European Space surveillance and tracking 2023 – 2026 R&D activities

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Space Situational Awareness – Status report and previsions

Number of Launch and Decay per month and the cumulative count of object remained in orbit as function of Time (Source : Spacetrack)

Number of object orbiting around Earth per type: Payload, Rocket Body, Debris and unknown object (Source : Spacetrack)

→ A Scalable and efficient SST environment is required

Number of cumulative collisions in LEO in the simulated scenarios of long-term evolution of the environment (Source : Esa’s annual space environment report)
Service provision - 3 Operational & Added Value Services

Collision Avoidance (CA)
Risk assessment of collision and generation of collision avoidance alerts

Fragmentation Analysis (FG)
Detection and characterisation of in-orbit fragmentations

Re-entry Analysis (RE)
Risk assessment of space objects re-entry into the Earth’s atmosphere

Key features
- User-tailored service (SCD)
- Hot redundancy scheme involving ES (S3TOC) and FR (FR-SSA) with harmonised service level and single service provider per registered user
- Enhanced Analysis & Risk Mitigation support (e.g. covariance estimations, HBR estimations, PoC sensitivity analysis, CAM support)
- Provided by IT (C-SSA)
  - Short-term notification to confirm quickly an FG event
  - Medium-term FG analysis based on the orbital parameters of the catalogued fragments e.g. Gabbard Diagram
  - Long-term FG analysis (with simulations with breakup model)
- Provided by IT (C-SSA)
  - Long-term (within 30 days) re-entry predictions
  - Short-term (a few days) overflight predictions with ground tracks over customisable areas of interest
EU SST – Development strategy

- Improving the detectability and observability of overall objects orbiting the Earth
- Improving the number of objects identified
- Improving the quality of orbits in the catalogue
- Improving process and scalability of the CA, RE and FG service regarding the future space population
- Improving space situational awareness
- Contributing to new services (ADR, EOL, OOS)
- Securitizing and monitoring flux and data transactions
# Layer 1 – Data Acquisition

## Upgrade

<table>
<thead>
<tr>
<th>Optics</th>
<th>Upgrade Details</th>
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<tbody>
<tr>
<td><strong>CZ SHOT</strong></td>
<td>New CMOS camera to observe LEO, MEO and GEO</td>
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<tr>
<td><strong>FR-TAROT</strong></td>
<td>Real-time observation scheduling optimizations</td>
</tr>
<tr>
<td><strong>GR-KRYONERI</strong></td>
<td>Increasing quality of LEO, MEO and GEO data and reactivity of the system</td>
</tr>
<tr>
<td><strong>GR-BAKER-NUNN</strong></td>
<td>30% objects bigger than 35cm in GEO; 77% objects bigger than 35cm in MEO</td>
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<tr>
<td><strong>PT-SURV-DEPLOY</strong></td>
<td>Reallocated to Oceania</td>
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### RADARS

- **ES-S3TSR**: Almost all objects bigger than 12cm
- **FR-GRAVES**: Almost all objects bigger than 1m; 85% objects bigger than 50cm; 25% objects bigger than 25cm
- **FR-GRAVES-NG**: Almost all objects bigger than 50cm; 70% objects bigger than 10cm

### OPTICAL

- **GR-BAKER-NUNN**
Layer 1 – Data Acquisition

- **Sharing the burden related to the development of innovative solutions**

- **Promoting the European Industry**

- **Contributing to improving cataloguing capabilities (by 2026):**
  - **LEO:**
    - 50% of the objects above 7cm
    - 70% above 10cm
  - **MEO/GEO:**
    - All objects above 35cm

- **Being able to characterize objects orbiting the Earth**
Layer 1 – Data Acquisition

Task 1: Benchmark and test
- Benchmarking technology capabilities and performances for SBSS applications
- Building-up a breadboard to test the system in near real conditions
- Lossless algorithm design and implementation
- On-board / On-ground optimal task delegation

Task 2: Optical capabilities
- Designing the optimal optical observation strategy contributing to SST
- Identifying the best observation / observed objects configuration as function of (non-exhaustive list):
  - Sub GEO -> GEO
  - GEO -> MEO

Task 3: Future missions
- Simulating complete SBSS mission (satellite + ground segment) to face the different constraints
- Assessing on-board cross technology based solutions (non-exhaustive list):
  - Optical + Passive RF
  - Optical + Laser
Layer 2 – Cataloguing

Current Situation

<table>
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<th>Quality</th>
<th>RMS≤20m on cooperative objects</th>
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<tbody>
<tr>
<td>Object limitations</td>
<td>Not accurate enough on uncooperative objects (98.8% of objects orbiting the Earth)</td>
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<tr>
<td>Observation limitations</td>
<td>Useable in Full night</td>
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Objectives

- Improving catalogue methods to include lasers data related to uncooperative objects
- Assessing daylight tracking feasibility
- Assessing transversal improvement feasibility thanks to lasers data
Layer 2 – Cataloguing

Task 1: Model and set of parameters
- Assessing consequences of propagations and models on catalogue accuracy
- Identifying optimal configuration per orbital regime considering:
  - Accuracy
  - Computational runtime

Task 2: Space Weather
- Assessing consequences of the error of space weather model in propagated orbits
- Enhancing realism by modeling the error (e.g. solar activity, atmospheric model)

Task 3: New methods or technics
- Assessing the feasibility to use dual-frequency tracking radars for cataloguing
Layer 2 – Cataloguing

Propagation method:
- Numerical (Runge-Kutta, Dormand-Prince, …) → Relatively accurate (in short time) but time consuming
- Analytical (SGP4) → Efficient but accuracy is limited
- Many uncertainties origin (such as geometry, attitude, dissipative force model)

→ Need a compromise between uncertainties and computation time

Objectives
- Modeling uncertainties in analytical propagation
- Modeling error model (such as thermosphere densities)
Layer 3 – Service Provision

Task 1: Exhaustivity
- Developing All vs All optimized screening environment
- Developing uncertainties characterization method and algorithms
- Improving risk estimations methods thanks to alternative methods (e.g., Hall, LAAS)

Task 2: Maneuver computation
- Performing Maneuver Computation to provide operative recommendations

Task 3: Risks at launch
- Implementing risk assessment at launch methods (CNES method inheritance) to provide operative recommendations
Layer 3 – Service Provision

- Collision Avoidance Service Improvement
- R&D on RE
- R&D on Fragmentation

**Task 1: Realism improvement**
- Uncertainties characterization reworks based on Scaled Ballistic Coefficient, taking into account Orbital covariance
- Propagation methods improvement in low altitude phase

**Task 2: Break-up model improvement**
- Implementing MonteCarlo breakup simulation to evaluate fragments spread
Layer 3 – Service Provision

- **Task 1: Realism improvement**
  - Implementing Large vs Large concept for chain reactions assessment
  - Increasing cooperation with CA service

- **Task 2: Break-up model improvement**
  - Implementing MonteCarlo breakup simulation to evaluate fragments spread
  - Enhancing the model thanks to real fragments orbital information

- Collision Avoidance Service Improvement
- R&D on RE
- R&D on Fragmentation
**Layer 4 - Ecosystem and knowledge improvement**

- **Building EU SST space population model based on pragmatic scenarios**
- **Defining long-term scenarios taking into account:**
  - Effect of incremental number of object increasing
  - Effect of satellites spiraling-up / down
  - Effect of satellite defects
  - Effect of fragmentations
- **Quantifying the potential of any mission to degrade the orbital environment**
- **Implementing Long-term statistical / stochastic propagation**
- **Assessing the accumulated risk for a satellite (or constellation) overall the duration of the mission**
- **Analyzing space capacity and consequences of future mission**
## Layer 4 - Ecosystem and knowledge improvement

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<td><strong>Space population evolution and potential hazardous objects</strong></td>
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<td><strong>Environmental Index</strong></td>
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<td><strong>Manoeuvre detection from data fusion</strong></td>
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### Preparing potential future EU SST service: Compliancy reporting with Space Debris Mitigation Standards
- Increasing EU SST autonomy regarding this highly strategic topic
- Acting as major stakeholder in STM regulation works

### Defining useful set of indicators for assessing compliancy
- Defining sources and data fusion process to collect data of interest for assessing compliancy
- Designing Compliancy Monitoring Software

### KPIs list and recommendations to assess compliancy
- System requirements to implement in the future the Compliancy Monitoring Software
Layer 4 - Ecosystem and knowledge improvement

- Space population evolution and potential hazardous objects
- Environmental Index
- Manoeuvre detection from data fusion
- Attitude mode detection from data fusion
- Interference prediction
- Simulation bench and twin concept
- Data Governance system

**Task 1: Method improvement**
- Developing and implementing filtering methods helping for maneuver detection
- Implementing new propulsion model (such as low-thrust model) and strategies (such as station-keeping) for detecting maneuvers

**Task 2: Detection methods**
- Assessing different methods feasibility and performances for maneuver detection:
  - Stochastic methods
  - Artificial methods
  - Statistical methods
  - Data fusion based correlation (radar + optical)
- Assessing data fusion influence on maneuver detection feasibility
Layer 4 - Ecosystem and knowledge improvement

- Implementing data fusion environment to collect and process cross-technologies data (optical, radars)
- Assessing AI-based attitude estimation feasibility (CNES previous studies inheritance)
- Assessing adaptive optics based attitude estimation feasibility
- Implementing analysis environment:
  - Providing attitude regime analysis to support ADR operators
  - Providing long-term analysis for End Of Life activities, especially assessing compliancy with EoL requirements

Detrended light curve of COSMOS 2277 satellite in tumbling at 36.28s and epoch folding showing mean folded data obtained
(Source: EU SST Studies)

Example of selected candidates (initial frequencies in plot) and optimized candidates (analyzed frequencies in plot)
(Source: EU SST Studies)
Layer 4 - Ecosystem and knowledge improvement

Task 1: Knowledge improvement
- Implementing algorithm dedicated to extract third party emissions from ground station antenna logs
- Developing the database hosting observations and object frequency analysis

Task 2: Simulation environment
- Developing emission predictions environment
- Developing automated RFI detection

- Space population evolution and potential hazardous objects
- Environmental Index
- Manoeuvre detection from data fusion
- Attitude mode detection from data fusion
- Interference prediction
- Simulation bench and twin concept
- Data Governance system
Layer 4 - Ecosystem and knowledge improvement

Objectives
- Improving realism of the Architecture design environment
- Assessing long-term scalability of EU SST

Technical content
- Implementing twin concept in current architecture software
- Implementing synthetic population replicating the real current population observable
- Modeling Network Coordinated Scheduler (COPLA) within both FR / ES simulation chains
- Implementing CA / RE / FG simulation modules based on EU SST long-term population file

Outputs
- Highest realistic simulation short and long-term simulation environment
- Improved bank of simulation for assessing EU SST scalability and development plan
- Improved development decision making process

Space population evolution and potential hazardous objects
Environmental Index
Manoeuvre detection from data fusion
Attitude mode detection from data fusion
Interference prediction
Simulation bench and twin concept
Data Governance process
Layer 4 - Ecosystem and knowledge improvement

Objectives

- Assessing the feasibility to use DLT to contribute to secure data and transactions
- Implementing an operative Proof of Concept

Technical content

- Assessing the best technology to protect transactions (such as DLT)
- Implementing a bank test to manage measurements (data volume extracted from last year)
- Implementing a bank test to manage catalogue (data volume extracted from last year)
- Simulating use as operational environment to provide services

Outputs

- Recommendations on feasibility to use DLT (and which one) to manage EU SST data
- Proof of Concept to manage multi-layer system of data based on DLT

Space population evolution and potential hazardous objects

Environmental Index

Manoeuvre detection from data fusion

Attitude mode detection from data fusion

Interference prediction

Simulation bench and twin concept

Data Governance System
Thank you

User Registration
https://sst.satcen.europa.eu

General Information
www.eusst.eu