ESA's SST DATA CENTRE INTEGRATION

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ABSTRACT

As part of its Space Situational Awareness programme, ESA has launched an activity to integrate the Space Surveillance and Tracking data centre based on different subsystems developed in previous years. This paper describes the progress achieved so far in the integration and validation of ESA's SST Data Centre, and the main challenges to be faced in the near future together with the designed solutions. The paper also describes the tests foreseen to be performed with real sensors.

1 INTRODUCTION

The integration of ESA's Space Surveillance and Tracking Data Centre aims at producing and demonstrating a full-fledged SST data centre with the following functionalities and subsystems:

- **Catalogue maintenance**, for the maintenance of a man-made space objects catalogue based on measurements from a network of SST sensors.
- **Sensor planning**, for the planning and tasking of observations.
- **Conjunction prediction**, for the detection and characterization of high-risk collisions.
- **Re-entry prediction**, for the detection and characterization of high-risk object re-entry events.
- **Fragmentation detection**, for the detection and characterization of in-orbit fragmentations.
- **Sensor simulation**, as a replacement of actual sensors for internal validation activities.
- **Graphical representation**, for the 2D/3D visualization of objects orbital information and relevant SST events over the web.

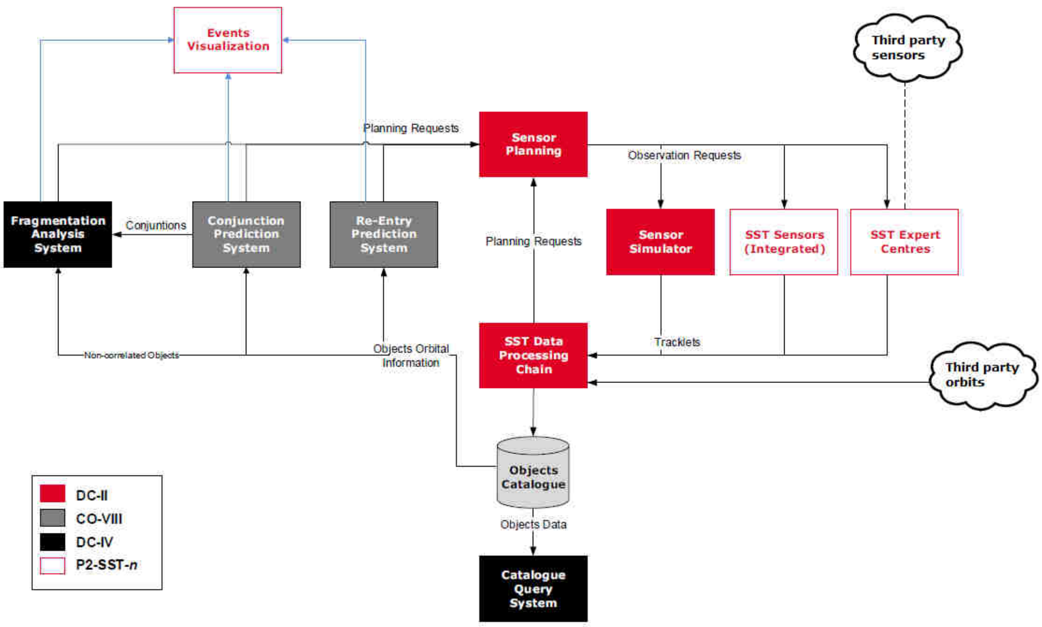

Figure 1: High-level overview of ESA's SST data centre

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Each of the functionalities above is implemented by a different subsystem, although the various subsystems available do not yet work together in an orchestrated manner, as they were developed in different activities. One reason for this is that these applications do not yet share the same objects catalogue. The landscape of subsystems is quite heterogeneous in terms of technological stack and degree of maturity. The activity aims at homogenising as much as possible the various subsystems in terms of technologies and maturity level. Special attention is paid to simplifying the data workflow across the chain, in order to foster an SST data centre which is easily maintainable and operable while also improving the runtime performances when executing the various tasks. Additionally, several gaps and shortcomings have been identified at the beginning of the activity that will be addressed during the integration of the data centre.

Whenever possible the external interfaces of the data centre will be made fully compliant with CCSDS standards, thereby facilitating future interaction with end users of the system, such as spacecraft operators, sensors or other external entities.

The activity also considers the collection of new data through dedicated campaigns and end-to-end validation at system level using replayed data from different sensors available in Europe as ESA internal or external, third-party assets. This includes radars, telescopes and laser ranging stations. The following sensors are considered:

- ESA's radars: monostatic breadboard radar in Santorcaz, Spain and bi-static radar in Palaiseau, France.
- ESA's telescopes: OGS telescope in Tenerife, Spain, robotic TBT telescopes.
- Telescopes and radars from several European institutions such as Starbrook, DeSS, Zimmerwald, TJO and TFRM telescopes, and Eiscat radars.

The interface with the sensors is achieved through a dedicated expert centre in charge of the coordination of a group of sensors.

An integration environment will be prepared, allowing the generation and injection of test data for unit-level, integration and end-to-end tests.

The hardware needed to support this environment will be also defined and procured in the frame of this activity with the aim of carrying out the assembly, integration and verification (AIV environment) of the software resulting from this activity as well as the future follow-on developments that might be tackled soon.

2 GAPS AND SHORTCOMINGS: LIMITATIONS IN EXISTING SUBSYSTEMS PREVENTING THEIR INTEGRATION

The SST Segment is composed by several subsystems that have been developed in different phases within ESA's SSA Programme. Differences in schedule, inputs availability and diverse shortcomings have contributed to the proliferation of solutions that in some cases overlap and do not even work together. Figure 2 depicts the heterogeneous diagram of technologies used per subsystem and projects, having different application servers, using different Java versions and different databases

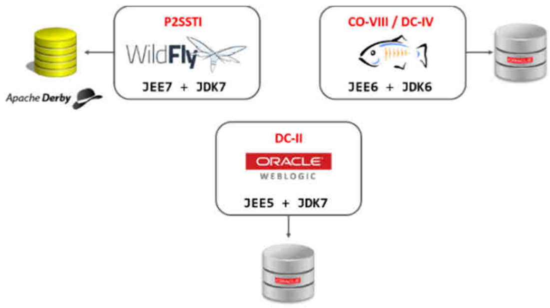

Figure 2: SST Subsystem technologies

Indeed, one of the main objectives of this activity is to reduce the proliferation of different technology stacks as well as integrating the different subsystems solving the functional gaps that may exist.

The gaps and shortcomings to be tackled in the frame of this activity are explained in the following sections according to the subsystem in which they are going to be implemented and a general section to explain the issues at system level.

2.1 Overall System

One of the most important problems from the system point of view is the usage of Oracle proprietary technologies that have been proved to be significantly unstable and with a steep learning curve. Furthermore these technologies require vendor specific developments that strongly limit portability. In order to solve these problems PostgreSQL DB has been selected to replace the Oracle RDBMS and the WildFly Application Server is going to be used instead of the Oracle SOA suite.

A detailed analysis of the subsystems that make up the SST Data Centre has been carried to detect and reduce the duplicated elements and as a result of this, it has been decided to create a single Man Made Space Objects Catalogue (MMSO) that manages, in a centralized way, the detected objects as well as their associated orbital information. This is an important topic covered by this activity since the catalogue is a key component and its information must be managed in a centralized way in order to guarantee that the different subsystems are using the same data.

During the past activities it has been found that the strict adherence to SOA standards has led to unnecessary data circulation through the web service interfaces limiting the runtime performance. This topic has been tackled at interface design level to avoid re-calculation of data already existing and to change the work flows to better usage of HW resources.

It is important to adopt standard interfaces and data types to facilitate the integration process. In this regard, the external interfaces of the subsystems are reviewed to enforce the application of CCSDS standards. This issue is also tackled at system level since the interoperability within ESA's SST Data Centre must be ensured.

2.2 Data Processing Chain (DPC)

As a consequence of the removal of the Oracle components, the Data Processing Chain shall be fully refactored to provide a more robust and efficient architecture to be able to cope with the full system integration and the maintenance of the man-made space objects catalogue based on measurements from the SST sensors network.

This activity would imply several key tasks:

- Perform a harmonisation process on the different databases used across ESA's SST Data Centre, offering a single entry point to all components accessing the data. Procedures for the population of the SST Catalogue with external TLEs and to allow operators to run cleaning routines shall be implemented also.
- Review of the external interfaces provided by the DPC that allow external sensors to ingest observation and third-party data, closing the full loop with the Planning System and ensuring that these interfaces will be made fully compliant with CCSDS standards.
- Adaptation of the different DPC components (database, algorithms, SOAP web services and DPC HMI) in order to consider the eventual SLR observations, i.e. the functionality to receive and process them (data management, correlation, orbit determination process, etc.).
- Improvements in the DPC core algorithms such as generation of mean elements from the estimated osculating vectors and the capability to remove and merge objects from the SST Catalogue and the quality check routines.

2.3 Sensors Planning System (SPS)

The Sensor Planning System is undergoing a major re-factorization to adapt its business logic so it can be deployed as standard web services on the target Wildfly application server. The following core services were previously developed as BPMN composite applications on Oracle Fusion Middleware:

- SensorPlanningRequest: Application in charge of managing the high level workflow for processing incoming planning requests, launching the processes needed to:
  - Compute the observation opportunities for the request.
  - Running the Plan generation process if the request is High priority
  - Storing all received and generated data in the DB
  - Sending out notifications to requesters and PS operator when applicable.
- SensorPlanning: Application in charge of the high level workflow used to:
  - Generate plans, upon user request or scheduled
  - Cancel the generation of plans that are being generated
  - Validate an already generated plan. This operation is triggered by the user and implies delivering the Observation Requests to the sensors.
- MessagesCorrelation: Application in charge of handling conversational data that is needed at the transaction level for asynchronous communications between the Planning System and its externally interfaced systems within ESA's SST data centre.
- PlanningPropertyInspector: ancillary application used to read/write configuration properties used by the Planning System.

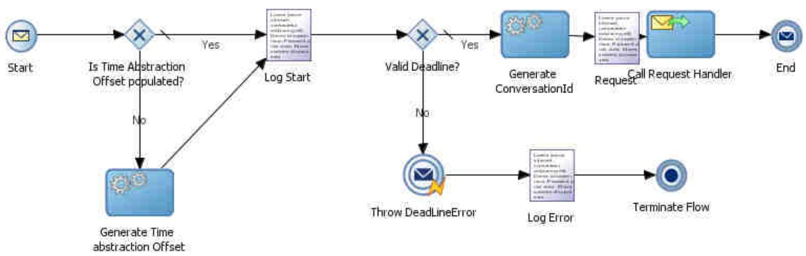

Figure 3: A process of the SensorPlanningRequest composite that needs to be re-factored

In the scope of this activity, these applications are being re-factored into standard web services. Within this major task, other shortcomings are being solved to improve the Planning System performance and usability:

- Restructure the management of overlapping plans state transitions.
- Reduce data transfer with external interfaces
- Remove unnecessary dependencies with generic services

It is also worth to mention that additional functionality is also being included in the scope of this activity, enhancing the Planning System capabilities by adding support to planning of SLR observations.

2.4 SST Services

A functional gap preventing the integration of the SST Services with the Planning System has been identified: the ability of sending requests to obtain a sensor planning in order to update the SST Catalogue with the most recent orbital information about the objects involved in a conjunction or a re-entry detected by the System.

Once the System updates the orbital information of the related objects, the conjunction or re-entry analyses will be executed automatically to re-assess the high risk events. Another gap has been detected strictly related to this matter since the Re-entry Prediction System (RPS) is not able to re-launch an automatic analysis triggered by the update of the orbital information of certain object. This automatic re-analysis functionality is going to be implemented in the frame of this activity.

Another issue to be solved in the frame of this activity is the refurbishment of Conjunction Prediction System (CPS) plots based on Flash technologies that have been demonstrated as a security problem since most of the current web browsers are abandoning the support to this technology. This is going to be achieved in two ways, on the one hand integrating ESA’s SST Visualization Tool to display the CPS Earth globe plots and on the other hand migrating the other 3D plots to WebGL technologies, widely supported by the modern web browsers (e.g. D3 javascript).

Other minor issues to increase the configurability and the integration of the SST Services are also going to be implemented, like for example the creation of a CPS Web Service layer to manage the conjunction analysis execution and to provide a well-defined interface within the SST Data Centre.

2.5 Generic Services

In the previous activities more than one implementation of the same service were developed due to schedule discrepancies. Therefore, it is needed to first of all analyse and compare the duplicated elements to decide the best solution to be used. Apart from that, a complete assessment of the usage and the functionality offered by the Generic Services is also made to determine whether an element can be removed, as it is not going to be used anymore in the new design (like the SMS Service or the Orbit Service), or it has to be redesigned since its interface is not fully adapted to its functionality. This is the case of the File Service and Shell Service that has been refurbished to be a software library instead of a web service.

The Catalogue Service (MMSO) deserves a special mention since it is a central piece of the system. In previous activities, two different implementations of it were developed in different projects and they are going to be merged in a single component in such a way that only one component manages and stores the orbital information within a unique database to avoid duplication of data that may lead to inconsistences.

2.6 SST Visualization Tool (SVT)

In the frame of previous activities ESA’s SST Visualization Tool (SVT) was developed to visualize the orbital information of the objects as well as the SST events (conjunctions, re-entries and fragmentations). The SVT is not yet fully integrated with the SST Services because they do not provide all the operations required by the SVT to retrieve the information about the SST events. This issue is going to be tackled in the frame of this activity.

2.7 SST Sensor Simulator (SSIM)

The current architecture of the Sensor Simulator and the core standalone components (SIMSAT HMI and Kernel) shall remain as they are for providing the capability of sensor simulation, as a replacement of actual sensors for internal validation activities.

Updates in this component will be focused on improving its performances and the integration with the Data Processing Chain and the Planning System components via external interfaces that shall be refactored and adapted to the new system architecture.

3 INTEGRATION ACTIVITIES: AIV STRATEGY AND EXPECTED OUTPUTS

An overall re-design of ESA’s SST Data Centre has been performed to identify the different components and the way in which they are linked to each other.

Figure 4 depicts the different nodes and subsystems that comprise ESA’s SST Data Centre:

- WS: this is the Web Server located in the frontend network and it is in charge of securing the access to the SST Services Web Portal through HTTPS. It also secures the access to ESA's SST Visualization Tool.

- AS: the Application Server where the SST Services Web Portal is deployed.
- SVT: the server where the SVT is deployed.
- DPC: it contains the web services exposed by the Data Processing Chain (DPC) as well as the DPC computational components.
- PS: it contains the Planning System (PS) Services and the Planning executable.

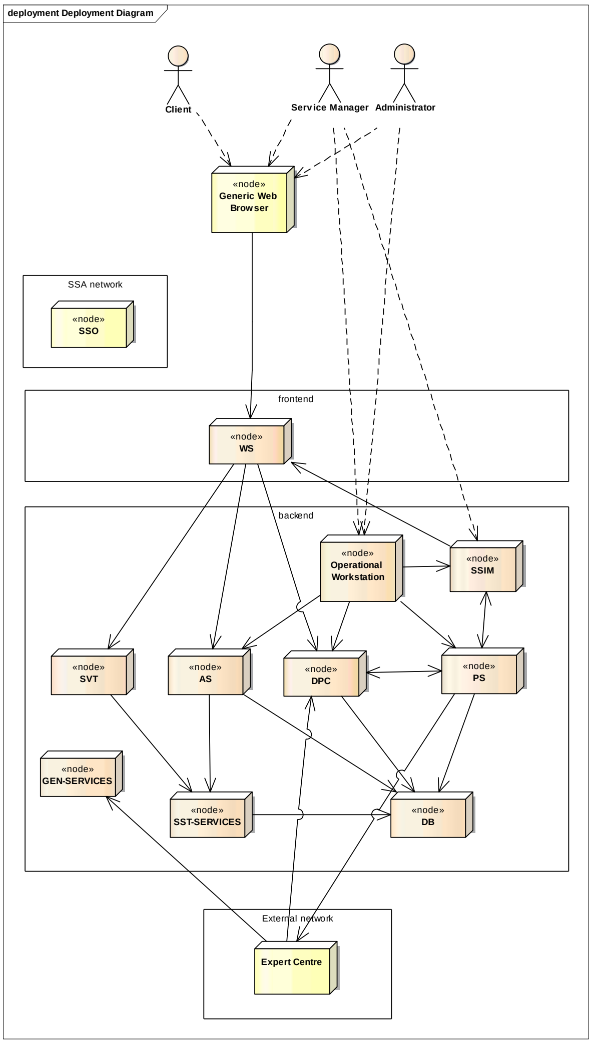

Figure 4 SST Data Centre deployment diagram

- GEN-SERVICES: this is the node that gathers all the Generic Services, including the Sensor Service and the common Catalogue Service (MMSO)
- SST-SERVICES: it gathers the CPS, RPS, CQS and FAS in the same node.
- SSIM: it contains the Sensor Simulator (SSIM).
- DB: only one node will contain the different databases used by SST Services, SPS and DPC databases.
- Operational Workstation: it depicts the workstation(s) that the operators use to interact with the System.
- Generic Web Browser: it depicts a generic computer with a web browser for accessing the System.
- SSO: it depicts the Single Sign-On server that is shared along the SSA segments.
- Expert Centre: it is the centre that provides measurements from external sensors.

The interactions between ESA's SST Data Centre components is also depicted in the figure, with the exception of the GEN-SERVICES node that have been omitted for the sake of clarity since all the subsystems access this node to make use of the Generic Services

The Expert Centre, that represents an external centre to provide the measurements coming from real sensors, will be integrated through the following workflow: ESA's SST Data Centre (PS node) sends requests to the Expert Centre to plan the sensors, and they, in turn, will send the obtained measurements back to the SST Data Centre (DPC node). The Expert Centre will provide the information about the sensor network to the Sensor Service deployed in the GEN-SERVICES node.

The main outcome of this activity will be an integrated system composed by a set of harmonized components with clear external and internal interfaces. This system must be subject to end-to-end verification. The system engineering and integration activities can be summarized in these nearly consecutive tasks:

- Definition of the specification, interfaces and design of ESA's SST Data Centre and the definition of the common technologies for components harmonisation.
- Preparation of the test and integration plan to be followed during the integration activities
- Actual integration activities, following the integration plan defined before.
- Verification activities, following the test plan defined before

4 AIV ENVIRONMENT

The elements of the AIV environment hardware are:

- sstwks: the workstation provided to the operators for system management.
- sstdev: the compilation machine where all the compilers and build tools are installed in order to compile the complete system.
- sstws: it hosts the WS to expose to the outside the SST Services Web Portal and the Software

Visualization Tool securing its access through HTTPS.

- sstcs: this physical server contains the VMWare ESXi vSphere Hypervisor where the following virtual machines run:
    - sstdpc: it hosts the DPC
    - sstssim: it hosts the SSIM
    - sstps: it hosts the PS
    - sstas: it hosts the SST Services Web Portal (WBFE).
    - sstsvt: it hosts SVT
    - sstservices: it hosts the SST Services (CPS, RPS, FAS and CQS).
    - sstgenserv: it hosts the Generic Services
    - sstdb: it hosts the SST Database.
- The switch is intended to connect the elements within the AIV environment and to other external networks. There will be two different configurations depending on the scenario: the configuration needed to integrate and test the System during the FAT campaign at Consortium premises and the one required for OSAT at ESA premises.

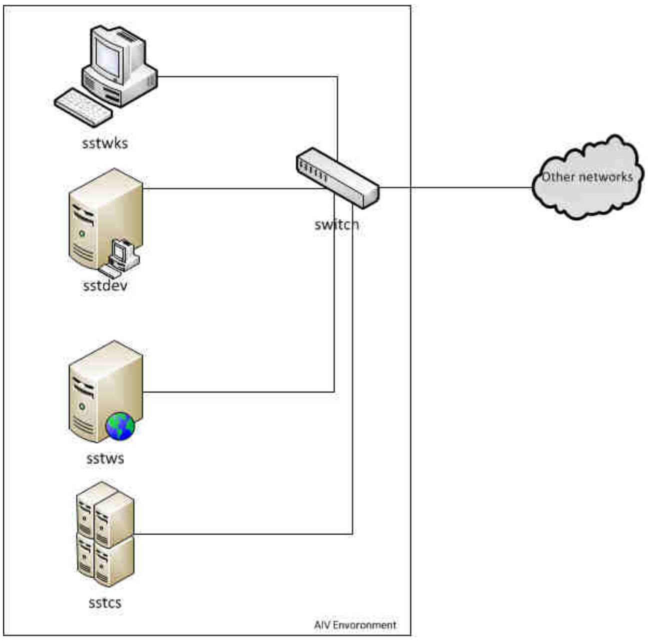

Figure 5: AIV environment on ESA's premises

5 TEST AND VALIDATION CAMPAIGN

The System will not only be tested against simulated data (coming from SSIM) but also against real data.

Test cases will include nominal and non-nominal scenarios. Nominal are those respecting the reference scenario or involving data flows considered operationally normal. Non-nominal scenarios shall be defined so that ESA's SST Data Centre is exercised with unexpected data flows ensuring the system conforms to expected test outcomes.

The outcome of the activity will be the integrated and verified SST Data Centre and a set of intensive test cases (and their respective results) used during the integration and verification process. These test cases will be conducted as part of a Factory Acceptance Testing (FAT) in the AIV environment at GMV premises. As soon as the FAT is considered successful, the system will be qualified and ready for deployment at ESOC.

The definition and planning of an observation campaign will be performed with the supporting set of ESA's optical telescopes, ESA SST expert centres and two ESA's demonstrator radars.

These campaign plans will be previously agreed with ESA, and Service Level Agreements will be defined with operators of the ESA's SST expert centres, site owners of the two ESA's robotic telescopes and site owners of the two ESA's demonstrator radars.

6 CONCLUSIONS

This paper has presented the overall approach for the integration of the different subsystems composing ESA's SST data centre from the following points of view:

- Analysis of gaps and shortcomings both at system and subsystem level.
- Integration activities at system level.
- Assembly, integration and validation environment.
- End-to-end test and validation campaigns with real sensors of various types.

The main challenges of this integration process have been identified and solutions for them proposed.