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EUROPEAN EXPERT CENTRE PROVIDING SERVICES AND SUPPORT FOR SPACE SURVEILLANCE AND TRAFFIC MANAGEMENT

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Thomas Schildknecht[1], Christophe Paccolat[2], Peter Pessev[3], Palash Patole[4], Tim Flohrer[5], Beatriz Jilete[6], and Emiliano Cordelli[7]
[1][2][3][4] *Astronomical Institute, University of Bern, Sidlerstr. 5, CH-3012 Bern, thomas.schildknecht@aiub.unibe.chl*
[5][6][7] *ESA ESOC, Darmstadt, Germany*

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ABSTRACT

Developed within ESA's Space Safety Programme, the Expert Centre provides subject matter expertise and operational services to coordinate SST data acquisition by a multitude of diverse sensors. It supports a variety of applications including tasked tracking, survey, and characterization observations by means of passive optical, satellite laser ranging (SLR), and radar techniques. A core service consists in the validation and qualification of sensors for the mentioned applications. The service includes technical support to sensor operators by experts to achieve compliance with data calibration and quality, as well as data formatting requirements. All formats and interfaces used by the Expert Centre are based on international standards and the data quality requirements are derived from the user community.

Coordinating observation campaigns for customers, in particular ESA, is another important service offered by the Centre. Such campaigns may include very heterogeneous types of sensors operated by commercial companies, academia, government, and inter-governmental institutions. The Expert Centre takes care of the sensor planning, the data quality control, calibration and reformatting of the data if necessary, as well as the monitoring of key performance indices defined in service level agreements.

In terms of object characterization, the Expert Centre focuses in particular on establishing and maintaining a catalogue of attitude information by fusing observations from different techniques, such as light curves, SLR and radar measurements.

The paper will illustrate the different services and operational capabilities with examples of sensor qualifications and extensive survey, tracking and characterization observation campaigns which involved more than a dozen optical and SLR and radar sensors.

The Expert Centre is hosted and operated by the Astronomical Institute of the University of Bern, Switzerland (AIUB) and may serve as a reference for future national expert centres and site-specific deployments within ESA.

INTRODUCTION

Some years ago ESA was starting an activity to set up and deploy a first version of an Expert Coordination Centre in the context of its Space Situational Awareness Programme. The center should serve as the focal point for the interfacing with a multitude of optical sensors and assets. These sensors should include optical passive telescopes and laser ranging sensors capable to measure ranges of objects which are not equipped with laser retroreflectors, also called non-cooperative targets. One of its prime task is to organize coordinated observation campaigns with a set of heterogeneous sensors and to provide calibrated and validated measurement data in well-defined standardized formats to ESA. Consequently, a strong technological focus is put on the complex networking and integration of a heterogeneous sensor network. The Expert Centre should thus act as single interface for user request and product delivery for the customer. Main functions were defined to address both, support and operational, tasks:

- Operations
    - Coordination of sensors for tracking or surveillance (through ICDs) with the customer (service function, data processing function and data acquisition function),
    - Establishing and monitoring of Service Level Agreements with with sensors, i.e. harmonized and comprehensive management and monitoring of availability, timeliness, and performance,
    - Routine and ad-hoc calibration of sensors

- Support
    - Evaluation and qualification of sensors,
    - Definition of data processing schemes, techniques, and interfaces
    - Evaluation of new techniques (hardware and software),
    - Research and development and collection and provision of expert support, e.g. support in interfacing with external technical entities at national and international level.

Over the years the Expert Centre was further developed and new functionalities and services were established. The expert Centre is currently hosted and operated by the Astronomical Institute of the University of Bern (AIUB), Switzerland.

CAPABILITIES AND SERVICES

The Expert Centre, addressing optical passive, laser ranging and radar observations, deployed and operated at AIUB, is currently further equipped as a reference system for optical and radar data. A subsystem breakdown is shown in Figure 1:

- I/O subsystem that enclose the heterogeneous interfaces with a customer backend segment, External Sensors, ILRS SDSG, other sensors and external experts
- Planning and coordination subsystem that allows the Expert Centre to coordinate ad-hoc validation, qualification and calibration campaigns. It will collect also the planning data coming from the customer backend segment, perform the observation planning and coordinate external sensors and ILRS SLR stations.
- Data format conversion subsystem, that allows to have a uniform format compliant with CCSDS formats

- Data calibration and evaluation subsystem, supports the calibration and evaluation of sensor data, for SLR system cooperates with ILRS SDSG for calibration
- Sensor validation and qualification subsystem: performs optical passive, and non-ILRS SLR validation and qualification
- SLA monitoring subsystem, monitors the input/output to check for SLA compliance, sends the noncompliance notifications to affected sensors
- R&D and expertise provision subsystem, performs the R&D and evaluation of data acquisition and processing techniques activities
- Sensor status subsystem, receives and sends the status of sensors

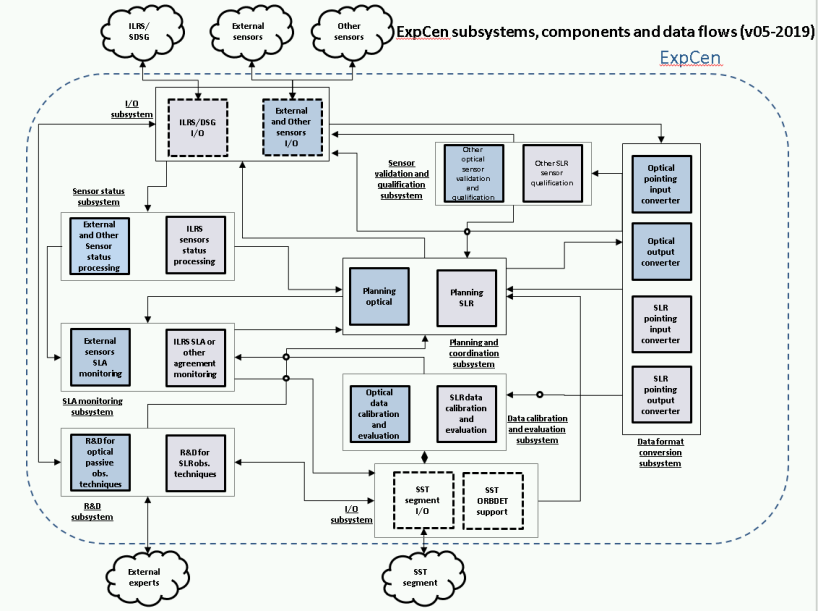

Figure 1: Expert Coordination Centre subsystems, components and data flows

Validation and qualification of sensors

Optical passive and active laser sensors are qualified in two steps. In a first step they are tasked to provide tracking observations of a few calibration objects in a well-defined format (e.g., CCDSDS TDM). The purpose of this step is to establish the communication interfaces, to ensure that the sensor is able to provide tracking data of the tasked objects, and to validate that the formats are correctly implemented.

The second part of the validation and qualification procedure, the qualification, shall certify that a sensor can reliably provide data in a certain orbital regime respecting defined quality criteria. A qualification campaign consists of 3 full observation nights. Within each night the sensor is tasked to provide observations of 12 calibration objects and 4 program objects in quarter-night batches. Calibration objects are objects with fiducial orbits, e.g. GNSS satellites, were high accuracy orbits are available at AIUB. Successful qualification requires a set of key performance indices (KPI) to be above an agreed thresholds (see Table 1). Figure 2 shows a graphical representation of the KPI from a qualification campaign of a passive optical sensor.

Table 1: Key performance indices for sensor qualification.

Efficiency	number of objects successfully tracked and processed with respect to tasked objects
Latency	time span between observation and data delivery

Epoch offset	epoch offset w.r.t. UTC as derived from processing the calibration objects (GNSS s/c)
Epoch offset stability	stability of the epoch offset within one night and from night to night
Astrometric accuracy (after time bias correction)	astrometric accuracy as derived from processing the calibration objects (GNSS s/c)
Miss-correlation	observations which do not belong to the tasked object

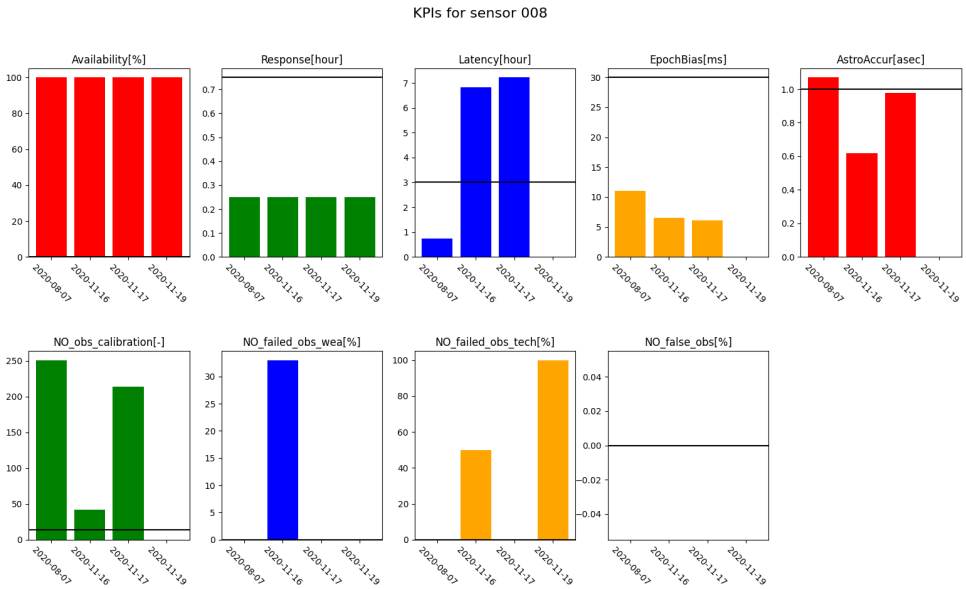

Figure 2: Example of key performance indices from a sensor qualification campaign.

Often data provided by sensors at the beginning of a qualification campaign do not fully comply with format and coordinate system requirements, or show an epoch bias exceeding the qualification requirement. Subject matter experts from the Expert Centre will the support the sensor operators to resolve such issues and improve the data quality. Figure 3 shows an example where the epoch bias and the astrometric accuracy of a sensor could be significantly improved over time.
Similar KPIs are used for the qualification a laser ranging sensors. Once a sensor successfully passed the Expert Centre qualification procedure it becomes a certified sensor and is eligible to provide data in observation campaign coordinated by the Expert Centre.

Data Acquisition campaigns

Coordinating observation campaigns for customers, in particular ESA, is another important service offered by the Expert Centre. Such campaigns may include very heterogeneous types of passive optical, laser ranging and radar sensors operated by commercial companies, academia, government, and inter-governmental institutions. Bases on the high-level customer requirements, the Expert Centre takes care of the sensor planning, the data quality control, calibration and reformatting of the data if necessary, as well as the monitoring of key performance indices. All communication and data exchange with the customer are done via standardized interfaces. For observation campaigns, service level agreements are established with all participating sensors.

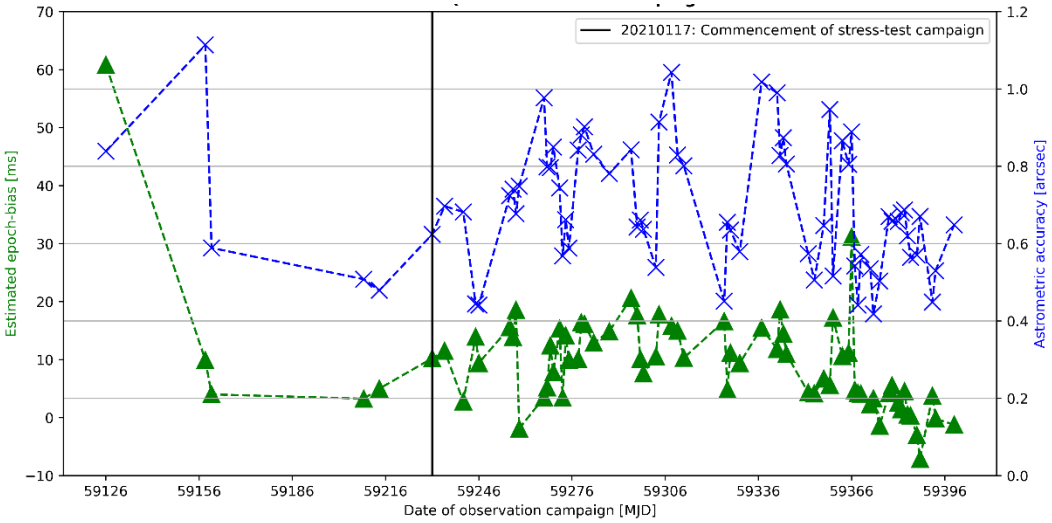

Figure 3: Example of a qualification where the epoch bias and the astrometric accuracy of a sensor could be significantly improved over time.

The expert center organized several extensive survey, tracking and characterization observation campaigns which involved more than a dozen optical, SLR and radar sensors (Figure 4)

Figure 4: Example sensors participating in one of the observation campaigns.

Attitude information service

Expert Centre is currently extending its capabilities to provide support to attitude estimation. In this context an attitude information catalogue will be built-up and maintained. Attitude information is derived primarily from optical light curves, but laser ranging and radar data may be fused with optical data for the modelling of attitude states. This service will include the planning, scheduling, acquisition, and processing

of the basic observation data needed for attitude estimation. Algorithms are developed to automatically categorize attitude motion of space objects into simple categories like “stabilized”, “slow rotator”, “fast rotator”, etc. including the estimation of the rotation rates. Figure 5 provides an example of the basic observation data for attitude information.

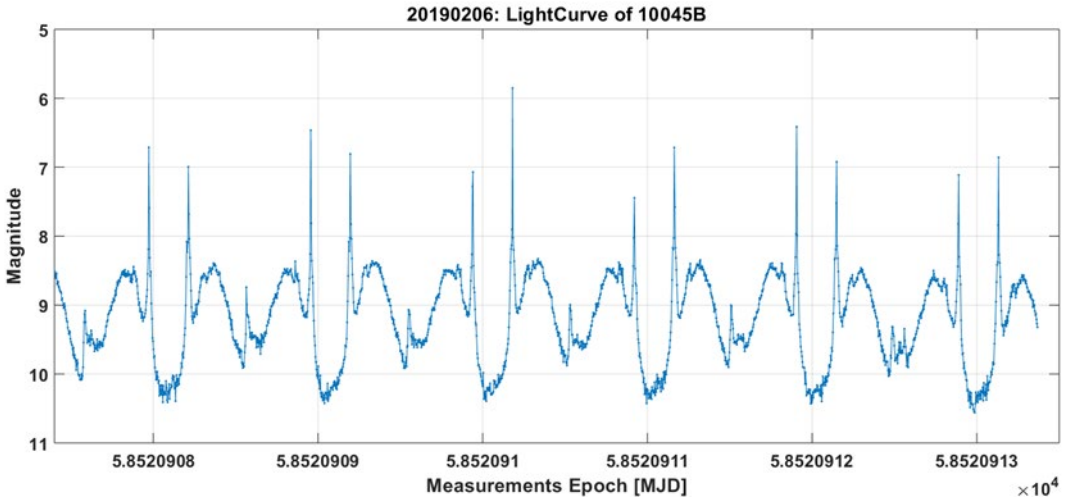

Figure 5: Example of a light curve of a tumbling upper stage.

Support to standardization

Data format and standards became absolutely central for the complex networking and integration of a heterogeneous sensor network. Similarly, standards are essential for the communication with the customer to ensure that this interface is agnostic to various customer backends. The Expert Centre is further addressing the development of data exchange standards and networking concepts in the international context. It is in particular supporting the review of standards in the CCSDS, ECSS, CEN/CENELEC, or other bodies.

Services under development

The Expert Centre is currently developing and implementing the capacity to ingest conjunction data messages (CDM) to trigger ad-hoc observation requests for high risk conjunction events in LEO and GEO orbits. The service will include the possibility to improve the orbit prior to the provision of the orbital information back to the customer. Similarly, the capacity to process reentry data messages (RDM) to trigger corresponding observation requests for imminent re-entry events is developed and implemented.

SUMMARY

The Expert Centre, established and hosted at the Astronomical Institute of the University of Bern (AIUB), Switzerland and under test operation as part of ESA's Space Safety Programme, provides a multitude of services in support of space surveillance and traffic management. The coordinated data acquisition by a multitude of diverse sensors is at the core of its activities. It supports a variety of applications including tasked tracking, survey, and characterization observations by means of passive optical, laser ranging, and radar techniques.

The centre provides extensive validation and qualification services for the mentioned applications and sensor types in order to certify them for future observation campaigns. Subject matter experts from the Expert Centre support the sensor operators in this process.
Another core service of the Expert Centre consists in coordinating observation campaigns for customers, in particular ESA. Several extensive survey, tracking and characterization observation campaigns, which involved more than a dozen optical, SLR and radar sensors, were already performed.
A test service to provide support to attitude estimation, including the build-up and maintenance of an attitude data base, will be available soon. The capacity to ingest conjunction data messages and reentry data messages to trigger corresponding observation requests is currently developed.
These additional services will be critical components in support of safe and sustainable operations in space.