

# GMV's capabilities for SST system architecture simulation

Space Surveillance and Tracking for Spacecraft Operations – Connecting the dots between modelling, design and practice

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Virtual Workshop

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# Outline

- GMV in SST/STM/SDA Highlights
- Processing and simulation capabilities
- Examples of architecture simulations
- Conclusions

# GMV in SSA/SST/STM/SDA Highlights

10M€

100+

35%  
yearly



**Focusoc**

**Focusear**

**Ecosstm**



Working on SST with ESA since 90's. Main contributor to Space Safety Program (SST Core SW, CREAM)

Impressive footprint on EU-SST since 2015 in 7 countries (ES, FR, DE, PL, RO, PT & UK)

Leader of Spanish SST Operations Centre (S3TOC) development and operations for CDTI/AEE within S3T

Developer of BAS3E SST simulator and new advanced algorithms for collision avoidance for CNES

Leader of GSSAC Mission System (GMS) and EU-SST Catalogue development for DLR

SST-related activities in UK, PL, RO, PT for ESA and National Agencies also within EU-SST

Commercial Ops Centre (**Focusoc**): CA/COLA services for 10+ operators worldwide and 80+ satellites

Proprietary Passive RF tracking network for GEO satellites, to be extended to LEO

COTS SW solutions covering the whole SSA/SST domain, available in the following systems:

Spanish, Polish, Romanian and Greek National Civilian SST Ops Centres contributing to EU-SST

German military SDA Centre (**Weltraumlagezentrum**), whole SDA C2 capability

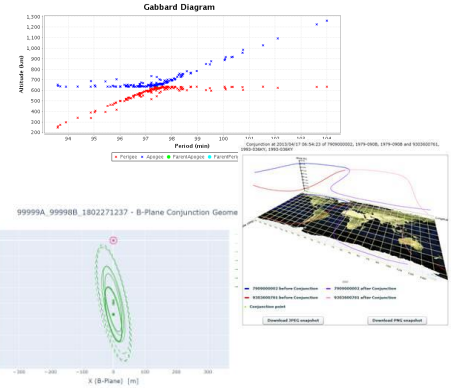
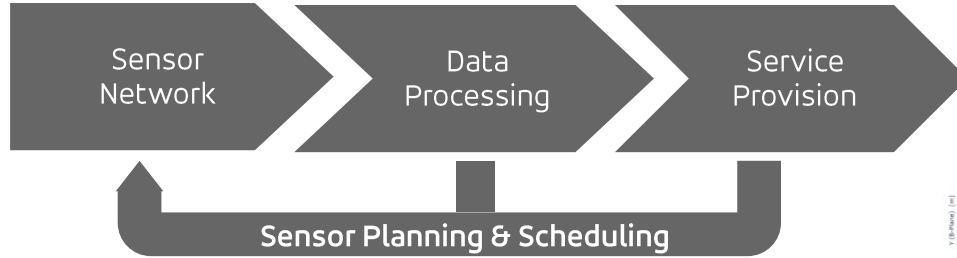
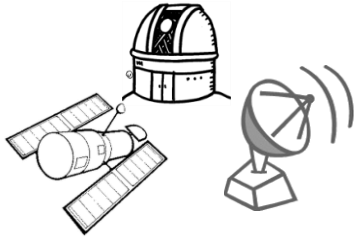
Spanish military SDA Centre (**COVE**), whole SDA C2 capability and support to Global Sentinel exercises

US Space Force's JCO (JTF-SD Commercial Ops Cell), SST Data Curation and support to SACT exercises

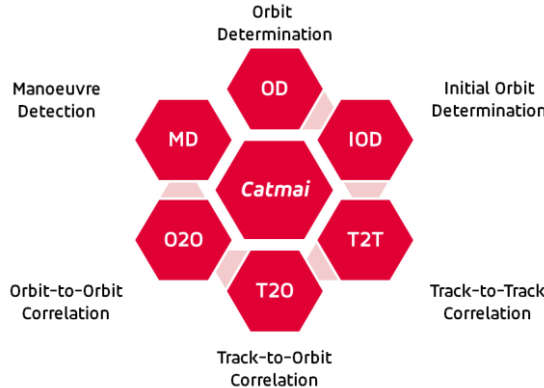
Involved in EC, EUSPA, Eurospace, SSC, ESA's Zero Debris Charter, PPF's Net Zero Space, IAF, ECSS & CEN

# GMV processing and simulation capabilities

# SST Architecture

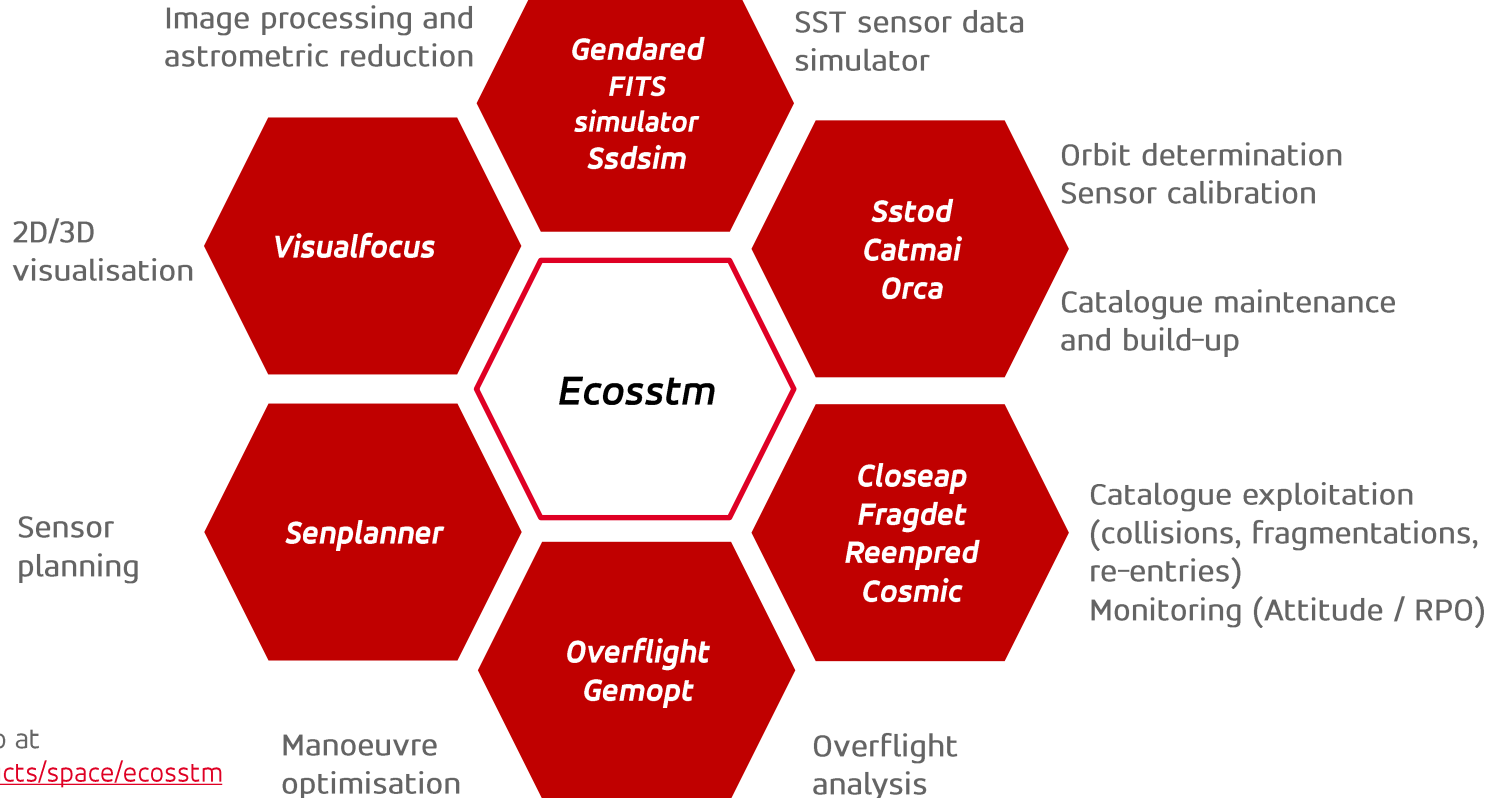
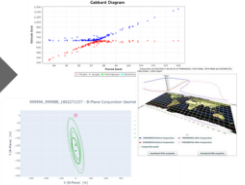


- Telescopes
- Radars
- SLR
- Passive ranging
- Space-based sensors



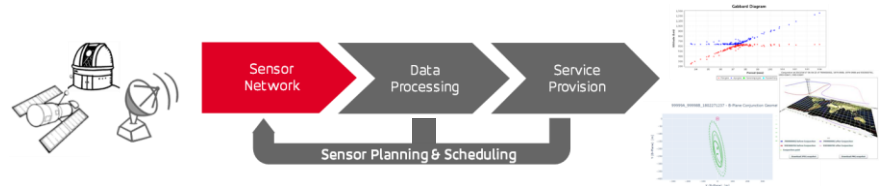
- Collision Assessment
- Reentry Prediction
- Fragmentation Det.
- Attitude Monitoring
- RPO Monitoring

# GMV's Ecosstm



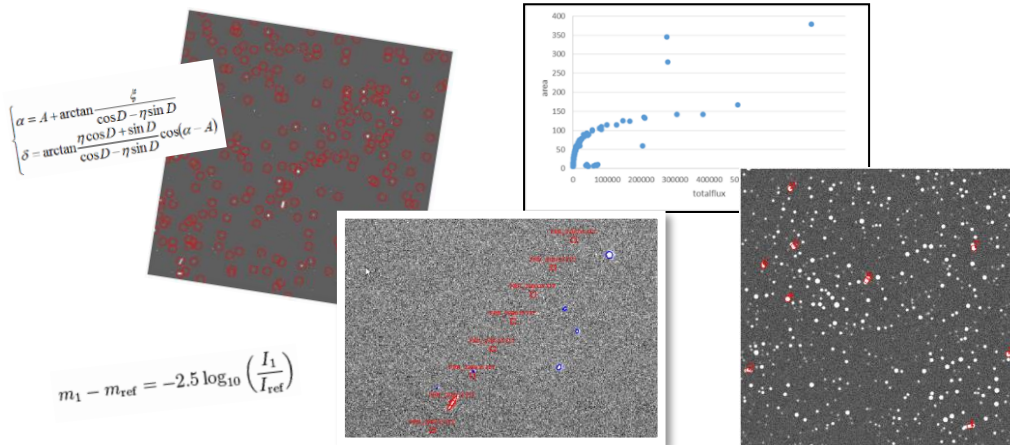
More info at  
[www.gmv.com/en/products/space/ecosstm](http://www.gmv.com/en/products/space/ecosstm)

# Sensor Processing & Simulation



## ■ Gendared & FITS simulator

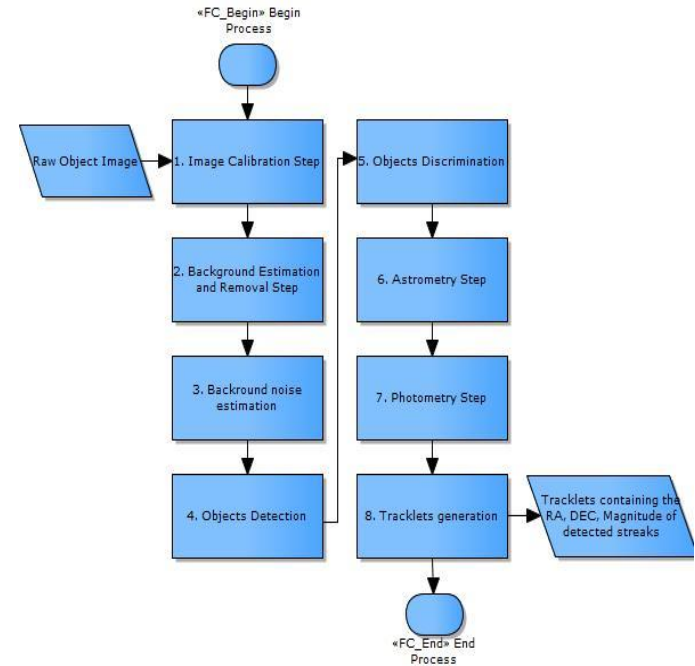
- GMV's proprietary solution for **Astrometric and photometric** telescopes data reduction (FITS to CCDSDS)
- Modular and operational processing framework developed with ESA
- Includes FITS simulation capability for validation and testing
- Available in all Romanian telescopes contributing to EU-SST
- Available in German GSSAC & GRNOC for their telescopes



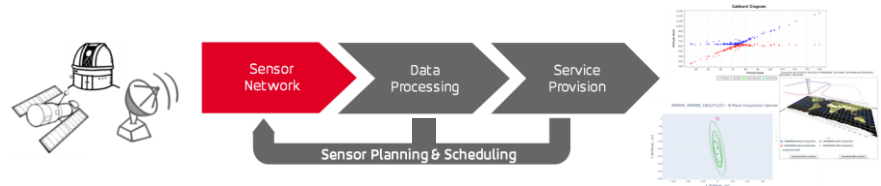
$$\alpha = A + \arctan \frac{\eta \sin D}{\cos D - \eta \sin D}$$

$$\delta = \arctan \frac{\eta \cos D + \sin D}{\cos D - \eta \sin D} \cos(\alpha - A)$$

$$m_1 - m_{\text{ref}} = -2.5 \log_{10} \left( \frac{I_1}{I_{\text{ref}}} \right)$$

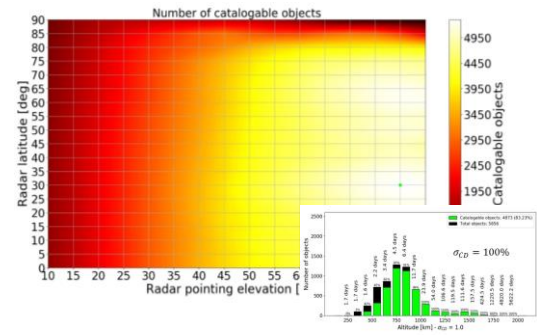
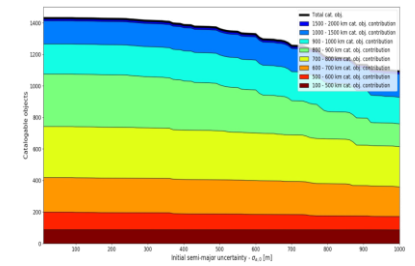
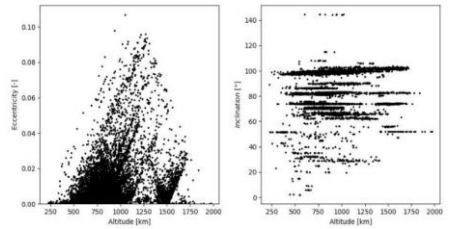
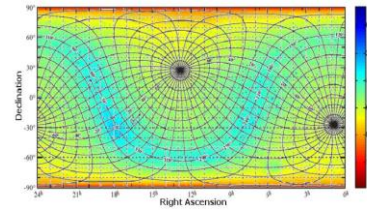


# Sensor Processing & Simulation



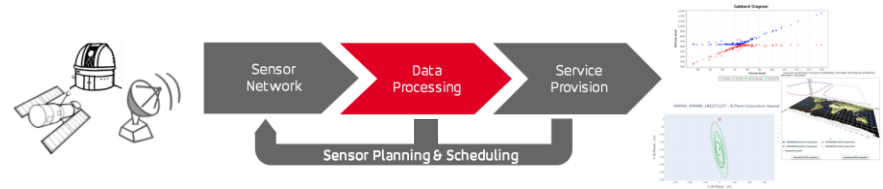
## ■ Sdsim

- GMV's proprietary solution for sensor data simulation
- Object population simulation with external data (**MASTER, TLE, OMM**) and different statistical model for augmentation on missing data (e.g., A2M ratio, drag coefficient).
- Supports complete sensor network of **radars, telescopes, SLRs, and/or Passive RF stations.**
- Complete sensor, **observability and detectability** models (e.g., FoV, power, Sun, Moon, galactic plane constraints)
- Survey strategy selection and optimization.
- Simulation of **fragmentations** (NASA Standard Breakup Model).
- Simulation of typical manoeuvres.
- CCSDS standards for orbits (ODM) and observations (TDM).
- Includes tools and statistical characterisation of the population and cataloguing performance.
- **Sdsim** has supported EUSST architecture studies S3T CDTI/AEE activity, Chilbolton studies, GMV SW validation...





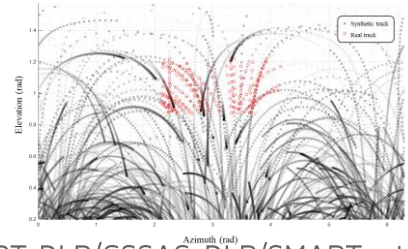
# SST Data Processing



## ■ *Catmai* catalogue maintenance and *Sstod*: orbit determination

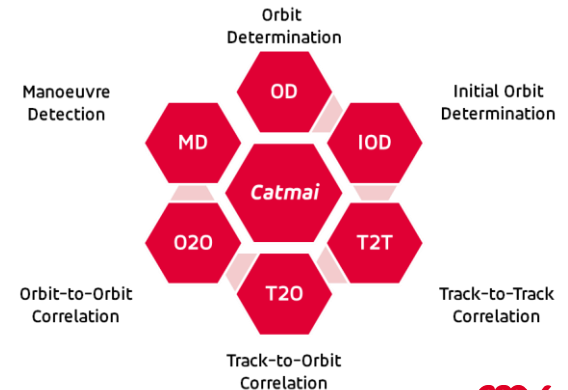
- GMV's proprietary SW for objects cataloguing and orbit determination
- Heritage from operational **Flight Dynamics** and **POD applications**.
- Parallel processing, state-of-the-art algorithms and models and standard interfaces (CCSDS)
- Proven with data from hundreds of real sensors.

- **Telescopes:** ExoAnalytics, Numerica, L3 Harris, ISON, ESA's OGS, AG's GEOtracker, Airbus's ART, DLR/GSSAC, DLR/SMARTnet, CNES's TAROT, StarBrook, TFRM, TJO, DeSS, IAC-80, Bootes, AIUB, 6ROADS, AO-AMU, Solaris, Panoptes, BITNET, Neemo, SHOT, Teplice, Astros, Kryoneri, Skinakas...
- **Radars:** LeoLabs, TIRA, Chilbolton, ESA's MSSR & BSSR, S3TSR
- **SLR:** Graz and ROA for non-cooperative objects, ILRS stations
- **Passive RF:** GMV's **Focusear**, SDS's WeTrack (for several operators), Eutelsat, JSAT

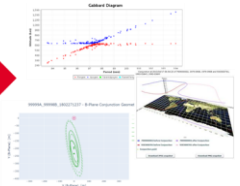


## ■ GMV Expertise

- ESA (P2-SST-I Catalogue Simulator & Catalogue in SST Core SW)
- CNES (BAS3E SST simulator and OSMOSE telescopes OD & CAT)
- DLR (Development of Algorithms for SST Data Processing, BaSSTDa)
- US-JCO (SST Active Data Curation)



# Collision Assessment & Avoidance

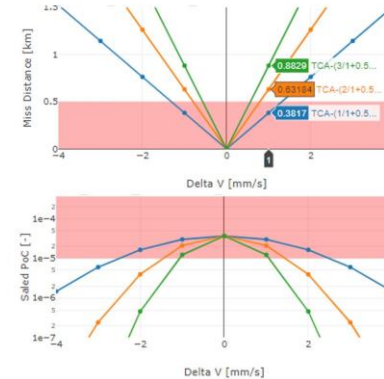


## ■ Closeap

- GMV's proprietary tool for detection of conjunction events and characterization of collision risk (i.e. collision probability)
- State-of-the-art algorithms (from **CRASS**) and infrastructure
- Functionality within **Focussuite** operational Flight Dynamics Systems
- Missions > Galileo, PAZ, SEOSAT, Eutelsat, Hispasat, StarOne, NBNC0

## ■ GMV Expertise

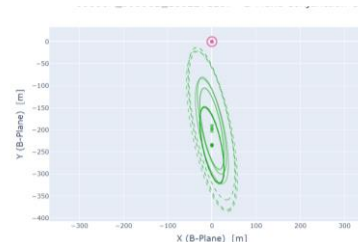
- ESA (CRASS, CPS), CNES (CRABIM), S3T, etc...
- Autonomous CA: ESA (AUTOCA, CREAM#1, CREAM#2, CREAM#3)
- EU-SST: Development of EU-SST Collision Avoidance Tool (CONAN) for CDTI
- **Closeap** has been used for Flight Dynamics in GEO and LEO satellite operators, S3TOC, WRLageZ...
- **FocusOC** service for GEO Satellite operators



## CONJUNCTION DETECTION REPORT

Execution Time: 2015/05/18 10:39:09.239  
 Report Interval Start: 2015/05/18 00:00:00.000  
 Report Interval End: 2015/05/28 10:39:09.239  
 Number of detected conjunctions: 8 Conjunctions

| Id  | Target | Chaser          | Target Src/Age | Chaser Src/Age | TCA                  | Miss Dist (km) | Collision Prob | Max Collision Prob | Rnd Dist (km) | Along Dist (km) | Cross Dist (km) | High Risk |
|-----|--------|-----------------|----------------|----------------|----------------------|----------------|----------------|--------------------|---------------|-----------------|-----------------|-----------|
| 520 | SAT1   | SL-32           | DPS/1.9        | TLE/3.0        | 2015/05/20 -16:46:07 | 28.562         | 1.014 E-022    | 2.965 E-004        | 18.771        | -21.087         | -4.333          |           |
| 523 | SAT3   | ARIANE 44LP DEB | DPS/1.9        | TLE/3.0        | 2015/05/23 -21:16:20 | 1.384          | 2.550 E-009    | 6.115 E-003        | 1.348         | 0.157           | 0.273           | X         |
|     |        |                 | DPS/1.9        | CDI/0.7        | 2015/05/23 -21:16:23 | 1.760          | 1.405 E-052    | 2.078 E-003        | -1.705        | -0.191          | -0.395          | X         |
|     |        |                 | CDI/0.2        | CDI/0.7        | 2015/05/23 -21:16:20 | 1.959          | 2.827 E-070    | 0.030 E-004        | -1.934        | -0.255          | -0.179          | X         |
| 524 | SAT5   | ARIANE 44LP DEB | DPS/1.9        | TLE/3.0        | 2015/05/23 -21:16:38 | 23.061         | 1.579 E-009    | 3.472 E-004        | 20.607        | 1.504           | 10.242          |           |
|     |        |                 | DPS/1.9        | CDI/0.7        | 2015/05/23 -21:16:41 | 20.015         | 0.000 E+000    | 1.027 E-004        | 17.539        | 1.149           | 9.575           |           |
| 525 | SAT2   | RADUGA          | CDI/1.1        | CDI/1.1        | 2015/05/22 -12:06:00 | 1.500          | 2.144 E-006    | 1.545 E-003        | -1.289        | -0.722          | -0.262          | X         |
|     |        |                 | DPS/0.2        | TLE/0.4        | 2015/05/28 -01:16:22 | 2.630          | 1.760 E-009    | 3.220 E-003        | 2.515         | 0.263           | 0.726           | X         |



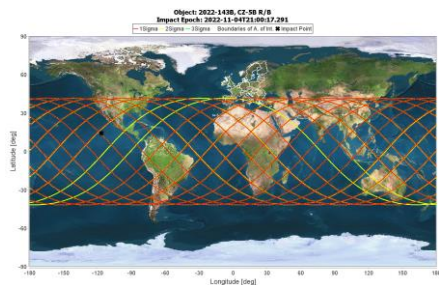
# Reentry & Fragmentation

## ■ *Reenpred*

- GMV's proprietary tool for orbital lifetime, re-entry prediction and on-ground risk assessment.
- State-of-the-art algorithms and models.

## ■ GMV Expertise

- ESA (RPS), CNES (OPERA, DEBRISK, PAMPERO), S3T, UKSA
- Support to controlled re-entries: ATV Flight Dynamics and operations
- *Reenpred* has supported to US SACT, Global Sentinel exercises and available for WRLageZ.

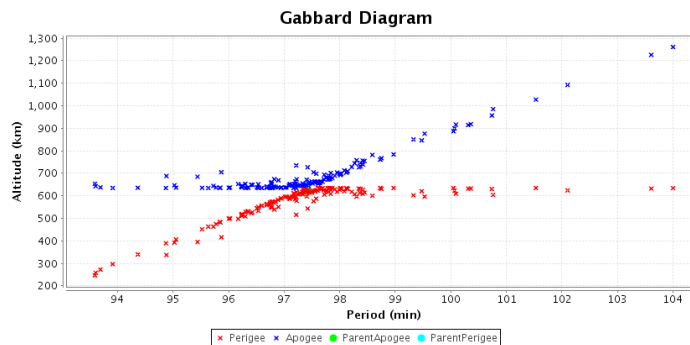


## ■ *Fragdet*

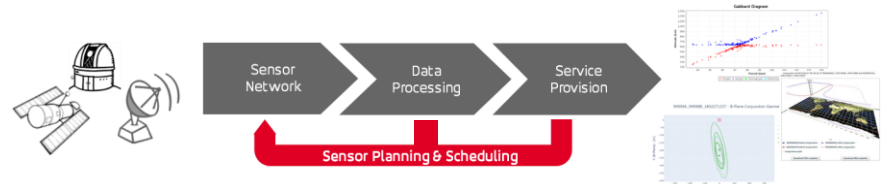
- GMV's proprietary tool for fragmentation detection and analysis
- State-of-the-art algorithms and models.

## ■ GMV Expertise

- ESA (FAS), S3T
- *Fragdet* has supported to Global Sentinel exercises and available for WRLageZ.



# Sensor Planning & Scheduling

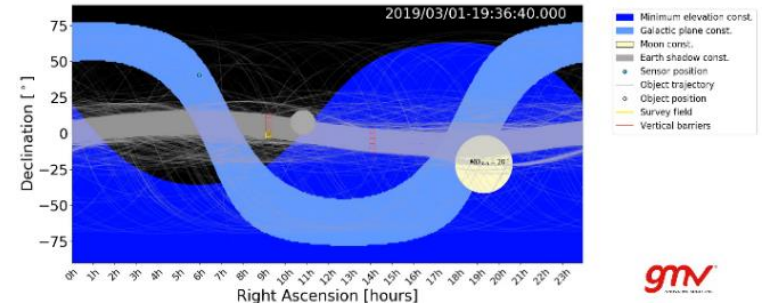
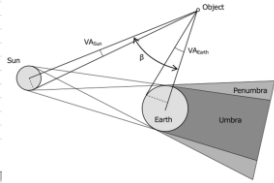
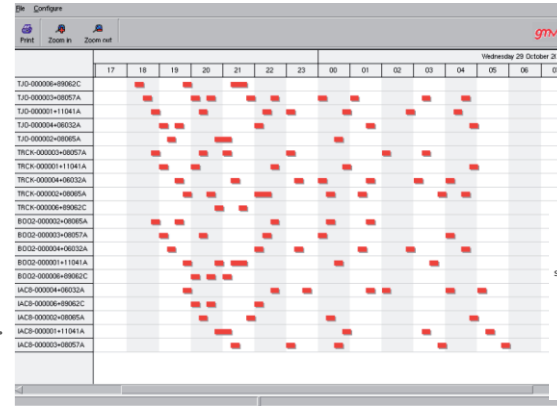


## ■ *Senplanner*

- GMV's proprietary solution for sensors planning and scheduling.
- **Ground and Space** based sensors (Telescopes, Radars and SLR)
- State-of-the-art algorithms and models.
- Contractual, observability and detectability constraints.
- **Survey strategy optimization** (Telescopes).
- **Sensor network** simultaneous **scheduling** to achieve global optimum.

## ■ GMV Expertise

- ESA (SST Sensors Scheduling Simulator & Sensors Planning System)
- S3T sensors tasking and intensive campaigns for ESA & GEO operators
- **Flexplan** > Mission Planning Metop, Sentinel-3, LRO, SGSS, ...
- Development of EU-SST **Sensors Scheduler (COPLA)** for AEE/ CDTI
- **Senplanner** operational in the S3TOC, RO-NOC and WRLageZ and supported ESA (SST-XIX, SST-XXII, SC-06...) and CNES activities related to sensor campaigns



# Examples of architecture simulation studies

# Architecture Studies (AEE S3T – GMV *Ecosstm*)

- **EUSST Architecture simulations for AEE:** catalogue maintenance with *Ssasim*, tool, precursor of *Catmai* and *Ssdsim* tools.
  - Up to 5 projects conducted in the past decade to support EUSST architecture simulations.
  - **Capabilities: catalogue build-up and maintenance**, propagation, track-to-orbit correlation, **orbit determination**, initial orbit determination, re-entry detection and evaluation tools.
  - Simulation of several **network of sensors** for the different regimes (LEO, MEO/GTO, GEO), including analysis of network reconfiguration:
    - Use of **MASTER** based population,
    - Modelling of a network of sensors, with different **configurations** and technology status (noises, etc)
    - Construction of a catalogue, both from scratch and for maintenance.
    - Evaluation of the sensor network (cataloguing capabilities, added-value and redundancy analyses)
  - Additional analyses, simulation of new sensors, analysis of full **EUSST dataflow**.

# Architecture Studies (CNES – BAS<sup>3</sup>E)

## ■ **BAS<sup>3</sup>E**: maintenance, evolution and exploitation

- +10 years providing support to CNES
- Day-to-day use of the simulation test bench
- **Capabilities: catalogue build-up and maintenance**, propagation, visibility opportunity computation, measurement generation, visibility and measurement statistics computation, track-to-orbit correlation, orbit determination, initial orbit determination, re-entry detection, explosion and fragmentation generation, sensor scheduling, catalogue maintenance and evaluation tools.
- Delivery of simulation-based analyses requested by the EUSST Partnership:
  - Modelling of an orbital population,
  - Modelling of a network of ground/space-based sensors (radars, telescopes, lasers)
  - Construction of a catalogue
  - Modelling the data flow of services proposed by the EUSST platform
  - Evaluation of the sensor network (coverage, cataloguing capabilities, added-value and redundancy analyses)
- Ad hoc studies and analyses (algorithms, simulation of new technologies/sensors characteristics, ...)

# Conclusions



# Conclusions

- Whole SST capabilities and tools available for operational and architecture simulations
- Long standing experience on development and operational environments
- Expertise on SST architecture and sensor network design studies
- Challenges on ZERO DEBRIS policy
  - **Accuracy** → Development of new sensors, technology limitations, and improve modelling of **covariance propagation** (e.g. VLEO) and **covariance realism** algorithms (e.g. atmosphere uncertainty).
  - **Data sharing** → Not only measurements but also metadata related to sensor characteristics, quality, interfaces and automation.
  - **Quality assessment and monitoring** → Many potential sensors coming, need of calibration, qualification and active data curation before processing.

# Thank you

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