Laser ranging initiatives at ESA in support of operational needs and space surveillance and tracking

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Content

Research and development initiatives for SLR to (uncooperative) debris targets

1) Revisit of the motivation and objectives of the SLR-related activities at ESA
    - SSA/SST
    - Space debris office
2) Outline of the current status of these activities
    - SST expert centres
    - Operational Support
3) Outlook to future key SLR areas: research and development, operational support, and SSA/SST work

SSA Programme introduction

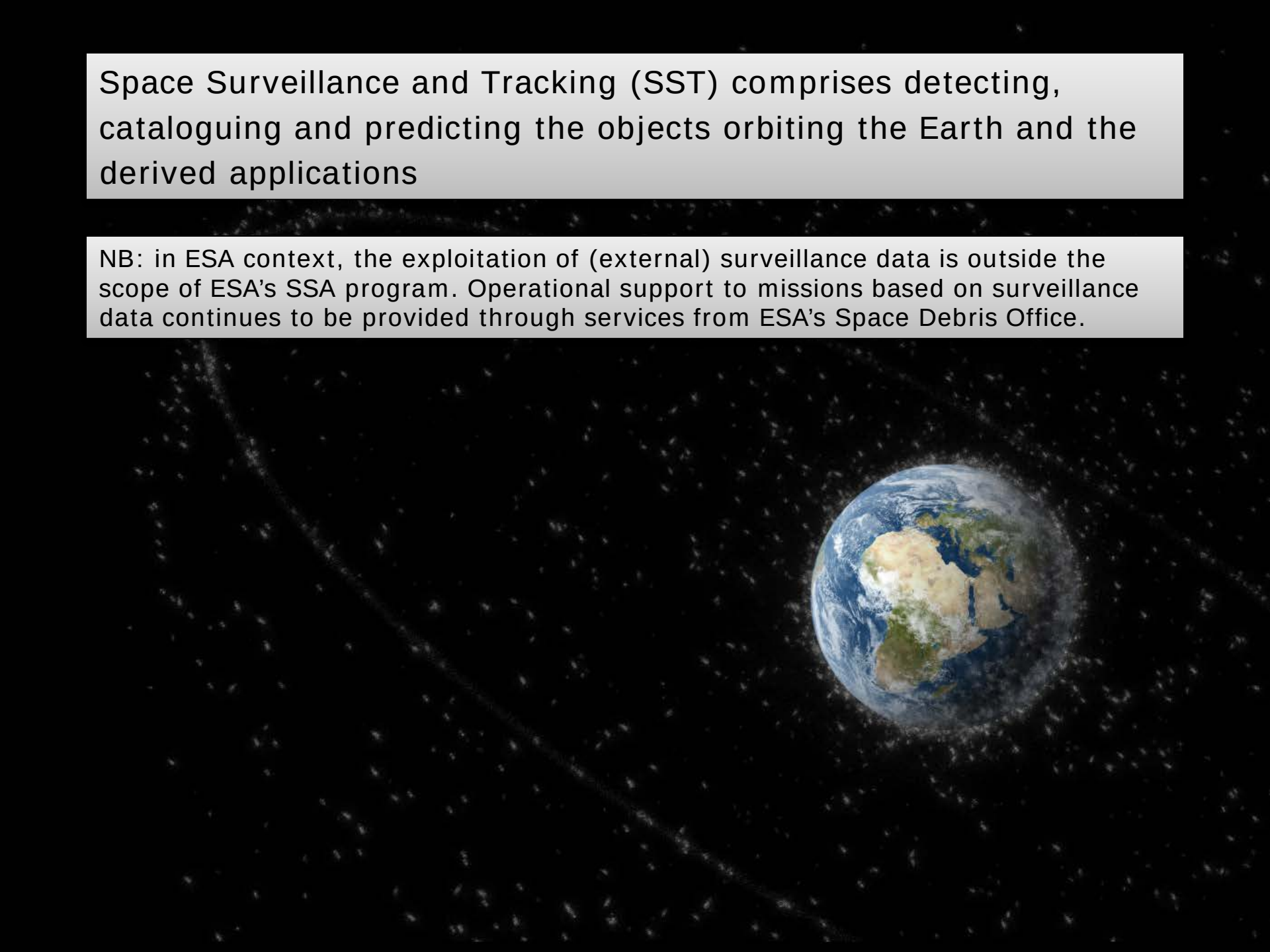
- **Objective:**
  - Protection of space and ground assets against adverse effects from space
  - Three main areas or segments:
    - Space Weather (SWE)
    - Near Earth Objects (NEO)
    - Technology R&D for Space Surveillance and Tracking (SST)

- **SSA Programme initiated in April 2008** (ESA Council, SSA Enabling Resolution as an optional programme

- **SSA Programme executed in Periods**
  - Period 1 decided at MC in November 2008 (Prep. Programme)
  - Period 2 decided at MC12 in November 2012
  - Period 3 to be decided at MC in 2016

Space Surveillance and Tracking (SST) comprises detecting, cataloguing and predicting the objects orbiting the Earth and the derived applications

NB: in ESA context, the exploitation of (external) surveillance data is outside the scope of ESA's SSA program. Operational support to missions based on surveillance data continues to be provided through services from ESA's Space Debris Office.



ESA's SSA / SST objectives

SST Overall objectives

- Creating and maintaining a catalogue of man-made space objects
- Conjunction prediction and risk analysis
- Re-entry prediction
- Fragmentation detection
- Special mission support
- Characterising sub-catalogue objects

Per periods

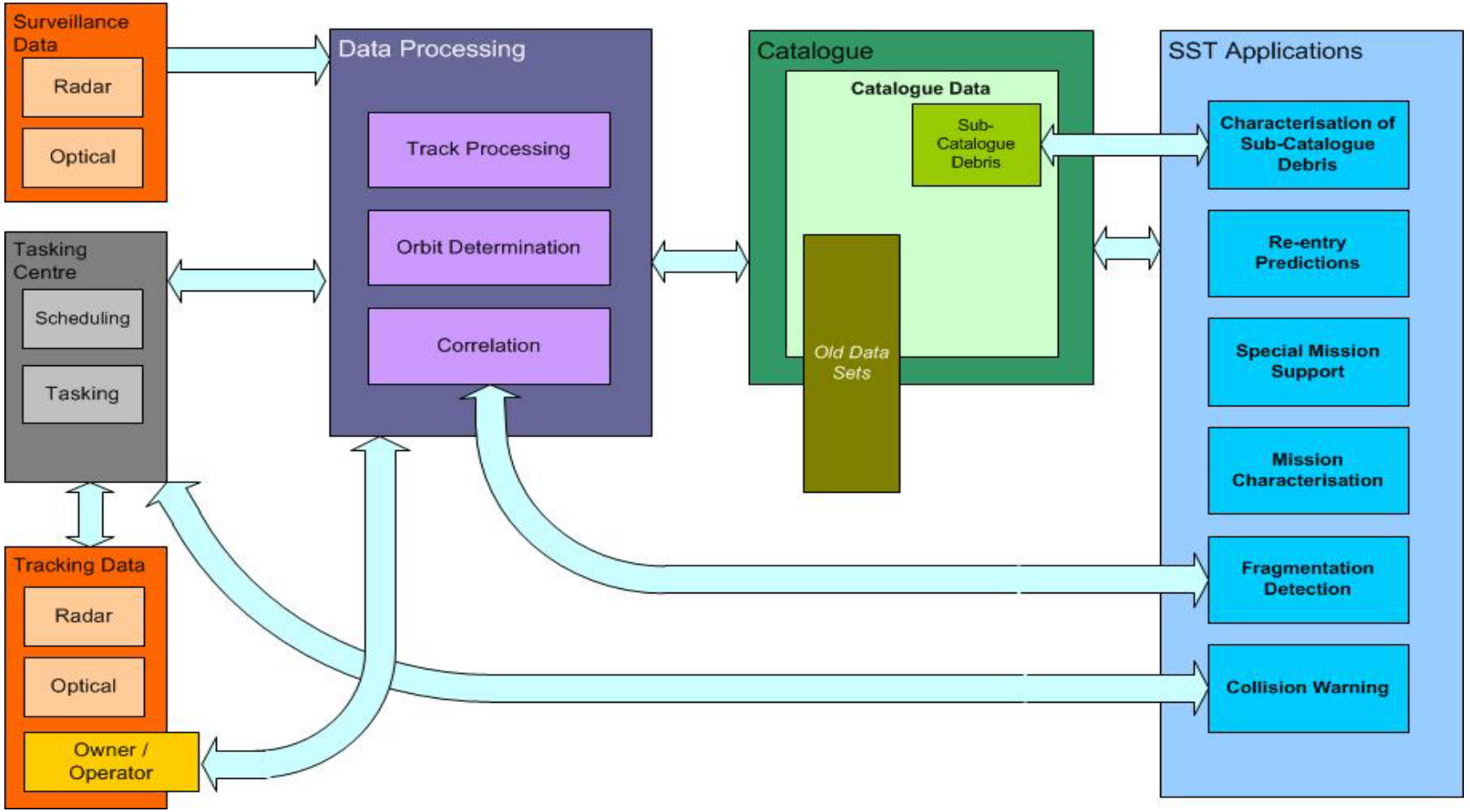
- P1

  Developing a system architecture
  Development of core technology (radars and the data centre)
  Evaluation of precursor systems
- P2

  Developing, prototyping and integrating a system that provides applications to European end users – focus on research, development and technological aspects

  Related end-to-end functionality demonstration
  Expert Centres

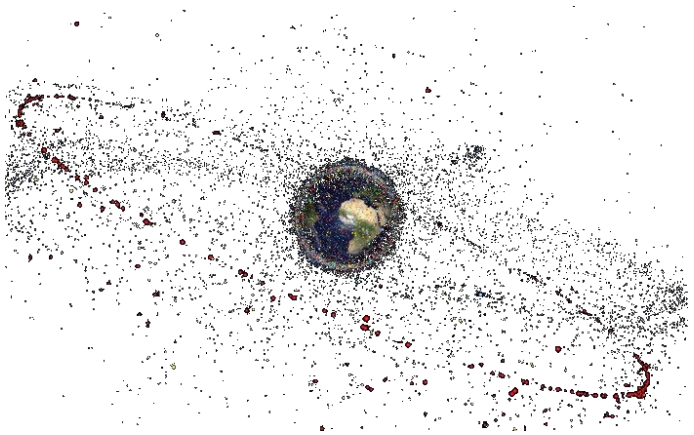
SST Functional Architecture and Data Flow



ESA Space Debris Office

Space Debris Office is in charge of development and maintenance of an infrastructure in support of ESA's commitment on space debris mitigation and risk reduction

- Development & maintenance of debris environment and risk analysis **tools** → MASTER-2009, DRAMA, see sdup.esoc.esa.int
- Acquisition & processing of **measurement** data
- **Operational & contingency** support to ESA and 3rd party missions
  (mainly LEOP, collision avoidance & re-entry)
- Coordination of **ESA debris research**
- Contribution to ECSS, CCSDS and ISO **standards**
- **Engineering** Support (SSA, Clean Space)
- Promotion of ESA-internal & **public awareness on space debris** issues



Motivation for activities for satellite laser ranging (SLR) in ops and SSA

- SSA program: R&D, Demonstration for
  - SLR data as contribution to **catalogue** build-up and maintenance
  - **Expert centres** in SST segment
  - **Evaluation** of national sensors
- Space Debris Office: research and development for **operational support** to ESA missions and third party missions
  - Tracking of debris objects for
    - Resolving **close approach situations** to active satellites
    - Improving **re-entry** predictions of time and locations
    - Support during **contingency** situations
  - Determination of attitude and attitude motion of uncooperative objects from any combination of SLR, light-curve, and radar imaging data
  - Support from observation strategies, such as "stare and chase"
  - Contribution to improvement and validation of **space debris environment models** (such as ESA's MASTER)

SSA/SST

EXPERT CENTRES

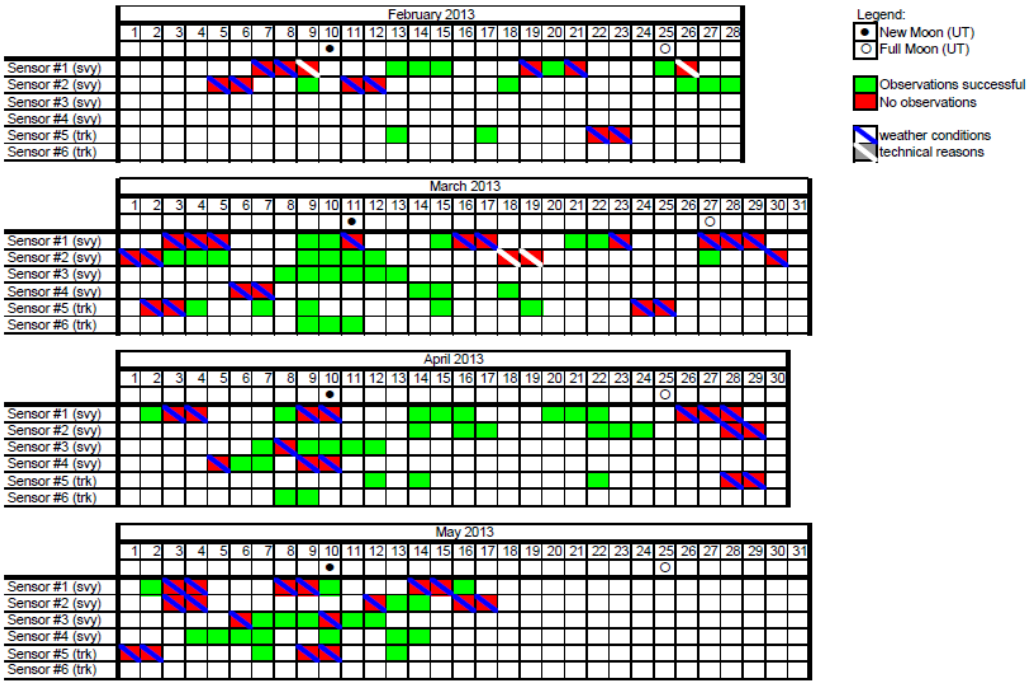
Motivation for SST Expert Centre: working with external sensors

Overhead for coordinating external sensors

proprietary formats and interfaces, sensor capabilities and availability

➔ proxy between the backend SST system and the sensors

as interface, for support services and research, for technology development



Schildknecht et al., 2013

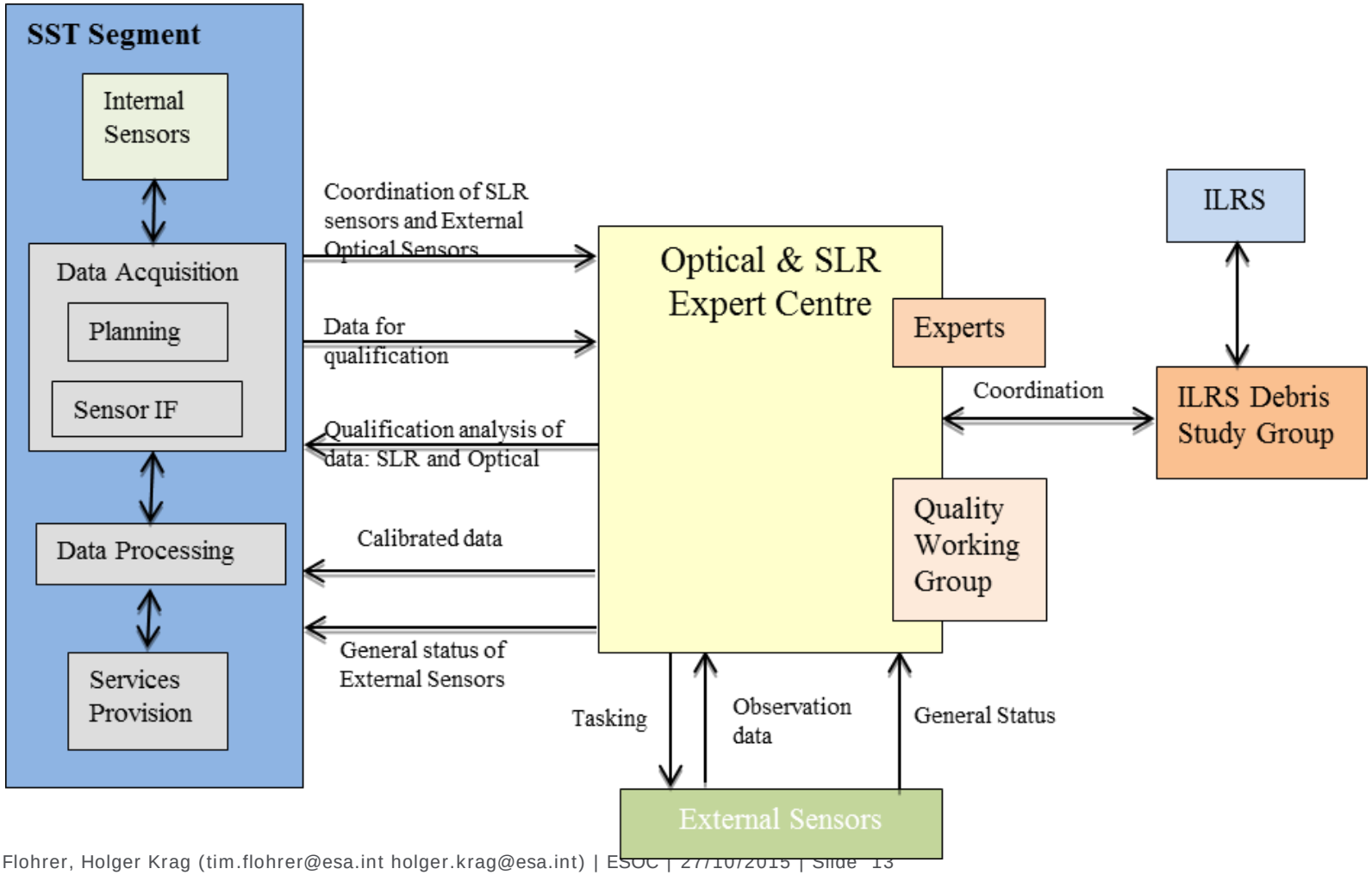
Benefits of SST expert centre

- Benefits of establishing SST expert centres as proxy
  - Lower costs, functionality increases, performance gains
  - Expert support to the external sensors
  - Data quality checks and applying consistent modelling
  - Centralized scheduler meeting backend SST/sensor status
  - Standardisation of data exchanges
  - Test environment for advanced SST data processing techniques

Expert Centre Functions (top-level)

- External to the SST System
- Interact with external (federated) optical Sensors and SLR Sensors
- Not replacing any SST functionalities
- Operations functions
    - Coordinate the sensors for tracking and surveillance tasks
    - Qualify external data sources
    - Monitor SLAs
- Support functions
    - Calibration of sensors
    - Evaluation of observation and processing techniques
    - Data quality control
    - Expert support and research and development
- Expert groups (→ ILRS SDSG)

System architecture for Expert Centre



ESA Space Debris Office

OPERATIONAL SUPPORT

Determination of Attitude and Attitude Motion

- GSTP-supported “Debris Attitude Motion Measurements and Modelling” with AIUB/FHR/HTG/IWF
- Exploitation of SLR/passive optical/radar imaging observation techniques:
    - To selected candidate targets in LEO and GTO (spacecraft and upper-stages)
    - In a collaborative approach to provide a representative data set as input for the selection of **removal technologies**
    - Develop mechanisms for a full investigation of the determination of the attitude motion vector and its evolution for **spacecraft contingencies**
- Develop 6 DoF simulator for various force models
- Conduct collaborative attitude measurements
- Develop attitude predictions and, for selected objects, perform a long-term prediction of the attitude motion vectors (calibrate predictions)

Tracking space debris to address challenges in operations

- GSTP-supported *"Accurate orbit determination of space debris with laser tracking/tasking"* with DLR/IWF/TUM
- Assessment of the needs for active optical observations and formulation of user and system requirements
- Development of **hardware** components, software **algorithms** supporting operational needs, and the execution of **test campaigns** (single/multistatic)
- To demonstrate that
    - Space debris objects in LEO can be observed
    - Acquired data has been demonstrated to support collision avoidance and re-entry prediction needs at ESOC
    - Underlying orbit determination accuracy is known and validated
    - Benefits from active optical observations in supporting spacecraft operations have been identified and quantified

Stare and Chase

- Scenario where a unknown object is detected in a surveillance campaign and a tracking device is commanded immediately to track the object before the pointing information is inaccurate

- Well-established tracking of cooperative targets vs. emerging tracking of uncooperative targets
- Achievable data volume and quality vs. a-priori information needs

- SLR for surveillance (stare): Is it feasible to follow-up with SLR detections from a optical fence?
- What are the technical and operational requirements for hand-over between SLR and passive (co-located) sensors?

Other issues

- Lessons learnt from past events
  - Support and facilitate collection of laser ranging measurements quickly after s/c failures, as contingency support and for later ADR!
  - Standardisation – reflection of laser ranging in CCSDS messages and knowledge of CCSDS among laser stations
- Further research ideas (incomplete!)
  - Can SLR help to track and discriminate and identify multiple small satellites?
  - Is there a way for laser-induced collision avoidance?
  - Which sensor technology developments are upcoming and are relevant for ESA (addressing SSA/SST or Space Debris needs)?
  - Are there specific needs for OD methods (tests?), can SLR support data correlation tests?
- There are plenty of topics for scientific conferences, see, e.g., 7th European Conference on Space Debris

Conclusions

- ESA is interested in SLR to (uncooperative) objects in the frame of the SSA Programme (SST) and as part of operational support and space debris research
- Several ongoing activities for SST Expert Centres, Operational Support, Attitude and Attitude motion determination, Stare and Chase
- SSA upcoming P3 aims at testing and validation of functions with strong technological focus in a coherent SST segment based on enormous European expertise
- SST towards external sensors needs efficient interfacing, coordination, monitoring, sensor evaluation, parallel calibration, support of SST research and development, plus standardisation ➔ expert centres → external expert involvement, like through SDSG(?)
- Operations may benefit from SLR for collision avoidance, re-entry support and contingency resolution, to be demonstrated
- SLR support to future ADR mission(s), to be demonstrated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