Galileo Constellation Operations Simulator

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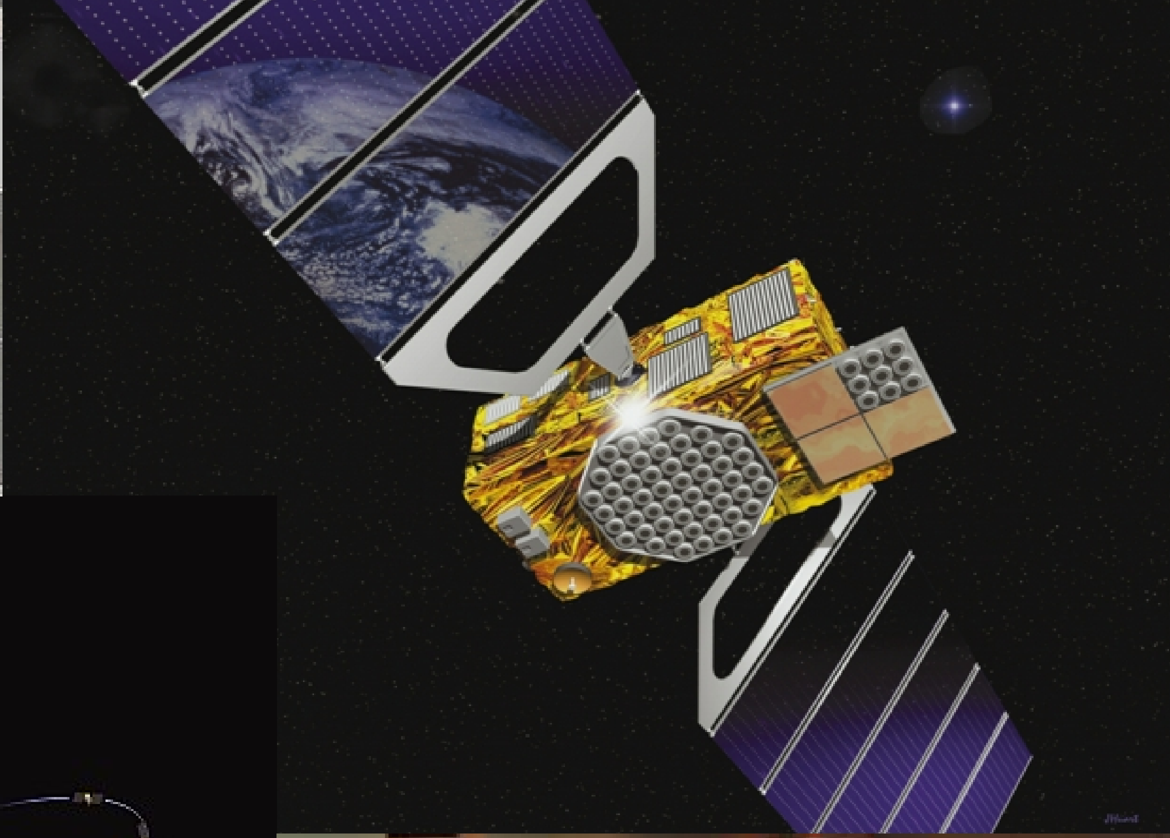
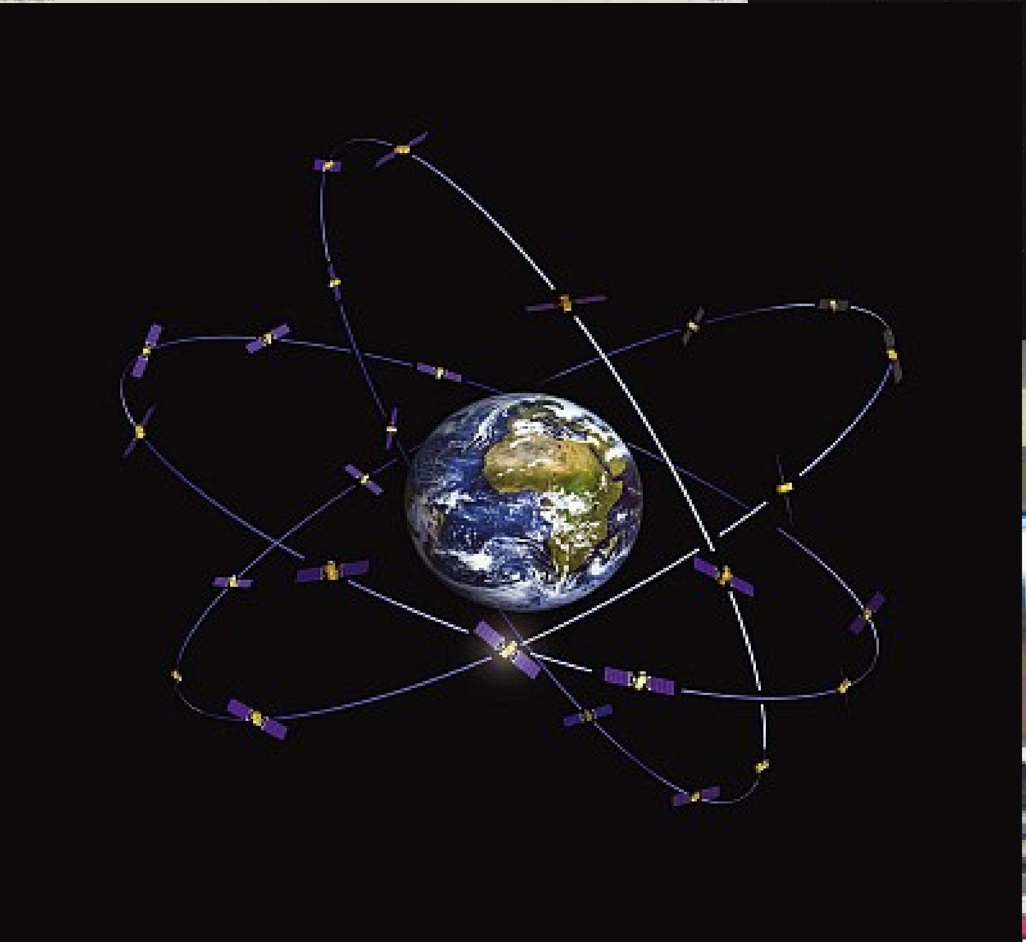
Overview

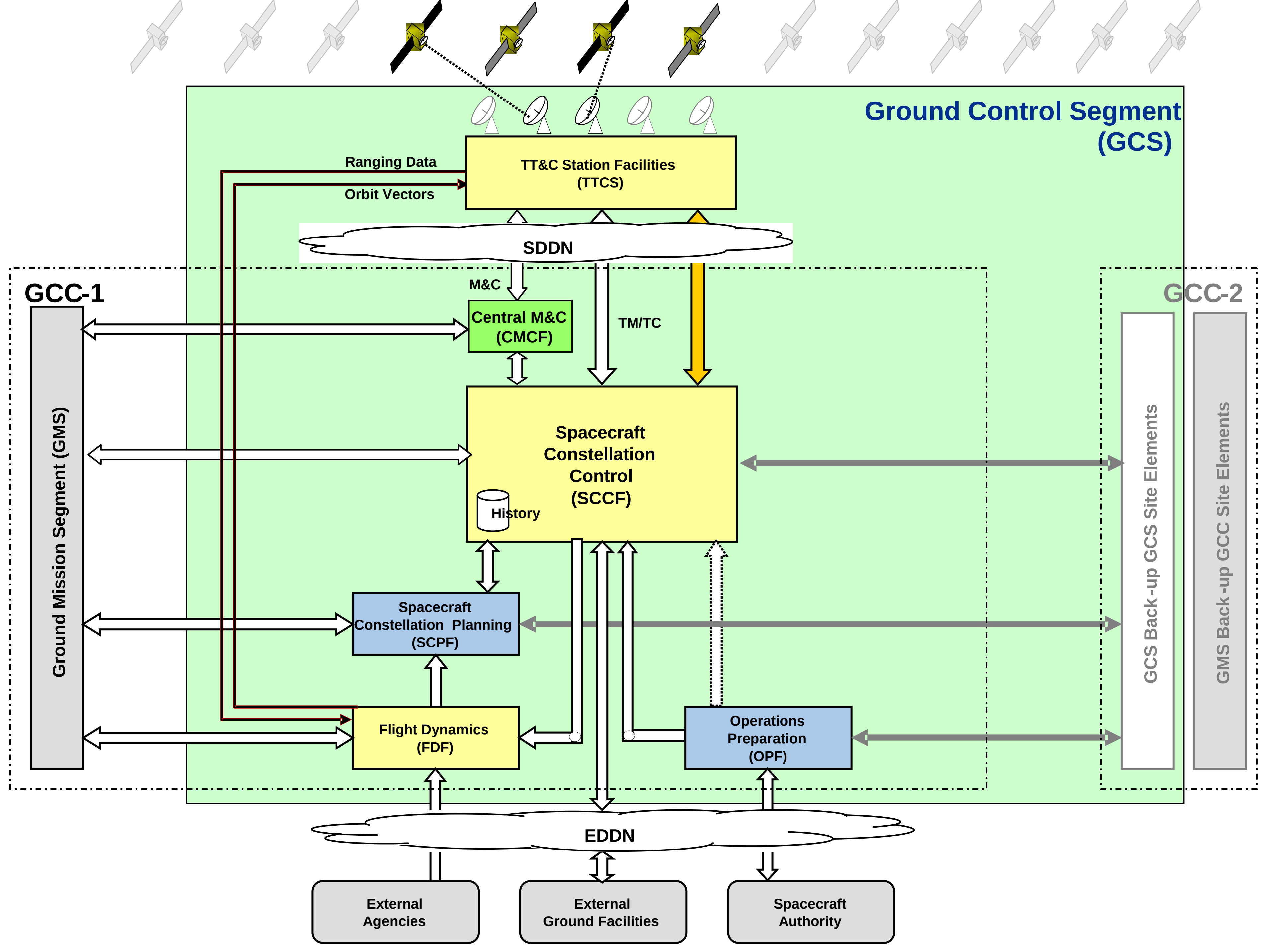
- An Introduction to CSIM
  - What it is
  - Operations context and Use Cases
- Architecture Overview
  - Design Drivers and Trade-Offs
  - High-Level Architecture
  - Spacecraft Model Distribution
  - Constellation Support
- Current Status
- Conclusions

What is the Constellation Simulator?

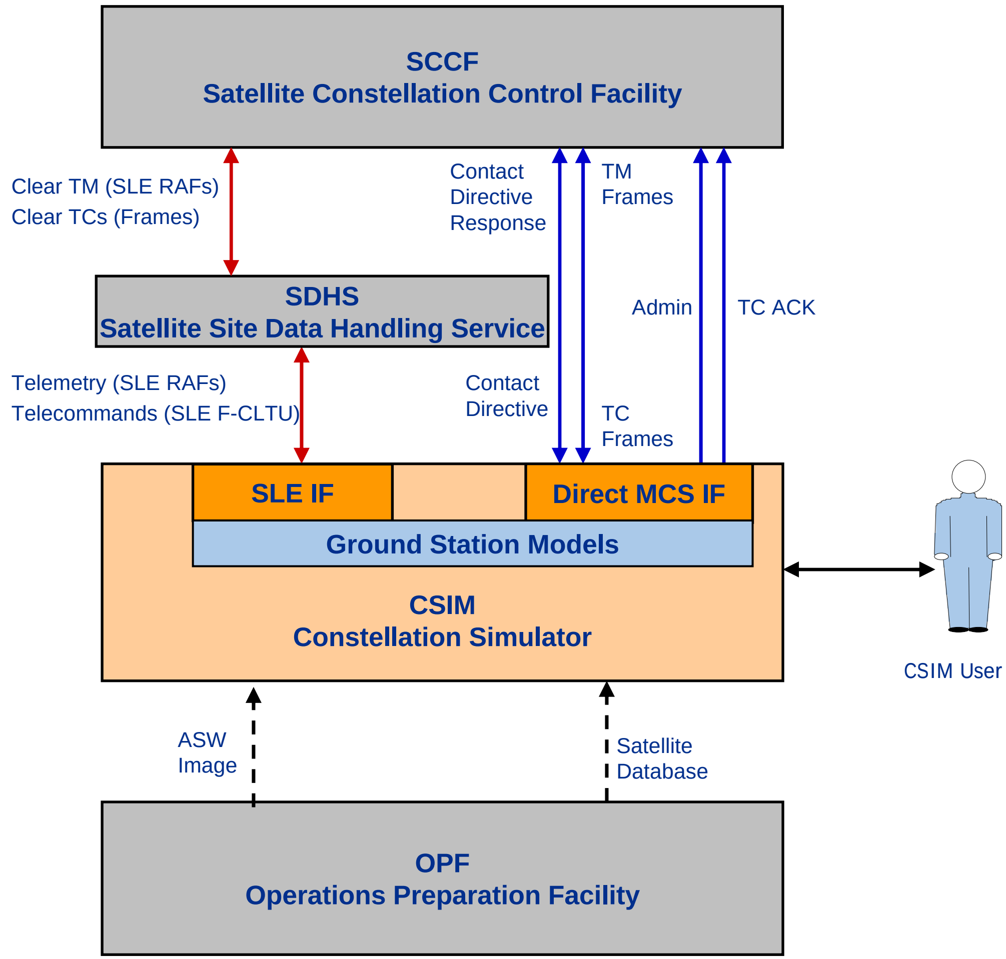
- Simulates the Galileo spacecraft constellation to support ground segment validation & operations
- Features
  - ⇨ Models all spacecraft in and out of ground contact
  - ⇨ Accepts TC from the control system & responds appropriately
  - ⇨ Generates payload and platform housekeeping TM
  - ⇨ Models onboard mass memory (stores TM when out of ground station contact)
  - ⇨ Runs the real onboard software image
  - ⇨ Models predefined failure cases
- Supports Galileo IOV (4 spacecraft)
- Demonstrate it will support FOC (41 spacecraft in the current worst case replenishment scenario)






Ground Control Segment (GCS)
TT&C Station Facilities (TTCS)
Ranging Data
Orbit Vectors
SDDN
M&C
TM/TC
GCC-1
GCC-2
Central M&C (CMCF)
Ground Mission Segment (GMS)
Spacecraft Constellation Control (SCCF)
History
GCS Back-up GCS Site Elements
GMS Back-up GCC Site Elements
Spacecraft Constellation Planning (SCPF)
Flight Dynamics (FDF)
Operations Preparation (OPF)
EDDN
External Agencies
External Ground Facilities
Spacecraft Authority

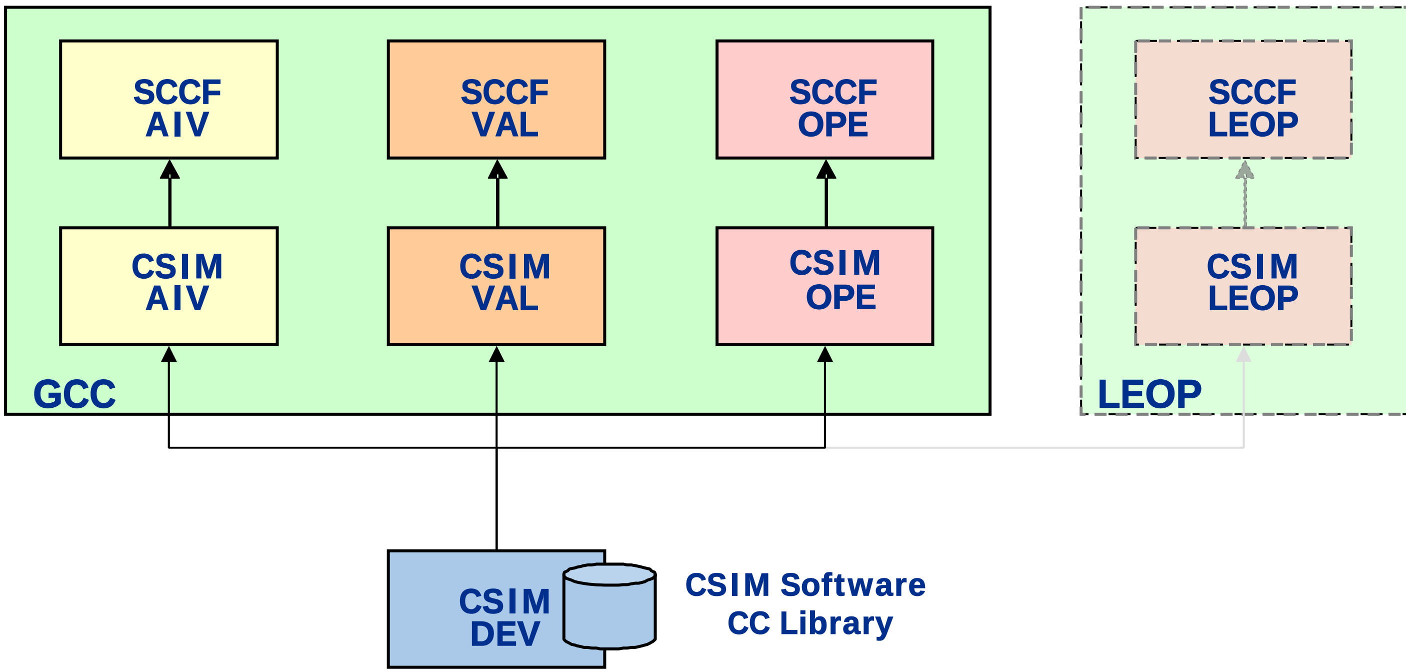
CSIM Operational Context



Use Cases ... Different Configurations

- Testing
  - ⇨ GCS Functionality
  - ⇨ Spacecraft Database
  - ⇨ Overall Ground Segment
- Operations Procedure Validation
- Operations Rehearsals
  - ⇨ Operator (Nominal and Simulated Anomalies)
  - ⇨ Manoeuvre Operations
  - ⇨ On-Board Software Maintenance
  - ⇨ Satellite Deployment/LEOP (planned)
  - ⇨ Two GCC Operation
- Simulation Scenario Preparation

CSIM Hardware Chains



Key Design Drivers

- Support
  - ⇨ Up to 6 high-fidelity (emulated) spacecraft
  - ⇨ Up to 36 low-fidelity spacecraft plus 5 high fidelity
- Capable of supporting a heterogeneous fleet
  - ⇨ Different OBSW and Satellite Database (SDB) versions
  - ⇨ Different onboard hardware (later FOC spacecraft?)
  - ⇨ Different spacecraft configurations (failures etc.)
- Provide a single user interface from which to run and control the entire constellation simulation
- Multiple spacecraft contacts to multiple ground stations
- Long duration mission (20 years)
- Cost and Schedule

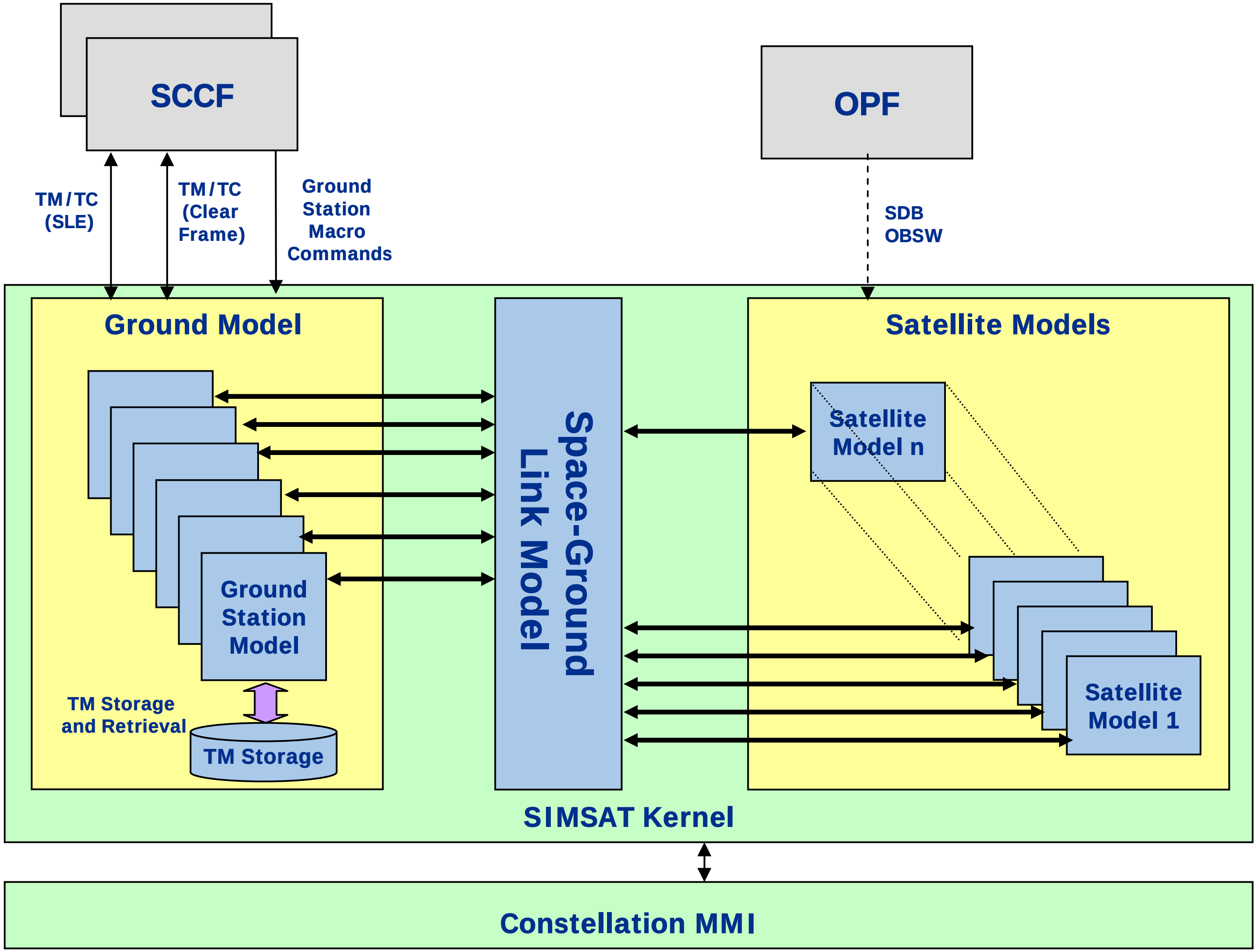
Fidelity

- A modern spacecraft simulator has to model the onboard software – several options:
  - ⇨ **Software Emulator** (high-fidelity, CPU hungry, uses real OBSW image, new images/patches can be loaded)
  - ⇨ **Recompilation of OBSW** (high-fidelity, moderate CPU, cannot easily integrate new OBSW versions, patching not possible)
  - ⇨ **Full functional model** (moderate CPU, replicates most functions of OBSW, difficult and expensive to develop & maintain, patching not possible)
  - ⇨ **Simple functional model** (very limited functionality – mainly TM/TC, simple or no AOCS control laws, low CPU, little need to align with OBSW)
- CSIM requires a balance between **fidelity** and **performance**

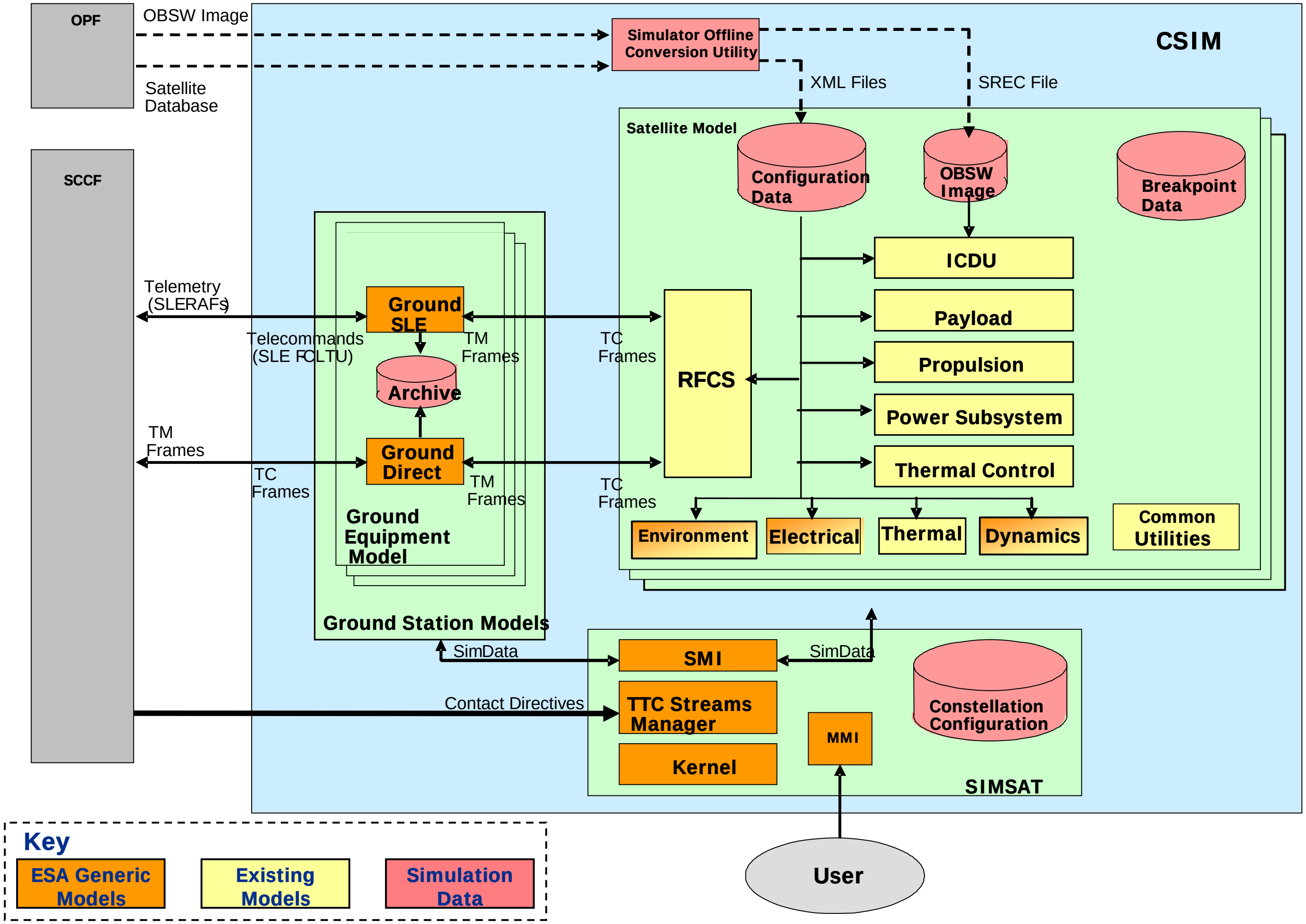
Design Trade-Offs

- High-fidelity emulated models for spacecraft in ground contact, low-fidelity for out of contact
  - ⇨ (2+2) for IOV
  - ⇨ (5+36) for FOC
  - ⇨ (6+0) for FOC LEOP
- No inter-spacecraft links – simplifies architecture
- Reuse of existing ESA infrastructure
  - ⇨ SIMSAT 3.0 (LINUX) => SIMSAT 4.0
  - ⇨ SMP2 Simulation Model Portability Standard
  - ⇨ Generic Models (Orbit, Dynamics, Power, Ground)
  - ⇨ ESA 64-bit ERC32 software emulator
- QERC emulator for “low fidelity” models in D2
- Reuse existing models of similar equipment provides a *starting point* - reduced cost and risk

CSIM Overview

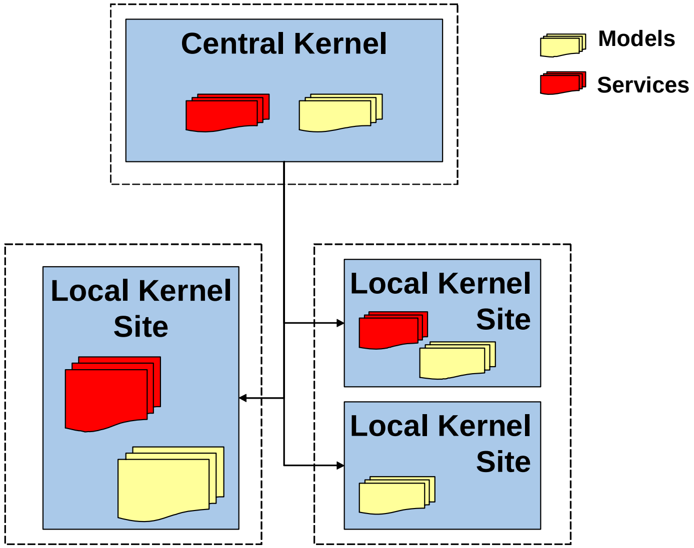


Spacecraft Models and Reuse

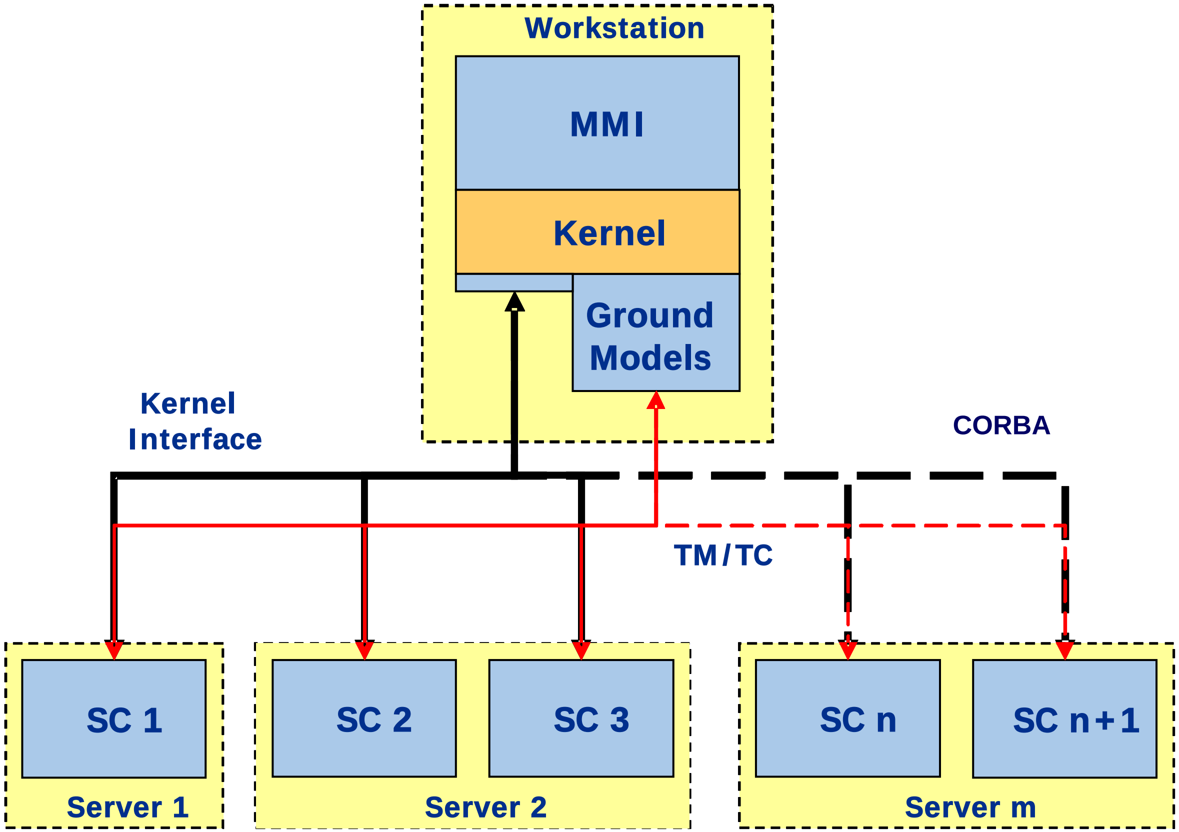


Constellation Infrastructure Enhancements

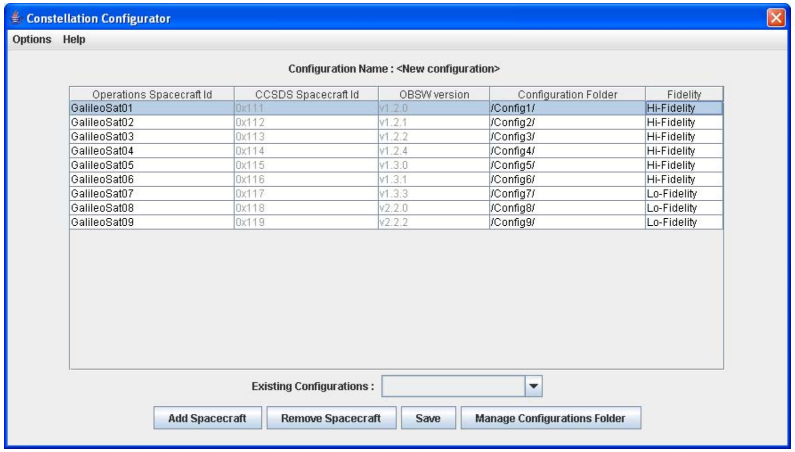
- Support for Constellation MMI
  - ⇨ Summary view of spacecraft status
  - ⇨ Constellation commanding, monitoring & management
  - ⇨ Drill-down to details of individual spacecraft
- Distributed Simulation
- Central Kernel
  - ⇨ Ground models
  - ⇨ Overall schedule
- Local Kernel Site
  - ⇨ Spacecraft model Scheduling
  - ⇨ Logging
  - ⇨ Data Grouping (to MMI)
  - ⇨ Save & Restore



CSIM Model Distribution



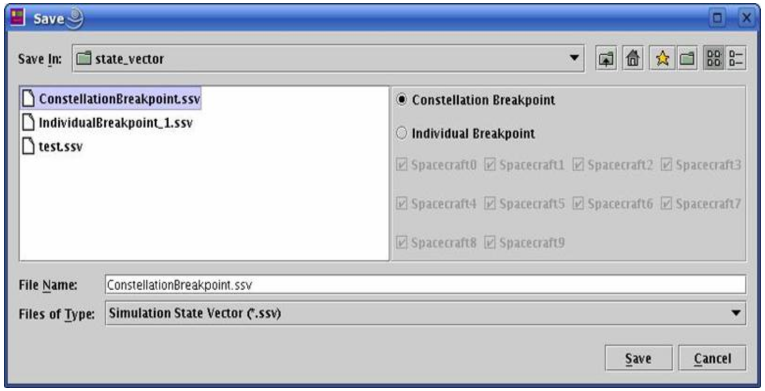
Constellation Management Support



- Supports user creating a constellation configuration from individual spacecraft
- Configuration used to support initialisation of spacecraft models
- User can
  - ⇨ Add spacecraft
  - ⇨ Remove spacecraft
- Spacecraft each has
  - ⇨ Unique operations name
  - ⇨ CCSDS spacecraft ID (stored in the OBSW)
  - ⇨ Specified OBSW version
  - ⇨ Fidelity
- User can save and load a named configuration

Constellation “Breakpoint”

- Ability to save/restore the state of the entire constellation
- Allow spacecraft to be reinitialised in a different orbit/epoch
- Scripts place SC state into safe mode allowing epoch and orbit position change before save and restore back into fine-pointing mode.
- All spacecraft breakpoints independent of each other
- Scripts to save/restore run in parallel for each spacecraft
- Constellation enlargement by allowing individual spacecraft to be restored into a constellation breakpoint



Current Status

- CDR successfully completed in February 2008
  - ⇨ Detailed Design
  - ⇨ Consolidation of Ground Control Segment issues affecting CSIM
- Deliveries
  - ⇨ D1: January 2009
    - IOV Constellation Capable
    - ESOC ERC32 Emulator
    - One workstation, 2 servers (2 SC per server) **per chain**
    - Used to support GCS Segment Integration
  - ⇨ D2: June 2009
    - Launch planned for May-2010, latest.
    - Used to support IOV Launch Preparations
    - Will integrate QERC high-performance processor emulator
    - No additional hardware
    - Full constellation capability demonstration on combined HW from three chains

Conclusions

- CSIM is a highly challenging simulator development
  - ⇨ Up to 41 **heterogeneous** spacecraft
  - ⇨ Distributed simulation
- Careful design choices allow risk to be minimised
  - ⇨ Minimal changes to the simulation infrastructure
  - ⇨ Avoid “throwing hardware at it”
  - ⇨ Reuse of existing models of similar equipment
  - ⇨ Support for IOV and scalable to FD
- Development is ongoing for D1
  - ⇨ Completion of spacecraft models (driven by SC design information)
  - ⇨ Integration of OBSW v1 (TM/TC and Data Handling)
  - ⇨ Integration of OBSW v2 (most AOCS modes, no payload)
  - ⇨ Integration of OBSW v3 (FDIR)
  - ⇨ Validation of constellation infrastructure

Acknowledgements

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