EU SST
Space Surveillance and Tracking

Ensuring space safety
and sustainability

Space Situational Awareness

FUTURE EVOLUTIONS OF EUSST COLLISION AVOIDANCE SERVICE

04/05/2024

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#EUSpace

PROGRAMME OF THE
EUROPEAN UNION

Current EUSST Service

Collision Avoidance (CA)

Risk assessment of conjunctions and generation of collision avoidance alerts

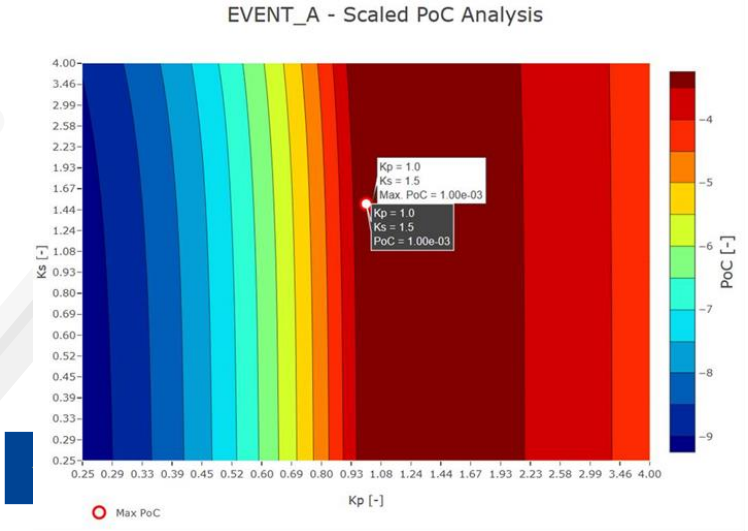
Described in the EUSST Service portfolio :
https://portal.eusst.eu/portalng/public-download/ServicePortfolio

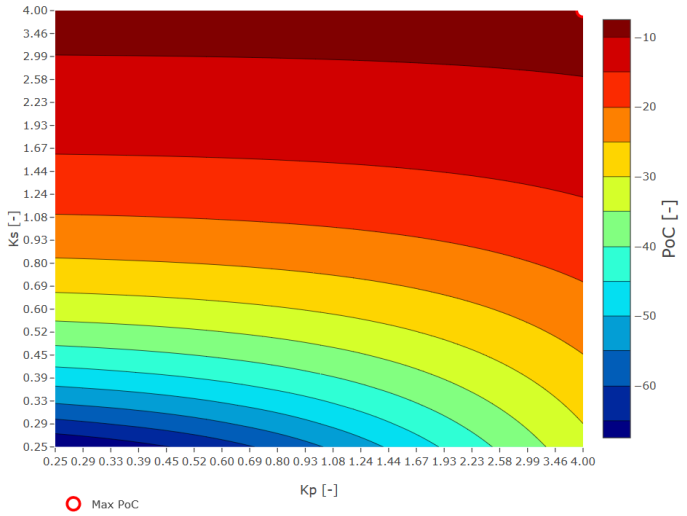
Key features

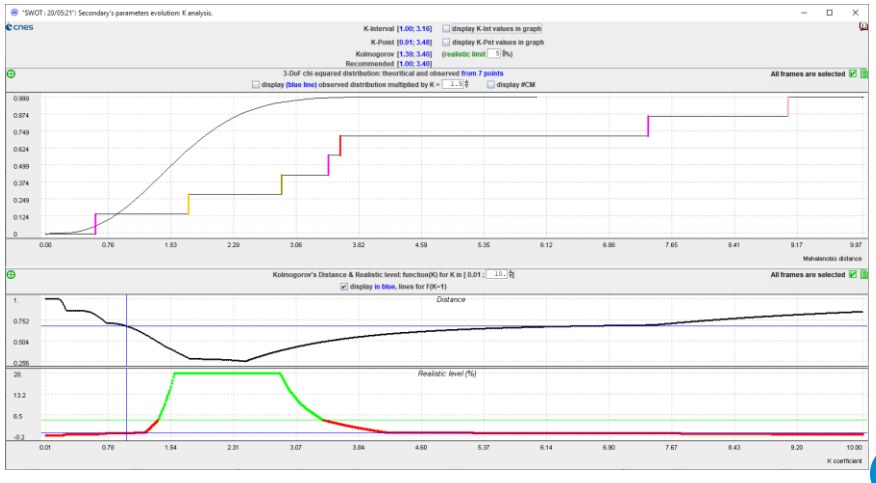
- **Provision of CDM** upon several set of thresholds (INFO, WARNING, ALERT)
- **User-tailored** service (Service Configuration Document):
  - Ephemerides and Maneuver Information are welcomed in CCSDS format, but other formats are also accepted
  - Thresholds (PoC , Radial Separation & Miss Distance, Time to TCA) can be configured
- **Hot redundancy scheme involving ES (S3TOC) and FR (CAESAR)** with harmonised service level and single service provider per registered user
- **Enhanced Analysis** support (e.g. covariance estimations, HBR estimations, PoC sensitivity analysis and Scaled PoC computations)
- **Risk Mitigation** support : CAM support if requested
- **On call team** available 24/7 to perform analysis, ensure the coordination with operators, provide support to operators requests
- Support to **exceptional operations** (LEOP, End of Life, relocations,…)

Key Concept - Scaled PoC

- EU SST uses the **Scaled PoC** to compute the risk level
- **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 (combined 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
- Realistic intervals of kp and ks are computed automatically from past CDMs of the conjunctions



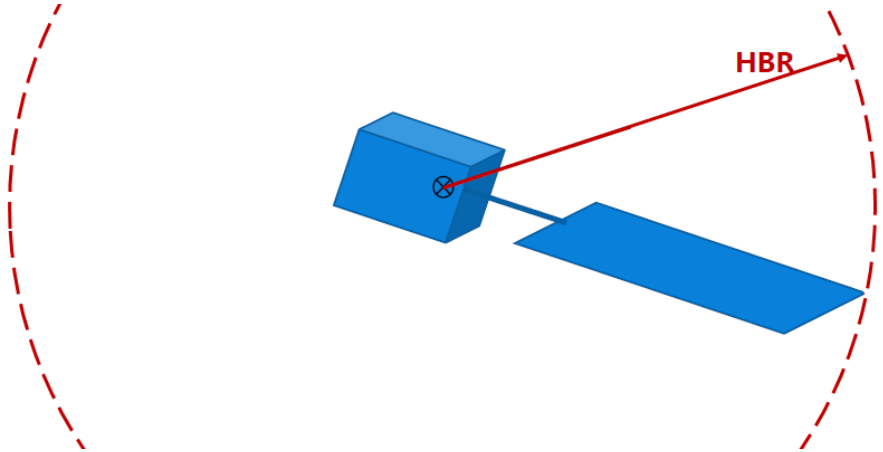




Key Concept - Hard Body Radius

- The concept of Hard Body Radius (HBR) is used to compute the Scaled PoC, **HBR refinement leads to a higher quality of the CA service**
  - Too conservative HBR leads to higher PoC
    - → Refinement needed to avoid unnecessary avoidance manœuvres
    - → Refinement needed to avoid oversized manœuvres

  - HBR = radius of the sphere, centered at the Center Of Gravity, containing the whole S/C
  - HBR of S/C can be decreased if attitude is known
    - Users can provide an attitude ephemeris or a look-up table
  - HBR of secondary objects may be computed from:
    - DISCOS database for payloads or R/B
    - SATCAT information



Key Concept – CDM Management

- EUSST manages several data sources of orbit
  - For primary objects
    - O/O ephemerides : “Ops”
  - For secondary objects
    - O/O ephemerides uploaded to EUSST portal: “Ops”
    - O/O ephemerides shared (for instance on Space-Track.org, or by mail) for non-EUSST users : “Ext”
    - 19th SDS & CARA orbits: “19th”, “SP_E”
    - Operational Center catalog, built from EUSST contributing sensors and national measurements: “Cat” for EUSST catalog

→ When managing a conjunction, the analyst needs to identify the most accurate orbit data source and “create” the best CDM at the time of the analysis

Key Concept – CDM Management

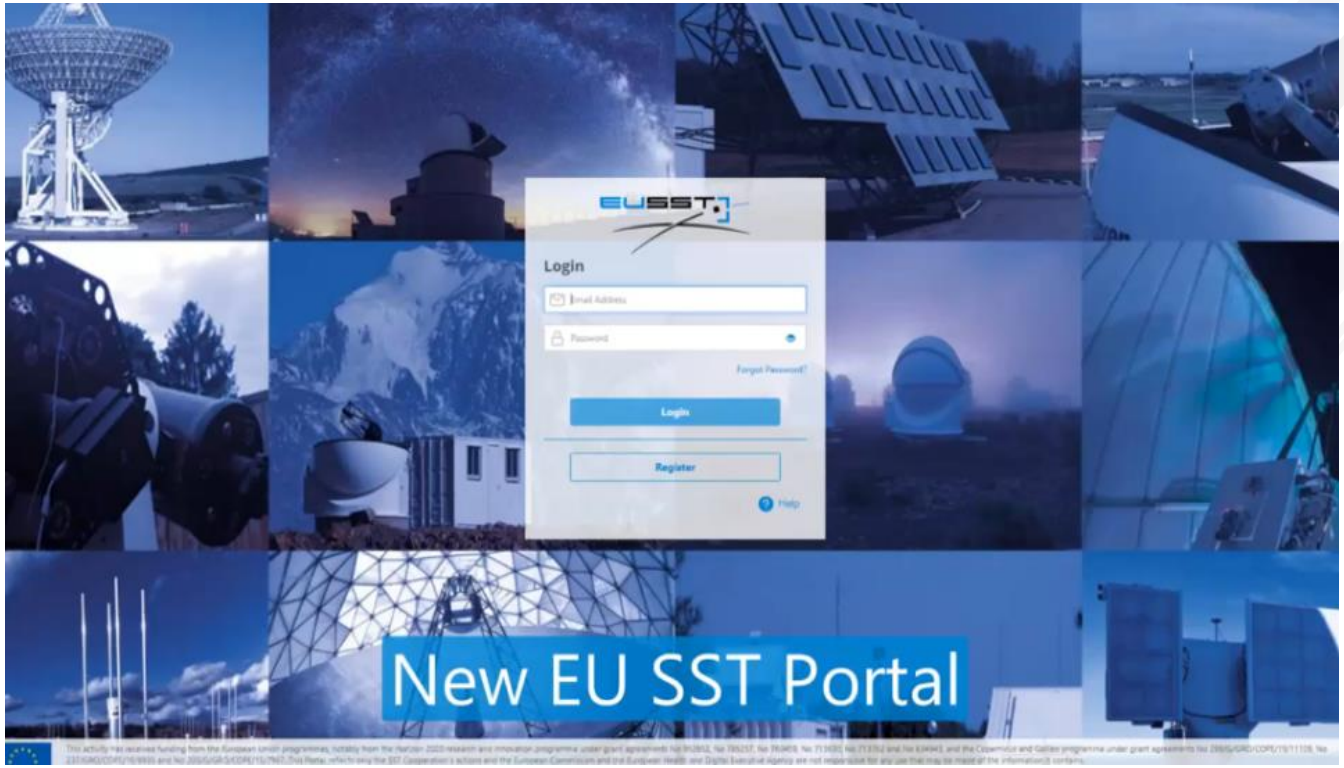
- What is the “Best CDM” ?
  - Best CDM is the one having the best sources for the Primary and Secondary
    -

source	description	advantage	drawback
Ops or Ext	EUSST or external operator ephemerides	With maneuvers	
19th SDS	Most up to date US data (in CDM)		Without maneuvers
SP_E	US Precise Ephemerides		Without maneuvers Without covariance
CAT	OC in house catalog	Autonomous product	Without maneuvers

  - Building the best CDM means identifying the best OD among those available for the current conjunction, which depends not only on the source, but also on:
    - Freshness of measurements
    - Relative quality of the position and covariance

EU SST Portal

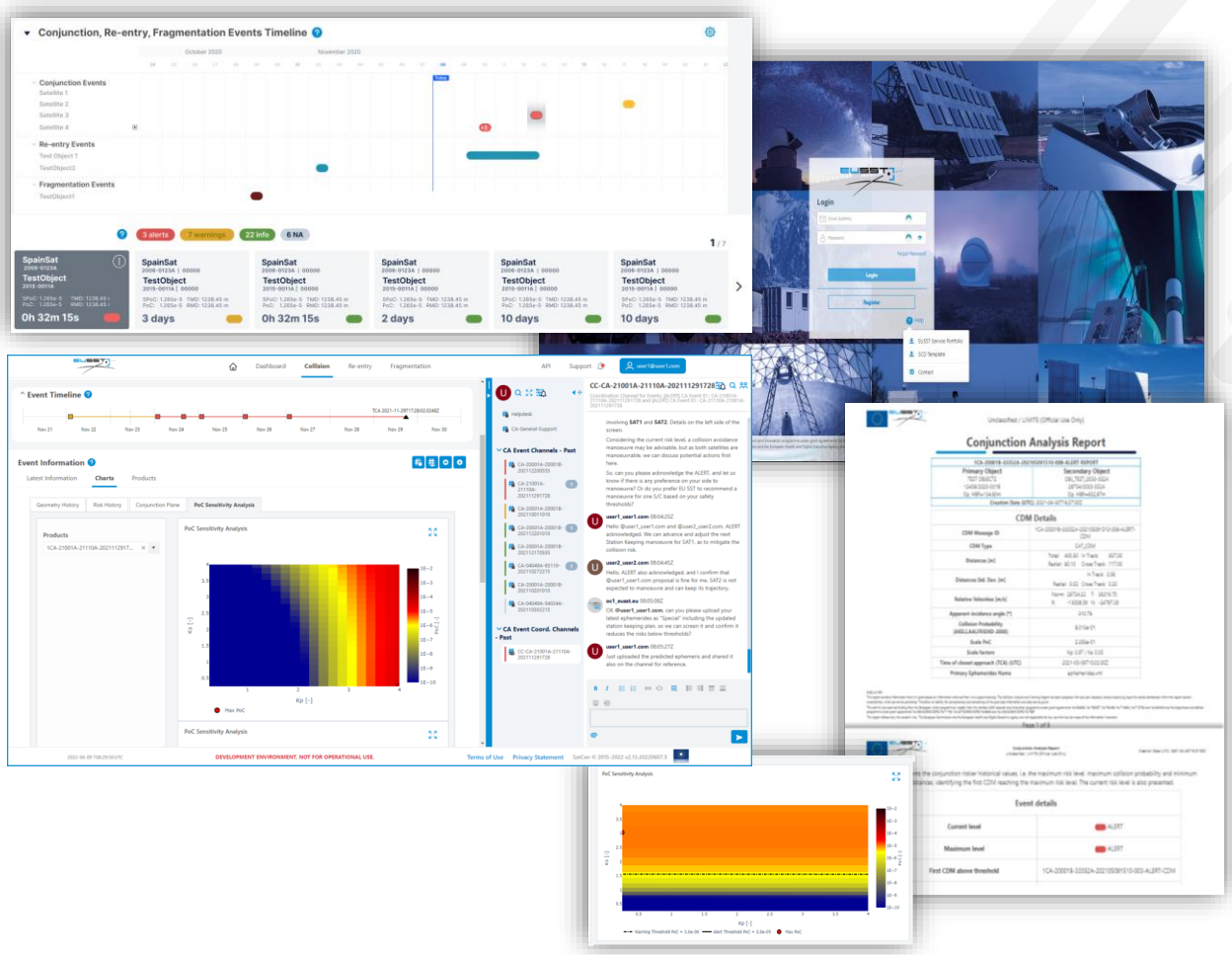
- Operational since 2016
- Overall availability >99.9%
- Scalable Architecture
- Agile SW Development
- Continuous Integration
- Monthly releases with updates and new features



The interface for the provision of SST services

EU SST Portal: https://portal.eusst.eu/

- Dashboard page with timeline and most relevant conjunctions' information
- Conjunction event pages (timeline, latest information update, evolution charts, products – CDM/PDF/HTML) with different CDM types, ephemerides, users' planned maneuvers
- CA dynamic services' information charts (geometry and risk evolution, 2D conjunction plan, PoC sensitivity analysis)
- Communication and Coordination Platform allowing operators to exchange when potential collisions are detected
- REST API for operators and OCs
- Fleet access management feature for operators
- Built-in CA service configuration feature



Short to mid term Evolutions

- **Smooth management of S/C in EUSST Portal**
  - With the increasing number of users, the number of S/C registered to EUSST CA Service is evolving constantly with launches and End-of-Life operations.

→ OCs will be able to automate the management of the S/C receiving the service and update their respective service configurations in the OCs systems, as per the EUSST SCD.

- **Transition from a temporary to a definitive identification** (international designator and SATCAT number) on EUSST portal and Space-Track .
- **Information on best CDM at a given moment**
  - Identification of the best CDM at a given time may not be obvious in several cases
  - For instance:
    - Active secondary providing an ephemeris – no maneuver until TCA:
      - Is the O/O orbit better than 19th SDS or EUSST Operational Center ones ? (for instance, if not based on a GNSS)
      - What to do if no covariances are available?
    - Defunct large object:
      - Is the EUSST Operational Center orbit better than 19th SDS at the beginning of the follow-up of the event ? Or when EUSST is receiving additional tracking from its sensor network?

Short to mid term Evolutions

- **Improved TEST ephemerides screening**
  - EUSST has the ability to screen ephemerides with a high priority for critical phases (LEOP, EoL,…)
  - Need to be requested by the user and agreed by the Operational Center
    - Dedicated tag (TEST, SPECIAL) to be used in the name of the ephemeris
    - Manual actions from the OC side to set up a dedicated chain

  → Need to smooth this process which has a good feedback from users

  → Need to study if an extension of the mechanism to test mitigation actions can be implemented

  For instance, constraints on the HW must be evaluated

- **Avoidance maneuver visualization**
  - For each CDMs with maneuver recommendation, users will be able to visualize different avoidance maneuvers
  - Information on the impact of different maneuvers
    - Proposition of different magnitudes and/or dates (e.g. N.5 orbits before TCA)
    - Visualization of the evolution of SPoC, total distance… based on the chosen maneuver

Evolution – Automated maneuver recommendation

- Currently, EUSST provides mitigation actions by mail, and can help the user to find a trade-off between flight dynamics and user system constraints
  - E.g. On orbit position of the maneuver may be de-optimized

- Users may need a recommendation in:
  - Impulse Along-Track Delta-V (m/s) at a given date (typically N.5 orbits before TCA)
  - Total Delta-V (m/s), for low-thrust systems
  - Semi-major axis change (m) at a given date (typically N.5 orbits before TCA)
  - Radial Separation (m) at TCA
  - Stop thrust time, for continuous thrusts systems (e.g. EOR)

- Other needs may arise in the future

Evolution – Automated maneuver recommendation

- All constraints cannot be taken into account:
  - Forbidden on orbit positions to maneuver
  - Need to split the mitigation action into several burns
  - Complex FDS computing burns for the next week

  → Maneuver recommendations cannot be finely tailored to the needs of each users

- But need to automate the provision of maneuver recommendation

  → Provision of theoretical maneuvers, to be adapted by the users with regards to the constraints of their system

- EUSST will continue to support the users with the definition of maneuvers upon user requests
- After definition of mitigation action, users are expected to provide their ephemerides for screening

Evolution – Automated maneuver recommendation

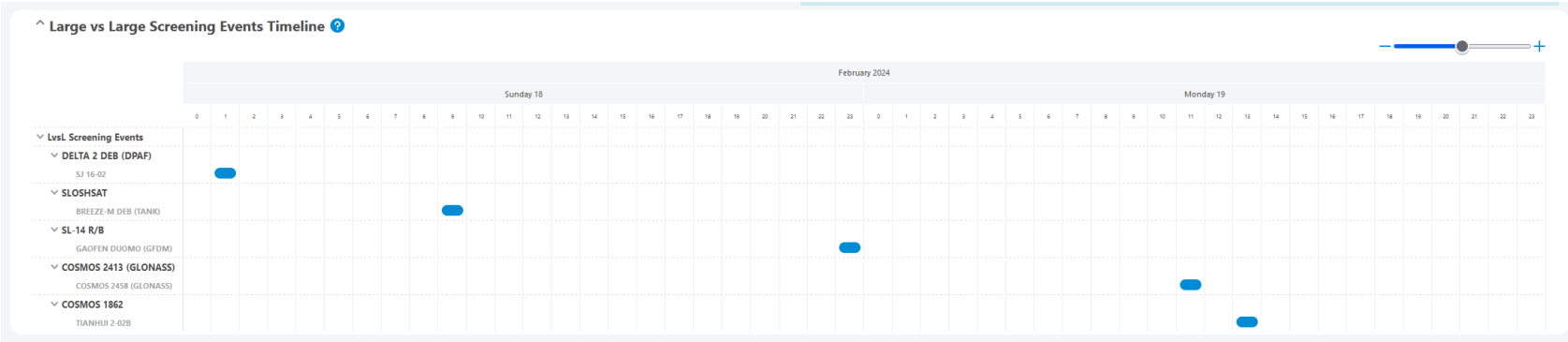
- Maneuvers scenarios will be provided on the portal through OPM associated to CDMs
  - Only for the current best CDM
  - Probably not for conjunctions between maneuverable S/C

- Existing OPM fields do not cover all the cases (e.g. recommendation of a radial separation)
  - Dedicated USER_DEFINED_xxx fields will be created
  - SCD will have to be updated
  - Users will have to select in the SCD the kind of the recommendation they need

- Feedback from users about the performed maneuver
  - Pop-up on the portal to get feedback on the mitigation action for a specific event
  - Feedback is important for future mitigation recommendations

Evolution – Large vs Large screening

- Since Mid-January 2023, the Large vs Large screening is available to users
  - Visualization of the timeline of events
  - Details of each conjunction, such as radial and total miss distances



Large vs Large Screening Events List

DELTA 2 DEB (DPAF) 2006-016D 29110 Autonomous Orbit: No	Radius: 2.26 m AP: 614.43 km PE: 601.46 km	SJ 16-02 2016-043A 41634 Autonomous Orbit: No	Radius: 5.48 m AP: 609.79 km PE: 598.35 km	TCA: 2024-02-18T01:44:37Z	RMD: -8.01 m MD: 300.19 m CDM Type: SPCAT/SPCAT	CA-06016D-16043A-202402180144
SLOSHSAT 2005-005C 28544 Autonomous Orbit: No	Radius: 0.79 m AP: 31591.00 km PE: 275.00 km	BREEZE-M DEB (TANK) 2009-034C 35495 Autonomous Orbit: No	Radius: 3.02 m AP: 13458.00 km PE: 314.00 km	TCA: 2024-02-18T09:35:49Z	RMD: -4808.43 m MD: 4905.64 m CDM Type: SPCAT/SPCAT	CA-05005C-09034C-202402180935
SL-14 R/B 1990-018B 20511 Autonomous Orbit: No	Radius: 10.00 m AP: 646.24 km PE: 607.75 km	GAOFEN DUOMO (GFDM) 2020-042A 45856 Autonomous Orbit: No	Radius: 10.00 m AP: 649.99 km PE: 633.16 km	TCA: 2024-02-18T23:05:03Z	RMD: -1.53 m MD: 1659.34 m CDM Type: SPCAT/SPCAT	CA-90018B-20042A-202402182305
COSMOS 2413 (GLONASS) 2004-053A 28508 Autonomous Orbit: No	Radius: 4.56 m AP: 19151.00 km PE: 19109.00 km	COSMOS 2458 (GLONASS) 2009-070C 36113 Autonomous Orbit: Yes	Radius: 4.45 m AP: 19147.00 km PE: 19116.00 km	TCA: 2024-02-19T11:05:10Z	RMD: 979.60 m MD: 4112.40 m CDM Type: SPCAT/CAT	CA-04053A-09070C-202402191105
COSMOS 1862 1987-055A 18152 Autonomous Orbit: No	Radius: 10.00 m AP: 540.66 km PE: 506.98 km	TIANHUI 2-02B 2021-074B 49072 Autonomous Orbit: No	Radius: 1.66 m AP: 524.29 km PE: 506.36 km	TCA: 2024-02-19T13:14:11Z	RMD: -6.65 m MD: 351.74 m CDM Type: SPCAT/SPCAT	CA-87055A-21074B-202402191314

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Thank You

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