and Technology Award of Academia Sinica (1989)  
The Second Excellent Essays Award for the Young in Shanghai (1984)  
The Fourth Science and Technology Award of Seismology Bureau of China (1984)

**Publications:**

Dong, D., T. Yunck, and M. Heflin, The origin of international terrestrial reference frame, submitted to *J. Geophys. Res.*, under review, 2002  
Zhang, F. P., et al., Seasonal vertical crustal motions in China detected by GPS, *Bulletin of Science*, 47, #18, 1370-1377, 2002.  
Dong, D., P. Fang, Y. Bock, M. K. Cheng, and S. Miyazaki, Anatomy of apparent seasonal variations from GPS derived site position time series, *J. Geophys. Res.*, 107, B4, ETG 9-1 – ETG 9-16, 2002  
Shen, Z-K, et al., Crustal deformation along the Altyn Tagh fault system, western China, from GPS, *J. Geophys. Res.*, 106, 30607-30622, 2001  
Shen, Z-K, et al., Contemporary crustal deformation in East Asia constrained by Global Positioning System measurements, *J. Geophys. Res.*, 105, 5721-5734, 2000  
Argus, D. F., et al., Shortening and thickening of metropolitan Los Angeles measured and inferred by using geodesy, *Geology*, 27, 703-706, 1999  
Hager, B. H., et al., Reconciling rapid strain accumulation with deep seismogenic fault planes in the Ventura Basin, California, *J. Geophys. Res.*, 104, 25207-25219, 1999  
Dong, D., T. A. Herring and R. W. King, Estimating Regional deformation from a combination of space and terrestrial geodetic data, *Journal of Geodesy*, 72, 200-214, 1998

---

**Sharon Kedar Ph.D.**


---

*Jet Propulsion Laboratory · 4800 Oak Grove Drive , Pasadena, CA 91109*

*Tel: (818) 393-6808 · Fax: (818) 393-4965 · E-mail: Sharon.Kedar@jpl.nasa.gov*

---

**Qualifications**


---

- Data reduction and processing
- Data analysis
- Computer modeling
- Experiment design and execution
- Software development

---

**Education**


---

06/1996 Ph.D. Geophysics California Institute of Technology  
 06/1989 B.Sc Geophysics and Planetary Sciences Tel Aviv University

---

**Work Experience**


---

08/2001 – present Member of Technical Staff JPL / Satellite Geodesy and Geodynamics Systems  
 GPS data analysis and applications

04/2000 – 04/2001 Staff scientist California Institute of Technology / Seismological Laboratory,  
 Data analysis and computer modeling

07/1996 – 06/1998 NSF postdoctoral fellow - United States Geological Survey - Volcano Hazards  
 Broad-Band monitoring of active volcanoes  
 Hazard assessment  
 Continuous Seismic and Electromagnetic monitoring at Long Valley

06/1989 – 06/1996 Ph.D. Student California Institute of Technology  
 Underwater pressure measurement inside Old Faithful Geyser, Yellowstone  
 Development of slow earthquake detection scheme for Southern California  
 Nuclear explosion detection

---

**Awards**


---

1996 National Science foundation Geosciences postdoctoral fellowship -2<sup>nd</sup> place nationally

---

**Select Publications**


---

Waveform inversion of very long period impulsive signals associated with magmatic injection beneath Kilauea Volcano, Hawaii , Ohminato, T., Chouet, B. A., Dawson, P. B., and Kedar S., *Journal of Geophysical Research*, 103, no. 10, 23,839-23,862, 1998

Bubble collapse as the source of tremor at Old Faithful Geyser, Kedar, S., Kanamori, H., Sturtevant, B., *Journal of Geophysical Research*, 103, no. 10, 24,283-24,299, 1998

Kedar, Sturtevant and Kanamori; The Origin of Harmonic Tremor at Old Faithful Geyser, *Nature*, 379, 708-711, 1996

Kedar and Kanamori; Continuous Monitoring of Seismic Energy Release, *Bulletin of the Seismological Society of America*. 86 (1A), 255-258, 1996

Dr. Nancy King, US Geological Survey

**EDUCATION**

June 1990 Ph.D., Earth Sciences, University of California, San Diego  
June 1973 B.A., Mathematics, University of California, San Diego

**PROFESSIONAL EXPERIENCE**

May 1997-present Geophysicist, U.S. Geological Survey, Pasadena  
Sep 1990-May 1997 Geophysicist, U.S. Geological Survey, Menlo Park  
Jun 1990-Sep 1990 Postgraduate Research Geophysicist, UC San Diego  
Sep 1984-Jun 1990 Graduate Student Researcher, UC San Diego  
Aug 1973-Sep 1984 Mathematician, U.S. Geological Survey, Menlo Park

**RELEVANT PUBLICATIONS**

King, N.E., J.L. Svarc, E.B. Fogleman, W.K. Gross, K.W. Clark, G.D. Hamilton, C.H. Stiffler, and J.M. Sutton, Continuous GPS observations across the Hayward fault, California, 1991-1994, *Journal of Geophysical Research*, 100, 20271-20283, 1995

King, N.E., and Thatcher, W., The coseismic slip distributions of the 1940 and 1979 Imperial Valley, California, earthquakes, *Journal of Geophysical Research*, 103, 19069-18086, 1998

Scientists from the U.S. Geological Survey, Southern California Earthquake Center, and California Division of Mines and Geology, Preliminary report on the 16 October 1999 M 7.1 Hector Mine, California, Earthquake, *Seismological Research Letters*, 71, 11-23, 2000

Hudnut, K.W., H.E. King, J.E. Galetzka, K.F. Stark, J.A. Behr, A. Aspiotes, S. van Wyk, R. Moffitt, S. Dockter, and F. Wyatt, Continuous GPS observations\ of postseismic deformation following the 16 October 1999 Hector Mine, California, Earthquake (M 7.1), *Bulletin of the Seismological Society of America*, 92, 1403-1422, 2002

King, N.E., K. Hurst, J. Langbein, M. van Domselaar, Comparison and combination of solution from the Southern California Integrated GPS Network, *Eos, Transactions, American Geophysical Union Fall Meeting*, Suppl. 82, F292, 2001

King, N.E., M. Heflin, T. Herring, Hurst, K., Kedar, S., Langbein, J., and L. Prawirodirdjo, Toward an ITRF2000 Combined Solution for the Southern California Integrated GPS Network, *AGU Fall Meeting*, (no Eos reference yet), 2002

Dr. Michael Heflin, Jet Propulsion Laboratory

**Education**

GPA 4.8/5.0      Massachusetts Institute of Technology, Cambridge, Massachusetts.  
Ph.D. in physics received September 19, 1990.

GPA 3.8/4.0      Miami University, Oxford, Ohio.  
Bachelor of Science in physics received December 20, 1985.

**Employment**

9/90 - present      Jet Propulsion Laboratory, Senior Member of Technical Staff.  
Research and development related to the Global Positioning System.  
<http://sideshow.jpl.nasa.gov/mbh/series.html>

2/86 - 9/90      Massachusetts Institute of Technology, Research Assistant.

**Experience**

Software

1. Co-patent holder for JPL's award-winning GIPSY software package.
2. Operating systems: Linux/Unix, Windows, Mac OS
3. Software development: VC++, VB, PERL, XHTML, FORTRAN, CSH
4. Use of advanced physical models and numerically stable algorithms.

Highlights

Ohio Academic Scholarship as high school valedictorian.  
R. L. Edwards Physics Scholarship.  
George B. and Carolyn Arfken Physics Scholarship.  
Phi Beta Kappa and Sigma Xi.  
Three NASA tech brief awards for innovative technology.  
Major NASA award for software development.  
Winner of JPL's award for excellence.

**Comparison of a GPS Defined Global Reference Frame with ITRF2000**, Heflin, M., D. Argus, D. Jefferson, F. Webb, and J. Zumberge, *GPS Solutions*, Vol. 6, 72-75, 2002.

**Examining the C1-P1 Pseudorange Bias** D. Jefferson, M. Heflin, and R. Meullerschoen, *GPS Solutions*, Vol. 4, No. 4, 25-30, 2001.

**The co-seismic geodetic signature of the 1999 Hector Mine Earthquake**

Hurst, K., D. Argus, A. Donnellan, M. Heflin, D. Jefferson, G. Lyzenga, J. Parker, M. Smith, F. Webb, and J. Zumberge, *GRL*, Vol. 27, No. 17, pp. 2733-2736, 2000.

**Seismic cycle and plate margin deformation in Costa Rica: GPS observations from 1994 to 1997**, Lundgren, P., M. Protti, A. Donnellan, M. Heflin, E. Hernandez, and D. Jefferson, *JGR*, v. 104, no. B12, p28915-28926, December, 1999.

**Shortening and Thickening of Metropolitan Los Angeles Measured and Inferred using Geodesy**, Argus D., M. Heflin, A. Donnellan, F. Webb, D. Dong, K. Hurst, D. Jefferson, G. Lyzenga, M. Watkins, and J. Zumberge, *Geology*, Vol. 27, No. 8, pp. 703-706, 1999.

**Rate change observed at JPLM after the Northridge earthquake** Heflin, M., D. Dong, A. Donnellan, K. Hurst, D. Jefferson, M. Watkins, F. Webb, and J. Zumberge, *Geophysical Research Letters*, Vol. 25, No. 1, pp. 93-96, 1998.

## 8.0 REFERENCES

- Bawden, G. W., W. Thatcher, R. S. Stein, C. Wicks, K. Hudnut, and G. Peltzer, Tectonic contraction across Los Angeles after removal of groundwater pumping effects, *Nature*, v. 412, p. 812-815, 2001
- Bock Y., S. Wdowinski, P. Fang, J. Zhang, J. Behr, J. Genrich, S. Williams, D. Agnew, F. Wyatt, H. Johnson, K. Stark, B. Oral, K. Hudnut, S. Dinardo, W. Young, D. Jackson, and W. Gurtner, Southern California Permanent GPS Geodetic Array: Continuous measurements of crustal deformation between the 1992 Landers and 1994 Northridge earthquakes, *J. Geophys. Res.*, 102, 18,013-18,033, 1997.
- Bock, Y., R. Nikolaidis, P. J. de Jonge, and M. Bevis, Instantaneous resolution of crustal motion at medium distances with the Global Positioning System, *J. Geophys. Res.*, 105, 28,223-28,254, 2000.
- Deng, J. S., K. Hudnut, M. Gurnis, E. Hauksson, Stress loading from viscous flow in the lower crust and triggering of aftershocks following the 1994 Northridge, California, earthquake *Geophys. Res. Lett.*, v. 26, p. 3209-2212, 1999.
- Dong, D., P. Fang, Y. Bock, M. K. Cheng, and S. Miyazaki: Anatomy of apparent seasonal variations from GPS-derived site position time series, *J. G. R.*, 107, B4, ETG 9-1 - ETG 9-16, 2002
- Donnellan, A., and G. A. Lyzenga, GPS observations of fault afterslip and upper crustal deformation following the Northridge earthquake, *J. Geophys. Res.*, v. 103, p. 21285-21297, 1998.
- Gan, W. and W. H. Prescott: Crustal deformation rates in central and eastern U.S. inferred from GPS, *Geophys. Res. Lett.*, 28, 3733-3736, 2001
- Hager, B. H., et al.: Reconciling rapid strain accumulation with deep seismogenic fault planes in the Ventura basin, California, *Jour. Geophys. Res.*, 104, 25207-25219, 1999
- Hardebeck J. L., Nazareth J. J., Hauksson E., The static stress change triggering model: Constraints from two southern California aftershock sequences, *Jour. Geophys. Res.*, V103, B10, p 24,427-24,437, 1998
- Harris R. A., Introduction to special session: Stress triggers, stress shadows, and implications for seismic hazard, *Jour. Geophys. Res.*, V103, B10, p 24,347-24,358, 1998
- Heflin M., Dong D., Donnellan A., Hurst K., Jefferson D., Watkins M., Webb F., Zumberge J., Rate change observed at JPLM after the Northridge earthquake, *Geophys. Res. Lett.*, V25, No. 1, p 93-96, 1998
- Hudnut, K. W., Y. Bock, M. Cline, P. Fang, Y. Feng, J. Freymueller, X. Ge, W. K. Gross, D. Jackson, M. Kim, N. E. King, J. Langbein, S. C. Larsen, M. Lisowski, Z.-K. Shen, J. Svarc, and J. Zhang, Co-seismic displacements of the 1992 Landers earthquake sequence, *Bull. Seism. Soc. Amer.*, v. 84, p. 625-645, 1994.
- King N., Heflin M. B., Hurst K., Kedar S., Herring T., P rawirodirdjo L., Noise levels in Southern California Integrated GPS Network (SCIGN) data; Preliminary results, *Eos Trans. AGU*, 83(47), 2002
- Leduc J. P., Spatio-Temporal wavelet transforms for digital signal analysis, *Signal Processing*, 60, p. 23-41, 1997
- Nikolaidis, R., Y. Bock, P. Shearer, P. J. de Jonge, D.C. Agnew, and M. Van Domselaar, Seismic wave observations with the Global Positioning System, *J. Geophys. Res.*, 106, 21,897-21,916, 2001.

- Peltzer, G., P. Rosen, F. Rogez, K. Hudnut, Poroelastic rebound along the Landers 1992 earthquake surface rupture, *J. Geophys. Res.*, v. 103, p. 30131-30145, 1998.
- Peltzer, G., F. Crampe', S. Hensley, and P. Rosen, Transient strain accumulation and fault interaction in the eastern California shear zone, *Geology*, v. 29, p. 975-978, 2001.
- Savage, J. C., and M. Lisowski, Viscoelastic coupling model of the San Andreas fault along the big bend, southern California, *J. Geophys. Res.*, v. 103, p. 7281-7292, 1998.
- Savage, J. C., and J. L. Svarc, Postseismic deformation associated with the 1992 Mw=7.3 Landers earthquake, southern California, *J. Geophys. Res.*, v. 102, p. 7565-7577, 1997.
- Savage, J. C., J. L. Svarc, and W. H. Prescott: Strain accumulation near Yucca Mountain, Nevada, 1993-1998, *J. G. R.*, 106, 16483-16488, 2001.
- SCIGN 2001-2002 Accomplishments, <http://www.scign.org/>.
- SCIGN Analysis Committee Report, 2001, <http://www.scign.org/>.
- SCIGN Publication List, [http://www.scign.org/docs/SCIGN\\_publications\\_9-30-02.pdf](http://www.scign.org/docs/SCIGN_publications_9-30-02.pdf).
- Segall P., Matthews M., Time dependent inversion of geodetic data, *Jour. Geophys. Res.*, V102, No B12, p 22,391-22,409, 1997.
- Shen, Z.-K., D. D. Jackson, Y. Feng, M. Cline, M. Kim, P. Fang, and Y. Bock, Postseismic deformation following the Landers earthquake, California, 28 June 1992, *Bull. Seism. Soc. Amer.*, v. 84, p. 780-791, 1994.
- Stein R. S., The role of stress transfer in earthquake occurrence, *Nature*, 402 No. 6762, p p605-609, 1999
- Svarc, J. L., J. C. Savage, W. H. Prescott, and A. R. Ramelli: Strain accumulation and rotation in western Nevada, 1993-2000, *Jour. Geophys. Res.*, 107, B5, ETG 2-1 - ETG 2-11, 2002
- Thatcher, W., Strain accumulation and release mechanism of the 1906 San Francisco earthquake, *J. Geophys. Res.*, v. 80, p. 4862-4872, 1975.
- The Plate Boundary Observatory, Creating a Four-Dimensional Image of the Deformation of Western North America *White Paper*, <http://www.earthscope.org>, 1999.
- Solid Earth Science Working Group, *SESWG Solid Earth Science Working Report*, August 2002
- Watson, K. M., Y. Bock, and D. T. Sandwell, Satellite interferometric observations of displacements associated with seasonal groundwater in the Los Angeles basin, *J. Geophys. Res.*, v. 107 (B1), 10.1029/2002JB000470, 2002.
- Wdowinski S., Bock Y., Zhang J., Fang P., Genrich J., Southern California Permanent GPS Geodetic Array: Spatial filtering of daily positions for estimating coseismic and postseismic displacements induced by the 1992 Landers Earthquake, *Jour. Geophys. Res.*, V102, p. 18,057-18,070, 1997.
- Wood H. O., Gutenberg B., Earthquake prediction, *Science*, 82, No 2123, p. 219-220, 1935.



## **9.0 PROPOSED COSTS**

### **9.1 *Budget Breakdown by Fiscal Year***

The following NASA budget sheets show the total program costs, the program costs for the USGS, the program costs for SIO, and the program costs for the Open Source efforts. The costs for USGS and SIO are accounted as sub-contracts from JPL. A cost savings of ~\$80k per year could be realized if the NASA funds were distributed directly to those USGS and SIO.

# GPS Data Products for Solid Earth Science

## Year 1 Budget Summary

	For Period From February 2003 to December 2003		NASA USE ONLY	
	A	B	C	
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	\$188.1			
2. <u>Other Direct Costs:</u>				
a. Subcontracts (includes Open See accompanying sheets for	\$724.7			
b. Consultants	\$0.0			
c. Equipment	\$4.0			
d. Supplies	\$0.0			
e. Travel	\$10.3			
f. Other (MPS & ADC)				
1. MPS & ADC	\$105.1			
2. Services	\$0.0			
3. <u>Facilities and Administrative Costs</u>	\$74.1			
4. <u>Other Applicable Costs</u>				
1. Award Fee	\$16.3			
2. Government Co-I				
5. <b><u>SUBTOTAL--Estimated Costs</u></b>	\$1,122.5			
6. <u>Less Proposed Cost Sharing (if any)</u>				
7. <u>Carryover Funds (if any)</u>				
a. Anticipated amount :				
b. Amount used to reduce budget				
8. <b><u>Total Estimated Costs</u></b>	\$1,122.5			XXXXXX
9. <b>APPROVED BUDGET</b>	XXXXXXX	XXXXXXX		

# GPS Data Products for Solid Earth Science

## Year 2 Budget Summary

	For Period From January 2004 to December 2004		NASA USE ONLY	
	A	B	C	
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	\$269.1			
2. <u>Other Direct Costs:</u>				
a. Subcontracts (includes Open <u>See accompanying sheets for</u>	\$725.0			
b. Consultants	\$0.0			
c. Equipment	\$1.0			
d. Supplies	\$0.0			
e. Travel	\$9.8			
f. Other (MPS & ADC)				
1. MPS & ADC	\$141.7			
2. Services	\$0.0			
3. <u>Facilities and Administrative Costs</u>	\$85.7			
4. <u>Other Applicable Costs</u>				
1. Award Fee	\$17.0			
2. Government Co-I				
5. <b><u>SUBTOTAL--Estimated Costs</u></b>	<b>\$1,249.3</b>			
6. <u>Less Proposed Cost Sharing (if any)</u>				
7. <u>Carryover Funds (if any)</u>				
a. Anticipated amount :				
b. Amount used to reduce budget				
8. <b><u>Total Estimated Costs</u></b>	<b>\$1,249.3</b>			XXXXXX
9. <b>APPROVED BUDGET</b>	XXXXXXX	XXXXXXX		

# GPS Data Products for Solid Earth Science

## Year 3 Budget Summary

	For Period From January 2005 to December 2005		NASA USE ONLY	
	A	B	C	
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	\$259.9			
2. <u>Other Direct Costs:</u>				
a. Subcontracts (includes Open <u>See accompanying sheets for</u>	\$704.3			
b. Consultants	\$0.0			
c. Equipment	\$3.0			
d. Supplies	\$0.0			
e. Travel	\$9.8			
f. Other (MPS & ADC)				
1. MPS & ADC	\$136.2			
2. Services	\$0.0			
3. <u>Facilities and Administrative Costs</u>	\$84.9			
4. <u>Other Applicable Costs</u>				
1. Award Fee	\$15.6			
2. Government Co-I				
5. <b><u>SUBTOTAL--Estimated Costs</u></b>	\$1,213.7			
6. <u>Less Proposed Cost Sharing (if any)</u>				
7. <u>Carryover Funds (if any)</u>				
a. Anticipated amount :				
b. Amount used to reduce budget				
8. <b><u>Total Estimated Costs</u></b>	\$1,213.7			XXXXXX
9. <b>APPROVED BUDGET</b>	XXXXXXX	XXXXXXX		

# GPS Data Products for Solid Earth Science

## Year 4 Budget Summary

	For Period From January 2006 to December 2006		NASA USE ONLY	
	A	B	C	
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	\$304.8			
2. <u>Other Direct Costs:</u>				
a. Subcontracts (includes Open <u>See accompanying sheets for</u>	\$709.0			
b. Consultants	\$0.0			
c. Equipment	\$0.0			
d. Supplies	\$0.0			
e. Travel	\$9.8			
f. Other (MPS & ADC)				
1. MPS & ADC	\$156.9			
2. Services	\$0.0			
3. <u>Facilities and Administrative Costs</u>	\$93.0			
4. <u>Other Applicable Costs</u>				
1. Award Fee	\$16.6			
2. Government Co-I				
5. <b><u>SUBTOTAL--Estimated Costs</u></b>	\$1,290.1			
6. <u>Less Proposed Cost Sharing (if any)</u>				
7. <u>Carryover Funds (if any)</u>				
a. Anticipated amount :				
b. Amount used to reduce budget				
8. <b><u>Total Estimated Costs</u></b>	\$1,290.1			XXXXXX
9. <b>APPROVED BUDGET</b>	XXXXXXX	XXXXXXX		

# GPS Data Products for Solid Earth Science

## Year 5 Budget Summary

	For Period From October 2006 to September 2007		NASA USE ONLY	
	A	B	C	
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	\$273.2			
2. <u>Other Direct Costs:</u>				
a. Subcontracts (includes Open <u>See accompanying sheets for</u>	\$719.4			
b. Consultants	\$0.0			
c. Equipment	\$0.0			
d. Supplies	\$0.0			
e. Travel	\$7.4			
f. Other (MPS & ADC)				
1. MPS & ADC	\$141.3			
2. Services	\$0.0			
3. <u>Facilities and Administrative Costs</u>	\$89.9			
4. <u>Other Applicable Costs</u>				
1. Award Fee	\$16.0			
2. Government Co-I				
5. <b><u>SUBTOTAL--Estimated Costs</u></b>	\$1,247.1			
6. <u>Less Proposed Cost Sharing (if any)</u>				
7. <u>Carryover Funds (if any)</u>				
a. Anticipated amount :				
b. Amount used to reduce budget				
8. <b><u>Total Estimated Costs</u></b>	\$1,247.1			XXXXXX)
9. <b>APPROVED BUDGET</b>	XXXXXXX	XXXXXXX		

# GPS Data Products for Solid Earth Science

## Grand Total Budget Summary

	For Period From February 2003 to December 2007		NASA USE ONLY	
	A	B	C	
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	\$1,295.1			
2. <u>Other Direct Costs:</u>				
a. Subcontracts (includes Open <u>See accompanying sheets for</u>	\$3,582.4			
b. Consultants	\$0.0			
c. Equipment	\$8.0			
d. Supplies	\$0.0			
e. Travel	\$47.0			
f. Other (MPS & ADC)				
1. MPS & ADC	\$681.1			
2. Services	\$0.0			
3. <u>Facilities and Administrative Costs</u>	\$427.7			
4. <u>Other Applicable Costs</u>				
1. Award Fee	\$81.4			
2. Government Co-I	\$0.0			
5. <b><u>SUBTOTAL--Estimated Costs</u></b>	\$6,122.7			
6. <u>Less Proposed Cost Sharing (if any)</u>	\$0.0			
7. <u>Carryover Funds (if any)</u>				
a. Anticipated amount :	\$0.0			
b. Amount used to reduce budget	\$0.0			
8. <b><u>Total Estimated Costs</u></b>	\$6,122.7			XXXXXX)
9. <b>APPROVED BUDGET</b>	XXXXXXX	XXXXXXX		

## ***JPL Cost Accumulation System***

The NASA prime contract—NAS7-1407—is a Cost Reimbursable Award Fee type instrument. All costs incurred are billed to the Government on a 100% reimbursable basis. The costs to be charged for the proposed work must be consistent with contractual provisions and established procedures for costing under the current contract between NASA and Caltech. All charges developed at the Laboratory, including JPL applied burdens, are billed to the Government as direct charges at the rates in effect at the time the work is accomplished. Government audit is performed on a continuing basis by a Defense Contract Audit Agency team in residence.

Allocated Direct Costs (ADC) is the term for “JPL applied burdens.” ADC includes activities (accounts) benefiting multiple tasks. The cost collection system groups common Allocated Direct Cost accounts into three groups. The groups are as follows:

- 1) Labor: Engineering and Science ADC
- 2) Procurement: Purchase Order ADC and Subcontract ADC.
- 3) General: a percentage of all subordinate costs on direct projects. (Similar to the General and Administrative expense in industry.)

Each grouping contains like functions or activities. The accounting process distributes these costs on a 100% reimbursable basis.

Multiple Program Support (MPS) is a distributed direct factor per JPL and accountable contractor workhour on respective program office direct accounts.

Labor—Employee Fringes consist of one composite labor fringe rate applied to JPL labor as follows:

- Benefits is a percentage of straight time and overtime labor cost.

Award Fee—the NASA / Caltech contract for the operation of the federally funded research and development center (FFRDC) is a cost plus award fee contract. As such, all sponsors placing funds on contract contribute a small percentage of task order dollars toward the award fee.

---

For this proposal the estimated costs have been built up in the same manner as above. However, their presentation in the required tables have been adapted in the following ways:

1. The costs for Employee Fringes is included in Direct Labor costs stated in this proposal.
2. Engineering and Science ADC and Procurement ADC along with MPS costs are displayed in the “Other” category in the Other Direct Costs section.
3. Since the JPL General ADC costs are similar to G&A and are derived in the same fashion—a percentage of the subtotal of all costs—they are displayed in the Facilities and Administrative Costs section.
4. The Award Fee is displayed in the Other Applicable Costs section. The Award Fee annual percentage is 1.5% in Year 1, 1.4% in Year 2 and 1.3% in subsequent fiscal years.



USGS Budget Summary  
CY03

NASA USE ONLY  
B C

	A	B	C
1. <u>Direct Labor</u>	\$ 139,154.89		
2. <u>Other Direct Costs:</u>			
a. Subcontracts			
b. Consultants	\$ 73,602.00		
c. Equipment			
d. Supplies			
e. Travel			
f. Other			
3. <u>Indirect Costs</u>	\$ 76,384.30		
4. <u>Other Applicable Costs</u>			
5. SUBTOTAL	\$ 289,141.19		
6. <u>Less Proposed Cost Sharing</u>			
7. <u>Total Estimated Costs</u>	\$ 289,141.19		
8. APPROVED BUDGET			

USGS Budget Summary  
CY04

NASA USE ONLY

A                      B                      C

- |                                      |               |  |  |
|--------------------------------------|---------------|--|--|
| 1. <u>Direct Labor</u>               | \$ 129,906.98 |  |  |
| 2. <u>Other Direct Costs:</u>        |               |  |  |
| a. Subcontracts                      |               |  |  |
| b. Consultants                       | \$ 91,872.00  |  |  |
| c. Equipment                         |               |  |  |
| d. Supplies                          |               |  |  |
| e. Travel                            |               |  |  |
| f. Other                             |               |  |  |
| 3. <u>Indirect Costs</u>             | \$ 77,262.78  |  |  |
| 4. <u>Other Applicable Costs</u>     |               |  |  |
| 5. SUBTOTAL                          | \$ 299,041.76 |  |  |
| 6. <u>Less Proposed Cost Sharing</u> |               |  |  |
| 7. <u>Total Estimated Costs</u>      | \$ 299,041.76 |  |  |
| 8. APPROVED BUDGET                   |               |  |  |

USGS Budget Summary  
CY05

NASA USE ONLY

A                      B                      C

- |                                      |               |  |  |
|--------------------------------------|---------------|--|--|
| 1. <u>Direct Labor</u>               | \$ 111,411.16 |  |  |
| 2. <u>Other Direct Costs:</u>        |               |  |  |
| a. Subcontracts                      |               |  |  |
| b. Consultants                       | \$ 91,872.00  |  |  |
| c. Equipment                         |               |  |  |
| d. Supplies                          |               |  |  |
| e. Travel                            |               |  |  |
| f. Other                             |               |  |  |
| 3. <u>Indirect Costs</u>             | \$ 69,625.30  |  |  |
| 4. <u>Other Applicable Costs</u>     |               |  |  |
| 5. SUBTOTAL                          | \$ 272,908.47 |  |  |
| 6. <u>Less Proposed Cost Sharing</u> |               |  |  |
| 7. <u>Total Estimated Costs</u>      | \$ 272,908.47 |  |  |
| 8. APPROVED BUDGET                   |               |  |  |

USGS Budget Summary  
CY06

NASA USE ONLY

A                      B                      C

- |                                      |               |  |  |
|--------------------------------------|---------------|--|--|
| 1. <u>Direct Labor</u>               | \$ 111,411.16 |  |  |
| 2. <u>Other Direct Costs:</u>        |               |  |  |
| a. Subcontracts                      |               |  |  |
| b. Consultants                       | \$ 91,872.00  |  |  |
| c. Equipment                         |               |  |  |
| d. Supplies                          |               |  |  |
| e. Travel                            |               |  |  |
| f. Other                             |               |  |  |
| 3. <u>Indirect Costs</u>             | \$ 69,625.30  |  |  |
| 4. <u>Other Applicable Costs</u>     |               |  |  |
| 5. SUBTOTAL                          | \$ 272,908.47 |  |  |
| 6. <u>Less Proposed Cost Sharing</u> |               |  |  |
| 7. <u>Total Estimated Costs</u>      | \$ 272,908.47 |  |  |
| 8. APPROVED BUDGET                   |               |  |  |

USGS Budget Summary  
CY07

NASA USE ONLY

A                      B                      C

- |                                      |               |  |  |
|--------------------------------------|---------------|--|--|
| 1. <u>Direct Labor</u>               | \$ 106,787.21 |  |  |
| 2. <u>Other Direct Costs:</u>        |               |  |  |
| a. Subcontracts                      |               |  |  |
| b. Consultants                       | \$ 114,840.00 |  |  |
| c. Equipment                         |               |  |  |
| d. Supplies                          |               |  |  |
| e. Travel                            |               |  |  |
| f. Other                             |               |  |  |
| 3. <u>Indirect Costs</u>             | \$ 73,621.01  |  |  |
| 4. <u>Other Applicable Costs</u>     |               |  |  |
| 5. SUBTOTAL                          | \$ 295,248.22 |  |  |
| 6. <u>Less Proposed Cost Sharing</u> |               |  |  |
| 7. <u>Total Estimated Costs</u>      | \$ 295,248.22 |  |  |
| 8. APPROVED BUDGET                   |               |  |  |

USGS Budget Summary  
CY03 - CY07

NASA USE ONLY

A B C

- |                                      |    |              |  |
|--------------------------------------|----|--------------|--|
| 1. <u>Direct Labor</u>               | \$ | 598,671.41   |  |
| 2. <u>Other Direct Costs:</u>        |    |              |  |
| a. Subcontracts                      |    |              |  |
| b. Consultants                       | \$ | 464,058.00   |  |
| c. Equipment                         |    |              |  |
| d. Supplies                          |    |              |  |
| e. Travel                            |    |              |  |
| f. Other                             |    |              |  |
| 3. <u>Indirect Costs</u>             | \$ | 366,518.70   |  |
| 4. <u>Other Applicable Costs</u>     |    |              |  |
| 5. SUBTOTAL                          | \$ | 1,429,248.11 |  |
| 6. <u>Less Proposed Cost Sharing</u> |    |              |  |
| 7. <u>Total Estimated Costs</u>      | \$ | 1,429,248.11 |  |
| 8. APPROVED BUDGET                   |    |              |  |

SIO/IGPP  
 BUDGET SUMMARY  
 Year One  
 For period from 2/26/03 - 12/31/03

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	181,111	_____	_____
2. <u>Other Direct Costs:</u>			
a. Subcontracts	_____	_____	_____
b. Consultants	_____	_____	_____
c. Equipment	20,000	_____	_____
d. Supplies	10,000	_____	_____
e. Travel	11,042	_____	_____
f. Other	6,930	_____	_____
3. <u>Indirect Costs*</u>	103,954	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	333,037	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
a. Anticipated amount:	_____	_____	_____
b. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	333,037	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs

SIO/IGPP  
 BUDGET SUMMARY  
 Year Two  
 For period from 1/1/04 – 12/31/04

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	185,876	_____	_____
2. <u>Other Direct Costs:</u>			
g. Subcontracts	_____	_____	_____
h. Consultants	_____	_____	_____
i. Equipment	20,000	_____	_____
j. Supplies	10,000	_____	_____
k. Travel	6,785	_____	_____
l. Other	6,580	_____	_____
3. <u>Indirect Costs*</u>	103,798	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	333,039	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
c. Anticipated amount:	_____	_____	_____
d. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	333,039	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs



SIO/IGPP  
 BUDGET SUMMARY  
 Year Three  
 For period from 1/1/05 – 12/31/05

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	190,768	_____	_____
2. <u>Other Direct Costs:</u>			
m. Subcontracts	_____	_____	_____
n. Consultants	_____	_____	_____
o. Equipment	10,000	_____	_____
p. Supplies	10,000	_____	_____
q. Travel	7,086	_____	_____
r. Other	7,380	_____	_____
3. <u>Indirect Costs*</u>	106,661	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	331,895	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
e. Anticipated amount:	_____	_____	_____
f. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	331,895	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs

SIO/IGPP  
 BUDGET SUMMARY  
 Year Four  
 For period from 1/1/06 – 12/31/06

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	193,850	_____	_____
2. <u>Other Direct Costs:</u>			
s. Subcontracts	_____	_____	_____
t. Consultants	_____	_____	_____
u. Equipment	5,000	_____	_____
v. Supplies	10,000	_____	_____
w. Travel	7,425	_____	_____
x. Other	8,155	_____	_____
3. <u>Indirect Costs*</u>	108,581	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	333,011	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
g. Anticipated amount:	_____	_____	_____
h. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	333,011	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs

SIO/IGPP  
 BUDGET SUMMARY  
 Year Five  
 For period from 1/1/07 – 12/31/07

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	198,561	_____	_____
2. <u>Other Direct Costs:</u>			
y. Subcontracts	_____	_____	_____
z. Consultants	_____	_____	_____
aa. Equipment	_____	_____	_____
bb. Supplies	5,000	_____	_____
cc. Travel	7,790	_____	_____
dd. Other	8,155	_____	_____
3. <u>Indirect Costs*</u>	108,345	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	327,851	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
i. Anticipated amount:	_____	_____	_____
j. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	327,851	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs

SIO/IGPP  
 BUDGET SUMMARY  
 ALLYEARS  
 For period from 2/26/03 to 12/31/07

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	950,166	_____	_____
2. <u>Other Direct Costs:</u>			
ee. Subcontracts	_____	_____	_____
ff. Consultants	_____	_____	_____
gg. Equipment	55,000	_____	_____
hh. Supplies	45,000	_____	_____
ii. Travel	40,128	_____	_____
jj. Other	37,200	_____	_____
3. <u>Indirect Costs*</u>	531,339	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	1,658,833	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
k. Anticipated amount:	_____	_____	_____
l. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	1,658,833	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs

Open Source  
 BUDGET SUMMARY  
 Year One  
 For period from 2/26/03 - 12/31/03

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	49,606	_____	_____
2. <u>Other Direct Costs:</u>			
a. Subcontracts	_____	_____	_____
b. Consultants	_____	_____	_____
c. Equipment	5,000	_____	_____
d. Supplies	5,000	_____	_____
e. Travel	5,960	_____	_____
f. Other	1,935	_____	_____
3. <u>Indirect Costs*</u>	32,501	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	100,002	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
a. Anticipated amount:	_____	_____	_____
b. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	100,002	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs

Open Source  
 BUDGET SUMMARY  
 Year Two  
 For period from 1/1/04 – 12/31/04

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	50,849	_____	_____
2. <u>Other Direct Costs:</u>			
g. Subcontracts	_____	_____	_____
h. Consultants	_____	_____	_____
i. Equipment	10,000	_____	_____
j. Supplies	4,000	_____	_____
k. Travel	2,694	_____	_____
l. Other	1,700	_____	_____
3. <u>Indirect Costs*</u>	30,806	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	100,049	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
c. Anticipated amount:	_____	_____	_____
d. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	100,049	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs

Open Source  
 BUDGET SUMMARY  
 Year Three  
 For period from 10/1/05 - 09/30/06

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	52,121	_____	_____
2. <u>Other Direct Costs:</u>			
m. Subcontracts	_____	_____	_____
n. Consultants	_____	_____	_____
o. Equipment	5,000	_____	_____
p. Supplies	5,000	_____	_____
q. Travel	2,810	_____	_____
r. Other	1,900	_____	_____
3. <u>Indirect Costs*</u>	32,152	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	98,983	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
e. Anticipated amount:	_____	_____	_____
f. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	98,983	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs

Open Source  
 BUDGET SUMMARY  
 Year Four  
 For period from 1/1/05 – 12/31/05

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	53,614	_____	_____
2. <u>Other Direct Costs:</u>			
s. Subcontracts	_____	_____	_____
t. Consultants	_____	_____	_____
u. Equipment	5,000	_____	_____
v. Supplies	4,000	_____	_____
w. Travel	2,950	_____	_____
x. Other	1,935	_____	_____
3. <u>Indirect Costs*</u>	32,499	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	99,998	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
g. Anticipated amount:	_____	_____	_____
h. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	99,998	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs



Open Source  
 BUDGET SUMMARY  
 Year Five  
 For period from 1/1/06 – 12/31/06

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	54,917	_____	_____
2. <u>Other Direct Costs:</u>			
y. Subcontracts	_____	_____	_____
z. Consultants	_____	_____	_____
aa. Equipment	_____	_____	_____
bb. Supplies	2,500	_____	_____
cc. Travel	3,096	_____	_____
dd. Other	2,200	_____	_____
3. <u>Indirect Costs*</u>	32,611	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	95,324	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
i. Anticipated amount:	_____	_____	_____
j. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	95,324	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs

Open Source  
 BUDGET SUMMARY  
 ALLYEARS  
 For period from 2/26/03 to 12/31/07

	A	<u>NASA USE ONLY</u>	
		B	C
1. <u>Direct Labor</u> (salaries, wages, and fringe benefits)	261,107	_____	_____
2. <u>Other Direct Costs:</u>			
ee. Subcontracts	_____	_____	_____
ff. Consultants	_____	_____	_____
gg. Equipment	25,000	_____	_____
hh. Supplies	20,500	_____	_____
ii. Travel	17,510	_____	_____
jj. Other	9,670	_____	_____
3. <u>Indirect Costs*</u>	160,569	_____	_____
4. <u>Other Applicable Costs:</u>	_____	_____	_____
5. <u>SUBTOTAL--Estimated Costs</u>	494,356	_____	_____
6. <u>Less Proposed Cost Sharing</u>	_____	_____	_____
7. <u>Carryover Funds</u>			
k. Anticipated amount:	_____	_____	_____
l. Amount used to reduce budget	_____	_____	_____
8. <u>Total Estimated Costs</u>	494,356	_____	_____
9. APPROVED BUDGET	_____	_____	_____

\*Facilities and Administrative Costs

## 10.0 FACILITIES AND EQUIPMENT

<b>10.1 Computing Equipment</b>	
JPL	Relevant JPL computer facilities for this project include a cluster of 5 HP computers with Intel P4 processors running the Linux Operating system. These are network with two Network Appliance and two RaidZone network attached storage (NAS) with over 12 TB of storage. These devices are used for locally buffering large volumes of data for processing.
USGS	<p>The USGS computing facilities consist of two Dell Poweredge 4600 servers and 4 VA Linux 1100 servers used for post processing of GPS data, 2 Dell servers for near real time processing, one Sun Ultra server, 11 Dell Optiplex computers used for data collection, and two custom Intel based dual processor systems for specialized post processing. Several systems are kept as hot spares to replace any failing equipment.</p> <p>The systems are split between two computing facilities at the California Institute of Technology to provide a fault tolerant environment and to ensure continued operations after a unexpected shutdown of the other facility. Each facility has been specifically designed and built to house the USGS/Caltech seismic monitoring system to continue operating during a major seismic event in Southern California. All systems are on battery and generator power backup to provide consistent operations even during an extended power outage.</p>
SOPAC & CSRC	SOPAC/CSRC computer facilities consist of one Sun Enterprise 3000 server, two Sun Enterprise 240R servers, one Sun Ultra workstation, four Sun Ultra 100 workstations, four Dell PowerEdge 4400 servers, one Dell PowerEdge 2550 server, one Dell PowerEdge 2400, two Dell Optiplex computers for real time data collection, four Dell Optiplex/Dimension computers used for development, 24 Intel and AMD-based dual-processor PC's used to analyze data, and four Intel-based PC's to download data. The primary systems are maintained in a high availability environment including fault tolerant sub-systems, RAID arrays, redundant storage, and battery backup. SOPAC – Scripps Orbit and Permanent Array Center. CSRC – California Spatial Reference Center.
IGPP	IGPP has installed a visualization system in the Revelle Conference Room with the support of Cal-(IT) <sup>2</sup> . The Cal-(IT) <sup>2</sup> <i>Control Room</i> provides advanced graphical views of data streams that will aid in the assessment of the GPS network's performance. Furthermore, many of the data streams will be converted to information, which can also be visualized. To strike a balance between graphics acceleration, CPU horsepower, and the ability to remotely export visualization via graphic pipes, we have acquired a SGI Onyx 3400 server with group visualization on a Panoram GVR-120 E cylindrical wall display that is some 24 feet in width. This graphical supercomputer is driven by at least 8 processors (R12000 CPUs) (likely 16 processors) with visual output through 2 graphic pipes. This system is based on the new SGI NUMA architecture, which increases memory bandwidth and reduces memory latency thereby enhancing graphical and computation output. The modular "brick" design of the new Onyx 3400 will enable easy upgrades to graphic, CPU, I/O and other sub-systems when the need arises. This system is located on the Scripps campus, with

	the immersive environment sited at the IGPP Revelle Conference Room. A collaborative effort between Panoram Technologies, Cox Cable and TeraBurst will allow immersive images to be exported via an ultra-high speed network to other campuses or agencies, such as San Diego State University or Caltrans, for real-time interaction.
<b>10.2 Mass Store</b>	
USGS	The USGS storage system is comprised of several high availability storage systems totalling 1.6 TB of data. The goal of the USGS archiving facility is to ensure that data is immediately available after collection in a highly redundant matter. Data is passed up from our geographically dispersed data collection systems. Initial storage is done on our data collection machines with a total capability of .4TB. The data is then mirrored between the two facilities at the Caltech campus. Each facility is capable of storing .6 terabytes of data. The data is divided between two servers at each facility using RAID 5 to provide for data redundancy. Long term storage of data is accomplished using DVD-RAM located at each facility.
CSRC	SOPAC/CSRC's archiving facility consists of four tiers of storage. The first tier is designed for speed and consists of 2 TB of on-line disk space in RAID sets comprised of three Sun A1000 hardware RAID arrays and four Dell PowerVault 201/211 disk arrays controlled by Dell PERC RAID controllers. The second tier is designed for high on-line capacity, but with a slower access speed and consists of 30 mirrored firewire and IDE drives attached to four hosts supporting 3.5 TB of older data. The third tier consists of 600 GB near-line data on a HP 600FX eight-drive MO jukebox. The fourth tier consists of an 8 TB six-drive DLT tape library. The MO jukebox and the DLT (Digital Linear Tape) tape library are being used in cooperation with the IGPP Digital Library.
IGPP	The core of the IGPP Digital Library comprises a 20 TB DLT mass storage device from StorageTek, a SUN Enterprise 250 server, and GbE network connections throughout IGPP and to/from SDSC. The Library software consists of AMASS (copyrighted through the Advanced Digital Information Corporation – ADIC), and various library users superimpose a variety of database applications (for example, SOPAC/CSRC uses Oracle 9i as a relational database). The Library is well suited for large datasets with large file sizes.
<b>10.3 GIS Laboratory</b>	
SOPAC/ CSRC	SOPAC/CSRC is in the process of configuring its GIS Laboratory, which consists of one Dell Precision 530 workstation, one Dell Precision 330 workstation, a Sun A1000 hardware disk array supporting spatial data, and a HP ScanJet Digital Scanner. IGPP maintains multiple wide-format plotters and color printers. GIS-related software includes Oracle Enterprise 9i database server, Oracle Spatial Option, ESRI ArcGIS, ESRI ArcView and ESRI Internet Map Server.
<b>10.4 Experimental Facilities</b>	
HPWREN	In August 2000 the National Science Foundation (NSF) awarded a \$2.3 million, three-year research grant to UC San Diego to create, demonstrate, and evaluate a non-commercial, prototype, high-performance, wide-area, wireless network for research and education. The project involves a multi-institution collaboration led by Hans-Werner Braun of the NLANR group at SDSC and Frank Vernon of the Cecil H. and Ida M. Green Institute for

	<p>Geophysics and Planetary Physics (IGPP) at SIO, and includes researchers from other institutions such as Paul Etzel, Director of Mount Laguna Observatory and Chair of the San Diego State University (SDSU) Astronomy Department, and Sedra Shapiro, Acting Director of the Field Stations at San Diego State University.</p> <p>HPWREN is creating a wireless backbone network in southern California that currently includes nodes on the UC San Diego campus and several mountaintops in San Diego County including Mt. Woodson, North Peak, Stephenson Peak, Mt. Laguna, and Mt. Palomar (Figure 1). To increase network robustness, and to provide additional coverage, new network links will be installed on Red Mountain and Toro Peak in Riverside County. Researchers in various disciplines and educational communities will be able to gain Internet connection through this backbone network.</p>
CSRC	<p>The California Spatial Reference Center is located at the Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics (IGPP). A group of surveyor activists started a grass roots movement to leverage the GPS infrastructure established for earthquake research in California as the basis for defining and maintaining a statewide geodetic reference frame. They felt that California had special geodetic needs because of its tectonic setting, extensive land subsidence, and natural hazards, along with one of the largest economies in the world. This effort eventually coalesced into the California Spatial Reference Center, a major outreach program of the geophysical community in California.</p> <p>The CSRC has the following mandate in California, in partnership with the National Geodetic Survey (NGS) at NOAA (National Oceans and Atmosphere Administration) and the California Dept. of Transportation (Caltrans):</p> <ol style="list-style-type: none"> <li>1. Provide the necessary geodetic services to ensure the availability of accurate, consistent, and timely spatial referencing data.</li> <li>2. Establish the legal spatial reference system for California.</li> <li>3. Monitor temporal changes in geodetic coordinates due to tectonic motion, volcanic deformation and land subsidence.</li> </ol> <p>For more information see <a href="http://csrc.ucsd.edu/">http://csrc.ucsd.edu/</a></p>
SOPAC	<p>The Scripps Orbit and Permanent Array Center (SOPAC) is located at the Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics (IGPP). SOPAC's primary scientific role is to support high precision geodetic and geophysical measurements using Global Positioning System (GPS) satellites, particularly for the study of earthquake hazards, tectonic plate motion, plate boundary deformation, and meteorological processes.</p> <p>SOPAC investigators conduct research on the implementation, operation and scientific applications of continuously monitoring GPS arrays and Synthetic Aperture Radar (SAR) interferometry.</p> <p>SOPAC is a major participant in the International GPS Service for Geodynamics (IGS), serving as a Global Data Center and a Global Analysis Center, the Southern California Integrated GPS Network (SCIGN), and the University NAVSTAR Consortium (UNAVCO). The National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), U.S. Geological Survey (USGS), the Southern</p>

	<p>California Earthquake Center (SCEC), the National Oceanic and Atmospheric Administration (NOAA), and the William M. Keck Foundation fund these activities.</p> <p>SOPAC provides the following services and products to the scientific community:</p> <ol style="list-style-type: none"> <li>1. Precise near real-time and predicted GPS satellite orbits,</li> <li>2. Precise polar motion and Earth rotation variations,</li> <li>3. On-line data archive of continuously operating GPS tracking stations, for data collected since 1990,</li> <li>4. Time series of daily three-dimensional positions for the global and California stations with respect to the International Terrestrial Reference Frame (ITRF),</li> <li>5. Software for remote downloading of continuous GPS data,</li> <li>6. Consultation on installation and operations of continuous GPS arrays.</li> <li>7. Web-based user applications based on Oracle 9i RDBMS.</li> </ol> <p>Data from the SOPAC archive may be retrieved via anonymous ftp, http, or through the SOPAC home page:</p> <p><a href="ftp://garner.ucsd.edu">ftp://garner.ucsd.edu</a>; <a href="http://garner.ucsd.edu">http://garner.ucsd.edu</a> login: anonymous; password: your email address</p> <p>For more information see <a href="http://sopac.ucsd.edu/">http://sopac.ucsd.edu/</a></p>
GPS in Orange County	<p>The California Spatial Reference Center has been awarded \$1M in FY2001 from the National Geodetic Survey, to support two primary tasks: height modernization and real-time GPS networks.</p> <p>Building upon the database and web interface of the Scripps Orbit and Permanent Array Center (SOPAC), CSRC has become a full-service online data portal for GPS coordinates and metadata in California. CSRC has demonstrated a real-time three-dimensional GPS network capability in collaboration with the Geomatics/Land Information Division of Orange County's Public Facilities and Resource Department (PFRD). The central telemetry sites receive data continuously from the 12 continuous GPS sites in the county and relay the data to a central facility at the CSRC Operational Center in La Jolla and to a mirror facility at PFRD. The data are analyzed for integrity, stored on data servers, and GPS real time kinematics (RTK) data are streamed via the Internet at both facilities. Surveyors are able to receive RTK data through cellular modems and obtain real-time three-dimensional position fixes with cm-level horizontal precision and 5-cm vertical precision. Longer occupations at a site will allow improved precision in both the horizontal and vertical coordinates. PFRD has matched the CSRC contribution to this effort (\$300,000) with \$80,000 of funds necessary to purchase the telemetry equipment for installation in Orange County.</p>
<b>10.5 Software</b>	
JPL	<p>For GPS processing, JPL uses its GPS-Inferred Positioning System called GIPSY. GIPSY was the winner of the NASA Software of the Year award in 1999 and is widely used for GPS analyses within NASA, other federal agencies, universities, government agencies, and in the aerospace industry.</p>

	<p>See <a href="http://gipsy.jpl.nasa.gov">http://gipsy.jpl.nasa.gov</a> for more detail.</p> <p>QOCA (Quasi-Observation Combination Analysis) is a software package which was designed and developed at JPL. It combines various loosely constrained geodetic site coordinate and velocity solutions (as quasi observations) to obtain crustal deformation information. QOCA is used as the post-processing software package by many geodetic data analysis groups. Currently it can combine space-geodetic quasi-observations (GPS, VLBI, SLR) and terrestrial geodetic survey quasi-observations (EDM, triangulation, leveling,). It has the potential to combine SAR data and gravity, seismicity, and ground motion data.</p>
USGS	<p>Sharc (Sharc Acquires Receivers Contents)</p> <p>Sharc is a cross-platform tool for retrieving episodic and real time data from remotely connected GPS receivers. As an open source project written at the US Geological Survey with ongoing support from the University Navstar Consortium (UNAVCO), Sharc has rapidly become a standard for GPS data collection.</p> <p>Schedg (Schedule GPS)</p> <p>Schedg is a client-server scheduling software to collect episodic GPS data. Based on the Simple Object Access Protocol (SOAP) model, Schedg allows for a centralized approach to data collection while allowing for high availability by failing over to different servers during network or server outages.</p> <p>MapSurfer</p> <p>MapSurfer allows for rapid visualization of network problems by using standard GIS formats and open source Map generation tools. It also allows for plotting of arbitrary map based data and rapid deployment of new visualization tools.</p> <p>JavaPlotter</p> <p>JavaPlotter is used as a web based plotting utility that can plot arbitrary time based data for multiple data streams with multiple data types. It also allows a user to superimpose data from multiple sources so that the data can be visually compared.</p> <p>Scientific Computing</p> <p>Through Caltech, we have access to MATLAB and GIS. We also have MATLAB on a linux machine.</p>
SDSC SRB	<p>The SDSC Storage Resource Broker (SRB), implemented at SDSC, is client-server middleware that provides a seamless, uniform interface for connecting to heterogeneous data resources over a network and accessing replicated data sets. SRB, in conjunction with the Metadata Catalog (MCAT), provides means for accessing data sets and resources based on their attributes rather than their names or physical locations. The SRB provides access to archival resources such as HPSS, UniTree and ADSM, file systems such as Unix File System, NT File System and Mac OSX File System and databases such as Oracle, DB2, and Sybase. The SRB provides a logical representation for storage systems, digital file objects, and collections and provides several features for use in digital libraries and persistent archive or collection management systems. SRB also provides capabilities to store replicas of data, for authenticating users, controlling access to documents and collections, and auditing accesses. The SRB can</p>

	<p>also store user-defined metadata at the collection and object level and provides search capabilities based on these metadata.</p> <p>The SRB has been implemented on multiple platforms including IBM AIX, Sun, SGI, Linux, Cray T3E and C90, Windows NT, Mac OSX, etc. The SRB has been used in several efforts to develop infrastructure for GRID technologies, including the Particle Physics Data Grid (NSF/DOE), Information Power Grid (NASA) and GrPhyN (NSF). The SRB also has been used for handling large-scale data collections, including the Digital Sky Survey Collection for 2MASS data (10 TB of 5 million files), NPACI datasets (over 150 TB), and the Digital Embryo collection (20 TB leading up to 500 TB) and LTER hyper-spectral datasets. More details on the SRB can be found at: <a href="http://www.npaci.edu/DICE/SRB/">http://www.npaci.edu/DICE/SRB/</a>.</p>
IGPP Seamless Archive	<p>The University NAVSTAR Consortium (UNAVCO) is developing a seamless archive for the GPS Geodesy/Geophysics community, called the GPS Seamless Archive Center (GSAC). SOPAC is the leader in this development. GSAC is a collection of GPS data archives and their operating agencies that agree to exchange information about their individual data holdings in order that users need not contact each archive separately to locate desired information. The Scripps Orbit and Permanent Array Center (SOPAC) is actively participating in the GSAC as a functioning Wholesaler, creating Data Holdings Records (DHRs) in a regular and automated fashion for both Data Holdings Files (DHF) and Monument Catalog (MC) holdings. SOPAC will begin implementing GSAC functionality into its regular data collection processes shortly, making use of other GPS archive centers' GSAC participation. SOPAC will also serve as a GSAC Retailer, providing a gateway for the GSAC to GPS users around the world.</p> <p>A large part of SOPAC's participation in the GPS Seamless Archive Center is to develop and support Perl-based software for the GSAC's functioning. SOPAC is providing the following software components:</p> <ul style="list-style-type: none"> <li>• Wholesaler GSAC Data Holdings Publication</li> <li>• Retailer GSAC Data Holdings Collection</li> <li>• Retailer GSAC Data Holdings Serving</li> <li>• Wholesaler &amp; Retailer GSAC Database Management</li> <li>• Wholesaler &amp; Retailer GSAC Database Reporting</li> </ul>



**11.0 COOPERATIVE AGREEMENT PAYMENT SCHEDULE**

Table 3 shows the milestones for the project. The initial milestone is for the period February to December 2003, then on a December/ June basis for the remaining term of the cooperative agreement. Each milestones is defined as the delivery of science information and/or services and participation in and support for the Federation and SEEDS



## Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay

Other agencies (including NSF) to which this proposal has been/wi

Investigator: <b>YEHUDA BOCK</b>	Other agencies (including NSF) to which this proposal has been/wi		
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support			
Project/Proposal Title: <b>THE WILLIAM M. KECK FOUNDATION GPS ARRAY FOR EARTHQUAKE RESEARCH</b>	<b>22-1054</b>		
	<b>IGPYB43</b>		
Source of Support: USC/KECK Foundation			
Total Award Amount: \$ 1,677,168	Total Award Period Coverage: 8/1/97 - 12/14/03		
Location of Project: IGPP/SIO			
Person-Months Per Year Committed to the Project. Cal: 4.4	Acad:	Sumr:	
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support			
Project/Proposal Title: <b>FUNDAMENTAL SUPPORT FOR GPS RESEARCH - UNAVCO FUND</b>	<b>IGPUCAR</b>		
Source of Support: UCAR			
Total Award Amount: \$ 431,700	Total Award Period Coverage: 10/1/99 - 9/30/03		
Location of Project: IGPP/SIO			
Person-Months Per Year Committed to the Project. Cal: 1.0	Acad:	Sumr:	
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support			
Project/Proposal Title: <b>INTEGRATED INSTRUMENTATION FOR BROADBAND OBSERVATIONS OF PLATE BOUNDARY DEFORMATION (Matching Funds)</b>	<b>21-1154</b>		
	<b>IGPPARK</b>		
Source of Support: USC/Keck Foundation			
Total Award Amount: \$ 85,000	Total Award Period Coverage: 8/1/97 - 12/14/03		
Location of Project: IGPP/SIO			
Person-Months Per Year Committed to the Project. Cal:	Acad:	Sumr:	
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support			
Project/Proposal Title: <b>JOINT PROJECT AGREEMENT CONCERNING THE NATIONAL REFERENCE SYSTEM IN CALIFORNIA</b>	<b>21-1398 &amp; 22-3044</b>		
	<b>NOAYB83</b>		
Source of Support: NOAA			
Total Award Amount: \$ 1,996,000	Total Award Period Coverage: 05/1/01 - 06/30/03		
Location of Project: IGPP/SIO			
Person-Months Per Year Committed to the Project. Cal: 6	Acad:	Sumr:	
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support			
Project/Proposal Title: <b>INTEGRATED INSTRUMENTATION FOR BROADBAND OBSERVATIONS OF PLATE BOUNDARY DEFORMATION</b>	<b>EAR 9977823</b>		
Source of Support: NSF			
Total Award Amount: \$ 160,225	Total Award Period Coverage: 9/1/99 - 8/31/03		
Location of Project: IGPP/SIO			
Person-Months Per Year Committed to the Project. Cal:	Acad:	Sumr:	
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support			
Project/Proposal Title: <b>THE THERMO-KINEMATIC EVOLUTION OF THE TAIWAN MOUNTAIN BELT</b>	<b>99-1501</b>		
	<b>IGPTWAN</b>		
Source of Support: TEXAS A & M			
Total Award Amount: \$ 37,500	Total Award Period Coverage: 1/1/00 - 11/30/02		
Location of Project: IGPP/SIO			
Person-Months Per Year Committed to the Project. Cal:	Acad:	Sumr:	

\*If this project has previously been funded by another agency, please list and furnish information for immediate

**Current and Pending Support**

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay

Investigator: <b>YEHUDA BOCK</b>	Other agencies (including NSF) to which this proposal has been/wi
----------------------------------	---

Support:     Current     Pending     Submission Planned in Near Future     \*Transfer of Support  
 Project/Proposal Title:

**IMPLEMENTATION OF A REAL-TIME PRECIPITABLE WATER  
 CAPABILITY USING THE GLOBAL POSITIONING SYSTEM** **22-9445**

Source of Support:                      NOAA  
 Total Award Amount:                 \$ 60,000                                      Total Award Period Cov 07/01/02 - 06/30/03  
 Location of Project:                    IGPP/SIO  
 Person-Months Per Year Committed to the Project.    Cal: 1.0            Acad:            Sumr:

Support:     Current     Pending     Submission Planned in Near Future     \*Transfer of Support  
 Project/Proposal Title:

**Infrastructure Support for Southern California Integrated GPS Net** **22-2283**

Source of Support:                      SCEC/USC  
 Total Award Amount:                 \$ 75,000                                      Total Award Period Cov 02/01/02 - 01/31/03  
 Location of Project:                    IGPP/SIO  
 Person-Months Per Year Committed to the Project.    Cal: 1.0            Acad:            Sumr:

Support:     Current     Pending     Submission Planned in Near Future     \*Transfer of Support  
 Project/Proposal Title:

**Calibration of the TOPEX/POSSEIDON and Jason-1 microwave radiometers using  
 GPS derived tropospheric delays** **22-2188**

Source of Support:                      NVI, Inc.  
 Total Award Amount:                 \$ 25,769                                      Total Award Period Cov 04/15/02-12/31/02  
 Location of Project:                    IGPP/SIO  
 Person-Months Per Year Committed to the Project.    Cal:                Acad:            Sumr:

Support:     Current     Pending     Submission Planned in Near Future     \*Transfer of Support  
 Project/Proposal Title:

**CONTINUOUS GEODETIC MEASUREMENTS FROM A GPS-ACOUSTIC  
 COASTAL-BUOY: CALIFORNIA BORDERLAND** **UCSD-MPL**

Source of Support:                      NASA  
 Total Award Amount:                 \$ 688,481                                      Total Award Period Cov 01/01/03 -12/31/05  
 Location of Project:                    IGPP/SIO  
 Person-Months Per Year Committed to the Project.    Cal:                Acad:            Sumr:

Support:     Current     Pending     Submission Planned in Near Future     \*Transfer of Support  
 Project/Proposal Title:

**Development of a Real-Time GPS/Seismic Displacement Meter:** **22-8825**  
**Applications to Civilian Infrastructure in Orange and Western Riverside Counties, C**

Source of Support:                      NASA  
 Total Award Amount:                 \$ 567,386                                      Total Award Period Cov 10/01/02 -09/30/05  
 Location of Project:                    IGPP/SIO  
 Person-Months Per Year Committed to the Project.    Cal: 3.0            Acad:            Sumr:

\*If this project has previously been funded by another agency, please list and furnish information for immediate

### **13.0 SPECIAL MATTERS**

Current SCIGN Officers, Boards, Committees and Councils (as of 12 June 2002)

#### **Executive Committee**

- Ken Hudnut, Coordinating Board Chair, (U. S. Geological Survey)
- Yehuda Bock, Coordinating Board Vice Chair, (Scripps Institution of Oceanography, U.C. San Diego)
- Frank Webb (NASA/Jet Propulsion Laboratory)
- Bill Young (League of California Surveying Organizations)

#### **Coordinating Board**

- Duncan Agnew (Scripps Institution of Oceanography, U.C. San Diego)
- Donald Argus (NASA/Jet Propulsion Laboratory)
- Yehuda Bock (Scripps Institution of Oceanography, U.C. San Diego)
- Dick Davis (California Department of Transportation)
- Tom Herring (Massachusetts Institute of Technology)
- Ken Hudnut (U. S. Geological Survey)
- Ken Hurst (NASA/Jet Propulsion Laboratory)
- Marti Ikehara (National Atmospheric and Oceanic Admin./National Geodetic Survey)
- David Jackson (University of California, Los Angeles)
- Nancy King (U. S. Geological Survey)
- Susan Owen (University of Southern California)
- Will Prescott (UNAVCO)
- Frank Webb (NASA/Jet Propulsion Laboratory)
- Frank Wyatt (Scripps Institution of Oceanography, U.C. San Diego)
- Bill Young (League of California Surveying Organizations)

#### **Ex Officio members of Coordinating Board**

- Tom Jordan, SCEC (University of Southern California)
- Tom Henyey, SCEC (University of Southern California)
- Bernard Minster, SCEC (University of California, San Diego)

#### **Other SCIGN Officers**

- John McRaney, Network Administrator (University of Southern California)

- Keith Stark, Network Coordinator (U. S. Geological Survey)

**Advisory Council**

- Jeff Freymueller, Chair (University of Alaska)
- Michael Bevis (University of Hawaii)
- Roland Burgmann (University of California, Berkeley)
- Herb Dragert (Pacific Geoscience Center)
- Diane Evans (NASA/Jet Propulsion Laboratory)
- Brad Hager (Massachusetts Institute of Technology)
- Egill Hauksson (California Institute of Technology)
- Teruyuki Kato (University of Tokyo)
- Charles Kennel (University of California, San Diego, Scripps Institute of Oceanography)
- John Orcutt (University of California, San Diego, Scripps Institution of Oceanography)
- Jim Savage (U. S. Geological Survey)
- Paul Segall (Stanford University)

**Interagency Committee**

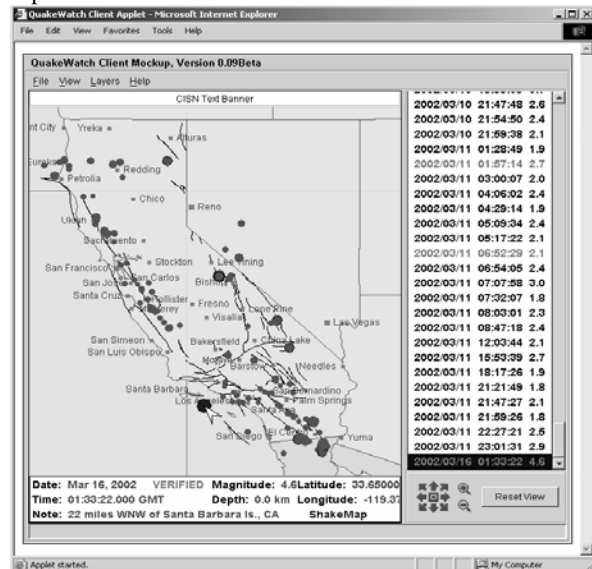
- John Filson (U. S. Geological Survey)
- John Unger (U. S. Geological Survey)
- Robin Reichlin (National Science Foundation)
- Jim Whitcomb (National Science Foundation)
- Herman Zimmerman (National Science Foundation)
- John Labrecque (National Aeronautics and Space Administration)



## Reliable Delivery of Real-time CISN Earthquake Information to Critical Users

### Project Summary

The California Integrated Seismic Network (CISN) is developing the CISN display to provide statewide real-time earthquake information. The CISN Display is an integrated 24/7 Web-enabled earthquake notification system. The application provides users with real-time seismicity, and following a large earthquake will make available other earthquake hazards information, such as ShakeMap, automatically. It will replace the Caltech/USGS Broadcast of Earthquakes (CUBE) and Rapid Earthquake Data Integration (REDI) Display as the principal means of delivering graphical earthquake information to emergency responders and 24/7 operations centers within minutes after an event. The application will feature a client/server architecture written in Java, allowing for platform independence and leveraging the full capabilities of the Internet or other data communications facilities.



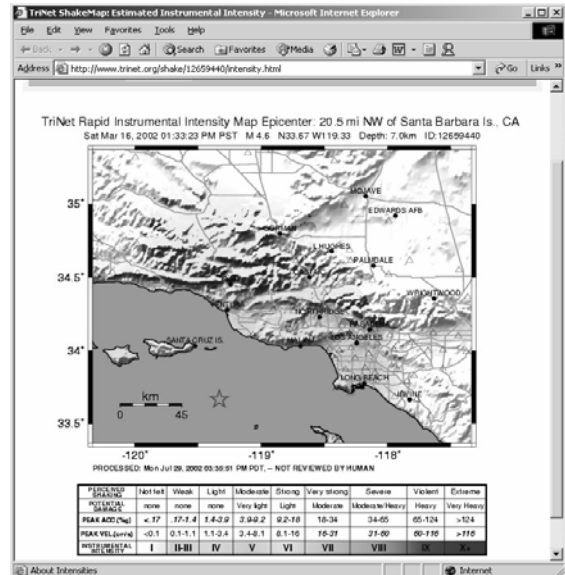
CISN Display with highlighted event indicating a 'ShakeMap' link

### Gateway to Other Earthquake Products

What distinguishes the CISN Display from other tools currently available on the Web is that it can automatically associate specific events on its display map to other available earthquake products as soon as they are generated for circulation. Analytic information presently feasible for deliverable to the CISN display are:

- ShakeMap
- Focal Mechanisms
- Ground Displacement Information
- Rapid Earthquake Notification
- OES Reports
- Earthquake Commentary
- And custom Java applets written for a particular task

These products will be made available through clickable hyperlinks, or users may configure their clients to automatically download these files, above a given magnitude threshold, for analysis.



ShakeMap for highlighted event on CISN Display

### Technology

Central to the CISN Display's role as a gateway to other sources of information is its comprehensive XML messaging schema. The message model starts with present CUBE format, and then extends it by provisioning additional descriptive attributes for currently available products, and many others yet to be considered. The supporting metadata in the XML-message provides the information necessary for the automated creation of hyperlinks on the client.

At the heart of the CISN Display's robustness is a well-established and reliable set of communication protocols for best-effort delivery of data. The application employs several CORBA methods that alert users of changes in the link status. Loss of client connectivity to the server triggers a broad strategy that attempts to reconnect through various physical and logical paths. For critical users this effort is further enhanced by the use of a stateful connection via a dedicated signaling channel.

Additionally, using an open source GIS mapping tool organizations can plot assets on the CISN Display map, key to operational readiness. This allows critical end users the ability to overlay organizational information against ground accelerations following a significant earthquake. Emergency response managers can use this information in allocating limited personnel and resources during a recover effort to restore functional operations.

### Partnerships

The CISN Display is being developed as part of CISN, a cooperative project of Caltech, CGS, USGS, UCB, and OES. The CISN is funded by OES, USGS, FEMA/OES Hazards Mitigation Grants Program, and other partners. For information regarding the CISN Display and to sign up as a beta test site contact Margaret Vinci, ERA/Caltech Programs Manager, at 626 395-6318 or Hugo Rico, project lead, at 626 395-2407.

**14.0 LETTERS OF SUPPORT**



# CALIFORNIA INSTITUTE OF TECHNOLOGY

SEISMOLOGICAL LABORATORY 252-21  
Pasadena, California 91125

Monday, November 18, 2002

Dr. Frank Webb  
JPL,  
Oak Grove Drive,  
Pasadena, CA 91109

Dear Frank:

The California Integrated Seismic Network (CISN) includes federal, state, and academic institutions engaged in real-time earthquake monitoring in California. The CISN represents California as a designated region of the Advanced National Seismic System (ANSS), a US Geological Survey program. The core partners in CISN are the California Institute of Technology (Caltech), U S Geological Survey (USGS), California Geological Survey (CGS), UC Berkeley (UCB) and the California Office of Emergency Services (OES). The mission of the CISN is to operate a system for uniform earthquake monitoring and to deliver near real-time standardized information products following both small and large earthquakes.

We support the proposal from JPL and USGS entitled: "GPS Data Products for Solid Earth Science". Adding real-time capabilities to the Southern California Integrated GPS Network (SCIGN) will be very beneficial to earthquake monitoring in southern California. For instance, new products such as coseismic strain maps and displacement maps will be an important future tool for emergency response agencies and major lifeline operators.

We are pleased to work with SCIGN to facilitate the distribution of these new products. The CISN provides emergency managers with the CISN DISPLAY application that allows them to monitor earthquake activity in California near real-time. We are pleased to include links in the CISN DISPLAY that will allow emergency managers to access SCIGN products, such as maps of the crustal deformation field following a major earthquake.

Further, we can assist with creating awareness in the emergency response community for these new products. The outreach component of CISN and the Earthquake Research Affiliates Program at Caltech, hold regular user workshops to keep emergency managers informed about new technologies. We are pleased to include presentations about SCIGN products as part of our workshop agendas.

Sincerely,



Egill Hauksson,

Chair CISN Program Management Group  
Senior Research Associate, Caltech

# UNAVCO, Inc.

17 November 2002

Frank Webb  
Jet Propulsion Laboratory  
Mail Code 238-600  
4800 Oak Grove Drive  
Pasadena, CA 91109

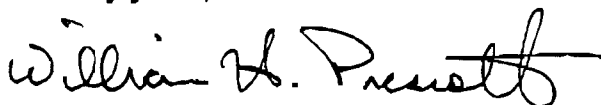
fhw@jpl.nasa.gov  
818-354-4670, FAX 818-393-4965

Dear Frank:

I am eager to see progress towards the goals outlined in your proposal "GPS Data Products for Solid Earth Science." The ability to generate and disseminate geodetic time series, deformation velocity fields, strain rate maps, fault models, near-real-time earthquake response information, surveying support and reference systems, and information for other applications is critical to our ability to utilize the data from continuous GPS networks. These abilities will become even more important with the advent of the Earth Scope/Plate Boundary Observatory (PBO) which will provide several times the quantity of data that currently is obtained from SCIGN and the Southern California Seismic Network.

This proposal will result in tools and techniques which will be useful both to SCIGN now, and to EarthScope/PBO in the future, and I strongly support the proposal.

Sincerely yours,



William Prescott, President  
UNAVCO, Inc.

---

William Prescott, President  
UNAVCO, Inc.  
3360 Mitchell Lane, Suite C  
Boulder, CO 80301-2245

Tel. 720-565-5973  
Fax. 720-565-5992  
prescott@unavco.org  
<http://www.unavco.org>



## U. S. Geological Survey

525 South Wilson Avenue  
Pasadena, CA 91106-3212  
Phone: (626)583-7810  
FAX: (626)583-7827

November 19, 2002

Dr. Frank Webb  
Jet Propulsion Laboratory  
4800 Oak Grove Drive  
Pasadena, CA 91109

Dear Dr. Webb,

The U.S. Geological Survey Earthquake Hazards Team supports the proposal "GPS Data Products for Solid Earth Science Research and Applications" submitted to NASA by the Jet Propulsion Laboratory (JPL), and, pending selection by NASA, is committed to performing the work described in it. This proposal describes work to produce and distribute high-level geodetic data products from the Southern California Integrated GPS Network (SCIGN). We support the proposed continued collaboration between USGS and JPL on the 250-station SCIGN array. The proposed data products, which include coseismic and postseismic displacement, strain, and tilt fields, support USGS's mission to provide timely, high quality scientific results after earthquakes and communicate them to emergency response agencies, the media, and the public. The proposal's emphasis on automated Web services will enhance our ability to communicate scientific information to a wide audience. We look forward to continued collaboration between JPL and USGS.

Sincerely yours,

A handwritten signature in black ink, appearing to read "Lucile M. Jones", written in a cursive style.

Dr. Lucile M. Jones  
Seismologist  
Scientist-in-charge, Pasadena Field Office  
U.S. Geological Survey  
(626)583-7817  
jones@usgs.gov



**MWD**

*METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA*

**Date:** November 14, 2002  
**To:** Dr. Nancy King, U.S. Geological Survey, Pasadena Field Office  
**From:** Michael A. Duffy, Geodetic Engineer, MWD of Southern California  
**Subject:** GPS Data Products for Solid Earth Science Research and Applications

As you know, the Metropolitan Water District of Southern California has had a long standing working relationship with the Southern California Integrated GPS Network (SCIGN) over the past eight years that has benefited both organizations. The installations of 19 Continuous Operating Reference Stations (CORS) on Metropolitan property have helped us reduce our surveying overhead costs, especially in the area of deformation monitoring and control surveys. The unique vertical sensitivity of our water delivery systems demands us to continue pursuing all available means to identify deformations and strains in our tectonically active service area.

In the area of emergency response, Metropolitan has had an ongoing dialogue with the USGS through our Emergency Response Center concerning GPS data products that could be provided to us following an disaster, be it natural or man-made. SCIGN's ability to produce and deliver products such as: geodetic time series, deformation velocity fields, strain rate maps, fault models, near real-time earthquake response information and aquifer recharge modeling, have valuable uses within our organization.

Our company is very interested and supportive of SCIGN expanding both the utility and availability of GPS and higher-level data products. We are also interested in pursuing ways to protect the availability of these SCIGN products against interruption in emergency situations. With this type of partnership Metropolitan could guarantee our customers a faster resumption of normal service after an earthquake or other major event.

Michael A. Duffy, PLS  
Field Survey & Geometronics Team