Magnetospheric MultiScale MSS) System Manager

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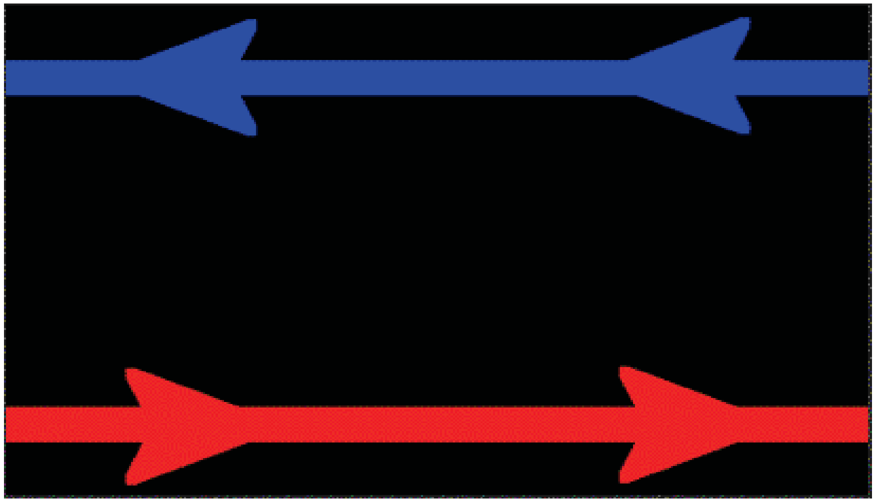
THE MISSION

Science of Magnetic Reconnection

- Study magnetic reconnection in the Earth's magnetosphere
- Magnetic reconnection converts magnetic energy into kinetic energy
  - Oppositely directed parallel field lines are pinched
  - They join and snap apart like a breaking rubber band

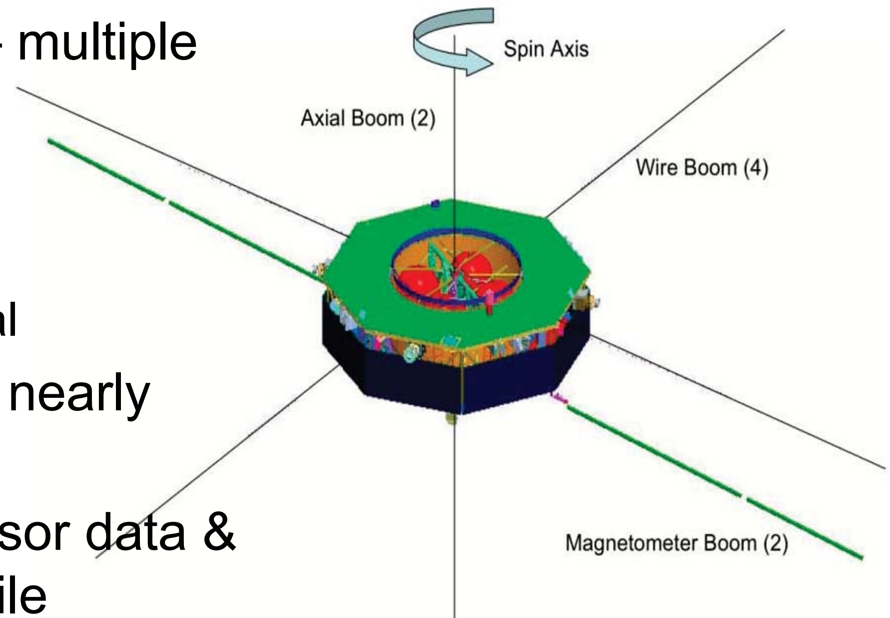


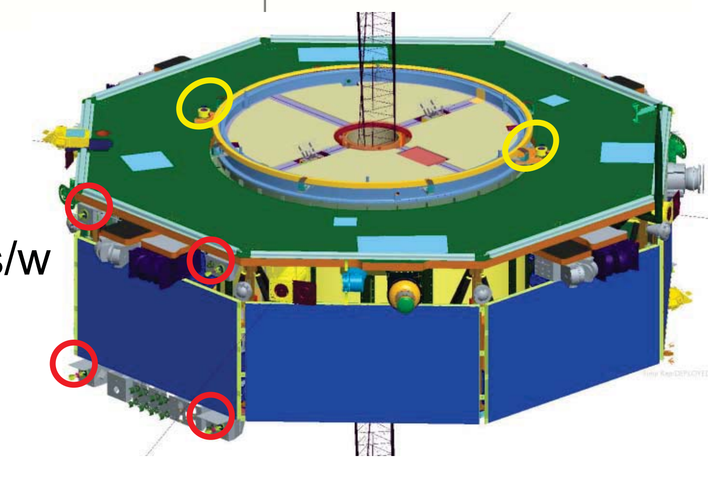
Credit: European Space Agency

- Benefit: understanding of how the Earth lives with the Sun (e.g. Class X Flash 0156 GMT Tuesday, Feb. 15, 2011)
  - Power grid problems
  - Communications disruption
  - Aurora formation

Spacecraft Description

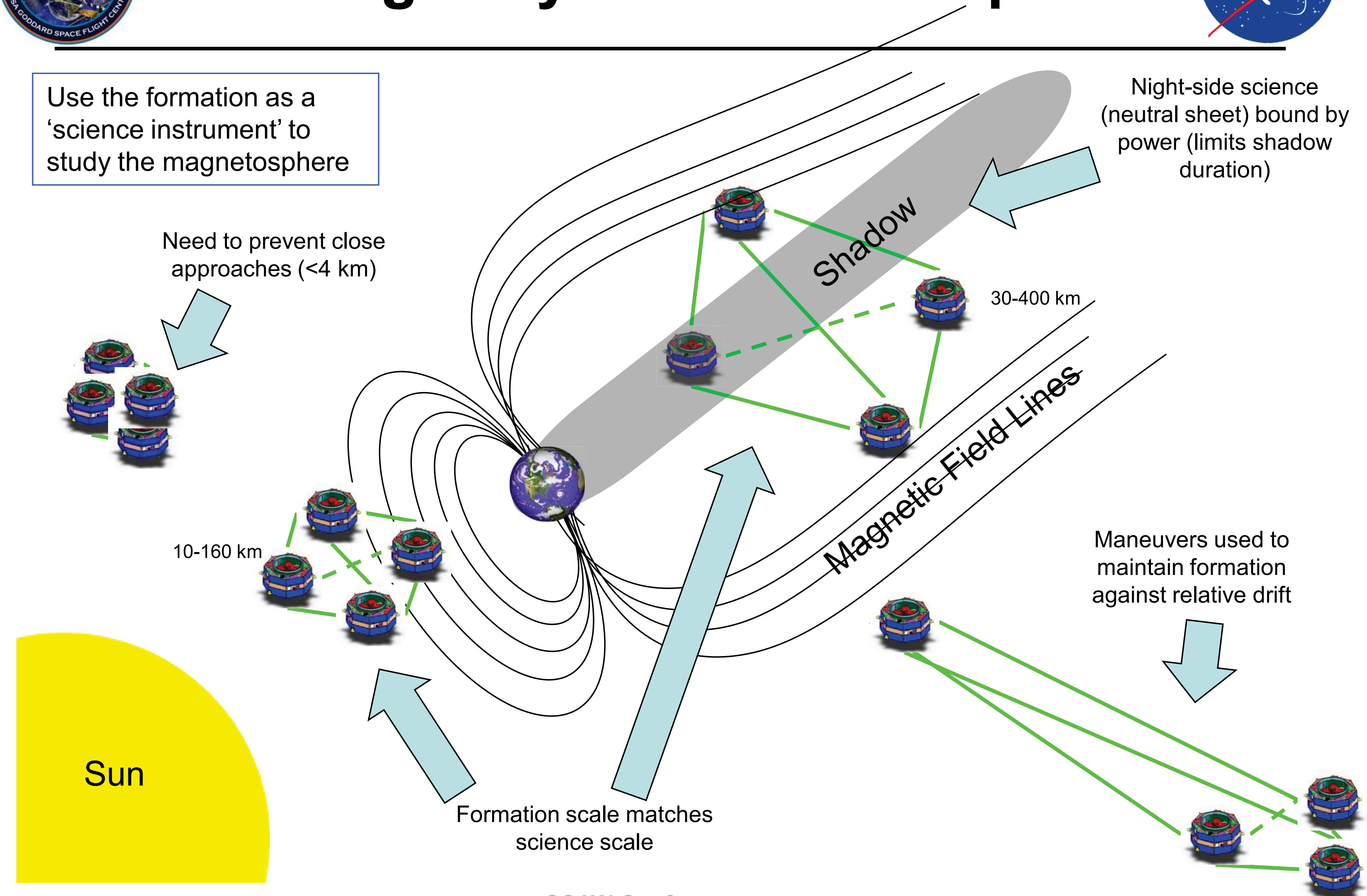
- The 4 MMS Spacecraft are
  - Equipped with the standard 'particles and fields' instrument suit (7 types of instruments – multiple copies per spacecraft)
  - Equipped with 8 science booms
    - 2 Axial (E-field)
    - 4 Wire (E-field) & 2 Magnetometer Radial
  - Spin-stabilized at 3.0 rpm with spin-axis nearly parallel to ecliptic north
  - Onboard controllers process GN&C sensor data & fire thrusters to achieve accurate ΔV while keeping the booms safe
    - Digital Sun Sensor & Star Camera
    - Accelerometer
    - Navigator GPS receiver with GEONS navigation s/w
  - Equipped with 12 thrusters
    - 4 Axial 1-lbf (yellow)
    - 8 Radial 4-lbf (red)





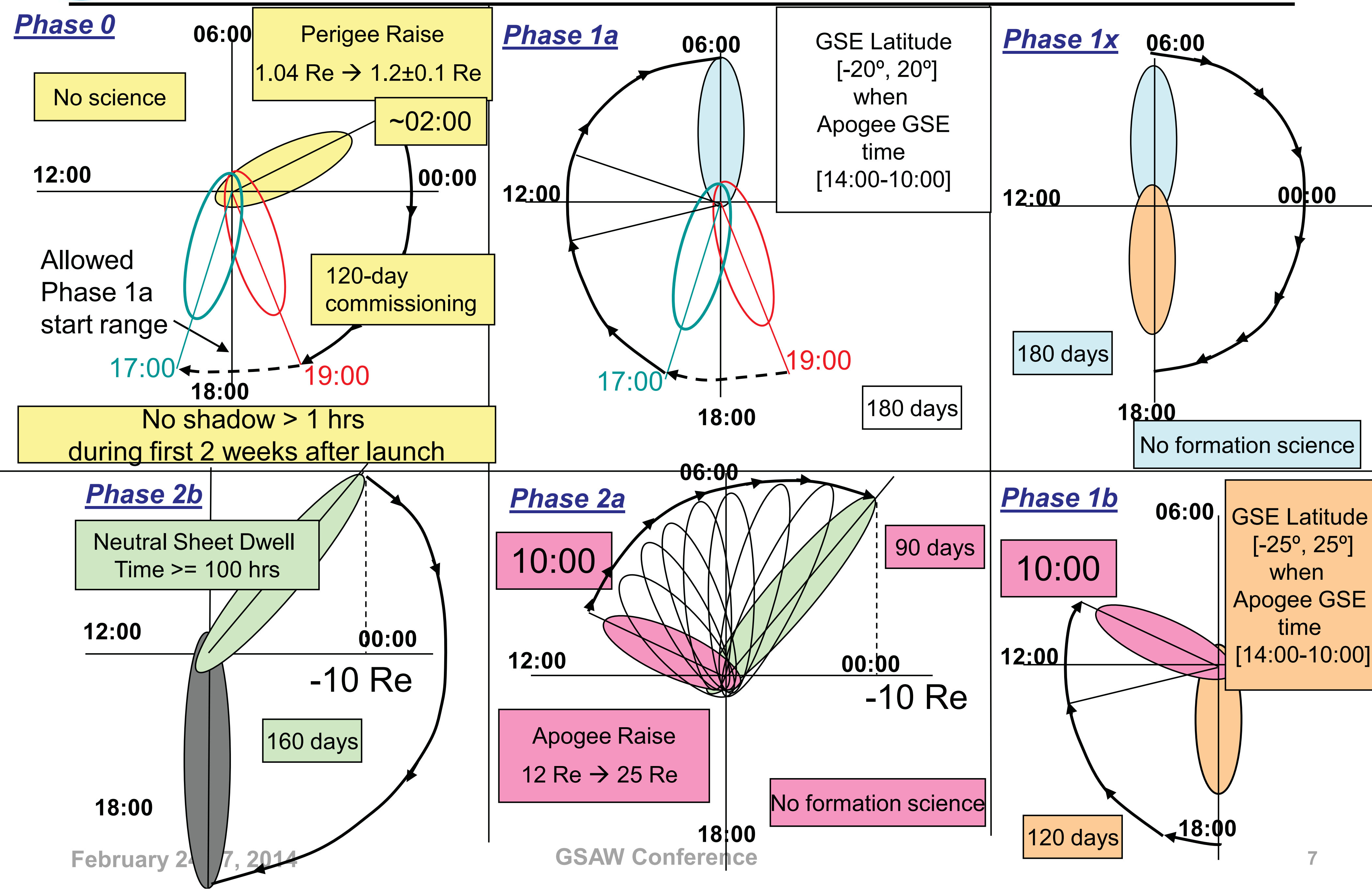
Flight Dynamics Concept

Use the formation as a 'science instrument' to study the magnetosphere

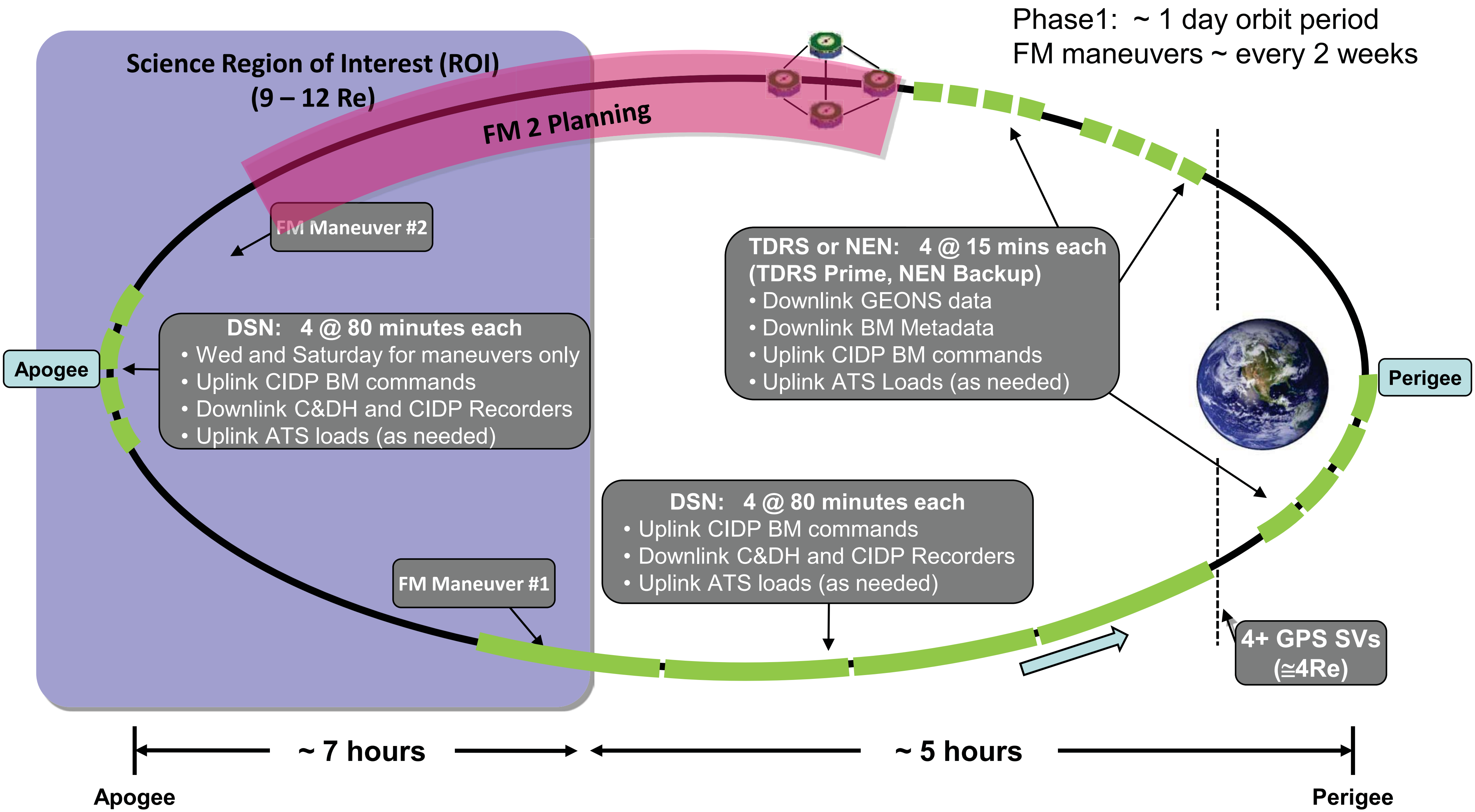


MMS Mission Summary

(approximately 2.5 years in duration)



Phase-1 Orbit in the Life
with Formation Maintenance Maneuvers



System Manager

Why Automate? And How To?

- **Automation needed handling the complexity**
  - Large number of interactions
  - Goal to reduce human error and operations cost
  - Want dependable agent – must act like an 'ideal operator' that is never sick, always on time, able to handle multiple processes once taught
  - Want smart agent – must adapt to changing situations and know when to ask for help
- **System Manager Automation framework using agents**
  - ***User-defined Agents*** – core automation objects that respond to events or defined schedules by triggering forward-chain or backward-chain processes.
  - ***Process Control*** – collaborative set of agents that achieve objectives based on the state of the process flow via user-defined rules.
  - ***Adaptive Scheduling*** – existing schedules are altered based on incoming events
  - ***Operations Planning/Automated Recovery*** – target operational state is used to plan a proper course of action via backward-chaining (inferring the cause that gives a desired effect)

System Manager – Component Based Architecture

Define Agents Activate Agents

Enjoy Results

Agent Editor
•Assistant

End User Agents
•Mission Operations Tasks

End User Displays
•Mission Operations Displays

Logic System
•Rules
•Forward Chaining
•Backward Chaining

System Components
•***Database****
•Communications
•***Scheduling****
•***Event Detection****

Simulation/Visualization
•Orbital Events
•Monitor Windows
•3D Modeling, 2D Plots

Component-Based Architecture

Visio

.NET Framework
•Code Generation (C#, C++, Visual Basic, J Script)
•Run-time Type Discovery
•Parallel Task Library

XNA

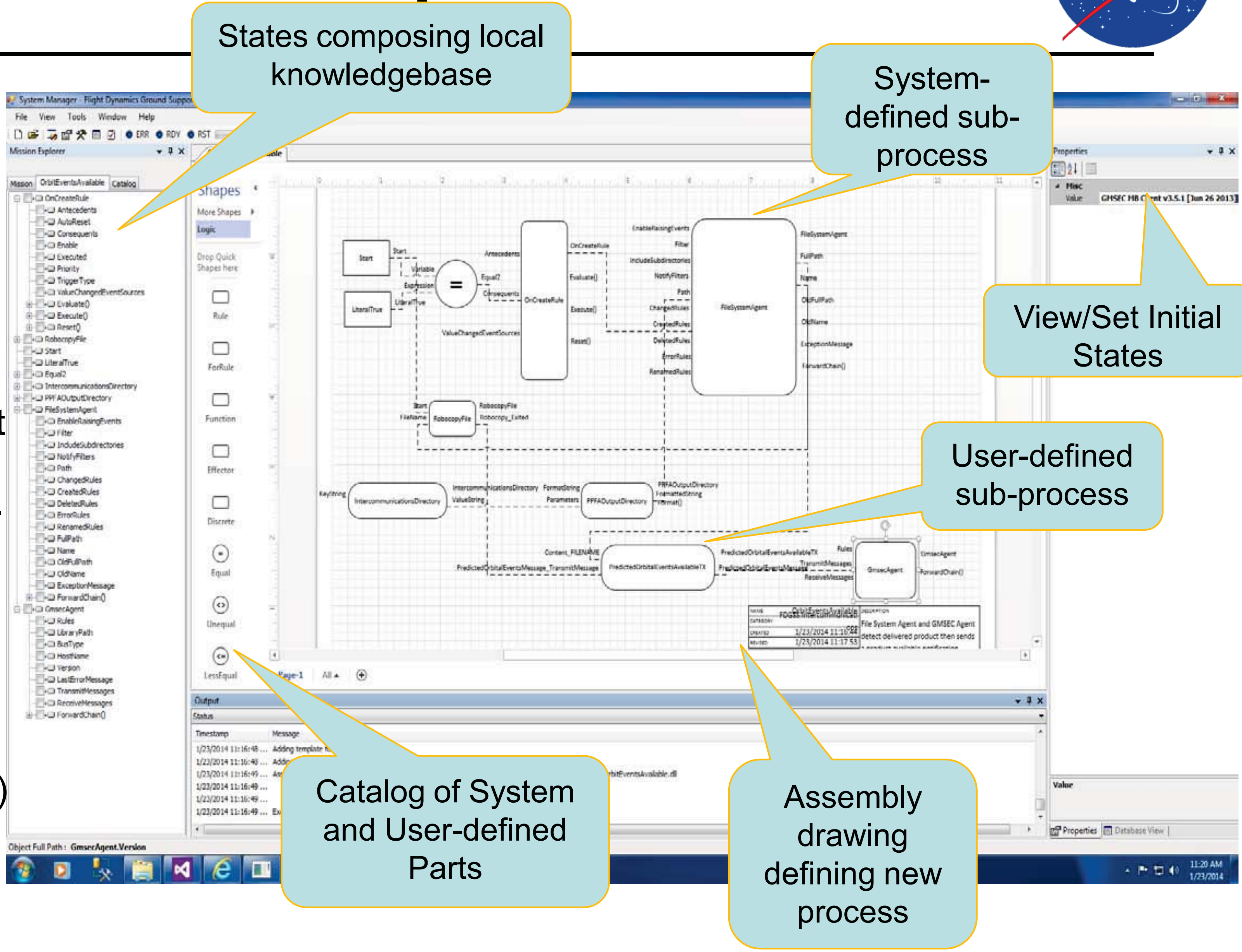
DirectX

Mission Operations | System Manager | Industry Standard Software

* - components discussed below

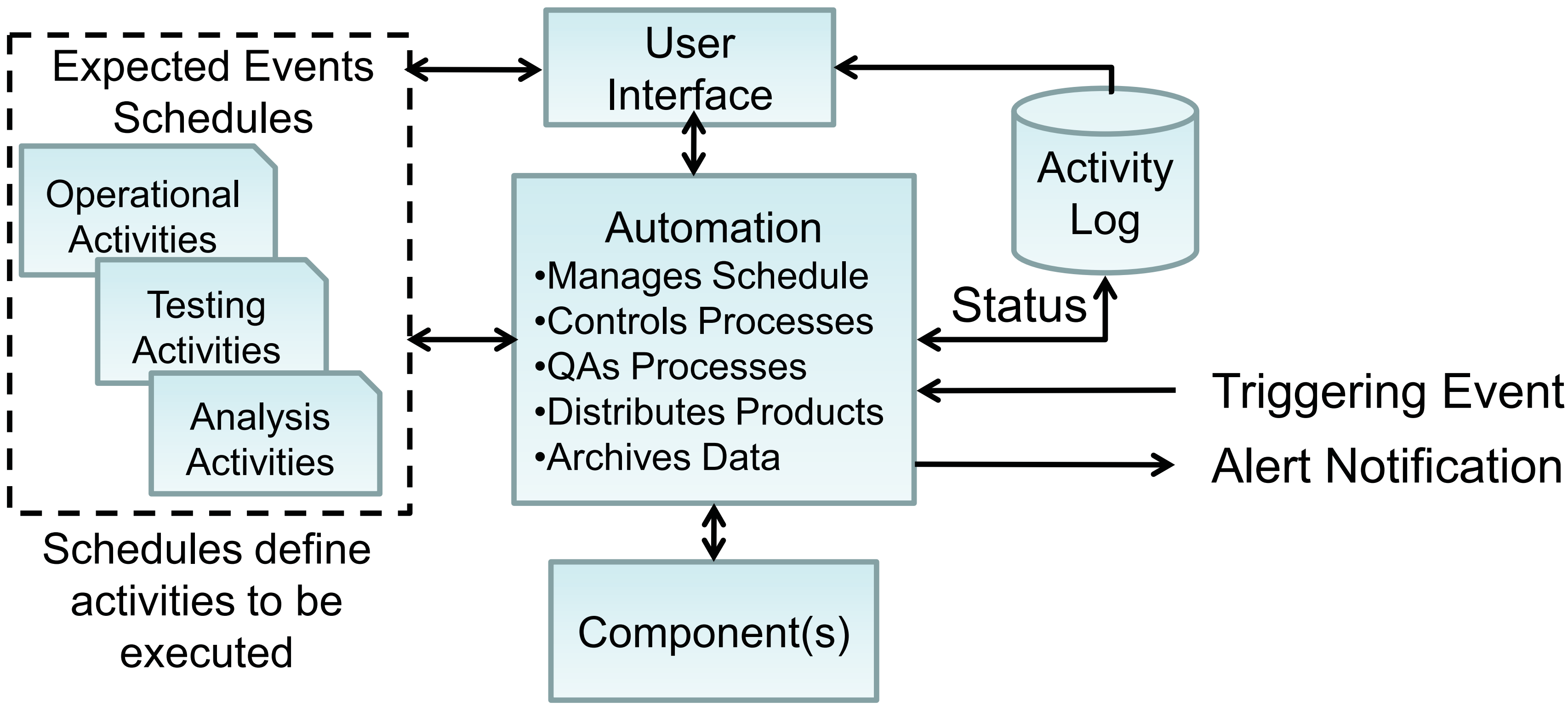
Process Representation

- *Microsoft Visio* is used to represent processes via assembly drawings.
- Shapes represent system- and user-defined sub-processes, called parts.
- Connectors specify the data and control (logic) linkages between parts.



Scheduling Concepts: Processes, Activities, & Events

- Response Schedule is a list of ***expected activities*** to be performed, using defined processes, as a response to an event
- Response Schedule is ***dynamic*** – based on external special requests (i.e. from MOC) and automated response to events, user/agents can add or remove activities
- Automation uses the schedule in two ways:
  1. Perform activities currently on schedule (schedule-driven)
  2. Add an activity to the schedule as a response to a detected event (event-driven)



Database

- Database functionality using the Entity Framework forms the backbone for the automation

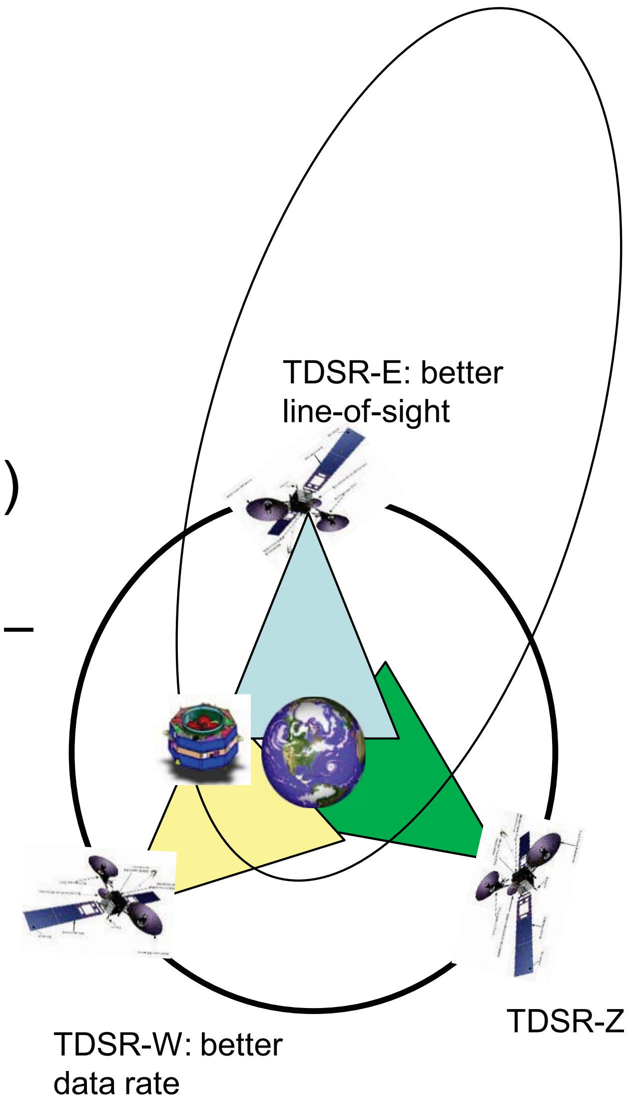
- Serves as the intermediary for inter-process communications
  - Used as media to transfer data between processes.

- Enables data mining and querying
  - User queries using transformations and operators defined by entities.
  - Metadata-based model allows for queries specifying multiple physical, dimensions, engineering units, coordinates systems, etc.
  - ‘Snapshot’ functionality allows for GUI data monitors and visualization to show internal state of process being executed
    - User entry point for debugging
    - Automated fault detection and (where possible) correction

Contact Analysis Implementation

Contact Analysis: Problem Definition

- Contact between the MMS spacecraft and the TDRS fleet is needed every perigee (see slide 7)
  - Important for science retrieval
  - Critical for formation maneuvers
- Motion model (line-of-sight & distance vs. time)
  - TDRS in correct geostationary boxes
  - MMS following its elliptical trajectory
- Antenna model (gain pattern & field-of-view (FOV))
  - TDRS-E/W S-band Single Access (SSA) antennas with 4 FOVs (simple, primary, elliptical extended x2 – ordered approximately from most to least available)
  - TDRS-Z SSA with simple FOV
  - MMS has upper & lower deck s-band omni (‘garden weasel’) antennas
- Objective
  - Find the simplest operational scenario (number of handoffs) that maximizes data rate (link margin)



Contact Analysis: System Manager Approach

- System Manager generated a set of predicted events
  - Logical yes/no for link between MMS and TDRS at a given data-rate (typical operations approach)
  - Constraint transitions (yes-to-no or no-to-yes) placed in a decision tree (not so-typical in operations)
    - Decision tree hierarchy based on the importance of mission rules/constraints (e.g. occultation has higher precedence than FOV)

- System Manager used an A* search algorithm to generate the optimal contact schedule
  - A* search works by finding the ‘shortest path’ across a ‘set of nodes’
  - The decision tree provides the nodes based on the constraint transitions
  - Link margin, antenna availability, data rates, etc. automatically built-in

Contact Analysis: Results

- System Manager analyzed a typical 2.5-year mission scenario
  - Able to find the best schedule (smallest number of hand-offs for the maximum date rate)
  - Statistically characterized the mission probability of successful contacts – e.g. 87% percent meet requirements, remaining 13% needs a workaround
  - Results consistent with official results from Space Network Loading and Modeling
- Performance
  - Analysis took several seconds on a typical Windows-based workstation
  - Results successfully vetted against hand-computations of all permutations (days of work)
- Operational benefit
  - Provides a robust way to find optimal results for given mission scenario
  - Gives a sense of how often MMS will have to work around network constraints
  - Makes a rapid response possible should base assumptions change