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Flight Dynamics System

For GLAST Spacecraft Operations

Jonathan DeGumbia/Omitron

Mark Woodard/NASA

Mission Overview

- Gamma-ray Large Area Space Telescope (GLAST)
  - NASA/DOE gamma-ray orbiting space science observatory
  - Launches August, 2007
- Goldbelt Orca, LLC and Omitron, Inc. are teamed to proved the Mission Operations Center at GSFC
- Under the guidance of NASA/FDF, the Flight Dynamics System (FDS) is under development as a component of the MOC

Flight Dynamics System

Principal Functions of the FDS

- Orbit determination
- Orbit events product generation
- TDRSS Scheduling
  - Attitude dependent TDRSS scheduling
  - Schedule validation

Challenges for the FDS (1 of 2)

- Need for accurate orbit determination
  - GPS Inaccuracies
  - Limited TDRS contact time
  - 17-24 day TDRS scheduling lead time

- Need for attitude dependent contact scheduling
  - Limited effective field of view of Ku antenna
  - Limited TDRS contact time
  - Complex and immovable attitude profile

Challenges for the FDS (2 of 2)

- Need to optimize TDRS contact schedule
  - Complex and numerous scheduling constraints
  - Must quickly and accurately deconflict constraints
- Need to be highly automated
  - Reduce burden on flight operations staff
  - Reduce risk of manually performing lengthy complex procedures

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GPS Improvement with OD Tool Kit

- Telemetry data from the GPS receiver is expected to have good position knowledge but relatively poor velocity knowledge.
- Velocity knowledge must be improved before propagating the orbit
- The OD Tool Kit provide filtering/smoothing of GPS point solutions to incorporate high fidelity force models
- Orbit propagation accuracy is expected to improve by roughly 2 orders of magnitude

Orbit Determination Results

- Raw GPS telemetry was simulated with 20 cm/sec RSS velocity uncertainty
- OD ToolKit reduced RSS velocity uncertainty to 0.29 cm/sec at the center of the solution interval
- OD Toolkit results compare favorably to Goddard Trajectory Determination System (GTDS) results, 0.25 cm/sec RSS

Attitude Modeling Problem Definition

- Need for attitude dependent scheduling
  - Gimbaled, narrow beam antenna used to downlink science data through TDRS
  - Unfortunate placement of the antenna
  - Complex, immovable, non-repeating attitude profile
- Must predictively model GLAST attitude using weekly bus pointing commands issued by science center to determine when TDRS contacts are possible
- STK/Pro & STK/Attitude “canned” attitude profiles were not adequate

Attitude Modeling

- Vector Geometry Tool used to create a custom orbit frame-of-reference (similar to LVLH) to match what is used by the spacecraft vender
- Perl plug-in scripts used to create a custom vectors within the custom frame-of-reference
  - One plug-in script needed for each mode (Sky Survey and Inertial Point)
  - Scripts simulate the bus pointing control logic provided by the spacecraft vender
- STK/Attitude “Aligned and Constrained” attitude profile used as a baseline for custom attitudes
  - “Aligned” vector is set to align the body z-axis with the custom vector
  - “Constrained” vector simply set to constrain the body x-z plane on the Sun, always keeping the solar arrays normal to the Sun

Attitude Modeling

- Segmented attitude profiles are then used to switch between the different science gathering modes
- A simple, well-defined sensor fixed to the spacecraft body simulates the effective field-of-view of the combined science downlink antenna and its gimbal
- A line-of-sight access report between the sensor and each TDRS provide attitude dependent view periods

Attitude Modeling Results

Sky Survey mode

- Zenith orientation with a timewise-varying rocking angle about the velocity vector
- Yaw-steering performed to maintain Sun vector normal to the body y-axis
- Sun must always be on +x body side of bus causing high-rate yaw flips twice per orbit (as $\pm z_{body}$-axis approaches sun vector.)
- Complex sun avoidance maneuver reduces body rates during yaw flips

Attitude Modeling Results

Inertial Point mode

- $\pm z_{body}$-axis inertially fixed on target
- Yaw-steering performed to maintain Sun vector normal to the body y-axis on +x body side of bus
- Earth limb-tracing when target is occulted by Earth
- Time varying additional radial offset during Earth limb trace, offset a function of the angle of the target off of the orbit plane

TDRSS Contact Scheduling

- Highly constrained scheduling problem mandated the need for STK/Scheduler
- Attitude TDRS access and other event reports are ingested in STK/Scheduler
- Each constraint modeled as time windows in STK/Scheduler
- Optimizing engine used to determine best contact schedule
- Resulting contact schedule used to request TDRS resource time from NCCDS

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TDRS Schedule Validation

- Just prior to upload to GLAST, planned contact times must be validated
  - Predictive ephemeris is now much more accurate
  - Bus pointing commands may have changed
- Independent constraint validation routine within STK/Scheduler used to ensure all constraints are met
  - Updated info used to create attitude dependent timeslots in STK/Scheduler as normal
  - Confirmed TDRS contact schedule from NCCDS used to manually assign contacts to timeslots (STK/Scheduler's optimizer not used)
  - Independent STK/Scheduler validation is run
  - Conflict report provides all necessary information about any constraints that are violated

Conclusions

- GLAST mission provided challenging & unique requirements for the MOC FDS
- Were able to select STK components to satisfy the majority of the requirements
- Wherever STK tools could not perform the necessary functions we were able to integrate custom code and modify work flow to meet GLAST needs
- STK tools allowed for automation

Back-up Slides

Why Sun Avoidance Maneuvers?

Sun Avoidance maneuvers bound the body yaw rates and prevent the rates from becoming infinite as Sun vector approaches body z-axis