GPS Data Products for Solid Earth Science

NASA Cooperative Agreement (CAN)

CAN-02-OES-01

Earth Science Research, Education and Applications Solutions Network (REASoN)

Notices of Intent Due: November 1, 2002

Proposals Due: November 26, 2002

Notes on Proposal Formats

Proposals shall contain:

- Transmittal letter
- Cover pages
- Table of Contents
- Abstract
- Project description
- Technology Development
- Preferences for participation in the Federation and SEEDS working group(s)
- Metrics
- Management approach
- Personnel
- Proposed costs
- Cooperative Agreement payment schedule
- Statement of current and pending support
- Identification/description of special matters

Proposals must be written in English and are expected to be concise. The total length of proposal ***excluding*** transmittal letter, cover page, Curriculum Vitae, budgetary information, certifications, statement of support, and list of references shall not exceed **20 pages** of 8.5" x 11" paper, with a maximum of 52 lines per page (font size 12 or larger, with 1-inch margins). ***Exception to page length:*** Proposals that include new technology development and/or open source prototyping, as described in the CAN and so indicated as a proposal topic for evaluation on the cover sheet, shall not exceed 25 pages. ***Proposals using type smaller than 12 points, compressed type, or less-than normal leading (space between lines), will be returned un-reviewed.***

Transmittal Letter

<u>Note to Proposers</u>: You do not need to prepare a transmittal letter. When your final proposal has been submitted to Karen Piggee (x4-9154), Karen will prepare this letter.

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Proposal Cover Page

TWO proposal cover pages are required as part of the proposal.

The first is a **hard copy** (see the CAN for instructions on how to acquire the proposal hardcopy from the online system) which must be signed by the Principal Investigator and an official by title of the investigator's organization who is authorized to commit the organization. This authorizing signature also certifies that the proposing institution has read and is in compliance with the required certifications printed in full, therefore, these certifications do not need to be submitted separately. This page will not be counted against the page limit of the proposal.

The second proposal cover page must be submitted **electronically** to the SYS-EYFUS Web site located at **http://proposals.hq.nasa.gov/**. If the respondent has submitted an electronic Notice of Intent (Appendix E) to SYS-EYFUS, the same user UserID and password can be used to complete the electronic proposal cover page. If the respondent obtained a User ID and password in the process of submitting a proposal for a previous research opportunity announcement, the same user UserID and password can be used to complete the electronic proposal cover page in response to this research opportunity announcement. Be sure to click on "Edit Personal Information" if any of your correspondence information in SYS-EYFUS is not current.

If you do not have a SYS-EYFUS UserID or password, you may obtain one electronically by going to *http://proposals.hq.nasa.gov* and performing the following steps:

- Click the hyperlink for **new user, which** will take you to the Personal Information Search Page.
- Enter your first and last name. SYS-EYFUS will **search** for your record information in the SYS-EYFUS database.
- Confirm your personal information by **choosing** the record displayed.
- Select **continue**, and a User ID and password will be e-mailed to you.
- Once you receive your User ID and Password, **login** to the SYS-EYFUS Web site and follow the instructions for **New Proposal Cover Page.**

Respondents without access to the Web or who experience difficulty in using this site may contact the Help Desk at proposals@hq.nasa.gov (or call 202.479.9376) for assistance. After you have submitted your notice of intent or proposal cover page electronically, if you are unsure if it has been successfully submitted, do not re-submit. Please call the Help Desk. They will be able to promptly tell you if your submission has been received. Please note that submission of the electronic cover page does not satisfy the deadline for proposal submission.

Table of Contents

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1.0 ABSTRACT

Over the past decade, regional and global networks of continuously operating Global Positioning System (GPS) ground stations have been developed and deployed around the globe that support NASA Solid Earth Science priorities and ESE flight projects. The primary objective of many of these networks is for understanding the deformations of the solid earth in tectonically and volcanically active regions. The networks provide raw GPS observables that are then used by a relatively small community of power users capable of analyzing the raw data for geophysically meaningful signals. In order to expand the utility of these GPS networks, we propose to provide data and higher -level data products to scientists, local governments, and surveyors from the GPS networks in western North America.

The focus of the project will be on the Southern California Integrated GPS Network (SCIGN), a multi-agency project that was jointly sponsored by NASA, NSF, USGS, and the WM Keck Foundation for the study of earthquake hazards in southern California. Over the next five years, SCIGN will transition from a standalone project to an integral part of the multi-agency and multi-disciplinary NSF-lead Plate Boundary Observatory (PBO), a distributed observatory of high-precision geodetic instruments covering western North America, scheduled for installation beginning in 2003. PBO is part of the NSF EarthScope initiative and will serve a broader community of scientists, government agencies, and surveyors than SCIGN does now.

To deliver these data products to the different user communities that these networks serve, this project will build on current capabilities within SCIGN for analysis, verification, validation, and information systems, and disseminate the following data products: geodetic time series, deformation velocity fields, strain rate maps, fault models, near-real-time earthquake response information, surveying support and reference systems, and aquifer recharge monitoring. As SCIGN transitions into PBO towards the end of the proposed 5-year CA, these products will be transitioned and integrated into the PBO data system.

The specifications of the data products will be developed through existing contacts with the following organizations: PBO/UNAVCO, SCEC, CSRC, CISN, and the SCIGN Science Advisory Council, and through participation in the SEEDS Standards and Interface work group and the Federation of Earth Science Information Partners (ESIP) as a Research (Type 2) ESIP. All the products will be archived and made publicly available via a SEEDS compliant data system and web interface.

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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 [*SESWG*, 2002;, SCEC reports; *PBO White Paper*, 1999; GeoNET].

A cornerstone of this growth has been the Southern California Integrated GPS Network (SCIGN), a 250-station network of continuously operating GPS receivers (Fig. of SCIGN). SCIGN is jointly sponsored by NASA, NSF, USGS, and WM Keck Foundation and operates under the auspices of the Southern California Earthquake Center (SCEC). It is governed by a multi-agency and multi-organization coordinating board (Fig. of SCIGN Org) consisting of project members, universities, local, state, and federal government officials, and scientific community members. An independent science Advisory Council (AC) provides critical input on its operations, goals, and responsiveness to the community. A website (www.scign.org) is maintained that documents the project, including annual reports, and project status and Level-0 GPS data are provided to users via the SCIGN archive.

When SCIGN was first proposed, there was only a 3-station GPS network in southern California that was dedicated to monitoring crustal strain. Following the valuable contribution from these stations to both the 1992 Landers [*Hudnut et al*., 1994; *Shen et al*., 1994; *Wdowinski* et al., 1997], and 1994 Northridge [*Heflin et al*., 1998; *Donnellan and Lyzenga*, 1998; *Deng et al*., 1999] earthquakes,SCIGN was proposed as a 7-year experiment into both the utility of applying GPS network technology to studying the Earth and the understanding of the processes driving tectonics in southern California.

One of the primary concerns at that time was the ability of the community to retrieve, distribute, and process the observations from such a large network. Since its inception, SCIGN has demonstrated that these obstacles can be overcome, resulting in the development of other regional GPS networks and the initiation of the biggest integrated strain network in history, the Plate Boundary Observatory (PBO) (Fig or other networks and PBO). The PBO, which SCIGN will become an integral part of, enjoys wide community support and is progressing as through the National Science Foundation as part of the EarthScope initiative. PBO, together with the other systems that compose EarthScope (Fig) is certain to result in quantum changes in the way we view earthquakes, volcanoes and the evolution of the Earth.

Since its installation, SCIGN has been able to meet the needs of the then perceived users of the network [*King et al*., 2002; *SCIGN 2001-2002 Accomplishments*, 2002; *SCIGN Analysis Committee Report*, 2001]. Over the last 7 years, as the utility of this type of monitoring has been realized, the requirements of the users have also grown. SCIGN was originally conceived as an observatory, providing Level-0 data products from the networks to users who would then process them for geophysical parameters. The value of the observations has been recognized by the community in a number of ways such as through publications [*SCIGN Publication List*, 2002] and new projects and feedback from the SCIGN science Advisory Council (AC). Growth in community interest in the information contained in the data from SCIGN has 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.

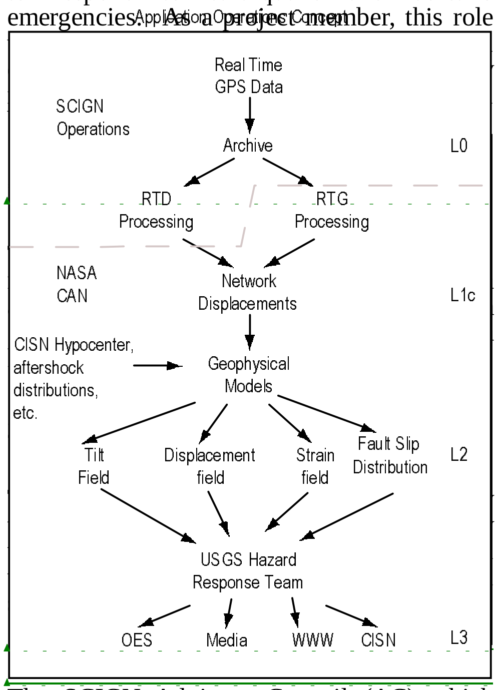
We propose to provide high-level (L1C-L3) data products to the community of geophysicts studying earthquake processes, crustal evolution, and magmatic systems. These data products will be at the level just below interpretation. In addition we will also provide rapid geophysical parameters in response 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 proposed data products in Figure [??] are new products that have been requested by the community of science users through the AC, and the local government users through their participation on the SCIGN Coordinating Board and through the California Spatial Reference Center (CSRC). We plan for these data products to be derived from the SCIGN network initially, and as SCIGN transitions to the multi-agency EarthScope project in the next few years, the scope and basis of data products will be derived from the larger Plate Boundary Observatory (PBO).

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

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

The USGS has substantial depth and contact with emergency mangers and support systems through its congressionally mandated lead role to respond to earthquake and volcano emergencies. As a project member, this role



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

We will follow and expand the AC recommendations and those of NASA's Solid Earth Science Working Group (SESWG) by generating these high level data products 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 and recharge rates; and an event-driven rapid post-seismic deformation. The products will be archived and made available to the scientific community via a web interface.

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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, time-consuming and delicate data processing effort.

Table 1: Proposed products

Data Product	Product Level	Format	Data Product Description	Accessibility	Relevance of Data Services & Primary Users	Production
GPS Observables	*0*	*RINEX*	*RINEX files organized by station*	*GSAC and SCIGN Archive at ftp://lox.ucsd.edu http://sopac.ucsd.edu/dataArchive*	*Raw GPS observable used by scientists, surveyors, and others for calculating geodetic coordinates and their time history*	*Funded through SCIGN project*
Geodetic Time Series	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 any high-level data product. A lower latency and SCIGN combined product has been recommended by the science community through the SCIGN Advisory Council (AC)	Independent processing using GIPSY and GAMIT, followed by verification, validation, and combination into an official SCIGN time series
Velocity Field	2	TBD through negotiations with user communities	Automated daily update of the velocity filed of SCIGN	SCIGN web-site at http://www.scign.org/ as machine readable observations and graphical displays	Long-term, high-resolution monitoring of changes in the Earth's surface addressing ESE goals in Solid Earth Science. Recommended by SCIGN AC and SESWG.	Existing software for strain estimation will be extended to produce automated velocity maps from the SCIGN time series.
Strain and Strain Rate Field	3	TBD	Automated daily update of strain and strain rate fields	SCIGN web-site at http://www.scign.org/ as machine readable	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 an spatial-temporal (S-T) filter
Aquifer undulations	3	TBD	Aquifer discharge and recharge rates provided for water resource management with	SCIGN web-site at http://www.scign.org/ as machine readable observations and		
Earthquake Fault Parameters	3	TBD	Fault slip rates derived from the SCIGN velocity maps will be provided on a long term, and event	SCIGN web-site at http://www.scign.org/ as machine readable observations		
Co-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 Co-seismic	Office of emergency services, local authorities, utilities, transportation and media outlets will be the primary users of this	Independent near real time analysis systems will be implemented.

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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.

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. [REFERENCES] 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.

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 uttenberg*, 1936; *Thacher*, 1975; *Harris*, 1998; *Hardebeck et al*., 1998; *Stein*, 1999; *Peltzer et al*., 2001;] (Figure ???). Strain differentials and rates, fault slip rates, aquifer undulation, and co-seismic and post-seismic fault slip rates will be calculated using the methodology of a spatial-temporal (S-T) filter [*Segall and Matthews*, 1997] through the calculation mechanism of the JPL developed Quasi-Observation Combination Analysis software (QOCA) [Dong et al., 1998; http://gipsy.jpl.nasa.gov/qoca]. QOCA is an open structure software which can assimilate a variety of measurements (SAR, EDM, VLBI, SLR) with the GPS station position estimates. QOCA is used all over the world for strain and deformation analysis [*Svarc et al*., 2002; *Dong et al*., 2002; *Gan et al*, 2001; Savage et al., 2001; Hager et al., 1999], and is the tool of choice of the USGS.

*****GAMIT/GLOBK reference here**

The S-T filter is an extension of QOCA software. It estimates the amplitudes of various Green's functions directly, and as a result performs 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 (aquifers) 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

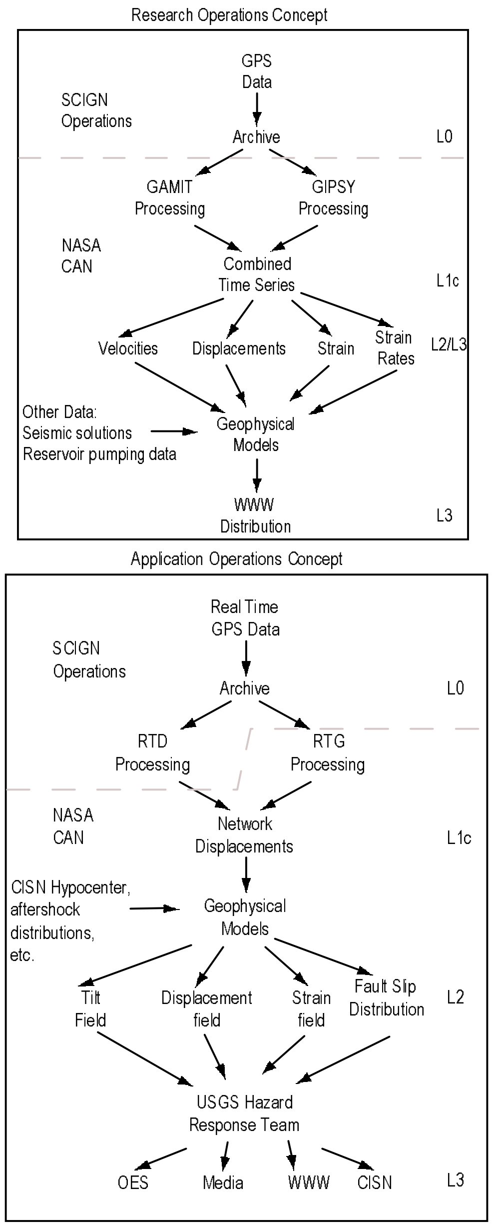
2.2.1.1 Summary of Current Status

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 abput 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 8.1 RDBMS.

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

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

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



2.2.1.2 Objectives

The primary objective of this proposal is the production of higher-level research and application data products listed in Table 1, according to the production scheme outlined in Figure 3. 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/differences in the solutions and feedback this information to the analysis centers. Once a consistent time series is generated, a long-term (years) and short-term (weeks-months) crustal motion model will be calculated. As described earlier, derivatives of the time series will be combined to produce corresponding dilatation and shear-strain maps, and other higher-level products The scientific community representative within SCIGN, the Science Advisory Council, will be periodically consulted during the development and implementation stages of the higher-level products to make sure that the communities' needs are being met.

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

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

(1) Inclusion of the above data types as integrable services in the **GPS Explorer** described in the next section. This is essential for the production of level-2 and above products.

(2) An additional service of the **GPS Explorer** that provides users with the ability to calculate epoch-specific coordinates for any GPS site, using sophisticated time series models. This is of particular use to surveyors and GIS professionals.

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

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

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

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

2.2.2 Data Distribution and User Support

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

(1) Adaptive Seamless Archive System - XML Web Services for GPS Data Discovery, Exchange and Storage

(2) GPS Explorer - An Integrated Data/Metadata Discovery and Research Tool

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

2.2.2.3 Adaptive Seamless Archive System

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

With SIO/SOPAC's extensive experience in the development and maintenance of a seamless archive system we are uniquely suited to this component of our SEEDS proposal. The GSAC software/system developed by SOPAC for UNAVCO uses a variety of web-based software components, a custom communication language, and relies on relational databases at each retailer. This experience lends itself to rapid development of more advanced, integrative, seamless archive features built on Web Services technology. As an international GPS data portal service the GSAC has enormous potential to attract further participation from additional GPS-related agencies/individuals in the United States and abroad. Our development of Web Services for the integration of GPS-related data products into applications with GSAC access, as well as those without, will offer SEEDS a standardized conduit for the GPS world into the broader expanse of Earth sciences applications and decision support systems.

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

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

Besides the "ticket" use of XML to describe a user's request for an ad-hoc dataset, there are many GPS-related products and/or information that could be exchanged among individuals and agencies alike, using an XML data format. This same data could then be made available over an additional XML Web Service for which applications such as the GPS Explorer (described next) could easily utilize. Such services would open the doors for users to request subsets of data files, or just certain pieces of information rather than be burdened by files, formats, and compressions they might be unfamiliar with or unable to deal with on their local machine. In particular, we foresee the immediate need to develop XML schemas/DTDs for the hierarchy of product levels described earlier (see Table 2).

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 "explorer" (or wizard) that will aid users in the GPS community (and beyond) in the location, selection, metadata acquisition, research-oriented analysis and acquisition of GPS site/network-related data, metadata and analytical products This CGI-based tool will allow users to interact with dynamic geodetic content in a variety of contexts, including: mapping interfaces, graphical charts and reports, time series, movies and a myriad of nominal/attribute information about all GPS sites/networks registered in the SOPAC database.

Built to support a large portion of the Southern California Integrated GPS Network (SCIGN) information system, maintained in an Oracle 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 being, 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, 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.

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

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

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

For example, many GPS data centers organize their data collections in hierarchical trees based on traditional file systems starting with data type, then year or GPS week, then serial day of year. When users access an archive through FTP they are actually walking through the file system. Server load can be adversely affected depending on the number of files in each directory, and the number of users traveling through the file system. The VA, communicating with the DDS, could offer this traditional scheme to the user, but it could also provide, for example, an upside down scheme starting with year, then serial day of year, and finally data type. Or, it could start with GPS site, then data type, then year, then serial day of year. The options are vast and, we hope, can be adapted to suit data center contexts beyond those specializing in GPS.

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

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

1. The **Virtual Archive** (VA) CGI application, complete with the ability to be configured by the local data center agency.

2. The SOAP server **Data Delivery Service** (DDS).

3. The XML schema or DTD describing the XML messaging communication between the VA and the DDS.

4. The generic relational database schema (conceptual) applicable to serving a data center with Earth Systems-related data sets.

5. A utility to add, delete, and update data through the DDS.

SIO/SOPAC has experience developing software in a public environment with multiple stakeholders. Open-Source projects are often more free-flowing than development performed in software corporations, evolving over time depending on the interests and demands of the developers involved with the project. We believe that this project has a high potential for software reuse both as a component of future projects and as the basis for customized versions of the software supporting different types of data archives. We also believe that this project represents sufficient technical merit along with being general enough to be a good prototype for demonstrating reusable asset deployment using Open-Source methods and resources.

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

2.4 SEEDS Guiding Principles

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 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 Navistar Consortium (UNAVCO), GPS Seamless Archive (GSAC), California Spatial Reference Center (CSRC), Southern California Earth Quake Center (SCEC), SCIGN, and PBO.

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

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 RDBMS that unifies collection, archive, analysis and dissemination of Level-0 data and metadata on GPS stations. The higher level data products generated under this project will be added to the database for access by users.

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

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

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

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

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

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

2.5.1 Data Format and Content

There are many different types of data that already exist. Some of the data formats are de facto standards, such as RINEX and SINEX. RINEX is widely accepted as a standardized exchange format for GPS data observations and is actively maintained and adapted by the GPS community. Likewise, SINEX is widely accepted as a standardized user exchange format. Different groups are developing other data types; such as the XML-based site information logs for GPS metadata by SIO (level-0) and GPS time series by JPL (level-1).

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

2.5.2 Interface Standards

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

2.5.3 Software Reuse

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

2.5.4 Evolution

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

2.5.5 Technology Utilization

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

2.5.6 Levels of Service

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

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

2.5.7 Metrics

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

2.6 *Compliance with REASoN Project Requirements*

The project will maintain a WWW-compliant presence at www.scign.org. This web site will be enhanced over its current capabilities to provide high level data and information to the

Deleted: *<#>¶*
<#>Non-proprietary Data for the ESE Data Systems Cost Model¶
<#>Provide non-proprietary data for the ESE Data Systems Cost Model currently under development (see the SEEDS homepage Cost Estimation link for information on the model).¶
¶
<#>Participation of the Project Investigators and Staff on SEEDS Working Groups¶
<#>The proposal will discuss the participation of the project investigators and staff on SEEDS Working Groups. Discuss special expertise the project collaborators can contribute to SEEDS study activities (Appendix J). At a minimum, NASA expects the projects to participate in at least one Working Group at a level of .25 FTE. The proposal should discuss the contributions the project will make to its preferred and, at least, one other alternate working group.¶
¶
<#>Projects can optionally propose to develop an Open-Source Prototype/testbed for the Architecture and Reuse Working Group. Projects proposing to develop an open-source prototype should discuss their technical approach for completing the prototype in detail and should specifically address contributions they will make to the SEEDS Architecture and Reuse study goals.¶

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

a) *Each proposal should include a negotiated process for determining whether there is a need to archive data with a NASA Distributed Active Archive Center (DAAC), a NOAA Data Center, or a World Data Center for final disposition and distribution of the data set. For example, a NASA DAAC might utilize its User Working Group to determine the priority for acquiring a particular information set. Each information set must be accompanied with clear, comprehensive, and concise documentation so that specialists and non-specialists alike will be able to understand how the data can be used.*

SIO to address this point

2.7.2 Distribution of End Products

b) *Adequate funds must be included in the proposal to ensure the smooth distribution the end-products of research activities, including complete documentation, applicable metadata and supporting peer-reviewed articles. Proposals should include concurring correspondence from the selected archive to ensure that the included funding profile is realistic.*

SIO to address this point

2.8 *Additional Application REASoN Project Elements*

2.8.1 Description of Application

The USGS Earthquake Hazards Program is charged with a task of national importance. USGS is responsible for scientific earthquake response and for communicating results to researchers, the media, and emergency responders; this is a Type 1 application using NASA data products to support decisions made for Disaster Management (National Application #7, Appendix 7). USGS provides 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.

These earthquake response data products differ from those produced by the SCIGN Solution Center (SSC). To verify and validate the small deformations (a few mm/yr at each station) that occur during the inter-seismic period, the SSC will use two independent solutions from JPL and SIO, a sophisticated reference frame adjustment, and the most precise orbit available. For earthquake response, the near-field displacements are on the order to 10 cm to several meters. Therefore some precision may be sacrificed in order to produce fast results. The earthquake response application uses rapid or predicted orbits to produce one solution in a nominal ITRF2000 reference frame. Comparison of USGS fast results to more precise JPL and SIO co-seismic displacements for the M 7.1 1999 Hector Mine earthquake showed discrepancies of a few mm.

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.

		Roles and Responsibilities		
Task		***JPL***	***SIO***	***USGS***
Project Management		**Leads Project**	Leads SIO activities	Leads USGS activities
Data Retrieval			Backup data retrieval	**Primary data retrieval ***
Daily Data Processing		**Process network data with GIPSY ***	**Process network data with GAMIT ***	
Near Real Time Data Processing		**Process network data with RTG**	**Process network data with RTD**	
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	Time Series	Generation of GIPSY time series	Generation of GAMIT time series	**Generation of combined time series from combined solution ***

		Roles and Responsibilities		
	Velocity Field	Support generation of combined velocity field	Support generation of combined velocity field	**Generation of combined velocity field (SCIGN Velocity map) ***
	Strain and Strain Rate Field	**Modify existing software for spatial and temporal filtering**	Consult on 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**	**Support Near Real Time Data retrieval**	**Assimilation of deformation measurement with seismic data + interface with authorities / utilities/ media ***
SEEDS		Support project participation in SEEDS	**Participation in SEEDS Technology Infusion Work Group ***	Support project participation in SEEDS
Archive			**Maintenance and Development of SEEDS compliant SCIGN archive ***	
Product Delivery / WWW		Product support	**Development and maintenance of www.scign.org ***	**Interact and implement feedback from scientific community ***

3.0 PREFERENCES FOR PARTICIPATION IN THE FEDERATION AND SEEDS WORKING GROUP(S)

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 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 Navistar Consortium (UNAVCO), GPS Seamless Archive (GSAC), California Spatial Reference Center (CSRC), Southern California Earth Quake Center (SCEC), SCIGN, and PBO.

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

The participation of this project in the ESIP Federation is 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 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)[2], ??? 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.

4.0 METRICS

Successful respondents will be required to submit metrics indicating the state of the project and the success in meeting project and NASA objectives. All projects will be required to meet the metrics established and adopted by the Federation. In addition, and to the extent that the Federation metrics do not provide the same information, the projects will respond to the metrics described in Section 3.4.5)g. and provide the following on quarterly basis:

SCIGN is familiar with reporting metrics to NASA in accordance with the Government Performance Results Act (GPRA) and provided these 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, etc. Under this project, we will provide these metrics to NASA and will work with the Federation to establish and report on these metrics.

SIO to address this point

4.1 Inputs

1) *Inputs: Data, models, and other information and products used to complete and carry out the project. This includes human and physical capital and materials required for the research, applications or education process or function. It describes the cost of doing business and includes: budget, number of researchers/teams, participating users, data required, and use of other assets e.g., ancillary data.*

4.2 Outputs

2) *Outputs: Immediate observable products of the project. Outputs include data sets and models developed, number of presentations made, papers published, number of graduate students supported (if applicable), and other direct results of the project.*

4.3 Outcome

3) *Outcome: Longer term results to which the project contributes such as understanding gained, applications demonstrated, resulting programmatic decisions enabled.*

4.4 Impact

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

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

5.0 MANAGEMENT APPROACH

5.1 Management Approach

SCIGN is governed by a set of bylaws http://www.scign.org/bylaws.html and by a Coordinating Board that operates as a standing committee of the Southern California Earthquake Center (SCEC). The coordinating board consists of representatives from SCEC, the United States Geological Survey (USGS), the Jet Propulsion Laboratory, Scripps Institution of Oceanography of the University of California, San Diego (SIO), NASA, the National Geodetic Survey (NGS), the California Department of Transportation (Caltrans), the California Committee on Reference Stations (CORS) and the Center Director and Science Director of the Southern California Earthquake Center, who are members ex-officio. The day-to-day operations of the network are managed by an Executive Committee 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. The EC and CB are chaired by a board member who is elected by the board at the annual meeting. Interagency funding issues are resolved by an interagency steering committee composed of member representatives from the NSF, USGS, and NASA.

The management of this project is modeled after the successful management of the implementation of the SCIGN network by JPL for NASA. The PI will have overall responsibility for the project and will work with the project members at the partner institutions to implement the tasks. The lead Project Members at SIO and at the USGS will be responsible for the work efforts at their institutions.

5.2 Coordination Between Participants

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

5.3 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 approved by the SCIGN CB.

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

3. *Automation of Level 1 Data Products*
Solicit user community feedback at the SCIGN and UNAVCO annual meetings; implement combined time-series production; automate daily and sub-daily data processing and develop performance metrics; enhance

SCIGN web page to deliver products based on input from SEEDS Standards and Metrics working groups. *Success criteria*: Combined SCIGN time series available on the SCIGN web page.

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

5. *Automation of Level 2 Data Products*
Solicit user community feedback at the SCIGN and UNAVCO annual meetings; implement velocity field production; automate daily and sub-daily data processing and develop performance metrics; enhance SCIGN web page to deliver products based on input from SEEDS Standards and Metrics working groups. *Success criteria*: SCIGN velocity field available on the SCIGN web page.

6. *Level 3 Product Development - Geophysical Parameters*
Implement S-T filter algorithm and develop software; define input and output formats and user interface; validate strain rate, aquifer undulations and fault slip rates with independent data sets; integrate into QOCA; participation in SEEDS Standards working groups; solicit user community feedback at the SCEC annual meeting. *Success criteria*: prototype operation of S-T filter software; validated geophysical parameters.

7. *Automation of Level 3 Data Products*
Solicit user community feedback at the SCIGN and UNAVCO annual meetings; Implement geophysical parameters production; automate daily and sub-daily data processing and develop performance metrics; enhance SCIGN web page to deliver products based on input from SEEDS Standards and Metrics working groups. *Success criteria*: SCIGN strain-rates, aquifer undulation, and fault slip-rates available on the SCIGN web page.

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

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

5.4 *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, the manager of the SCIGN archive, and a lead member of the 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 community represented by the CSRC.

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.

Table 3. Milestone Schedule

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Task	FY03		FY04		FY05		FY06		FY07	
	JUN	DEC	JUN2	DEC2	JUN3	DEC3	JUN4	DEC4	JUN5	DEC5
1. System Requirements Definition and Design										
2. Level 1 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 Level 1 Data Products										
User community feedback - SCIGN & UNAVCO annual meetings										
Implement combined time series production										
Daily										
Sub-daily										
Develop performance metrics										
SEEDS metrics WrkGrp Participation										
SEEDS Standards WrkGrp Participation										
Enhance web interface to deliver L1 products										
4. Level 2 Product Dev. - Velocity Field										
Velocity scheme development										
Output format definition										
User community feedback - SCEC annual meeting										
SEEDS Standards WrkGrp Participation										
5. Automation of Level 2 Data Products										
User community feedback - SCIGN & UNAVCO annual meetings										
Implement velocity field production										
Daily										
Sub-daily										
Develop performance metrics										
SEEDS metrics WrkGrp Participation										
SEEDS Standards WrkGrp Participation										
Enhance web interface to deliver L2 products										
6. Level 3 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 Level 3 Data Products										
User community feedback - SCIGN & UNAVCO annual meetings										
Implement geophysical parameter production										
Daily										
Sub-daily										
SEEDS metrics WrkGrp Participation										
SEEDS Standards WrkGrp Participation										
Enhance web interface to deliver L3 products										
8. Integrate with independent Data Products										
Develop interfaces for Level 3 Product Generation										
Integrate with system										
User community feedback - SCEC annual meeting										
SEEDS Standards WrkGrp Participation										
9. Incorporate PBO data into products										

6.0 PERSONNEL

The biographical sketches and publication lists for the PI and each PM can be found at the end of this section.

Deleted: *For each PI or PM, submit a brief biographical sketch referencing related work, along with citations of the most relevant recent publications and any exceptional qualifications covering the past five years. The biographical sketch and publications list shall not exceed one page per PI or PM. A summary of other participants shall not exceed one page. Include qualifications for participants involved in technology development.¶ The Principal Investigator is responsible for direct supervision of the work and participates in the conduct of the project regardless of whether or not compensation is received under the award. Omit social security number and other personal items which do not merit consideration in evaluation of the proposal. Give similar biographical information on other senior professional personnel who will be directly associated with the project. Give the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Universities should list the approximate number of students or other assistants participating in the proposed effort, together with information as to their level of academic attainment. Any special industry-university cooperative arrangements should be described.¶*

Frank Webb: Dr. Webb is the Principal Investigator with overall responsibility for the performance of the work. He has over 12 years of experience at JPL where he has been a Senior Member of the Technical Staff, a Project Element Manager, Proposal Manager, and PI on several NASA space geodetic proposals. Currently, he is the group supervisor of the Satellite Geodesy and Geodynamics Systems Group and an intern in the Mission Architect Development Program at JPL. He received his PhD from Caltech in 1991 and has worked at JPL since 1990.

Sharon Kedar:. Dr. Kedar is a member of the technical staff at the Satellite Geodesy and Geodynamics Group at NASA's Jet Propulsion Laboratory. He received his Ph.D. in Geophysics from the California Institute of Technology in 1996, where he specialized in volcano seismology. Prior to his arrival to JPL, Dr. Kedar was involved in all aspects of volcanic data acquisition, processing, analysis and modeling at the United States Geological Survey, Volcano Hazards. He was part of several field installations in various active geothermal areas (Kilauea, Long Valley, Coso), and was part of the crisis team that monitored Long Valley Caldera during the summer of 1997 dramatic increase of activity. At Caltech Dr. Kedar lead a development and research team which built an instrument that successfully measured underwater pressure and temperature inside Old Faithful Geyser, Yellowstone [*Nature*, 1996].

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8.0 PROPOSED COSTS

If proposals include an optional technology development component or an open source prototype demonstration, these costs will be uniquely identified and totaled by year as an identifiable cost.

8.1 Budget Breakdown by Fiscal Year

8.2 Facilities and Equipment

9.0 COMPUTING EQUIPMENT

JPL	JPL computer facilities consist off
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.

10.0 MASS STORE

JPL	Raid Zone
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 as a relational database). The Library is well suited for large datasets with large file sizes.
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.
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 8.1 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.
11.0 SOFTWARE	
JPL	GIPSY (GPS-Inferred Positioning System) QOCA (Quasi-Observation Combination Analysis) is a software package which was desined 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.
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

<u>INSTRUCTIONS FOR BUDGET SUMMARY</u>

1. *<u>Direct Labor (salaries, wages, and fringe benefits)</u>: Attachments should list th e number and titles of personnel, amounts of time to be devoted to the grant, and rates of pay.*

2. *<u>Other Direct Costs</u>:*
   a. *<u>Subcontracts</u>: Attachments should describe the work to be subcontracted, estimated amount, recipient (if known), and the reason for subcontracting.*
   b. *<u>Consultants</u>: Identify consultants to be used, why they are necessary, the time they will spend on the project, and rates of pay (not to exceed the equivalent of the daily rate for Level IV of the Executive Schedule, exclusive of expenses and indirect costs).*
   c. *<u>Equipment</u>: List separately. Explain the need for items costing more than $5,000. Describe basis for estimated cost. General purpose equipment is not allowable as a direct cost unless specifically approved by the NASA Grant Officer. Any equipment purchase requested to be made as a direct charge under this award must include the equipment description, how it will be used in the conduct of the basic research proposed and why it cannot be purchased with indirect funds.*
   d. *<u>Supplies</u>: Provide general categories of needed supplies, the method of acquisition, and the estimated cost.*
   e. *<u>Travel</u>: Describe the purpose of the proposed travel in relation to the grant and provide the basis of estimate, including information on destinati on and number of travelers where known.*
   f. *<u>Other</u>: Enter the total of direct costs not covered by 2a through 2e. Attach an itemized list explaining the need for each item and the basis for the estimate.*

3. *<u>Indirect Costs</u>**: Identify F&A cost rate(s) and base(s) as approved by the cognizant Federal agency, including the effective period of the rate. Provide the name, address, and telephone number of the Federal agency official having cognizance. If unapproved rates are used, explain why, and include the computational basis for the indirect expense pool and corresponding allocation base for each rate.*

4. *<u>Other Applicable Costs</u>: Enter total explaining the need for each item.*

5. *<u>Subtotal-Estimated Costs</u>: Enter the sum of items 1 through 4.*

6. *<u>Less Proposed Cost Sharing (if any)</u>: Enter any amount proposed. If cost sharing is based on specific cost items, identify each item and amount in an attachment.*

7. *<u>Total Estimated Costs</u>: Enter the total after subtracting items 6 and 7b from item 5.*

** Facilities and Administrative (F&A) Costs*

Budget Summary

For period from ___________ to __________

				| NASA USE ONLY |		
			A	**B**		**C**
1.	Direct Labor (salaries, wages, and fringe benefits)					
2.	Other Direct Costs:					
	a. Subcontracts					
	b. Consultants					
	c. Equipment					
	d. Supplies					
	e. Travel					
	f. Other					
3.	Indirect Costs *					
4.	Other Applicable Costs					
5.	**SUBTOTAL—Estimated Costs**					
6.	Less Proposed Cost Sharing (if any)					
7.	**Total Estimated Costs**					XXXXXXX
8.	**APPROVED BUDGET**		XXXXXXX	XXXXXXX		

*Facilities and Administrative Costs.

12.0 COOPERATIVE AGREEMENT PAYMENT SCHEDULE

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Table X 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 a verifiable event in the project that is defined as the delivery of science information and/or servicesand participation in and support for the Federation and SEEDS

13.0 CURRENT AND PENDING SUPPORT

Following the budget section, the proposal shall contain a summary of current and pending Federal support of all projects with substantial involvement of the PI and each PM for whom support is requested. The information content shall include: source of support, project title with grant or contract number, award amount by Government fiscal year, and total award amount, award period, level of effort in person-months, and the location where the work is to be performed.

Person	Source of Support	Project Title (Grant or Contract #)	Award Amount by Fiscal Year	Total Award Amount	Award Period	Level of Effort	Location of Work

14.0 SPECIAL MATTERS

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Include any required statements of environmental impact of the work, human subject or animal care provisions, conflict of interest, or on such other topics as may be required by the nature of the effort and current statutes, executive orders, or other current Government-wide guidelines.

Respondents should include a brief description of the organization, its facilities, and previous work experience in the field of the proposal. Identify the cognizant Government audit agency, inspection agency, and administrative contracting officer, when applicable.

All commercial awardees will be subject to terms and conditions under NASA Grant and Cooperative Agreement Handbook, Part 1274, Sections 901 through 942 unless otherwise indicated in this CAN, when Cooperative Agreements are negotiated after notification of selection. Respondents should pay careful attention to these referenced provisions and conditions and indicate in their proposal if they take exception to any of these terms and conditions.

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MS Word Styles Recommend by JPL

The following MS Word Styles are defined in this template:

Body

- Bullet 1
- Bullet 2

Equation

Figure 1:Figure Caption

1.0 HEADING 1

1.1 Heading 2

1.1.1Heading 3

1.1.1.1Heading 4

Picture (for use with images and illustrations)

Table 1:Table Caption

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Theme Statement

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