Radar Satellite Constellation Tasking Simulation with STK

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Background

- This future radar satellite constellation would provide ground moving target indication (GMTI), synthetic aperture radar imaging (SAR) and other specialized modes
- Thousands tasking requests per day per satellite
- Data produced from the constellation would be on hundreds of gigabytes per day

Problem

- Realistic simulation of a constellation of multi-mode radar satellites, communications links and radar contact with a large number of targets
- Evaluation of design choices on operation of constellation
- Evaluation of benefits and drawbacks of various scheduling algorithms
- Demonstrating dynamic tasking and real-time scheduling for time critical targets

Constellation

- 9 satellites in a modified Walker constellation
  - Small offset for “co-planar” satellites for repeating ground traces
- X-band radar with multiple radar modes
    - SAR: Synthetic Aperture Radar
    - GMTI: Ground Moving Target Indicator
    - ESM: Electronic Support Measures
- Agile electrically steerable phased array antenna (AESA)
  - AESA coverage area modeled as a rectangular beam
  - Small SAR and GMTI beams operating within the AESA range

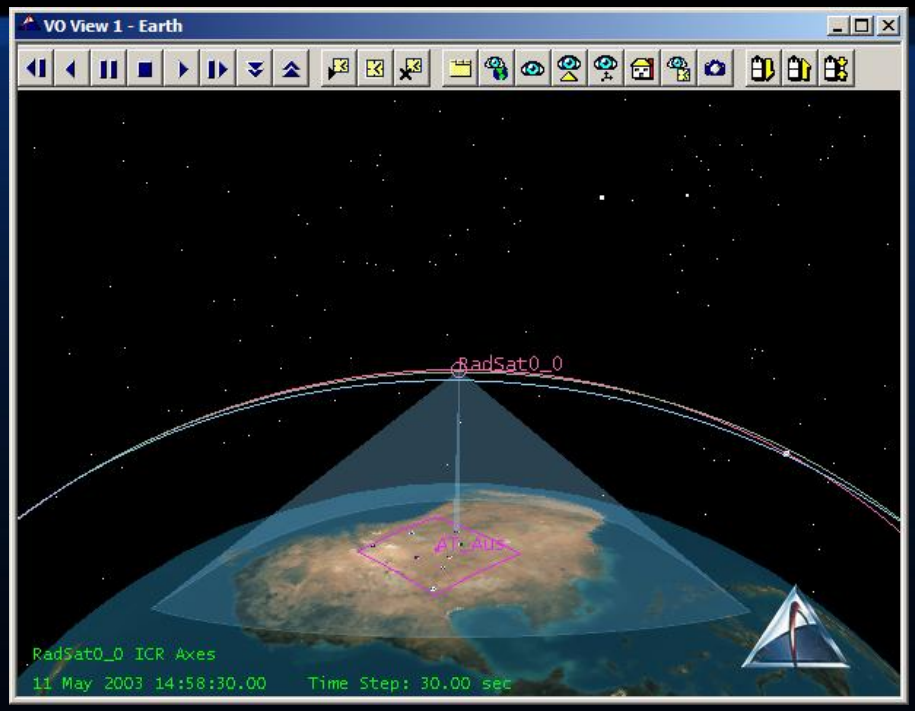
Communications

- Low forward data rate requirements (~ 10 Kbit/sec)
- High return data rate requirements (~ 10 Gbit/sec)
- High speed communications links between radar satellites with links to geosynchronous relay satellites
- Limited on board data storage

Simulated Data Collection

- Restrict SAR data collections to
  - Targets near perpendicular to vehicle trajectory
    - Range rate between +/- 200 m/s
  - Targets at grazing angles between 12 and 70 degrees
- Restrict GMTI data collections to
  - Targets close to the vehicle trajectory
    - Range rate greater than 1000 m/s
  - Targets at grazing angles between 6 and 60 degrees
- Although the collection time depends upon a number of parameters during this simulation a fixed collection time of 20 seconds is used for both SAR and GMTI products

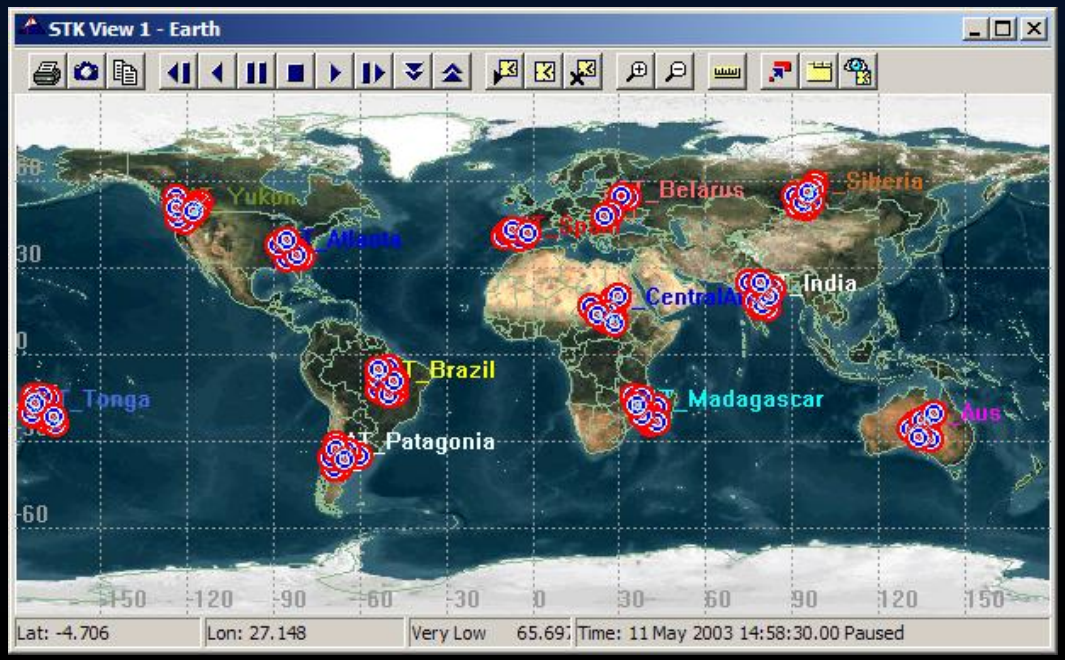
Visualizing the Data Collection



- AESA coverage area covers a very large area
- Narrow radar beam can be directed throughout the coverage area on a pulse-by-pulse basis

Scenarios

- Area targets are distributed around the globe
  - In the least controversial locations I could image
- GMTI and SAR targets randomly located within area targets
  - Small, medium and large scenarios with varying numbers of targets



Generating Simulated Targets

- Two approaches to creating a large number of targets in an STK simulation
  - Socket interface
    - Provides a dynamic interface but can be slow as the number of targets increases
  - Writing the STK configuration files directly
    - Must be created before the simulation is run but is much faster when a large number of targets is being created
    - .t, .t3, .sn, .sc files all need to be written
    - Currently undocumented
- Deck access tool provides the fastest way to compute access from satellites to a large number of targets, but deck access targets cannot be imported into STK/Scheduler
- Targets are added through the socket interface when new “tasks” are added

Simulation Flow

- Scenario is initialized with targets and tasking requests
- Schedule is created
  - Evaluate possibilities and schedule tasks based on the figure of merit
- New tasking is injected
  - Randomly
  - Interactively through a Visual Basic application
- Add the target to the scenario and a task to the schedule

Tasking Console Prototype

- Capabilities based tasking – specify the task in terms of the desired product rather than
  - Product
    - Provide a simple interface for requesting data products
  - Revisit rate
    - One time, periodic, criteria based
  - Prioritization
    - Enable immediate response for time critical targets
- Add a new target to the STK simulation and a task in the Scheduler using the socket interface then update schedule

Scheduler

- Provides flexibility for evaluating various scheduling algorithms, different figures of merit (FOM)
- Large number of targets with multiple satellites results in a large number of potential scheduling opportunities
  - Partitioning problem by scheduling each area target separately reduces the scale of the problem and provides a means of load balancing and prevents one area from consuming more than its share of resources
- On-board data storage and battery power are modeled as consumable resources
  - On-board storage is replenished with a Data Transfer task that moves the data through the geo-sync relay
  - Battery power is replenished with a once-per-orbit solar power refresh
- Future releases will allow scheduling based on parameter value constraints (v2.2) and later, time-varying desirability within a timeslot so scheduling can be optimized within timeslots that meet the parameter value constraints

Summary

- STK provided the capability to generate a simulation of the radar satellite constellation and the associated sensor coverage, communications links and a large number of targets
- Localized, hierarchical scheduling of targets reduces the scale of the problem
- Co-scheduling of the on-board resources (batteries and data storage) and communications links increases the level of complexity
- Currently a work in progress with a focus on developing fast, dynamic scheduling and improving the fidelity of the simulation