

Converged CCS

A unified Tests and Operations Environment from tests definition to tests data analysis and in-orbit satellite control

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I. INTRODUCTION

Testing a satellite during its progressive assembly phases, and operating it or performing in-orbit support in case of anomaly require a huge amount of test and operational data to be prepared and validated.

In the frame of NEOSAT program, a large convergence initiative has been decided internally to Thales Alenia Space in order to optimize test and operational data reuse all along program life cycle, and in order to minimize ground test and control software development, validation and qualification effort induced by the new satellite platform design.

This convergence initiative has been divided in different activity streams having complementary objectives:

- A stream dedicated to tests and operational data preparation tools rationalization which main objective was to define a unified preparation environment allowing operational data definition independently from used Central Check-Out System (CCS) or Satellite Control Centre (SCC).
- A stream dedicated to real-time tests and operations legacy solutions unification to guarantee incremental validation of operational data from early IVVQ (Integration, Verification, Validation and Qualification) to in-orbit operations, and to ease mid-term convergence with EGS-CC (European Ground Systems Common Core) kernel.
- A stream dedicated to tests and satellite data long term archiving and analysis on the basis of big data technologies, with the objective of building a unified data model and a shared data lake hosting all these data to allow their long term availability for detailed analysis / investigations.
- A stream dedicated to the harmonization of the way to test and operate a satellite in order to maximize reuse of operational data all along satellite life cycle (from early IVVQ to In-Orbit operations)

As a result of this initiative a unified preparation, execution and analysis framework has been developed and is progressively being deployed in Thales Alenia Space. This paper describes its general architecture and components, its application to IVVQ activities and its future convergence with EGS-CC kernel.

II. ARCHITECTURE OVERVIEW

The Thales Alenia Space Converged Central Check Out System (CCS) environment has been built to cover all testing activities through the satellite life cycle. It includes the following products :

- SCOPE : a unified Operations Preparation Environment
- SDB NEXT : the next generation of Space System Reference DataBase (SRDB) for TM/TC definitions
- CCS : a converged Central Check Out System
- ETDHS : a standardized way to display and validate test results
- BIG DATA for SCC/CCS : a reference architecture for tests data storage and analysis

Each product has been developed to be able to operate on stand-alone mode independently from the used execution Kernel, Satellite Control Centre or Satellite Reference DataBase. The converged CCS initiative integrates them together into a generic and unified testing framework agnostic from satellite programs. Its general architecture is depicted in Fig 1.

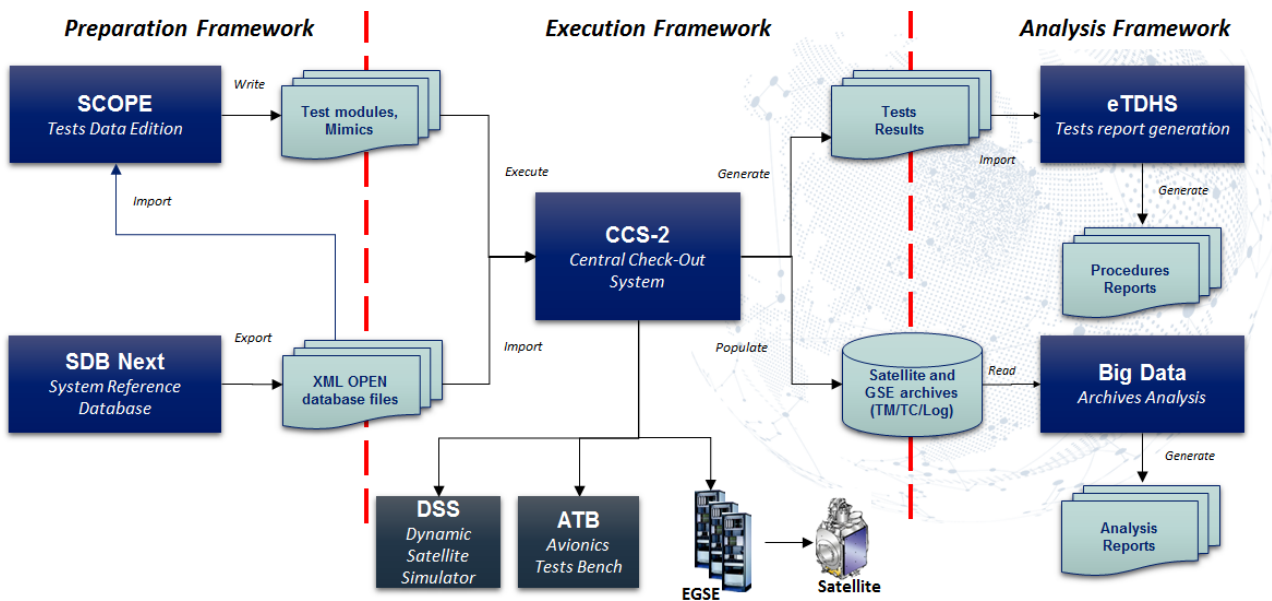


Fig 1. Converged CCS Architecture

Its general behaviour is described as follows:

- Preparation Framework : a unified test data edition environment (namely SCOPE) allows the preparation of operational data to build Tests procedures using TM/TC definitions imported from the Satellite Reference Database (SDB-NEXT in the frame of NEOSAT program).
- Execution Framework : a Central Check-out System (such as CCS-2) allows the execution of the test procedures and the generation and storage of test data results.
- Analysis Framework : a test report generation tool (such as eTDHS) allows to display and validate the data results in real time. Big Data technologies are used for tests data storage and analysis.

This modular architecture, based on reusable building blocks, provides the needed flexibility to cope with each satellite program needs. As an experienced example, Thales Alenia Space preparation environment has been successfully interfaced with different CCS and SCC, allowing maximal reuse of tests and flight operational procedures from one program to another. On the other hand, Thales Alenia Space storage and analysis framework is also interfaced with different execution kernels and GSEs (Ground Support Equipments) in order to provide high level of data valorisation capability.

III. PREPARATION FRAMEWORK

SCOPE : a Unified Operations Preparation Environment

To ease the generic development of operational data such as flight operational procedures, Thales Alenia Space has progressively developed a user oriented extensible environment, so called SCOPE, allowing operators and engineers to develop operational data independently from the concrete execution environments (CCS or SCC).

SCOPE allows the edition and the preparation of operational data with respect to a SRDB on which consistency and validity checks are performed, including but not limited to:

- Flight Control Procedures (FCP)
- Telemetry User's displays (SVG),
- Action Sequences (AS),
- On-Board control procedures (OBCP),
- Commands stacks (STACK),
- On-board TC File (TCFILE),
- Diagnostic packets edition (DIAG),
- Derived Parameters (DP),
- Limits Monitoring (MON),
- Fault Detection, Isolation, Recovery (FDIR)

SCOPE has been built to be able to load definition data coming from different SRDB, and produces operational data in link with TM/TC physical definition using various input formats:

- Native implementation of XML OPEN Thales Alenia Space interface (Open SCC native format)
- Native implementation of MIB S2K interface

Data import in XTCE and EGS-CC CDM XMI format will be available soon.

The product is massively used by Thales Alenia Space for all tests and operational data production. TM/TC data definition can be imported from the SDB NEXT reference database through an export-import process of XML OPEN files. Moreover, thanks to a highly extensible architecture, the product provides also a set of procedures translators allowing its complete connectivity with most of existing Satellite Control Centers and TM/TC execution kernels.

SDB NEXT : the Next Generation of Space System Reference DataBase for TM/TC Definitions

To ease standardization and better compliance of the command/control interface with customers and partners, Thales Alenia Space has developed SDB NEXT, the new reference database to elaborate TM/TC definitions & On Board Software missionization and distribute them to the ground means (CCS or SCC).

The main benefits of SDB NEXT are the following:

- A better efficiency in data administration with import/export automation and user oriented tools
- A better TM/TC definition, at each system level, using inheritance mechanisms from Board to Ground Interfaces
- A better space system representativeness through Building Blocks
- A better Product Line management by a catalogue of shared components

SDB NEXT allows monitoring and control data all along the system development cycle and guarantees the following capabilities :

- Hold reference information in a repository by maintaining data consistency
- Provision data into the database (through man-machine interfaces, business editors, or inbound bridges)
- Deliver information contained in the database into various formats to the different stakeholders/consumers (through man-machine interfaces or outbound bridges)

The product is based on the convergence of the MTG SRDB data model with ESA standard model (EGS-CC model). SDB-Next is currently being used in the frame of NEOSAT program and is considered by Thales Alenia Space as the reference database for new satellite deployments. TM/TC data definition can be imported into SCOPE and CCS-2 through an export-import process of XML OPEN files.

TM/TC data definition export in EGS-CC CDM XMI format will be available soon.

IV. EXECUTION FRAMEWORK

CCS-2 : a Converged Central Check Out System

CCS-2 has been designed and customized for providing a unified way of testing and operating a satellite, thanks to the automation of procedures execution coming from the preparation framework :

- Complete representation of Core Command module states
- TC session configuration
- Sending sequence verification
- Time-tag window management
- Both automatic and manual modes, including replay
- Execution status displayed in highlighted procedures
- Storage of actual times and values times for archiving and post-analysis

It implements last CCSDS / ESA standards :

- CCSDS and PUS (Packet Utilisation Standard) Telemetry and Telecommand standards
- XTCE standard for TM/TC database exchanges
- Flight Control Procedures (FCP) and On-Board Control Procedures (OBCP)

As a first result of this convergence, the product is used by NEOSAT FCV, AIT and OPS teams facilitating operational data validation and securing NEOSAT Satellite Control Centre readiness for first satellite operations. It executes the Test procedures developed with SCOPE and can be natively integrated with Dynamic Satellite Simulators (DSS), Avionics Tests Benches and EGSEs (Electrical Ground Support Equipments).

CCS-3 : an EGS-CC based Central Check Out System

As part of its global convergence roadmap, Thales Alenia Space is currently adapting its ground products to integrate the EGS-CC product line in order to create a unique EGS-CC based Testing Execution solution providing:

- Unified Data Model and associated Operational Data Edition
- Interface and Kernel standardization
- High level of share/exchange between Thales Alenia Space IVVQ actors, satellites industrials and Institutional Agencies

The future converged EGS-CC based CCS architecture can be seen as an evolution of the CCS reference architecture previously presented. It is depicted in Fig 2.

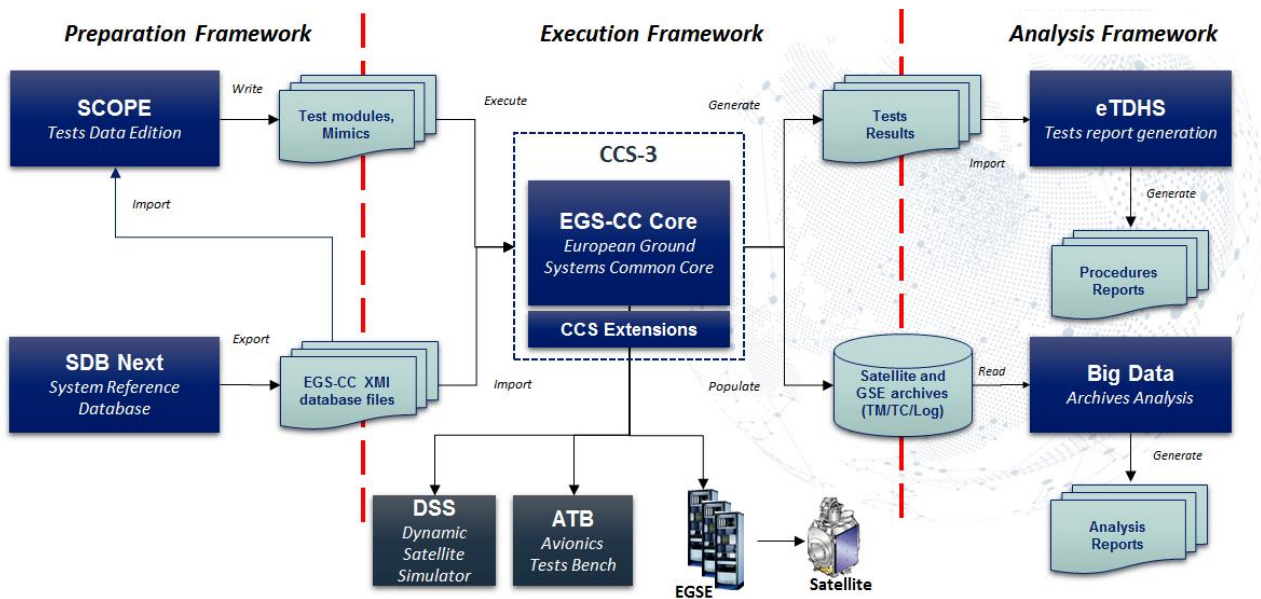


Fig 2. Converged EGS-CC based CCS Architecture

CCS-3 product will be based on a strong reuse of existing Preparation and Analysis building blocks. Its development will be based on the integration of the EGS-CC kernel topped with legacy CCS-2 based extensions such as procedure executor, UI's....

Data exchange will be based on the EGS-CC interfaces, transformation/adapters will be developed for each product.

V. ANALYSIS FRAMEWORK

ETDHS : a Standardized Way to Display and Validate Test Results

To be able to display and validate test results following a standardized approach, Thales Alenia Space has developed eTDHS. This tool allows to access, archive, display, validate and export test data :

- Test data import
- Test results display in real time
- Export test results in XML (raw) or PDF (report)
- Trend analysis
- Validation process of test results

It is massively used by Used by AIT, Engineering and Customers to share test data in real time.

BIG DATA : a Reference Architecture for Tests Data Storage and Analysis

To ease reporting, analysis and monitoring on huge amounts of data, Thales Alenia Space has developed Big Data for SCC/CCS.

Most of the stages of a satellite's lifecycle produce large amounts of data. Each module of a satellite has to undergo an extensive testing phase before it can be integrated onto the main structure. The amount of acquired data during a test case can vary from some Megabytes up to several Gigabytes, for the case of tests of high throughput buses like 1553.

But the test phases are not the only heavy data generating stages. All the coming phases, from the setup at the launch platform up to the In-Orbit Support phase, produce huge amounts of data. An appropriate solution for the monitoring and analysis is crucial for the success of a mission.

Big Data solution is separated into three building blocks which embody the three principal layers of a big data architecture:

- Data Ingestion
- Data Storage
- Data Access

The Big Data solution is based on an open and plugin-ready architecture, it allows to extract data from heterogeneous data sources, like databases, application buses, CSV/XML files, applications and system log messages. It allows to apply transformations on the given data in order to obtain a proper format and finally load the data into a target destination (like databases, files, application buses). Data from the data store can then be used for long term analytics, fault predictive or deep learning algorithms.

The global integration of the Big Data solution in Thales Alenia Space opens the door for data mining and analytics on data coming from completely different sources and provides the traceability of a satellite's components during their whole lifetime.

VI. IMPACT ON IVVQ ACTIVITIES

A Unified Team

The deployment of a converged CCS environment in the frame of NEOSAT avionics has enabled the set-up of a unified IVVQ (Integration, Verification, Validation, and Qualification) team including all the following specialties :

- Avionic and Payload engineering
- OBSW (On-board software) development
- OBSW validation (VLV)
- Functional chain validation (FCV)
- Satellite assembly integration & test (AIT)
- On orbit operations (OPS)
- Benches and tools development & maintenance

Around 50 people are dedicated to this integrated team called “NEOSAT Avionics IVVQ Plateau”.

The objectives of the IVVQ team are to :

- Validate NEOSAT avionics for product line and first application programs :
 - Improve the quality of avionic product
 - Secure AIT milestones for NEOSAT application programs
 - Provide validated procedures for all IVVQ specialties
 - Follow procedures execution and handle lessons learned
 - Minimize AIT TM/TC Cross Check and functional tests duration
 - Cover all the avionic specifications and SDB (Satellite data base)
 - Validate the Spacecraft simulator
- Optimize validation organisation from OBSW to on orbit validation :
 - Share and capitalize the knowledge and know-how
 - Distribute test effort between skills
 - Coordinate means specifications with building blocks definition
 - Reuse of procedures and configuration sequences
 - Define priorities with a global IVVQ overview
 - Manage the configuration of common sequences
 - Manage programs variability for generic procedures

In order to provide a converged CCS, user specification has been shared by all the specialties and specific tools dedicated to each skill have been integrated on the package.

Different trade-offs have been led by the IVVQ team to define the means compliant to each need.

Test Synergies Development

TRS (Test requirements) have been organised in order to optimise procedures sharing / reuse and anticipate the validation. As consequence, several synergies have been pointed up, in particular :

- Common procedures for integration and functional tests between FCV and AIT
- Definition of common configuration sequences for FCV, AIT and OPS called “Common Primitives”
 - OPS primitives defined by OPS team and used by all skills
 - IVVQ primitives defined and shared by FCV and AIT teams
- Validation of operation sequences during FCV test campaign

The result of these synergies can be seen in Fig 3.

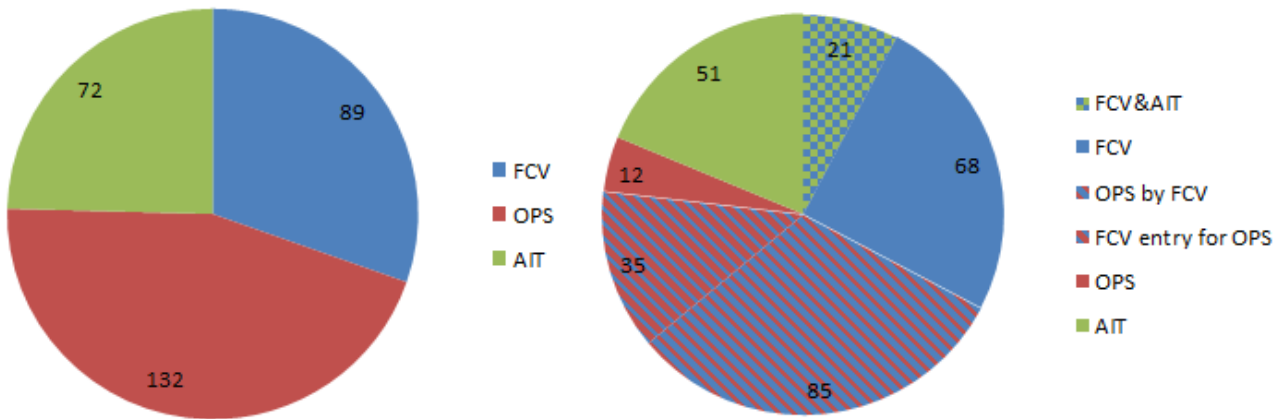


Fig 3. Test Sequences Total Number (left side) & Sharing (right side) - 11/2018

141 Test Sequences over 272 (52%) are now shared. As a consequence development and validation effort has been significantly optimised.

Note : This statistic doesn't take into account the general use of common primitives and validation anticipation, in particular for the benches and tools.

VII. CONCLUSION

The deployment of a unified preparation, execution and analysis framework has allowed the construction of converged teams and methods leading to an optimised validation effort.

Positive effects can be clearly highlighted for the integration of the first NEOSAT platform especially in terms of schedule and quality.

- The avionic module of the first model has been integrated and tested in approximately 3 months instead of 6 months usually.
- A significant reduction of anomalies has been recorded leading to :
 - No Major Non Compliances
 - Very few Non Compliances caused by Equipment, OBSW or SDB (Fig 4.)

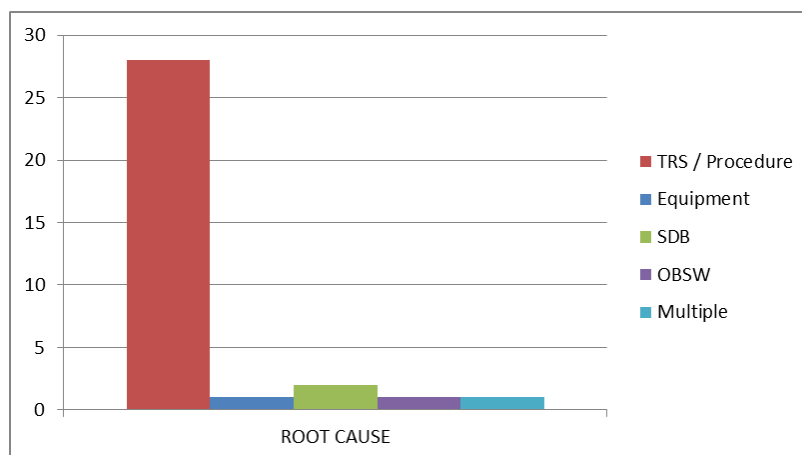


Fig 4. Non Compliances Root Cause - 01/2019