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Prototype Flight Dynamics Ground System Leveraging a Service-Oriented Architecture and Reusable COTS Services

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Service Oriented Architectures

- Approach: Each ground system component acts as a service, communicating with other services through a message bus
  - Each service has a single, common interface to the bus, rather than a separate interface for each of the other components
  - Flight dynamics, TT&C, scheduling, etc.
- Result: Modular system architecture
  - Flexibility to incorporate services from multiple vendors
  - Services can be added or removed without having to rebuild surrounding components
  - Rapid system development – components can be designed, built, and tested without knowing implementation details of other services
  - Reduced effort and cost when adding, removing, or upgrading components over time
  - Services can be shared and reused in other systems

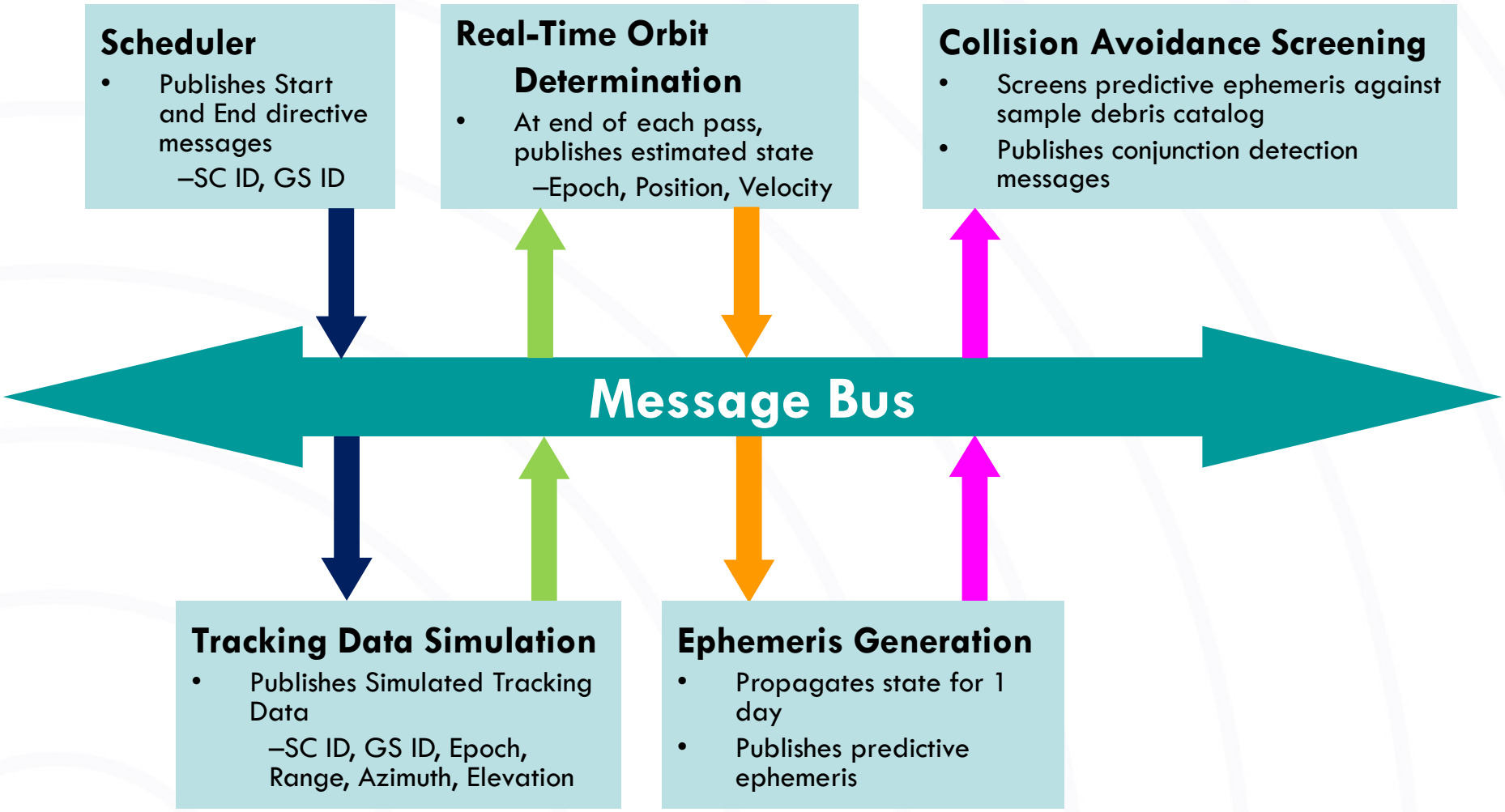
Prototype Flight Dynamics Ground System

- Goal: Develop a prototype flight dynamics ground system to demonstrate a service-oriented architecture with real-world astrodynamic applications
- Framework: GMSEC (Goddard Mission Services Evolution Center)
  - Publish/subscribe capabilities
  - Standardized message formats
  - Middleware for several message bus platforms
- Development Environment: COTS flight dynamics software FreeFlyer®
  - High-fidelity astrodynamics engine
  - Flexibility through scripting language and Extensions SDK
  - Unrestricted integration with any ground system environment

Flight Dynamics Services

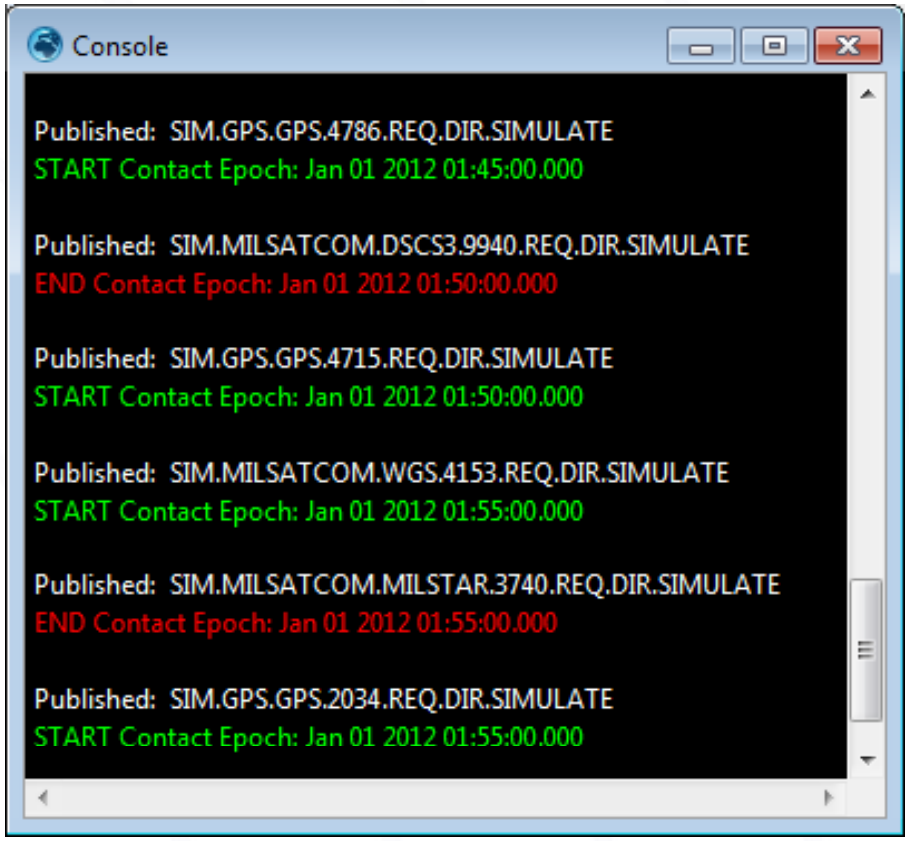
- Six services perform real-time flight dynamics analysis for a set of 60 GPS and geosynchronous satellites
  - Each service is a reusable component that communicates through the message bus using standardized data formats
  - Services run simultaneously and autonomously, each performing a different function
- A separate instance of FreeFlyer executes each service
  - Scheduler
  - Tracking Data Simulation
  - Real-Time Orbit Determination
  - Ephemeris Generation
  - Collision Avoidance Screening
  - Maneuver Planning

Data Flow Diagram



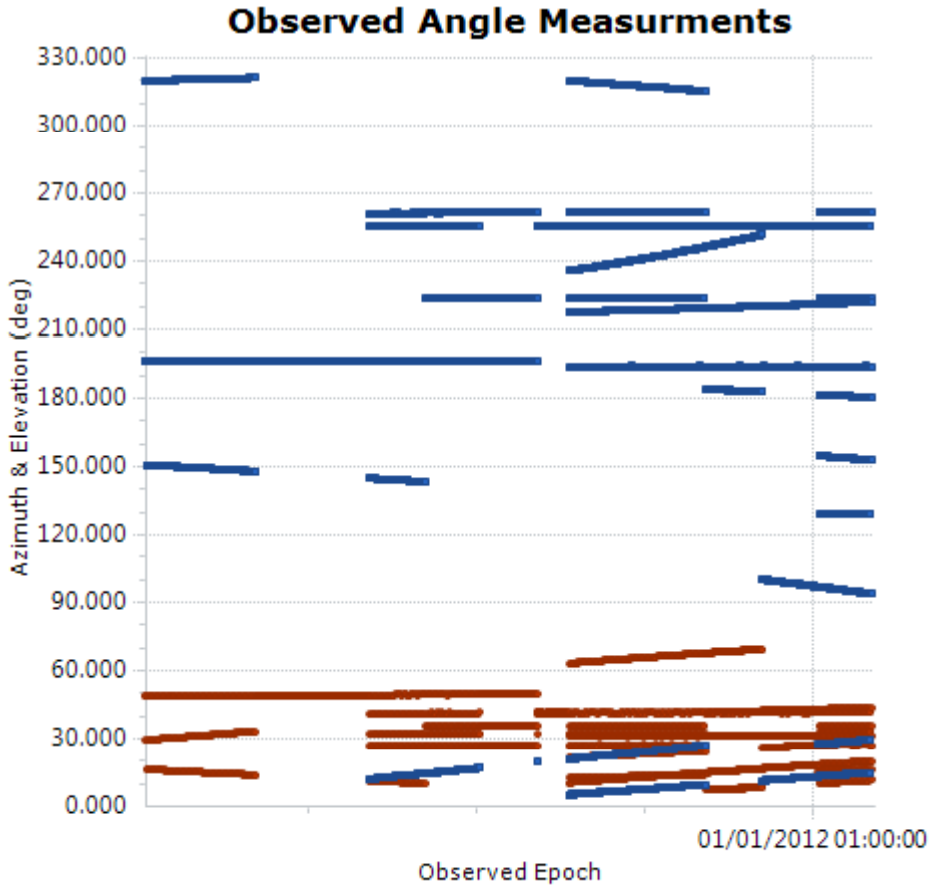
Scheduling Service

- Keeps track of the simulation epoch
- Identifies the spacecraft and ground station ID to simulate
- Publishes start and end simulation directives through the GMSEC connection



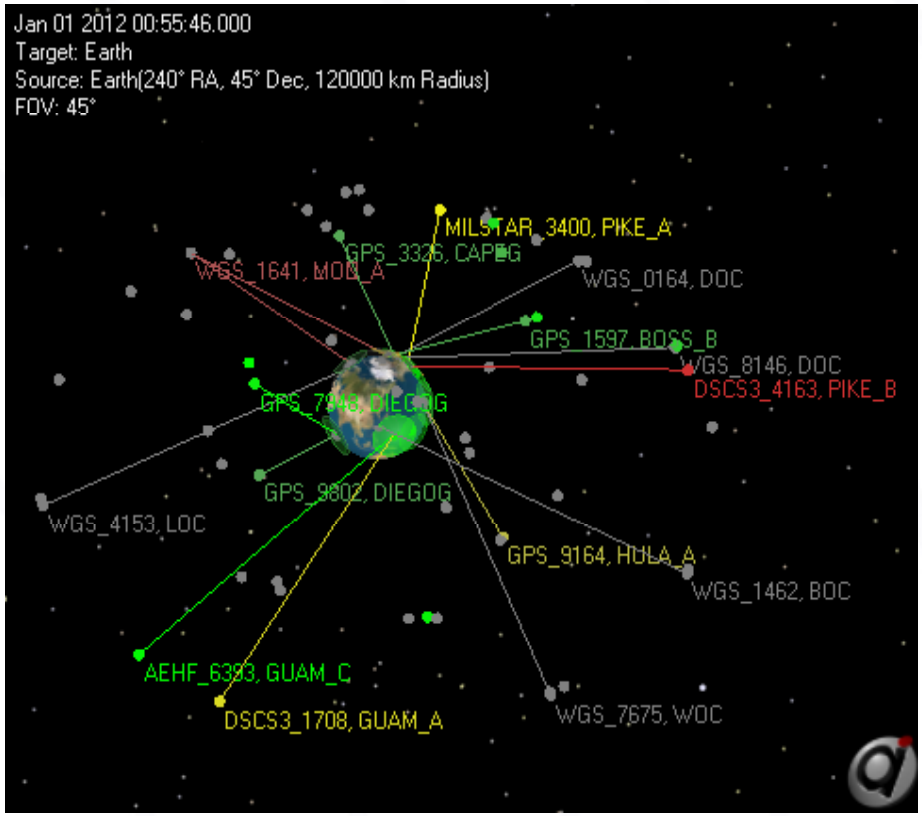
Tracking Data Simulation Service

- Subscribes to start and end tracking directives for GPS and GEO satellites
- No a-priori knowledge of the tracking schedule or the number of satellites or ground stations
  → single or multi-mission support
- Simulates observations of each satellite from the commanded ground station
- Observations are published in the AFSCN SIS 508 1/Sec Status message format



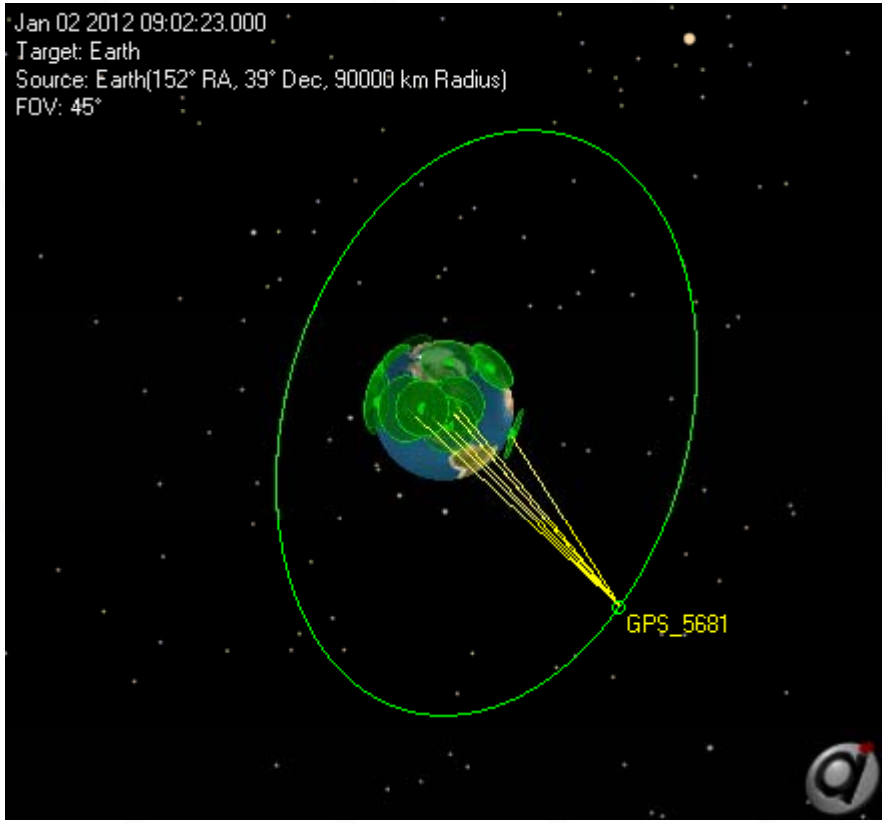
Real-Time Orbit Determination Service

- Uses separate Kalman Filters to estimate state and covariance for each satellite
- Processes each AFSCN 508 observation as it is received
- Updates estimated state for the corresponding satellite in real time
- 2D and 3D visualizations for situational awareness of constellation and ground station State of Health
- At the end of each pass, a solution state is published in CCSDS format



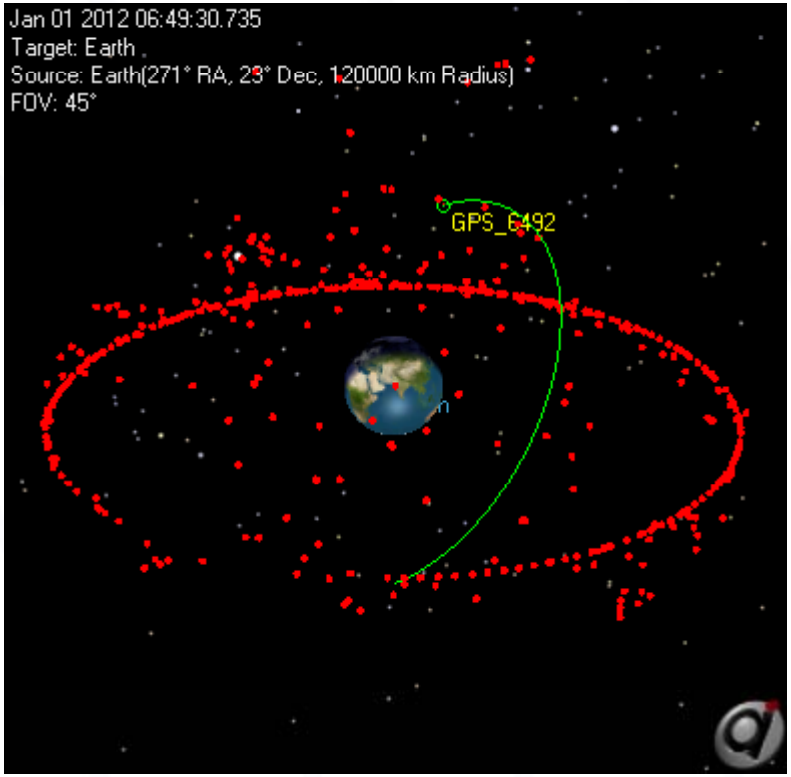
Ephemeris Generation Service

- The estimated state is used to create a 1-day predictive ephemeris in CCSDS format
- Predictive products are generated, including visibility times and look-angles to ground stations
- Such products are used operationally for contact planning

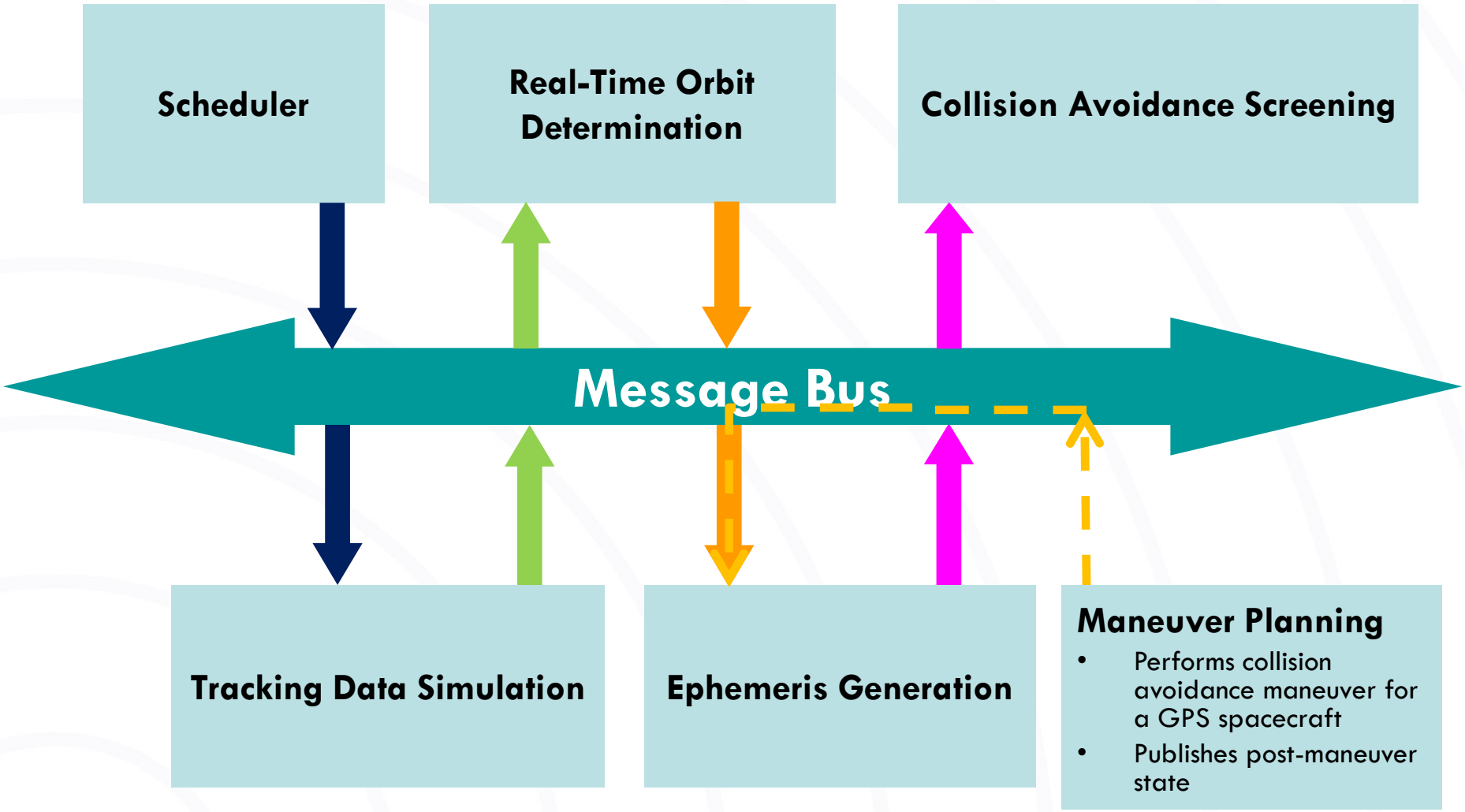


Collision Avoidance Screening Service

- The predictive ephemeris is screened against a sample catalog of 500 objects
- Catalog objects are filtered by apogee/perigee
- Objects within a specified miss distance will trigger a conjunction detection message which includes:
  - Time of closest approach (TCA)
  - Range at TCA
  - Probability of Collision (Pc)

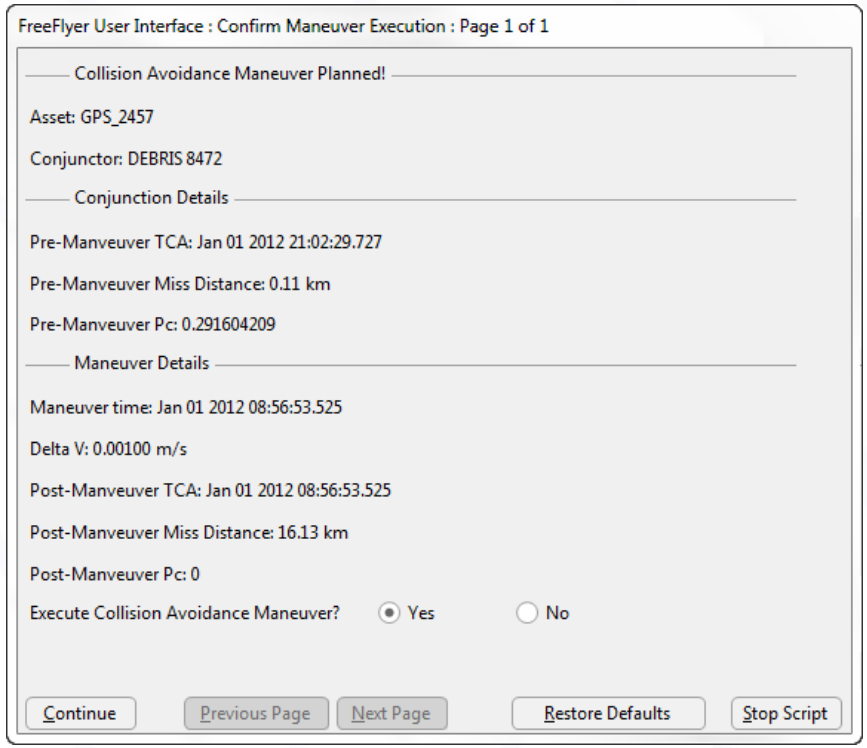


Data Flow Diagram Revisited



Maneuver Planning Service

- Operator requests a screening
- If a conjunction is detected, a risk mitigation maneuver is planned
- Custom GUI displays details
- If operator executes the maneuver, the service publishes the post-maneuver state
  - Generates a new predictive ephemeris
  - Re-screens against the catalog



Observations and Conclusions (1)

- Because of the standardized GMSEC message format and the flexibility of FreeFlyer's scripting environment, individual astrodynamics services were easy to reconfigure
  - Adding messages for conjunction detection near the end of development required minimal effort
    - Desired metrics were already calculated by the COTS tool
    - Message architecture was already in place
  - A single Collision Avoidance Screening and Maneuver Planning service was easily separated into two services
    - No hardcoded dependencies on the number of components in the system or which component publishes particular messages
  - Additional services or space/ground assets could be added in the future

Observations and Conclusions (2)

- This prototype has also been used to demonstrate ease of interoperability with other GMSEC-compliant systems
  - An IRAD effort to create a real-time GMSEC interface in the web browser
  - The SMC/SN Compatible Satellite C2 Prototype coordinated by Aerospace Corporation
- In both cases, the integration effort was minimal, as each system had been configured to communicate using the same GMSEC standards prior to integration

Questions?