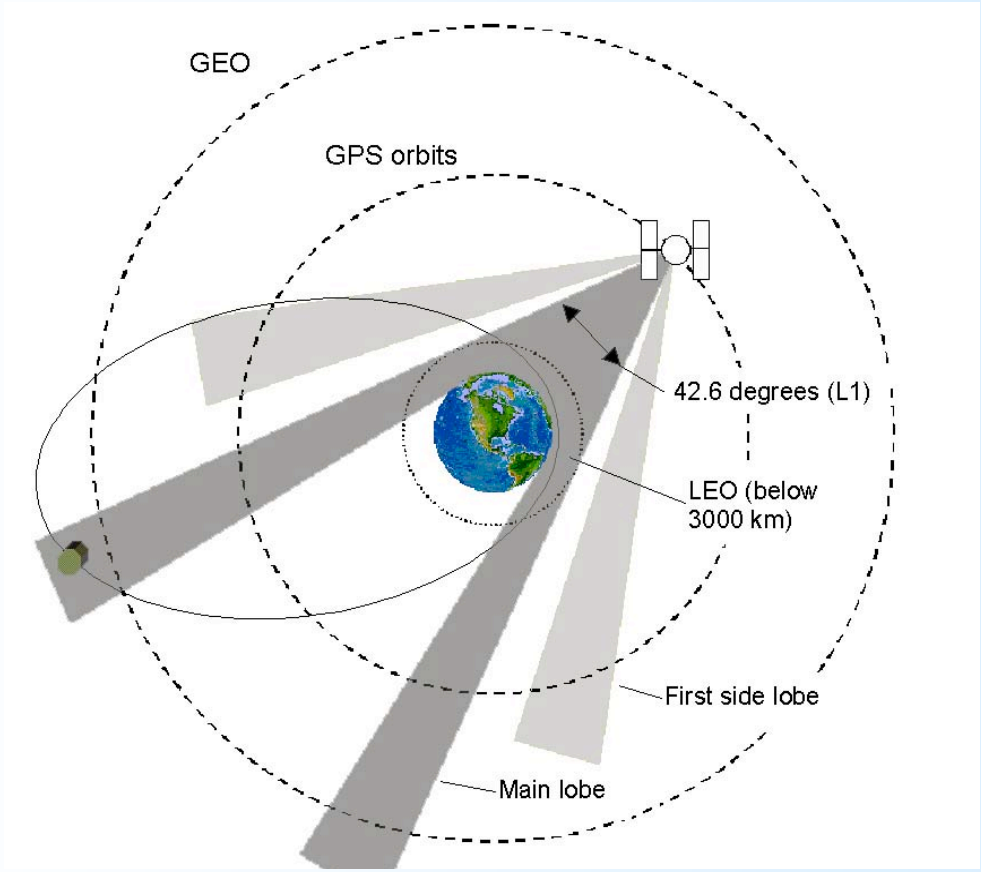
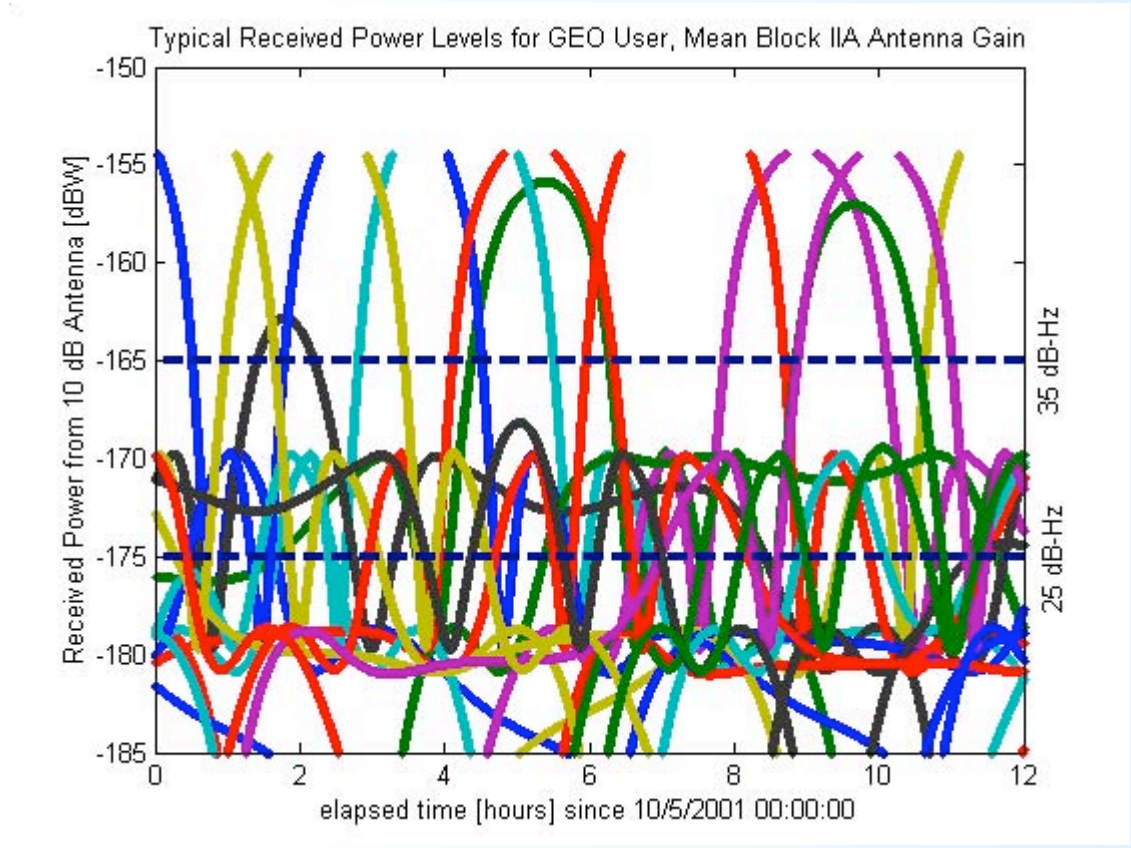
Navigator GPS Receiver for Fast Acquisition and Weak Signal Space Applications

NASA-Goddard Space Flight Center

Motivation I

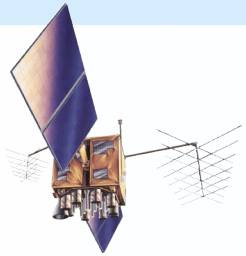


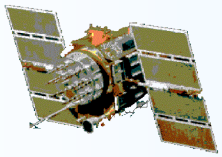
Motivation II

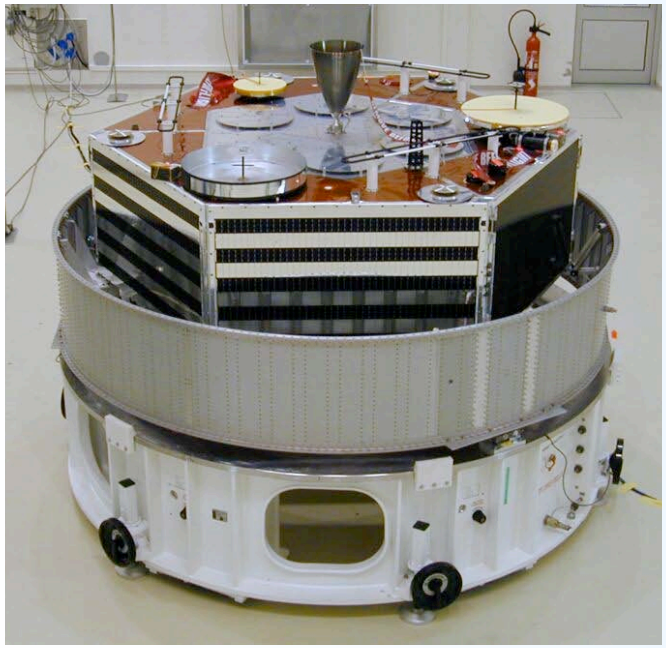


- **Power levels computed from "typical" block IIA transmitted power levels and mean IIA antenna gain pattern**
- **C/No calculation assumes:**
  - thermal noise density = -204 dBW-Hz
  - receiver losses = 4.5 dB

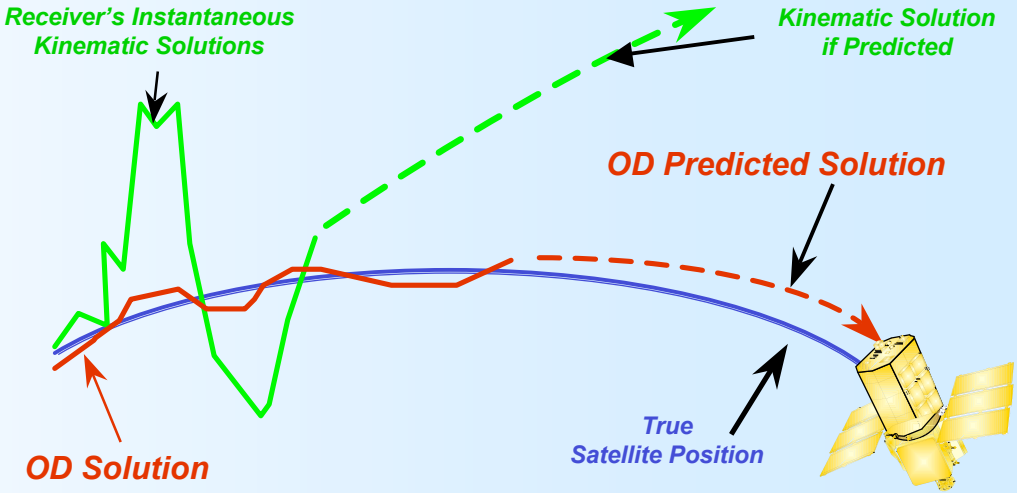
Goddard High Altitude GPS Work







AMSAT AO-40 Flight Experiment



GEONS Software

PiVoT GPS Receiver

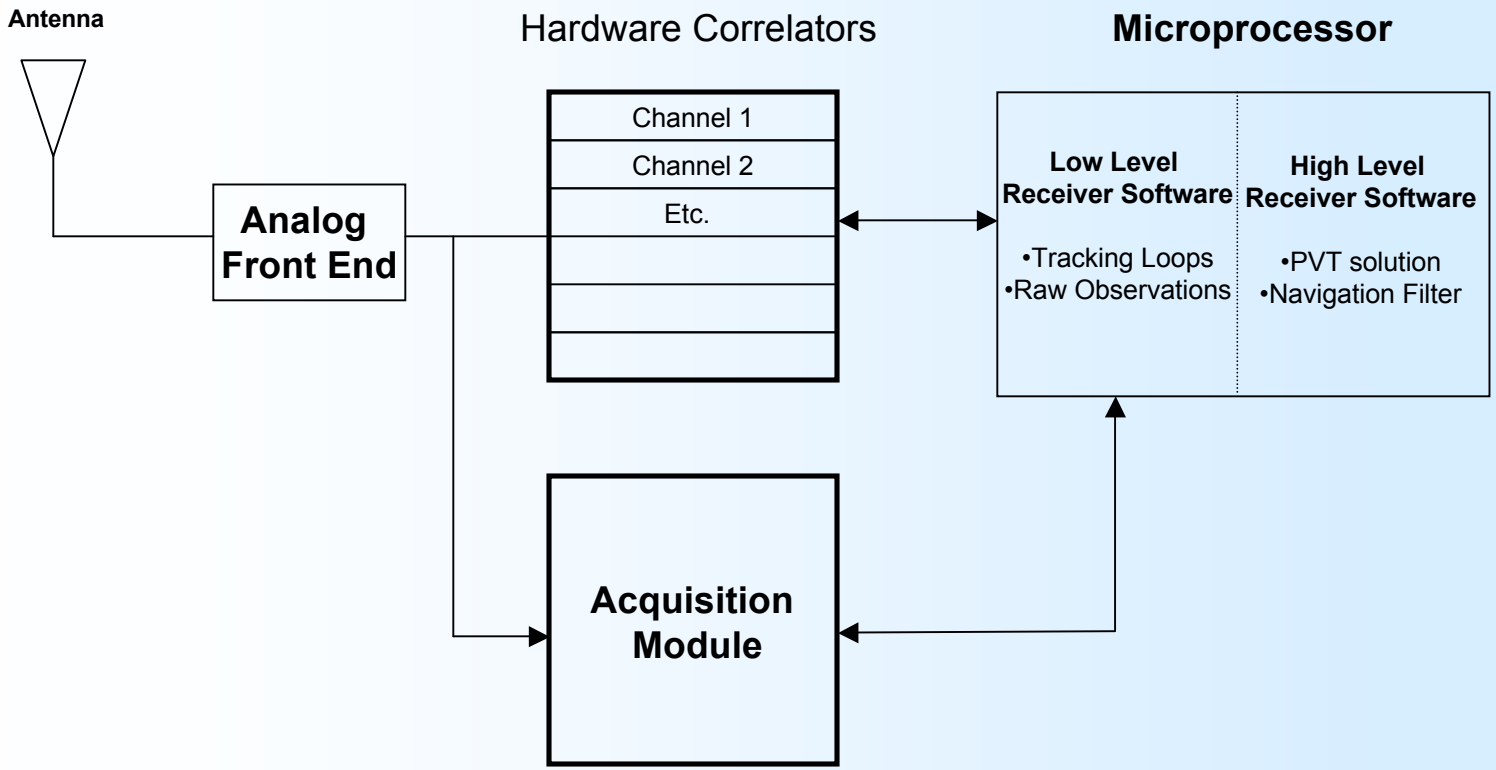
Navigator Specifications/Goals I

- **Build a fully space qualified GPS receiver that can operate effectively at HEO well as LEO**
  - Stringent radiation requirements
- **Design for complete autonomy**
  - Zero a priori knowledge, no aiding
- **Acquire and track weak signals down to 25 dB-Hz**
- **Acquire GPS signals quickly**
  - Within one second for strong signals (>40 dB-Hz)
  - Within one minute for weak signals (<40 dB-Hz)

Navigator Specifications/Goals II

- **Implement algorithms in FPGAs**
  - Allows for easy modification, upgrade, and customization
- **Provide open source software**
  - Provides an excellent platform for GPS development

Receiver Hardware Concept



Navigator Methods

- **Improved acquisition speed/sensitivity from FFT based calculation of extended correlations**
  - Employs “frequency domain” correlation of the C/A code
  - Equivalent to having >300,000 parallel correlators
  - Enables extended correlation intervals without prohibitively long acquisition times
  - *Reference*: Psiaki, M. L. “Block Acquisition of Weak GPS Signals in a Software Receiver,” *Proc. of ION GPS 2001.*
- **Improved tracking sensitivity using essentially standard PLL/DLL methods with correlations extended to 20ms**

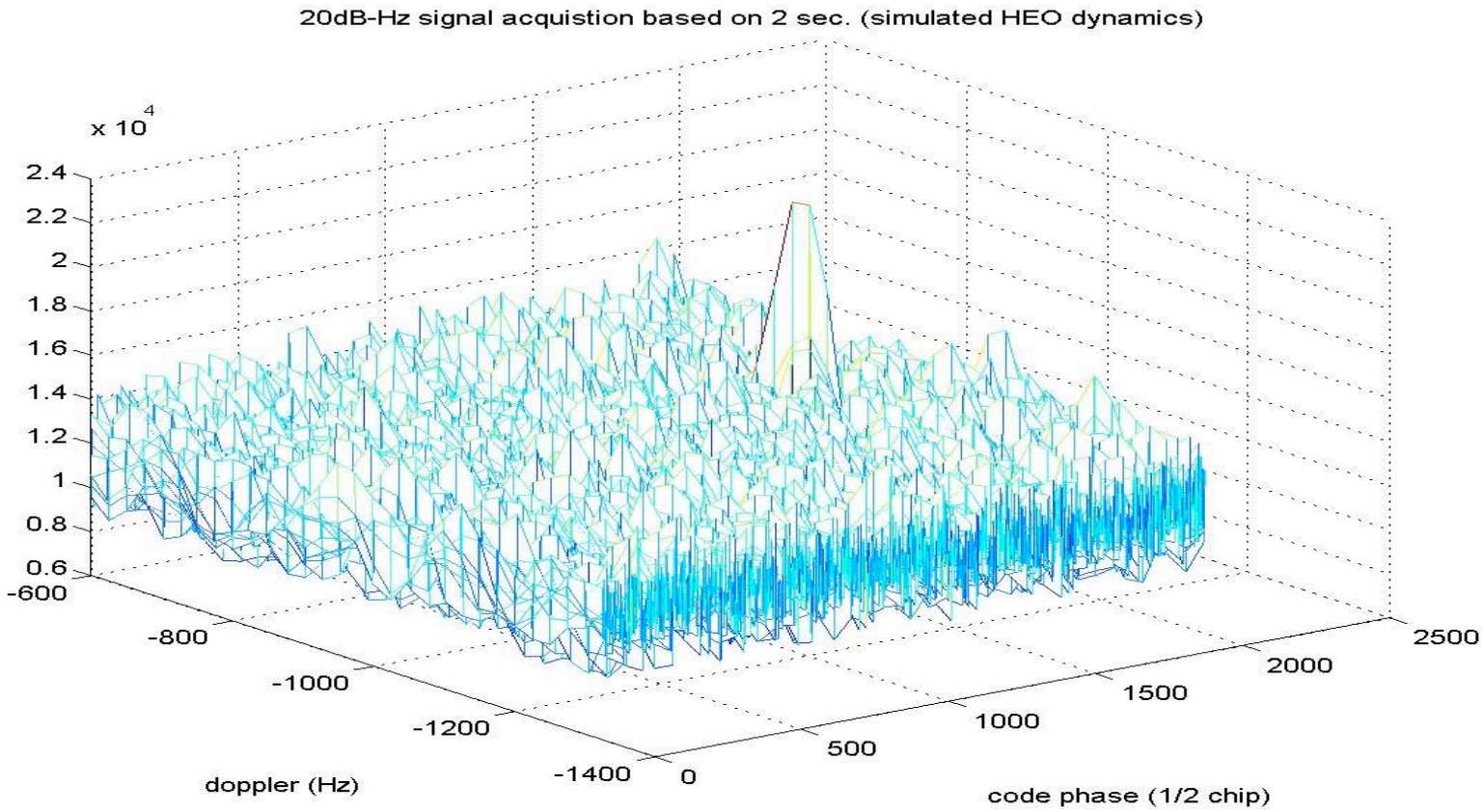
Navigator Acquisition I

- **Strong Signal Mode**
  - Based on 1ms correlation
  - Effective down to ~40dB-Hz, appropriate for “below the constellation” applications
  - Acquisition of all visible signals in a few seconds
- **Weak Signal Mode**
  - Based on combined 10ms coherent/extended non-coherent correlation in alternating blocks of 10ms to avoid GPS data bit transitions
  - Effective even below 25dB-Hz, enabling “above the constellation” applications: GEO, HEO, etc.
  - Large Memory requirements

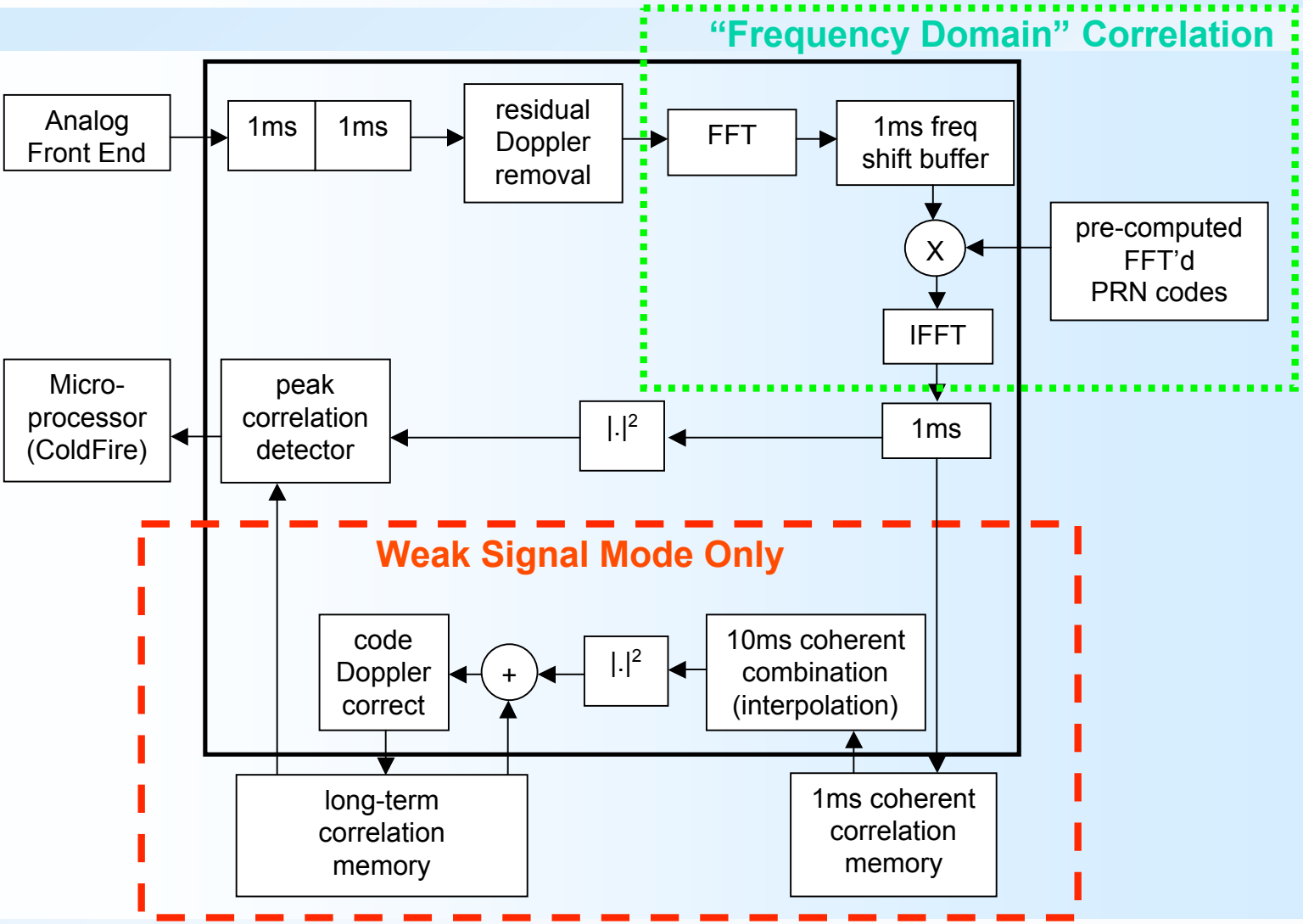
Navigator Acquisition II

- **Algorithm is completely embedded in FPGA**
  - Commanded with SV#, Doppler range/search granularity, and integration time – returns largest correlation and coordinates
- **Operates in real-time, no buffering/post-processing or "catch-up" period**
- **10-bit, 2048 point FFT engine at core**

Sample Acquisition at 20dB-Hz



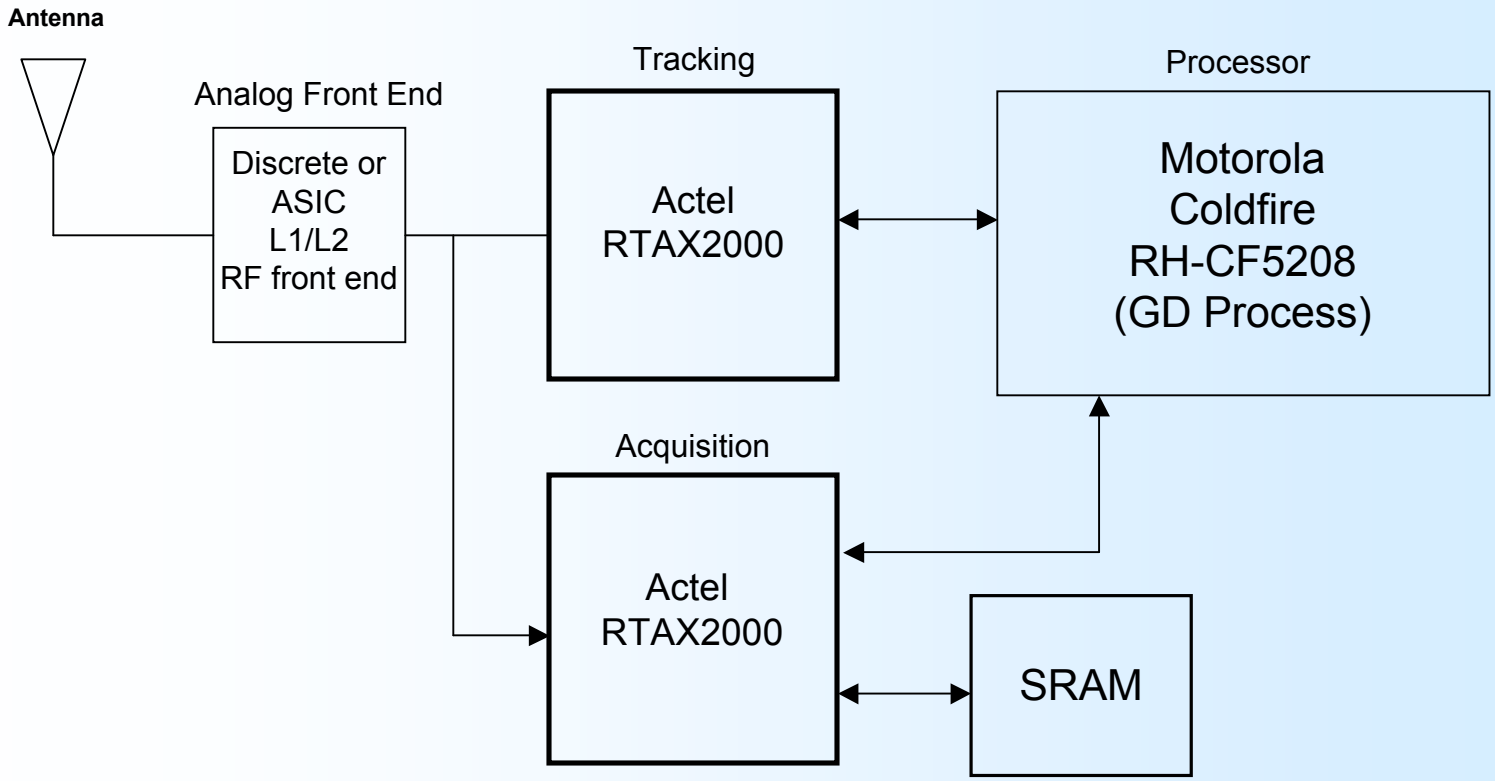
Dual Mode Acquisition



Navigator Tracking

- **Essentially standard tracking correlators/channels**
  - FPGA implementation implies easy upgrade e.g. L2C code generators soon
- **Basic unit is a 12 channel time-shared correlator block**
  - Ultimately 2 or 3 of these blocks for a total of 24 or 36 channels

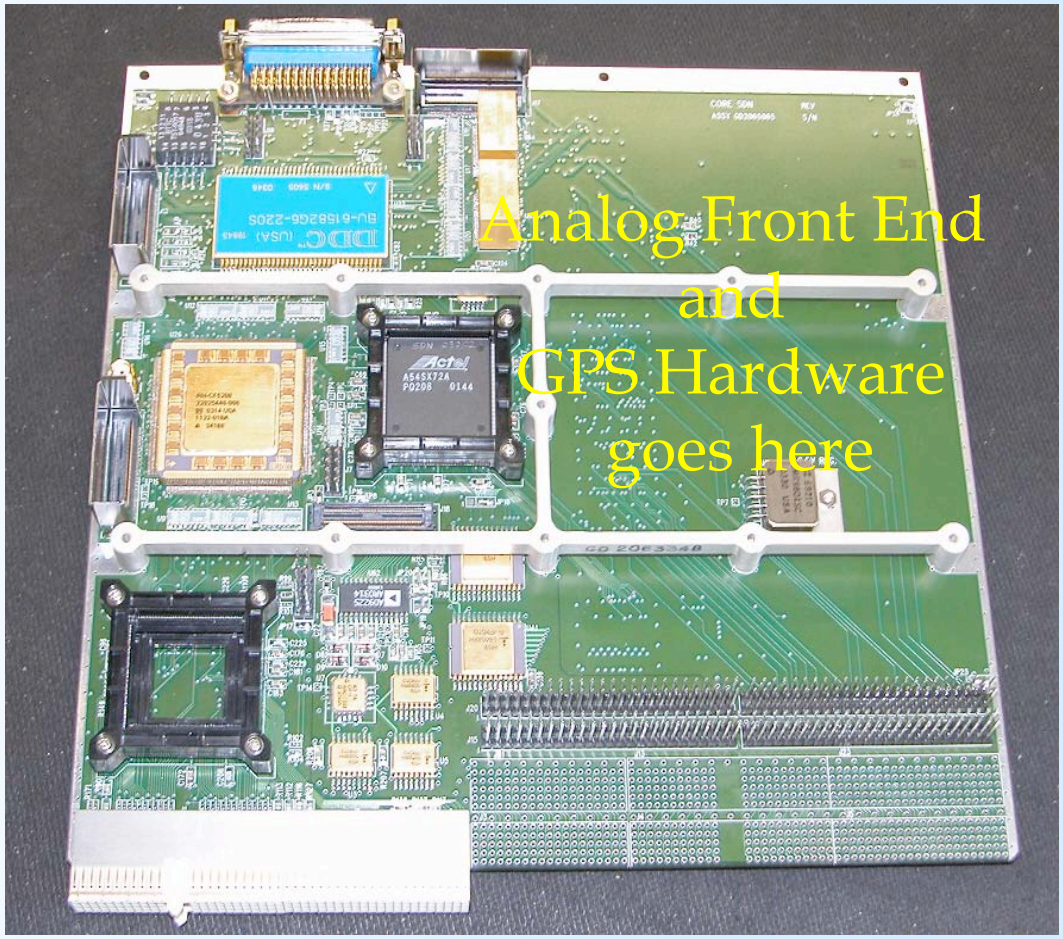
Hardware Implementation

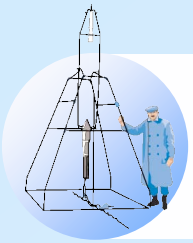


Future Flight Board (Core SDN)

- Taking advantage of NASA's Solar Dynamics Observatory Mission's Subsystem Data Node (SDN) development

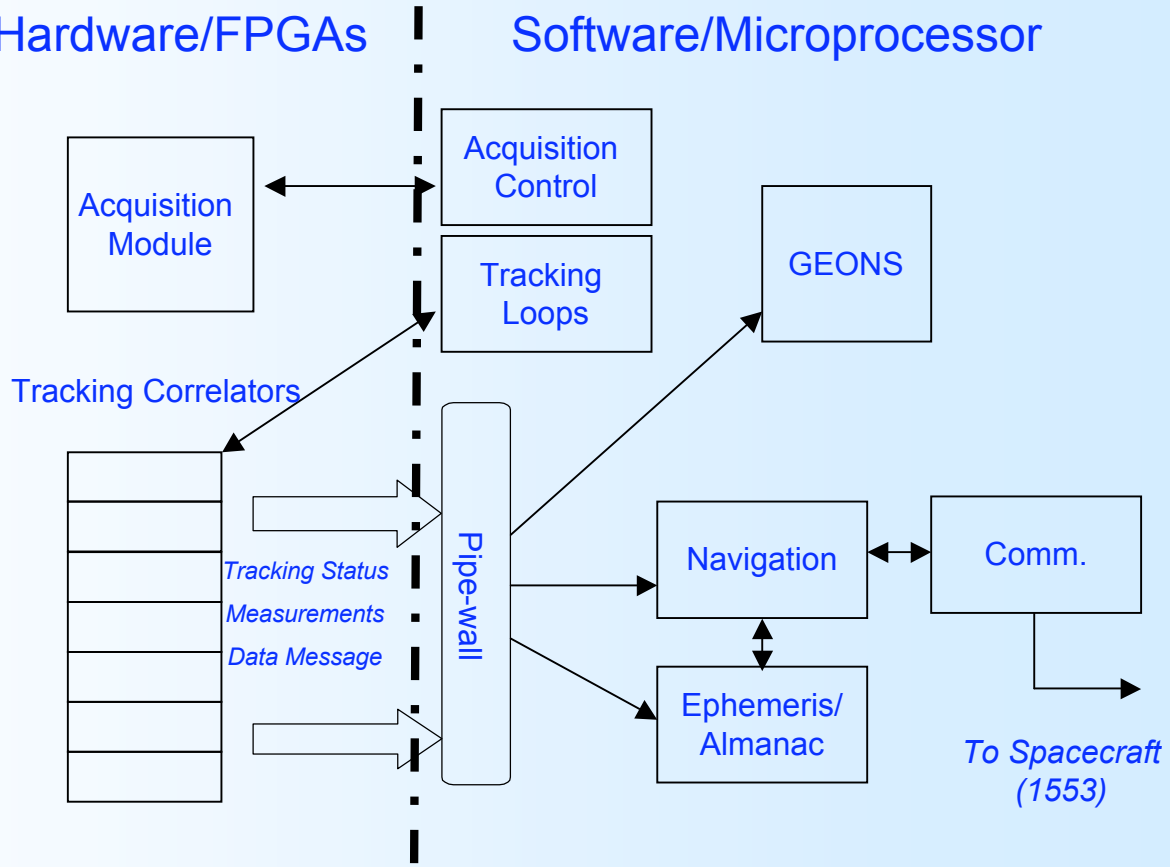
- 6U-220 cPCI card
- Rad-Hard ColdFire
- EEPROM
- cPCI
- RS422
- 1553
- ADC

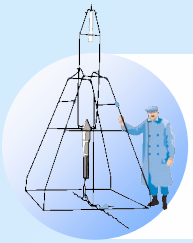




Software

- **New development**
  - Allows open source
  - Applying extensive experience
- **Runs under Nucleus RTOS**
- **Low-level hardware interface and control**
- **Basic Core Navigation**
- **GEONS**
- **Special Applications**
  - e.g. Attitude determination





Navigator Status I

- **Algorithms implemented and tested in non-real time software receiver**
  - Tuned for FPGA implementation
- **Implemented in VHDL/C and tested on Xilinx/ColdFire based development board**
  - Strong signal acquisition/tracking complete
  - Weak signal acquisition/tracking demonstrated to work at 25dB-Hz
  - Low-level receiver software completed

Navigator Status II

- **GPS Navigation software - Ongoing**
  - Basic PVT capability demonstrated
  - Experience with GEONS real-time application on PiVoT receiver being directly applied to Navigator
- **Breadboard Level Design in works**
  - Employs flight (or commercial equivalent) parts
  - Uses Core SDN processor card breadboard
  - Provides fully functional stand-alone receiver for testing in high altitude scenarios in FFTB

Thank You

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