Mission Families: a cost effective approach to Mission Control System development

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Overview

- Reuse strategy at ESOC
- The ESOC Software Infrastructure
- The "Delta" Approach
- Concept of Mission Families
- The Delta Approach applied to Mission Family
- The Earth Explorer mission family

- Conclusions

Reuse Strategy at ESOC

- ESOC approach is to maximize the reuse of:
  - Experience
  - Procedures
  - Software
  - Operational Concept
- A large number of ESOC Projects has already applied the software reuse in the context of Mission Control System (MCS)development
- Software Reuse is a strategy for:
  - **Cost reduction**: a small amount of code has to be developed and maintained by a new mission
  - **Risk reduction**: the re-used software has been already validated by previous mission

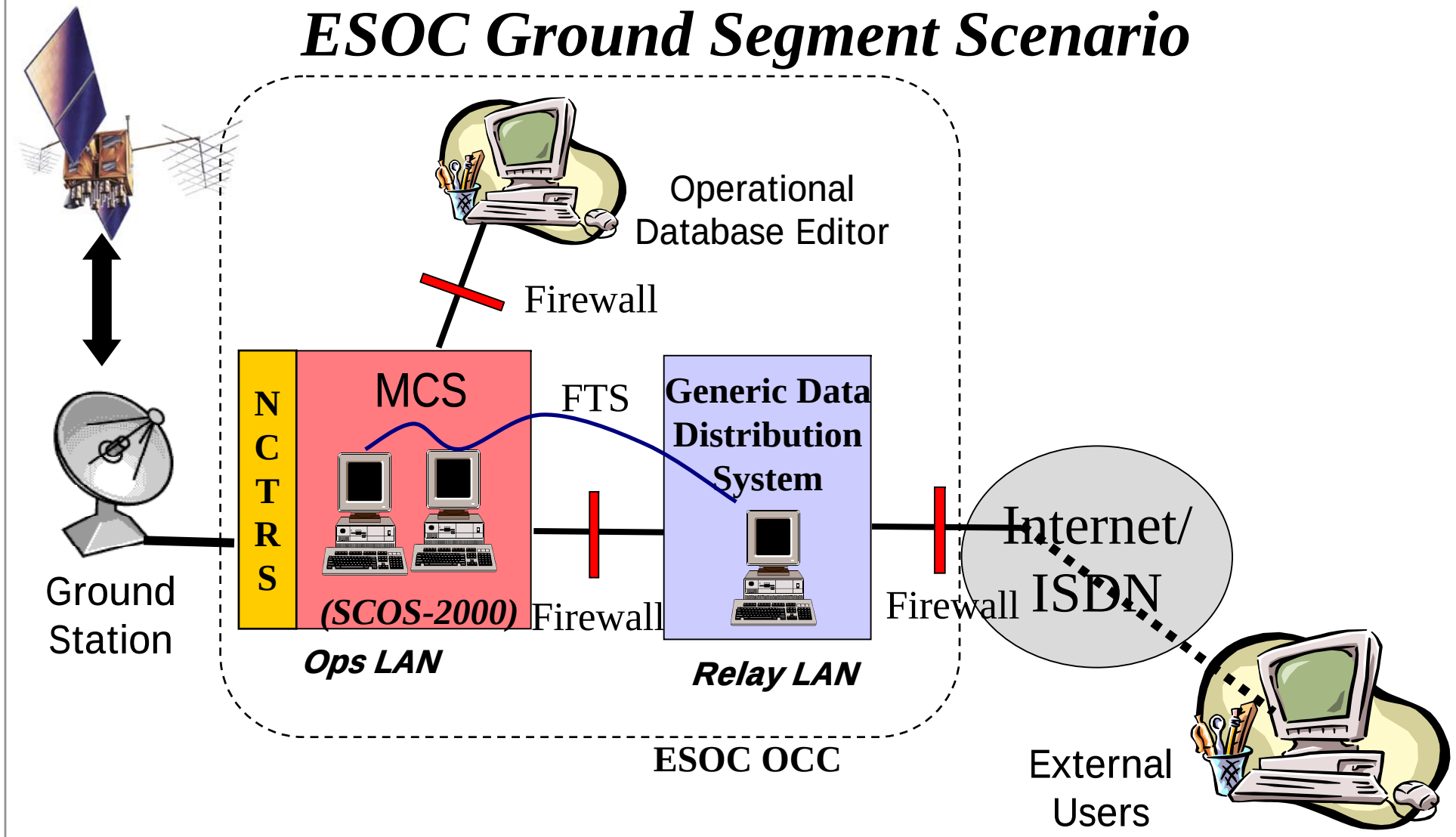
Software Reuse Bases

- Design
  - Mission control software components expressly designed for reuse (infrastructure components)
  - Needs of specific mission designed in a generic way at benefit of other missions
  - Harmonisation in the design of spacecrafts in all respects affecting the ground segment
- Use of standards
  - Packet TM/TC standards (from CCSDS)
  - Packet Utilisation Standard (ECSS)
  - Space Link Extension (SLE)
  - XML

ESOC Software Infrastructure

- **The Spacecraft Control and Operations System (SCOS-2000)**
  - Based on distributed client-server architecture, it covers generic services for telemetry reception and processing, telecommand uplink and verification, data archiving, display and retrieval.
- **The Network Control and TM/TC Router System (NCTRS)**
  - Interfaces between MCS and the Ground station network (SLE for non-ESA stations)
- **Generic Data Disposition System (GDDS)**
- **Telemetry Data Retrieval Services (TDRS) and WebRM**
  - Web based interfaces to provide live telemetry and command verification, telemetry retrieval and statistics to external users (e.g. payload owners)
- **Other software largely reused, resulting from a generic design on a mission specific need**
  - File Transfer System (XMM)
  - Mission Planning System (Envisat)
  - Database Editors (Cryosat)

ESOC Ground Segment Scenario



The "Delta" Approach

- MCS requirements are no longer produced in full, but rather as "delta" with respect to the Software Infrastructure (typically SCOS-2000)
  - Slim requirement document quicker to write and review
  - Higher level of detail from an early phase
  - Highlights very clearly where new developments are needed
  - Allows better cost estimation and development risk assessment
- The approach can be extended to rest of the software life cycle
  - Architectural phase: the design is also "delta" with respect to SCOS-2000 and interfaces are, wherever possible, kept untouched
  - Development phase: large part of the software is re-used
  - Testing and validation phase: tests can be focused mainly on mission specific features. Common software is tested concurrently by several missions.
  - Maintenance phase: the SCOS-2000 kernel is maintained under independent arrangements hence minimizing the size of the system that needs to be maintained specifically for each mission

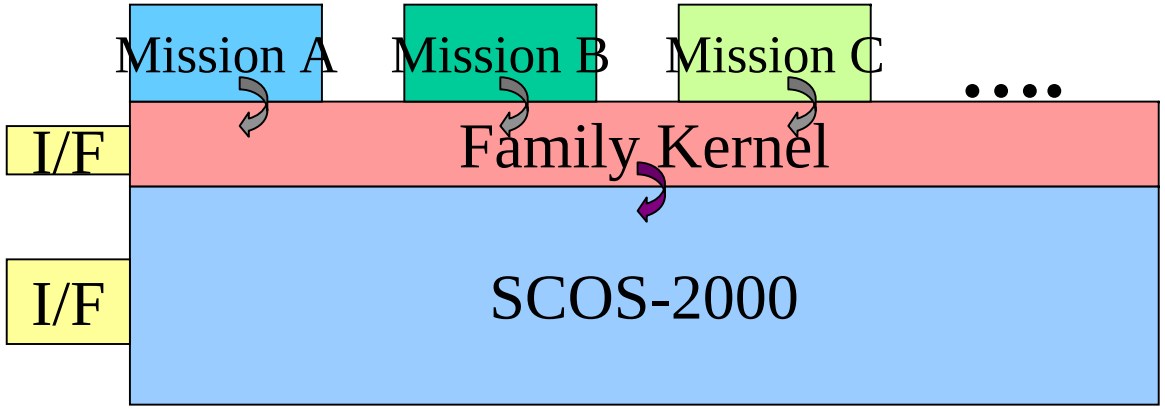
Why Mission Families?

- The Software reuse pushed the need of commonality between spacecrafts
- Missions with a similar profile require the development of similar mission-specific features
- However, these features are not included in SCOS-2000 as they are not generic enough
- They can be grouped into classes that map into well-defined “Mission Families” (generic design within a subset of missions)

Delta Approach applied to Mission Families

- Cost saving approach can be now applied twice

1. Using the SCOS-2000 infrastructure
2. Using the applicable “family kernel” (i.e. common needs within a mission family are grouped in the mission family kernel as a software layer on top of SCOS-2000 infrastructure)



Mission Families at ESOC

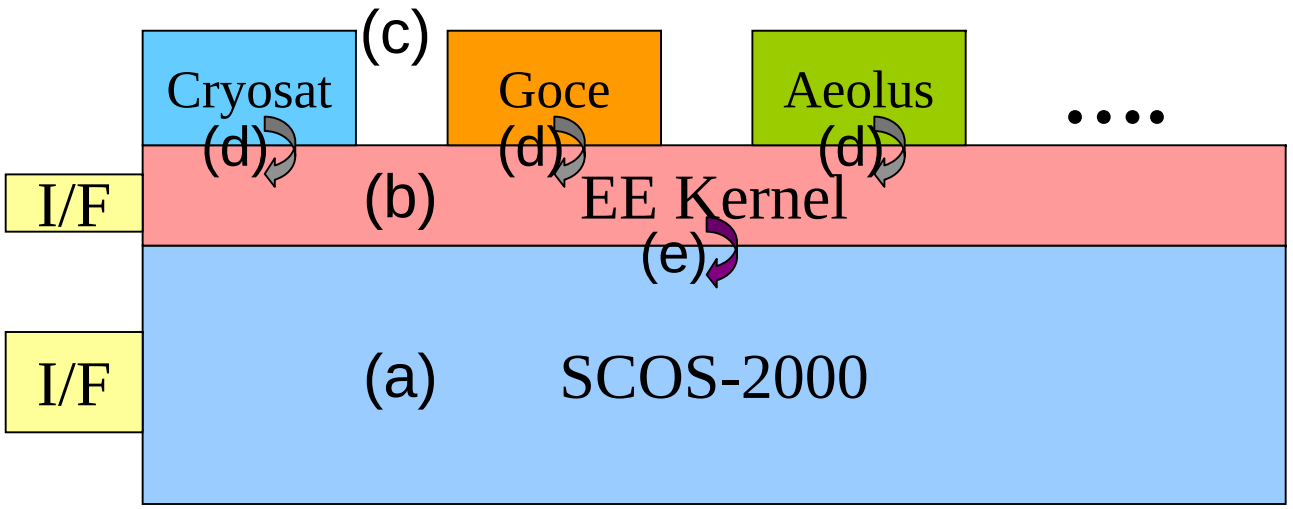
- Earth Explorer mission family
  - low earth orbit, short visibility periods
- Planetary mission family
  - long propagation delay, on-board autonomy
- Observatory mission family
  - long visibility periods, proposal based observations

The Earth Explorer Mission Family Evolution

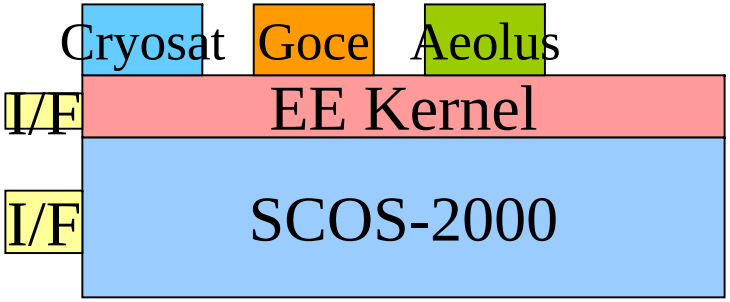
- Cryosat was the first mission for which the “delta” reuse approach was applied (delta against SCOS-2000)
- Goce applied the delta reuse approach against Cryosat, making concrete the definition of the Earth Explorer (EE) Mission Family Kernel
- Aeolus has been defined as delta against the EE Mission Family Kernel
- Each mission would contribute in increasing the Kernel functionalities and the Kernel would contribute in increasing the SCOS-2000 functionalities
- Future missions take benefit of implementation developed by previous (e.g. SWARM)
- Delta approach is applicable along the whole software life (e.g. requirements, design and test documentation)

The EE Mission Family Requirements Sets

a. SCOS2000 Requirements fully reusable by any EE Mission today
b. EE Kernel Requirements common to all EE missions
c. Mission Specific requirements (used today only by one mission)
d. Requirements implemented by mission but common to other EE Missions (candidate for repatriation in EE Kernel)
e. Requirements implemented as common to the EE Mission family but common to any other family (candidate for repatriation in SCOS-2000)



The EE Mission Family Requirements Definition



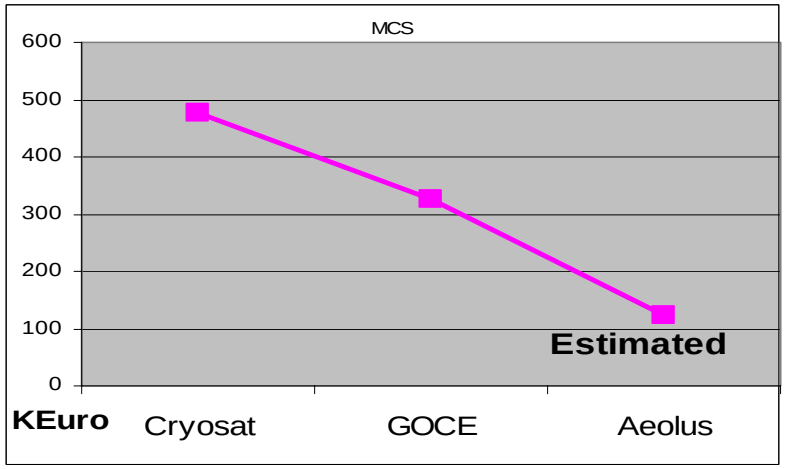
The Delta approach allows to distinguish between generic and mission specific req. already at definition phase

Requirements at Definition Phase	Kernel	Mission Specific	Total
Cryosat SRD	406	35	441
Goce SRD	129	62	191
Aeolus SRS	57	115	172
	592	212	804

The EE Mission Family Heritage Today

- Kernel requirement (by definition)
- Mission specific requirements repatriated to Kernel
- New Kernel requirements (change requests)
- Mission specific requirements (possible reuse for incoming mission in the family)
- Kernel requirements repatriated to SCOS-2000

EE Requirements Heritage	
Kernel (*)	680
Cryosat Specific	35
Goce Specific	42
Aeolus Specific	115
Total EE Family Req.	872



Missions contribution to the EE Kernel (1)

CRYOSAT

- Offline Database Editor and Consistency Check (*) System
- Extension to Command Subsystem (Command and Parameter Identifier) (*)
- Playback telemetry processing including command verification (*)
- Mission Planning System
- File Transfer System
- Scheduler, Standing Order and Polling Tool
- Handling of bad time quality telemetry configurable per Virtual Channel
- On Board Software Maintenance (memory devices fully configurable + range checks)
- On Board Queue dump processing and automatic generation of delete commands
- All files related to the Ground Segment interfaces conform to XML-based syntax
- Concept of two real-time servers (prime and backup) and offline archive server architecture

(*) Already repatriated or candidate for SCOS-2000

Missions contribution to the EE Kernel (2)

GOCE

- Mission Planning System Enhancement (e.g. multiple planning files)
- Telemetry Data Gap Identification
- Task Parameter Files supporting multiple sequences and microseconds
- Automatic Telemetry Replay
- Time Correlator

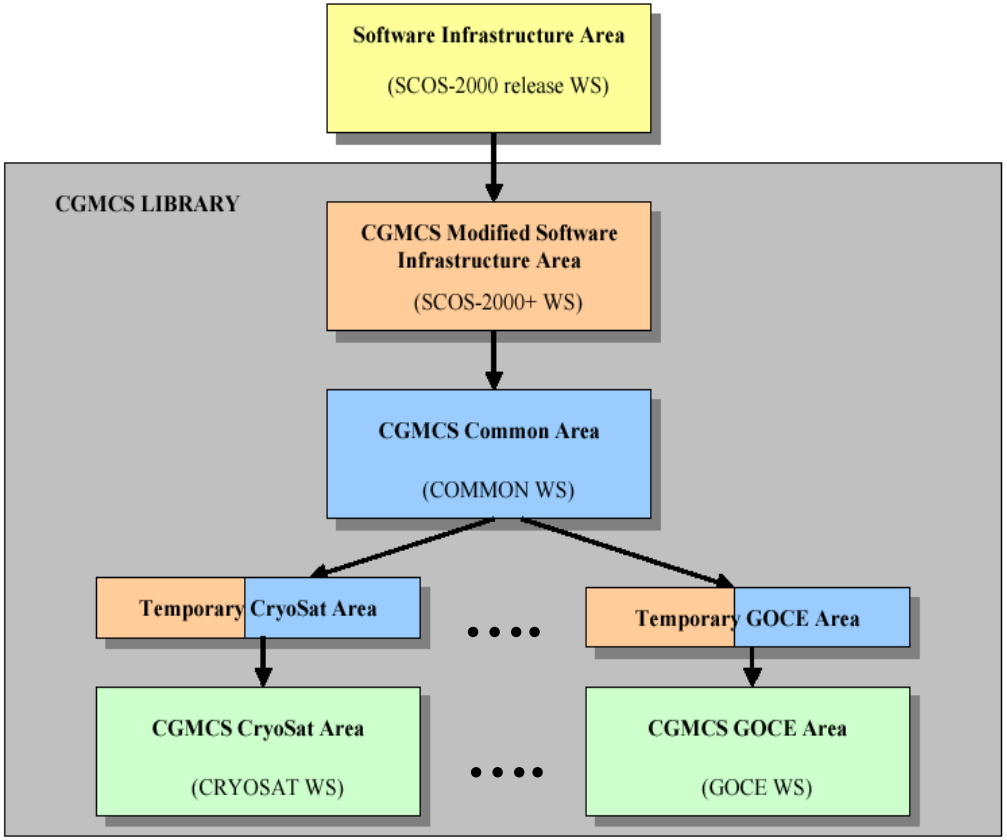
AEOLUS

- Management of weekly consolidation of playback telemetry data
- On Board Software Management Enhancements (e.g. Increased Configuration Control Generation through sequences stored into Central File Archive)
- Handling of Orbital Coordinates (MPS and Commands)
- Network Interface System Automatic Schedule Execution (NCTRS)

The Development Workspace

- Single system – separate installation for each mission
- System highly configurable
- Strong configuration control
- Maximum effort in generic design
- Isolation of EE Kernel requirements
- Requirement review process at each delivery
- High flexibility of maintenance to accommodate mission operational requirements

  (critical phases – LEOP, SVTs)



Conclusions

- ✓ The involvement of the ground segment teams in the design of the satellite TM/TC implementation is strongly beneficial in terms of reduction of the overall costs
- ✓ The adoption of the same TM/TC data types, structures and services by several satellites with similar needs allows cost savings in the MCS design, development and maintenance (cross-mission harmonisation)
- ✓ The adoption of a 'delta' approach for the specification and design of SCOS-2000 based control systems allows significant cost savings and high detailed system already from an early development stage
- ✓ Design and development of specific additions with generic solutions to allow the reuse at minimum cost by future missions in the family or integration into SCOS-2000
- ✓ The overall described approach leaves margin for enhancements and perfective developments without prohibitive costs
- ✓ Project successful in terms of product quality and schedule

Links

Earth Explorer Missions

http://www.esa.int/export/esaLP/earthexplorers.html

Cryosat Mission

http://www.esa.int/export/esaLP/cryosat.html

Goce Mission

http://www.esa.int/export/esaLP/goce.html

Aeolus Mission

http://www.esa.int/export/esaLP/aeolus.html