EU SST and a closer look to its Collision Avoidance (CA) service

Cristina Pérez
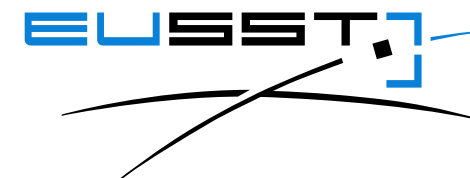
Outline

❚ What is EU SST?
- Sensor network
- Operational overview
- EU SST DataBase
- Service Provision
- Users

❚ Overview of the CA Service
- Operational interfaces
- Key concepts to understand EU SST CA Service

❚ Looking at the future
- New services
- Communication and Coordination Platform Prototype

What is EU SST?

What is EU SST?

EU SST is:

▌ A working example of multilateral cooperation at the intersection of space safety and space security

▌ A consortium of 7 Member States* expanding towards a new SST partnership composed of up to 15 Member States of the European Union

We:

▌ Are fully **operational 24/7**, we deliver high quality public services to users (CA, RE, FG)

▌ Perform **research and development** of capabilities to improve the level of performance and autonomy

▌ Foster innovation and **competitiveness** of the European industry and start-ups, we support the consolidation of a commercial ecosystem around SSA, strengthening strategic autonomy in Europe

▌ Are **security** relevant (e.g. data sharing) and we take into account the dual dimension

▌ Mature and expand as a fully-fledge security component of the **EU Space Programme** 2021-2027

*France, Germany, Italy, Poland, Portugal, Romania, Spain

Sensors for space surveillance and tracking
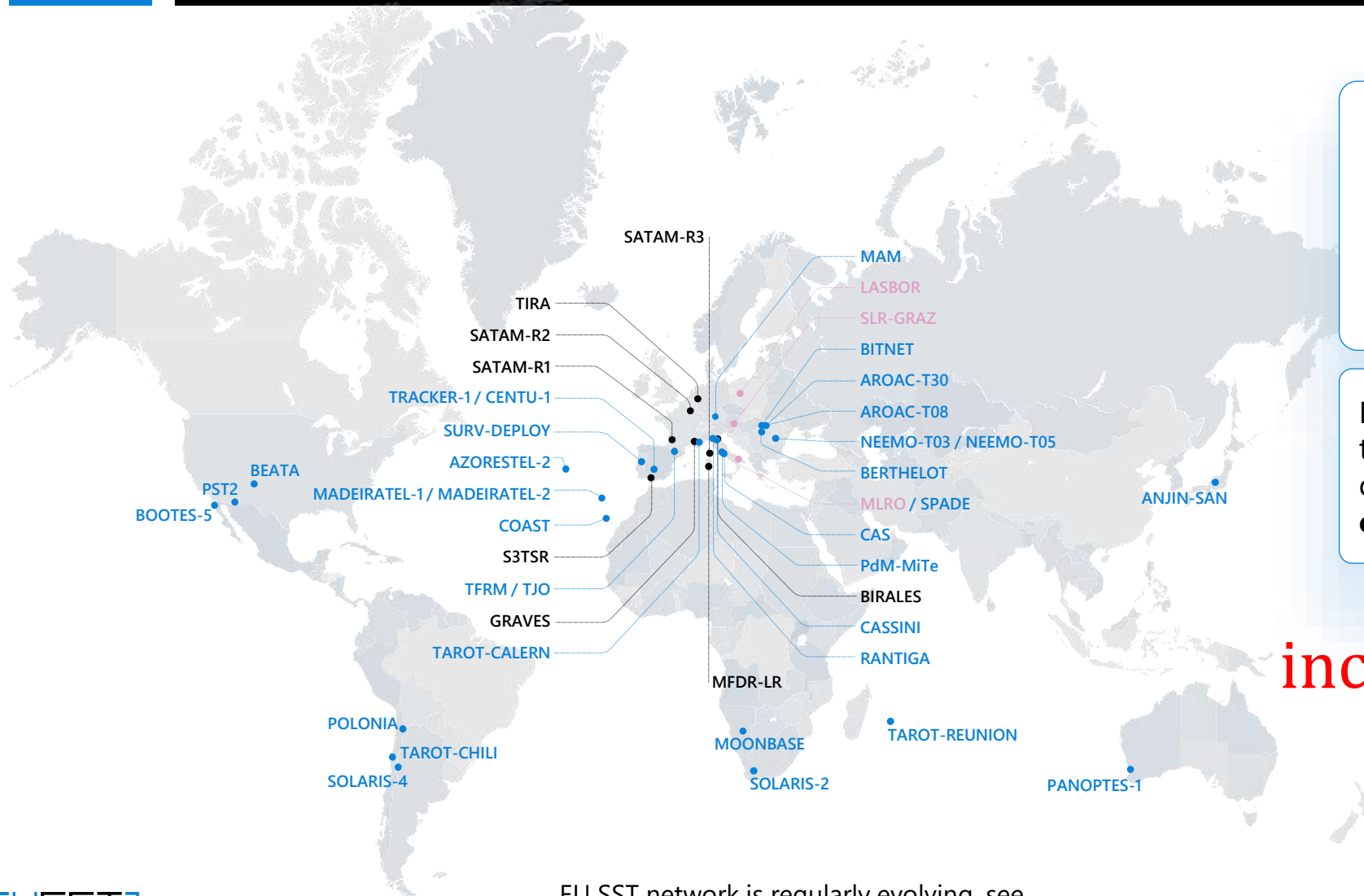
- **3 Lasers**
- **8 Radars**
  (2 surveillance, 6 tracking)
- **33 Telescopes**
  (17 surveillance, 16 tracking)

Dual approach which enables the use of sensors of different origins: **scientific, military and commercial**
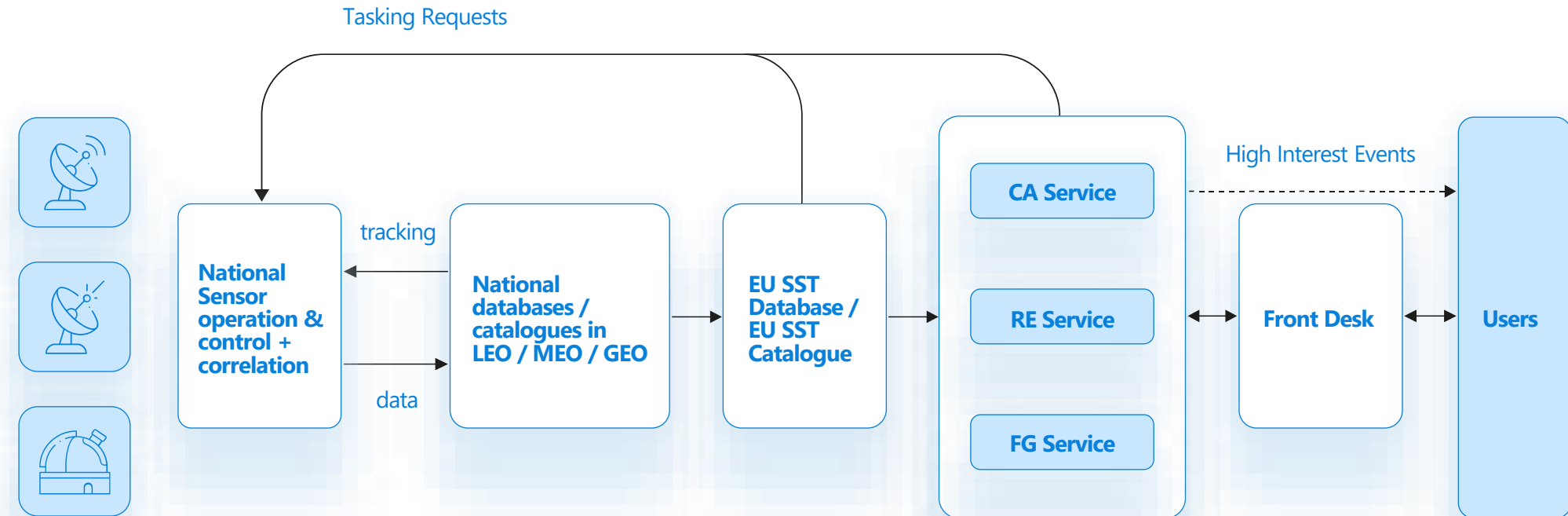
incl. "In Integration"

Map labels:
SATAM-R3, TIRA, SATAM-R2, SATAM-R1, TRACKER-1 / CENTU-1, SURV-DEPLOY, AZORESTEL-2, MADEIRATEL-1 / MADEIRATEL-2, COAST, S3TSR, TFRM / TJO, GRAVES, TAROT-CALERN, BEATA, PST2, BOOTES-5, POLONIA, TAROT-CHILI, SOLARIS-4, MOONBASE, SOLARIS-2, MFDR-LR, MAM, LASBOR, SLR-GRAZ, BITNET, AROAC-T30, AROAC-T08, NEEMO-T03 / NEEMO-T05, BERTHELOT, MLRO / SPADE, CAS, PdM-MiTe, BIRALES, CASSINI, RANTIGA, TAROT-REUNION, ANJIN-SAN, PANOPTES-1

EU SST network is regularly evolving, see
https://www.eusst.eu/about-us/

Operations ▪ Overview

Sensor Network

Data Processing

Service Provision

Tasking Requests

High Interest Events

tracking

data

National Sensor operation & control + correlation

National databases / catalogues in LEO / MEO / GEO

EU SST Database / EU SST Catalogue

CA Service

RE Service
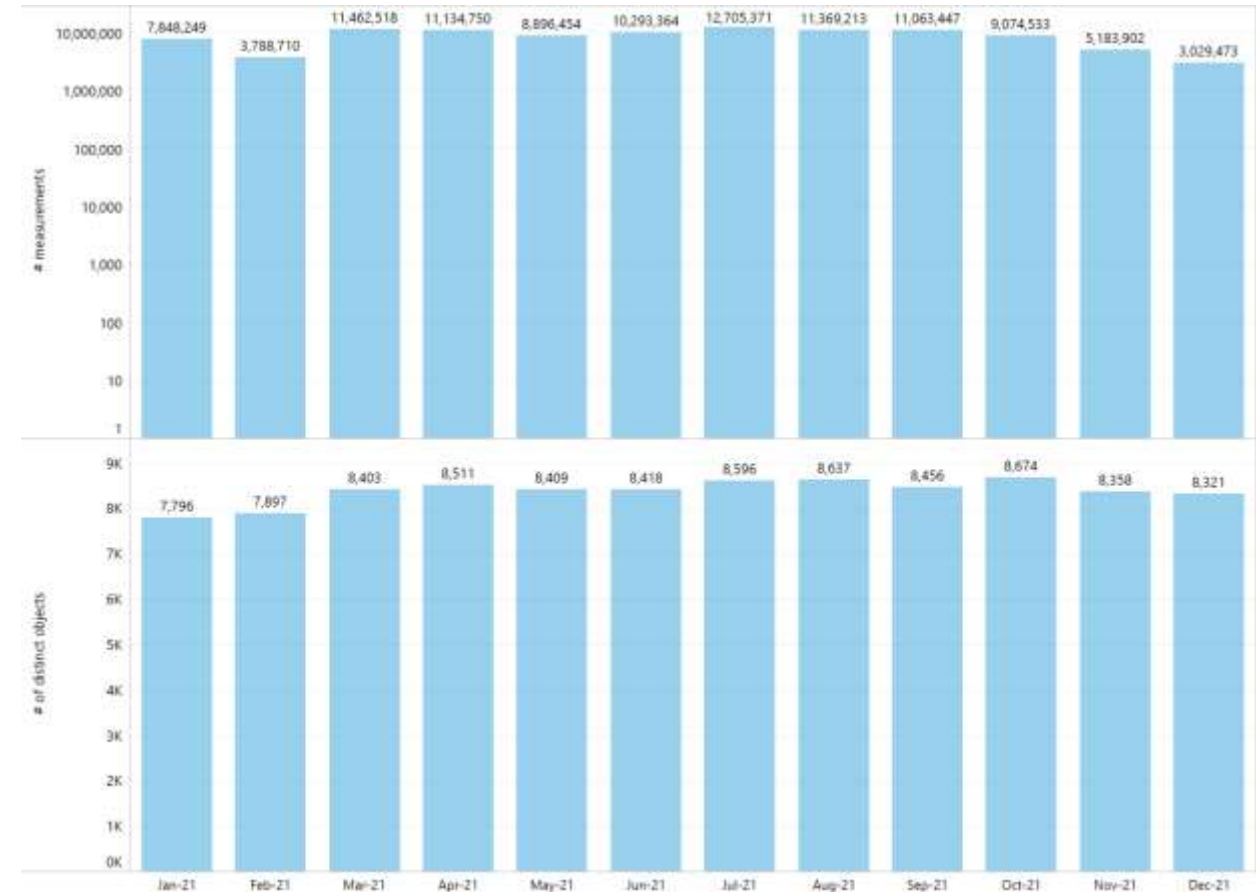
FG Service

Front Desk

Users

European database: data sharing in 2021

❚ Measurements exchanged in year 2021

- **TOTAL:**
  - ❑ 105 849 984 **(>100 million)**
  - ❑ 11 457 distinct objects**
- Average/day
  - ❑ 291 598 measurements/day
  - ❑ 3 595 distinct objects/day
- Maximum/day
  - ❑ 1 832 185 meas. (on 9 Aug)
  - ❑ 6 836 distinct objects (on 25 Oct)

** the number of distinct objects observed does not
imply they catalogued or even well observed

Service provision ▪ 3 Operational Services

Collision Avoidance (CA)

Risk assessment of collision and generation of collision avoidance alerts

Re-entry Analysis (RE)

Risk assessment of space objects re-entry into the Earth's atmosphere

Fragmentation Analysis (FG)

Detection and characterisation of in-orbit fragmentations

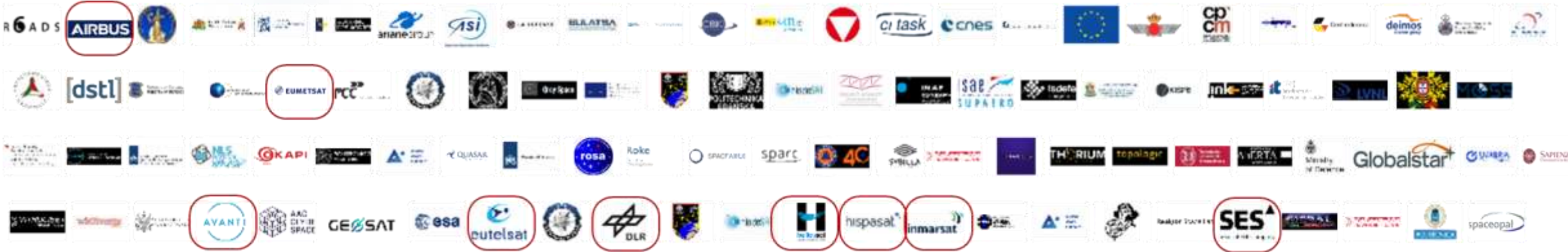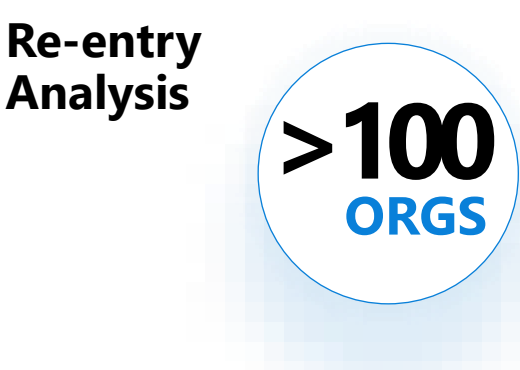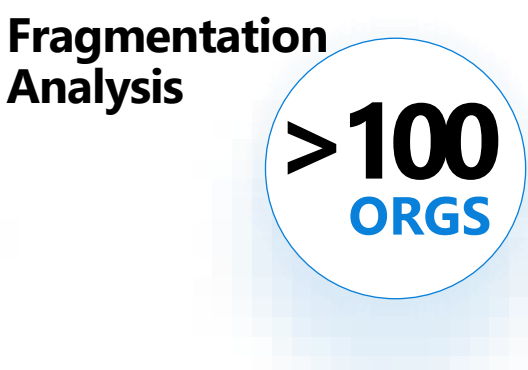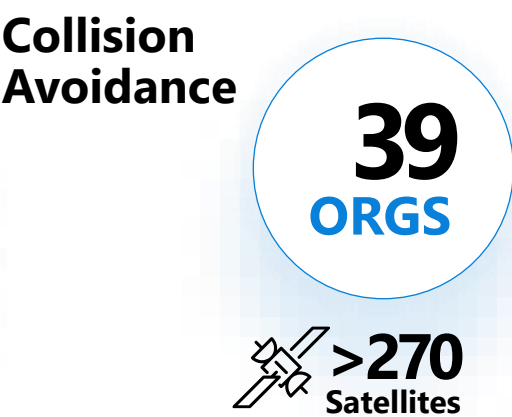|	Collision Avoidance (CA)	Re-entry Analysis (RE)	Fragmentation Analysis (FG)
Key features	▪ User-tailored service (SCD) ▪ Hot redundancy scheme with a single service provider ▪ Enhanced Analysis & Risk Mitigation support (e.g. covariance estimations, HBR estimations, PoC sensitivity analysis, CAM support, support for exceptional operations)	▪ Long-term (within 30 days) re-entry predictions ▪ Short-term (a few days) overflight predictions with ground tracks over customizable areas of interest	▪ 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)
Products	▪ Autonomous and enhanced CDMs ▪ CA Reports ▪ Monthly reports	▪ 30 days re-entry list ▪ RE reports	▪ Short-term notification ▪ Medium-term report ▪ Long-term report
Portal	▪ Access, download and upload information (API and web interface) ▪ Access documentation, administer fleets and configure notifications alerts ▪ View evolution of key parameters e.g. PoC and interactive graphs	▪ Access and download information (API and web interface) ▪ Configure notifications ▪ View evolution of re-entry window, and interactive ground track plots	▪ Access and download information (API and web interface) ▪ Receive notifications ▪ Access interactive graphs, fragment viewer and other dedicated content

Service provision ▪ Users

> **140 ORGS** 22 EU MS

Collision Avoidance — **39 ORGS** — **>270 Satellites**

Fragmentation Analysis — **>100 ORGS**

Re-entry Analysis — **>100 ORGS**

Satellites split by type

278 Satellites
251 manoeuvrable

LEO — 112

BIROS
SAR-LUPE 1, 2, 3, 4, 5
TET-1
TANDEM-X
TERRASAR-X
REAKTOR HW, Sunstorm, W-CUBE
DEIMOS 1, 2
METOP B, C
SENTINEL 1A, 1B, 2A, 2B, 3A, 3B, 5P, 6A
PAZ
UPMSat-2
ION-SCV 1, 2, 3
CHEOPS
TRISAT
Brik-II
NEPT-1
FossaSat 2E1, 2E2, 2E3, 2E4, 2E5, 2E6
Suomi-100

HELIOS 2A, 2B
VENµS
SARAL
CSO-1, 2
CALIPSO
JASON 3
PLEIADES 1A, 1B
SMOS
BRITE PL-1,PL-2
EYESAT
ANGELS
CERES 1,2,3
ELO3
XR-1, ICEYE-X9, X8, X7, X6, X5 , X4, X2, X1, X11, X12, X13, X14, X15, X16
GMS-T, Odin
NETSAT-1,2,3,4
GomX-4A. 4B

Globalstar M065, M066, M069, M070, M071, M072, M073, M074, M075, M076, M077, M078, M079, M080, M081, M082, M083, M084, M085, M086, M088, M089, M090, M091, M092, M093, M094, M095, M096, M097

MEO — 48

GSAT / Galileo 0101, 0102, 0103, 0104, 0201, 0202, 0203, 0204, 0205, 0206, 0208, 0209, 0210, 0211, 0207, 0212, 0213, 0214, 0215, 0216, 0217, 0218, 0219, 0220, 0221, 0222, 0223, 0224

O3B PFM, O3B FM 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

GEO — 118

COMSATBW-1, 2
XTAR-EUR
SPAINSAT
METEOSAT-8, 9, 10, 11
HYLAS 1, 2, 4
ASTRA 1KR, 1L, 1M, 1N, 1G, 2A, 2C, 2D, 2E, 2F, 2G, 3A,,3B, 5B
AMC 1, 3, 4, 6, 8, 11, 15, 18, 21
SES 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11,12, 14, 15 , 16/Govsat-1, 17
NSS 6, 7, 9, 10, 11, 12
SIRIUS 4, QUETZSAT 1, CIEL 2
EDRS-C

ATHENA-FIDUS
SYRACUSE 3A, 3B, 4A
HELLAS-SAT 2, 3, 4
INMARSAT 3F1, 3F2, 3F3, 3F5, 4F1, 4F2, 4F3, AF1, 5F1, 5F2, 5F3, 5F4, GX5, 6F1
EUTELSAT 10A, 16A, 172A, 21B, 25B, 28A, 28B, 36B, 3B, 5WA, 65W, 7WA, 70B, 7A, 7B, 8WB, 9A, 9B, HB 13B, 13C, 13D, KASAT 9A, 12WB, 172B, 7C, 5 WEST B, Konnect, Quantum
BULGARIASAT-1
AMAZONAS 2, 3, 5, HISPASAT 30W-5, 30W-6, 36W-1, 74W-1, 143W-1
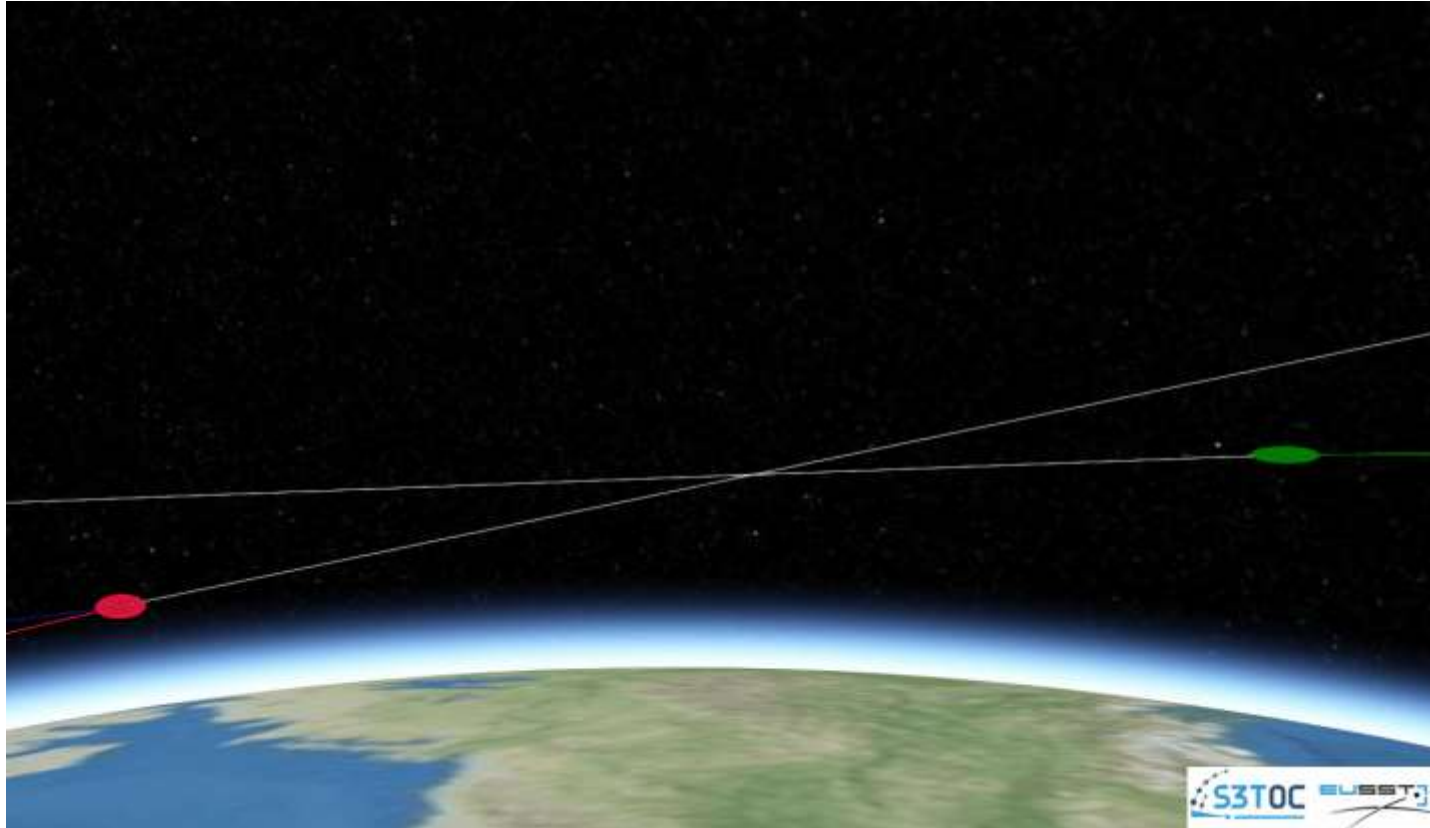Turksat 5B

Commercial 187 — **Govern./IGOs 62** — **Military 22** — **Universities / Research 7**

Updated as of 21/03/2022

Key concepts to undestand EU SST CA service

Operational interfaces and levels of service

▌ CA service provided by two OCs in Hot Redundancy: one nominal, one hot redundant per O/O: COO/CNES (FR) and S3TOC (ES)
- Nominal is the single point of contact, hot redundant analyses all conjunctions in background
- Allows for: independent verification, redundancy and fallback system in case of need

▌ Levels of service: according to Space Regulation 2021/696 art. 55.2

"SST services shall be available at any time without interruption"
- Two OCs available 24/7
  - Direct communication in case of high interest events (phone, mail)
  - Ad-hoc screenings and support per request
- Front Desk:
  - EU SST Service Provision Portal as main secure interface: availability of >99.9%
  - Helpdesk highly available ~CET office hours for user support, registration, enquiries

▌ Security: *"secure exchange of SST data and SST information"*
- information and data policy governing the handling of data
- security by design principle
- regular security assessments and penetration tests

CA service characteristics

▌ Tailored thresholds

- For three levels of event severity: **HIE (alert), IE (warning)** and **INFO**
- For providing manoeuvre recommendations (if required)

▌ To start the CA service the users shall...

- Give Access to FR and ES to 18th SPCS CDMs
- Share ephemerides with EU SST
- Agree on the interfaces and level of thresholds for the service provision
  → The service is provided in three levels according to
  - Geometry and/or
  - Scaled probability of collision (see next slide)

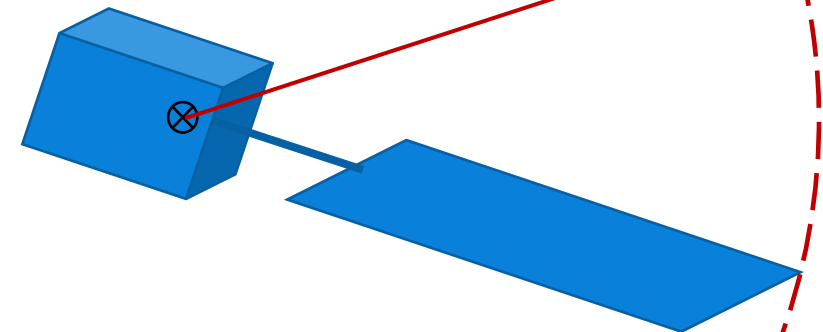# Key concepts to understand EU SST CA service (1/3)

▌ EU SST uses the **Scaled PoC to compute the level of risk**

- **Covariance is the key factor** to compute Probability of Collision
- Coefficients kp and ks for magnitude of variation of dispersions for primary and for secondary have been chosen from a statistical analysis in the past.
- C (covariance) = kp Cp + ks Cs with kp and ks independent scale factors applied to respective covariance
- Scaled PoC is defined as the maximum value of PoC when kp and ks are in a realistic interval chosen after statistical analysis in the past

EVENT_A - Scaled PoC Analysis
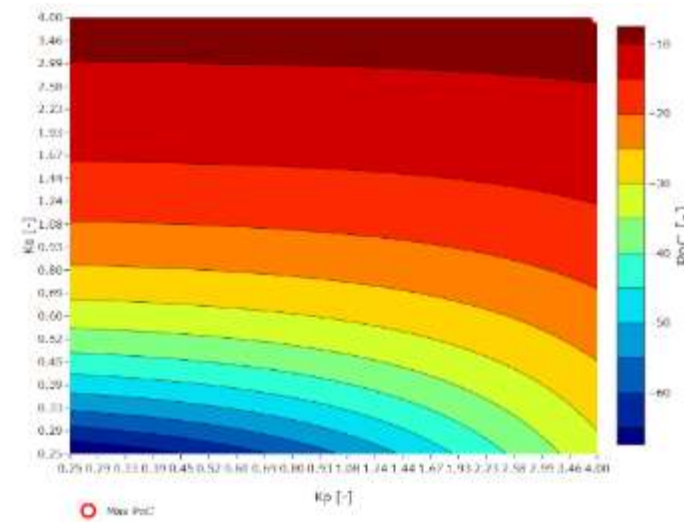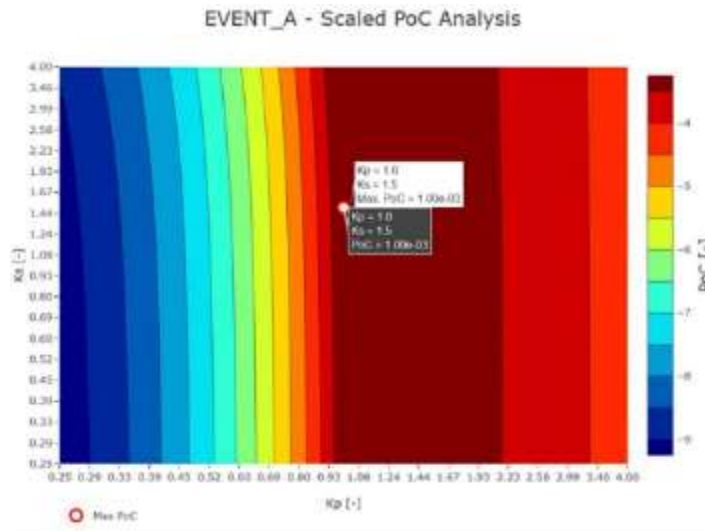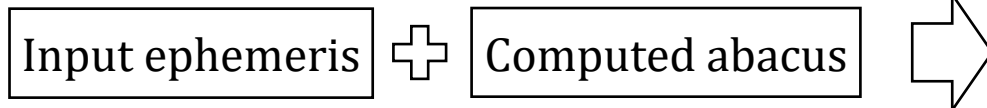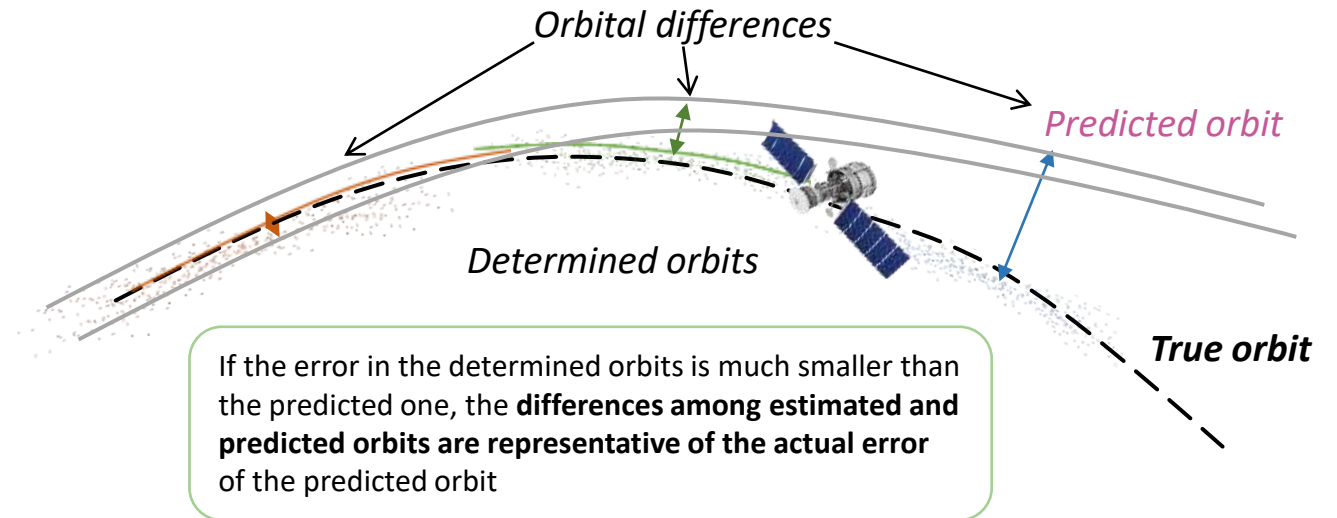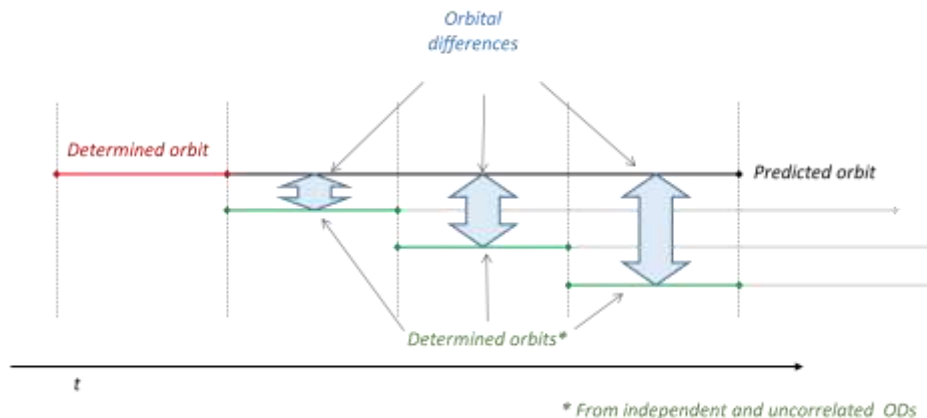
Key concepts to understand EU SST CA service (2/3)

▌ The concept of Hard Body Radius (HBR) is used to compute the Scale PoC, **HBR refinement leads to a higher quality of the CA service**

- Too conservative HBR leads to higher PoC → Need to avoid unnecessary avoidance manoeuvres
- HBR is defined as the radius of the minimum sphere centered at the centre of gravity of the S/C that contains the whole spacecraft when all deployable components, if any, are extended (e.g. the distance between the centre of gravity of the spacecraft to the outermost component).
  - HBR of S/C can be decreased if attitude is known
    - User can provide an attitude ephemerides or a look-up table
  - HBR of secondary objects may be computed from:
    - DISCOS database for payloads or R/B
    - Satcat information

HBR

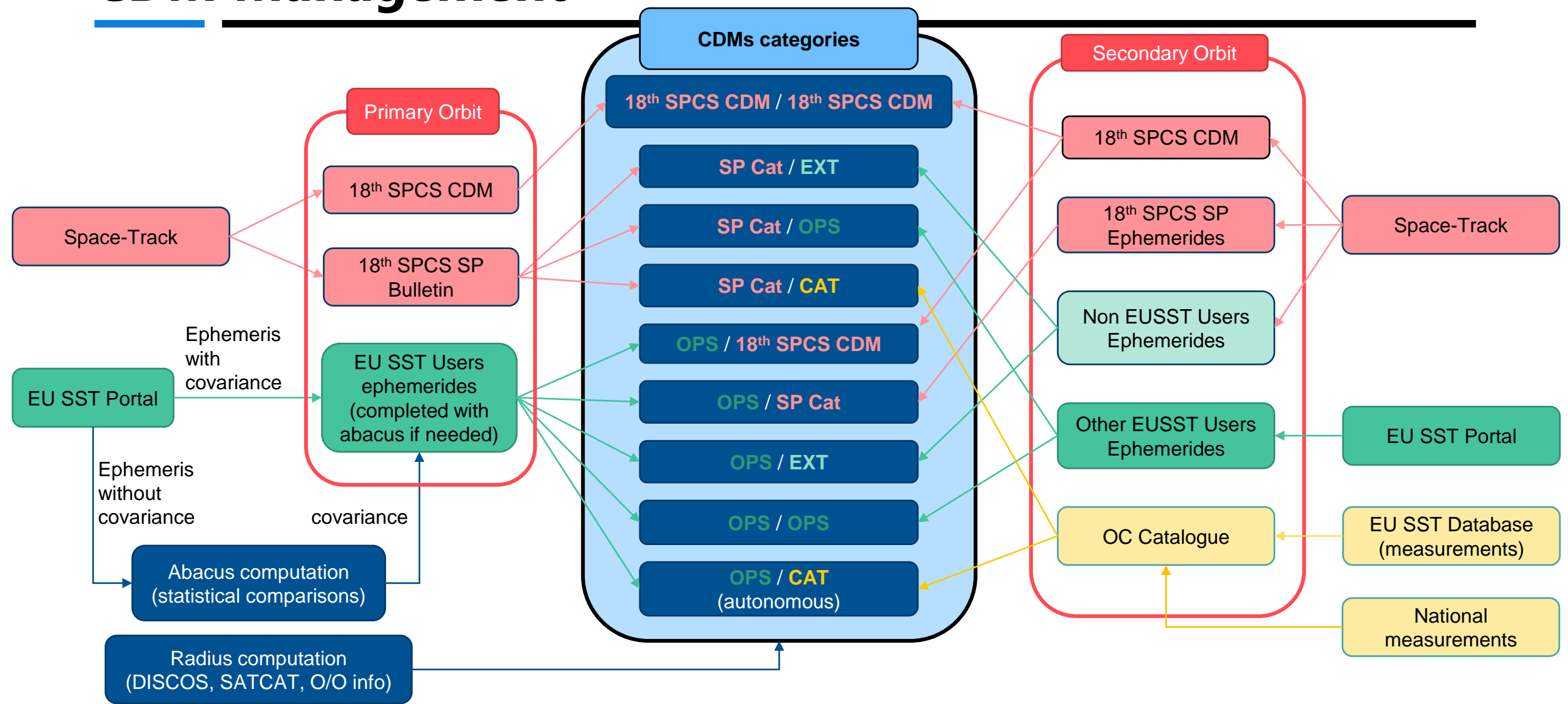# Key concepts to understand EU SST CA service (3/3)

- **O/O ephemeris analysis** to enhance quality of CA service
  1. Computation of a covariance abacus: Covariance is **not usually provided** by most ephemerides sources or it might not be realistic, thus requiring methods to estimate it with no more information than sets of ephemerides


If the error in the determined orbits is much smaller than the predicted one, the **differences among estimated and predicted orbits are representative of the actual error** of the predicted orbit

Input ephemeris ➕ Computed abacus ➡ OEM with covariance used for the CA analysis

CDM Management

CDMs categories

- 18th SPCS CDM / 18th SPCS CDM
- SP Cat / EXT
- SP Cat / OPS
- SP Cat / CAT
- OPS / 18th SPCS CDM
- OPS / SP Cat
- OPS / EXT
- OPS / OPS
- OPS / CAT (autonomous)

Primary Orbit

- 18th SPCS CDM
- 18th SPCS SP Bulletin
- EU SST Users ephemerides (completed with abacus if needed)

Space-Track

EU SST Portal

Ephemeris with covariance

Ephemeris without covariance

covariance

Abacus computation (statistical comparisons)

Radius computation (DISCOS, SATCAT, O/O info)

Secondary Orbit

- 18th SPCS CDM
- 18th SPCS SP Ephemerides
- Non EUSST Users Ephemerides
- Other EUSST Users Ephemerides
- OC Catalogue

Space-Track

EU SST Portal

EU SST Database (measurements)

National measurements

CA service characteristics: Support to Mitigation actions

▌**Mitigation recommendation** and **manoeuvre support**
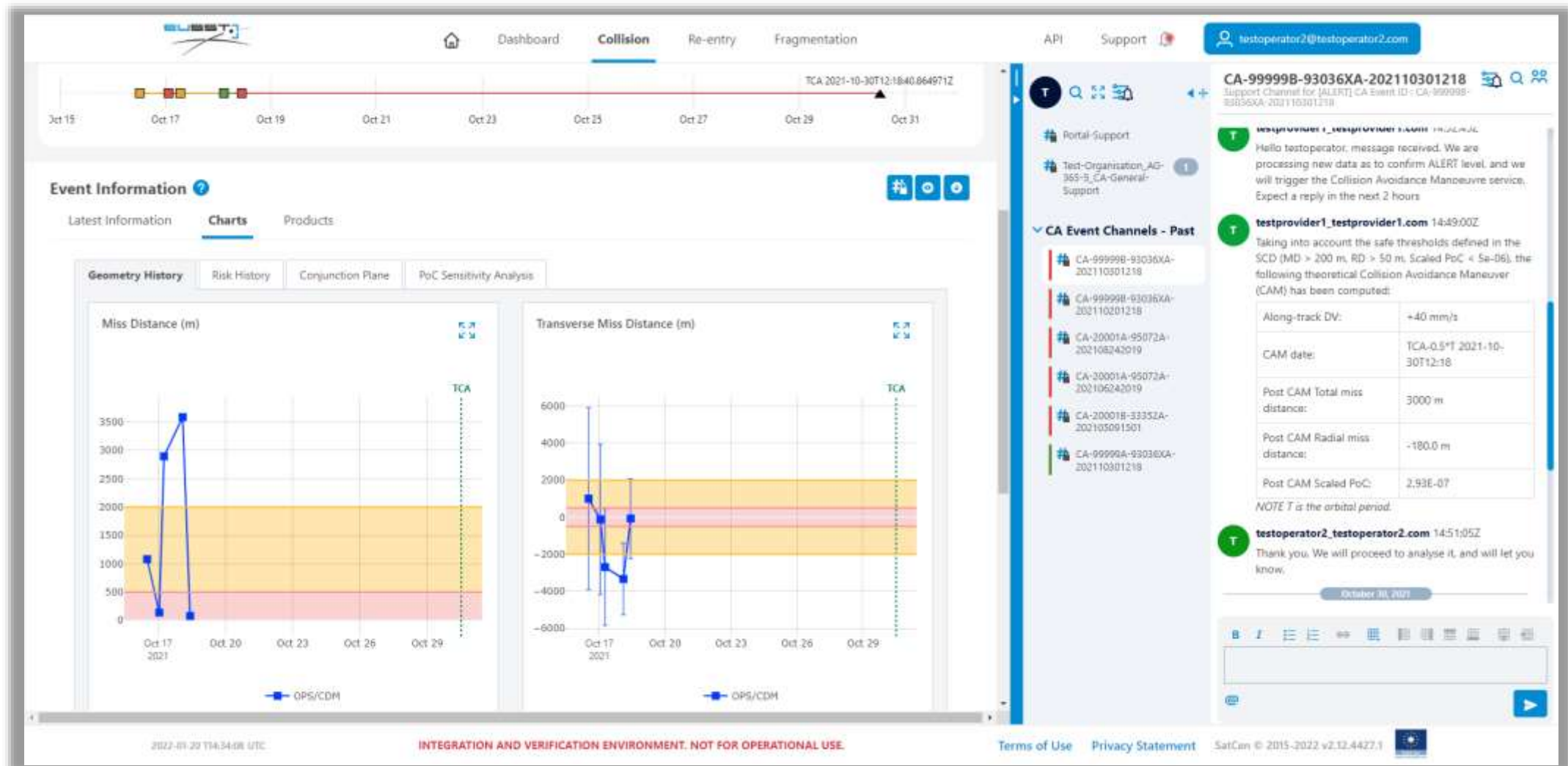- Triggered by HIE detection or at O/O request
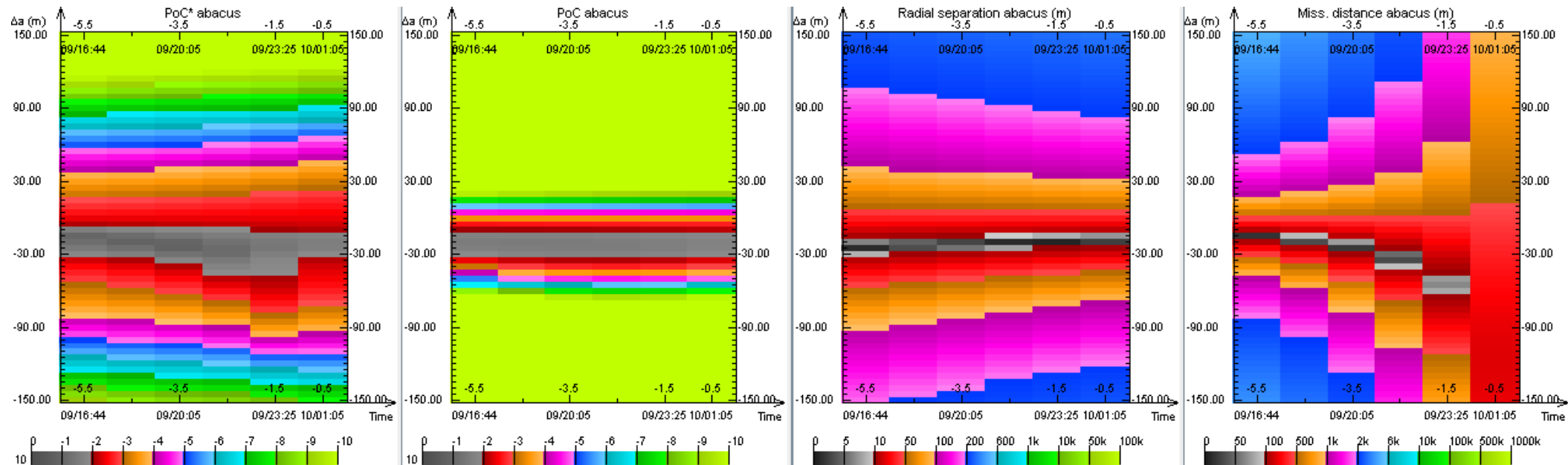
Looking at the future
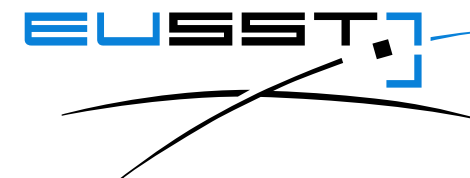
Future services or expansion of current ones

▮ Inter-Orbit Radio Frequency Interference (RFI) anticipation and characterization

▮ On-Ground RFI localization

▮ O/O post-manoeuvre analysis and support to EOL operations & LEOP / EOR follow-up phases

▮ Platform for communication and coordination of S/C operators registered as CA users in EU SST

▮ In-orbit contingency / anomaly support

▮ ADR and in orbit proximity operation support through attitude and relative orbit characterization

▮ Potential hazardous objects identification

▮ Monitoring and Supporting of the compliance with international guidelines / standards (offline) on Safety of Operations in Space

▮ Publicly available subset of the EU SST catalogue for commercial, non-commercial and research purposes

▮ ...

Communication and Coordination Platform Prototype

Thank you