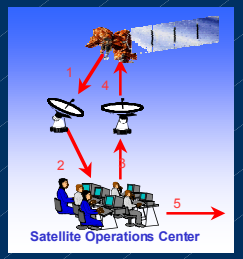
GEONS

GPS-Enhanced Onboard Navigation System

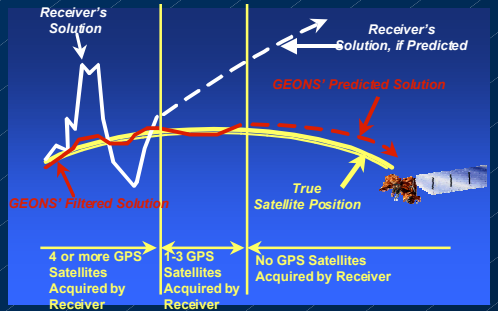
BEFORE
Ground-Based Navigation Scenario



2-30 Day Delay

AFTER
GPS-Based Navigation Scenario

Instantaneous



GSFC PiVoT GPS Receiver

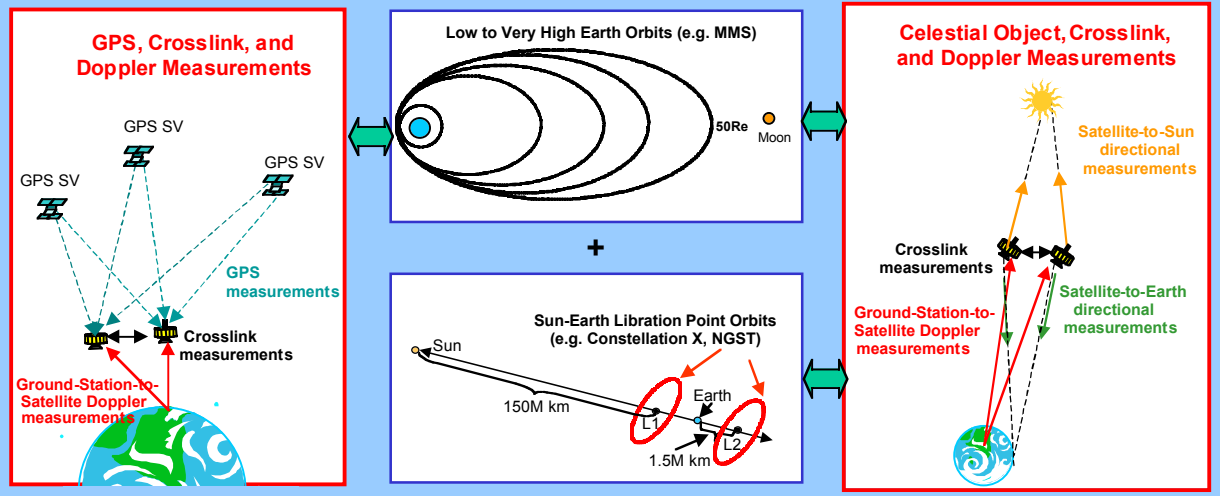
Technology Transfer

- Jointly developed by NASA GSFC and Computer Sciences Corporation (CSC); CSC copyright assigned to U.S. Government
- Commercially licensed to Orbital Sciences Corporation and Ball Aerospace
- Infused into ITT Low Power Transceiver and GSFC PiVoT GPS receiver
- Transferred to Air Force Research Lab, NASA LaRC, Aerospace Corporation, FAA (in work)

Demonstrated Capabilities

- Low Earth Orbit GPS
  - Flight data validation: Extreme Ultraviolet Explorer
  - Flight qualification: Lewis
  - Flight proven: Earth Observer-1
- High Earth Orbit GPS
  - Analytic proof-of-concept for up to 10x50 RE
  - Flight data validation for 1.15x10 RE (AMSAT Phase 3-D) in work
- Celestial Navigation
  - Analytic proof-of-concept for libration point orbits (LPO)
  - Flight data validation for HEO (POLAR) and LPO (SOHO)

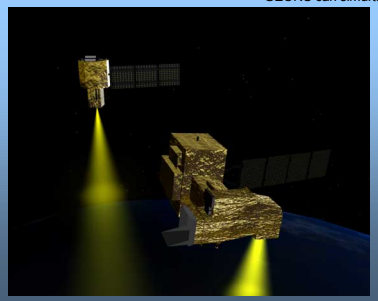
Mission Orbit Types

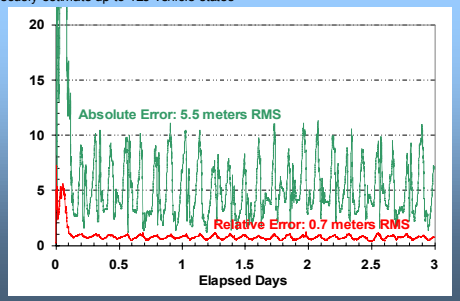


Planned Capabilities

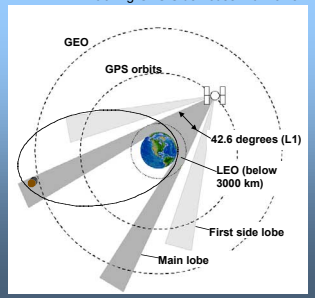
- Tracking and Data Relay Satellite (TDRS) Onboard Navigation
  - Flight data validation: Extreme Ultraviolet Explorer
  - Flight proven: Terra
- GPS attitude determination
- Lambert targeted orbital maneuvers
- Decentralized formation control

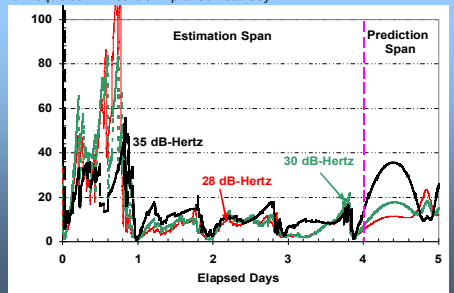
GEONS can simultaneously estimate up to 128 vehicle states





Tracking GPS Side Lobes with Lower Receiver Acquisition Threshold Improves Accuracy





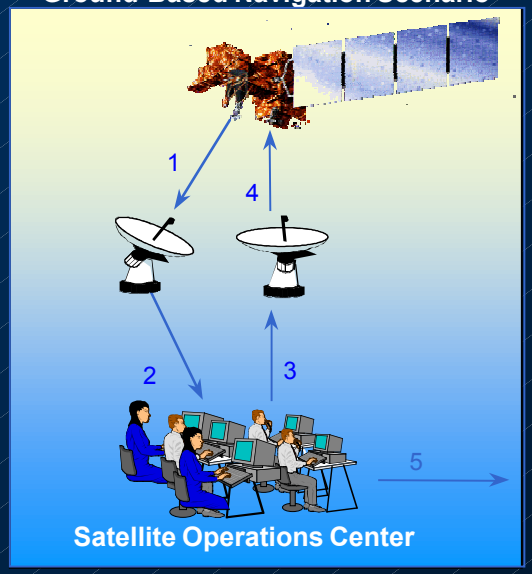
Development Status

- GPS absolute navigation: TRL 8-9
  - Flight-qualified against operational standards for SSTI-Lewis
  - Flight-proven subset (GEODE-Lite) on EO-1
  - Embedded into ITT low power transceiver to fly on STS-107
  - Basis for onboard orbit determination of OSC's Orbview commercial remote sensing satellites
- Onboard absolute navigation using ground contacts: TRL 4
  - Embedded in Motorola 4th-generation transponder
- TDRSS Onboard Absolute Navigation: TRL 8-9
  - Flight-proven on Terra
  - Capability to be added to GEONS
- Relative nav. in any Earth orbit using GPS + crosslinks: TRL 3-4
  - Validated via simulation for missions up to 10 x 50 Earth radii
  - Simultaneous estimation of up to 128 user satellites
- Celestial nav. for deep-space and libration missions: TRL 3
  - Absolute and relative navigation

Impact: "Lights-out" Satellite Operations

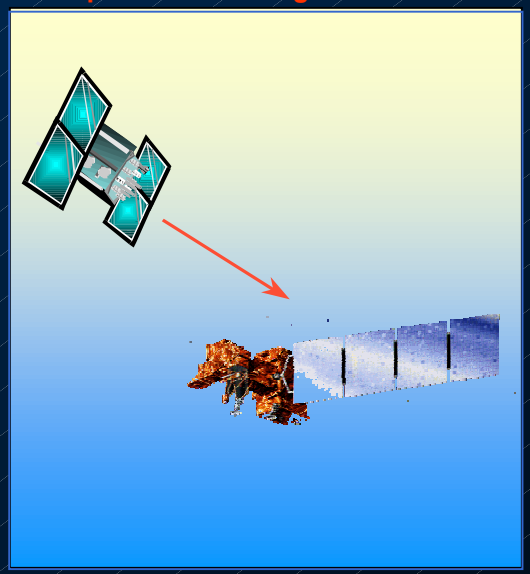
- High accuracy navigation products
  - Increase accuracy of satellite orientation control
  - Provide more precise scientific measurements
  - Enable autonomous maneuver planning and control
- High reliability reduces risk
- Streamlined operations provide satellite position instantaneously in science data stream and drive down ground operations costs

BEFORE
Ground-Based Navigation Scenario



2-30 Day Delay

AFTER
Sample GEONS Navigation Scenario



Instantaneous

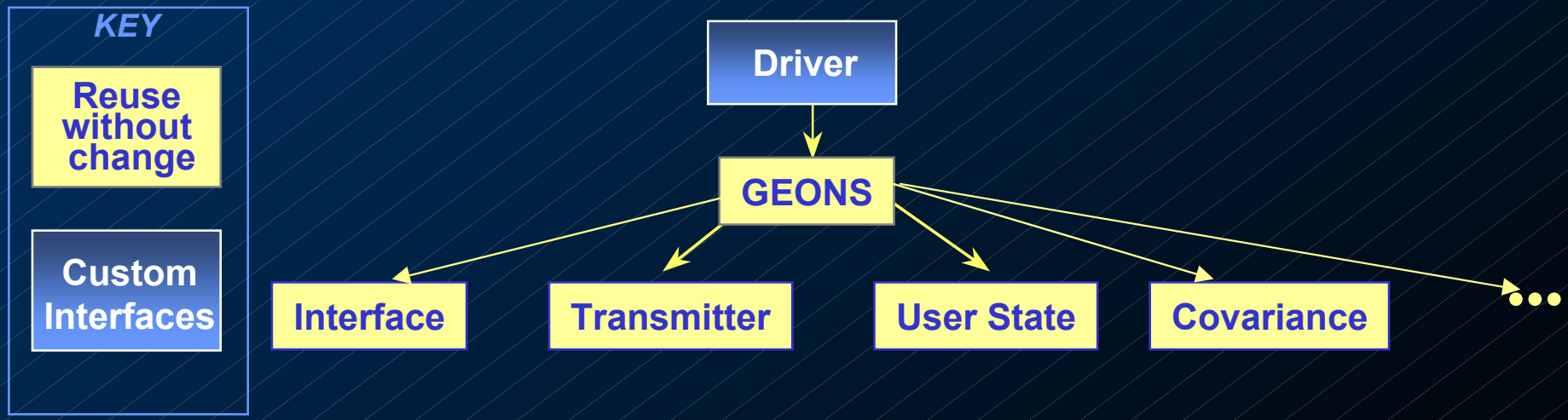
- "Lights-out," autonomous satellite operations eliminate ground tracking and orbit determination to save $Millions per year, significantly reducing the cost of formation-flying missions

Usability

- Comprehensive set of documentation: Software Requirements Specification, Mathematical Specifications, System Description and User's Guide (included in evaluation package)
- Software configuration maintained using CVS
- *Bugzilla* used to track bugs reports, technical support requests
- ANSI standard C, environment-independent implementation to maximize portability (sample source code included in evaluation package)
- Object-based architecture with standardized interfaces to maximize reuse
  - Options such as measurement types and number of vehicles to be simultaneously estimated may be set at compile or run time
- Open architecture development fosters NASA/academic/commercial collaboration to produce a better product at a lower cost
- Personalized training available upon request

Quality Factors

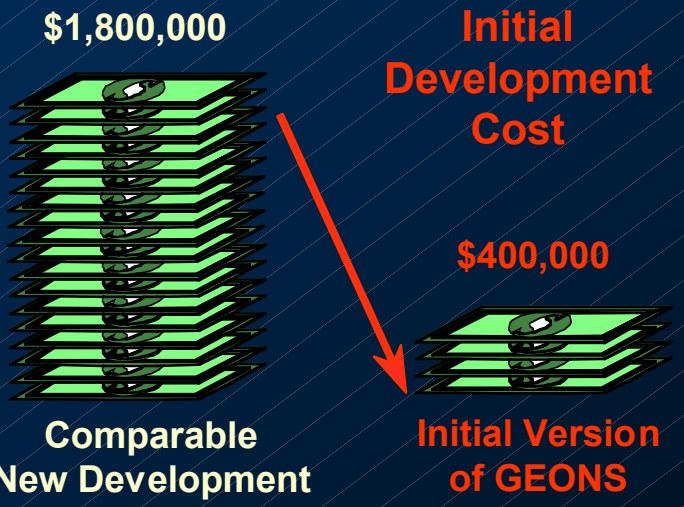
- Object-oriented architecture selected to build in flexibility to support a wide range of mission types and enhance maintainability
- ANSI C language selected to reduce code size and for ease of portability
- Designed to be operating-environment independent; successfully executed in the following environments:
  - PC/Windows, Sun/HP/ Unix, Dec Alpha/Linux

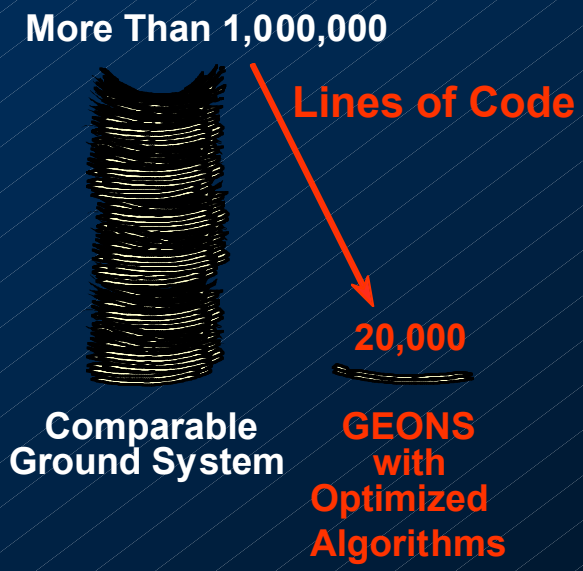


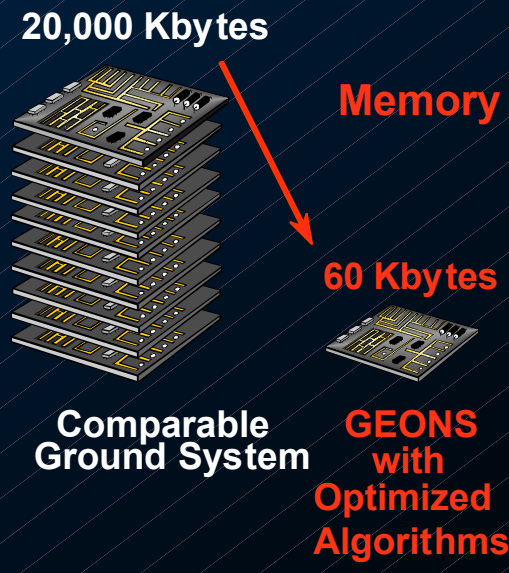
Object-based architecture with standardized interfaces maximizes reuse

Engineered to Satisfy Cost and Resource Constraints

- Reused GSFC-developed TONS S/W components to save more than $1,400,000 in initial development
- Engineered to fit within the constraints of an onboard processor without compromising accuracy







State-of-the-Art Algorithms Optimized for the Space Environment

Innovative Algorithms	Benefits
High fidelity model for satellite motion (gravity, Earth's atmosphere, etc.)	Can coast through data outages for more than 24 hours
Kalman filter for computation of corrected position and velocity	Computes real-time corrections Provides high-accuracy velocity solutions Can handle sparse, incomplete, and noisy measurement data
Combination of accurate model and Kalman filter	Significantly reduces impact of Sensor measurement errors
Simultaneous estimation of up to 128 vehicles	Enhanced performance for formations and constellations

Intellectual Property Status

- Jointly developed by NASA GSFC and Computer Sciences Corporation
- Copyright for CSC portion assigned to NASA
- Freely available (source code included) to all US Government programs (including contractors)
- Licensing fees for commercial applications
  - Currently, fees go to US Treasury
  - Planned enhancements include incorporation of existing GSFC patented innovations (GPS attitude determination), which will allow NASA to retain licensing fees