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**Principal Investigator: Geoffrey Blewitt**  
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**Workshops to Establish a Stable North American Reference Frame for EarthScope**

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**PART 1: PROJECT ACTIVITIES**

**GOALS AND OBJECTIVES**

This award funded a proposed series of 4 workshops aimed at coordinating and enabling research to improve and further develop a stable North American reference frame (SNARF). SNARF is defined as a geodetic reference frame attached to stable North America in some useful way for EarthScope investigators. SNARF is therefore fundamental to the generation of operational products of the Plate Boundary Observatory, and is useful for the interpretation of PBO data by EarthScope investigators. The concept was to bring together a relatively small group of interdisciplinary experts as participants of a working group who meet regularly at these workshops. Note that the funding covered only travel of the participants to the workshops, and the research was conducted on a “volunteer” basis (i.e., funded by other means). The eventual goal of the proposed project is to hand off operational and regular maintenance to the joint auspices of the US and Canadian national geodetic surveys, as part of their joint remit to maintain the “North American Datum”. Apart from resolving fundamental research issues related to reference frame definition and realization, the objectives of this project include educating the scientific community on the use of reference frames and their limitations as to the interpretation of station coordinate time series within such defined frames. To meet these objectives, it was proposed to post SNARF workshop reports, presentations, and products on-line at:

[http://www.unavco.org/research\\_science/workinggroups\\_projects/snarf/snarf.html](http://www.unavco.org/research_science/workinggroups_projects/snarf/snarf.html)

**OVERVIEW OF ACTIVITIES**

Activities for this project can be broadly categorized as follows:

1. Workshop activities (including workshop organization).
2. Scientific activities, toward the development of new SNARF products for use by EarthScope/PBO analysis.
3. Educational activities, including web publication at unavco.org, presentations by the participants (e.g., at AGU) on SNARF and SNARF-related research, and journal articles co-authored by the participants.

Each of these three areas of activity are now discussed in further detail.

## WORKSHOP ACTIVITIES

To provide some historical perspective, in 2003 the SNARF Working Group (WG) was officially approved and charged by two very different organizations: (1) UNAVCO Inc, by appointment of the Board of Directors, primarily in preparation for the Plate Boundary Observatory and as a service to UNAVCO member organizations in North America, and (2) the International Association of Geodesy, as part of a more global collaborative effort to standardize reference frames, under the sub-commission "NAREF" (North American Reference Frame), which has organizational links to the national geodetic surveys of both the USA (NGS) and Canada (NRCAN). NAREF is chaired by Mike Craymer (NRCAN) and Richard Snay (NGS), who are both actively participating members of the SNARF WG. Geoff Blewitt was appointed Chair of the SNARF WG in 2003 and since then (as of March 2008) has organized a total of 9 workshops.

The first 4 workshops of the SNARF WG were funded by a prior NSF award (P.I. Kristine Larson, Chair Geoff Blewitt). This award (P.I. Geoff Blewitt) extended the series with an additional 5 workshops. As a result of a no-cost extension to the prior NSF award, both the prior and current awards partially funded two workshops in 2006. (This explains why not all the funding from the current award was expended). The scientific organization of workshops was led by the chair, and conducted by the participants. The logistical organization of the workshop was conducted by UNAVCO Inc staff.

The invited workshop participants cover a broad range of expertise in problems relating to SNARF research and development, ranging from mathematical geodesy and reference frames, to physical Earth models, tectonophysics, and GPS observation modeling. The participants come from the US and Canada, and from university or governmental institutions. In addition to scientific expertise, the group also includes key experts on legal and public implications related to the definition of a North American Datum.

During this two-year project (2006-2007), 4 workshops have been held, plus a post-award workshop:

(1) The 5<sup>th</sup> SNARF WG Workshop was held at the Brown Palace Hotel, Denver, CO, on March 15, 2006, in conjunction with the UNAVCO Science Workshop 2006. This workshop was attended by 11 participants, featuring 5 major presentations, which were followed by in-depth discussion interspersed with minor presentations.

[http://www.unavco.org/research\\_science/workinggroups\\_projects/snarf/2006\\_mar\\_workshop/2006\\_mar\\_workshop.html](http://www.unavco.org/research_science/workinggroups_projects/snarf/2006_mar_workshop/2006_mar_workshop.html)

(2) The 6<sup>th</sup> SNARF WG Workshop was held at Natural Resources Canada, Ottawa, on Nov 16, 2006. This workshop featured 8 presentations, which were followed by in-depth discussion.

[http://www.unavco.org/research\\_science/workinggroups\\_projects/snarf/2006\\_nov\\_workshop/2006\\_nov\\_workshop.html](http://www.unavco.org/research_science/workinggroups_projects/snarf/2006_nov_workshop/2006_nov_workshop.html)

(3) The 7<sup>th</sup> SNARF WG Workshop was held at Monterey, March 27, 2007, immediately preceding the EarthScope National Meeting 2007. This workshop was attended by 14 participants, featuring 8 presentations, which were followed by in-depth discussion.

[http://www.unavco.org/research\\_science/workinggroups\\_projects/snarf/2007\\_mar\\_workshop/2007\\_mar\\_workshop.html](http://www.unavco.org/research_science/workinggroups_projects/snarf/2007_mar_workshop/2007_mar_workshop.html)

(4) The 8<sup>th</sup> SNARF WG Workshop was held at the Westin Hotel Market Street, San Francisco, December

11, 2007, in conjunction with a special poster session at the 2007 Fall Meeting of the American Geophysical Union: Session G21B “Developing a Stable North America Reference Frame.” There were 18 participants, and 12 presentations, with much in-depth discussion. The AGU poster session (convened and chaired by G. Blewitt and M. Craymer), which immediately preceded the 8<sup>th</sup> workshop, was very well attended, and proved to be an effective way to communicate the research of the SNARF WG to interested scientists.

[http://www.unavco.org/research\\_science/workinggroups\\_projects/snarf/2007\\_dec\\_workshop/2007\\_dec\\_workshop.html](http://www.unavco.org/research_science/workinggroups_projects/snarf/2007_dec_workshop/2007_dec_workshop.html)

(5) The 9<sup>th</sup> SNARF WG Workshop was held at the Millenium Hotel, Boulder, CO, on March 13, 2008, in conjunction with the UNAVCO Science Workshop 2008. In contrast, this was an educational/outreach type of workshop with the goal of informing EarthScope investigators on SNARF research and products. There were approximately 25 attendees, with 3 invited presentations, followed by discussion and questions.

[http://www.unavco.org/research\\_science/workinggroups\\_projects/snarf/2008\\_mar\\_workshop/2008\\_mar\\_workshop.html](http://www.unavco.org/research_science/workinggroups_projects/snarf/2008_mar_workshop/2008_mar_workshop.html)

## **SCIENTIFIC ACTIVITIES**

The scientific activities can be considered in two parts: (1) fundamental research toward SNARF goals, thus forming a scientific basis for discussion, and (2) participation in workshops, including discussion of the research and its implications with regard to defining SNARF, and the creative activity that pulls together various strands of research toward the common goal of realizing a new standard reference frame. More details on the research findings and progress on developing SNARF are given in Part 2 of the final report “Project Findings”.

The main areas of scientific research in which the participants were active and which were discussed at workshops are listed below:

- (1) Reference frame theory and practice;
- (2) Geodetic analysis for reference frame realization, including optimal analysis, station motion model, validation studies (e.g., software intercomparisons), error analysis, etc.;
- (3) Earth models, especially GIA (glacial isostatic adjustment) and secular loading associated with current climate change, and an assessment of whether such effects can be accurately included in the SNARF reference system definition;
- (4) Tectonic considerations regarding proximity to plate boundary effects;
- (5) Quality-affecting issues, such as data quality, multipath, monument stability, local- to broad-scale subsidence, hardware configuration, site selection, etc.
- (6) Transfer from research-mode activities to the operational activities of EarthScope's Plate Boundary Observatory and to the national geodetic agencies (NRCan in Canada, and NGS in USA). Specifically, in October 2006, SNARF was officially adopted as the reference frame for the production of PBO geodetic products, thus closing the loop on a major objective of the SNARF Workshops.

The list of publications and presentations given in this report provide more specific detail on each

specific research activity.

## **EDUCATIONAL ACTIVITIES**

Due to the highly specialized nature of this research, education activities are directed toward the scientific community itself. These activities can be categorized as:

(1) a collaborative project web-page hosted by unavco.org:

[http://www.unavco.org/research\\_science/workinggroups\\_projects/snarf/snarf.html](http://www.unavco.org/research_science/workinggroups_projects/snarf/snarf.html)

which contains information on the project goals and objectives, materials presented at workshops, and conclusions of the research and workshop discussion (which are discussed later).

(2) presentations at SNARF workshops, at conference special sessions such as the AGU co-authored by the participants, and plenary sessions of the UNAVCO Science Meetings and EarthScope National Meetings.

(3) journal articles on fundamental research related to SNARF co-authored by the participants.

References to publications and presentations are attached with Part 2 of this final report (Project Findings).