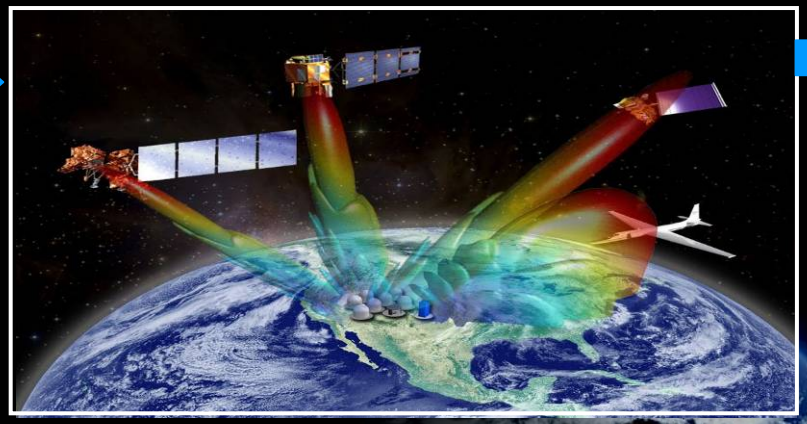
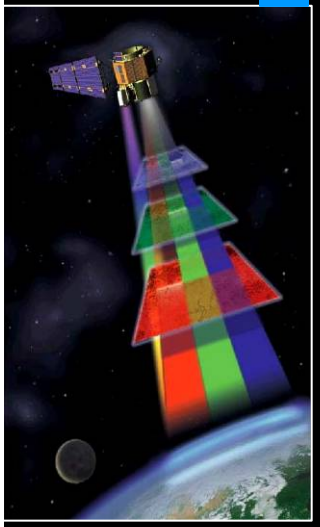
Goddard Space Flight Center



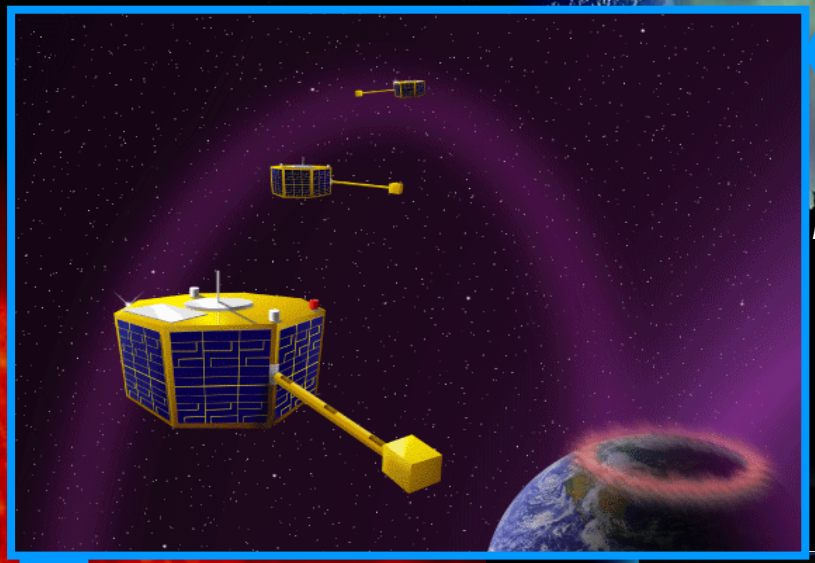
ISR Institute for Scientific Research, Inc.

NASA

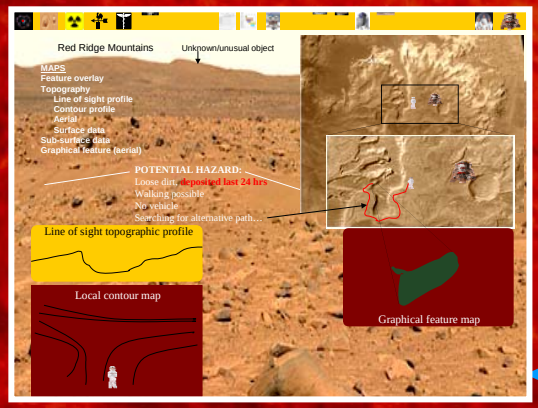


Flying the ST-5 Constellation with "Plug and Play" Autonomy Components and the GMSEC Bus

Bob Shendock
Ken Witt
Jason Stanley
Dan Mandl
Steve Coyle

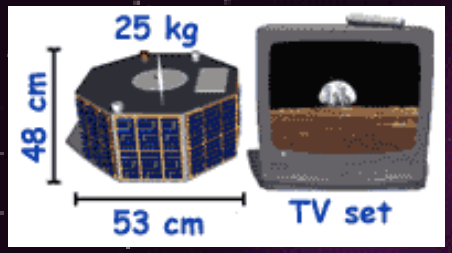


March 29, 2006

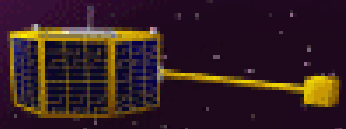


10th Anniversary 1997 to 2006
GSAW 06
Ground System Architectures Workshop

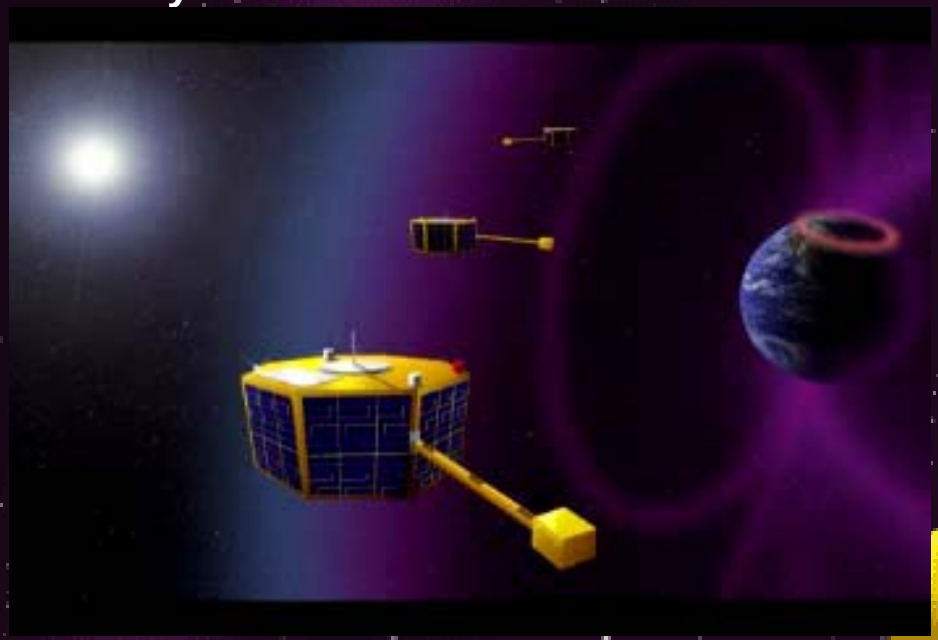
ST-5 Overview



Not much bigger than a large birthday cake or a small TV.

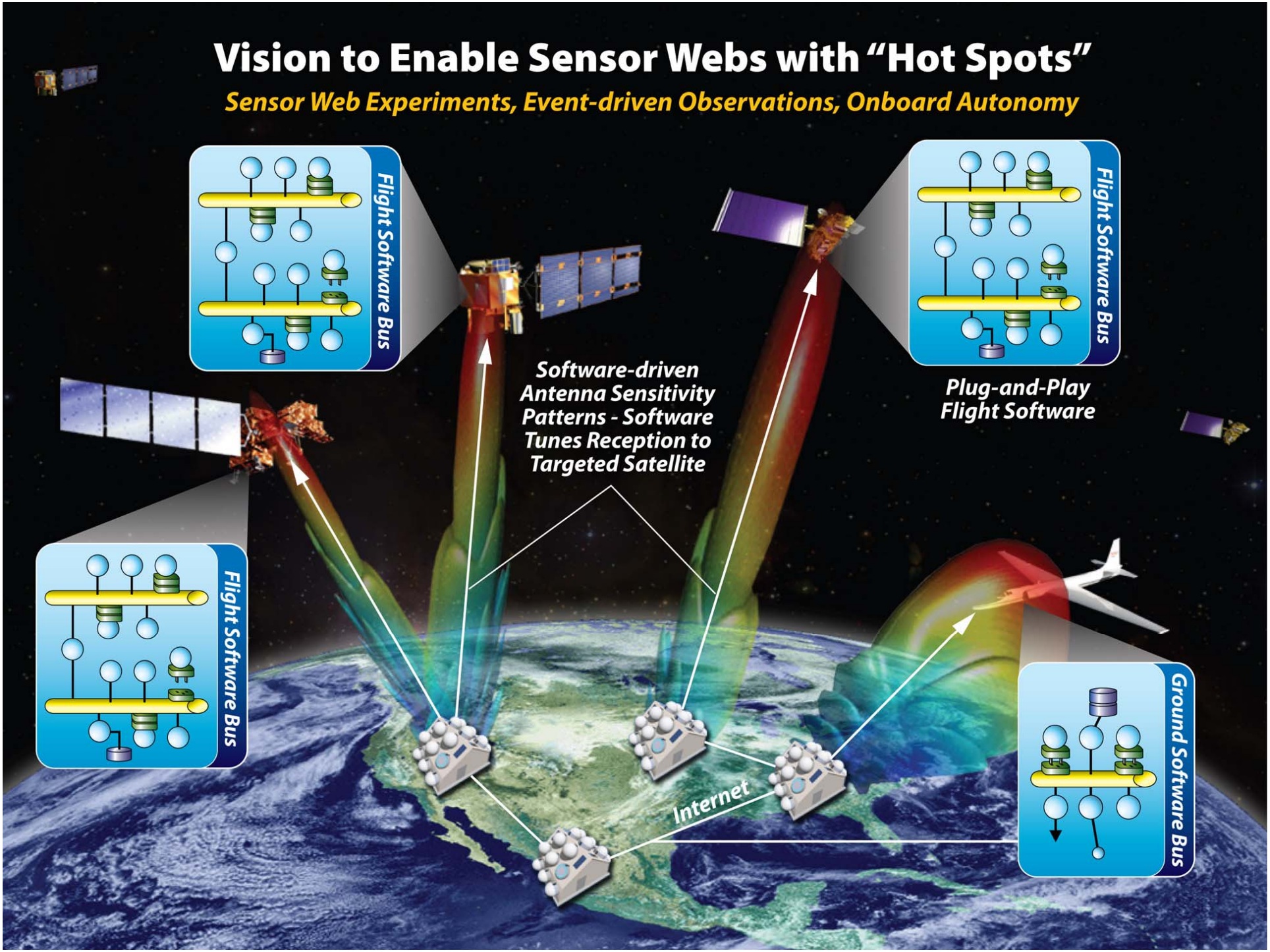


- ST-5 is a three satellite (micro-sat) constellation
- NASA New Millennium Program technology validation mission
- Help scientists understand the Earth's magnetosphere and its effect on space weather
- Uses the GMSEC architecture to enable cost-effective model-based operations to run the ST-5 constellations lights-out
- Launched March 22, 2006
  - Three month base mission
  - Possible mission extension



Space Technology 5

Tomorrow's Technology Today


Vision to Enable Sensor Webs with "Hot Spots"
Sensor Web Experiments, Event-driven Observations, Onboard Autonomy
Flight Software Bus
Flight Software Bus
Software-driven Antenna Sensitivity Patterns - Software Tunes Reception to Targeted Satellite
Plug-and-Play Flight Software
Flight Software Bus
Internet
Ground Software Bus

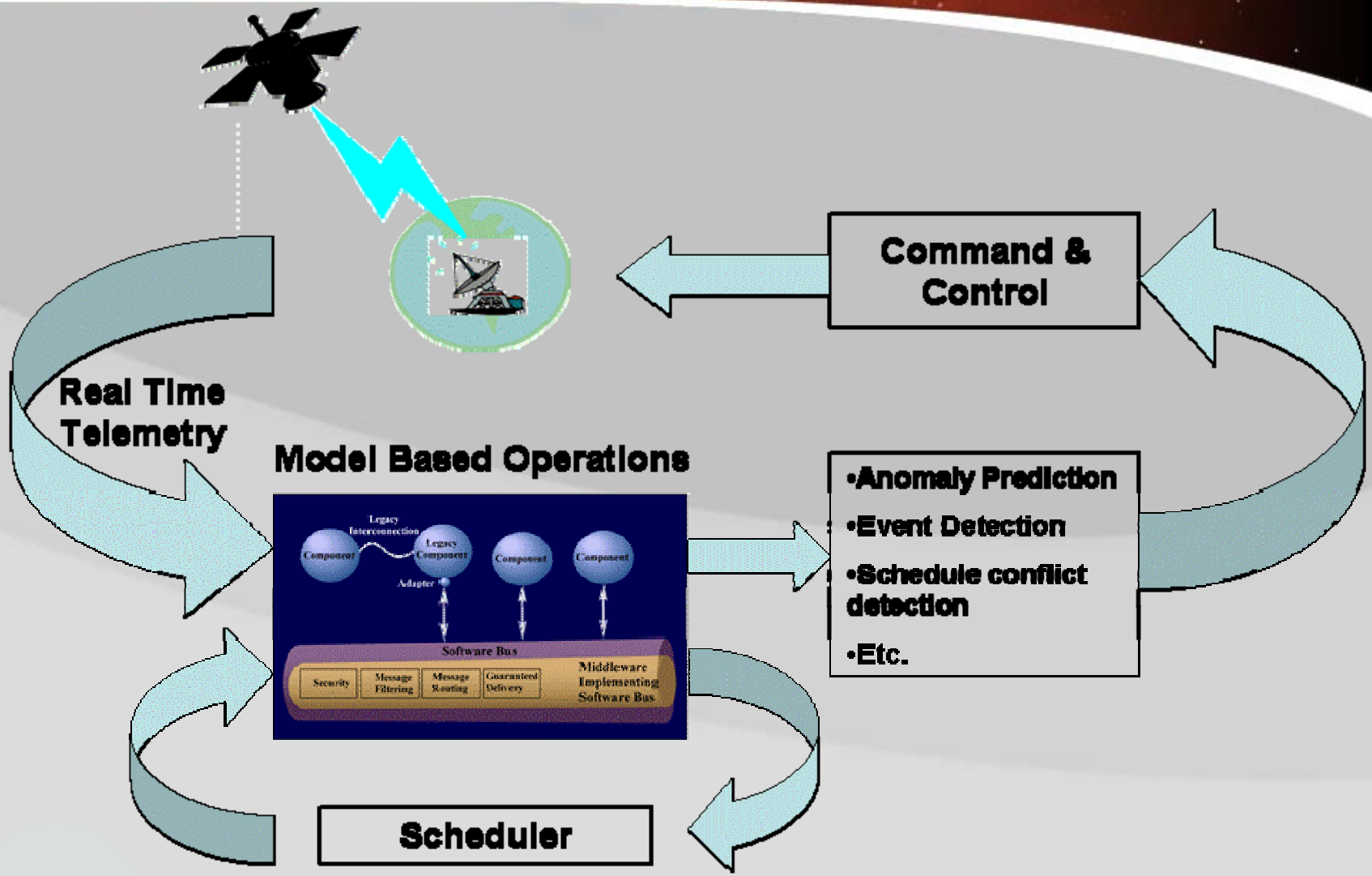
What we need to make this happen

- Transition from centralized mission control to distributed control
- Self-managing software components (autonomic computing)
  - (1) Components have self-awareness
  - (2) Self-optimizes
  - (3) Self-healing
  - (4) Self-protection
  - (5) Negotiates (peer-to-peer) for resources
  - (6) Functions in a heterogeneous world and with open standards
  - (7) Anticipates needed resources and hides details needed to obtain resources
- ST-5 mission will demonstrate parts of (1), (2), (5), (6) and (7)
  - Lights-out operations with model-based software
    - Predict problems before they happen and fix early
    - Models update themselves automatically
    - Modeling system is built on top of “plug and play” architecture to enable easy extensibility
  - Act as stepping stone for this type of capability for future missions
  - Possibly extend capabilities during the extended mission phase

Historical Background for for Model-Based Operations at GSFC

- 1987 ESP – time varying limits for GRO; Shendock, Mandl, Carlton
  - Attempted to more closely monitor telemetry alerts over orbit's worth of data and identify failure trends
- Mid- 1990's Altair – Model-based operations approach for MAP and IMAGE; Coyle, Shendock
  - State model to monitor health and safety of MAP and IMAGE, too expensive to maintain
- 2004-2006 – Self updating model-based operations on ST-5 constellation; Shendock, Witt, Stanley, Mandl et. Al.
  - Cost effective model to monitor health and safety since model can update self via telemetry and use GMSEC message bus to initiate correction actions

ST-5 Model-Based Operations Overview

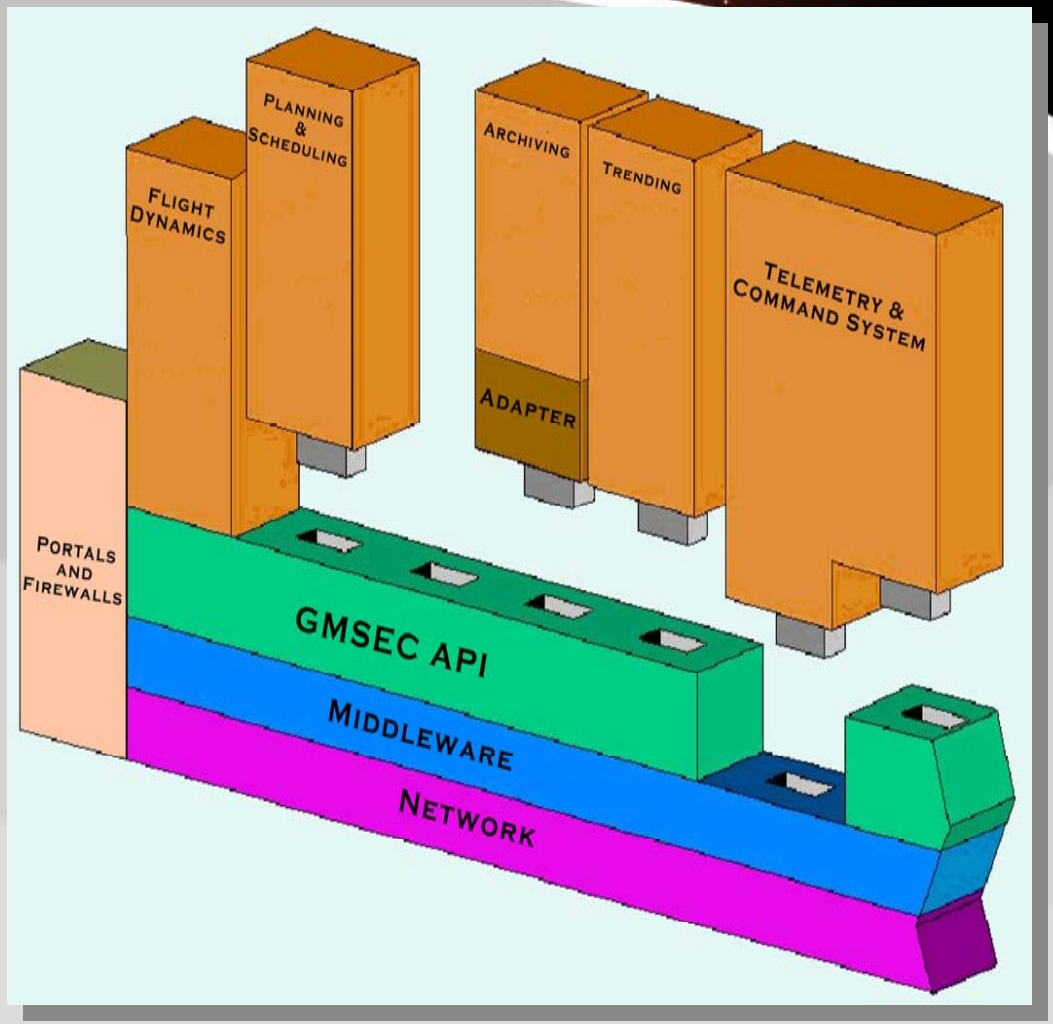


Underlying "Plug and Play" Message Bus Architecture-- Goddard Mission Services Evolution Center (GMSEC)

GMSEC architecture provides a scalable and extensible ground and flight system approach

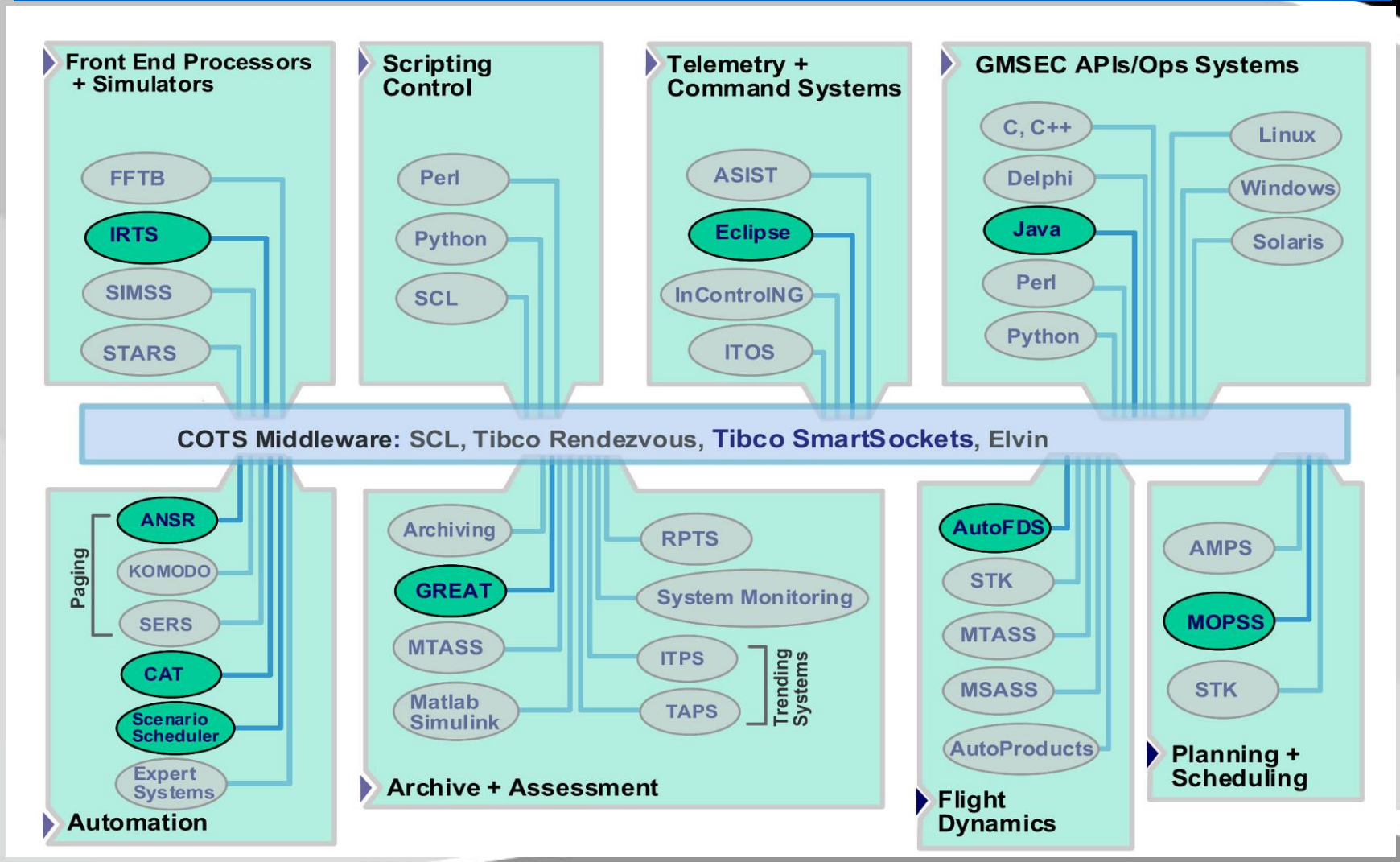
- Standardized messages formats
- Plug-and-play components
- Publish/Subscribe protocol
- Platform transparency

More info at: http://gmsec.gsfc.nasa.gov



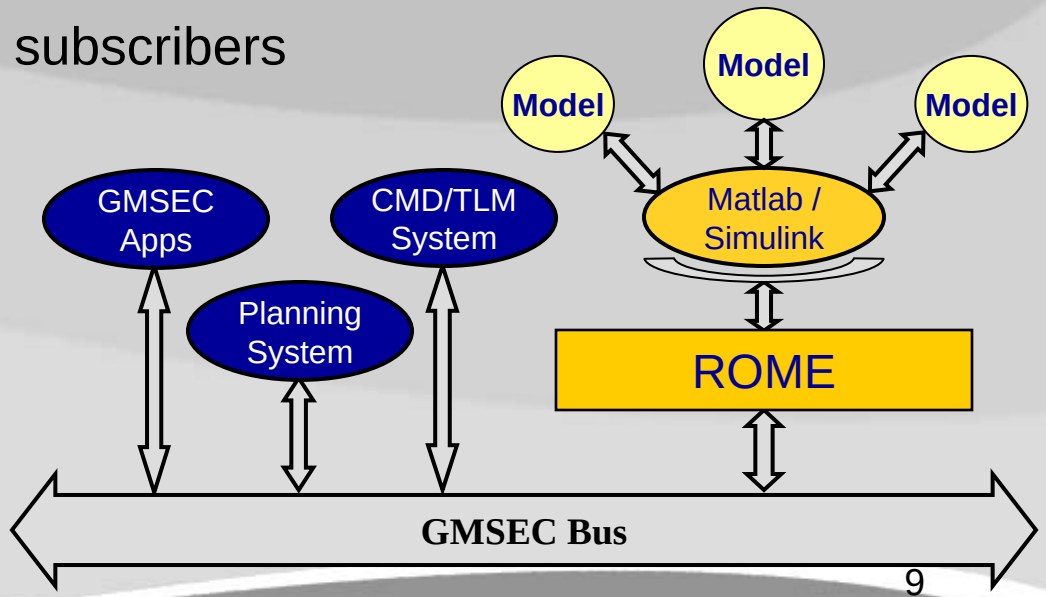
GMSEC Component Catalog

GMSEC approach gives users choices for the components in their system. The TRMM mission has selected key components from the GMSEC catalog.



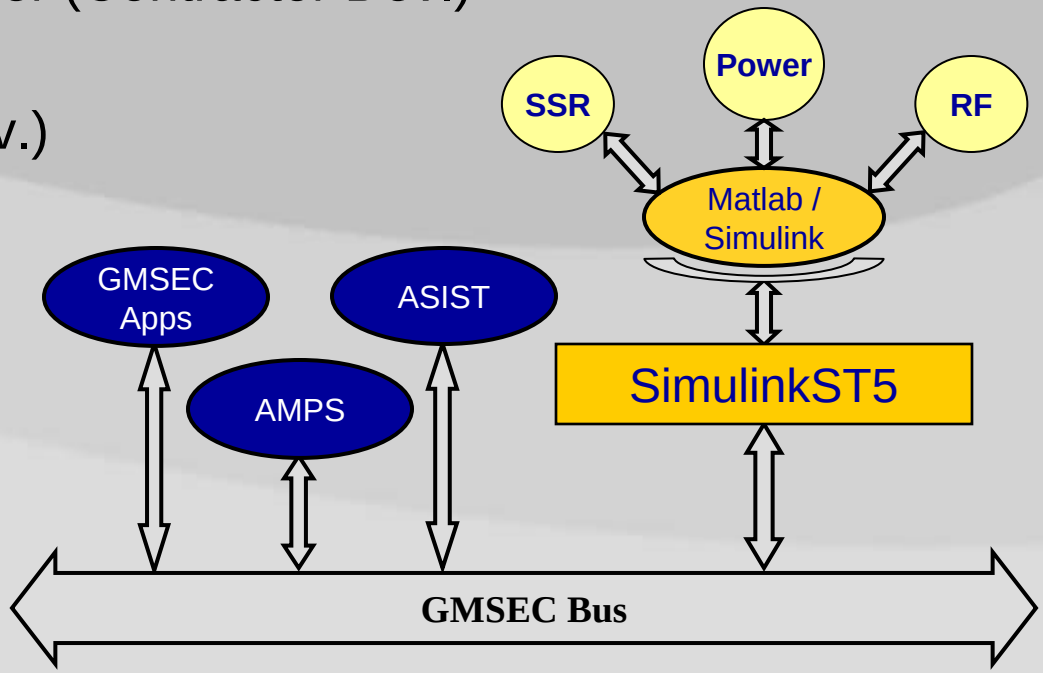
ROME Framework

- Real-time Object Modeling Executive
- Support multiple models and multiple spacecraft
- Leverage common engineering modeling environments
- Models from various sources are easily integrated
- Fully supports GMSEC bus
- Models initialized and maintained from telemetry
- Model control via configuration file or bus directive
- Results available to GMSEC subscribers
- Easily configured via XML
- Highly scalable



ST5 Specific Configuration

- ROME based implementation
- Dynamic characterization of sub-systems phenomenology
- Used by mission to manage constrained resources
- Models of Subsystems
  - Solid State Recorder (Contractor Dev.)
  - RF (Student Dev.)
  - Power (Project Dev.)



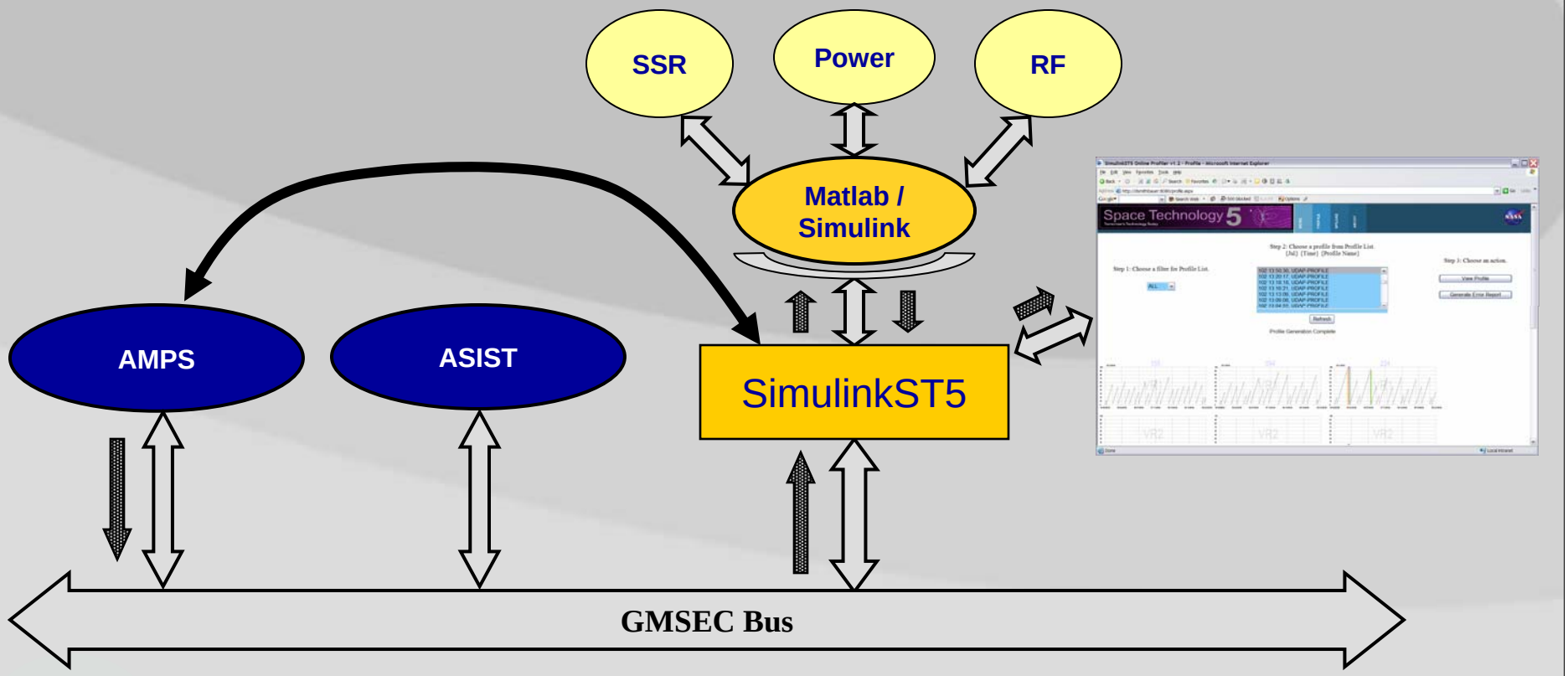
SimulinkST5 GMSEC Highlights

- Standardized messaging interoperability
- GMSEC Compliance
  - Directives
    - AMPS
    - ASIST
  - Mnemonic Value Messages
    - ASIST
    - ITOS capability
  - Heartbeat messages
  - Log messages
  - Product Messages
- Predictive Model-Based Operations
  - Subsystem models to anticipate platform conditions in a constellation environment.
    - Support Short and Long Term Mission Planning
  - Interact with AMPS and ASIST for control directives, telemetry, and profile events.
- Constellation Operations Support

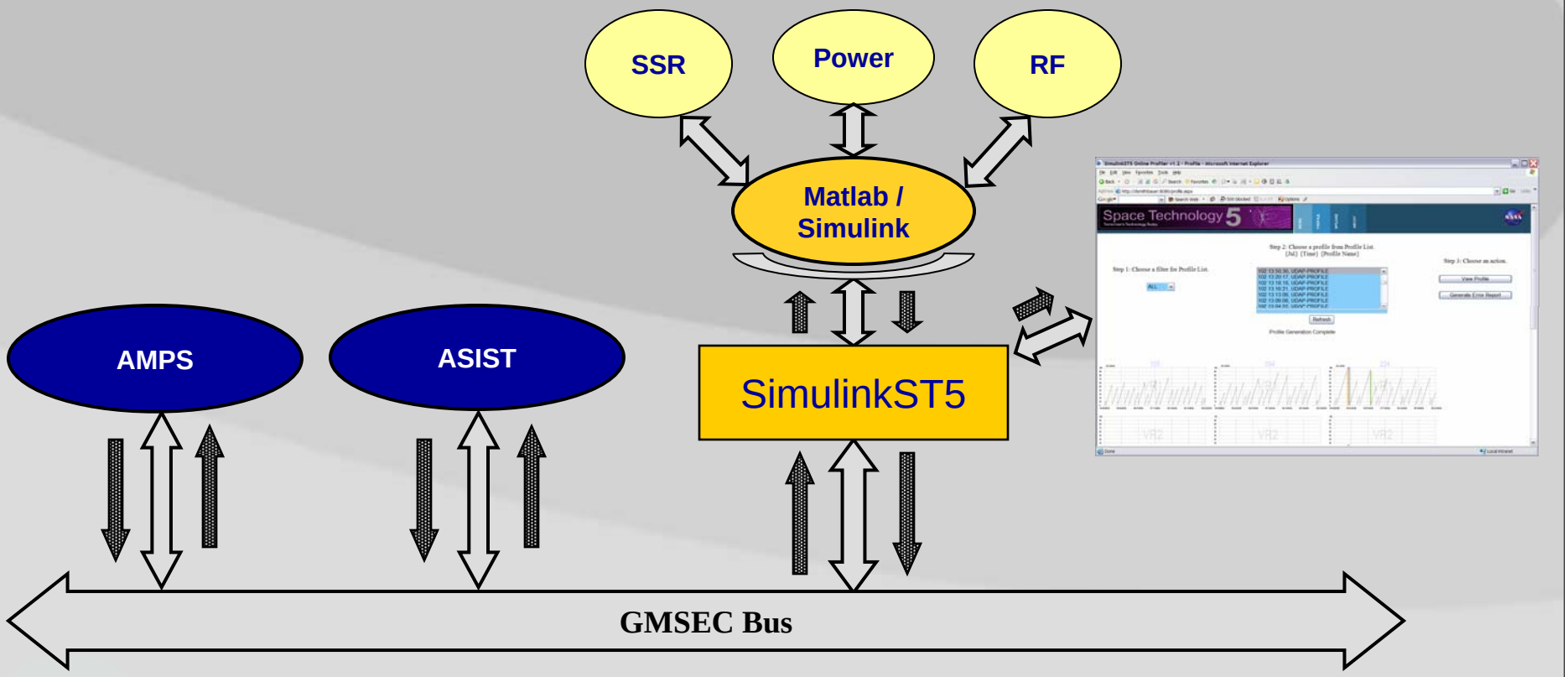
Advantages

- Mission Planning Support
  - Offline Profile– Entire duration of operational plan
  - Real-time Profile– 4 days from current point in time
    - Configurable via XML
- User Interface
  - SimulinkST5 console
  - Web interface
    - Configured for MOC access only
- Increases ability to move toward Autonomous Operations
  - Reduce resources needed to perform analysis

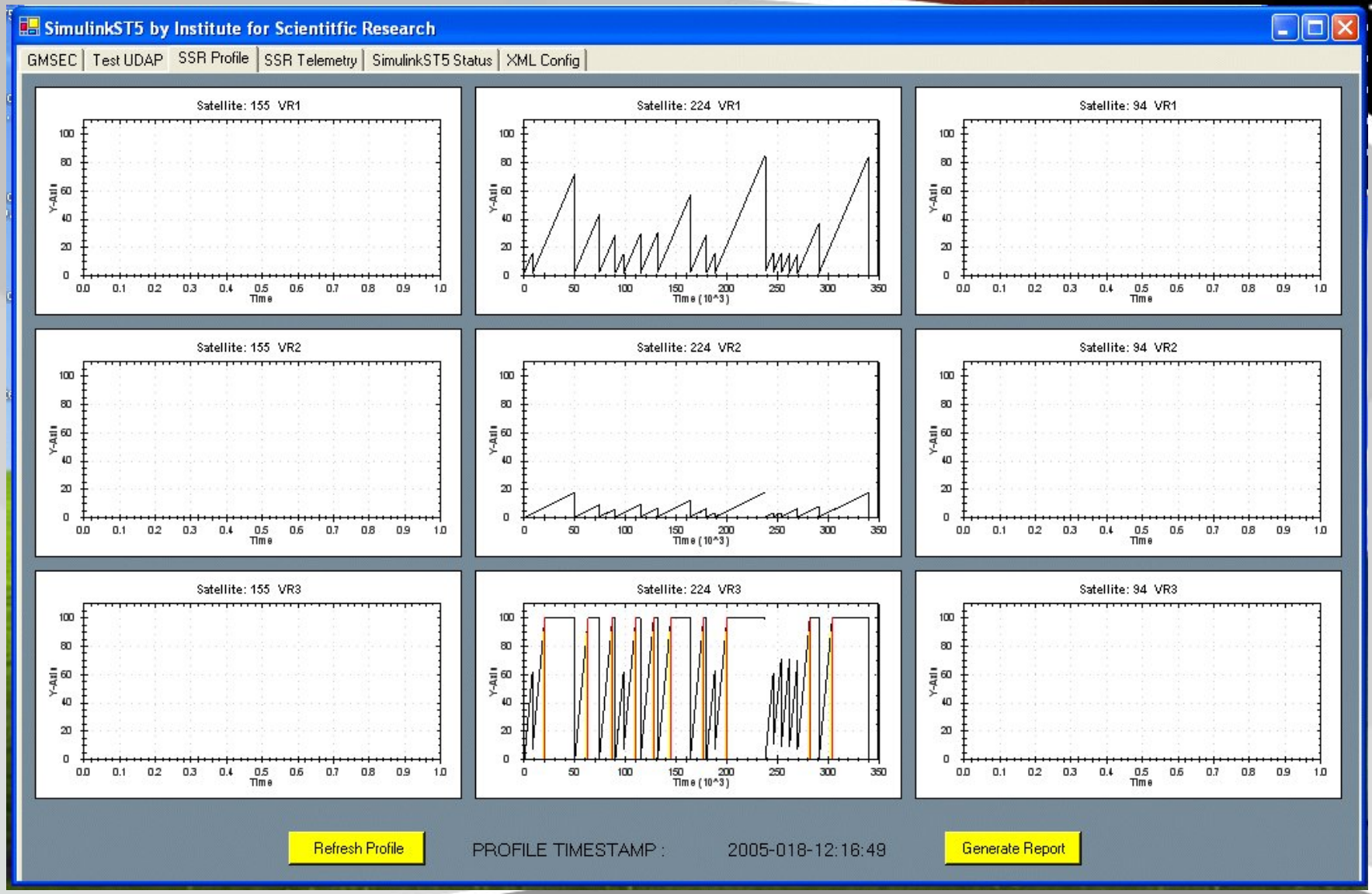
Long Term (Plan) Validation Flow



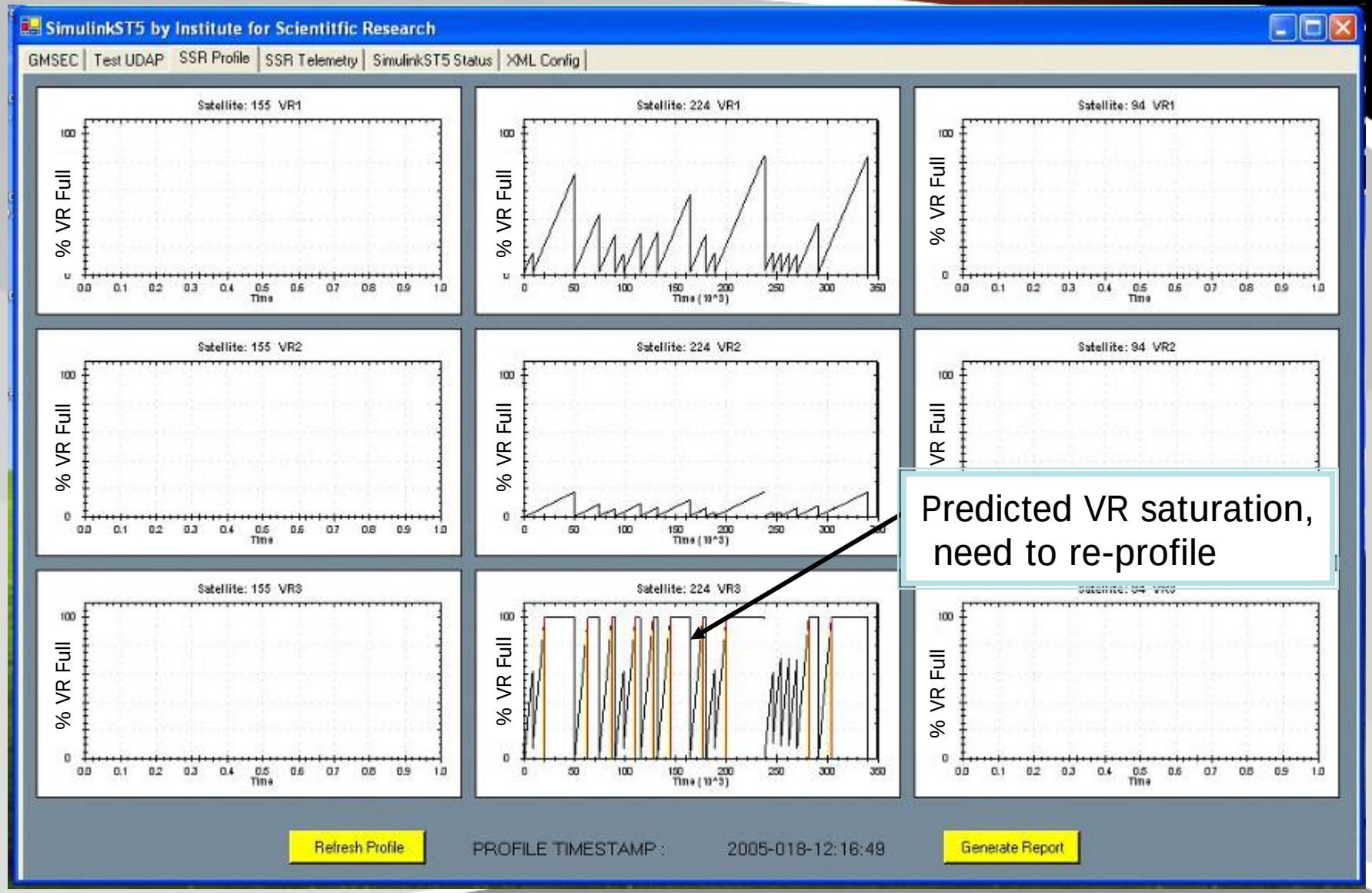
Real-time Profile Flow



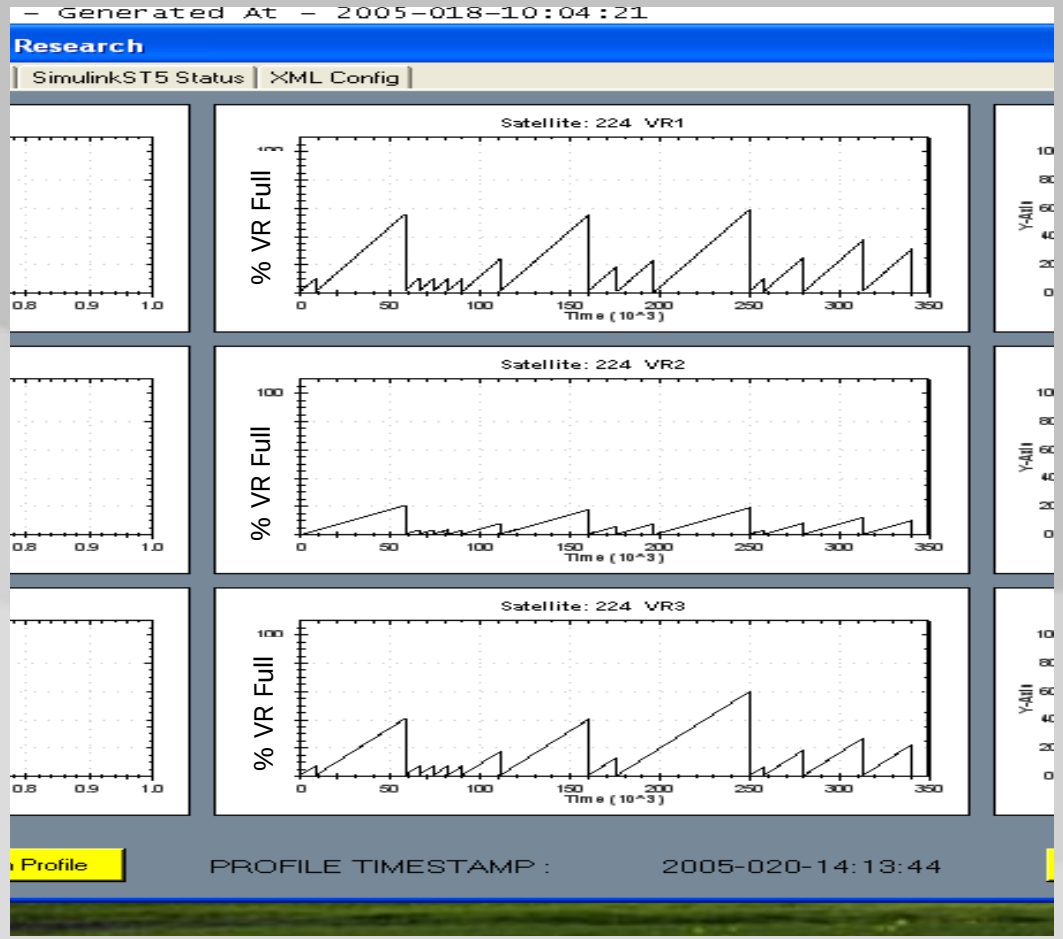
Sample SSR Model Display to Monitor 3 Virtual Recorders Each in 3 Satellites



SSR Model Profile Showing SC 224 FlatSat Data with VR3 Violations



SSR Model Profile After Commands Issued to FlatSat to Repartition SSR



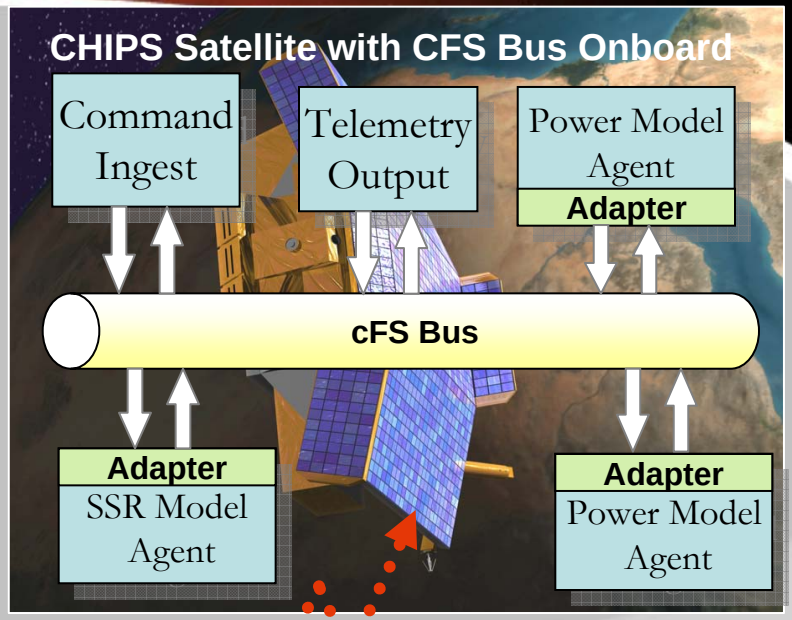
- Re-profile command was issued to eliminate future VR violations (i.e. early saturation of VR capacity)
- New profile for VR in question displayed showing that no VR saturations predicted with new profile

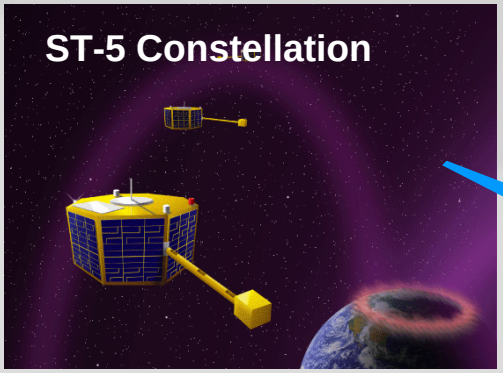
Possible Future Extensions of this Experiment in Extended Mission

- Transform predictive models into mobile agents that can run on the ground or spacecraft
  - Can be easily moved if desired, to another space-based or ground platform
- Simulate discovering needed service from another satellite and then requesting service
  - Move Simulink–based ROME models to Cosmic Hot Interstellar Plasma Spectrometer (CHIPS) environment
  - Run lights-out models from autonomy flight testbed, CHIPS testbed and CHIPS
- Build SensorML wrapper for ST-5 and allow ST-5 to discover predictive modeling service

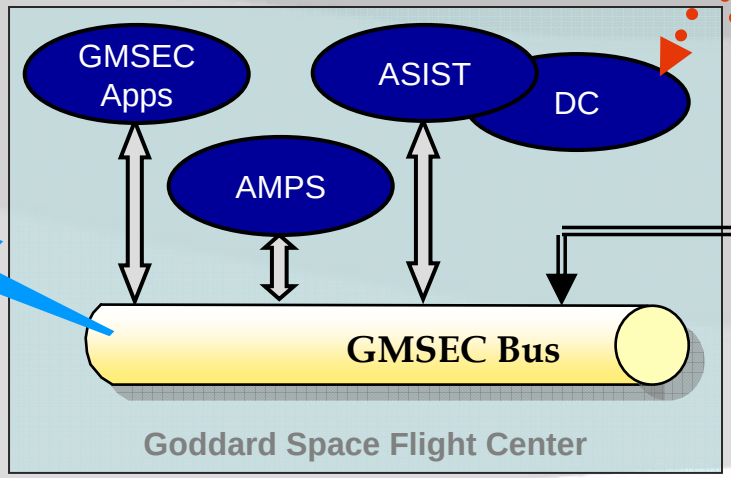
Moving Models Onboard CHIPS Satellite Under cFS to Demonstrate as Mobile Agents

- Models transformed into mobile agents
  - Working with SSR agent first
- Adapter built to make compatible with both GMSEC and Core Flight System (CFS)
- Demonstrate capability to move software running on GMSEC, moved onboard to run under CFS
- Beginning step to transform missions from central control to distributed control via self-managing software

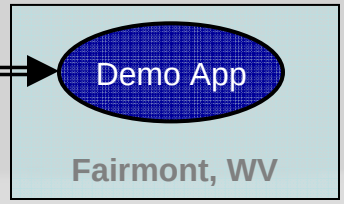




via DSN & McMurdo Ground Stations



via Berkeley & Wallops Ground Stations (UDP)



via TCP/IP

CHIPS – Cosmic Hot Interstellar Plasma Spectrometer
ST-5 – Space Technology 5
DC – Data Center
ASIST – Advanced Spacecraft Integration and System Test

Questions?

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