PROPOSAL COVER PAGE

(Date : Nov 20, 2002)

REASON-0156-0039

Name of Submitting Institution: Jet Propulsion Laboratory **Congressional District:** 27

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

Short Title:	GPS Data Products for Solid Earth Science
Full Title:	

[4] ... Proposed Start/End Date

Start Date:	02/01/2003
End Date:	12/31/2007

[5] ... Science Areas

Applications/Type I
Metrics Planning and Reporting
Research
SEEDS Open Source
Standards & Interfaces

[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 professionals. 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
Direct Labor	$178.00	$238.00	$247.00	$257.00	$249.00	$1,169.00
Other Direct Costs - Subcontracts	$704.00	$708.00	$684.00	$685.00	$701.00	$3,482.00
Other Direct Costs - Consultants	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Direct Costs - Equipment	$4.00	$1.00	$3.00	$0.00	$0.00	$8.00
Other Direct Costs - Supplies	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Direct Costs - Travel	$10.00	$10.00	$10.00	$10.00	$7.00	$47.00
Other Direct Costs - Other	$100.00	$127.00	$130.00	$134.00	$130.00	$621.00
Indirect Costs	$72.00	$81.00	$82.00	$86.00	$86.00	$407.00
Other Applicable Costs	$16.00	$16.00	$15.00	$15.00	$15.00	$77.00
Subtotal - Estimated Costs:	$1,084.00	$1,181.00	$1,171.00	$1,187.00	$1,188.00	$5,811.00
Less:Proposed Cost Sharing - Cost Sharing:	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Budget Total	**$1,084.00**	**$1,181.00**	**$1,171.00**	**$1,187.00**	**$1,188.00**	**$5,811.00**

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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-led 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 professionals. 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, geodetic 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].

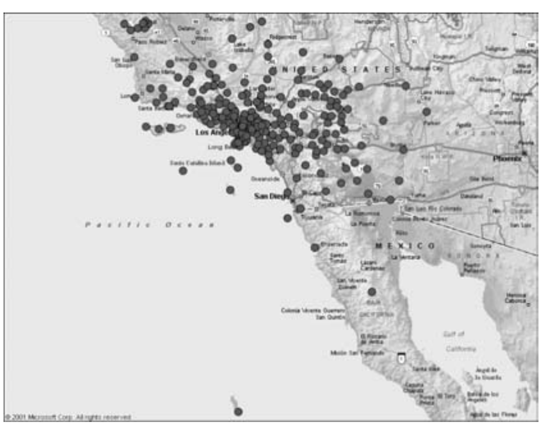

Figure 1: SCIGN GPS Station map

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 (CB) (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.

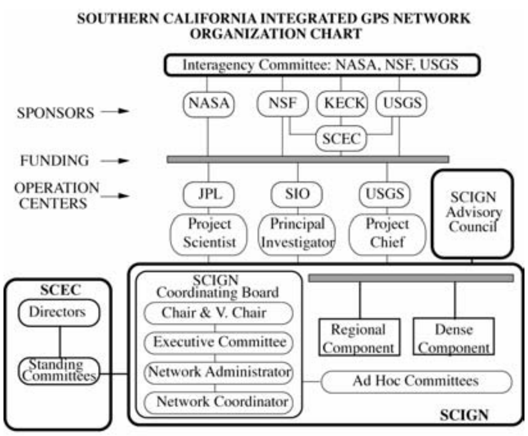

Figure 2: SCIGN Organization Chart

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.

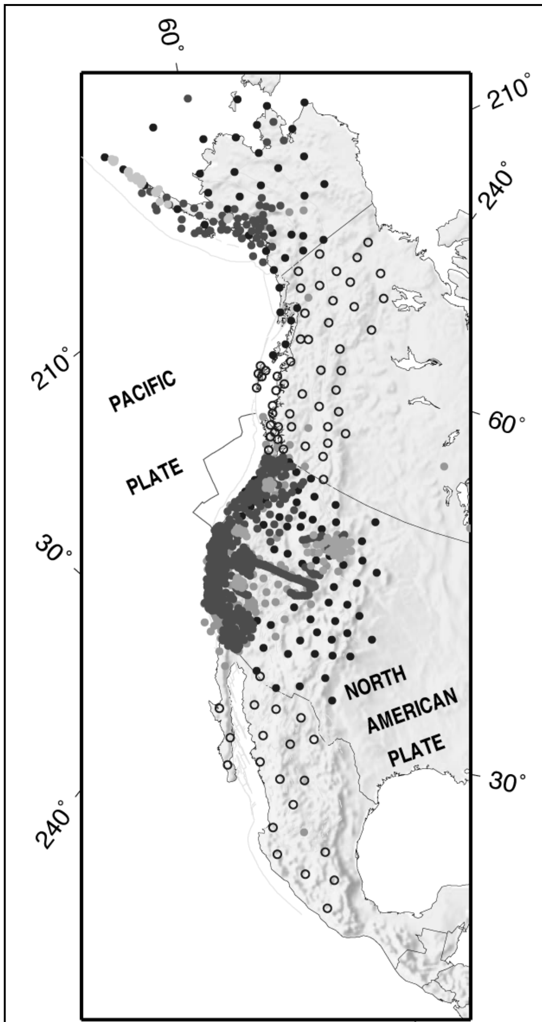

Figure 3. PBO Continuous GPS Stations

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 (CSRC) (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 AC. Growth in community interest in the information contained in the data from SCIGN has lead 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 provides key information to response to such events [*See Letters of Support*].

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 CB 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 AC.

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 Data Products and Relevance

The primary data products to be produced by the project, their relevance, users, and how they relate to the existing efforts are summarized in Table 1. The operational concept is shown in Figure 4.

Table 1. Data products, relevance, and users. Legend: Research ; Applications ; *Currently produced*

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 (http://sopac.ucsd.edu/scripts/SIMpl_launch.cgi/).*	*GSAC and SCIGN archive at ftp://garner.ucsd.edu http://garner.ucsd.edu http://gsac.ucsd.edu*	*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 http://www.scign.org/ 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 http://www.scign.org/ 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 http://www.scign.org/ 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. Independent near real time analysis systems will be implemented.
Aquifer undulations	3	TBD	Aquifer discharge and recharge rates provided for water resource management with tectonic signal removed	SCIGN web-site at http://www.scign.org/ as machine readable observations and graphical displays.		
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 http://www.scign.org/ 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 http://www.scign.org/ 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 http://csrc.ucsd.edu/ 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.*

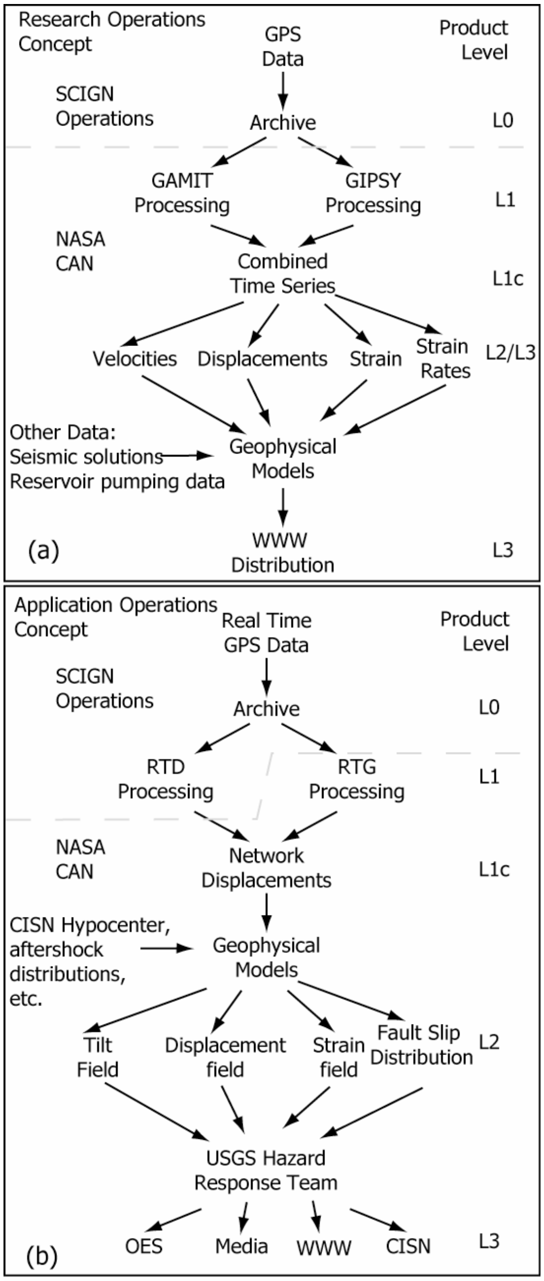

Figure 4. Shows operations concepts for the Research (a) and the Applications (b) elements of the project. In each panel, elements above the dashed line are provided by SCIGN's existing operations and below are elements to be provided under this project. Product levels are shown on the left.

The SCIGN 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 SESWG by generating these high level data products though 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/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 Guttenberg*, 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 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 worldwide 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 both 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 (EC) 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 AC, 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 database software 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 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 "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 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, graphs 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 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), 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.

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. Users will add the higher-level data products generated under this project to the database for access.

Currently, automated access to information in the RDBMS is provided by means of ftp and web-based applications that add spatial awareness to the products. Level-0 data is also available through the GSAC. This archive allows users to access several data archives through a common interface. SOPAC is a lead organization in the establishment and development of the GSAC. Access to the GSAC is primarily through http://gsac.ucsd.edu/ and http://sopac.ucsd.edu, and the database tools there, such as the Site Information Manager (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, led by SOPAC, have been involved in the UNAVCO community for over five years now in the development and implementation of the GSAC. GSAC development has accelerated, providing users with multiple central access points to GPS data in a common format. 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, as well as a command-line-based 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 GSAC 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 in the GPS community. 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. A goal of this project 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 communications protocol for information exchange in a decentralized, distributed environment. Based on XML, itself a standardized markup language, and gaining support from large software vendors (Microsoft, Oracle, IBM, Sun), SOAP has been selected as the primary means of communication in the Seamless Archive 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 use publicly available libraries, facilitating software reuse. We will be using both the Oracle 9i 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 for the database and to 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 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 XML messaging 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 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, these 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 coordinate where to install new GPS sites as well as the location of historical data sets. 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, 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 CISN, 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 this way delivery of the actual data files can: a) be optimized for periods of increased demand by distributing access to data files via multiple copies spread 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 theVA.

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 such 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 or tertiary source.

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

1. The **Virtual Archive** (VA) CGI-based 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 great 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 suit 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), UNAVCO, Inc., GSAC, CSRC, 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. 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

The breadth of civil and scientific applications of GPS-based precise positioning and navigation is enormous and growing (see for example letter of support from CSRC). A partial list of civil applications that will be impacted by this project includes:

(1) Machine control
(2) Precision agriculture
(3) Landslide warning systems
(4) Precise GIS and surveying
(5) Bridge and dam deformation
(6) Intelligent transportation
(7) Aircraft landing and harbor approach
(8) Emergency response (police, fire)
(9) Homeland security

That is, the dissemination of precise GPS data and data products as described in this proposal with result in significant socio-economic benefits for California, in particular, but also for the greater Earthscope/PBO region in the Western U.S. (including Alaska), Mexico, and Canada. These benefits will be tangible for local, state and federal government agencies, for the commercial sector, and the public. Some of these benefits have already been realized through the existing SCIGN project and its outreach program through the CSRC. For example, software provided commercially by GPS manufacturers extracts continuous GPS data automatically (and seamlessly) from the SOPAC archive to provide geodetic control for real-life surveying projects, and real-time GPS orbits from JPL. This is a testament to the utility of GPS data and data products, but also to the confidence of the commercial sector in the reliability of the archive and its data products.

The scientific benefits will not only be limited to the Solid Earth Sciences product and applications described in this proposal (see Table 1 and Figure 4). A partial list of other scientific applications that will be impacted by this project includes:

(1) Oceanographic tracking (buoys, research vessels, towlines).
(2) Tsunami warning systems
(3) Short-term weather forecasting and climatology ("GPS Met")
(4) Bio-diversity (e.g., tracking of large mammals such as southern California mountain lions as being done through SIO/SDSU's ROADNet project)
(5) Volcanology.

GPS is one of the classic cases of scientific research spun off into practical applications. The economic, disaster prevention, and hazard mitigation applications have exceeded what was imagined when precise GPS was being developed for monitoring crustal motion by a small community of expert users.

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 (Table 2).

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 (CB) that operates as a standing committee of the SCEC (Fig. 2). The CB consists of representatives from SCEC, the USGS, JPL, 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 SCEC, 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 CB and the AC 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 CB and the advice of the AC.

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, CISN, 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 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 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.

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

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 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.

Table 2. Roles and responsibilities of project partners. Lead organizations shown in **bold**.
Currently performed tasks in yellow

		Roles and Responsibilities		
Task		*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	**Modify existing software for spatial and temporal filtering**	Modify existing software for spatial and temporal filtering strategies	Consult on spatial and temporal filtering strategies
	Fault Models	**Implementation of faults parameter estimation into existing software**	Support modeling efforts	**Calculation of fault slip rates + assimilation with seismic data**
	Aquifer Models	**Implementation of aquifer parameter estimation into existing software**	**Generalization of Orange County work to other aquifers**	
	Earthquake response	**Implementation Near Real Time deformation field and strain rate calculation**	**Integrate seismic and GPS data in a tightly coupled system (NASA funded)**	**Assimilation of geodetic and seismic data + interface with authorities / utilities/ media**
Archive		Support project participation in SEEDS	**SEEDS Technology Infusion Work Group participation**	Support project participation in SEEDS
SEEDS			**SEEDS compliant SCIGN archive development**	
Product Delivery / User support		Product and user support	**Development and maintenance of www.scign.org**	Product and user support
Open Source / Software reuse			**Development and implementation**	

Table 3: Master schedule showing milestones to be completed for each task (in bold) and major tasks

Task	CY03		CY04		CY05		CY06		CY07	
	JUN	DEC	JUN2	DEC2	JUN3	DEC3	JUN4	DEC4	JUN5	DEC5
1. System Requirements Definition and Design										
2. Level1 product Dev. - Combined Geodetic Time Series										
Input format definition										
Combination scheme development										
Reference frame definition										
Output format definition										
User community feedback - SCEC annual meeting										
SEEDS Standards WrkGrp Participation										
3. Automation of Level1 Data Products										
User community feedback - SCIGN & UNAVCO annual meetings										
Implement combined time series production										
Daily										
Sub-daily										
Develop performance metrics										
SEEDS WrkGrp Participation										
Enhance web interface to deliver L1 products										
4. Level2 Product Dev. - Velocity Field										
Velocity scheme development										
Output format definition										
User community feedback - SCEC annual meeting										
SEEDS WrkGrp Participation										
5. Automation of Level2 Data Products										
User community feedback - SCIGN & UNAVCO annual meetings										
Implement velocity field production										
Daily										
Sub-daily										
Develop performance metrics										
SEEDS WrkGrp Participation										
Enhance web interface to deliver L2 products										
6. Level3 Product Dev. - Geophysical Parameters										
Model implementation										
Aquifer undulations										
Strain										
Fault slip										
S-T Filter development										
Software integration										
User community feedback - SCEC annual meeting										
SEEDS metrics WrkGrp Participation										
7. Automation of Level3 Data Products										
User community feedback - SCIGN & UNAVCO annual meetings										
Implement geophysical parameter production										
Daily										
Sub-daily										
SEEDS WrkGrp Participation										
Enhance web interface to deliver L3 products										
8. Integrate with independent Data Products										
Develop interfaces for Level3 Product Generation										
Integrate with system										
User community feedback - SCEC annual meeting										
SEEDS WrkGrp Participation										
9. Incorporate PBO data into products										

10. Adaptive Seamless Archive System
Planning of Adaptive Seamless Archive and Web Services infrastructure
Develop XML DTDs
Develop Web Services Infrastructure and Integrate with RDBMS
Develop Software to Upload GPS Analysis Data Into RDBMS
Implement Limited Beta Testing Access to Web Services
Develop Control Panel to Administer XML Web Services
Implement Public Access to Web Services
Web Services
Improve Inter-Archive Web Services Interaction
Seek Integration of GPS Web Services With Other Applications
Package Software Components for Other Archives
11. GPS Explorer
Planning of GPS Explorer
Purchase Required Equipment and Software
Develop Time Series Web Services Interface
Development of GPS Explorer
Public Release of GPS Explorer v1.0
Solicit Feedback From Potential Users and Peers
Testing and Performance Tuning of GPS Explorer
Begin Plans for Handheld GPS Explorer Prototype
Implement GIS and Mapping Features In GPS Explorer
Handheld GPS Explorer Web Service Development
Handheld GPS Explorer Client Development
Make Handheld GPS Explorer Available to Public
Solicit Feedback on Handheld GPS Explorer
Package Software Components for Other Archives
12. Spatial Services
Planning of GIS contextual mapping
Purchase Required Equipment and Software
Install and Configure Server and ESRI Software
Make First, Basic, GIS Layers Available to the Public
Solicit Feedback From Potential Users and Peers
Add To and Improve Upon GIS Number and Utility of GIS Layers
13. Open-Source Virtual Archive
Resource planning and requirements development
Solicit Feedback From Project Peers
Attend Open-Source Convention; Assess Reuse Potential
Post Project to Open-Source Sites
Outline & Document System Interfaces
Gather Feedback From Other GPS Archives
Identify Possible Open Source Code to Reuse In Project
Create Public Web Site To Support Project
Open Public Source Code Repository
Create Mailing List, FAQs and Supporting Resources
Software Development & Documentation
Beta Release of Virtual Archive Software
Integration of Software Into Production Environment
Announce Public Availability of Stable Source Code/Project
Identify Reuse of Software in Other Projects
Assess Community Support and Adapt Current Strategies
Document Project in Form of Academic Paper
Demonstrate Integration of Software in Other Projects

7.0 PERSONNEL

The biographical sketches and publication lists for the PI's and a partial list of project members can be found at the end of this section. The following are biographical summaries for other key project members:

Mr. Keith 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. Brent Gilmore is a Programmer Analyst with the University of California, San Diego. He received a B.S. in Information Systems and a M.S. in Business Administration Management from San Diego State University. As Computer Operations Manager for SOPAC and CSRC he is responsible for system administration, technical support, database administration, software development, and administration of a 3TB GPS archive. He has over twelve years of professional experience in the computer field with an emphasis in Internet-related software development, Unix system administration, and database administration and modeling. Brent is a Sun Certified Solaris Administrator and a Sun Certified Network Administrator.

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.

Mr. Michael Scharber holds a B.A in Geography from Macalester College (1995) and has completed two years of graduate coursework in the Masters of Geographic Information Science (MGIS) program at the University of Minnesota. He has more than 5 years of experience in database application development, systems programming, user interface development and minor systems administration. He has extensive familiarity with Perl, HTML, CGI, SQL, PL/SQL, ESRI GIS software, Unix shells and relational database theory and application. Since mid-1998 Mr. Scharber has worked at SIO under Yehuda Bock on an array of projects including SCIGN, CSRC, GSAC and PBO. He has been the primary developer for the Site Information Manager (SIM), SOPAC's Archive Data Manager (ADM) and the entire GSAC project.

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, RESPONSIBILITES, 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, J. Geophys. Res., in press, 2002.

Co-seismic slip from the July 30, 1995, Mw 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

Yehuda Bock, Scripps Institution of Oceanography

EDUCATION:

Ph.D. in Geodetic Science, The Ohio State University, 1982.
B.Sc. in Geodetic Engineering, Technion-Israel Inst. of Technology, 1977.
B.A. in Mathematics, New York University, 1971.

POSITIONS HELD:

Research Geodesist and Senior Lecturer, Scripps Inst. Oceanography (SIO), UCSD, 1989-
Director, California Spatial Reference Center (CSRC), SIO, 1999-
Director, Scripps Orbit and Permanent Array Center (SOPAC), UCSD, 1993-
Chair, Southern California Integrated GPS Network (1997-1998; Vice-Chair 1999-Present).
Member Governing Board, International GPS Service (IGS), 1991-1999
Staff Scientist, Jet Propulsion Laboratory, California Institute of Technology,1989-1992
Research Scientist, Dept. of Earth, Atmospheric, and Planetary Sciences, MIT, 1984-1989
Visiting Assoc. Prof., Ohio State Univ., at Gadjah Mada Univ., Yogyakarta, Indonesia, 1987
Geophysics Research Scholar, Air Force Geophysics Lab., Hanscom AFB, MA, 1982-1984

SCIENTIFIC CONTRIBUTIONS AND AWARDS:

(1) Crustal deformation studies in southern California, Indonesia, Middle East. (2) Developed Global Positioning System analysis techniques for earthquake research, including GAMIT software (with Robert King), precise orbit determination, reference frames, instantaneous positioning, and GPS seismology, real-time GPS. (3) Pioneered development and establishment of continuous GPS technology for crustal deformation (PGGA/SCIGN), open data policies, and outreach efforts (CSRC). (4) Supervised development of first global and regional GPS data archive and RDBMS (SOPAC), and first GPS seamless archive. (5) Certificate of Appreciation for Outstanding Service, International GPS Service, 1999. (6) The Karrina and Weikko A. Heiskanen Award, Dept. of Geodetic Science and Surveying, The Ohio State University, Columbus, 1989.

SELECTED PUBLICATIONS (Last 5 Years):

Bock Y., et al., S. 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.

Zhang, J., Y. Bock, H. Johnson, P. Fang, J. Genrich, S. Williams, S. Wdowinski and J. Behr, Southern California Permanent GPS Geodetic Array: Error analysis of daily position estimates and site velocities, *J. Geophys. Res.*, 102, 18,035-18,055, 1997.

Walls, C., T. Rockwell, K. Mueller, Y. Bock, S. Williams, J. Pfanner, J. Dolan, and P. Fang, Escape tectonics in the Los Angeles metropolitan region and implications for seismic risk, *Nature*, 394, 356-360, 1998.

Williams, S., Y. Bock, and P. Fang, Integrated Satellite Interferometry: Tropospheric noise, GPS estimates and their implications for Interferometric SAR products, *J. Geophys. Res*., 103, 27,051-27,067 1998.

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Wdowinski, S., Y. Sudman, and Y. Bock, Distribution of interseismic deformation along the San Andreas fault system, southern California, *Geophys. Res. Lett.*, 28, 2321-2324, 2001.

Chadwell, C. D. and Y. Bock, Direct estimation of absolute precipitable water in oceanic regions by GPS tracking of a coastal buoy, *Geophys. Res. Lett., 28*, 3701-3704, 2001.

Dr. Nancy King, U.S. 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

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Greg Anderson, U.S. Geological Survey

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.

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Anderson, G., S. Constable, H. Staudigel, and F.K. Wyatt, A seafloor long-baseline tiltmeter, *J. Geophys. Res., 102,* 20,269-20,285, 1997.

Danan Dong, Jet Propulsion Laboratory

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.

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Peng Fang, Scripps Institution of Oceanography

EDUCATION

Ph.D., 1989, Geodesy, Uppsala University, Sweden
B.Sc., 1977, Electrical Engineering, Huazhong University of Science and Technology, Wuhan, China

PROFESSIONAL EXPERIENCE

Specialist, Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, UC San Diego, 1994-present
Associate Specialist, Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, UC San Diego, 1991-1994
Post-Graduate Researcher, Department of Earth and Space Sciences, UC Los Angeles, 1989-1991
Research Assistant, Institute of Geophysics, Uppsala University, Sweden, 1984-1989 Visiting Research Associate, Institute of Geophysics, Trieste University, Italy, 1986
Research Engineer, Research Institute of Surveying and Mapping, China, 1977-1982

SERVICE AND AWARDS

Fellow, International Association of Geodesy (IAG), 1993-present
Member, International GPS Service (IGS), 1993-present
Member, American Geophysical Union (AGU), 1989-present

FIELD AND LABORATORY EXPERIENCE

Analysis, Southern California Permanent GPS Geodetic Array (PGGA), 1991-1996
Analysis, Scripps Orbit and Permanent Array (SOPAC), 1996-present
Analysis, International GPS Service (IGS) processing facility, 1992 -present

SELECTED PUBLICATIONS

Dong, D., P. Fang, Y. Bock, M.K. Cheng, and S. Miyazaki, (2002) Anatomy of apparent seasonal variations from GPS-derived site position time series, J. Geophys. Res., 107(B4), ETG 9, 1-18.
Fang, P., G. Gendt, T. Springer, and T. Mannucci (2001): IGS Near Real -time Products and Their Applications, *GPS Solutions*, Vol 4, No 4, 2-8.
Fang, P., M. Bevis, Y. Bock, S. Gutman, and D. Wolfe (1998): GPS meteorology: Reducing systematic errors for zenith delay, *Geophys. Res. Lett*., 25, 3583-3586.
Williams, S., Y. Bock, P. Fang (1998): Integrated satellite interferometry: Tropospheric noise, GPS estimates and implications for interferometic synthetic aperture radar products, *J. Geophys. Res*., 27051-27067.
Duan, J., M. Bevis, P. Fang, Y. Bock, S. Chiswell, S. Businger, C. Rocken, F. Solheim, T. Van Hove, R. Ware, S. McClusky, T.A. Herring and R. King (1996) GPS meteorology: Direct estimation of the absolute value of precipitable water, *J. Appl. Meteor.*, *35*, 830-838
Fang, P. and Y. Bock (1995) Scripps Orbit and Permanent Array Center Report to the IGS - 1995, 1994 Annual Report, International GPS Service for Geodynamics , J. F. Zumberge, R. Liu and R. E. Neilan, eds., IGS Central Bureau, Jet Propulsion Laboratory, Pasadena 233-246.

Sharon Kedar, Jet Propulsion Laboratory

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 -2nd place nationally

Select Publications

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

Kedar, S., Kanamori, H., Sturtevant, B., Bubble collapse as the source of tremor at Old Faithful Geyser, *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. 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.

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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.

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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., Prawirodirdjo 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.

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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 ScienceWorking 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. In addition, the Table 4 shows the FTEs by period, task, and organization.

Table 4: Master schedule showing milestones to be completed for each task (in bold) and major tasks

	CY03		CY04		CY05		CY06		CY07	
Task	JUN	DEC	JUN2	DEC2	JUN3	DEC3	JUN4	DEC4	JUN5	DEC5
0. Project Management	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
JPL	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
SIO	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
USGS	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1. System Requirements Definition and Design	1.8									
JPL	1.0									
SIO										
USGS	0.8									
2. Level 1 product Dev. - Combined Geodetic Time Series		1.8								
JPL		0.8								
SIO										
USGS		1.0								
3. Automation of Level 1 Data Products		1.5	2.2							
JPL		0.5	0.5							
SIO										
USGS		1.0	1.7							
4. Level 2 Product Dev. - Velocity Field				1.2						
JPL				0.5						
SIO										
USGS				0.7						
5. Automation of Level 2 Data Products					1.8					
JPL					0.5					
SIO										
USGS					1.3					
6. Level 3 Product Dev. - Geophysical Parameters			1.5	1.5	1.5	2.7				
JPL			0.8	0.8	0.8	1.3				
SIO										
USGS			0.8	0.8	0.8	1.5				
7. Automation of Level 3 Data Products							3.3			
JPL							1.3			
SIO										
USGS							2.1			
8. Integrate with independent Data Products								2.7		
JPL								1.3		
SIO										
USGS								1.5		
9. Incorporate PBO data into products									3.3	3.3
JPL									1.3	1.3
SIO										
USGS									2.0	2.0
10. Adaptive Seamless Archive System	1.3	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
JPL										
SIO	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
USGS	0.7	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
11. GPS Explorer	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
JPL										
SIO	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
USGS										
12. Spatial Services	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
JPL										
SIO	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
USGS										
13. Open-Source Virtual Archive	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
JPL										
SIO	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
USGS										
Totals	**5.7**	**6.6**	**7.0**	**6.0**	**6.6**	**6.0**	**6.6**	**6.0**	**6.6**	**6.6**
JPL	**1.4**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
SIO	**2.7**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**
USGS	**1.7**	**2.4**	**2.8**	**1.8**	**2.4**	**1.8**	**2.4**	**1.8**	**2.3**	**2.3**

GPS Data Products for Solid Earth Science

Year 1 Budget Summary

For Period From February 2003 to December 2003	A	NASA USE ONLY B	NASA USE ONLY C
1. Direct Labor (salaries, wages, and fringe benefits)	$177.6		
2. Other Direct Costs:			
a. Subcontracts (includes Open See accompanying sheets for	$703.8		
b. Consultants	$0.0		
c. Equipment	$4.0		
d. Supplies	$0.0		
e. Travel	$10.3		
f. Other (MPS & ADC)			
1. MPS & ADC	$99.5		
2. Services	$0.0		
3. Facilities and Administrative Costs	$71.5		
4. Other Applicable Costs			
1. Award Fee	$15.7		
2. Government Co-I			
5. **SUBTOTAL--Estimated Costs**	$1,082.3		
6. Less Proposed Cost Sharing (if any)			
7. Carryover Funds (if any)			
a. Anticipated amount :			
b. Amount used to reduce budget			
8. **Total Estimated Costs**	$1,082.3		XXXXXXX
9. **APPROVED BUDGET**	XXXXXXX	XXXXXXX	

GPS Data Products for Solid Earth Science

Year 2 Budget Summary

For Period From January 2004 to December 2004	A	NASA USE ONLY B	C
1. Direct Labor			
(salaries, wages, and fringe benefits)	$237.8		
2. Other Direct Costs:			
a. Subcontracts (includes Open	$707.7		
See accompanying sheets for			
b. Consultants	$0.0		
c. Equipment	$1.0		
d. Supplies	$0.0		
e. Travel	$9.8		
f. Other (MPS & ADC)			
1. MPS & ADC	$126.6		
2. Services	$0.0		
3. Facilities and Administrative Costs	$80.9		
4. Other Applicable Costs			
1. Award Fee	$16.0		
2. Government Co-I			
5. **SUBTOTAL--Estimated Costs**	$1,179.9		
6. Less Proposed Cost Sharing (if any)			
7. Carryover Funds (if any)			
a. Anticipated amount :			
b. Amount used to reduce budget			
8. **Total Estimated Costs**	$1,179.9		XXXXXXX
9. **APPROVED BUDGET**	XXXXXXX	XXXXXXX	

GPS Data Products for Solid Earth Science

Year 3 Budget Summary

For Period From January 2005 to December 2005	A	NASA USE ONLY B	NASA USE ONLY C
1. Direct Labor			
(salaries, wages, and fringe benefits)	$246.8		
2. Other Direct Costs:			
a. Subcontracts (includes Open	$684.1		
See accompanying sheets for			
b. Consultants	$0.0		
c. Equipment	$3.0		
d. Supplies	$0.0		
e. Travel	$9.8		
f. Other (MPS & ADC)			
1. MPS & ADC	$129.5		
2. Services	$0.0		
3. Facilities and Administrative Costs	$81.8		
4. Other Applicable Costs			
1. Award Fee	$15.0		
2. Government Co-I			
5. **SUBTOTAL--Estimated Costs**	$1,170.0		
6. Less Proposed Cost Sharing (if any)			
7. Carryover Funds (if any)			
a. Anticipated amount :			
b. Amount used to reduce budget			
8. **Total Estimated Costs**	$1,170.0		XXXXXXX
9. **APPROVED BUDGET**	XXXXXXX	XXXXXXX	

GPS Data Products for Solid Earth Science

Year 4 Budget Summary

For Period From January 2006 to December 2006	A	NASA USE ONLY B	C
1. Direct Labor			
(salaries, wages, and fringe benefits)	$257.4		
2. Other Direct Costs:			
a. Subcontracts (includes Open	$684.6		
See accompanying sheets for			
b. Consultants	$0.0		
c. Equipment	$0.0		
d. Supplies	$0.0		
e. Travel	$9.8		
f. Other (MPS & ADC)			
1. MPS & ADC	$134.2		
2. Services	$0.0		
3. Facilities and Administrative Costs	$85.6		
4. Other Applicable Costs			
1. Award Fee	$15.2		
2. Government Co-I			
5. **SUBTOTAL--Estimated Costs**	$1,186.8		
6. Less Proposed Cost Sharing (if any)			
7. Carryover Funds (if any)			
a. Anticipated amount :			
b. Amount used to reduce budget			
8. **Total Estimated Costs**	$1,186.8		XXXXXXX
9. **APPROVED BUDGET**	XXXXXXX	XXXXXXX	

GPS Data Products for Solid Earth Science

Year 5 Budget Summary

For Period From October 2006 to September 2007	A	NASA USE ONLY B	C
1. Direct Labor (salaries, wages, and fringe benefits)	$249.3		
2. Other Direct Costs:			
a. Subcontracts (includes Open See accompanying sheets for	$701.1		
b. Consultants	$0.0		
c. Equipment	$0.0		
d. Supplies	$0.0		
e. Travel	$7.4		
f. Other (MPS & ADC)			
1. MPS & ADC	$129.8		
2. Services	$0.0		
3. Facilities and Administrative Costs	$85.7		
4. Other Applicable Costs			
1. Award Fee	$15.3		
2. Government Co-I			
5. **SUBTOTAL--Estimated Costs**	$1,188.5		
6. Less Proposed Cost Sharing (if any)			
7. Carryover Funds (if any)			
a. Anticipated amount :			
b. Amount used to reduce budget			
8. **Total Estimated Costs**	$1,188.5		XXXXXXX
9. **APPROVED BUDGET**	XXXXXXX	XXXXXXX	

GPS Data Products for Solid Earth Science

Grand Total Budget Summary

For Period From February 2003 to December 2007	A	NASA USE ONLY B	C
1. Direct Labor			
(salaries, wages, and fringe benefits)	$1,168.9		
2. Other Direct Costs:			
a. Subcontracts (includes Open	$3,481.3		
See accompanying sheets for			
b. Consultants	$0.0		
c. Equipment	$8.0		
d. Supplies	$0.0		
e. Travel	$47.0		
f. Other (MPS & ADC)			
1. MPS & ADC	$619.6		
2. Services	$0.0		
3. Facilities and Administrative Costs	$405.5		
4. Other Applicable Costs			
1. Award Fee	$77.2		
2. Government Co-I	$0.0		
5. **SUBTOTAL--Estimated Costs**	$5,807.5		
6. Less Proposed Cost Sharing (if any)	$0.0		
7. Carryover Funds (if any)			
a. Anticipated amount :	$0.0		
b. Amount used to reduce budget	$0.0		
8. **Total Estimated Costs**	$5,807.5		XXXXXXX
9. **APPROVED BUDGET**	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.

SIO BUDGET SUMMARY
Year One
For period from 02/01/03-12/31/03

	A	NASA USE ONLY B	NASA USE ONLY C
1. Direct Labor (salaries, wages, and fringe benefits)	178,321	________	________
2. Other Direct Costs:			
a. Subcontracts	________	________	________
b. Consultants	________	________	________
c. Equipment	20,000	________	________
d. Supplies	10,000	________	________
e. Travel	11,042	________	________
f. Other	6,880	________	________
3. Indirect Costs*	103,007	________	________
4. Other Applicable Costs:	________	________	________
5. SUBTOTAL--Estimated Costs	329,250	________	________
6. Less Proposed Cost Sharing	______	________	________
7. Carryover Funds			
a. Anticipated amount:	________	________	________
b. Amount used to reduce budget	________	________	________
8. Total Estimated Costs	329,250	________	________
9. APPROVED BUDGET	________	________	________

*Facilities and Administrative Costs

SIO BUDGET SUMMARY
Year Two
For period from 01/01/04-12/31/04

	A	NASA USE ONLY B	NASA USE ONLY C
1. Direct Labor (salaries, wages, and fringe benefits)	185,876	________	________
2. Other Direct Costs:			
g. Subcontracts	________	________	________
h. Consultants	________	________	________
i. Equipment	19,916	________	________
j. Supplies	10,000	________	________
k. Travel	6,785	________	________
l. Other	6,580	________	________
3. Indirect Costs*	103,798	________	________
4. Other Applicable Costs:	________	________	________
5. SUBTOTAL--Estimated Costs	332,955	________	________
6. Less Proposed Cost Sharing	______	________	________
7. Carryover Funds			
c. Anticipated amount:	________	________	________
d. Amount used to reduce budget	________	________	________
8. Total Estimated Costs	332,955	________	________
9. APPROVED BUDGET	________	________	________

*Facilities and Administrative Costs

BUDGET SUMMARY
Year Three
For period from 01/01/05-12/31/05

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

*Facilities and Administrative Costs

SIO BUDGET SUMMARY
Year Four
For period from 01/01/06-12/31/06

		NASA USE ONLY	
	A	**B**	**C**
1. Direct Labor (salaries, wages, and fringe benefits)	193,850	________	________
2. Other Direct Costs:			
s. Subcontracts	________	________	________
t. Consultants	________	________	________
u. Equipment	________	________	________
v. Supplies	10,000	________	________
w. Travel	7,425	________	________
x. Other	8,155	________	________
3. Indirect Costs*	108,581	________	________
4. Other Applicable Costs:	________	________	________
5. SUBTOTAL--Estimated Costs	328,011	________	________
6. Less Proposed Cost Sharing	______	________	________
7. Carryover Funds			
g. Anticipated amount:	________	________	________
h. Amount used to reduce budget	________	________	________
8. Total Estimated Costs	328,011	________	________
9. APPROVED BUDGET	________	________	________

*Facilities and Administrative Costs

SIO BUDGET SUMMARY
Year Five
For period from 01/01/07-12/31/07

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

*Facilities and Administrative Costs

SIO BUDGET SUMMARY
ALLYEARS
For period from 02/01/03-12/31/07

		NASA USE ONLY	
	A	**B**	**C**
1. Direct Labor (salaries, wages, and fringe benefits)	947,376	________	________
2. Other Direct Costs:			
ee. Subconstracts	________	________	________
ff. Consultants	________	________	________
gg. Equipment	49,916	________	________
hh. Supplies	45,000	________	________
ii. Travel	40,128	________	________
jj. Other	37,150	________	________
3. Indirect Costs*	530,392	________	________
4. Other Applicable Costs:	________	________	________
5. SUBTOTAL--Estimated Costs	1,649,962	________	________
6. Less Proposed Cost Sharing	________	________	________
7. Carryover Funds			
k. Anticipated amount:	________	________	________
l. Amount used to reduce budget	________	________	________
8. Total Estimated Costs	1,649,962	________	________
9. APPROVED BUDGET	________	________	________

*Facilities and Administrative Costs

OPEN SOURCE BUDGET SUMMARY
Year One
For period from 02/01/03-12/31/03

	A	NASA USE ONLY B	C
1. Direct Labor (salaries, wages, and fringe benefits)	49,606	________	________
2. Other Direct Costs:			
a. Subcontracts	________	________	________
b. Consultants	________	________	________
c. Equipment	3,600	________	________
d. Supplies	5,000	________	________
e. Travel	5,960	________	________
f. Other	1,935	________	________
3. Indirect Costs*	32,501	________	________
4. Other Applicable Costs:	________	________	________
5. SUBTOTAL--Estimated Costs	98,602	________	________
6. Less Proposed Cost Sharing	______	________	________
7. Carryover Funds			
a. Anticipated amount:	________	________	________
b. Amount used to reduce budget	________	________	________
8. Total Estimated Costs	98,602	________	________
9. APPROVED BUDGET	________	________	________

*Facilities and Administrative Costs

OPEN SOURCE BUDGET SUMMARY
Year Two
For period from 01/01/04-12/31/04

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

*Facilities and Administrative Costs

OPEN SOURCE BUDGET SUMMARY
Year Three
For period from 01/01/05-12/31/05

	A	NASA USE ONLY B	C
1. Direct Labor (salaries, wages, and fringe benefits)	52,121	________	________
2. Other Direct Costs:			
m. Subcontracts	________	________	________
n. Consultants	________	________	________
o. Equipment	4,000	________	________
p. Supplies	5,000	________	________
q. Travel	2,810	________	________
r. Other	1,900	________	________
3. Indirect Costs*	32,152	________	________
4. Other Applicable Costs:	________	________	________
5. SUBTOTAL--Estimated Costs	97,983	________	________
6. Less Proposed Cost Sharing	______	________	________
7. Carryover Funds			
e. Anticipated amount:	________	________	________
f. Amount used to reduce budget	________	________	________
8. Total Estimated Costs	97,983	________	________
9. APPROVED BUDGET	________	________	________

*Facilities and Administrative Costs

OPEN SOURCE BUDGET SUMMARY
Year Four
For period from 01/01/06-12/31/06

		NASA USE ONLY	
	A	**B**	**C**
1. Direct Labor (salaries, wages, and fringe benefits)	53,614	________	________
2. Other Direct Costs:			
s. Subcontracts	________	________	________
t. Consultants	________	________	________
u. Equipment	________	________	________
v. Supplies	4,000	________	________
w. Travel	2,950	________	________
x. Other	1,935	________	________
3. Indirect Costs*	32,499	________	________
4. Other Applicable Costs:	________	________	________
5. SUBTOTAL--Estimated Costs	94,998	________	________
6. Less Proposed Cost Sharing	______	________	________
7. Carryover Funds			
g. Anticipated amount:	________	________	________
h. Amount used to reduce budget	________	________	________
8. Total Estimated Costs	94,998	________	________
9. APPROVED BUDGET	________	________	________

*Facilities and Administrative Costs

OPEN SOURCE BUDGET SUMMARY
Year Five
For period from 01/01/07-12/31/07

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

*Facilities and Administrative Costs

OPEN SOURCE BUDGET SUMMARY
ALLYEARS
For period from 02/01/03-12/31/07

		NASA USE ONLY	
	A	**B**	**C**
1. Direct Labor (salaries, wages, and fringe benefits)	261,107	________	________
2. Other Direct Costs:			
ee. Subcontracts	________	________	________
ff. Consultants	________	________	________
gg. Equipment	17,600	________	________
hh. Supplies	20,500	________	________
ii. Travel	17,510	________	________
jj. Other	9,670	________	________
3. Indirect Costs*	160,569	________	________
4. Other Applicable Costs:	________	________	________
5. SUBTOTAL--Estimated Costs	486,956	________	________
6. Less Proposed Cost Sharing	______	________	________
7. Carryover Funds			
k. Anticipated amount:	________	________	________
l. Amount used to reduce budget	________	________	________
8. Total Estimated Costs	486,956	________	________
9. APPROVED BUDGET	________	________	________

*Facilities and Administrative Costs

USGS Budget Summary
Y03

		A	NASA USE ONLY B	C
1.	Direct Labor	$ 127,135.68		
2.	Other Direct Costs:			
	a. Subcontracts			
	b. Consultants	$ 73,602.00		
	c. Equipment			
	d. Supplies			
	e. Travel			
	f. Other			
3.	Indirect Costs	$ 71,421.21		
4.	Other Applicable Costs			
5.	SUBTOTAL	$ 272,158.90		
6.	Less Proposed Cost Sharing			
7.	Total Estimated Costs	$ 272,158.90		
8.	APPROVED BUDGET			

USGS Budget Summary
CY04

		A	B (NASA USE ONLY)	C (NASA USE ONLY)
1.	Direct Labor	$117,887.78		
2.	Other Direct Costs:			
	a. Subcontracts			
	b. Consultants	$ 91,872.00		
	c. Equipment			
	d. Supplies			
	e. Travel			
	f. Other			
3.	Indirect Costs	$ 72,299.69		
4.	Other Applicable Costs			
5.	SUBTOTAL	$282,059.47		
6.	Less Proposed Cost Sharing			
7.	Total Estimated Costs	$282,059.47		
8.	APPROVED BUDGET			

USGS Budget Summary
CY05

	A	NASA USE ONLY B	C
1. Direct Labor	$ 99,391.96		
2. Other Direct Costs:			
a. Subcontracts			
b. Consultants	$ 91,872.00		
c. Equipment			
d. Supplies			
e. Travel			
f. Other			
3. Indirect Costs	$ 64,662.21		
4. Other Applicable Costs			
5. SUBTOTAL	$ 255,926.17		
6. Less Proposed Cost Sharing			
7. Total Estimated Costs	$ 255,926.17		
8. APPROVED BUDGET			

USGS Budget Summary
CY06

	A	NASA USE ONLY B	C
1. Direct Labor	$ 99,391.96		
2. Other Direct Costs:			
a. Subcontracts			
b. Consultants	$ 91,872.00		
c. Equipment			
d. Supplies			
e. Travel			
f. Other			
3. Indirect Costs	$ 64,662.21		
4. Other Applicable Costs			
5. SUBTOTAL	$ 255,926.17		
6. Less Proposed Cost Sharing			
7. Total Estimated Costs	$ 255,926.17		
8. APPROVED BUDGET			

USGS Budget Summary
CY07

	A	B	C
		NASA USE ONLY	
1. Direct Labor	$ 94,768.00		
2. Other Direct Costs:			
a. Subcontracts			
b. Consultants	$ 114,840.00		
c. Equipment			
d. Supplies			
e. Travel			
f. Other			
3. Indirect Costs	$ 68,657.92		
4. Other Applicable Costs			
5. SUBTOTAL	$ 278,265.92		
6. Less Proposed Cost Sharing			
7. Total Estimated Costs	$ 278,265.92		
8. APPROVED BUDGET			

USGS Budget Summary
CY03 - CY07

	A	NASA USE ONLY B	C
1. Direct Labor	$ 538,575.38		
2. Other Direct Costs:			
a. Subcontracts			
b. Consultants	$ 464,058.00		
c. Equipment			
d. Supplies			
e. Travel			
f. Other			
3. Indirect Costs	$ 341,703.24		
4. Other Applicable Costs			
5. SUBTOTAL	$ 1,344,336.62		
6. Less Proposed Cost Sharing			
7. Total Estimated Costs	$ 1,344,336.62		
8. APPROVED BUDGET			

10.0 FACILITIES AND EQUIPMENT

10.1 Computing Equipment	
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	The USGS computing facitilities 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 processer systems for specialized post processing. Several systems are kept as hot spares to replace any failing equipment. 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.
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)^2. The Cal-(IT)^2 *Control Room* 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.
10.2 Mass Store	
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.
10.3 GIS Laboratory	
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.
10.4 Experimental Facilities	
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

	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. 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.
CSRC	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. 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): 1. Provide the necessary geodetic services to ensure the availability of accurate, consistent, and timely spatial referencing data. 2. Establish the legal spatial reference system for California. 3. Monitor temporal changes in geodetic coordinates due to tectonic motion, volcanic deformation and land subsidence. For more information see http://csrc.ucsd.edu/
SOPAC	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. SOPAC investigators conduct research on the implementation, operation and scientific applications of continuously monitoring GPS arrays and Synthetic Aperture Radar (SAR) interferometry. 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

	California Earthquake Center (SCEC), the National Oceanic and Atmospheric Administration (NOAA), and the William M. Keck Foundation fund these activities. SOPAC provides the following services and products to the scientific community: 1. Precise near real-time and predicted GPS satellite orbits, 2. Precise polar motion and Earth rotation variations, 3. On-line data archive of continuously operating GPS tracking stations, for data collected since 1990, 4. Time series of daily three-dimensional positions for the global and California stations with respect to the International Terrestrial Reference Frame (ITRF), 5. Software for remote downloading of continuous GPS data, 6. Consultation on installation and operations of continuous GPS arrays. 7. Web-based user applications based on Oracle 9i RDBMS. Data from the SOPAC archive may be retrieved via anonymous ftp, http, or through the SOPAC home page: ftp://garner.ucsd.edu; http://garner.ucsd.edu login: anonymous; password: your email address For more information see http://sopac.ucsd.edu/
GPS in Orange County	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. 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.
10.5 Software	
JPL	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.

	See http://gipsy.jpl.nasa.gov for more detail. 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.
USGS	Sharc (Sharc Acquires Receivers Contents) 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. Schedg (Schedule GPS) 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. MapSurfer 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. JavaPlotter 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. Scientific Computing Through Caltech, we have access to MATLAB and GIS. We also have MATLAB on a linux machine.
SDSC SRB	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

	also store user-defined metadata at the collection and object level and provides search capabilities based on these metadata. The SRB has been implemented on multiple platforms including IBM AIX, Sun, SGI, Linux, Cray T3Eand 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: http://www.npaci.edu/DICE/SRB/.
IGPP Seamless Archive	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 (DHFs) 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. 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: • Wholesaler GSAC Data Holdings Publication • Retailer GSAC Data Holdings Collection • Retailer GSAC Data Holdings Serving • Wholesaler & Retailer GSAC Database Management • Wholesaler & Retailer GSAC Database Reporting

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

12.0 CURRENT AND PENDING SUPPORT

Person	Source of Support	Project Title (Grant or Contract #)	Status	Award Amount by Fiscal Year ($k)	Total Award Amount ($k)	Award Period	Level of Effort	Location of Work
Frank Webb	NASA / IIP	Volcano Monitoring System	P	608	1,216.3	2	20%	JPL
Sharon Kedar	NASA / IIP	Volcano Monitoring System	P	608	1,216.3	2	20%	JPL
Sharon Kedar	NASA / SENH	Integrated Broad-Band Strain Monitoring in Southern California Using SCIGN and TriNet Data	P	181	543.0	3	50%	JPL
Denan Dong	NASA / SENH	Integrating space-geodetic data through spatio-temporal filtering: application in secular, episodic and seasonal deformation analysis	P	103	310.8	3	30%	JPL
Yehuda Bock	See Below							

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: **YEHUDA BOCK**

Support: ✷ Current ❏ Pending ❏ Submission Planned in Near Future ❏ *Transfer of Support

Project/Proposal Titl **THE WILLIAM M. KECK FOUNDATION GPS ARRAY FOR EA QUAKE RESEARCH** **22-1054 IGPYB43**

Source of Support: USC/KECK Foundation

Total Award Amount: $ 1,677,168 Total Award Period Cov 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: ✷ Current ❏ Pending ❏ Submission Planned in Near Future ❏ *Transfer of Support

Project/Proposal Titl **FUNDAMENTAL SUPPORT FOR GPS RESEARCH - UNAVCO F** **IGPUCAR**

Source of Support: UCAR

Total Award Amount: $ 431,700 Total Award Period Cove 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: ✷ Current ❏ Pending ❏ Submission Planned in Near Future ❏ *Transfer of Support

Project/Proposal Title:

INTEGRATED INSTRUMENTATION FOR BROADBAND OBSE OF PLATE BOUNDARY DEFORMATION (Matching Funds) **21-1154 IGPPARK**

Source of Support: USC/Keck Foundation

Total Award Amount: $ 85,000 Total Award Period Cov 8/1/97 - 12/14/03

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: **21-1398 & 22-3044**

JOINT PROJECT AGREEMENT CONCERNING THE NATIONA REFERENCE SYSTEM IN CALIFORNIA **NOAYB83**

Source of Support: NOAA

Total Award Amount: $ 1,996,000 Total Award Period Cove 05/1/01 - 06/30/03

Location of Project: IGPP/SIO

Person-Months Per Year Committed to the Project. Cal 6 Acad: Sumr:

Support: ✷ Current ❏ Pending ❏ Submission Planned in Near Future ❏ *Transfer of Support

Project/Proposal Titl **INTEGRATED INSTRUMENTATION FOR BROADBAND OBSERVATIONS OF PLATE BOUNDARY DEFORMATION** **EAR 9977823**

Source of Support: NSF

Total Award Amount: $ 160,225 Total Award Period Cov 9/1/99 -8/31/03

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 Titl **THE THERMO-KINEMATIC EVOLUTION OF THE TAIWAN M BELT** **99-1501 IGPTWAN**

Source of Support: TEXAS A & M

Total Award Amount: $ 37,500 Total Award Period Cove 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: **YEHUDA BOCK**

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 Cove 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 Titl **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

13.1 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)

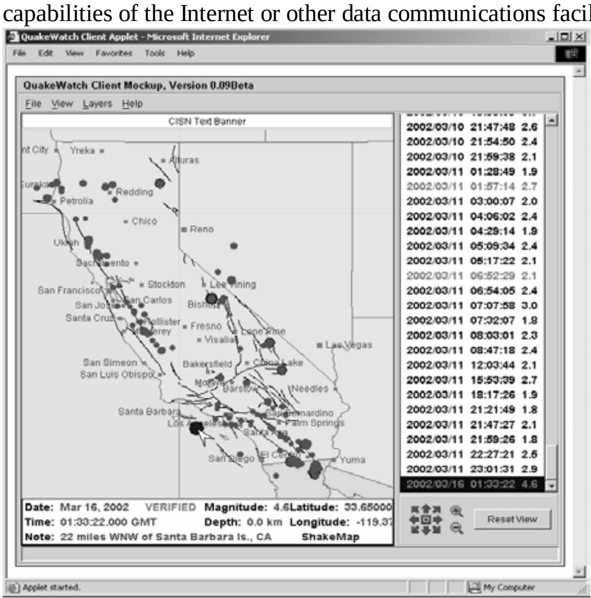
The CISN Display

CGS USGS CALTECH OES UCB

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 a 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.



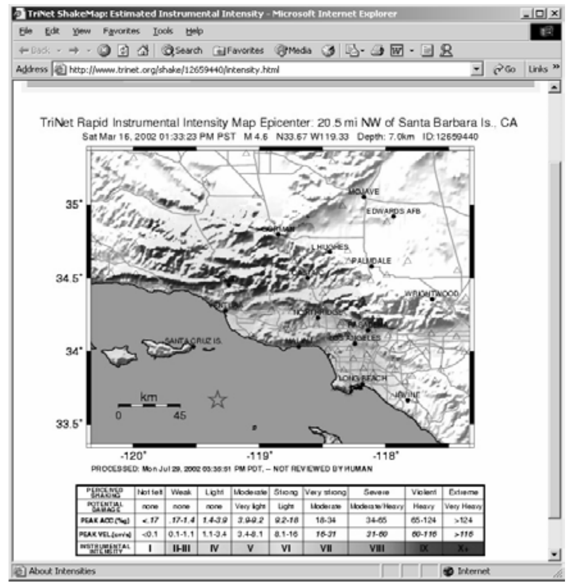
CISN Display with highlighted event indicating a 'ShakeMap' link

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 mangers 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 signup 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.

13.2 Acronyms

AC	SCIGN Science Advisory Council
CAN	Cooperative Agreement Notice
CB	SCIGN Coordinating Board
CISN	California Integrated Seismic Network
CSRC	California Special Reference Center
GAMIT	GPS At MIT
GIPSY	GPS Inferred Positioning System
GPS	Global Positioning System
GSAC	GPS Seamless Archive
EC	SCIGN Executive Committee
ESE	Earth Science Enterprise
IGS	International GPS Service
JPL	Jet Propulsion Laboratory
NASA	National Air and Space Administration
NSF	National Science Foundation
OES	Office of Emergency Services
PBO	Plate Boundary Observatory
QOCA	Quasi Observation Combination Analysis
RINEX	Receiver Independent Exchange
SCEC	Southern California Earthquake Center
SCIGN	Southern California Integrated Seismic Network
SESWG	Solid Earth Science Working Group
SIM	Site Information Manager
SIO	Scripps Institution of Oceanography
SINEX	Solution Independent Exchange
SOPAC	Scripps Orbit and Permanent Array Center
UNAVCO	University Navstar Consortium
USGS	United Stated Geological Survey

14.0 LETTERS OF COMMITMENT AND SUPPORT

UNIVERSITY OF CALIFORNIA, SAN DIEGO

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

CECIL H. AND IDA M. GREEN
INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS
SCRIPPS INSTITUTION OF OCEANOGRAPHY (0225)

LA JOLLA, CALIFORNIA 92093-0225

November 20, 2002

Dr. Frank Webb
Group Supervisor
Satellite Geodesy and Geodynamics Systems Group
Jet Propulsion Laboratory
4800 Oak Grove Drive
MS 238-625
Pasadena, CA 91109-8099

Dear Frank,

This is a letter of commitment for the proposal "GPS Data Products for Solid Earth Science" which you are submitting on November 26, 2002 to NASA's "Earth Science Research, Education and Applications Solutions Network (REASoN)," CAN-02-OES-01.

As described in detail in the proposal, the University of California San Diego, Scripps Institution of Oceanography is pleased to participate in this project. Although we intend to contribute to all project goals, our focus will be on data distribution and user support through 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.

Furthermore, we have proposed the option to build an Open-Source prototype for the purpose of demonstrating software reuse and identifying resources available from the Open-Source community.

We look forward to working with JPL and the USGS on this exciting project.

Sincerely Yours,

Yehuda Bock
Research Geodesist

Sandra Varond
SIO Contracts & Grants

Richard K. Eisner, FAIA
California Integrated Seismic Network & Earthquake Programs
California Governor's Office of Emergency Services
724 Mandana Boulevard
Oakland, California 94610-2421

November 19, 2002

Dr. Frank Webb
Group Leader, Satellite Geodesy and Geodynamics Systems
Jet Propulsion Laboratory
4800 Oak Grove Ave.
Pasadena, CA 91109

Subject: GPS Data Products for Solid Earth Science Research and Applications

Dear Dr. Webb:

I am writing in support of the proposal being submitted by the Southern California Integrated GPS Network (SCIGN) for the integration of SCIGN into the Plate Boundary Observatory and the development of new data products that will serve the interests of many users including those of emergency management in California. Over the past decade, the Governor's Office of Emergency Services has worked closely with the earth sciences community in the development of real-time information to enhance emergency response capabilities.

Throughout its development and operation, SCIGN has been sensitive to the needs of user groups in the southern California region and this proposal will expand the capabilities of SCIGN by merging it with other GPS networks and facilitating the rapid analysis of data and the delivery of critical information for the evaluation of seismic and volcanic hazards throughout the western region.

For us, this proposal represents another significant step in achieving a reliable real-time post-earthquake decision support system. Of particular interest to our agency is the integrated application of near real-time GPS with seismic and strong ground motion data to assess critical infrastructure after a major urban earthquake. For example, emergency response utilization of static displacement data will facilitate the evaluation of potential damage to utility infrastructure and may reduce outage time. Refinements in GPS data processing that will result from this project may also assist emergency services organizations by identifying areas of enhanced seismic and volcanic potential though rapid detection of anomalous geodetic data.

We are pleased to offer our support for this important project and will continue our close collaboration with SCIGN in pursuit of improved public safety. Please call me if you would like more information or clarification.

Sincerely,

Richard Eisner, FAIA
CISN & Earthquake Program Manager

California Spatial Reference Center
Scripps Institution of Oceanography
IGPP, 9500 Gilman Drive
La Jolla, CA 92093-0225
Ph: (858) 534-8031 (Susie Pike, Coordinator)
Fax: (858) 534-9873
Email: csrc@csrc.ucsd.edu

Dr. Frank Webb
Group Supervisor
Satellite Geodesy and Geodynamics Systems Group
Jet Propulsion Laboratory
4800 Oak Grove Drive
MS 238-625
Pasadena, CA 91109-8099

Dear Frank,

The California Spatial Reference Center is pleased to support the collaborative REASoN proposal to NASA from JPL, SIO and USGS.

The SCIGN project is the key element in maintaining a four-dimensional reference frame in southern California for a growing number of GPS users from local and state government agencies, the public, and the private sector. SCIGN provides 250 active geodetic control stations (CORS) with openly accessible data through its archive at no cost to the user. SCIGN has also been very cooperative in upgrading its stations to high-rate, low latency operations, most notably the now operational Orange County Real Time GPS Network (OCRTN). The OCRTN provides essential real-time data that provides tangible economic and public safety benefits. This model is also being applied to other parts of southern California (Los Angeles, Riverside and San Diego Counties), as well as to the San Francisco Bay Area.

Your project will ensure that SCIGN continues to be funded, but will also provide a modern IT infrastructure that will benefit the CSRC and its constituents directly, as well as whole new suite of data products that will be useful to our community in terms of productivity and public safety. We expect that your project will be closely coordinated with the CSRC's development of its data portal (see http://csrc.uscd.edu) to improve our distribution of spatial data and metadata to a growing user community.

Best Regards,

G A Helmer

Gregory A. Helmer, PLS
Chairman, California Spatial Reference Center

Participating Organizations: • American Congress on Surveying and Mapping (ACSM) • American Society of Photogrammetry and Remote Sensing (ASPRS) • BAsin and Range GEodetic Network (BARGEN) • Bay Area Regional Deformation (BARD) • Bureau of Land Management (BLM) • California Coastal Commission (CCC) • California Department of Water Resources (DWR) • California Land Surveyors Association (CLSA) • California State University Fresno • CalTrans • City of Vacaville • Civil Engineers and Land Surveyors of California (CELSOC) • County Engineers Association • ESRI • Geographical Information Systems Consultants • League of California Surveying Associations • Metropolitan Water District of Southern California (MWD) • National Geodetic Survey (NGS) • Office of Management and Budget • Orange County Surveyor's Office • Riverside County Flood Control and Water Conservation District • Robert Bein, William Frost & Associates • San Francisco Bay Conservation and Development Commission (BCDC) • Southern California Integrated GPS Network (SCIGN) • Stoddard and Associates • University of California, San Diego (UCSD) • U.S. Corps of Engineers • U.S. Geological Survey (USGS) • Urban and Regional Information Systems Association (URISA) •

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 H. Prescott

William Prescott, President
UNAVCO, Inc.

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USGS
science for a changing world

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,

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. Frank Webb, Jet Propulsion Laboratory

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

Michael A. Duffy, PLS
Field Survey & Geometronics Team