CONCEPTUAL DESIGN FOR EXPERT COORDINATION CENTRES SUPPORTING OPTICAL AND SLR OBSERVATIONS IN A SST SYSTEM

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ABSTRACT

In our work we will discuss the conceptual design of an Expert Coordination Centre (ExpCen) supporting observations performed by optical and satellite laser ranging (SLR) sensors. This ExpCen should suit as an interface between a Space Surveillance and Tracking (SST) system, as example for technology developments under ESA's SSA programme, and any external sensors. Presented will be identified ExpCen's functionalities, such as coordination of sensors, validation and qualification of data and research and development. Presented will be high-level architecture of the centre along with the defined interfaces. ExpCen will perform several different tasks, each performed by different subsystem. The subsystems architecture, interfaces, data flows and components will be shown. The current design of the ExpCen allows to perform in parallel functionalities for optical passive and SLR domain.

1 Introduction

1.1 Space Situational Awareness (SSA) programme

The main goal of European Space Agency's (ESA) Space Situational Awareness (SSA) programme is to support the independent European utilization and access to space. The SST focuses on research and technology development to maintaining the awareness of the population of man-made objects. Its major tasks are object cataloguing, conjunction risk analysis, re-entry predictions analysis, fragmentation analysis, special mission support, sub-catalogue characterization and mission characterization.

The SSA program consists of three main segments:

- Space Surveillance and Tracking (SST) of man-made objects,
- Space Weather (SWE) monitoring and forecast, and
- Near-Earth Objects (NEO) search and follow-up.

According to [1] Space Surveillance and Tracking (SST) it is required to maintain awareness of the population of man-made space objects. The SST segment is to develop technologies for object cataloguing, conjunction risk analysis, re-entry prediction analysis, fragmentation analysis, special mission support, sub-catalogue characterization and mission characterization.

The SSA Space Weather Coordination Centre (SSCC) is located at the Space Pole in Belgium. It provides a Space Weather Helpdesk and coordinates the overall provision of SSA Space Weather services. The SSCC monitors the overall service network, and provides scientific expert support with input from the Expert Service Centres which are themselves federated groups of European entities providing access to a wide range of key space weather data, products and expertise.

ESA's NEO Coordination Centre (NEOCC) serves as the central access point to a network of European NEO data sources and information providers. As for the SSCC, the NEOCC provides and integrates expert support in the field by federating new and existing European assets, systems and sensors into a future NEO system. Further, it is the focus point for scientific studies on NEO warning services, provides near-real-

Proc. 7th European Conference on Space Debris, Darmstadt, Germany, 18–21 April 2017, published by the ESA Space Debris Office
Ed. T. Flohrer & F. Schmitz, (http://spacedebris2017.sdo.esoc.esa.int, June 2017)

time data and coordinates with European national and international customers.

1.2 Expert Coordination Centres

In order to discover new space debris objects and to determine and maintain their orbits, optical passive and radar observations are used. The improved orbits, along with other applications, are used for collision avoidance purposes. Currently, also a possibility of using Satellite Laser Ranging (SLR) measurements to improve orbits of defunct satellites is explored.

Efficiently task several external optical sensors and SLR stations is a challenging goal. The observations (dedicated to survey, tracking, etc.) have to be optimized and the sensors should be employed according to their capabilities. A promising solution is a single entity which combines expertise in the field of observation techniques (optical passive and SLR) and maintains an overview on the sensors availabilities and capabilities. Conceptually, optical and laser expert centres are similar, while for the laser community through the ILRS a possible external expert group already exists. Hence, for a first phase a hybridised architecture with an interface with the ILRS Debris Study Group is to be selected. A potential future phase may continue with the establishment of laser and optical expert centres in either a continued hybridised, or in a standalone way [1], [2].

1.3 Current activity consortium

ESA is currently running an activity to design and deploy an Expert Coordination Centre (ExpCen) first at ESOC (European Space Operations Centre). This ExpCen should be a hybrid combining optical passive and SLR measurements. Activity is performed by a consortium which consists of four different international partners. The prime of the activity is Astronomical Institute University of Bern (AIUB) (Switzerland) which is also responsible for the optical passive measurements. AIUB currently operates two optical and one SLR system at its own Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald (hereafter Zimmerwald observatory) [3]. The Space Research Institute of the Austrian Academy of Sciences (IWF) (Austria) is second largest partner in the consortium responsible for the SLR measurements. IWF operates its own Graz SLR station (Austria) and it is involved in Space Debris Study Group (SDSG) by International Laser Ranging System (ILRS) which is responsible for support and development of technologies for the space debris observations by SLR [4]. Third partner responsible for the software development and deployment with a wide experience with SSA NEO segment is Space Dynamics Services s.r.l. (SpaceDyS) placed in Italy [5]. Last partner is Czech Technical University in Prague (CTU) situated in Czech Republic. It is responsible for hardware improvement in SLR measurements domain [6].

2 IDENTIFIED TASKS OF EXPERT COORDINATION CENTRE

2.1 Terms and definitions

In current stage the Hybrid Expert Coordination Centre (ExpCen) has been selected. Within the ExpCen recognized are three different types of sensors according to their level of qualification:

- Candidate sensor – sensor which had not proven the capability to observe the space debris observations
- Validated sensor – Candidate sensor which passed ExpCen's validation procedure
- Qualified sensor – Validated sensor which passed ExpCen's qualification procedure

The ExpCen's validation procedure is a compilation of methods which cover observation planning and processing in order to test investigated sensor interfaces and asses minimum observation capabilities. The ExpCen's qualification procedure is an extended version of validation procedure where also the data quality is investigated. To pass this procedure fulfilled must be strict criteria concerning the sensor performance (data latency, response time) and its data quality (e.g. astrometric and range accuracy).

Additionally, we recognize following sensors according to their relation to the ExpCen:

- Internal sensors - Qualified sensors, those fully controlled and operated by the SSA system backend
- External sensors - Qualified sensors which are not Internal sensors. They are ruled by SSA system backend through agreements with varying levels of service depending on each specific sensor
- ILRS SLR sensors - Qualified SLR sensors, those which are included within the ILRS network
- Other sensors - Optical passive or SLR sensors which are not Internal, not External and not belonging to ILRS SLR network. Here belong all sensors which are Candidate and Validated. Also Qualified sensors can belong to this group if there is no agreement between them and SSA backend

2.2 Tasks and functions

It has been found during the requirements analysis [1] that the optical and laser expert centres shall be able to request and manage acquiring observations, both tracking and surveillance, in order to provide relevant and accurate input to the data processing chain taking into account security constraints. Additionally, support operations such as research and development should be also provided by the centre. Finally, we identified following tasks for the ExpCen:

- Perform coordination of External and Other sensors
- Perform evaluation and calibration of data sources and provide evaluated data to SSA-SST
- Validate and qualify the Other sensors Provide a feedback to SSA-SST, External sensors and Other sensors
- Monitor SLA and other agreements compliances
- Perform research and development
- Provide expertise to SSA-SST, External sensors and SDSG ILRS
- Send the general status of External sensors to SSA-SST

3 ARCHITERCTURE

3.1 High-level architecture

Fig. 1 presents the high level interactions between the expert centre, the external sensors and the internal sensors (within the SST segment). The ExpCen acts as the interface between the SST segment (on the left) and the External and Other sensors (bottom), the ILRS SDSG (top) and external experts (right). It receives tracking and status requests (from the SDSG, right) and data for qualification from the SST segment. These requests are processed and, if needed, sent to the appropriate external entity (tasking request to sensors, etc.). The data returned by sensors is processed and sent to the SST segment, as are other products, such as data qualification results.

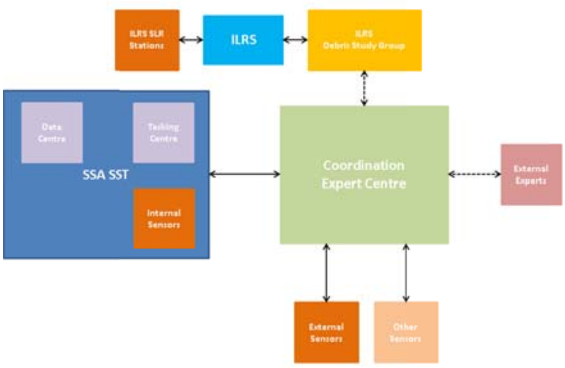

Figure 1. The current concept for the combined optical and laser SST expert centre [1]

3.2 Interfaces

We identified following interfaces with ExpCen:

- SSA-SST
- Other/External sensors
- SDSG/ILRS
- External experts

The interface with SSA-SST is dedicated to receive observation tasks from the system, request and data related to the calibration of Internal sensors calibration, to submit calibrated data to the system and to submit availability and other type of reports to the SSA-SST. Interface with Other/External sensor is used to send observation request and with it related data to the sensors, to receive the observation from sensors and to provide the sensors necessary expertise and support. SDSG/ILRS interface is established to retrieve or provide the expertise from and to this study group. External experts can be in case the expertise is not present within the ExpCen.

3.3 Functional architecture

The functional architecture can be seen in Fig. 2. It basically follows the tasks defined for ExpCen. First functions 1.0 defines that ExpCen shall perform coordination of External and Other sensors. That means it should be able to receive an observation request, tracking or survey request, from SSA-SST and then task the available and capable sensors according to this request. Function 2.0 is responsible for the calibration and evaluation of data. During this function identified are miss-correlations, extracted are biases present in the measurements and measurements are calibrated. Function 3.0 consists of series of procedures defining when sensor can be considered to be Validated or Qualified. These procedures are description of the observation campaigns to be performed by Other sensor and set of validation and qualification criteria defined via so-called Key Performance Indicators (KPI). Functions 4.0, 5.0 and 7.0 are responsible for the monitoring of sensors performance via KPIs and for provision of feedback to the Other/External sensors and SSA-SST in order to improve their performance and measurement data quality. Function 6.0 is dedicated to the research and development in the optical and SLR measurements acquisition, their processing and in hardware improvement. ExpCen is responsible also for the External sensors status monitoring. To this task is dedicated function 8.0.

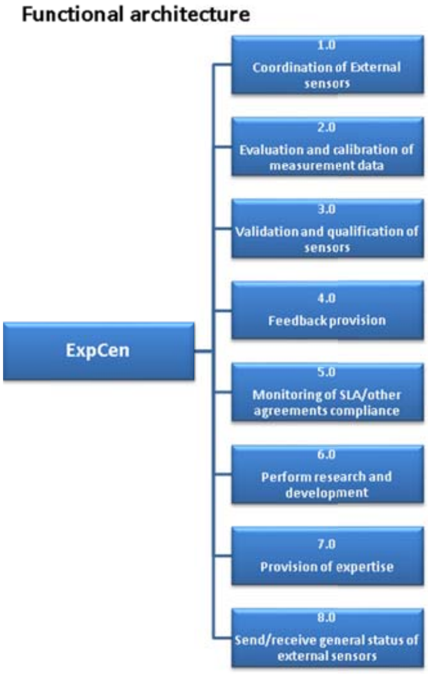

Figure 2. Functional architecture of ExpCen

3.4 Subsystem architecture

ExpCen consists from several subsystems in order to perform all the functions defined in section 3.2. These subsystems are plotted in Fig. 3. The I/O subsystem is responsible for all the interfaces with all other external entities, such as SSA-SST, Other/External sensors or SDSG/ILRS. Planning and coordination subsystem consists of series of tools able to predict ephemerides for specific target and sensor. Data format conversion subsystem is responsible to convert any type of data coming to or from ExpCen to the CCSDS (Consultative Committee for Space Data Systems) standards [7]. Data calibration and evaluation subsystem is responsible to perform function no. 3.0 for optical passive measurements with focus on identifying the epoch bias present in the data and astrometric accuracy of the data. For SLR measurements it is identification of the range bias. The subsystems 5.0 - Sensor validation and qualification subsystem, 6.0 – SLA monitoring subsystem, 7.0 – R&D and expertise provision subsystem and 8.0 – Sensor status subsystem are directly responsible for performing functions 5.0, 6.0, 7.0 and 8.0 plotted in Fig. 2.

4 Observation campaign

We plan to demonstrate the ExpCen's functionalities via real observation campaign where several sensors with different quality will participate. There should be generated the end-to-end test campaign plan considering multiple sensors, both passive and laser, multiple days and observation scenarios (survey, tracking, support, contingencies, small debris), and multiple orbital regimes. Currently we recognize two optical passive sensors to participate on this campaign, the AIUB's ZIMLAT system [3] and ESA's prototype telescope the test-bed telescope (TBT) Cebreros situated in Cebreros, Spain [8]. From SLR stations participate will Graz SLR station (ILRS code GRZL), Zimmerwald SLR station (code ZIML) and Borowiec SLR station (code BORL), Poland. The Borowiec SLR station is currently supported for the hardware and software improvement by the IWF for the SLR tracking to the non-cooperative targets (targets without the retro-reflectors). This is a part of the ExpCen's functionality provision of expertise. The observation campaign will take place in late spring 2017 and will be coordinated by AIUB.

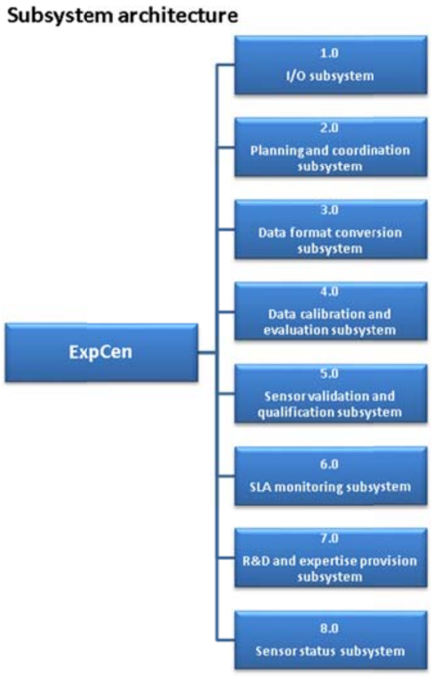

Figure 3. Subsystem architecture of ExpCen

5 SUMMARY

In our work we presented hybrid Expert Coordination Centre for optical passive and satellite laser ranging (SLR) measurements to be first deployed at ESOC, Darmstadt, Germany. This centre is currently under development in the SSA Programme of the European Space Agency (ESA) through an activity led by the Astronomical Institute University of Bern (AIUB) (Switzerland). The main objective for the expert centre is the coordination of all the External and Other sensors with a SST system. In particular, it is of special interest the definition of a generic (preferably single) interface between the SST planning and processing capabilities and these sensors.

We presented the centre's functional and system architectures which cover expertise in optical passive, as well in the satellite laser ranging (SLR) measurements. The current hybrid version of the centre is designed the way that the centre can be split into two independent expert centres, one dedicated to the optical passive measurements and the second to the SLR measurements. The ExpCen's functionality will be demonstrated via dedicated observation campaign which will take place later spring 2017.

6 REFERENCES

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