ESA Activities on Satellite Laser Ranging to Non-cooperative Objects

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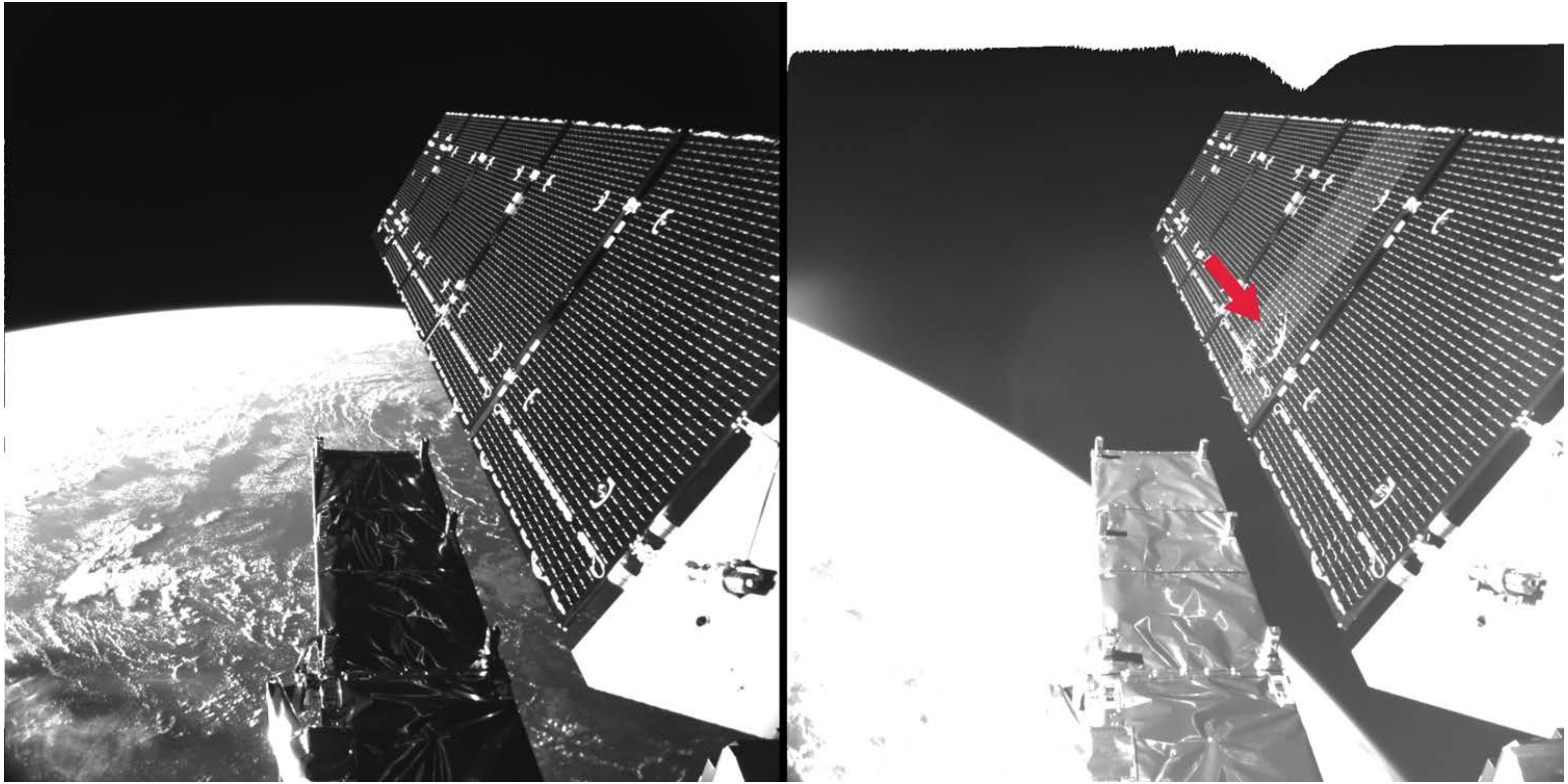
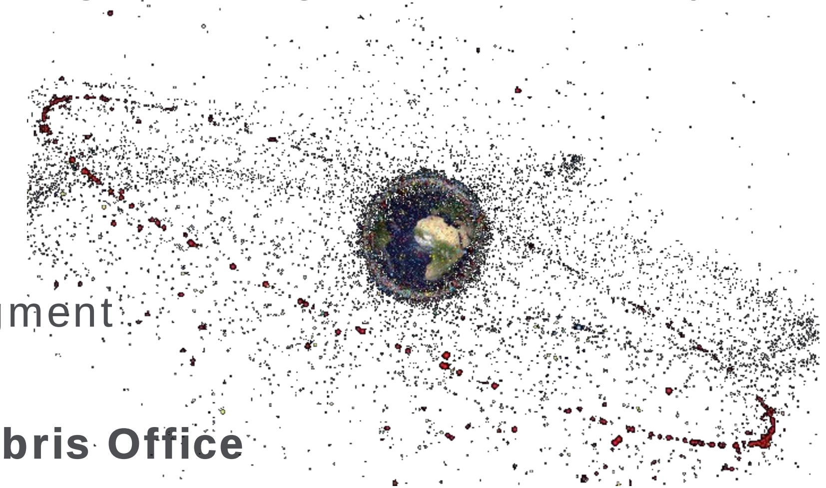
Copernicus Sentinel-1A satellite mm-size MMOD (well, debris) impact on 23 August 2016



Why laser ranging to space debris?

1. Technology push from emerging capabilities!
2. Technology pull to support operational, modeling and mitigation needs set by the space debris population



At ESA:

Space Situational Awareness (**SSA**) program with Space Surveillance and Tracking (SST) segment

Research and development activities with operational aspects are run by ESA's **Space Debris Office**

NB: See 2015 talk *Laser ranging initiatives at ESA in support of operational needs and space surveillance and tracking* for a revisit of the motivation and objectives of the SLR-related activities at ESA in SSA/SST and Space debris Office

This talk

- (Motivation and objectives)
- Status and plans of the various and parallel SLR-related SST and Space Debris Office activities at ESA
  - Need of **coordinating multiple stations** through
    - Expert centre, coordinating the contribution of SST system-external loosely connected SLR sensors, and providing back calibration and expert evaluation support to the sensors
    - SCOOP as platform for collaborative (ad-hoc) multi-technique observations
  - Potential **benefits of laser ranging** in operations to
    - Resolve close approaches
    - Improve re-entry predictions
    - Support contingency situations
    - Determine attitude and attitude motion -combination of radar imaging, optical, SLR
- **Standardisation** needs (data exchange and sensor interfaces)

- … references to subsequent talks in this session (Kucharski, Steindorfer, Sproll, Funke, Bamann)!

Coordinating multiple stations, feedback

SSA/SST EXPERT CENTRES

Benefits and top-level functions

Coordination overhead → PROXY between a SST system backend and the sensors

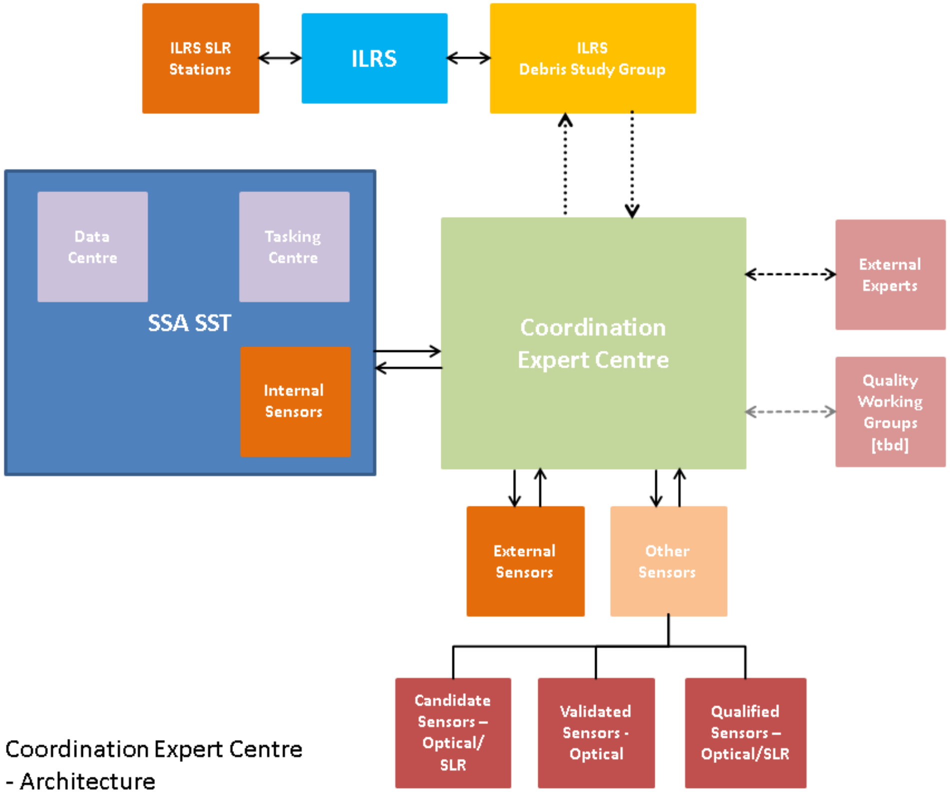
Benefits

- Data **quality checks** and applying consistent modelling, **feedback** to sensors
- **Centralized** scheduler
- **Standardisation** of data exchanges
- Lower costs, functionality increases, performance gains
- **Expert** support (calibration support) and test environment

Functions

- External component to a SST System, not replacing any SST functionalities
- Interact with external (federated) optical Sensors and SLR Sensors
- **Operations functions:** Coordination and Qualification, SLA monitoring
- **Support functions:** Calibration, Evaluation, Quality control, Research support
- **Expert groups** (→ ILRS SDSG) and **hosting experts** to work with SST data

System architecture for Expert Centre and Sensor interfaces



Coordination Expert Centre
- Architecture

Expert Centre Status

- SSA activity led by AIUB(CH) with team IWF(AT), SpaceDys(IT), TU Prague(CZ)

- Done: Expert Coordination Centre’s User requirements consolidation
- Done: Architecture and IF design consolidation
- On-going: Test campaign with passive robotic telescopes (Tenerife/Cebreros)
- On-going: SW tools and procedures consolidation
- Schedule:
    - CDR in November 2016
    - Test and demonstration 2017

- Further work in SSA period 3 (decision Dec 2016)

Platform for facilitating collaborative coordinated observations of spacecraft

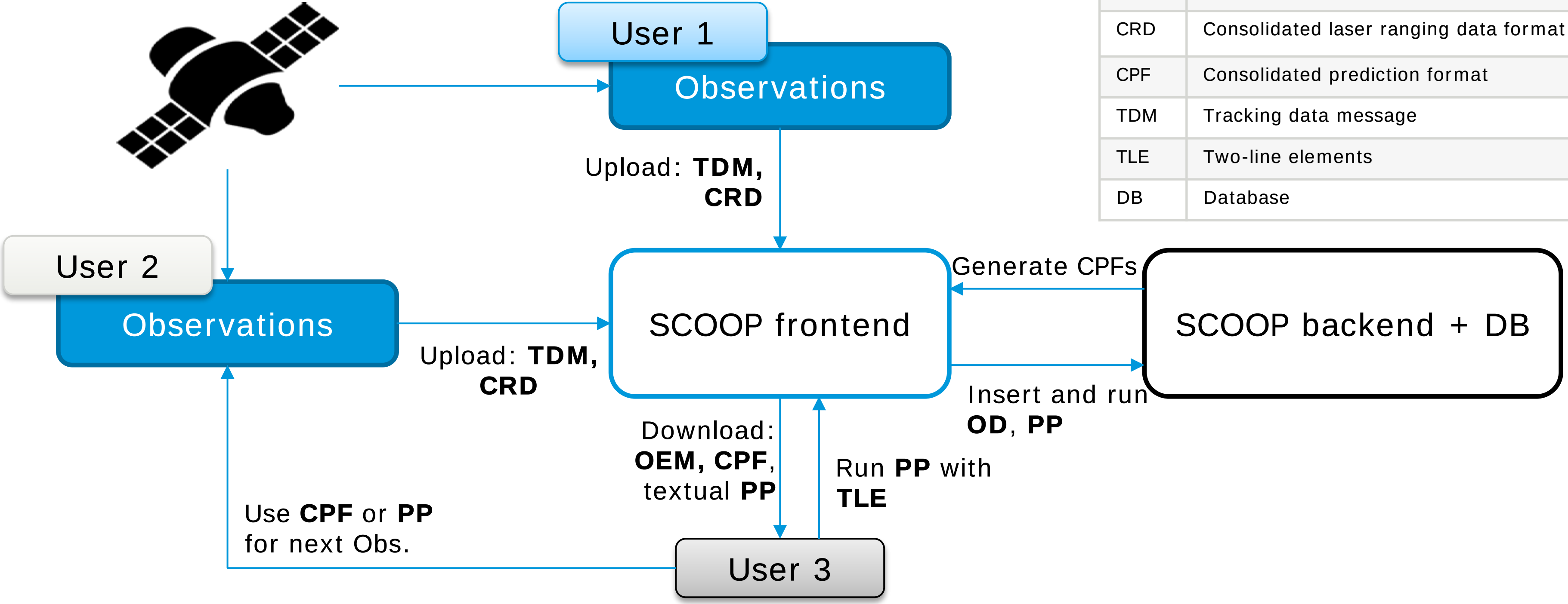
SCOOP

SCOOP Objectives

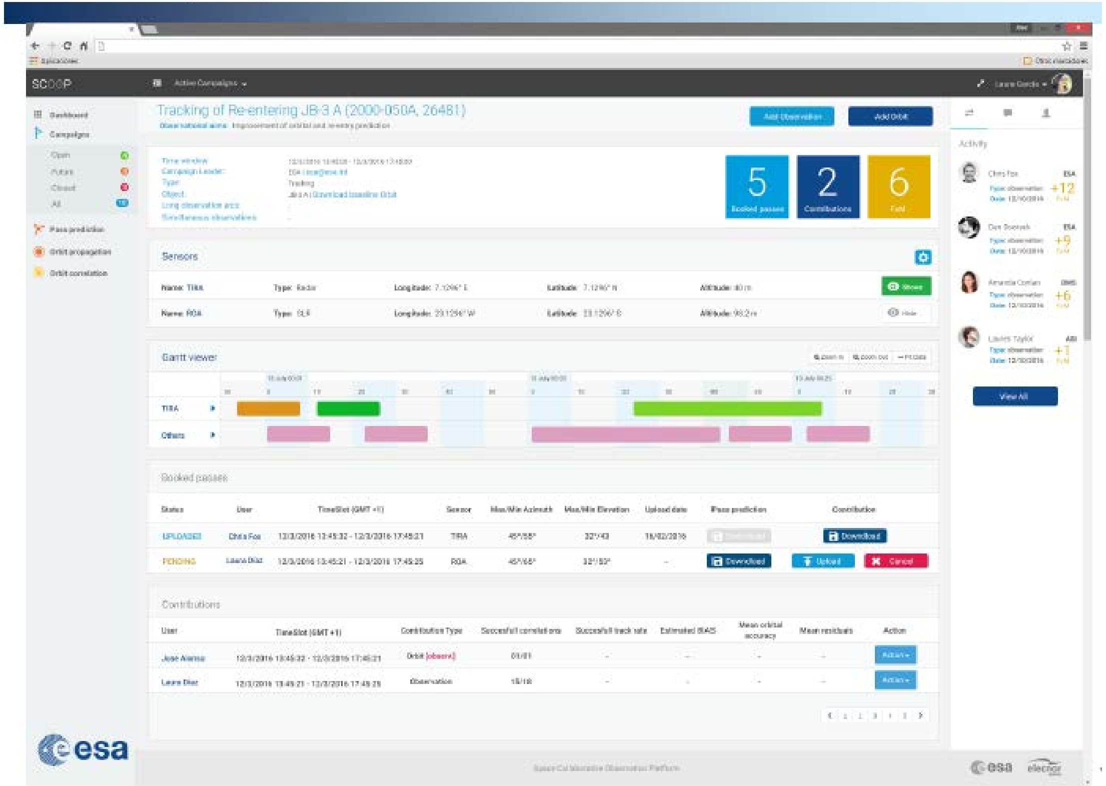
- Aims at multiple technologies, among them SLR
- Requirements from scientific space debris observer and modelling communities (e.g. in the IADC) for **coordinated, collaborative, observations** and other support functions to operations
- Design and implement **prototype web-based platform** hosted by ESA (SDO)
- Access to **services in backend**, allowing also to try out new methods:
  - orbit determination
  - pass prediction
  - data correlation
- Have **dedicated user workshops to obtain feedback** on the developed prototype and use this for optimizing the design

SCOOP Interfaces

PP	Pass prediction
OEM	Orbit ephemeris message
CRD	Consolidated laser ranging data format
CPF	Consolidated prediction format
TDM	Tracking data message
TLE	Two-line elements
DB	Database



Prototype screenshot of SCOOP



SCOOP project status

- Started in Nov. 2015, first user workshop in Jan. 2016
- First alpha version of frontend (look & feel) in Apr. 2016
- PDR in Jul. 2016, CDR in Nov. 2016

- Tentative **test campaign** Nov. / Dec. 2016
- **User workshop** Jan. / Feb. 2017

→ invitation to SLR community!

close approaches, re-entry predictions, contingency situations, attitude and attitude motion

POTENTIAL BENEFITS OF LASER RANGING IN OPS

SLR for space debris research

- Typical technology pull → comparably large volume studies at various TRL
  - **Attitude** status and attitude motion (contingencies, LEOPs, re-entries, removal missions)
  - **Orbit improvement** in short time from multi-static configurations (collision avoidance, contingency support, re-entries)
  - **Observation strategy** test and validation (stare and chase)

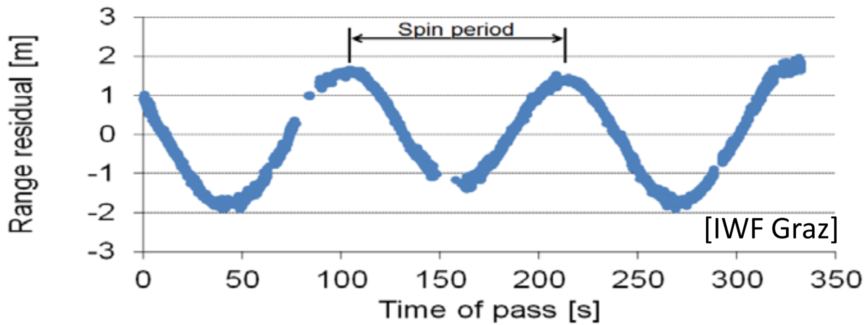
- **Technology development** in close coordination with ground station engineering and navigation support office
  → Mission support to ESA/non-ESA missions
  → Development of expertise in ESOC
- Key: participation in Space Debris Study Group of **International Laser Ranging Service**

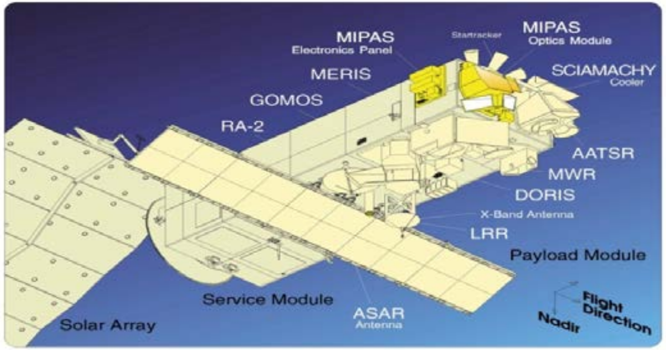
Determination of Attitude and Attitude Motion

- Study with AIUB/FHR/HTG/IWF, 2015 → 2017
- Exploitation of SLR/passive optical/radar imaging observation techniques:
  - Targets in LEO and GTO (spacecraft and upper-stages)
  - Data from collaborative approach as input for studying **removal technologies**
  - Develop mechanisms for a full investigation of the determination of the attitude motion vector and its evolution for **spacecraft contingencies**
- Develop **iOTA** - a 6 DoF simulator for various force models, and prediction
- Conduct collaborative attitude measurements – just done
- Long-term prediction of the attitude motion vectors (calibrate predictions)

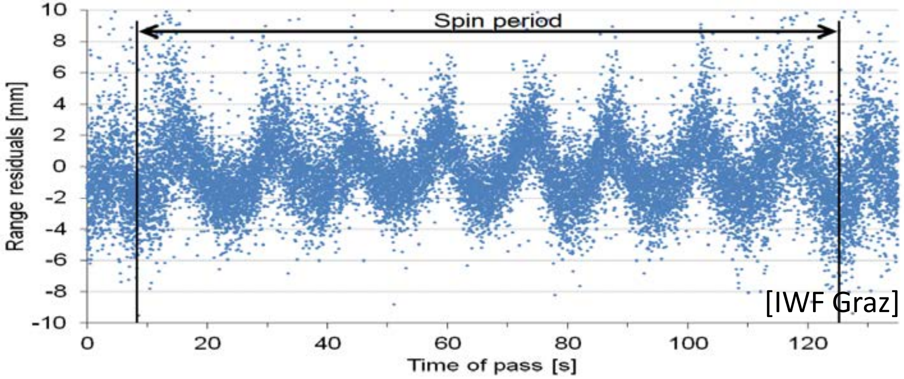
Determining the Attitude State

1) Analysis of meter-scale range oscillation due to 2.5 m offset between retro and spin axis of body.



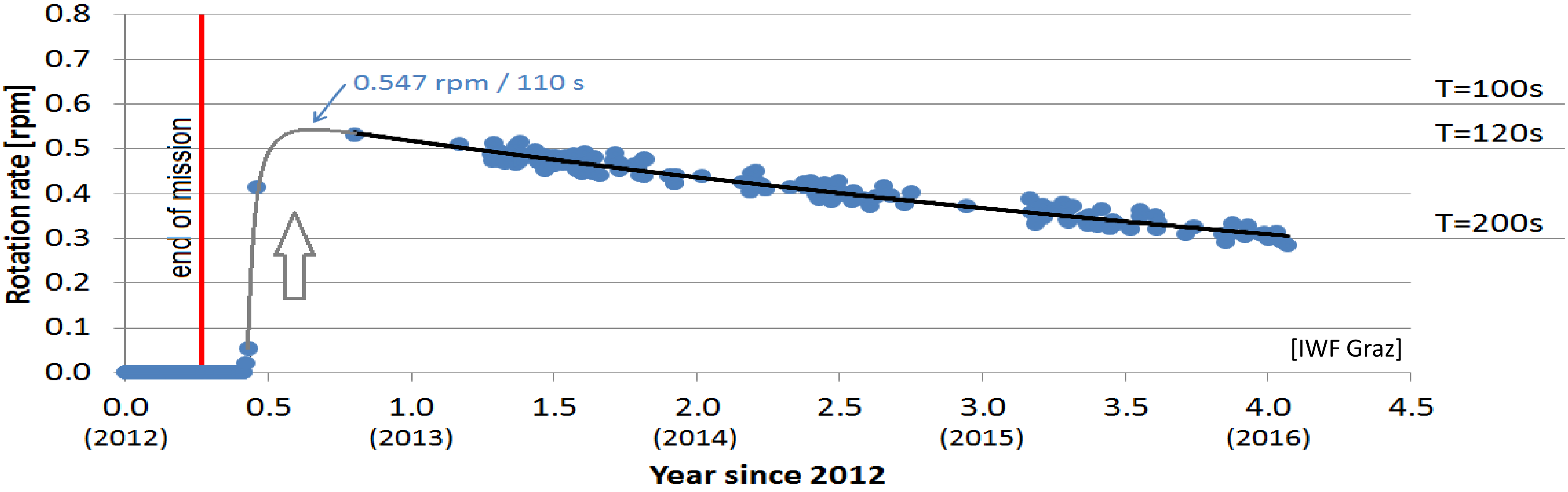


2) Analysis of the millimeter scale oscillations of the SLR kHz range residuals



retroreflector array of Envisat consists of 8+1 corner cube reflectors

ENVISAT: Inertial Spin, measured by SLR



The spin period of Envisat:

- increases by 72 ms/day
- doubles every 4 years
- will become equal to the orbital period (6000 s) in the year 2036

Tracking space debris for operational needs

- Study with DLR/IWF/TUM 2014 → 2017
- User and system requirements
- Development of **hardware** components, software **algorithms** supporting operational needs, execution of (single/multistatic) **test campaigns**
- 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

Multi-static Tracking of non-cooperative objects

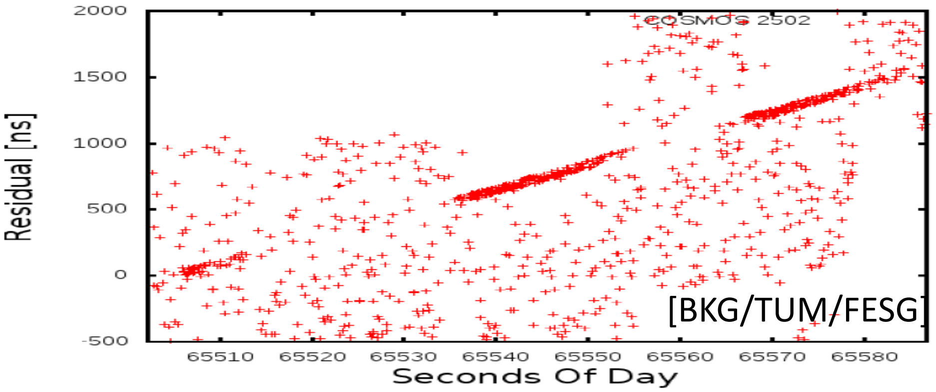
German Aerospace Center/
Institute of Technical Physics

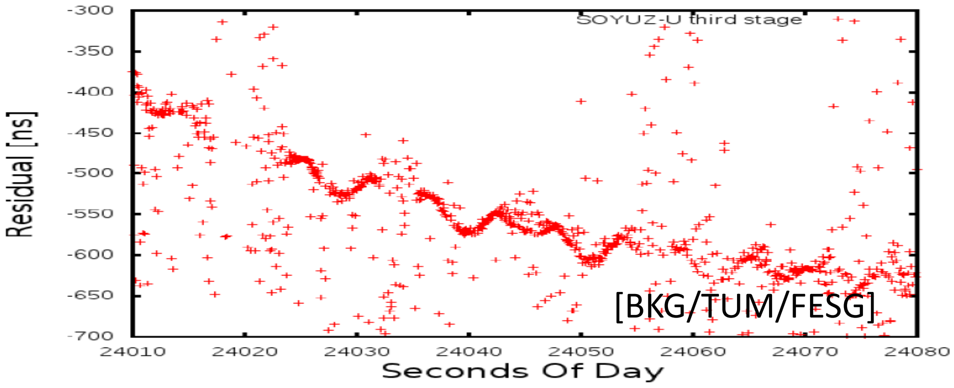
Austrian Academy of Science/
Space Research Institute

Technical University Munich/
FESG; Geodetic Observatory
Wettzell

Success in tracking of non-cooperative objects without reflector

- Ranging measurements to non cooperative targets (up to 2000km, 3m² area)
- Visible:
  - Rotation of objects visible
  - Finite dimension of objects
- Bi/Multi-static measurements – done, different wavelengths
- Orbit improvements under study





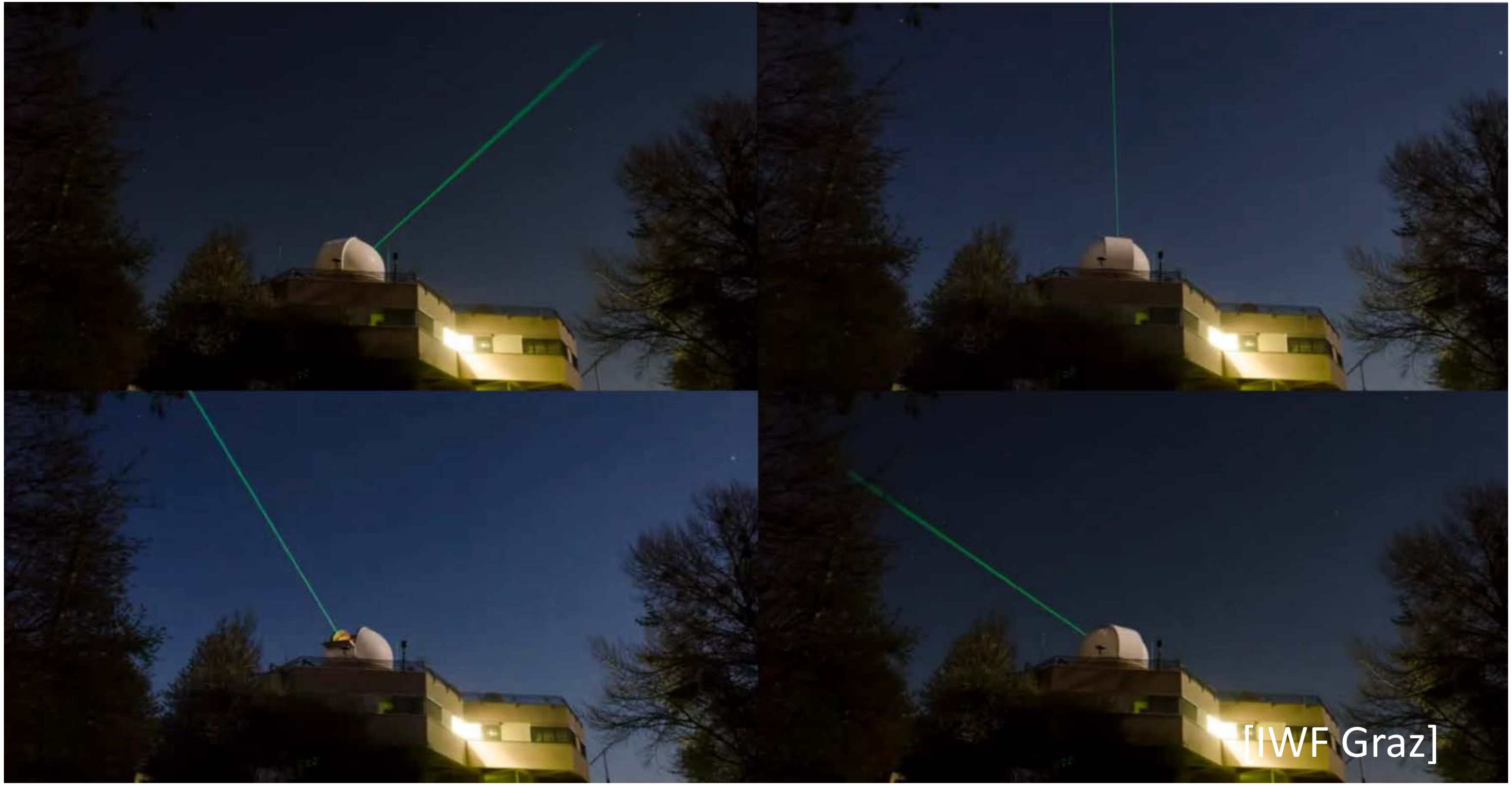
Stare and Chase

- Study with GMV (ES), AIUB (CH), IWF (AT); 2015/16

- Principle: Detected unknown from (any) surveillance campaign handed over to (any) tracking asset
- Tracking cooperative targets is well established!
- Learn about achievable data volume and quality vs. a-priori information needs
- Study needs set by assumed **radar system**

- BUT: Is it feasible to follow-up optical fence detections with SLR?
- Study extended to technical and operational requirements for hand-over between SLR and passive (co-located) sensors

Stare and chase demonstrated with GRAZ for cooperative and non-cooperative objects!



Data exchange with SST and OPS and sensor interfaces

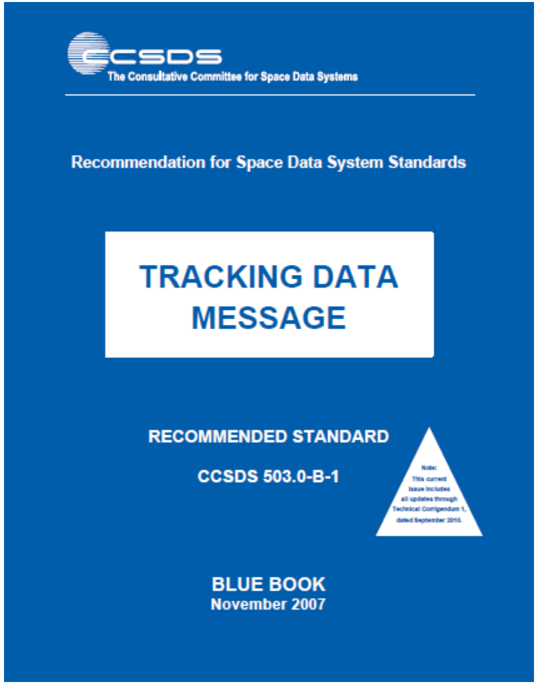
STANDARDISATION NEEDS

Standardisation needs

- Consultative Committee for Space Data Systems **(CCSDS)** is “the language” among satellite operators, emerging also for SST needs
- Adopted as ISO standards, too.
- ESA SSA/SST adopts CCSDS formats

SLR:

- Has proven interfaces and converters available
- Hot items calling for support:
  - Specifics of laser ranging in CCSDS messages (e.g. Tracking Data Messages, ECEF Ephemeris)
  - Knowledge of CCSDS among laser stations (extend to Orbit Data Messages for states and ephemeris), new ideas in SST domain (Sensor Data Messages, Scheduling Messages)



CONCLUSION

Conclusion

- ESA maintains **interest in SLR** to (non-cooperative) objects in the frame of the SSA Programme (SST) and as part of operational support and space debris research
- Several ongoing activities for SSA/SST **Expert Centres**, Operational **Support**, Attitude and **Attitude** motion determination, **Stare and Chase**
- ESA's SSA upcoming **P3** aims at testing and validation of functions with strong **technological focus** in a coherent SST segment based on enormous European expertise
- Driver from 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**!
→ **SLR support in SCOOP, test campaign ahead!**
- Further **research ideas** (incomplete!)
  - How 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, can SLR support data correlation tests?

ABSTRACT SUBMISSION

Authors are invited to submit their abstracts according to the procedure described below.
Each abstract (approximately 500 words) should clearly outline major achievements and innovative ideas.
Papers will be selected on the basis of:

- interest in the subject by the target audience
- relevance to the conference topics
- originality of the ideas presented
- quality and clarity of the content

Papers must be submitted in English, according to the "instructions to authors". English will also be the working language at the conference.

Abstracts must be submitted by 15 Nov 2016

A "No Paper – No Podium" rule applies.

TARGET AUDIENCE

The conference will provide a unique forum for information exchange, technical discussions and networking between space debris researchers, engineers & decision takers of industry, policy makers & space lawyers, insurance underwriters, space & ground system operators, institutional organisations (e.g. space agencies, EU, UNCOPUOS, IAA, COSPAR), academia and the defense sector.

IMPORTANT DATES

15 Nov 2016	Deadline for abstracts
16 Dec 2016	Notification of authors
24 Feb 2017	Final Programme
10 Apr 2017	Deadline for papers
18 - 21 Apr 2017	7th European Conference on Space Debris

CONFERENCE VENUE

European Space Operations Centre
ESA/ESOC, Robert-Bosch-Strasse 5
64293 Darmstadt, Germany

REGISTRATION FEES

Early registration	€ 450 (students € 225)
After 20 Jan 2017	€ 500 (students € 250)

Fees include the proceedings, a reception, free lunches and coffee breaks.

POINT OF CONTACT

Conference website
conference.sdo.esoc.esa.int

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Robert-Bosch-Straße 7
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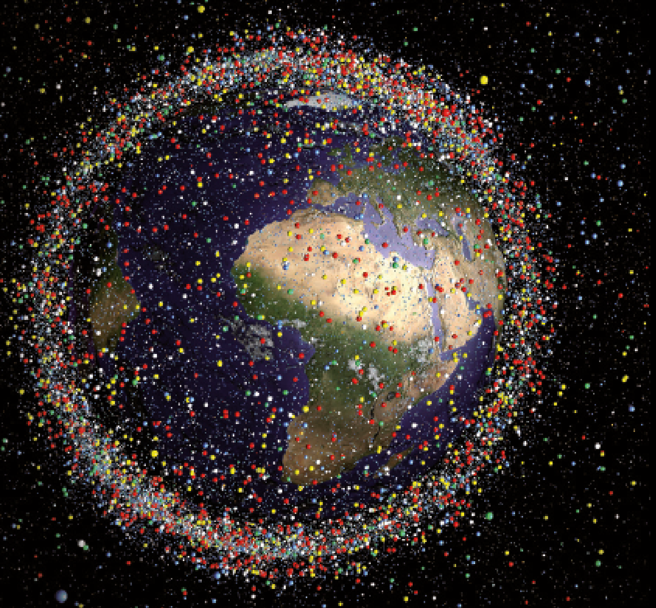
7TH EUROPEAN CONFERENCE ON SPACE DEBRIS



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18 – 21 APRIL 2017

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