An Integrated Software Defined Radio Navigation System for Space Navigation

ION GNSS 2007

Session C5: Software Receivers 1

September 28, 2007

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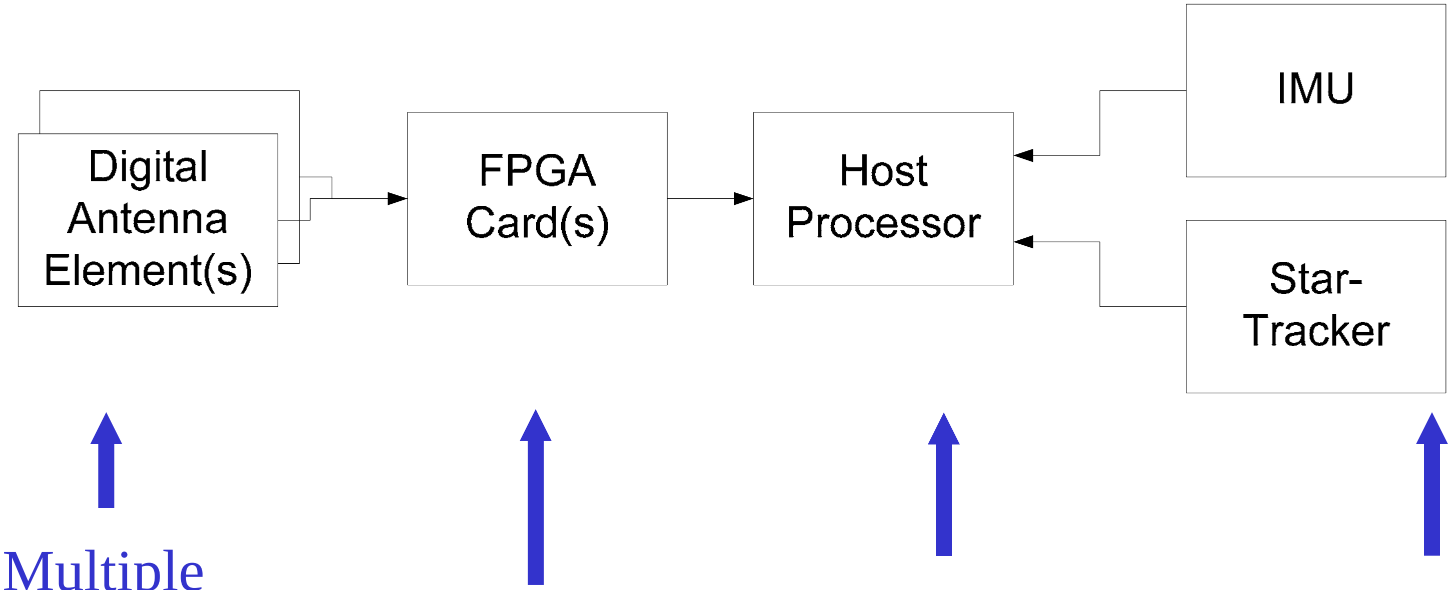
Problem Statement

- Existing space-qualified attitude control and navigation solutions are not suitable for deployment on microsatellites due to size, weight, power, and cost constraints
- Small spacecraft require higher bandwidth attitude control authority due to faster response needed to counter disturbance forces
- A small, flexible, and low-cost attitude control and navigation solution is required to support future microsatellite missions and applications

Benefits of a Software Defined Radio (SDR) Navigation Approach



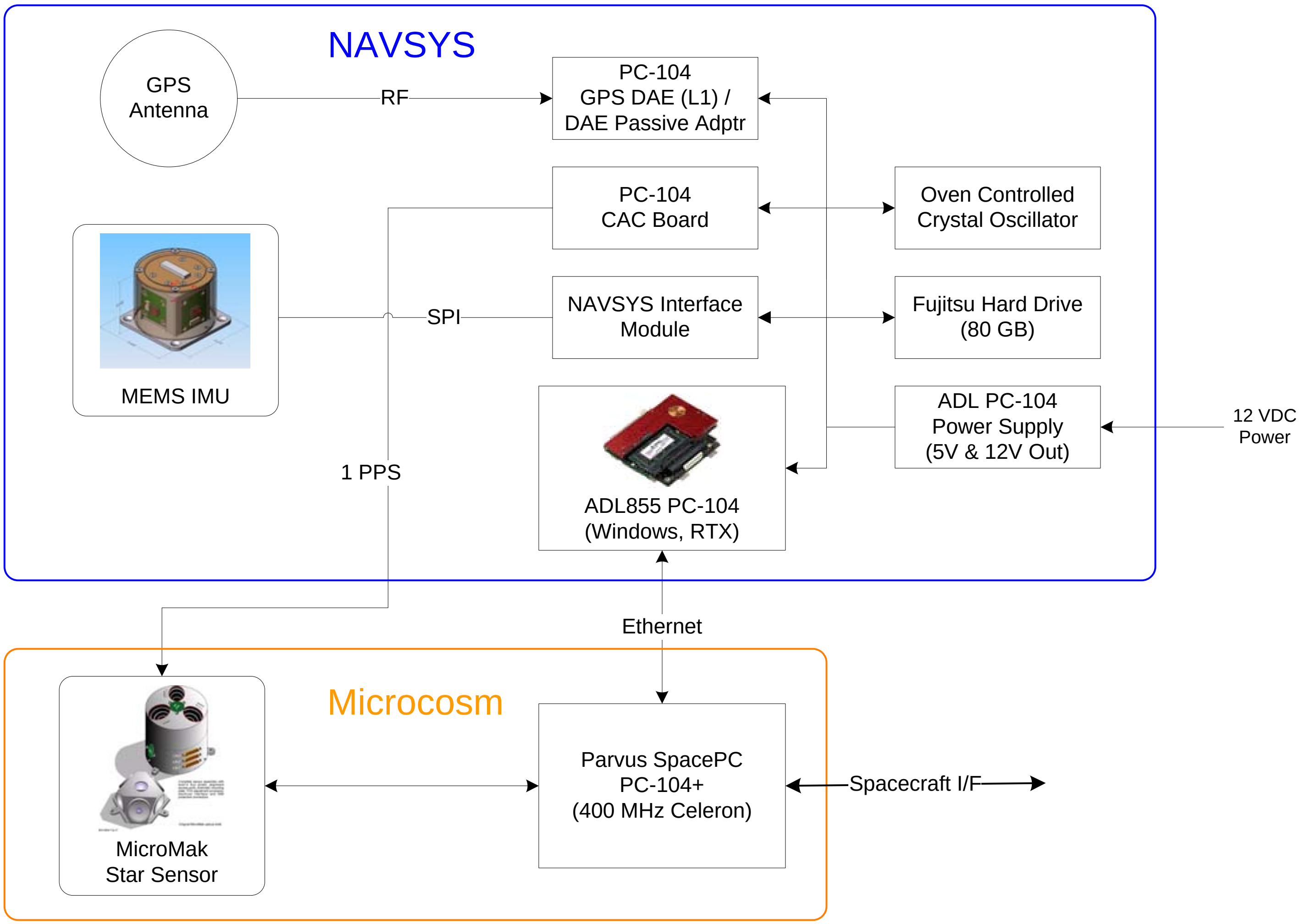
Multiple Frequencies supported by flexible RF/Digital Transceivers

Flexible waveform processing using FPGAs

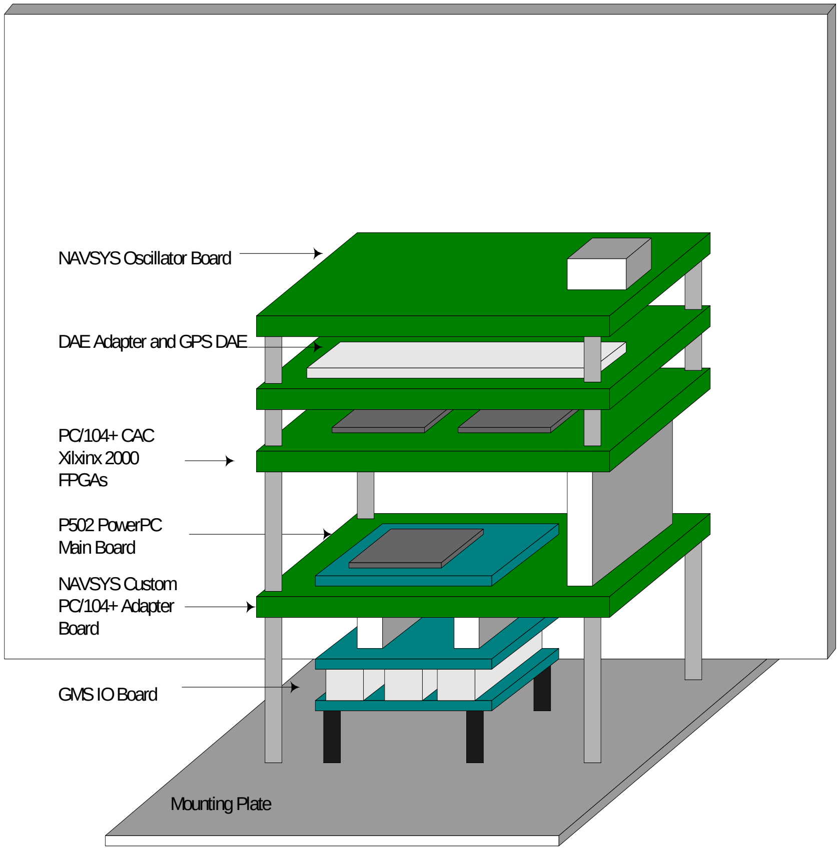
Software control of SDR configuration and operation

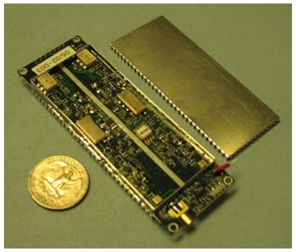
Easy integration of additional sensors and components

Integrated GPS / INS / Star-Tracker

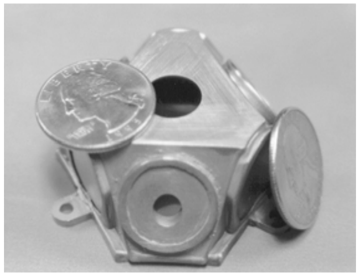


PC/104 SDR Components

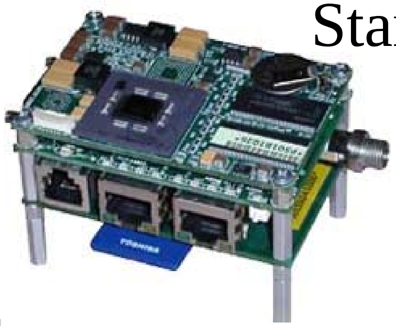




GPS DAE
Board

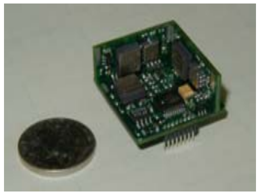


MicroMak
Star-Tracker



Pentium IV
SBC

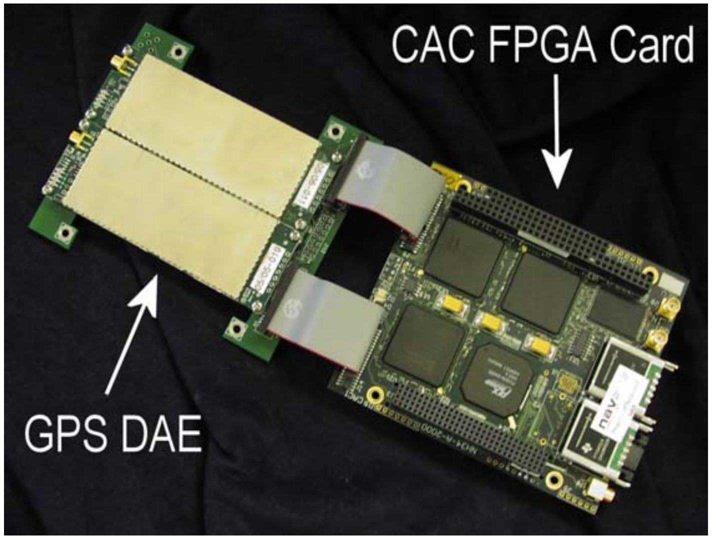
CAC FPGA
Board



Crista
MEMS IMU

Digital Antenna Element and Correlator Accelerator Card

- Digital Antenna Element
  - Front-end down-conversion and digitization
  - Frequency/waveform agile
  - Beamsteering/Beamforming



- GPS Correlator Accelerator Card
  - Firmware-based correlations under SW control
  - Can support other signal processing besides GPS
  - Snapshot acquisition for external post-processing

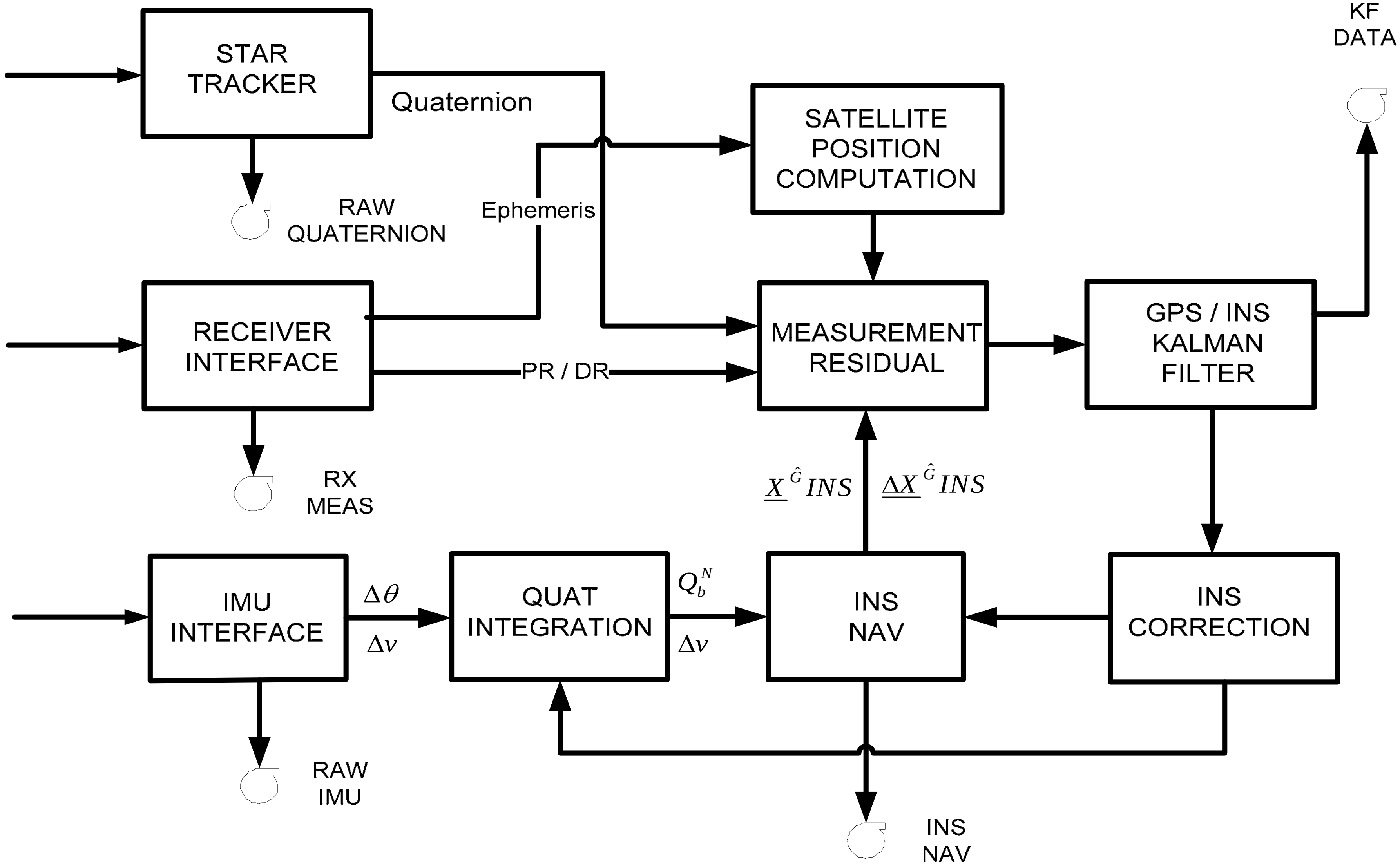
Integrated Navigation Filter

- Must gracefully fuse data from multiple and disparate sensors into an integration attitude and navigation solution
  - GPS – Satellite pseudorange / carrier-phase measurements
  - Star-Tracker – Low-rate, high precision attitude estimates for in-orbit operations
  - IMU – High rate inertial information during orbit insertion and augmentation of star-tracker during satellite in-orbit maneuvering

InterNav Modular Inertial Navigation Product

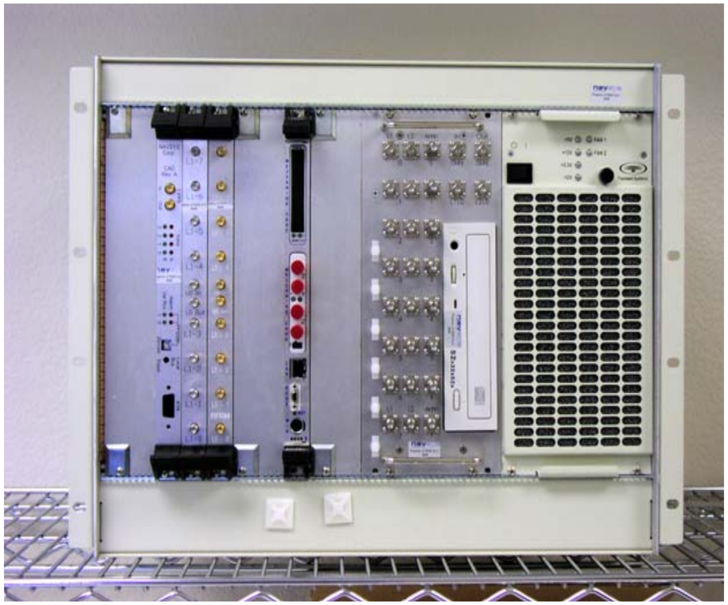
- Integrates GPS, inertial, and a variety of other sensor data
  - PR/DR or Pos/Vel
  - $\Delta\theta$, ΔV from gyros and accels
- Modular design facilitates integration of different sensors
  - Was modified under this effort to integrate star-tracker data into the combined navigation solution
- Performs inertial navigation functions
- Uses Kalman Filter for applying GPS updates
- Can be configured to optimize performance based on sensor characteristics

Filter Implementation



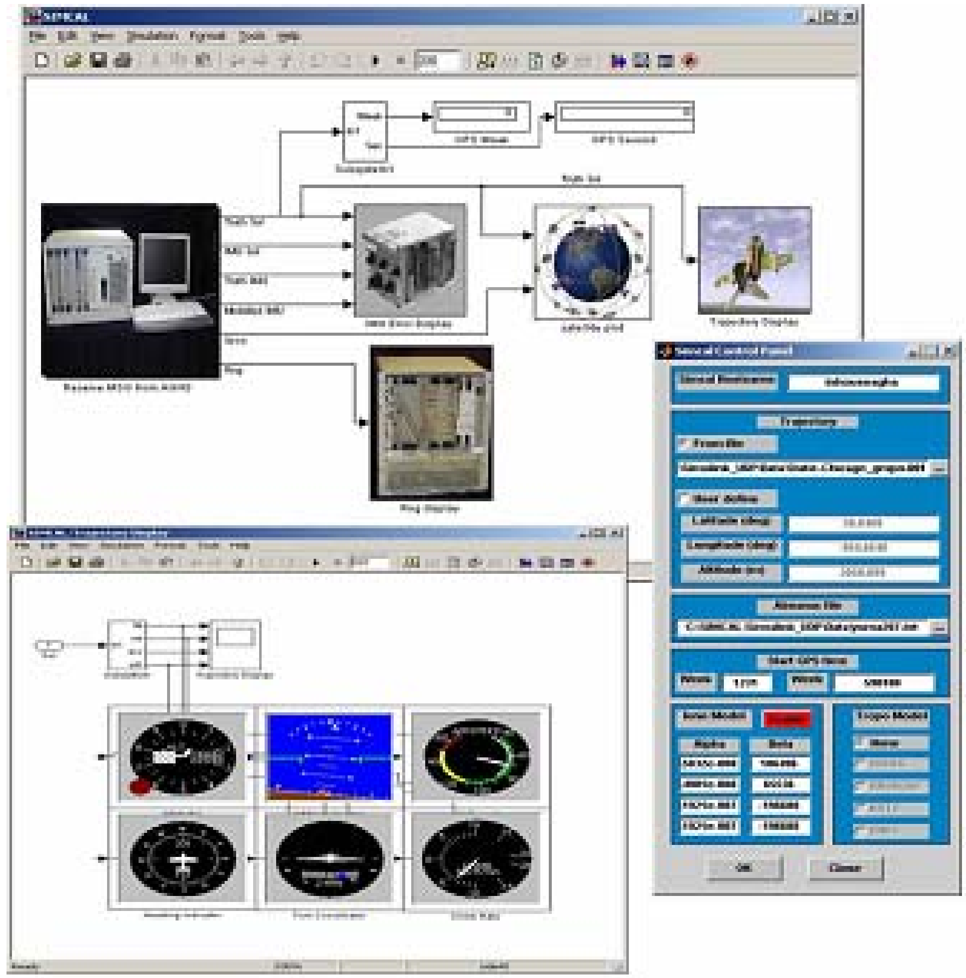
NAVSYS Advanced GPS Hybrid Simulator (AGHS)

- Simulator control provided through Matlab/Simulink interface
- Open architecture to facilitate integration with trajectory generators
- Precise digital signal generation under software control
- Multiple antenna elements for wavefront simulation (8+)
- Jammer simulation
- Simulated inertial output
- Simulated star-tracker output

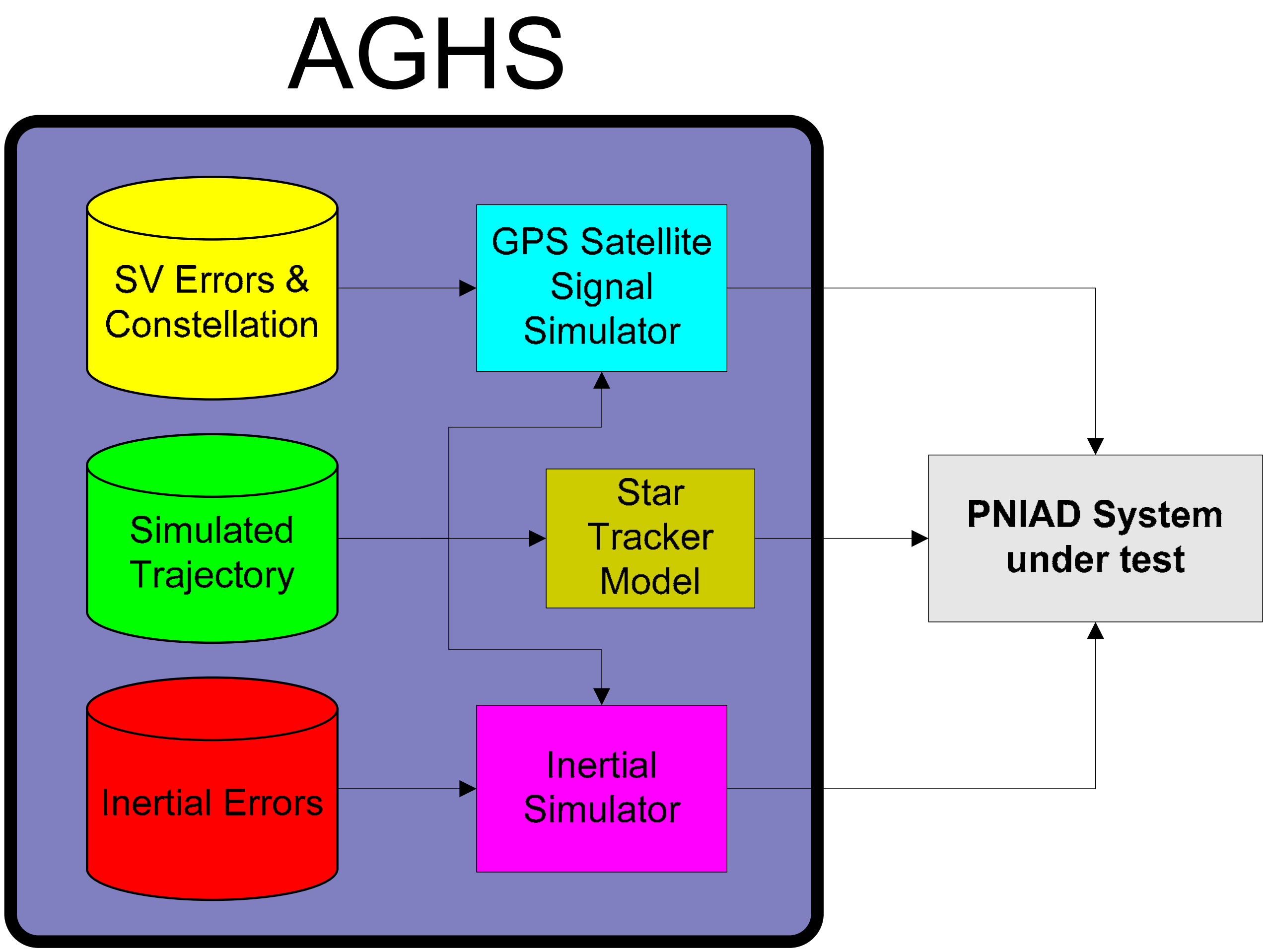


AGHS Simulink Interface

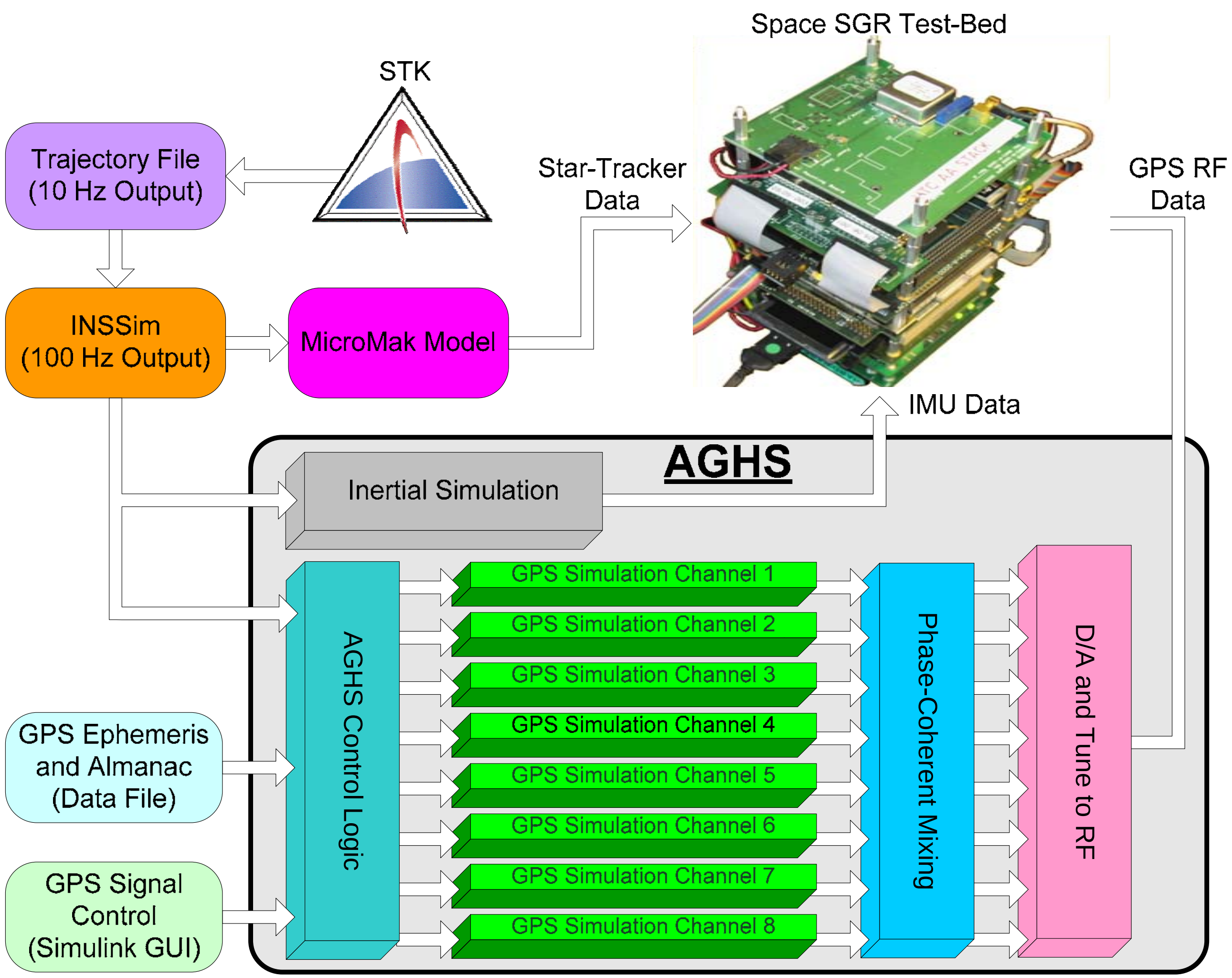
- Provides a user-friendly interface for simulation control and analysis
- Open, flexible architecture supports easy modification for prototyping – This architecture was leveraged for rapid insertion of star-tracker simulation capability



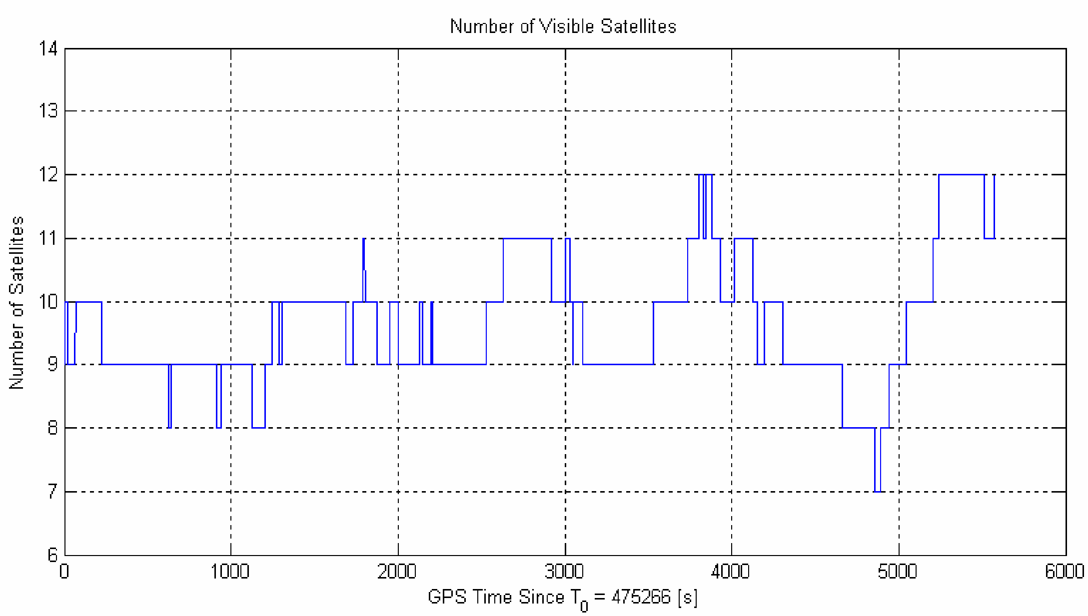
AGHS Test Set-Up

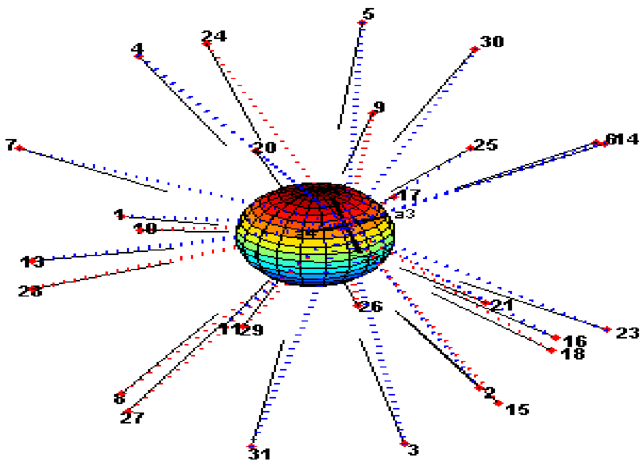


AGHS HWIL Test Architecture

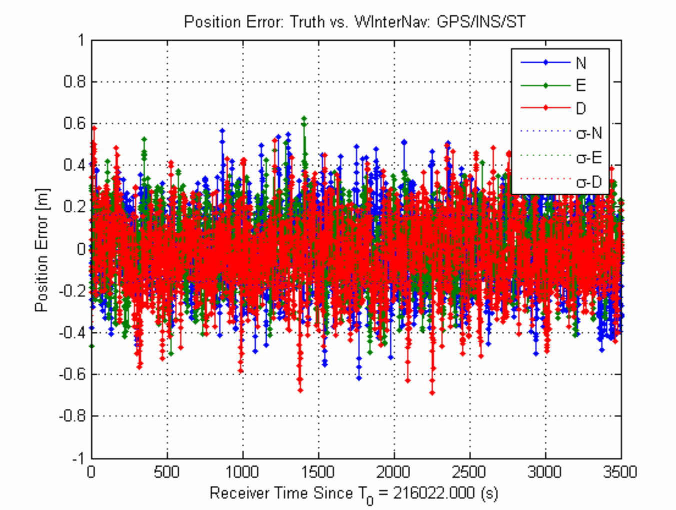


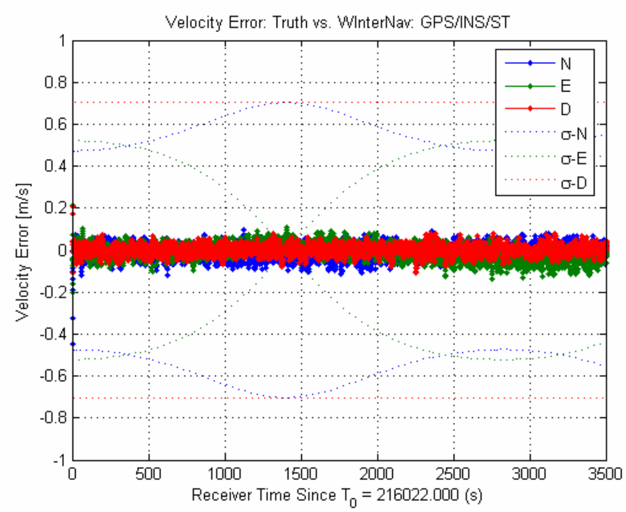
GPS Tracking Results

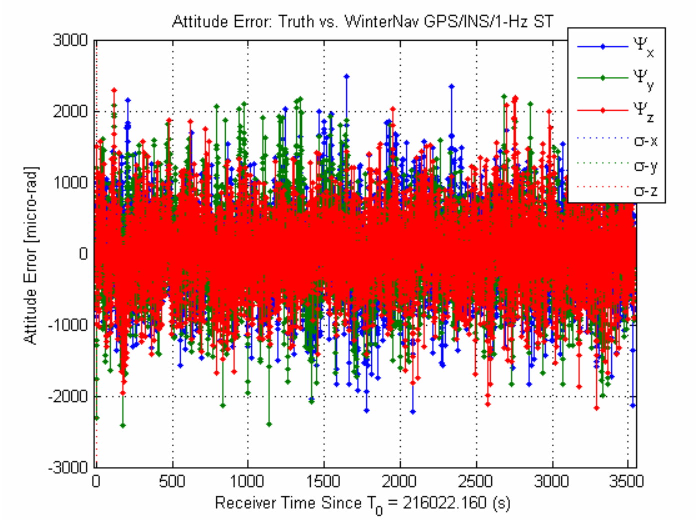


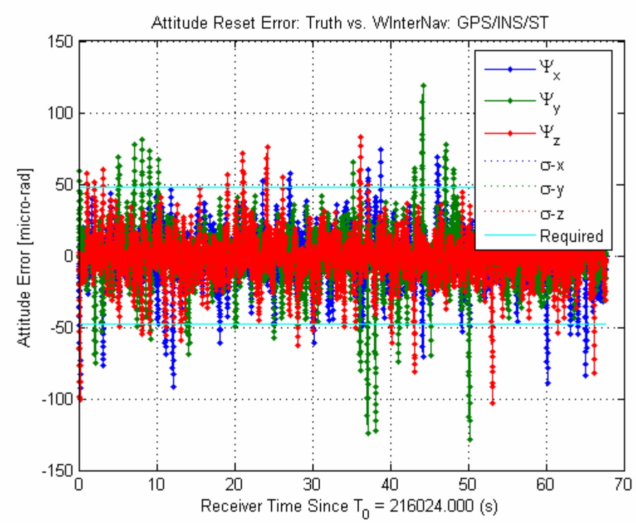


Integrated Filter Test Results



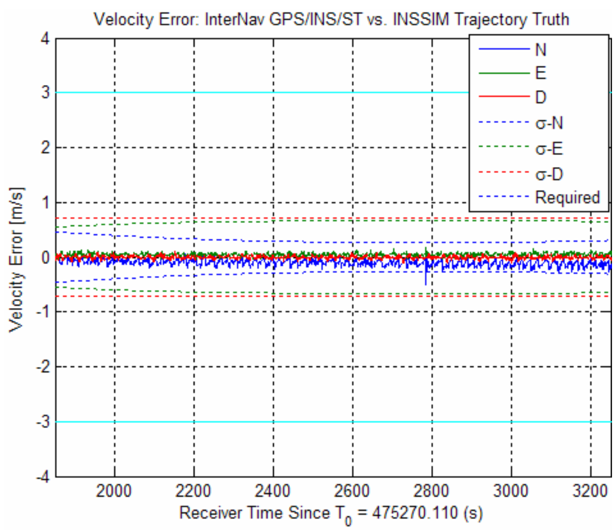




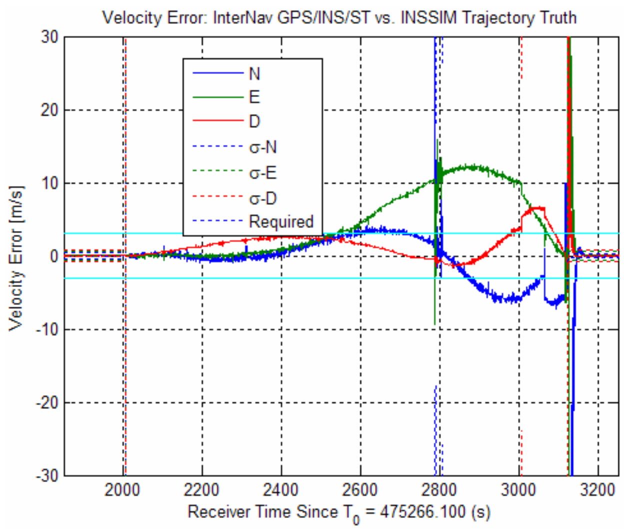


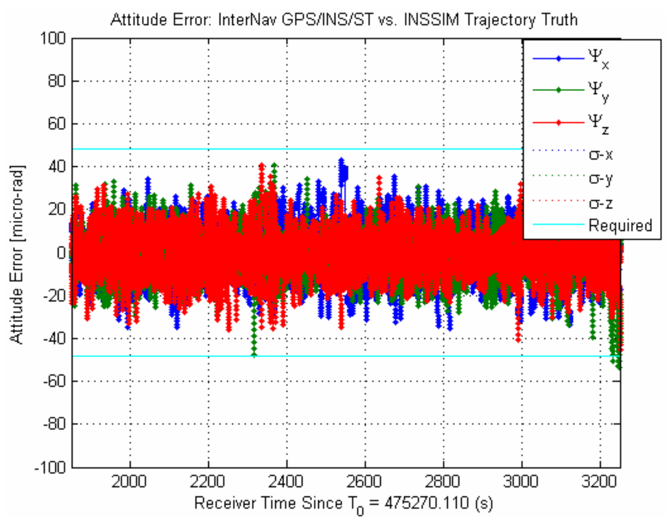
Importance of Star-Tracker Input

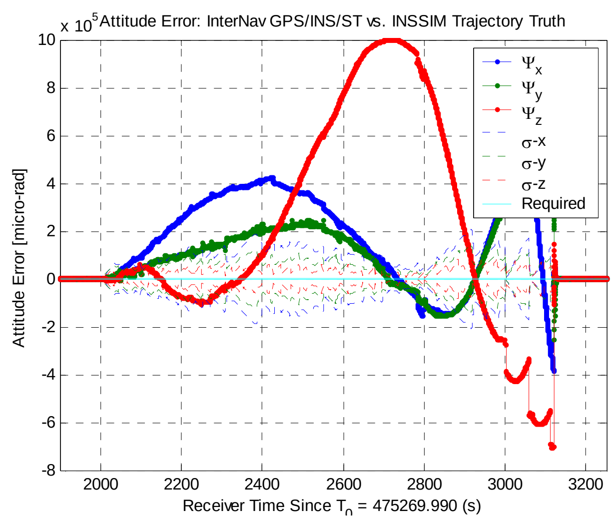
With Star-Tracker



Without Star-Tracker







Conclusions

- Prototype integrated space navigation receiver has been developed and tested
- Benefits of star-tracker integration into navigation filter have been shown
- Provides an affordable navigation option for low-cost microsatellite missions
- Future efforts are focusing on radiation hardening and incorporation of NAVSYS IMU

Questions?