GalileoSat System Simulation Facility (GSSF)

VEGA Informations-Technologien GmbH

Introduction

- GSSF Project Overview
- GSSF Requirements
- The GSSF System
  - Components
  - User Interface
  - Technology
  - Real-Time Simulator
  - Dedicated Analysis
  - Off-Line Analysis
- GSSF Lite
- The Future

GSSF Consortium

- VEGA are the prime contractors of the GSSF Consortium
  - VEGA: System Engineering
  - Science Systems: Ground Segment and Environment Models
  - Dataspazio: User Segment Models, Dedicated Analysis
  - CAE: Space Segment Models
  - Sener: Offline Analysis, Database, Scenario Preparation
  - Nottingham University: Navigation Consultancy
  - IFEN: Integrity Consultancy

- GMV now included in the consortium as a CCN to look at:
  - Phase 2 Dedicated Analysis Tools
  - Phase 2 Requirements for modelling EGNOS within GSSF
  - Reuse of EETES EGNOS models GSSF Phase 2

GSSF Purpose

- *System* Simulations Facility Supporting GalileoSat
  - System Requirements Definition and Validation
  - System Architecture Validation
  - Sub-System Verification
  - System Verification
  - System Qualification (TBC)
  - Operations
- Support validation of the GalileoSat *system* in an integrated tool
- Support system-level “what-if” analysis
- “Cradle to Grave” simulation across the lifecycle of a project

GSSF Could be used to...

- Support requirements allocation and refinement
- Analyse system behaviour and performance under nominal and degraded conditions
- Investigate the impact of failure modes on the system functions (including supporting RAMS Analysis)
- Estimate figures of merit for system performance
- Support Development (used by GalileoSat prime and subs?)
- Support System and Subsystem AIV Activities
- Support Verification (e.g. GSTB)
- Support Deployment (e.g. IOV)
- Support initial and Full Operations
- Support certification ?

GSSF Scope

- System Level Validation of GALILEOSAT
- Could be extended to cover other GALILEO elements
- Initially foreseen as a tool for ESA, but could also be used by GALILEO prime and major sub-contractors
- Intended to complement (NOT replace) lower level design tools
  - Can be used off-line to generate data for input to other tools/systems
  - Supports data exchange with other tools
  - Supports run-time interfaces to other tools/systems

GSSF Phases

- Phase 1 - PROTOTYPE
  - GSSF v1 Definition and Development
  - Demonstrate GSSF Concept and Architecture
  - GSSF System Requirements and Architecture Definitions
  - Provide GalileoSat models for all segments
  - To be used by ESA to support early phases of the GalileoSat design, up to PDR
- Phase 2
  - Provide greater integration of the GSSF Tools
  - Provide higher fidelity models (plus EGNOS from EETES)
  - Provide external interfaces (to hardware and other systems)
  - Will be used by ESA to support later stages of design and beyond

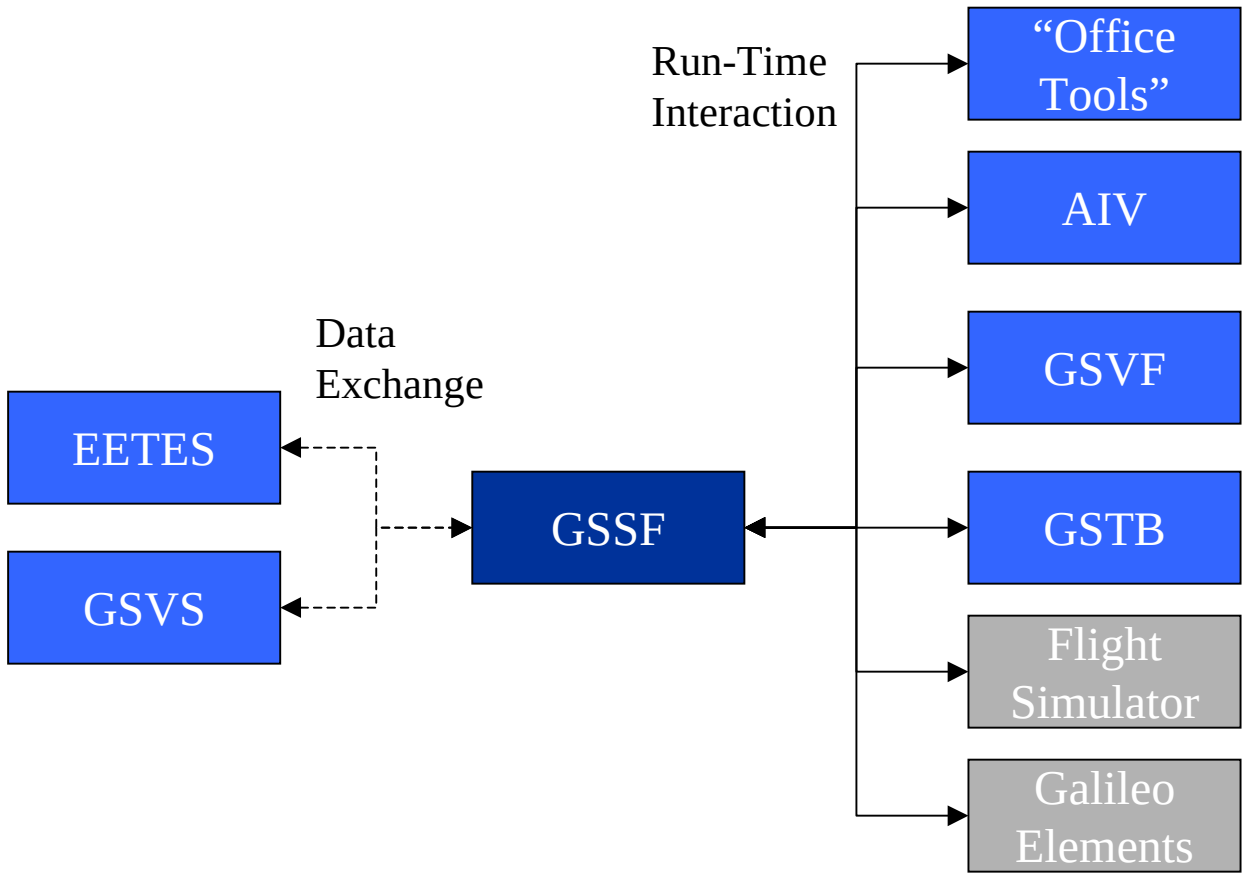
GSSF Timeline

Phase	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
GalileoSat - Defintion										
GSSF V1 - Development										
GSSF V1 - Operation										
GalileoSat - Design and Development										
GSSF V2 - Development (TBC)			v2.1 v2.2							
GSSF V2 - Operation										
GalileoSat - In-Orbit-Validation										
GalileoSat - System Deployment										
GalileoSat - Operations										

GSSF Requirements

- GSSF V1 User Requirements Derived from:
  - SP-10 Issue 1
  - Statement of Work
  - ESTEC GalileoSat Project
  - Alenia (review of the URD)
  - Internal consortium knowledge
  - GalileoSat BDR Data Pack
- GSSF V2 System Requirements Derived from:
  - SP-10 Issue 2
  - Statement of Work
  - ESTEC GalileoSat Project
  - GalileoSat Final Review (FR) Data Pack
  - V1 URD
  - GMV (EGNOS models)

GSSF Context with Other Tools/Systems



GSSF Components

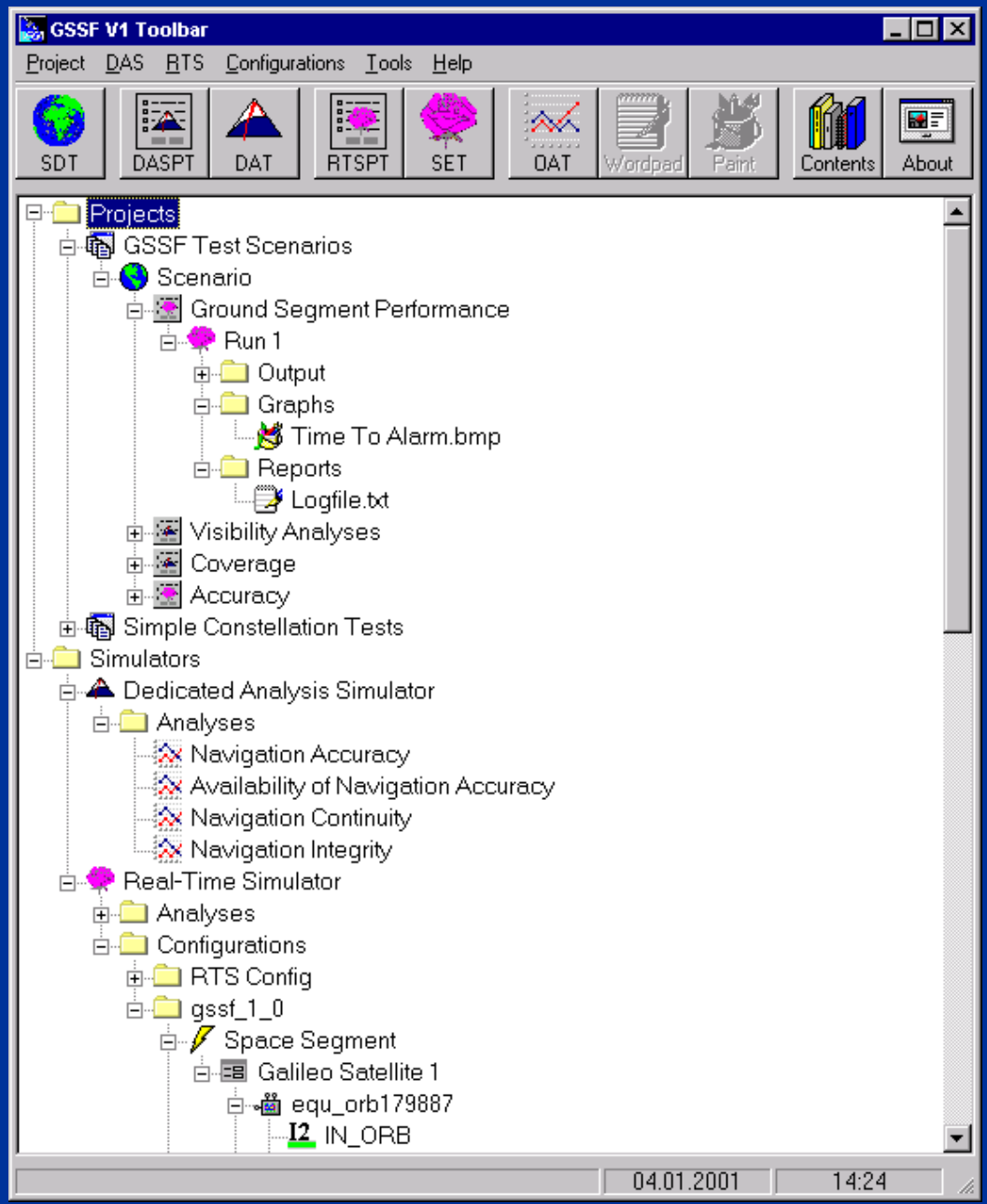
GSSF User Interface

Dedicated Analysis Simulator | Real-Time Simulator | Off-Line Data Analysis

GSSF Database

- GSSF User Interface based on Windows-NT
- DAS based on STK (with extra modules)
- RTS based on CAE ROSE
  (SIMSAT-NT for GSSF-lite, TBC)
- Offline Analysis performed with PV-WAVE
- GSSF Database based on ORACLE
  (MS-Access for GSSF-lite, TBC)

GSSF User Interface



GSSF Foundations

- Based on COTS hardware and software, integrated into a single system
  - GSSF runs on Windows-NT (all but RTS) and SGI (RTS only)
  - *"GSSF-Lite" allows users to have GSSF on their own PC for running simulations (Windows-NT/Windows 2000)*
- Open architecture supports run-time and file-based interfaces to external tools/systems:
  - "Open" database description
  - ODBC database access
  - ASCII/XML data file exchange (inputs and outputs)
  - COM interface for data exchange (interface to MS Office Applications) and database access (no need to know DB structure)
  - TCP/IP for point-to-point interfaces

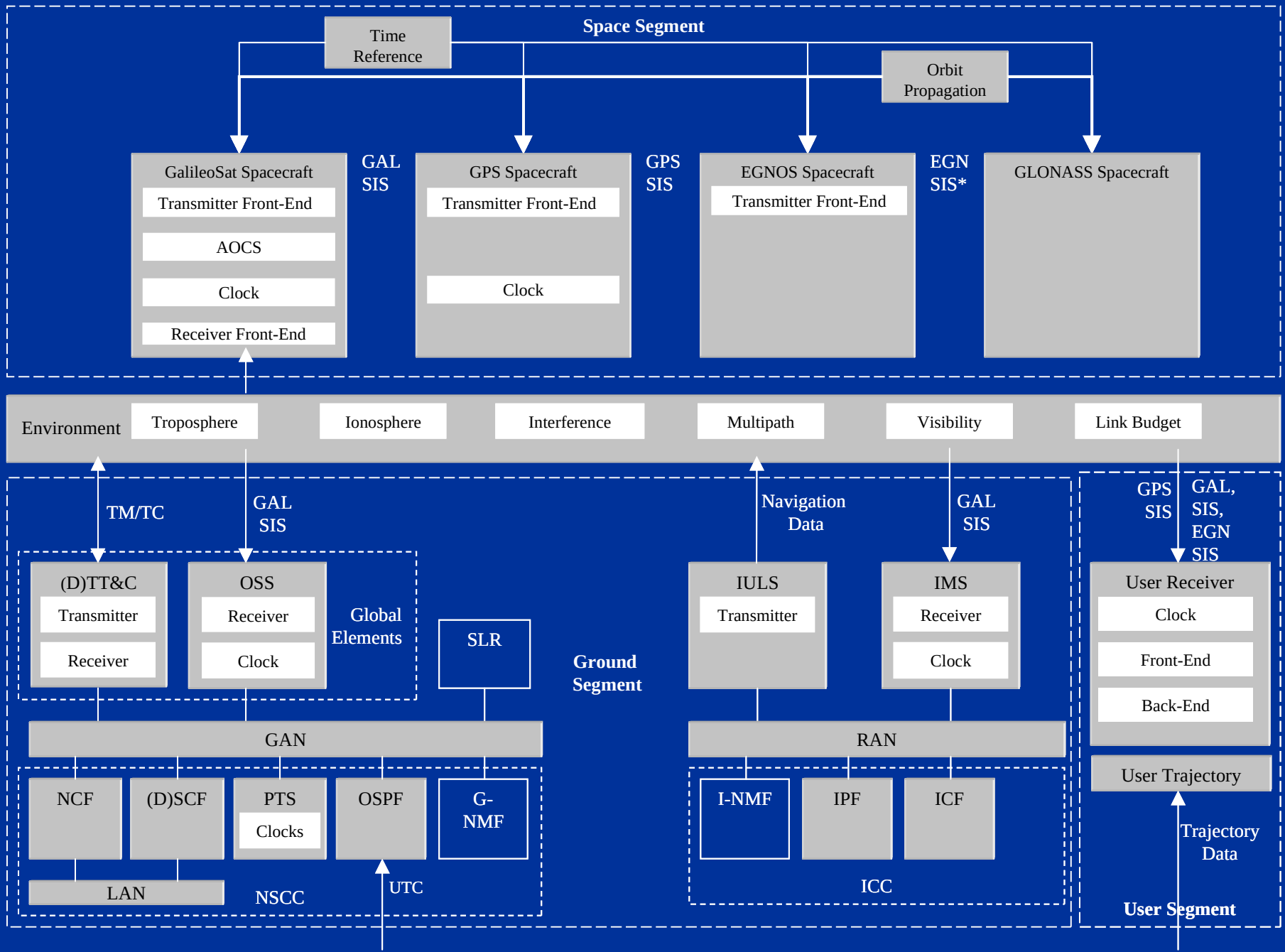
Real-Time Simulator - Overview

- Provides the system-level detailed, end-to-end, simulation capability
- Based on CAE ROSE, proven in **large system simulations**
- Can run models
  - In real-time
  - As fast as possible (as fast as CPU(s) will allow)
  - User selectable slower than real-time
  - In statistical mode (batch mode)
- Graphical Model Development, Integration, Test & Execution
- Models can be exported with an SMI interface
- Supports real-time interfaces to external systems and hardware e.g.
  - TCP/IP
  - VME
  - PCI

Real-Time Simulator - Configurations

- Supports different “configurations” of models e.g. for
  - Different fidelity models (e.g. many users will not need high-fidelity spacecraft models)
  - Different Galileo architectures (i.e. as it evolves)
  - Partial models (some users will not need all of the models)
- Each configuration can be initialised for a simulation run with different
  - Numbers of spacecraft, ground segment elements, users
  - Environmental conditions
  - Characteristics for each element
  - User trajectories
  - Timelines of events (e.g. failures)
- User can specify simulation data to output for each run, according to the Figure(s) of Merit they wish to calculate.

Real-Time Simulator - Models



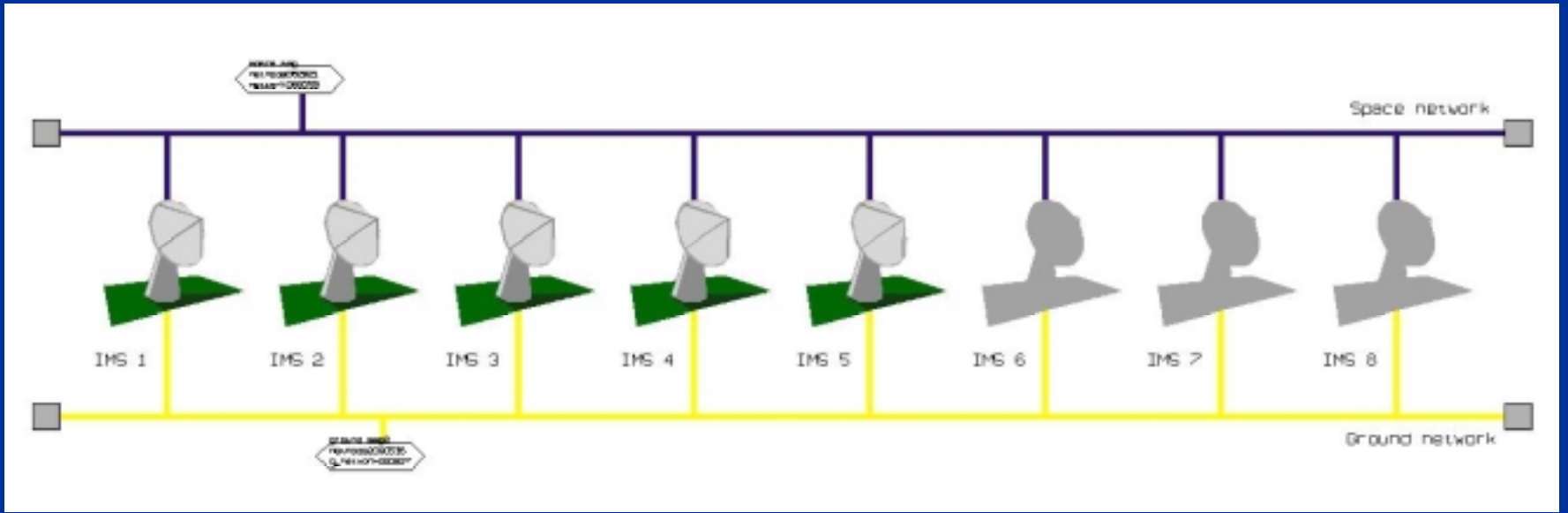
Real-Time Simulator - Model Technology

- Models developed with
  - CAE ROSE
  - C++ (integrated into ROSE objects via handlers)
  - Existing models (C/C++, FORTRAN) integrated behind CAE ROSE objects
- All models support (where applicable)
  - Behaviour
  - Failures (randomly injected or forced)
  - Redundancy
  - Maintenance and Repair down-time
- Generic models library created in CAE ROSE and used for:
  - User and Ground Segment Receivers
  - Transmitter Front-Ends
  - Ground Networks
  - Space-Ground “Network”

Real-Time Simulator - Ground Segment Model

- Satellite Control
  - SCF and DSCF - Simple M&C of the SV, TT&C antenna control
  - TT&C and DTT&C
- Navigation
  - OSS' - Reception of SIS, determination of clock and orbit errors
  - OSPF - Orbit and clock determination (Galileo algorithms, *TBC*)
  - PTS - *TBD*
  - NCF - Scheduling of OSPF ops, M&C of global assets etc.
  - GAN and LAN - Topology, latency, redundancy and switching
- Integrity
  - RAN - Topology, latency, redundancy and switching
  - IMS' - Determination of pseudo-range from multiple receivers
  - IULS' - Uplink of integrity flags to the spacecraft
  - IPF - Calculation integrity flags and alarms for each SV
  - ICF- M&C of assets, selection of SV to uplink integrity flags to

Real-Time Simulator - Partial Ground Segment Schematic



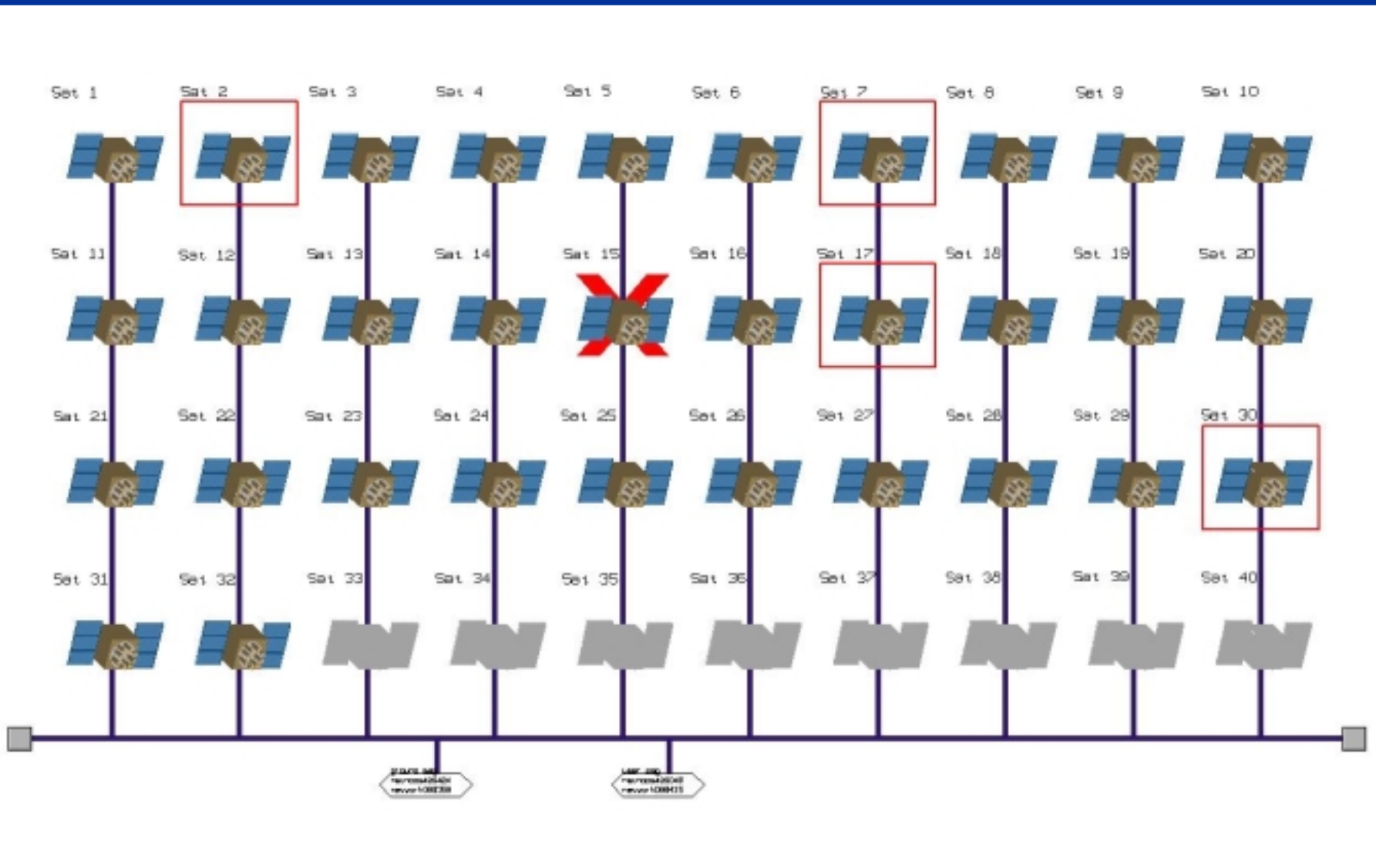
Real-Time Simulator - Space Segment

	Time Reference	Spacecraft					SIS	
		Orbit	Clock	Rx	Tx	Subsystems	Signal	Message
GalileoSat	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
GPS	Yes	Yes	Yes	No	Yes	No	Yes	Yes
EGNOS	Yes (TBC)	Yes	Yes (TBC)	Yes	Yes	No	Yes	Yes
GLONASS	Yes	Yes	Yes	No	Yes	No	Yes	Yes

	Nominal Constellation	Maximum Number Supported
GalileoSat	30	40
GPS	32	40
EGNOS	3	10
GLONASS	24	30
Totals	**89**	**120**

- Galileo Spacecraft models will become more detailed as the design evolves - but not all users will need detailed spacecraft subsystem models.

Real-Time Simulator - Space Segment Schematic



Real-Time Simulator - Signal-in-Space

- SIS divided into Signal and Message
- Signal characteristics (type, frequencies, power, pulse shape, chip rate, code length, antenna gain) are passed to the environment.
- Messages supported for
  - GalileoSat OAS, CAS1 and SAS services (unencrypted)
  - GPS C/A service
  - EGNOS service
  - GLONASS (TBD) service.
- Each transmitter will be able to transmit a maximum of four frequencies, and two services per frequency.
- Within the simulator, the SIS is always represented in engineering units.

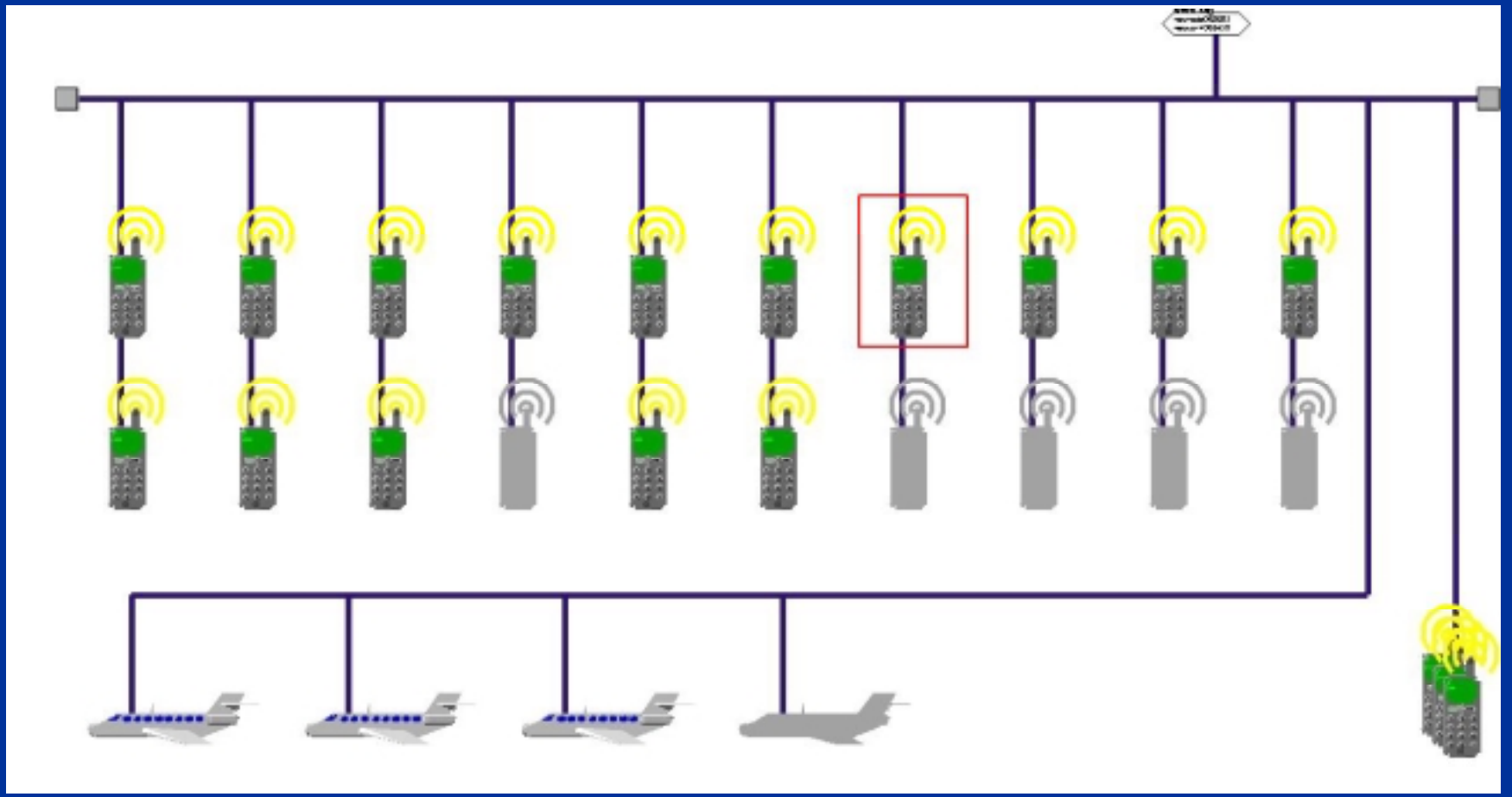
Real-Time Simulator - Environment

- Simulate the effect of the environment on the transmission of signals
  - Ionospheric Effects (Chiu and *IRI95*)
  - Tropospheric Effects (WAAS/EGNOS models, *TBD* models)
  - Multipath Effects (simple and *stochastic*)
- Simulate the connectivity between spacecraft, users and ground segment
  - Visibility (including elevation masking angle, *antenna orientation* and *field of view* for any Transmitter or Receiver)
  - Link Budget (including free-space, shadowing, *pointing*, *polarisation*, *antenna gain* and *orientation*)
- *Simulate interference from other CDMA codes*

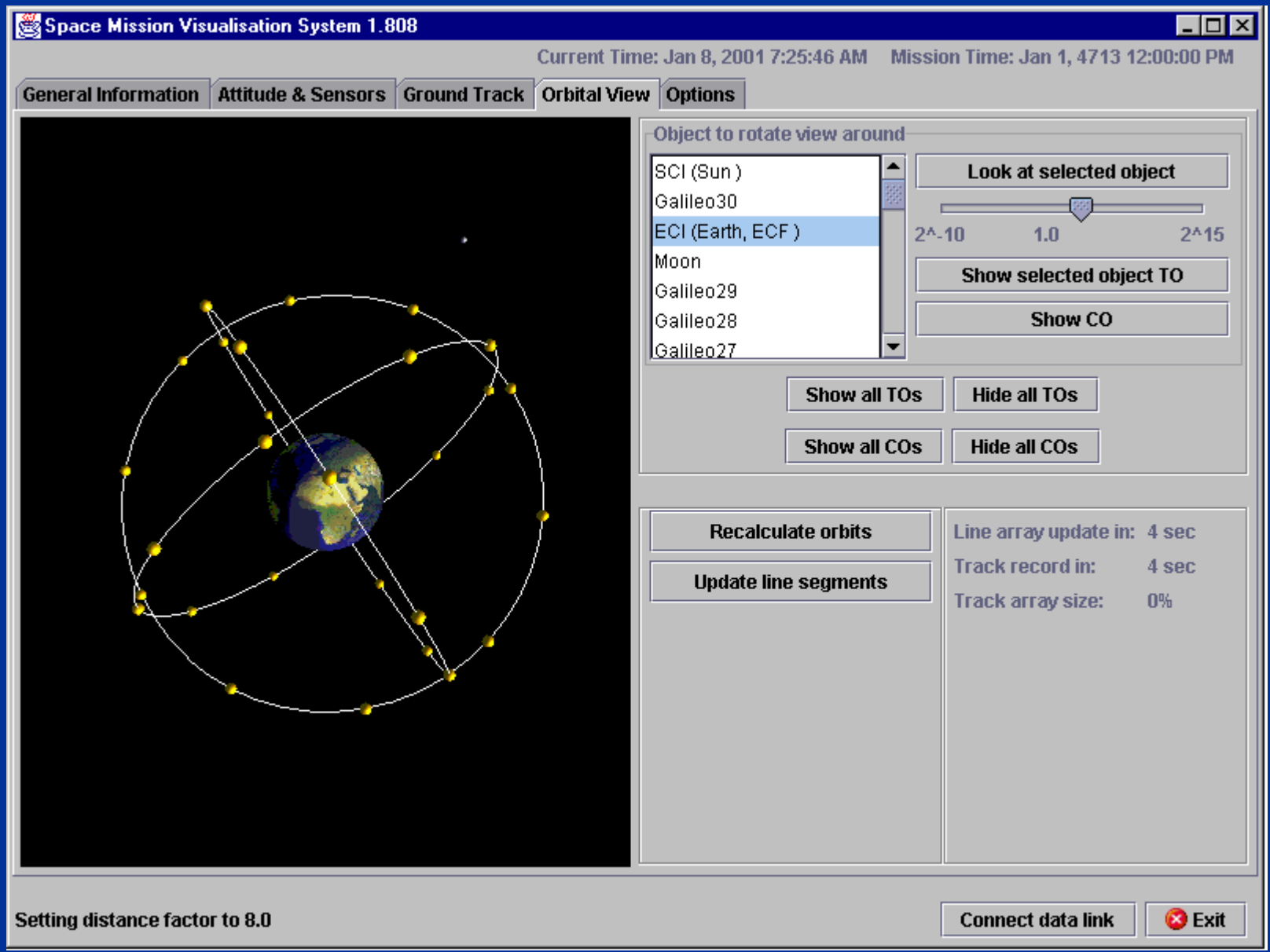
Real-Time Simulator - User Segment

- Define up to 100 (*TBC*) user receivers:
  - Any location on Earth's surface, aircraft, LEO or GEO spacecraft
  - Trajectory (position, region, local and multipath environment, masking, shadowing, antenna temp, azimuth and elevation)
- Receiver model supports one or more of:
  - GalileoSat Signals
  - GPS Signals
  - EGNOS Signals (*TBC*)
  - GLONASS Signals (*TBC*)
- Receivers supported for:
  - Ground Segment - Back-End determines pseudo-range, ADR
  - User Segment - Back-End determines position, velocity, RAIM

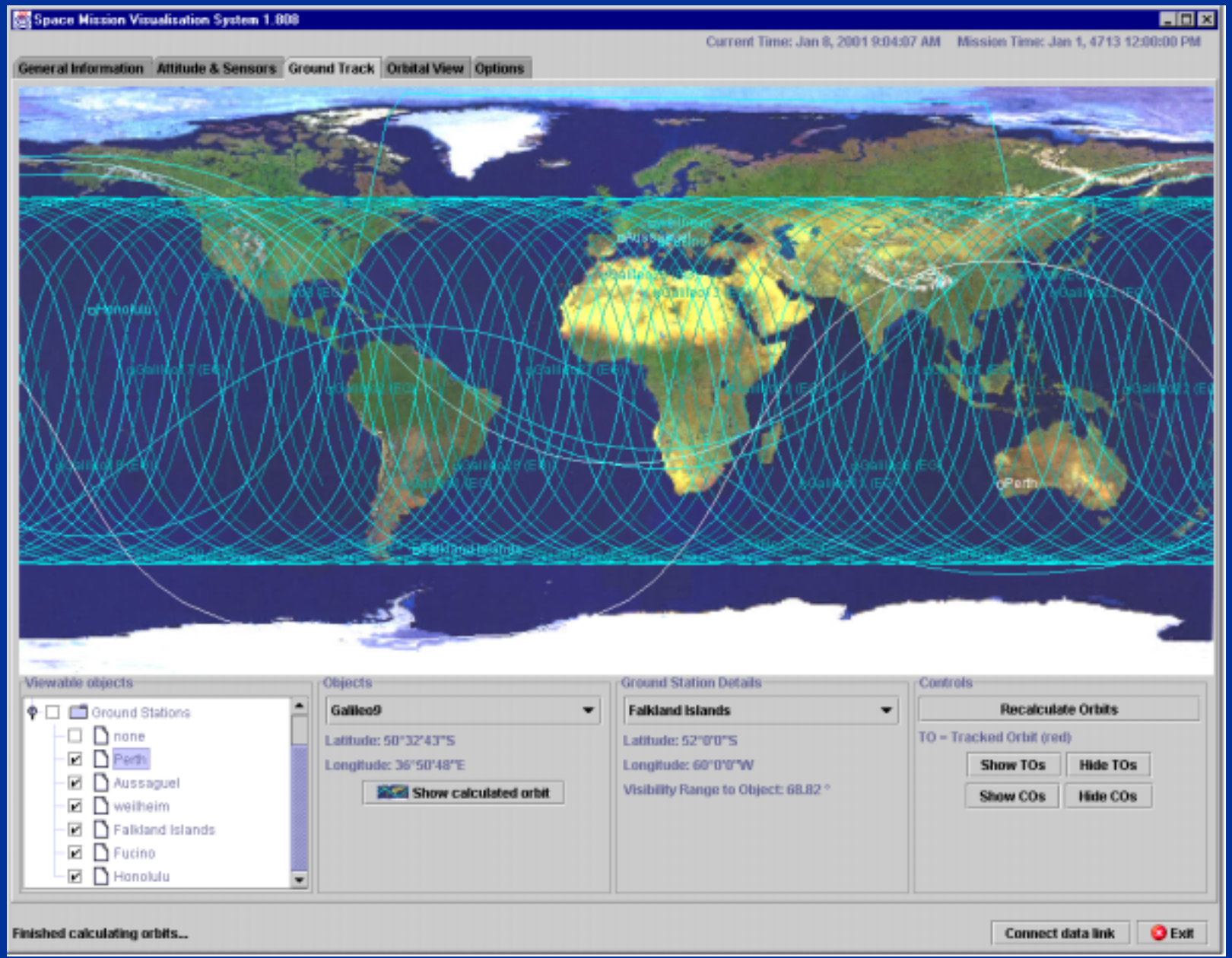
Real-Time Simulator - User Segment Schematic



Real-Time Simulator - Orbital View



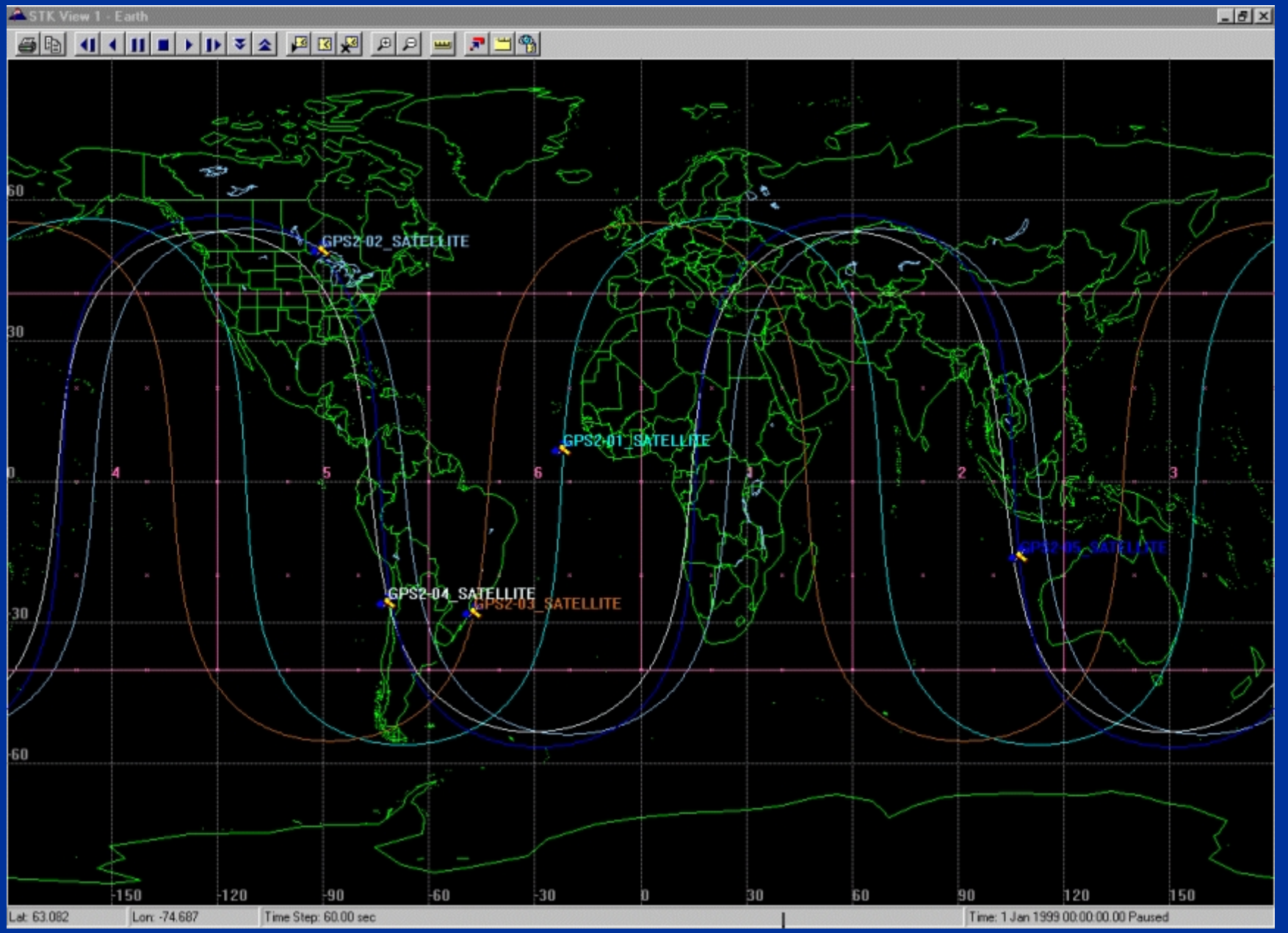
Real-Time Simulator - Ground Tracks



Dedicated Analysis

- Provides the Constellation level performance analysis capability
  - Navigation Accuracy
  - Availability of Navigation Accuracy
  - Navigation Integrity
  - Navigation Continuity
- Also supports deployment strategy analysis
- Based on STK integrated with the rest of GSSF

STK within GSSF



Off-Line Data Analysis - Functions

- Support post-run processing of data from the Real-Time Simulation
- Supports display of data generated by Dedicated Analysis Simulation
- Includes Pre-defined analysis
  - Customised a-priori for quick execution
  - Based on existing EETES analyses
- Provides the capability to customise for user defined analysis
  - Based on previous experience
  - The user can implement any type of analysis with the available data.

Off-Line Data Analysis - FOMS

- The following Figures of Merit are supported:
  - Percentile Accuracy
  - Availability
  - Integrity Risk
  - Continuity
  - Generic Percentile Accuracy
  - Generic Availability
  - Generic Missed Detection Probability
  - Availability of Accuracy
  - Availability of Integrity
  - Continuity of Accuracy
  - Continuity of Integrity
  - Availability of User Navigation Function
  - User Navigation Results
  - Availability of User Integrity function
  - Assessment of SISA parameters

GSSF-Lite

- Many users will want to use only a sub-set of the GSSF capability
- GSSF-Lite provides a simple, low cost version of GSSF
- Allows users to prepare scenarios, run simulations and post-process the results on their own PC (Windows-NT/Windows 2000)
- Runs as fast as the user's PC will allow (PC's now very capable)
- Replaces "industrial strength" COTS with "office" COTS
- Model development still performed in main GSSF, models "ported" to GSSF-Lite using SMI
- Data formats and database structure identical to GSSF to allow exchange of data between GSSF and GSSF-Lite (*TBD*)

The Future

- GSSF V1 currently under development and reflects the BDR design
- GSSF V1 Delivery due end-March 2001
- Users will use GSSF V1 leading up to PDR

- GSSF V2 System Requirements being defined in Phase 1
- GSSF V2 due to start May 2001
- As for GSSF V1, requirements will need to change with the GalileoSat architecture and design, as well as inputs from GSSF V1 users
- GSSF V2 Delivery after 18 months (*TBC*)