

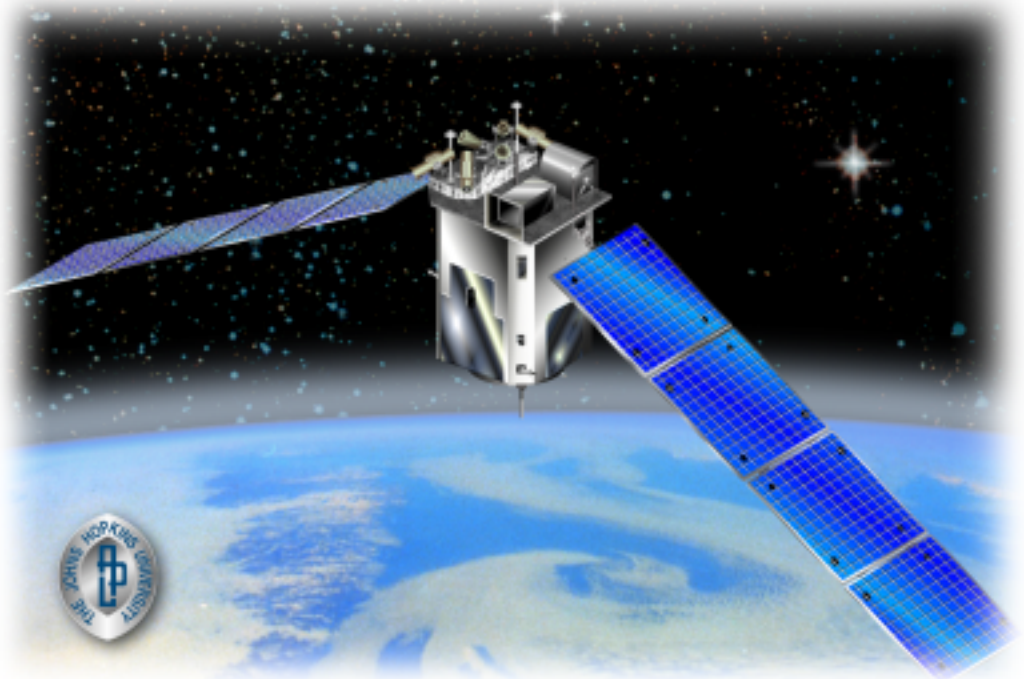
# *The GPS Navigation System*

The Johns Hopkins University Applied Physics Laboratory (APL) has developed an advanced spaceborne navigation system utilizing the global positioning system. The GPS Navigation System (GNS) provides autonomous, on-orbit positioning and navigation functions for spacecraft.

GNS incorporates commercial-off-the-shelf and custom hardware and software components. It is space qualified, radiation tolerant, and optimized for low- and medium-Earth orbit applications. Drawing on the Lab's three decades of GPS systems development expertise, the GNS is a state-of-the-art, space-based system. It offers superior performance over terrestrial designs that have been adapted for space applications.

The APL-developed GNS technology has extensive command and telemetry capability, providing access to raw and intermediate data products, as well as, on-orbit software reprogramming capabilities. The system accommodates the large GPS signal dynamic range resulting from orbital velocities, and implements robust signal acquisition, navigation, and orbit determination algorithms.

The GNS technology was first developed as a vital component of the Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics (TIMED) spacecraft, which APL designed for NASA's Solar Terrestrial Probe Program. TIMED is scheduled for launch in the first quarter 2001.



## *Provides Advanced Autonomous Navigation Capabilities for Spacecraft*

The GNS is a card-level system that is part of the TIMED integrated electronics module. A critical GNS component is the APL-designed, 12-channel, radiation-hardened GPS tracking application-specific integrated circuit (ASIC) called the GPS Tracking ASIC (GTA). The navigation software, based on an extended Kalman filter and orbit propagator, autonomously generates highly accurate estimates of TIMED's position, velocity, and time. This will allow TIMED's event-driven commanding mission operations to support reduced program life-cycle costs. In addition, position-based events will be detected in real time and predicted for days in advance. This capability is utilized by onboard systems and mission operations teams to reduce operations costs.

## Features

- **Fully Spacecraft Flight Qualified (Vibration and Thermal-Vacuum tested)**
- **Radiation-Hardened to > 300 krads (Si) (except memory)**
- **System designed around a JHU/APL designed GPS Tracking ASIC (GTA)**
  - 4 selectable inputs and 12 independent tracking channels
  - VHDL-based design
  - > 200,000 gates
  - 1 Mrad (Si)
  - Design permits cascading up to 6 GTAs
  - Designed to support P-Code tracking
- **Fully Autonomous Operation from Cold Start**
- **Navigation Software Utilizes an Extended Kalman Filter**
  - 9 dynamic states
  - Up to 36 satellite states (3 states per satellite)
  - Force model utilizes Jacchia High-Altitude Density Table and EGM96 15x15 Gravity Table
- **A Steered 1 PPS Output which is aligned with UTC 1-second Epochs**
- **Real-time Products output once a second**
  - Position (CIS in X, Y, and Z)
  - Position (CTS in Latitude, Longitude, and Height)
  - Velocity (CIS in X, Y and Z)
  - Velocity (CTS in East, North, and Up)
  - Time (CCSDS Unsegmented Time Code with 0h, Jan 6, 1980, starting epoch)
  - Earth to Sun Unit Vector (CIS in X, Y, and Z)
- **Real-time Event Notifications output once a second**
  - In/Out of Primary Ground Station Contact Region
  - In/Out of Backup Ground Station Contact Region
  - In/Out of Defined South Atlantic Anomaly (SAA) Region
  - In/Out of Defined Polar Region
  - Day/Night at Sub-Satellite Point for Terminator Crossing Notification
- **Acquisition Aids Generated once every 180 seconds**
- **Prediction products output once every 12 hours**
  - Propagates 60 hours into the future

- < 4 km position error after 36-hour propagation at Solar Max
- Table of Rise and Set Times for all Ground Station Contacts
- Table of SAA Entry and Exit times
- Table of State Vectors for all Ground Station Contacts
- Table of NORAD 2-line Orbital Element Sets for all Ground Station Contacts
- **Extensive Command and Telemetry Capabilities**
- **Supports On-/Orbit Reprogramming of Application Software**
- **Supports Commanded Uploading of Parameter Tables**
  - Solar Flux
  - Mean Solar Flux
  - Geomagnetic Index
  - Polar Wander X and Y
  - UT1-GPS
  - GPS Almanac
  - Ground Station Coordinates
  - SAA Coordinates
  - Polar Region Coordinate
  - Acquisition Aids Table
  - Default Sky-Search SV List
  - Gravity Table
  - Drag Table
  - State Vector (for Non-GPS Navigation)
  - Earth Nutation Table
  - Numerous Configuration Parameters

## Expected Performance

(The following uncertainties are based on system testing with a Nortel STR2760 GPS Simulator and Independent Verification and Validation testing with an IEC Model 2400 GPS Simulator)

- **Position uncertainty expected to be less than 10 meters, (rms)**
- **Velocity uncertainty expected to be less than 2 cm/sec, (rms)**
- **Time uncertainty expected to be less than 200 nsec (rms)**
- **Mean Time-to-First-Fix < 14 minutes**

For additional information, contact

***Al Chacos***

*Section Supervisor of GPS Applications*

240-228-8465

Fax: 240-228-6635

al.chacos@jhuapl.edu

The Johns Hopkins University  
Applied Physics Laboratory  
11100 Johns Hopkins Road  
Laurel, Maryland 20723-6099