Global Positioning Finds Applications in Geosciences Research

Randolph Ware
University Navstar Consortium, Boulder CO 80307-3000

Steven Businger
University of Hawaii, Honolulu HI 96822

Continuous global positioning satellite tracking networks are being established by a variety of national and international organizations to provide basic infrastructure for space-age navigation, surveying, science, engineering, and atmospheric sensing. The emerging networks present opportunities for a variety of geoscience applications. To make the most of these opportunities, the geoscience community should clarify and communicate its research goals to organizations establishing global positioning networks.

Global Positioning Satellites and Networks

Soon after the space age began, it was recognized that the orbits of satellites provided a valuable reference frame for global navigation systems. Today, the 24-satellite Global Positioning System (*GPS*) operated by the Department of Defense is the most widely used system, followed by a smaller group of Russian satellites called *GLONASS*. These systems may be augmented by future commercial low Earth orbit communication and positioning satellite services.

The reference frames of satellite orbits and the Earth's crust are linked using ground-based tracking networks. The first global *GPS* tracking network was established more than 15 years ago by the U.S. Department of Defense. This network included five tracking stations and was used to determine orbital positions with an accuracy of about 10 m. More recently, the International Association of Geodesy (*IAG*) established the International *GPS* Service for Geodynamics (*IGS*) comprising more than 50 international organizations, to support geodetic and geophysical *GPS* applications (e.g. Zumberge et al, 1994). The *IGS* network includes more than 50 globally distributed tracking stations that provide high accuracy *GPS* orbits (~10 cm), allowing users to place their *GPS* stations in the International Terrestrial Reference Frame with centimeter accuracy. *IGS* orbits are available within 2 to 3 weeks via anonymous ftp (*igscb.jpl.nasa.gov*) or World Wide Web (*http://igscb.jpl.nasa.gov*).

Regional continuous *GPS* networks designed mainly to monitor strain for earthquake research and forecasting have operated in Japan and California for several years. A similar network in Sweden, designed to measure post-glacial deformation, has operated for more than a year. Similar systems are being established across Europe, Australia, and other regions. In addition, networks designed to improve *GPS* accuracy are being established for aircraft and coastal navigation, to support surveying applications, for dam and dike monitoring, and for atmospheric measurements.

Applications

Although *GPS* was designed primarily for military objectives, the following valuable civilian applications have been developed:

Navigation

Increasingly, land, sea, and air vehicles are making increasing use of the capability of *GPS* to determine point positions with an accuracy of 100 m. Positioning with so-called Differential *GPS* (*DGPS*), which uses radio links between mobile and fixed *GPS* receivers, provides relative positions in real time with an accuracy of 10 cm to 1 m for civil aviation and coastal navigation. An example of the use of *DGPS* is the coordination of highway and railroad traffic.

Science

High accuracy *GPS* positioning has been improved by two orders of magnitude during the past decade, and now millimeter accuracies are being routinely achieved. This high accuracy makes *GPS* useful for tectonic, earthquake, volcano, Earth rotation, sea-level, satellite altimetry, glaciology, meteorology, global climate, ionosphere, hydrology and ecology studies.

Engineering, Surveying, and Resource Management

GPS is also being used for surveying, monitoring dams, dikes, landslides and subsidence, positioning civil infrastructure for use in geographic information systems, time transfer for telecommunications systems, automated construction and facilities management, precision farming, forest and resource management, and natural resource exploration.

Weather Forecasting

By exploiting delays in the *GPS* signals introduced by water vapor and other components of the atmosphere, *GPS* networks can provide valuable data for assimilation into numerical weather prediction models.

Multi-Disciplinary Use of GPS Networks

The emerging networks include approximately 400 currently operating and 1400 planned additional tracking sites (Table 1). These networks can be used for a variety of multidisciplinary geoscience applications. For example, tracking sites designed for navigation and atmospheric sensing can also be designed, in many cases, for geodetic positioning. In addition, if tracking sites designed for navigation or geodetic positioning are equipped to record pressure and temperature, the *GPS* measurements can be analyzed to provide accurate estimates of precipitable water [e.g. Bevis et al, 1992] valuable for weather forecasting [e.g. Rocken et al, 1995]. If the worldwide *IGS* sites are similarly equipped, a much-needed new type of global climate monitoring instrument will be created [e.g. Yuan et al, 1993].

Table 1. *Estimated number of sites operating and proposed in various tracking networks. Regional networks address civil and scientific applications in localized areas, national networks address aviation and coastal navigation, and international networks provide*

global tracking.

NETWORKS	CURRENT SITES	PROPOSED SITES
Regional	70	360
National	250	875
International	75	125
Subtotals	395	1360
Total Current and Proposed		1755

Other multidisciplinary geoscience applications are also emerging (e.g. UNAVCO Report, 1994). To succeed in these applications, the geoscience community must ensure that organizations establishing and operating *GPS* networks understand the value of multi-purpose installations and consider the requirements of other users in making equipment, data management and other application decisions. The authors are working with the National Research Council and several agencies to convene a workshop for this purpose. Also contributing to this activity are M. Bevis (U. Hawaii), Y. Bock (Scripps Inst.), R. Chadwick (NOAA), J. Davis (Harvard U.), R. Neilan (JPL), W. Prescott (USGS), and W. Strange (NGS).

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