



Draft: White Paper: Data Products, Formats and Applications of Real-Time GPS Position Data Products for Science and Hazard Monitoring

Results from a Community Workshop on Real-Time GPS Position Data Products and Formats held in Boulder, Colorado, March 26-28, 2012

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Introduction

Recent advances in GPS technology and data processing are providing position solutions with centimeter-level precision at high-rate (1 Hz) and low latency (*i.e.* the time required for data to arrive for analysis, in this case less than 1 second). These data have the potential to improve our understanding in diverse areas of geophysics including properties of seismic, volcanic, magmatic and tsunami sources, and thus profoundly transform rapid event characterization and warning. Scientific and operational applications also include glacier and ice sheet motions; tropospheric modeling; and space weather. Processed Real-Time GPS (RT-GPS) data will require formats and standards that allow this broad community to use these data and associated meta-data in existing research infrastructure.

A workshop hosted by UNAVCO and funded by the U.S. National Science Foundation (NSF) brought together 76 participants representing a spectrum of research fields, including geodesy, seismology, tropospheric weather, space weather and natural hazards with participants spanning the Western Hemisphere. Various educational institutions and cooperatives as well as Federal and State agencies including UNAVCO, IRIS, NSF, NASA, IGS, NOAA, NR-CAN and the USGS participated. The objective was to define a strategic plan for the current and future needs of various user communities for RT-GPS position data products, processing, formats, standards, analysis and distribution.

The community recognized broad support for RT-GPS and in particular the scientific, societal (hazards) and operational value of data products derived from these streams. The workshop members recommended that at least two focused working groups be formed with membership from the respective user communities. Participants concluded that UNAVCO should serve as the primary coordinator for facilitating these working groups.

The first workshop recommendation was that a working group on RT-GPS formats and metadata be formed to define and identify formats that suit the each user community. For example the seismic community has a deeply developed set of tools using the SEED format and primarily requires only position time-series. However, the nature of geodetic solutions and recent advances such as the availability of integrated geodetic and seismic time series may require expanded formats that contain information about parameter uncertainty, covariance and data quality.

The second recommendation was to form a working group to critically evaluate the robustness of RT-GPS time position series. Workshop participants presented multiple processing strategies and examples using various software packages. It was recognized that the best approach to employ depends on the application, with different strategies optimizing different parameters (*e.g.* precision, accuracy, completeness or geographic coverage). This working group will coordinate an open community exercise where data processors provide solutions based on common RT-GPS data sets. The results will be used to evaluate the effects of noise, displacement events, and incomplete data (including the impact of communications failures) on the resulting solutions. This working group will engage NSF and NASA program managers to develop support for this activity.

The workshop participants also recommended a strategy be developed for producing these data products for existing large geodetic networks like the EarthScope Plate Boundary Observatory (PBO).

Summary of Workshop

The workshop titled “*Community Workshop on Real-Time GPS Position Data Products and Formats*” was proposed to the NSF in summer of 2011, funded in early 2012 and held in Boulder Colorado on March 26-28, 2012. The workshop was logistically supported by UNAVCO. Significant support and representation from a broad range of US Federal and international organizations was present including UNAVCO, IRIS, NSF, NASA, IGS, NOAA, NR-CAN and the USGS.

The workshop was two and one-half days in length consisting of five plenary sessions with each session roughly proportioned into 60% verbal presentations and 40% open discussion. The agenda is attached as Appendix A.

Introductions were given in person by NSF representative Dr. Greg Anderson and, via phone and loudspeaker, NASA representatives John LaBrecque and Craig Dobson. Greg Anderson indicated that the NSF would like to see a “plan for a community based system for recording, archiving and processing of all the Federally-funded GPS stations in the western US” with the ultimate goal a proposal to the NSF based on this report. Of particular interest was the question inquiring if NSF was “willing to fund nationwide RT-GPS.” It was suggested that the NSF would like to see a plan and proposal for RT-GPS related to aspects of RT-GPS, which would have broad impacts and long-term science objectives. John LaBrecque noted the recent strong advancements, supported by NASA, in GNSS infrastructure and processing. In particular he noted NASA interests in airborne SAR, integrity assurance of GNSS constellations, science opportunities and RT-GPS applications and capabilities for disaster mitigation. It was also noted that JPL developed GIPSY-OASIS-II for global GPS/GNSS applications and that this software package is currently used for navigation applications within the FAA. Craig Dobson, the NASA Program Manager for Natural Hazards, noted NASA investments into RT-GPS networks for hazard monitoring and early warning systems. In particular tsunami hazard mitigation. In particular, the goal of “timeliness, accuracy, precision, and sustainability for long-term operation of non-seismic source network for rapid determination of earthquake magnitudes [from GPS] for tsunami early warning.” NASA currently has the pieces in place for a prototype early warning system and has active international initiatives in Russia, the Caribbean and Central America to improve monitoring.

A brief workshop report was published in Eos in 2012 (*Mencin, D., W. C. Hammond and J. Langbein, (2012), Applications of real-time GPS for science and hazard monitoring, Eos Trans. AGU, 93(50), 526*).

Plenary Session 1: Data Users and Applications. Chair: Bill Hammond.

Session 1 provided an overview of whom, from the UNAVCO and broader community, is using the data and data products along with its scientific and societal applications. This session highlighted the scientific value of real time data and data

products showing that the improvement of the EarthScope PBO's ability to record real-time high-rate data will result in new and improved science and science products. Specifically this session demonstrated the need for higher-level products based on real-time GNSS and that the feasibility of these data products has already been demonstrated. Highlights, comments and observations from this session include:

- There is a need for a uniform message to the media on the magnitudes for large earthquakes. It is damaging to the *science of hazards* if the media hear multiple messages (while the USGS maintains primary responsibility for hazard warnings under the Stafford Act, many regional data centers broadcast research grade information about earthquakes and other natural hazards).
- There is a need to leverage resources across agencies to provide consistent and authoritative information and clearly define appropriate roles and responsibilities.
- RT-GPS solves specific problems that arise when attempting to derive displacement from acceleration data.
- RT-GPS has proven to be useful and relevant application to finite source modeling of large earthquakes and is useful for tsunami hazard assessment and warnings.
- RT-GPS, in particular, will significantly speed up final moment determination of large earthquakes.
- There are several prototype networks already in operation (NSF, NASA and the USGS) with specific targets of large earthquakes, volcanoes and tsunamis.
- RT-GPS/GNSS is highly multi-faceted with applications in the solid earth sciences, natural hazards, volcanoes, tsunamis, structural monitoring, terrestrial weather, and space weather.
- There is general agreement that extensive research and testing that must be completed before operational deployment.

Speaker	Talk Title
Richard Allen	Applications of real-time GPS: A network-seismologist's perspective.
Diego Melgar	CMT Solutions, Tsunamis and Structural Monitoring
Brendan Crowell	Earthquake Early Warning and Finite Fault Slip
Ken Hudnut (also for Bill Leith)	Real-time GPS integration for prototype earthquake early warning and near-field imaging of the earthquake rupture process
Hans-Peter Plag	GPS-Determined Surface Displacements and Tsunami Early Warning: Potential, Obstacles, and Current Capabilities
Mike Lisowski	Real-time Volcano Deformation Monitoring
Paul Bodin	RTGPS operations within a regional seismic network
John Braun	Opportunities of RTGPS for Severe Weather Applications

Plenary Session 2: Data and Data Processing Strategies. Chair: Sue Owen.

Session 2 reviewed current community and user data and data product requirements and data processing strategies. This session provided an overview of exiting RT-GPS processing software packages and user experiences with these software packages. In particular, this session explored what data processing strategies apply to the current scientific objectives and what are the requirements for these objectives. This session established that RT-GPS data should be made available to multiple users and processing platforms. In addition the academic community should work with the commercial vendors to establish robust, reliable and open operational systems that can be used for critical systems like earthquake early warning systems. Highlights, comments and observations from this session include:

- Both double difference and Precise Point Positioning (PPP) methods are viable and required for robust operational solutions.
- The best processing method will be determined by problem being studied.
- Significant advances have been made in RT-GPS PPP solutions.
- There are many commercial and academic software packages available for multiple processing strategies.
- Community should adopt a model similar to PBO where data is processed in multiple ways and evaluated against each other for a particular application.
- Common formats and robust networks are still a major impediment.

Speaker	Talk Title
Tom Herring	TrackRT: Methods, Performance, and Output Formats
Geoff Blewitt	An Operational Precise Point Positioning Service with Ambiguity Resolution Robust to Large Random Displacements
Jim Johnson and Ted Iwabuchi	RTNet & RTES (real time epoch server) software
Ulrich Vollath	Trimble Contributions to UNAVCO and the Earth Science Community
Jianghui Geng	Precise Point Positioning with Ambiguity Resolution
Yehuda Bock	Precise Relative Positioning
Tim Melbourne	
Yoaz Bar Sever	GDGPS Software

Plenary Session 3: Data Formats. Chair: Ken MacLeod.

Speaker	Talk Title
Ken MacLeod and Loukis Argotis	RTCM-SC104 GNSS Data Formats for Real-Time IGS Applications
Kendall Ferguson	RTCM SC-104 Membership, Objectives, and Standard Operating Procedures
Yehuda Bock	RYO Format

Doug Neuhauser	SEED - Its Strengths and Weaknesses for Derived Time Series Data
Lou Estey and Ken Macleod	The BINEX GNSS Format

Plenary Session 4: Data Archiving and Distribution. Chair: Adrian Borsa.

Speaker	Talk Title
Harvey Benz	Comprehensive seismic monitoring: An NEIC perspective
Michael Schmidt, Herb Dragert, Yuan Lu, Ken MacLeod, Simon Banville	Real-time GPS: Comparison and Display of Different Analysis Techniques
Neil Spriggs	Apollo Server
Mindy Squibb, Ellen Yu, Yehuda Bock, Rob Clayton, Diego Melgar, Brendan Crowell, and Anne Sullivan	Real-Time GPS Data Archiving and Distribution by California Real Time Network and Southern California Earthquake Data Center
Frank Vernon	Sensing the Environment - Integration of Data Streams

Plenary Session 5: Technology Requirements – Network Design. Chair: David Mencin.

Speaker	Talk Title
Ken Austin	UNAVCO Requirements and Experiences in Upgrading the Cascadia Portion of the PBO Network to Real-Time
Ken Hudnut	Real-Time Geodesy: “What are the next big things?”

Workshop Recommendations

Workshop participants would like to acknowledge that NSF and NASA supported research in real-time GNSS directly benefits the hazard community. This is a positive outcome that is supported by basic research in geophysics, GPS data processing, and RT-GPS network development, installation and operations. *It is obvious that common ground exists between interested agencies (e.g. NSF/NASA/USGS/NOAA) and it is recommended that open discussions about the support of geodetic networks and related science should be encouraged and continue.*

The workshop participants would like to reaffirm the broad applications that RT-GPS supports, in particular those that relate to basic research and natural hazards. The overall summary of the potential uses of RT-GPS can be summarized as follows:

- Science applications that RT-GPS could have broad impacts on and fulfill long-term science objectives include but are not limited to: earthquakes including pre and post-seismic processes and early event characterization, tsunamis, volcanoes, lahars, landslides, cryosphere, hydrosphere including soil moisture and snow levels, oceanography, sea level change, troposphere/terrestrial weather and ionosphere/space weather.
- Operational or societal applications that RT-GPS could have broad impacts on include: natural disaster early warning, quality control of GNSS data (ambiguities), station integrity monitoring, emergency response, nuclear test monitoring, and positioning aircraft (e.g. UAV). In addition, while requiring significant resources, real-time networks are inherently more efficient to operate. These networks support science and are supported by science.
- Commercial applications: land surveying, navigation, effects of land/sea bottom motion on navigation, structural monitoring (e.g. in oceans – oil platforms), radio-frequency interference monitoring, autonomous vehicles, and possibly many more.

The above applications are not easily separable. It is recommended that one unified RT-GPS system and network be developed to support them all.

It is further recommended that UNAVCO form two working groups: the first working group to focus on standardization of formats for data, time series and meta-data and a second to critically evaluate the robustness of real-time GPS solutions. The above committees will report to UNAVCO, taking into account the new structure of UNAVCO governance.

Working group on Real Time GPS formats and metadata:

Charge: Develop specifications for information and data fields that should be included in GPS/GNSS RT data and displacement formats. This includes the content, products, and all associated metadata. The working group should consider and possibly include in its

membership a broad set of communities including solid earth, atmospheres, oceans, and cryosphere ensuring that data relevant to these communities are incorporated into the format.

This group should consider the following points from the workshop in any proposed data format specification:

- SEED should be supported (see next point for specifics).
- Independent of the adopted format for geodetic data/time series, it should contain all parameters that geodesists deem to be important. Accordingly, the adopted format should not be limited to what can fit into seismic-style data formats such as SEED. Whenever data in adopted format are provided, SEED and/or tools for converting to SEED should also be provided so that the data are easily accessed and used by seismologists. UNAVCO should maintain tools that convert data to SEED.
- All displacement time series data provided should be provided with explicit meta-data so that users know what kind of solutions they have (*e.g.* nominal precision as measured by RMS in east coordinate, frame, PPP vs. relative motions, etc.)
- This group should also consider formats and protocols such as BINEX, [E]RYO, RTCM, etc. The working group should also involve representatives from IGS, SOPAC, and UNAVCO.

Working Group on Evaluation of Real-Time GPS Time Series:

Charge: With the goal of characterizing stability and improving software and higher level products based on real-time GPS time series, this group will coordinate an open community activity where data processors can provide solutions based on common sets of RT-GPS data which simulate real world scenarios and events. This group will devise exercises and tests to compare and contrast processed results from different participants, processing strategies, and software packages. They will facilitate an additional effort to assess the results with an analysis of time series similarities and differences to evaluate robustness and effectiveness. The working group will engage program managers from appropriate sponsors (*e.g.* NSF/NASA) to see if they could support this community activity by possibly offering funding to contributing participants and/or the team that provides analysis of results (or stimulate the community to write proposals for this effort).

The exercise should measure the effects of the following on GPS time series and it's derived products:

- background noise
- antenna movement (steps, linear trends, sine waves, realistic earthquake-like motions)
- receivers dropping out and coming back online (realistic communications)
- interruption of communications (bulk regional failures due to specific carriers of an actual event)
- satellites rising and setting and various constellation outages

- differences in performance between real-time and simulated (retroactive) real-time.

This community exercise could partially follow the model of recent SCEC-organized events like the transient detection exercise and community modeling exercises.

Makeup of this committee should include people who are familiar with, as users of, GPS time series, what their issues are, what the error sources are. The group will not solely be composed of GPS data processors, but should also include end users (modelers and possibly cognizant response agencies). Group members should be aware of the different processing strategies, what types of errors are in the results, and have a broad view of the applications.

It was specifically requested at the workshop that the following points are considered in this working group:

- That UNAVCO should evaluate the robustness and accuracy of GPS/seismic data integration.

- That UNAVCO should buy Japan's Geonet dataset from the Tohoku-Oki event and make this data available to the US science community. Raw high-rate GPS data from other events should be collected, as well, and an event archive should be created. The data from major earthquake should be post-processed and provided.

- That UNAVCO should save both the 'raw' real-time data and also the 'fixed or corrected' data, which includes data that comes in late. Products that were used in real time should also be saved (*e.g.* clocks and orbits), so the solution could be reconstructed as if it were being done in real time.

Appendix A – Workshop Agenda

FINAL DRAFT

Monday, Mar. 28, 2012

8:00 **Breakfast** (provided)

9:00 Welcome and Charge: Chuck Meertens (UNAVCO)
NSF Comments: Greg Anderson (NSF)
NASA Comments: John LaBrecque (NASA)
USGS Comments: Nancy King (USGS)

9:30 Session 1: Data Users and Applications. Chair: Bill Hammond.

Overview of who is using the data and its applications for the UNAVCO and broader community. *15 minute talks with 10 minutes of discussion after each.*

Earthquakes

Richard Allen (title TBD)

Diego Melgar, (Scripps), "CMT Solutions, Tsunamis and Structural Monitoring"

Brendan Crowell, (Scripps), "Earthquake Early Warning and Finite Fault Slip"

Ken Hudnut, (USGS): "Real-time GPS integration for prototype earthquake early warning and near-field imaging of the earthquake rupture process"

Tsunamis

Hans-Peter Plag, (UNR), (title TBD)

Volcanoes

Mike Lisowski, (USGS) (title TBD)

Seismic Networks

Paul Bodin, (UW), Integrating RTGPS Within A Regional Seismic Monitoring Network - Operational Backdrop (title TBD)

Weather:

John Braun (UCAR) (title TBD)

12:30 Lunch (provided)

1:30 Session 2: Data and Data Processing Strategies. Chair: Sue Owen. User data requirements and data processing strategies. Including an overview of existing packages and user experiences. *15 minute talks with 10 minutes of discussion after each.*

Tom Herring, MIT, Track RT (title TBD):

Geoff Blewitt, UNR, (title TBD):

Jim Johnson, GPS Solutions, (title TBD):

Brian Frohing, Trimble, (title TBD)

Jianghui Geng, Precise Point Positioning with Ambiguity Resolution

Yehuda Bock, Scripps, Precise Relative Positioning

Tim Melbourne, CWU, (title TBD):

Yoaz Bar Sever, JPL, GDGPS Software (title TBD):

6:00 **Dinner** (provided)

7:00 **Posters**

Tuesday, Mar. 29, 2012

8:00 Breakfast (provided)

9:00 Session 3: Data Formats. Chair: Ken MacLeod, 20 minute talks with 10 minutes of discussion after each.

Ken MacLeod, (title TBD):
Yehuda Bock, (title TBD):
Doug Neuhauser, (title TBD):
Lou Estey, BINEX (title TBD):

12:00 Lunch (provided)

1:00 Session 4: Data Archiving and Distribution. Chair: Adrian Borsa 15 minute talks with 10 minutes of discussion after each.

Adrian Borsa, (UNAVCO), UNAVCO RT GPS Archiving and Distribution
Chad Trabant, (IRIS) IRIS Archiving and Distribution
Harley Benz, (USGS), Archiving and Distribution
Danny Harvey, Antelope Distribution
Neil Spriggs, (Nanometrics), title TBD
Frank Vernon, (UCSD) UCSD Archiving and Distribution
Melinda Squibb & Yehuda Bock, CRTN:

5:30 Dinner (NOT provided – on own)

Wednesday, Mar. 30, 2012

8:00 Breakfast (provided)

9:00 Session 5: Technology Requirements – Network Design (Dave Mencin), 20 minute talks with 10 minutes of discussion after each.

Ken Hudnut, (title TBD)
Dave Mencin, (title TBD):
Yehuda Bock, (title TBD):
Marcello or Walter, (title TBD):

11:00 Session Chair Roll-up

11:30 Closing comments NSF, organizing committee.

12:00 End formal proceedings

12:30 – 4:00 Report Writing (organizing committee).

Appendix B – Participant List

First Name	Last Name	Institution
Richard	Allen	UC Berkeley
Greg	Anderson	National Science Foundation
Erik	Arvesen	Trimble Navigation
Ken	Austin	UNAVCO
Yoaz	Bar-Sever	JPL
Rick	Benson	IRIS Data Management Center
Harley	Benz	U. S. Geological Survey
Geoffrey	Blewitt	University of Nevada, Reno
Yehuda	Bock	Scripps Institution of Oceanography
Paul	Bodin	University of Washington
Fran	Boler	UNAVCO
John	Braun	UCAR/COSMIC
Enrique	Cabral-Cano	Universidad Nacional Autonoma de Mexico, Instituto de Geofisica
Esteban	Chaves	Red Sismologica Nacional (RSN)
Jorge	Crempien	University of California, Santa Barbara
Brendan	Crowell	Scripps Institution of Oceanography
Daniel	Determan	U. S. Geological Survey
Nic	Donnelly	International GNSS Service Central Bureau
Lou	Estey	UNAVCO
Karl	Feaux	UNAVCO
Mathias	Franke	Kinematics
Brian	Frohring	Trimble Navigation
Pamela	Fromhertz	National Geodetic Survey/NOAA
Kendall	Furguson	Trimble Navigation
Jianghui	Geng	Scripps Institution of Oceanography
Christian	Guillemot	U. S. Geological Survey
Gordon	Hamilton	University of Maine
Bill	Hammond	University of Nevada, Reno
Danny	Harvey	Boulder Real Time Technologies
Thomas	Herring	MIT
Ken	Hudnut	U. S. Geological Survey
Ted	Iwabuchi	GPS Solutions Inc.
Paul Alberto	Jarrin	Instituto Geofisico - Escuela Politecnica Nacional – Ecuador

James	Johnson	GPS Solutions Inc.
Nancy	King	U. S. Geological Survey
Attila	Komjathy	NASA JPL
Yevgeniy	Kontar	Federal GEOS Funding
John	Langbein	U. S. Geological Survey
Michael	Lisowski	U. S. Geological Survey
Karen "Sara"	Looney	UNAVCO
Tom	Mackie	Trimble Navigation
Ken	Macleod	Natural Resource Canada, Geodetic Survey Division
Glen	Mattioli	University of Texas at Arlington
Chuck	Meertens	UNAVCO
Timothy	Melbourne	Central Washington University
Diego	Melgar	Scripps Institution of Oceanography
Dave	Mencin	UNAVCO
Meghan	Miller	UNAVCO
Mark	Murray	New Mexico Tech
Douglas	Neuhauser	UC Berkeley Seismological Laboratory
Benedikt	Ofeigsson	Icelandic Meteorological Office
Shelley	Olds	UNAVCO
Susan	Owen	JPL
Ezer	Patlan	University of Texas at El Paso
Bill	Petzke	UNAVCO
Hans-Peter	Plag	University of Nevada, Reno
Christine	Puskas	UNAVCO
Horst	Rademacher	Guralp Systems Ltd.
Felix	Rivera	University of Puerto Rico, Mayaguez Campus
Christian	Rocken	GPS Solutions Inc.
Natalia	Ruppert	GI UAF
Victor	Santillan	Central Washington University
Michael	Schmidt	Geological Survey of Canada
Charles	Sievers	UNAVCO
Lee	Snett	UNAVCO
Y. Tony	Song	JPL
Melinda	Squibb	SOPAC at UCSD

Keith
Walter
Charles
Chad

Andres
Frank
Ulrich
Guoquan
Ellen

Stark
Szeliga
Teng
Trabant

Vasquez
Vernon
Vollath
Wang
Yu

U. S. Geological Survey
Central Washington University
Trimble Navigation
IRIS Data Management System

Servicio Geológico Colombiano

UCSD

Trimble Navigation

University of Houston

California Institute of Technology

Appendix C – Workshop Participant Statistics

Registrants by State

State	Count
CA	23
CO	12
WA	8
NV	3
Puerto Rico	2
DC	2
TX	3
VA	2
Cundinamarca	1
DF	1
MA	1
ME	1
NM	1
AK	1
BC	1
Reykjavik	1
San Jose	1
Ohio	1
Ontario	1
Oregon	1
Pichincha	1

Registrants by Country

Country	Count
USA	62
Canada	2
Colombia	1
Costa Rica	1
Ecuador	1
Iceland	1
Mexico	1
Puerto Rico	1

Registrants by Position Type

Position Type	Count
Other	22
Researcher or research faculty	20
Regular faculty (college or university)	9
UNAVCO Staff	8
Student - Graduate	7
Sponsor	3
Post-doctoral researcher	1

Registrants by Other Position Type

Other Position Type	Count
Federal Government	2
GPS Network Manager	1
IT	1
Management	1
Manager	1
Manufacturer	1
Other	1
Staff	1
Telecommunications Support	1
Contractor	1

Registrants by Highest Degree

Highest Degree	Count
Doctoral Degree	32
Masters Degree	17
Bachelors Degree	9

Registrants by Highest Degree Year

Highest Degree Year	Count
1973	1
1977	1
1978	2
1979	1
1982	1
1983	1

1985	1
1986	1
1987	2
1988	1
1989	3
1990	3
1991	1
1992	1
1994	2
1995	1
1997	2
1998	1
1999	3
2000	1
2001	4
2003	1
2004	1
2005	2
2007	1
2008	2
2009	3
2010	4
2011	3
2012	1

Highest Degree Institution

Institution	Count
Caltech	3
Columbia University	2
Cornell University	1
CU Boulder	1
CWU	1
Engineer	1
Free University Berlin	1
Georgia Institute of Technology	1
Graduate University for Adavanced Studies, National Astronomical Observatory, Japan	1
INPAHU	1
Joseph Fourier University	1
Massachusetts Institute of Technology	3
Northwestern University	1

Ohio State University	2
Pepperdine University	1
Princeton	1
Simon Fraser University, Canada	1
Stanford University	2
Technion - Israel Istitute of Technology	1
UC San Diego	1
UC Santa Barbara	1
UCSD	1
UMBC	1
Univ. British Columbia	1
Univ. of Washington	1
Universidad de Costa Rica	1
University of Alaska Fairbanks	1
University of Calgary	1
University of California, San Diego	1
University of Colorado	5
University of Hamburg, Germany	1
University of Memphis	1
University of Miami	1
University of Missouri	1
University of Nottingham	1
University of Oregon	1
University of Otago, New Zealand	1
University of Puerto Rico	1
University of Texas at El Paso	1
University of Utah	1

Principal Count

Count
26

NSF Funding Count

Count
32

NASA Funding Count

Count
26

USGS Funding Count

Count
21

NOAA Funding Count

Count
8

Other Funding Count

Other Funding	Count
Colombian Geological Survey	1
Industry	1
Land Information New Zealand	1
Private company	2
private foundations	1
SCEC	1
Southern California Earthquake Center (SCEC)	1
State of California	2
State of Washington, Moore Foundation	1
UNESCO, IAEA, EC, Federal GEOS Funding	1

Registrants by Gender

Gender	Count
F	9
M	45
N	16

Registrants by Citizenship

Citizenship	Count
N/A	20

Non US Citizen	8
Permanent Resident	6
US Citizen	36

Registrants by Ethnicity

Ethnicity	Count
Hispanic Or Latino	10
N/A	29
Not Hispanic Or Latino	31

Black or African Amer Count
1
Native Hawaiian/Pacific Islan
Asian Count
6
Caucasian Count

Registrants by Disability

Hearing Impairment
Visual Impairment
Mobility Impairment
Other Disability
1

Registrants by Science Application

Application	Count
General Atmosphere / Ionosphere	2

General	Cryosphere	1
Solid Earth	Earthquake Deformation Cycle	15
General	Geo-Technical	4
General	Geodesy	16
General	Geodesy Education	3
Solid Earth	Glacial Isostatic Adjustment	2
General	Global Environmental Change	4
General	Hydrology	4
Solid Earth	Magma-Induced Deformation	3
General	Natural Hazards	15
General	Oceans	2
Solid Earth	Paleoseismology and Neotectonics	3
Solid Earth	Tectonic Plate Motion	10

Registrants by Science Technique

Technique		Count
LiDAR	Airborne swath mapping	4
Borehole Geophysics	Borehole Strainmeters	2
General	Education	4
General	Equipment purchase	4
General	GeoEarthScope geochronology services	1
General	GPS data collection, data products, and analysis software	15

General	InSAR	8
Borehole Geophysics	Strainmeters	3
LiDAR	Terrestrial laser scanning	4
Borehole Geophysics	Tiltmeters	3