SPACE-BASED POSITIONING, NAVIGATION, AND TIMING SYSTEMS

GPS

The primary system used throughout the world for space-based positioning, navigation, and timing is the Global Positioning System (GPS), a constellation of U.S. Government satellites providing continuous civil service free of direct user charges to an unlimited number of users for peaceful purposes. GPS is operated by the U.S. Air Force in support of critical military operations around the world. Additionally, GPS is critical to a wide range of civilian activities and represents a fundamental component of the global information infrastructure.

The GPS constellation, completed in 1995, consists of more than 24 satellites that circle the earth every 12 hours from an altitude of nearly 20,000 km. With four or more satellites in view, a GPS receiver can pinpoint its location anywhere on or above the surface of the Earth to within a few meters. Higher accuracy-within centimeters, or even millimeters-is often achieved by correcting the GPS signal with external augmentation systems.

GPS technology can be found in everything from cars and planes to cell phones and soda cans. It is being used to improve productivity in areas as diverse as farming, mining, construction, surveying, taxicab management, and package delivery. It is enhancing public safety by preventing transportation accidents and by reducing the response times of ambulances, firefighters, and other emergency services. GPS is also furthering scientific aims such as weather forecasting, earthquake prediction, and environmental protection. Furthermore, the precise GPS time signal, derived from atomic clocks, is being applied to critical economic activities such as synchronizing communication networks, managing power grids, and authenticating electronic transactions. This same technology, whether designed for military capabilities or not, provides inherent capabilities that can be used by adversaries, including enemy forces and terrorist groups. As such, the U.S. is committed to developing a range of capabilities to prevent potential hostile use of GPS services while protecting access to U.S./Allied national security services and preserving peaceful use of civil services outside an area of conflict.

Similar with the growth in civil and commercial applications, the positioning, navigation, and timing information provided by the Global Positioning System remains critical to U.S. national security, and its applications are integrated into virtually every facet of U.S. military operations. U.S. and Allied military forces

will continue to rely on the Global Positioning System military services for positioning, navigation, and timing services.

GPS currently provides two categories of service: the Standard Positioning Service, available free of charge to anyone in the world; and the Precise Positioning Service, available only to authorized U.S. and Allied military and select federal government users. Beginning in 2005, an additional civil signal and two new military signals will be incorporated into the constellation to increase overall system performance. In 2006, improvements will continue as satellites with a third civil signal will be launched into the constellation.

The United States and Europe recently agreed to establish interoperability and non-interference between GPS and Europe's planned Galileo satellite navigation system, as well as cooperation on a new civil signal that will be common to both systems. This is expected to further improve service for civilian users and accelerate the already healthy growth of the commercial satellite navigation market.

AUGMENTATIONS

In order for satellite navigation technology to meet all the requirements of civilian users, the U.S. Government has implemented augmentation systems to improve the performance of standalone GPS. Many augmentations rely on a technique known as differential GPS and use reference stations that continuously monitor the GPS signals. Since the position of the reference station has been precisely surveyed, the errors in the satellite signals can be calculated and corrections broadcast to users in the area of coverage. The user's differential GPS receiver applies the correction message to improve the accuracy of its own position. The differential broadcast may also include integrity warnings for any satellite signals that should not be used. A few examples of Augmentations to GPS are detailed below.

Nationwide Differential Global Positioning System (NDGPS)

NDGPS is a ground-based augmentation that provides real-time enhancements to GPS, including integrity monitoring and accuracy improvements to enable advanced highway, rail, and maritime applications. Future enhancements to the NDGPS, now in the final research and development stages, are planned to provide sub-meter accuracy.

The goal of NDGPS is to provide dual terrestrial coverage over the continental U.S. and portions of Alaska to

support a wide range of navigation and positioning requirements at the federal and state levels, as well as fulfilling the needs of current and future commercial applications. NDGPS currently provides single coverage service over 87% of the continental U.S., Alaska, Hawaii, and Puerto Rico, and dual coverage over approximately 55% of the same area. Dual coverage provides improved system availability, and will increase the availability of the system from the current 99.7% to 99.99%. NDGPS is built to an international standard (ITU-R-M.823). Compatible systems have been installed in more than 40 countries, covering all of Japan, most of Europe, most coastal areas, and many inland areas of South America.

Wide Area Augmentation System (WAAS)

WAAS, a space-based GPS augmentation system operated by the Federal Aviation Administration (FAA), provides increased accuracy, availability, and integrity for all phases of flight in the National Airspace System, including vertical guidance for precision approach applications. WAAS supports additional capabilities such as advanced (curved and segmented) arrival and departure procedures, parallel runway operations, missed approaches, vertical takeoffs, and enhanced surface movement operations.

WAAS was commissioned by the FAA in 2003 and is expected to attain full operational capability for single-frequency users in 2006. When the GPS third civil signal, L5, becomes available, dual-frequency WAAS users will achieve further performance improvements to include Category I precision approach. Although designed primarily for aviation users, WAAS is also widely available for use by other navigation user communities at the discretion of the appropriate operational authority.

Satellite-based augmentation systems (SBAS) similar to WAAS, but for other regions of the world are also being developed by Europe (European Geostationary Navigation Overlay System or EGNOS); Japan (Multi-functional Transport Satellite (MTSAT)-based Satellite Augmentation System or MSAS); and India ((GPS Aided Geo Augmented Navigation or GAGAN), and are being considered by additional nations such as Brazil.

Local Area Augmentation System (LAAS)

LAAS is a ground-based GPS augmentation system (GBAS) being developed by the FAA that provides differential corrections to aviation users via a localized VHF data broadcast. LAAS is expected to provide the required accuracy, availability, integrity, and continuity to initially support Category I precision approaches and eventually Category II and III precision approaches at

LAAS-equipped airfields. The LAAS program is currently in the research and development phase.

Australia is also developing a GBAS for aviation use known as the Ground-based Regional Augmentation System (GRAS). It is a regional system that uses a distributed network of reference stations for monitoring GPS, and a central processing facility for computing GPS integrity and differential correction information. The information is sent to a network of terrestrial stations for a local check and reformatting. Each site transmits a VHF Data Broadcast (VDB) signal.

Continuously Operating Reference Station (CORS) Network

The CORS program, managed by the National Geodetic Survey, comprises a nationwide network of permanently operating Global Positioning System (GPS) receivers supporting non-navigation, post-processing applications by providing users with ties to the National Spatial Reference System for accurate, 3-dimensional positioning. Typical uses of CORS include land management, coastal monitoring, civil engineering, boundary determination, mapping, and geographical information systems, geophysical and infrastructure monitoring, as well as future improvements to weather prediction and climate monitoring. The CORS program is a multi-purpose cooperative endeavor involving more than 130 government, academic, and private organizations-each of which operates at least one site. In particular, it includes all existing NDGPS sites and all existing FAA WAAS sites.

ADDITIONAL GLOBAL AND REGIONAL SYSTEMS

Galileo

The Galileo satellite navigation program is a joint initiative between the European Union and the European Space Agency to build and operate a 30-satellite constellation that provides similar capabilities to GPS, but as a commercially-operated, for-profit venture, not a public good. The system will offer four distinct positioning, navigation, and timing services and one search and rescue service.

- An "Open Service" with open access signals that is free of user charges.

- A "Safety of Life Service" will be a "guaranteed" service that provides integrity warnings to users when the system fails to meet certain accuracy requirements.

- A "Commercial Service" that is envisaged to

include service guarantees and a limited broadcasting capacity for messages from service centers to users.

- A "Public Regulated Service" will be a secured (encrypted) service for authorized governmental users (police, fire, emergency response, etc.).

- A "Search and Rescue Service" will transmit the alert messages received from distress emitting beacons as a contributor to enhancing the performance of the international COSPAS-SARSAT Search and Rescue system.

GLONASS

GLONASS is a Russian space-based navigation system comparable to the U.S. GPS system. The fully operational system will contain 21 satellites in 3 orbital planes, with 3 on-orbit spares. The GLONASS system is managed for the Russian Federation Government by the Russian Space Forces providing benefits to civil users through a variety of applications. The GLONASS system has two types of navigation signals: standard precision navigation signal (SP) and high precision navigation signal (HP). SP positioning and timing services are available to all GLONASS civil users on a continuous, worldwide basis. On December 10, 2003, three GLONASS spacecraft were placed into orbit in Plane 1, including one of the new generation of GLONASS-M satellites. The addition of these three satellites will bring the GLONASS constellation to a total of 11 operational satellites.

QZSS

The Quasi-Zenith Satellite System [Jun-Ten-Cho in Japanese] is a constellation of at least three satellites, configured such that one of them is always positioned at a high elevation angle over Japan. RF transmission will not be obstructed by tall buildings or mountains, because one of satellites will always remain near high in the sky over Japan at all times. As a result, signal degradation caused by building blockage and multiple signal paths will be less frequent, making the whole system ideal and reliable for mobile data communication and broadcasting. The system is also expected to increase accuracy to GPS users in the eastern Asia area. The service, planned for 2008, can be augmented with the geostationary satellites in Japan's MSAS, currently under development.

Beidou

Although China has not yet established an operational satellite navigation and positioning network, research for such a system has been underway for many years, and a future space-based navigation capability is an acknowledged goal. Beidou ('Big Dipper') is the satellite

component for the independent Chinese satellite navigation and positioning system. The Beidou satellite navigation and positioning system are consists of two satellites in geosynchronous orbit. The final Beidou constellation will include four satellites, two operational and two backups. Together with the ground stations, the Beidou system will provide navigation and positioning signals covering the East Asia region. However, to provide global signal coverage, satellites flying in other orbits around the world must complement the system. Three satellites have been launched to date.