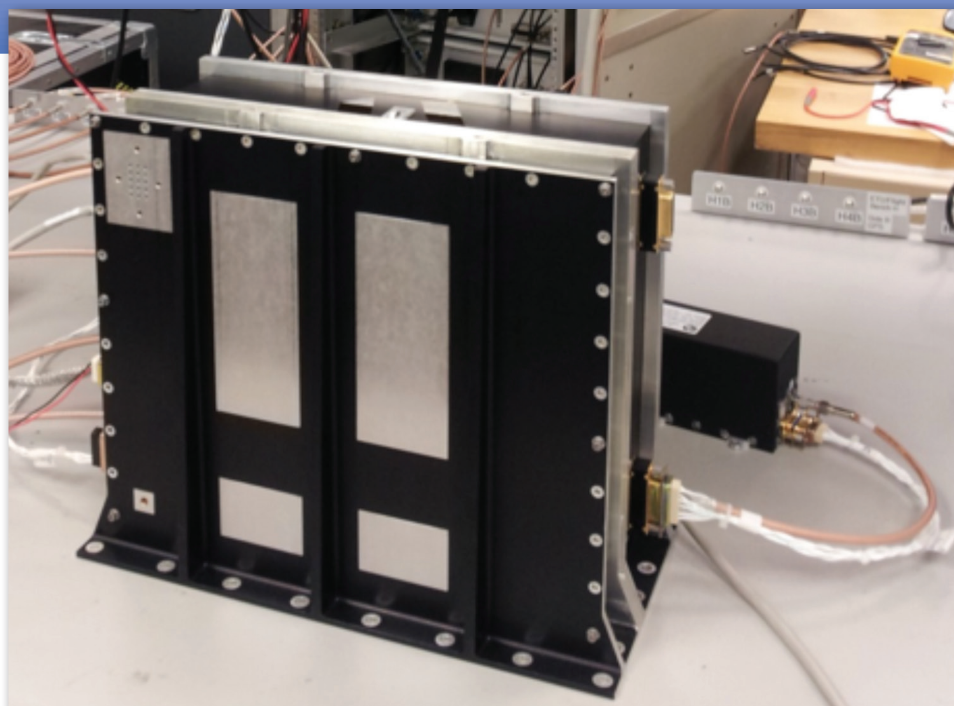
NASA Goddard Space Flight Center
Navigator GPS Receiver

Navigator Features

- Fast acquisition
- Weak signal acquisition and tracking (25 dB-Hz)
- Targeting multiple orbit regimes
  - LEO
  - GEO
  - HEO (12 Re +)
  - Launch
  - Re-entry
- Two or four independent RF chains
- On board Kalman filter (GEONS)
- Built from the ground up for challenging environments
- Rad tolerant >100 krad
- 1 PPS output
- Highly configurable Flight Software

Receiver Architecture

- GPS L1 C/A 1.57542 GHz
- Three electronics cards: Power, Signal Processing, RF
- External LNA, Optional external Ultra-Stable Oscillator (MMS)
- 12 Channels nominal, 24 used to handle seamless antenna handoff
- 2 (GPM) or 4 (MMS) independent RF chains
- Signal proc. in Rad-tolerant Actel RHAX200 FPGAs, Coldfire processor
- Highly configurable by telecommand



The NASA GSFC Navigator is a state of the art spaceborne GPS receiver built from the ground up to provide autonomous navigation solutions in the most challenging space environments. Acquisition and tracking algorithms embedded in FPGAs allow for rapid time to first fix with no a-priori information as well as high-sensitivity acquisition and tracking thresholds of better than 25 dB-Hz. The Goddard Enhanced Onboard Navigation System (GEONS) Kalman Filter provides continuous state information when the environment is not amenable to kinematic solutions. The Navigator is a TRL-9 receiver with flight heritage from the Hubble Servicing Mission 4, Global Precipitation Mission (GPM, Feb. 2014 launch), and Magnetospheric Multi-Scale Mission (MMS, March 2015 launch). As of early 2016, the MMS-Navigator represents, by far, the highest operational use of GPS-based satellite navigation with apogee at 76,000km radial distance (to be raised to 160,000 in 2017). The Navigator design has been licensed to Moog Broad Reach and Space Vector Corp., and the fast acquisition technology is incorporated in the Honeywell GPS receiver for NASA's Orion capsule to enable fast recovery from reentry radio blackout, a capability successfully demonstrated on EFT-1.

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Input/Output

- Spacewire (MDM 9 pin) telemetry connection (RS422 also available)
- One pulse-per-second output over LVDS or RS422
- 9 pin male Sub-D connector for power
- RF inputs SMA female 50 ohm

Solution Accuracy—LEO

Position (3D RSS RMS)	Sim No Errors	<3 m[a]
	Sim Typical LEO errors	<7 m[a]
	GPM on-orbit	<10 m[b]
Velocity (3D RSS RMS)	Sim No Errors	<1 cm/s[a]
	Sim Typical LEO errors	<2 cm/s[a]
	GPM on-orbit	<2 cm/s[b]

[a] Point solution and filter accuracy similar
[b] Filter formal error RSS sum of covariance matrix diagonal

Solution Accuracy—GEO

Position (3D RSS RMS)	No Errors	Not Measured
	Typical GEO errors	2 m
	On-orbit	Not Measured
Velocity (3D RSS RMS)	No Errors	Not Measured
	Typical GEO errors	0.03 cm/s
	On-orbit	Not Measured

Solution Accuracy—HEO

Position 3D RSS (3D RSS RMS)	MMS phase 1 on-orbit (76,000 km apogee)	12 m[a] worst, 5 m[a] typical
Velocity (3D RSS RMS)	Sim MMS phase 1 on-orbit (76,000 km apogee)	0.3 cm/s[a] worst, <0.1 cm/s[a] typical

[a] Filter formal error RSS sum of covariance matrix diagonal

Time To First Fix *(estimated)*

- Strong signal environment (e.g. LEO): 40 s cold[a], 6 s warm[b], <1 s reacq[c]
- Weak signal environment (e.g. GEO): 300 s cold, 120 s warm

[a] dominated by ephemeris decode
[b] dominated by subframe sync
[c] zero a-priori time to just reacquire code phase, Doppler in acq search

Measurement Precision

- Pseudorange strong signals environment: <1.5 m[a]
- Pseudorange weak signal @ -168 dBW: <13 m[b]
- Carrier phase strong signal environment: <1 mm[a]

[a] Zero-baseline double difference; two simulator runs LEO scenario not separated by C/N_0
[b] Measured with simulator modeling MMS 3 RPM spin ignoring spacecraft attitude, will be better for three-axis stabilized spacecraft

PPS Accuracy

- < 25 ns[a] (1σ) strong signal environment

[a] compared vs. truth 1PPS in LEO simulation with basic iono-sphere model and broadcast ephemeris errors

Orbital Dynamics

- Altitude: LEO to Beyond GEO (Operational for MMS >76,000 km)
- Velocity: Tested to 10 km/s

Signal Acquisition and Tracking Thresholds

- <-178 dBW (~25 dB-Hz)

Physical Characteristics *(approx.)*

- 11” x 11” x 6” (box only)
- 5 kg (box only)
- 30 W MMS, 23 W GPM (USO, front end included)

Environmental

- Radiation (data for GPM signal processing card, RF card TBD)
  - Total ionizing dose > 100 krad
  - SEU threshold > 37 MeV-cm²/mg[a]
  - SEL immune > 100 MeV-cm2/mg most parts; 59 MeV-cm2/mg weakest part (GPM)
  - No upsets on GPM and MMS to date
- Thermal
  - -20C to +50C operational (MMS)
  - -25C to +60C survival (MMS)
- Vibration
  - 12.5 g RMS (MMS)

[a] SRAM specified to 1×10^{-12} upsets/bit/day, SET at lower levels

R&D

- Modernized, Reduced Size, Weight, Power variants of receiver in development based on GSFC SpaceCube processor line
- GPS L2C demonstrated in simulation, L5 in development