European Commission

EU Space Surveillance and Tracking
Service Portfolio

EUSST

Space

Content

Cover image (from left to right and from top to bottom): CASSINI telescope (Italy), TJO telescope (Spain), GRAVES radar transmitter (France), NEEMO telescope (Romania), SOLARIS-2 telescope (Poland), MLRO laser (Italy), GRAVES radar receiver (France), TIRA radar (Germany), S3TSR radar (Spain).

The EU SST Service Portfolio
is available on the SST Portal at: https://portal.eusst.eu

Second edition

Disclaimer

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Foreword by the Chair of the SST Cooperation

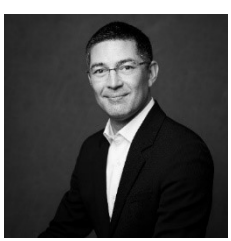
Space is becoming increasingly busy, with new and more diverse actors, the development of large constellations, and a multiplication of small satellites. The fast-changing environment brings many opportunities, but also the unprecedented risk of collisions, and potential threats given the dual nature of space activities.

To protect space-based infrastructure, facilities and services, Space Situational Awareness is a key capability. Knowing and understanding events across different orbital regimes underpins the resilience of European Union space programmes such as Galileo and Copernicus.

Space Situational Awareness is a shared responsibility. In 2014, the European Union established the Space Surveillance and Tracking (EU SST) Support Framework. France, Germany, Italy, Poland, Portugal, Romania and Spain, in cooperation with the EU Satellite Centre, have gradually networked their capabilities across sensor, data-processing and service functions to support the operations and decision-making of owners and operators of space assets, civil protection authorities and other European entities.

Today, more than 240 spacecraft of the European Union and its Member States – civil, military and commercial – are protected from risk of collision in all orbit regimes. For some members, there is a 40-years legacy in satellite operations and a large flight dynamic expertise which brings trust for our European users and operators. EU SST is also providing more than 130 organisations with free, added-value services in re-entry and fragmentation analysis. Our services are based on space surveillance and tracking data shared between EU SST Member States through an operational database and data provided by external partners.

EU SST and its services are presented in this document. With the adoption of the new EU Space Programme, more Member States will be part of EU SST, and more users will benefit from our services in the coming years. We invite you to register and become part of our growing SST user community.



Dr Pascal Faucher

Chair of the SST Cooperation

EU SST: Safeguarding European space infrastructure

The safety and security of European economies, societies and citizens rely on space-based applications such as communication, navigation and observation. However, due to the growing complexity of the orbital environment, space-based assets are increasingly at risk from collision with other operational spacecraft or debris. At the same time, objects may re-enter and cause damage on the ground. To mitigate these risks, we need to be able to survey and track such objects, and to provide this information to a variety of stakeholders.

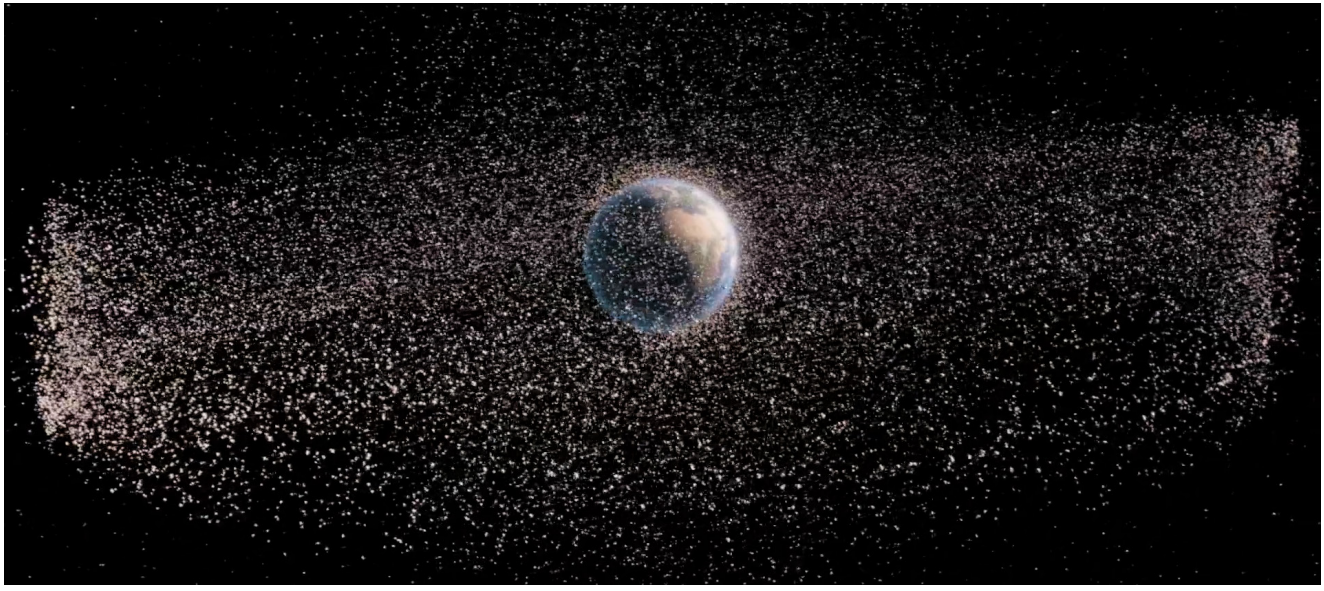


Illustration of space debris. It is estimated that about 1 million objects larger than 1cm currently orbit the Earth.

The Space Surveillance and Tracking (SST) Support Framework was established by the European Union in 2014[1], foreseeing the creation of an SST Consortium currently composed of seven EU Member States – France, Germany, Italy, Poland, Portugal, Romania and Spain. An SST system is a network of ground-based and space-based sensors capable of surveying and tracking space objects, together with processing capabilities aiming to provide data, information and services on space objects that orbit around the Earth.

[1] *Decision 541/2014/EU of the European Parliament and the Council Establishing a Space Surveillance and Tracking Support Framework.*

Since 2016, the SST Consortium and the European Union Satellite Centre (SatCen) have worked together to develop a European SST capability, and formed the SST Cooperation. The Consortium's Member States have networked their assets to provide, through the SatCen, a set of SST services to all EU countries, EU institutions, spacecraft owners and operators, and civil protection authorities.

The SST services assess the risk of in-orbit collisions and uncontrolled re-entry of space debris into the Earth's atmosphere, and detect and characterise in-orbit fragmentations.

The SST Consortium EU Member States are represented through their national designated entities: France (CNES), Germany (German Space Agency at DLR), Italy (ASI), Poland (POLSA), Portugal (PT MoD), Romania (ROSA), and Spain (CDTI).

GRAVES radar

MLRO laser ranging station

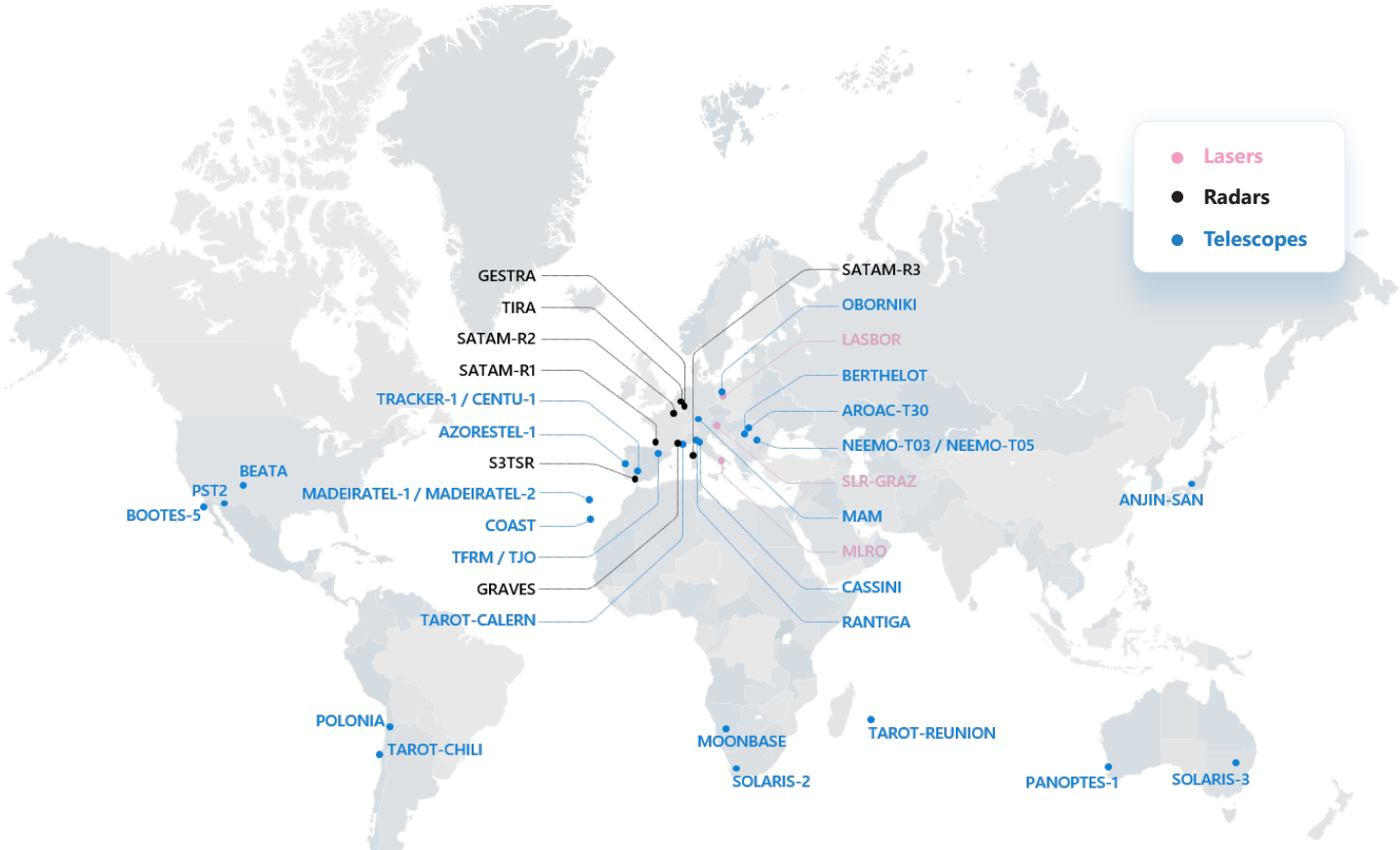
TIRA radar

TJO tracking telescope

The SST Capability

The SST capability consists of three main functions: sensor, processing and service provision. Sensors from Member States contribute data that is analysed in the processing function and feeds a joint database and ultimately a catalogue; from this, products are derived for three services, generated by the **Operations Centres (OCs)** and delivered to users via the **SST Service Provision Portal (SST Portal).**

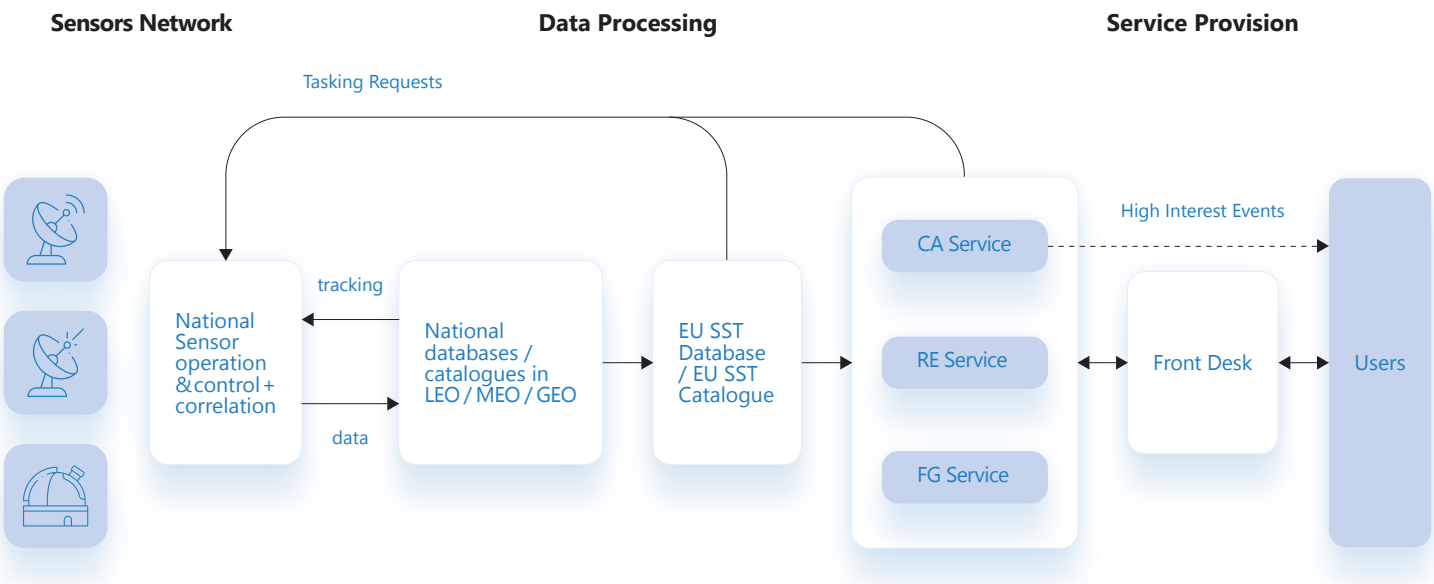
The **Sensor function** consists of a network of sensors to survey and track space objects in all orbital regimes (LEO, MEO, HEO and GEO). The network currently comprises 38 sensors of the Member States of the SST Consortium (incl. radars, telescopes and laser ranging stations).



EU SST Sensors Network (Oct 2021)
The network of sensors is updated regularly based on calibration and integration procedures.
Check the latest version on the EU SST website.

The **Processing function** aims to coordinate the data-sharing between the different OCs via a common database and to process thousands of daily measurements from the sensors contributing to EU SST. These data constitute the basis for a future EU SST Catalogue that will be used for the SST services. Germany is responsible for hosting the EU SST Database and generating the future EU SST Catalogue.

The **Service Provision function** is in charge of providing the SST services – Collision Avoidance (CA), Re-entry Analysis (RE) and Fragmentation Analysis (FG) – to users through a secure portal, managed by the SatCen, who acts as Front Desk. Currently, more than 130 organisations are receiving these services and 240+ European satellites are safeguarded from the risk of collision. The French and Spanish OCs are responsible for the CA service, while the Italian OC is in charge of the RE and FG services.

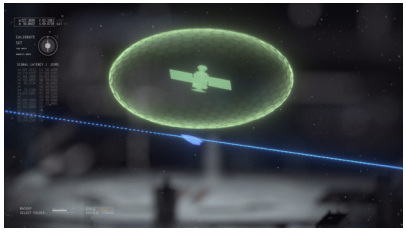


The SST Services

The SST capability provides three distinct services:

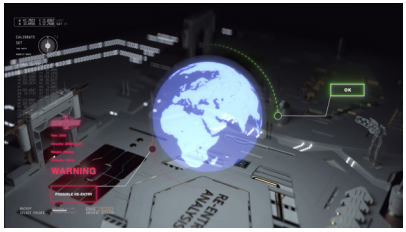
Collision Avoidance (CA)

The Collision Avoidance service provides risk assessment of collision between spacecraft or between spacecraft and space debris, and generates collision avoidance alerts.



Re-entry Analysis (RE)

The Re-entry Analysis service provides risk assessment of uncontrolled re-entry of man-made space objects into the Earth's atmosphere, and generates related information.



Fragmentation Analysis (FG)

The Fragmentation Analysis service provides detection and characterisation of in-orbit fragmentations, break-ups or collisions, and analyses all the available information regarding the object(s) involved in the event.

In all three services, for critical operations and events of media interest, EU SST produces in a timely and coordinated manner dedicated outputs to inform key stakeholders and for dissemination purposes.

The SST services are provided upon request to all EU Member States, the European Council, the European Commission, the European Union's External Action Service, public and private spacecraft owners and operators, and public authorities concerned with civil protection.

Access to the services is free of charge and requires registration in the SST Portal (https://portal.eusst.eu). To become a registered user and be able to access one or more SST services, it is necessary to fill in a registration form, upon which the request will follow an approval process.

Collision Avoidance Service

The Collision Avoidance (CA) service provides risk assessment of collision between spacecraft and between spacecraft and space debris, and generates collision avoidance alerts. It analyses all available information (e.g. EU SST contributing sensors data, external Conjunction Data Messages – CDMs) in order to detect:

- **Info Events (INFOs):** close approaches with a low level of risk;
- **Interest Events (IEs):** close approaches that require further analysis due to the level of risk, and
- **High-Interest Events (HIEs):** close approaches with a high level of risk, potentially requiring **Collision Avoidance Manoeuvres (CAMs)** to be performed by the Owner/Operator (O/O).

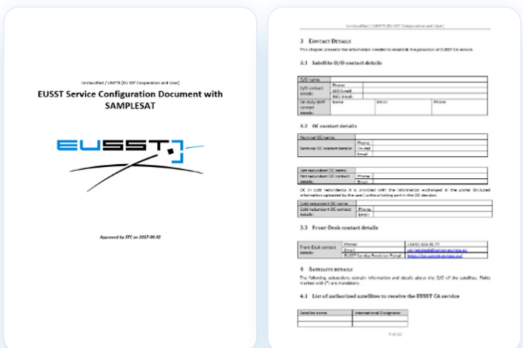
When required, tasking requests are sent to all sensors contributing to EU SST. Finally, a set of products are provided to the O/O. In case of need, direct dialogue can be established with the OC, 24/7, to help the O/O to better understand the event, discuss the products provided and enable the OC to propose CAMs based on the O/O constraints.

Key features

The CA service is a **user-tailored service**, allowing the user to configure the thresholds for risk-level categorisation (i.e. HIE, IE and INFO) and advice on CAMs, based on geometrical, probabilistic and time variables.

This is done through a **Service Configuration Document (SCD)**, where the operational interfaces are also defined (e.g. files format, points of contact). The definition of this document, done in a collaborative manner between the O/O and the OC in charge and the Front Desk, is required before the service is provided.

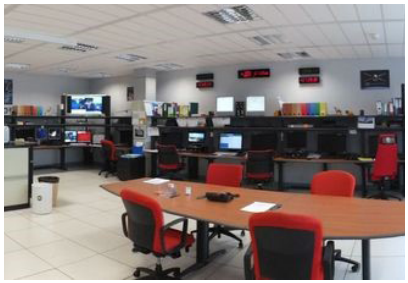
The Service Configuration Document is accessible at the SST Portal.



Service Configuration Document

The CA service is provided on a **hot redundancy scheme** involving the French and Spanish OCs (FR-SSA and S3TOC), whereby two different OCs are ready to provide the services as a **single service provider** (the nominal OC). This provides robustness to the services while minimising the interfaces with the user. This scheme allows cooperation between the two OCs and analysis of discrepancies, if any.

The hot-redundant OC processes and generates products simultaneously with the nominal OC (without contact with the O/O), has visibility on O/O inputs and products provided by nominal and direct dialogue, and takes the lead only in case of nominal OC failover.



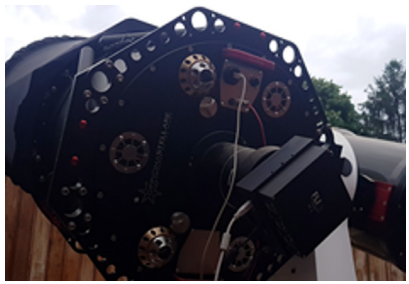
French SSA Center (FR-SSA)

SatCen SST Front Desk

SLR Graz laser ranging station

S3TSR radar

SOLARIS-2 telescope



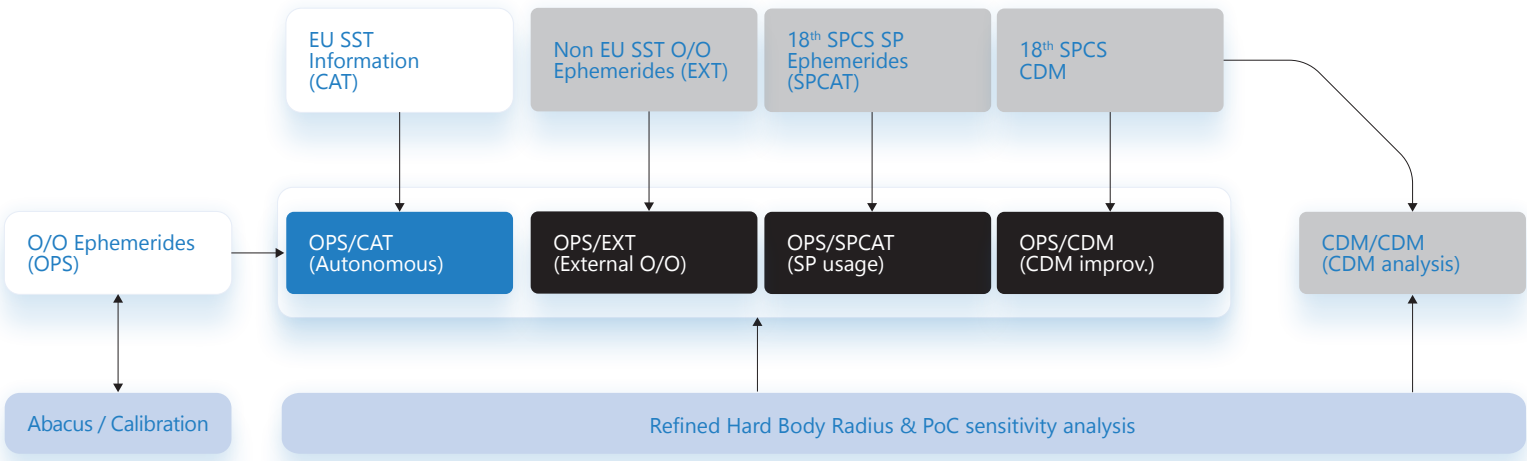
NEEMO telescope

The CA service provides three types of products: CDMs, reports associated with each CDM, and monthly reports.

The CDMs can be:

- **autonomous CDMs** (either OPS/CAT or OPS/EXT), based on the internal or external O/O ephemerides (known as OPS or EXT) and on data from the EU SST network of sensors (known as CAT, which are currently based on national catalogues), and
- **enhanced CDMs**, based on using and refining external information (such as the US 18th SPCS[1] CDMs and Special Perturbations (SPs) ephemerides). Using 18th SPCS SP ephemerides enables tasking sensors in advance of the first 18th SPCS detection/notification (1st 18th SPCS CDM) and confirming when an event decreased its risk level (and thus stopped being reported by the 18th SPCS).

The different combinations of input information and consequent main types of EU SST CA CDMs are displayed in the diagram below.



The EU SST will provide autonomous CDMs (when available) and enhance the CDM provided by the 18th SPCS. The users will receive one or more CDM types depending on the input data available for generating the CDMs.

For all CDMs produced, the OCs perform **O/O ephemerides analysis**, advance **management of Hard Body Radius (HBR)** values and **Probability of Collision (PoC) Sensitivity analysis**. Ultimately, support may be provided to the O/O to mitigate the risk and define a **CAM**. However, the O/O is the sole responsible for deciding whether or not to implement an avoidance action.

[2] The 18th Space Control Squadron (18th SPCS) performs the space surveillance mission for the US Air Force. 18th SPCS CDMs are provided through space-track.org, and access to them is required for the OCs to provide enhanced products.

Enhanced Analysis & Risk Mitigation support

O/O ephemerides

Covariance estimations. Compute covariance abacus by comparing statistically the predicted and determined (observed) orbits.

Ephemerides calibration on user request, or when an issue is detected by the nominal OC, based on an independent orbit determination using data from the EU SST contributing sensors (CATvsCAT CDMs).

Routine accuracy checks, e.g. consistency with the CA Service configuration document, and with external data sources.

HBR management

For the primary object, the HBR used is provided by the O/O. The O/O can ask for a concrete HBR value to be used for particular conjunction events (when geometry is known) and provide additional information to compute more realistic HBR.

For the secondary, HBR used is taken (in priority order) from ESA's DISCOS database, from space-track.org (SATCAT info with minimum of 1m for small objects), or from default values based on Operations Centre's information.

PoC sensitivity analysis

Non-precise estimations of the objects' covariance can result in an underestimation of the PoC value. It is best to find the maximum PoC by performing a parametrical analysis, reducing and incrementing the assumed covariance for both objects in an interval representative of the uncertainty of the covariance matrices. This analysis results in better insight into the conjunction event and provides a more conservative estimation of the PoC.

The OCs perform a sensitivity analysis of the PoC with respect to the covariance; the value used operationally is a scaled PoC.

CAM support

Definition of one or more potential avoidance manoeuvres, considering potential constraints from the O/O.

Verification against all available sources of information that the manoeuvre is also safe for other potential conjunctions.

Support for exceptional operations

Screening of large manoeuvres (specific screening volumes, specific methods to compute PoC).

Dedicated process to provide feedback as soon as possible.

Products

Conjunction Data Message (CDM). This product is a standard message for use in exchanging spacecraft conjunction information between originators of collision assessments and satellite O/Os. This format is used to exchange the orbital information and related uncertainties of both objects involved in a conjunction event. As it is provided for each type of CA product (autonomous or enhanced), the source of orbit information is included.

Collision Avoidance Report. This product complements each CDM delivered, containing a detailed analysis of the event with supporting information; e.g. risk level, scaled PoC, and different plots such as conjunction plane and risk evolution.

Monthly reports, which provide summary information to each O/O on all the close approaches analysed.

CA Report

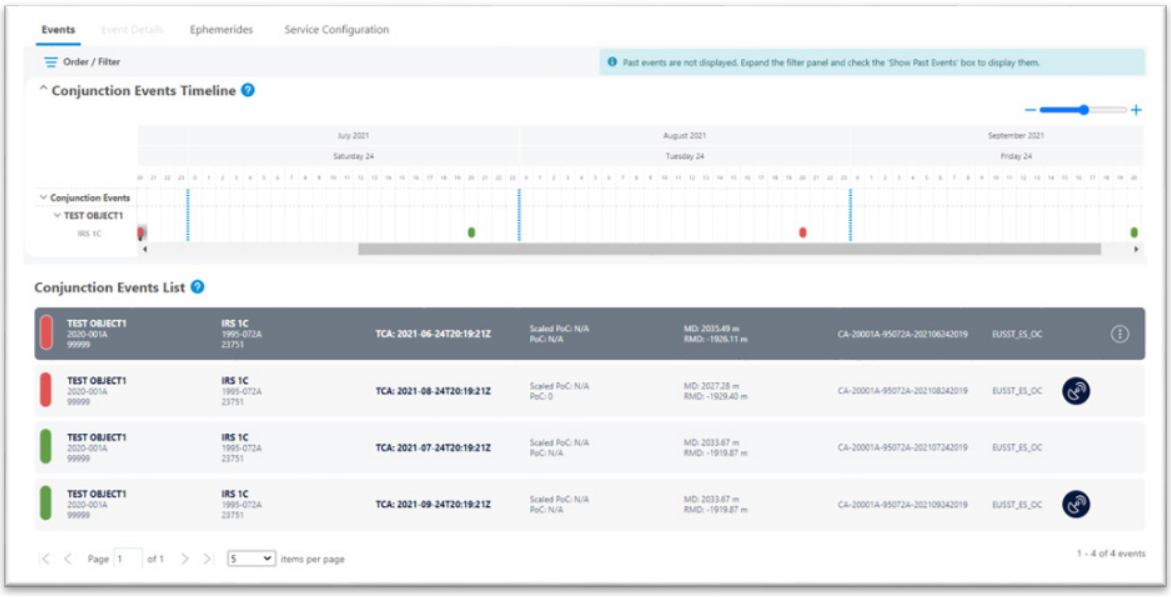
Portal

The delivery of the CA service between users and the nominal OCs is carried out via the SST Portal and complemented by direct dialogue between the O/O and the nominal OC established when needed according to the SCD (with traceability to SST Front Desk and redundant OC).

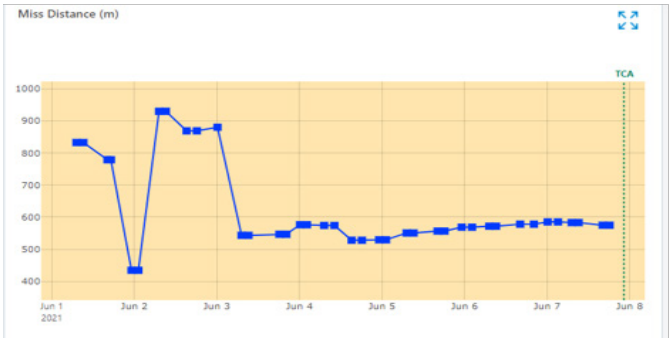
The SST Portal enables users to:

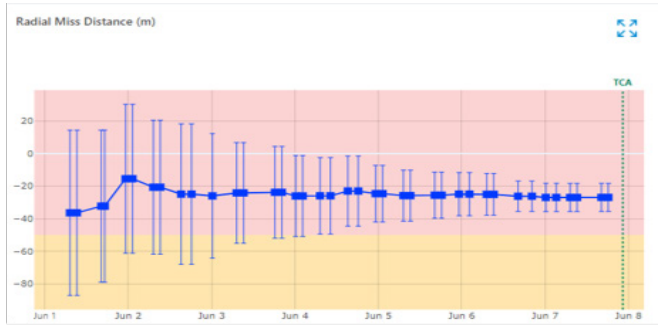
- access CA events and service products information, or download them, either through its REST API or through its web interface;
- upload ephemerides and manoeuvre information (or any other type of file), either through the REST API or the web interface;
- view the evolution of conjunctions (i.e. PoC, scaled PoC, and miss distance);
- download the applicable CA Service Configuration Document and its template document;
- customise the CA service's email notification configuration; and
- access the CA service monthly statistical report.

An integrated communications platform will be available in the SST Portal. It will allow the users to directly communicate with the OCs and the Front Desk on general and CA event specific matters, and will be the basis for a future O/O coordination platform.



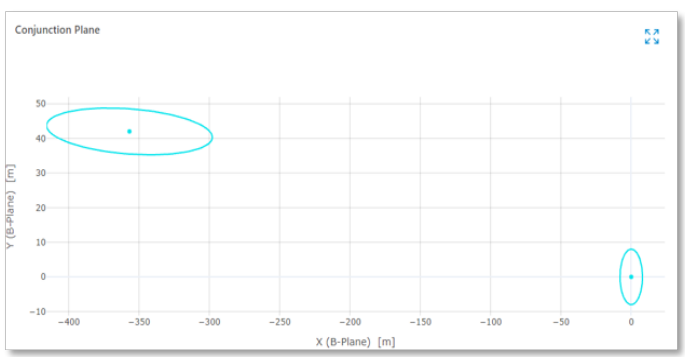
CA events in the SST Portal

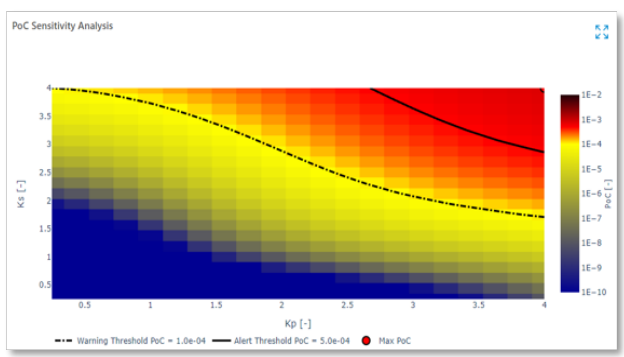




Example of the Miss Distance evolution

Example of the Risk History evolution based on PoC and Scaled PoC





Conjunction Plane and PoC Sensitivity Analysis

Re-entry Analysis Service

The Re-entry Analysis (RE) service provides risk assessment of the uncontrolled re-entry of manmade space objects into the Earth's atmosphere that may constitute a potential risk to the safety of EU citizens and to terrestrial infrastructure. All available information (data from sensors contributing to EU SST and other re-entry information from external sources) is analysed in order to carry out re-entry predictions, both **long-term** (within 30 days) and **short-term** (a few days). The latter include overflight predictions providing ground tracks over customisable areas of interest.

Key features

The RE service, provided by the Italian OC (C-SSA), routinely monitors all rocket bodies, specific objects of interest and objects with a mass greater than 2,000kg or, if no mass information is available, radar cross-section larger than 1m². When such objects are close to re-entry, C-SSA sends a tasking request to all sensors contributing to EU SST, in order to acquire additional data and improve the accuracy of predictions, generating autonomous products, if possible.

The service is customised by allowing users to select **Areas of Interest (AOIs)**, in the form of EU countries and their related territories, and receiving the re-entry products accordingly.

Considering the **uncertainties surrounding re-entry predictions, the AOI is derived from the overflight analysis**, without any certainty that the re-entering objects will impact on the specified territory.

Re-entry products are associated to a risk index related to the estimated mass of the object. The index can be adjusted by the OC in charge of the service on case by case analysis, based on the available knowledge on the re-entering object (composition, material, etc.), and on the computation approaches at its disposal.

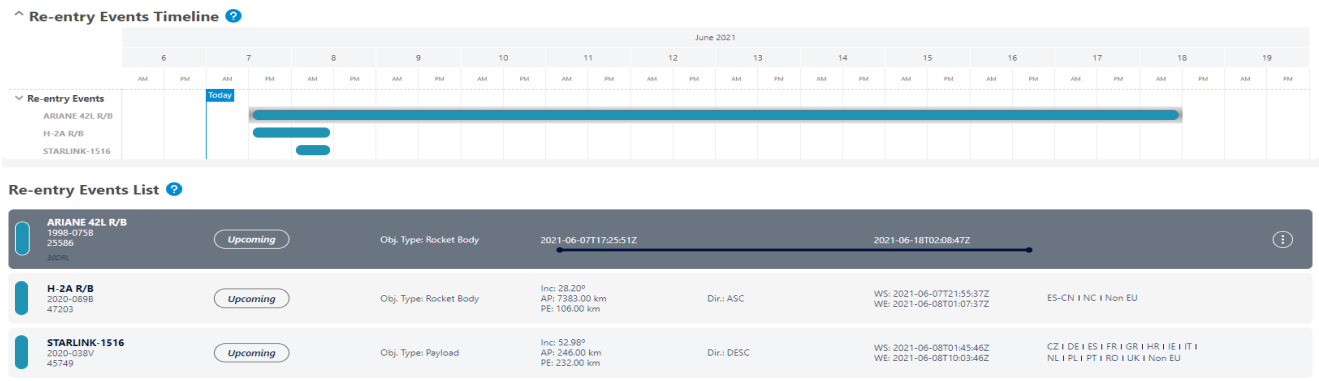
RE service AOIs configuration in the SST Portal

Object mass	Unknown mass	m < 5,000 kg	5,000 kg < m < 8,000 kg	m > 8,000 kg
Risk Index	Not available	Minor	Medium	Major

Object mass and Risk Index correlation for RE products

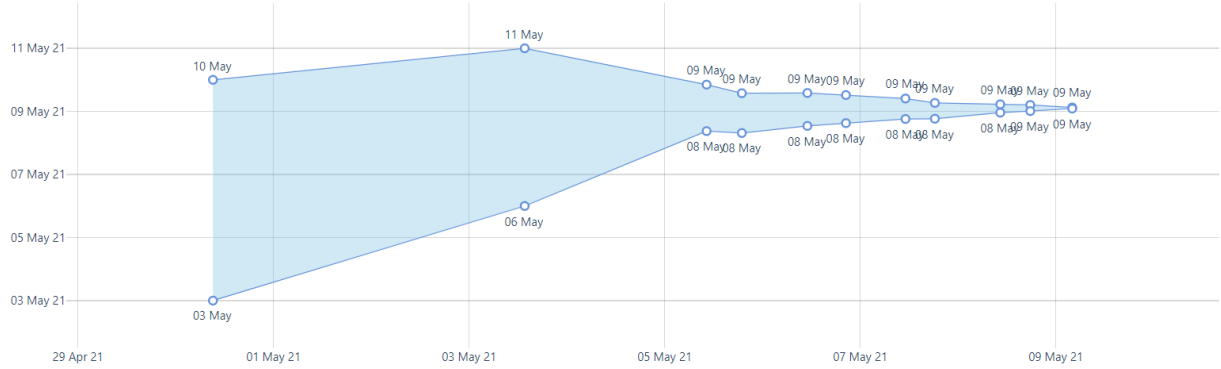
Products

30 Days Re-entry List. This product provides a list of all space objects predicted to re-enter the Earth's atmosphere in an uncontrolled manner within 30 days. The list is available to users through the SST Portal, and updated on a weekly basis or when necessary.



30 Days Re-entry List

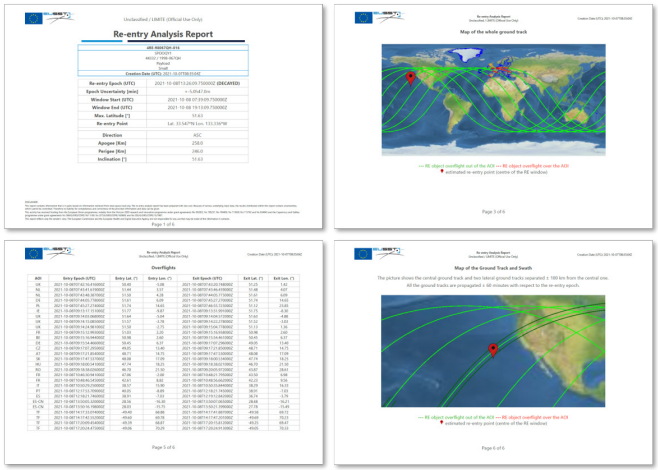
This long-term analysis prediction includes a re-entry window evolution with an accuracy of one day, as presented in the figure below.



RE Window Evolution in the SST Portal

Re-entry Report. This product includes a detailed analysis focusing on the objects expected to re-enter approximately 3-4 days before the predicted re-entry epoch. This Re-entry Report complements the 30 Days Re-entry List by providing orbital information, ground tracks as 2D maps for the overflight, and the ground swath to confirm the re-entry in the final report.

Confirmation of the re-entry event is also provided through a final/decay RE report, which is released either after space-track decay confirmation or no later than three days after the last re-entry epoch estimation, or after three no-shows by sensors contributing to EU SST.

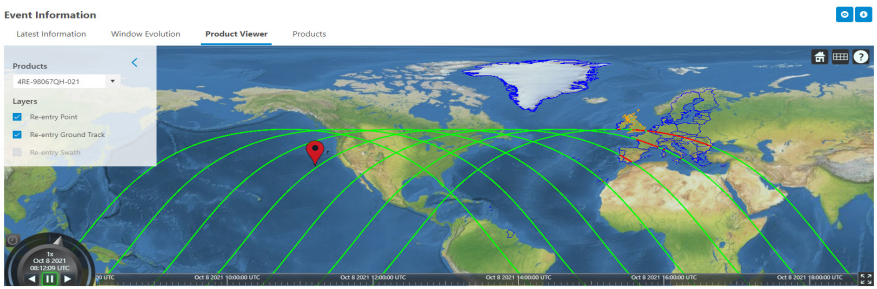


Re-entry Report

Portal

The delivery of the RE service between the approved users and the OC is carried out via the SST Portal, which enables users to:

- access RE service products information, or download the RE reports, either through its REST API or its web interface;
- customise the 30 days re-entry list or RE reports email notifications configuration;
- view the re-entry window prediction evolution of a particular space object, and
- configure the user's AOI.



RE Product Viewer

Fragmentation Analysis Service

The Fragmentation Analysis (FG) service provides detection and characterisation of in-orbit fragmentations. All available information (data from sensors contributing to EU SST and other fragmentation information from external sources, i.e. 18th SPCS or O/O) is subjected to short, mid and long-term analysis, concluding with the provision of different FG products.

Key features

The **Short-term FG analysis** aims to confirm quickly an FG event, providing:

- the data sources (from sensors contributing to EU SST and/or external sources);
- fragmentation event characterisation (e.g. FG event type, number of detected fragments, orbital regime), and
- object(s) identification and characterisation (e.g. object type, apogee/perigee of the parent object(s) at the event time).

The **Medium-term FG analysis** provides further details on the event, based on the orbital parameters of the catalogued fragments. This analysis includes:

- fragments distribution delivered as visual information (e.g. Gabbard diagram);
- 3D graph of the position of the object(s) at the event time;
- 3D cloud evolution of the fragments at the time of the report creation and after 1-2 months;
- orbital parameters dispersion of the fragments at different moments in time, and
- early Impact Risk Analysis for specific altitude layers including assets of interest (e.g. Galileo and Copernicus fleets).

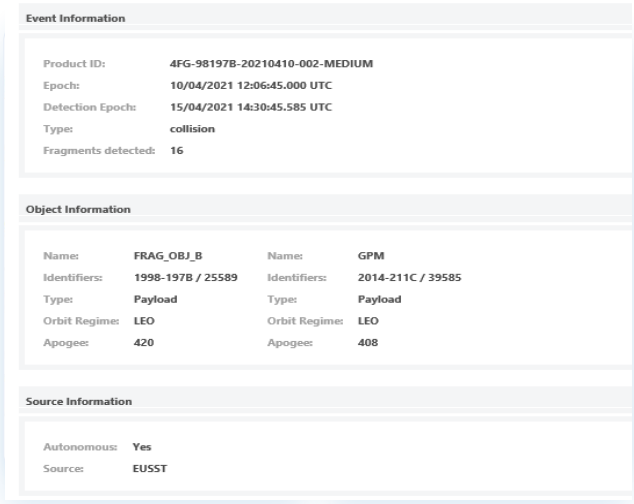
The **Long-term FG analysis** complements previous analyses, with information on:

- event update;
- simulations of the event using an adequate breakup/collision model;
- number of fragments expected greater than 7cm;
- Area to Mass ratio distribution;
- Delta Velocity distribution, and
- objects' spatial density evolution.

These analyses are subject to the information available for each FG event, with C-SSA sending a tasking request to the EU SST sensors as soon as the event is confirmed.

Products

- **Short-term FG analysis notification**. This product consists of an email notification sent once the event is confirmed. Since fragmentation events may be difficult to detect, the short-term product might take a few days to be delivered.
- **Medium-term FG analysis report**. This is generated when fragments are catalogued and their orbital parameters are known, within three weeks after the short-term FG analysis product.
- **Long-term FG analysis report**. This provides further analysis on the evolution of the fragments, within three months after the short-term FG analysis product.



Event Information

Product ID:	4FG-98197B-20210410-002-MEDIUM
Epoch:	10/04/2021 12:06:45.000 UTC
Detection Epoch:	15/04/2021 14:30:45.585 UTC
Type:	collision
Fragments detected:	16

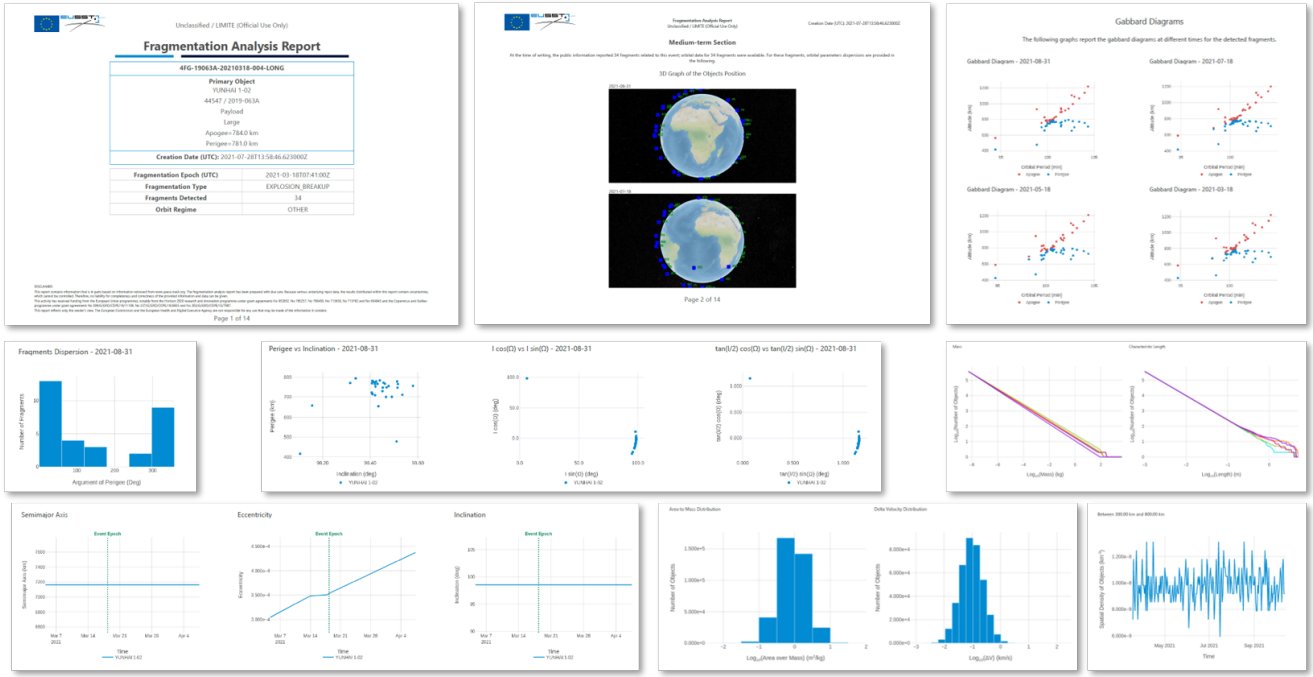
Object Information

Name:	FRAG_OBJ_B	Name:	GPM
Identifiers:	1998-197B / 25589	Identifiers:	2014-211C / 39585
Type:	Payload	Type:	Payload
Orbit Regime:	LEO	Orbit Regime:	LEO
Apogee:	420	Apogee:	408

Source Information

Autonomous:	Yes
Source:	EUSST

Email notifications (FG events)

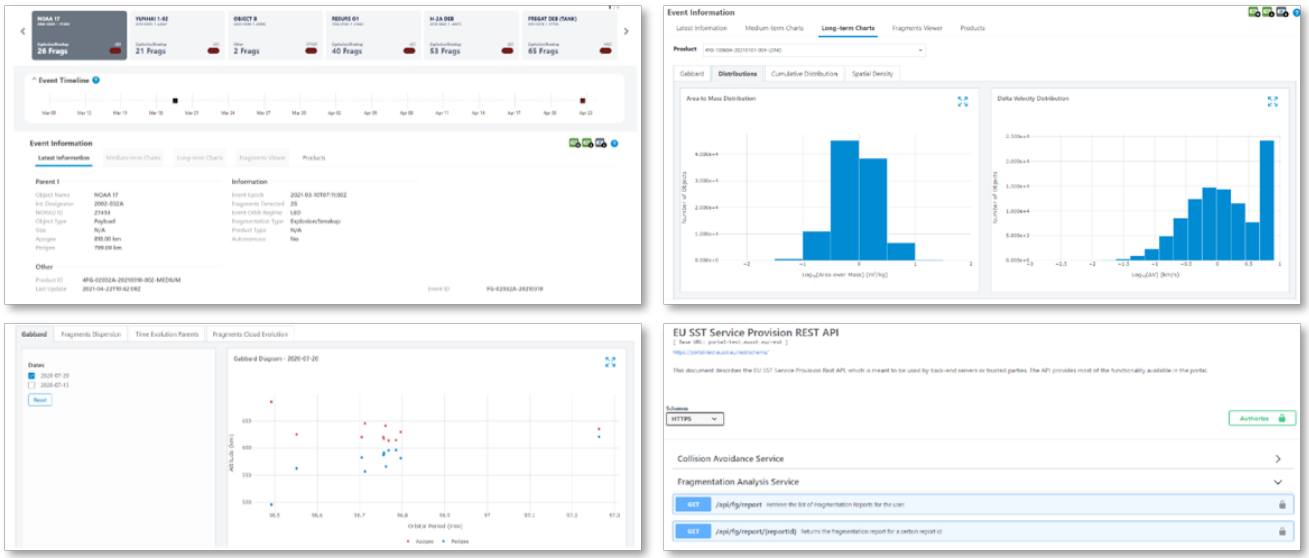


FG long-term analysis report

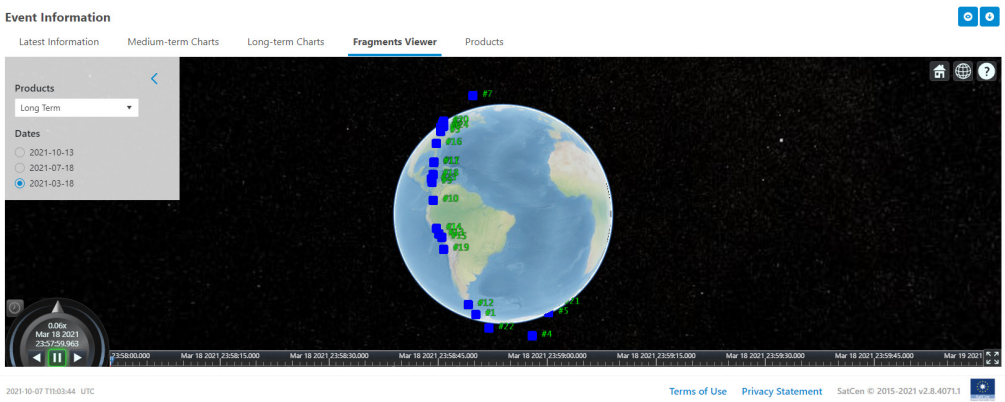
Portal

The delivery of the FG service between the approved users and the OC is carried out via the SST Portal, which enables users to:

- access the information of FG service products or download them, either through its REST API or its web interface, and
- receive email notifications when new/updated FG products are available.



FG service web and REST API interfaces



FG service fragments viewer on the SST Portal

Glossary

Autonomous Product
Product generated with data from national sensors contributing to EU SST.

Conjunction Event
Close approach of two or more space objects that triggers a set of analyses and produces SST information related to a single conjunction.

EU SST Catalogue
A catalogue of orbit data to be generated by the EU SST. It shall allow predicting the position, velocity and associated uncertainty of the objects for generating the EU SST services.

EU SST Database
A database that hosts data from EU SST contributing sensors, orbits from national catalogues, and from the EU SST Catalogue.

Fragmentation Event
Destructive disassociation of a single space object into two or more pieces that may trigger a set of analyses and produce SST information related to a single fragmentation and/or fragments.

High-Interest Event
Conjunction event that has miss distances less than or equal to and/or a collision probability higher or equal to given ALERT thresholds, defined by the O/O in the SCD.

Hot Redundant OC
Operation Centre in charge of supporting the service provision, simultaneously and collaboratively with the nominal OC.

Info Event
Conjunction event with a low risk level, provided optionally to the user to complement close approach products (with INFO thresholds defined by the O/O).

Interest Event
Conjunction event with miss distances less than or equal to and/or in a collision probability higher or equal to given WARNING thresholds defined by O/O in SCD.

Nominal OC
OC in charge of providing the service through the SST Portal.

Re-entry Event
Space object re-entering the Earth's atmosphere that may trigger a set of analyses and produce SST information related to a single re-entering object.

Service Configuration Document
Document containing the service configuration, and operational and technical interfaces between the O/O and SST Cooperation for the CA service.

SST Consortium
Consortium of national entities established in the context of the SST Support Framework, formed by France, Germany, Italy, Poland, Portugal, Romania and Spain.

SST Cooperation
Cooperation of the SST Consortium and SatCen in the scope of the SST Support Framework.

SST Front Desk
Infrastructure and related interfaces, SST Portal and Helpdesk, to provide SST services to users.

SST Portal
Main interface for delivering SST services to users in accordance with the Data Policy.

Acronyms

18th SPCS
US Air Force Space Control Squadron

AOI
Areas of Interest

API
Application Programming Interface

ASI
Italian Space Agency / Agenzia Spaziale Italiana

C-SSA
Italian Operations Centre / Centro Space Situational Awareness

CA
Collision Avoidance

CAM
Collision Avoidance Manoeuvre

CAT
OC CATalogue source for CDM generation

CDM
Conjunction Data Message. CCSDS standard.

CDTI
Centre for Development of Industrial Technology / Centro para el Desarrollo Tecnológico Industrial

CNES
National Centre of Space Studies / Centre National d'Études Spatiales

DLR
German Aerospace Centre (German Space Agency at DLR) / Deutsches Zentrum für Luft und Raumfahrt

ESA
European Space Agency

EU
European Union

EU SST
European Union Space Surveillance and Tracking

FG
Fragmentation Analysis

FR-SSA
French SSA Center

GEO
Geosynchronous Equatorial Orbit

HBR
Hard Body Radius

HEO
Highly Elliptical Orbit

HIE
High-Interest Event

IE
Interest Event

LEO
Low Earth Orbit

MEO
Medium Earth Orbit

O/O
Satellite Owner/Operator

OC
Operations Centre

OPS
O/O ePhemeriS source for CDM generation

PoC
Probability of Collision

POLSA
Polish Space Agency

PT MoD
Portuguese Ministry of Defence

RE
Re-entry Analysis

ROSA
Romanian Space Agency

S3TOC
Spanish SST Operations Centre

SatCen
European Union Satellite Centre

SCD
Service Configuration Document

SP/SPCAT
Special Perturbations catalogue from 18th SPCS

SST
Space Surveillance and Tracking

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