Italian SST Operations Center (ISOC)

The use of military tracking radar in Space Surveillance & Tracking

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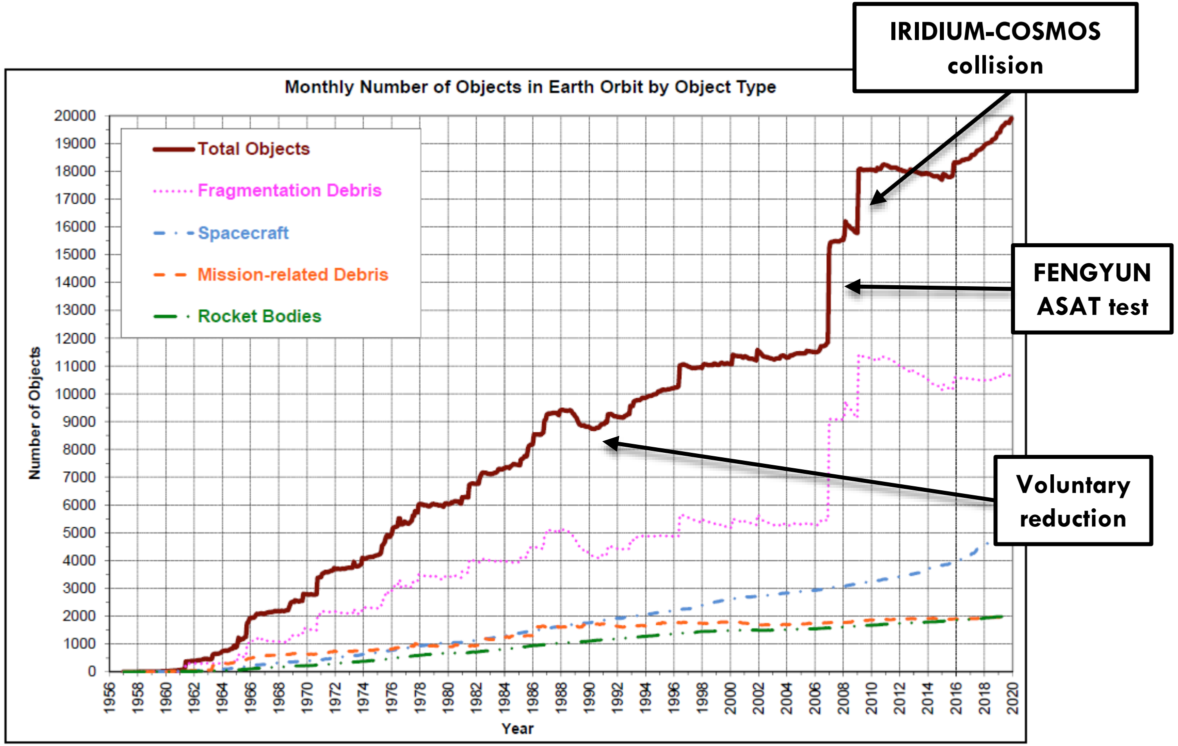
Agenda

- Space Debris & Space Surveillance and Tracking (SST)
- Italian SST Operations Center (ISOC)
- Test cases, outputs & results
- Conclusions

Space Surveillance & Tracking

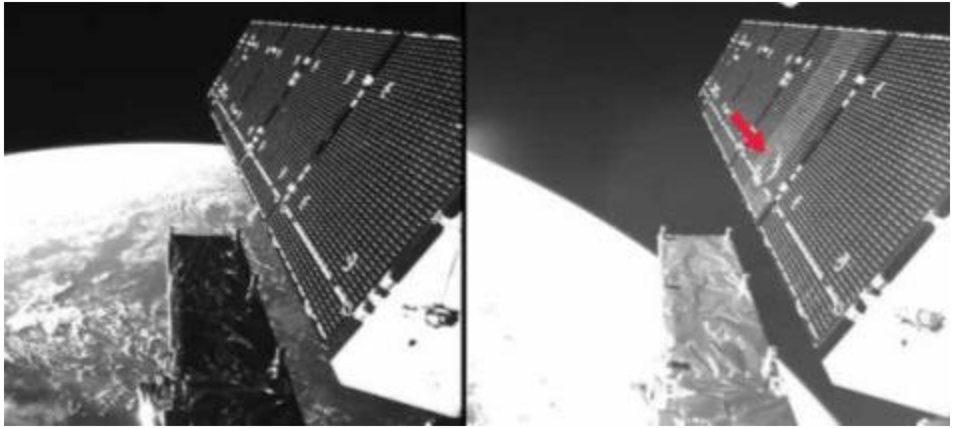
From Sputnik 1 launched in 1957, more than 8,000 spacecraft were placed in orbit.

Many aspects of our daily life may suffer the consequences of interaction of orbit structures with spatial debris.



[Credit: NASA]

Why SST?



Example of recent 1mm debris damage to Copernicus Sentinel-1A satellite [Credit: ESA]

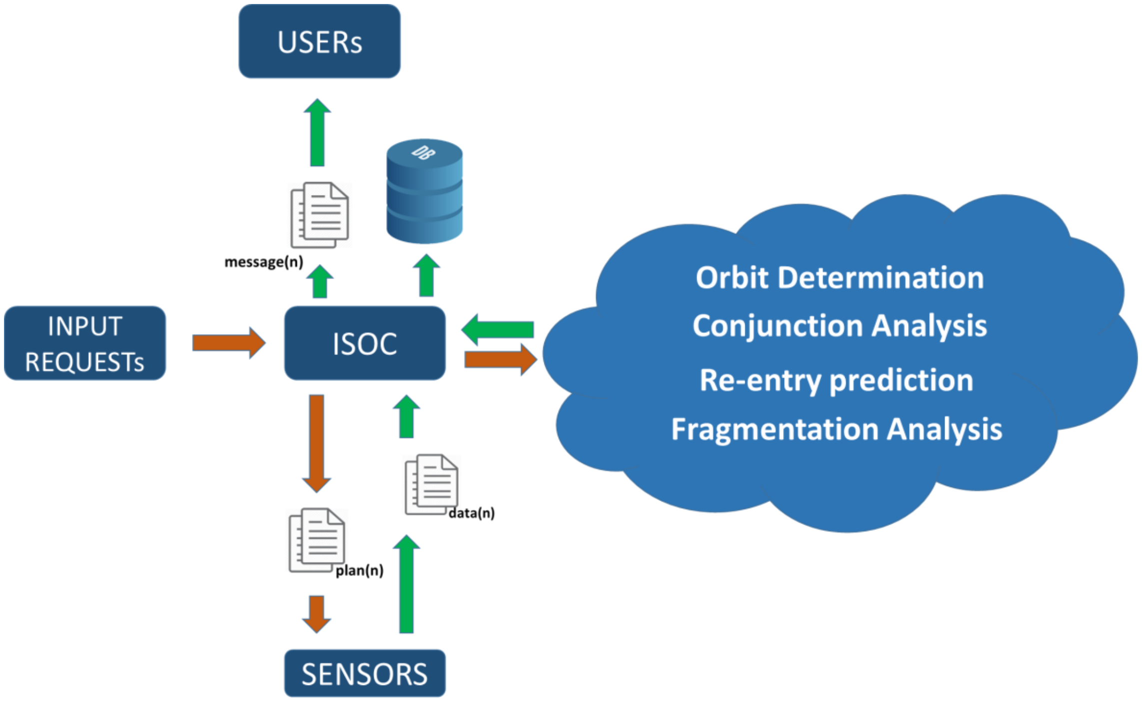
- Increasing need to protect spatial structures of national / EU interest from impacts with debris (consequences on navigation services, TLC, etc.) and to ensure access to space;

- Estimating the risk of collision through national SST capabilities, enabling satellite operators to plan mitigation measures and prevent the proliferation of spatial debris.

Italian SST Operations Center (ISOC)

- ISOC mission overview:
  - Hub for the national SST sensors network (radar, optical, laser) of ItMoD/ITAF/ASI/INAF;
  - Tasking of sensors;
  - Data processing for orbit determination (OD);
  - Generates and provides services for Conjunction Analysis, Re-entry and Fragmentation;
  - Develop a national object catalogue.

ISOC: C2 Chain



- RE and FG services provision
- ISOC is currently in charge of CA service only for national satellites

ISOC: SST Sensors Architecture

CASSINI

CAS - VdV

BIRALET

MFDR

TRF

BIRALES

PdM - MiTe

SPADE

MLRO

Test case: Sensor

MFDR Radar:

- Weibel Multi Frequency Doppler Radar (Phased Array)
- located in Sardinia (PISQ military base)
- Power: 320 Watt

Objectives

- Demonstrate the capability to track a space object
- Demonstrate the data quality goodness to ensure orbit determination (OD)

Test case: MetOp-B satellite

[credit: ESA – AOES Medialab]

- NORAD ID 38771
- Launched in 2012
- Mass 4.000 kg
- Size 17.6 m x 6.7 m x 5.4 m
- RCS ≈ 13.7 sqm
- Orbit Altitude ≈ 800 km (circular)
- Orbit Inclination 98.7°

Meteorological satellite with main task to measure temperature and humidity of the atmosphere, clouds, wind speed at sea level and ozone layer

Analysis

The analyses performed by ISOC started with a comparison

```
CCSDS_TDM_VERS = 1.0
COMMENT TDM file
CREATION_DATE = 2020-03-27T07:01:05
ORIGINATOR = ISOC

META_START
TIME_SYSTEM = UTC
START_TIME = 2020-03-25T09:18:56.700897
STOP_TIME = 2020-03-25T09:22:55.200867
PARTICIPANT_1 = MFDR-MR
PARTICIPANT_2 = 38771
MODE = SEQUENTIAL
PATH = 2,1
TIMETAG_REF = RECEIVE
RANGE_UNITS = km
ANGLE_TYPE = AZEL
META_STOP

DATA_START
ANGLE_1 = 2020-03-25T09:18:56.700897   13.312342
ANGLE_2 = 2020-03-25T09:18:56.700897   32.127444
RANGE = 2020-03-25T09:18:56.700897   1378.297
DOPPLER_INSTANTANEOUS = 2020-03-25T09:18:56.700897   -20362.062305

ANGLE_1 = 2020-03-25T09:18:56.800903 13.312185
ANGLE_2 = 2020-03-25T09:18:56.800903 32.148573
RANGE = 2020-03-25T09:18:56.800903 1377.7315
DOPPLER_INSTANTANEOUS = 2020-03-25T09:18:56.800903 -20357.411133
```

Radar Measurements

converted in TDM format

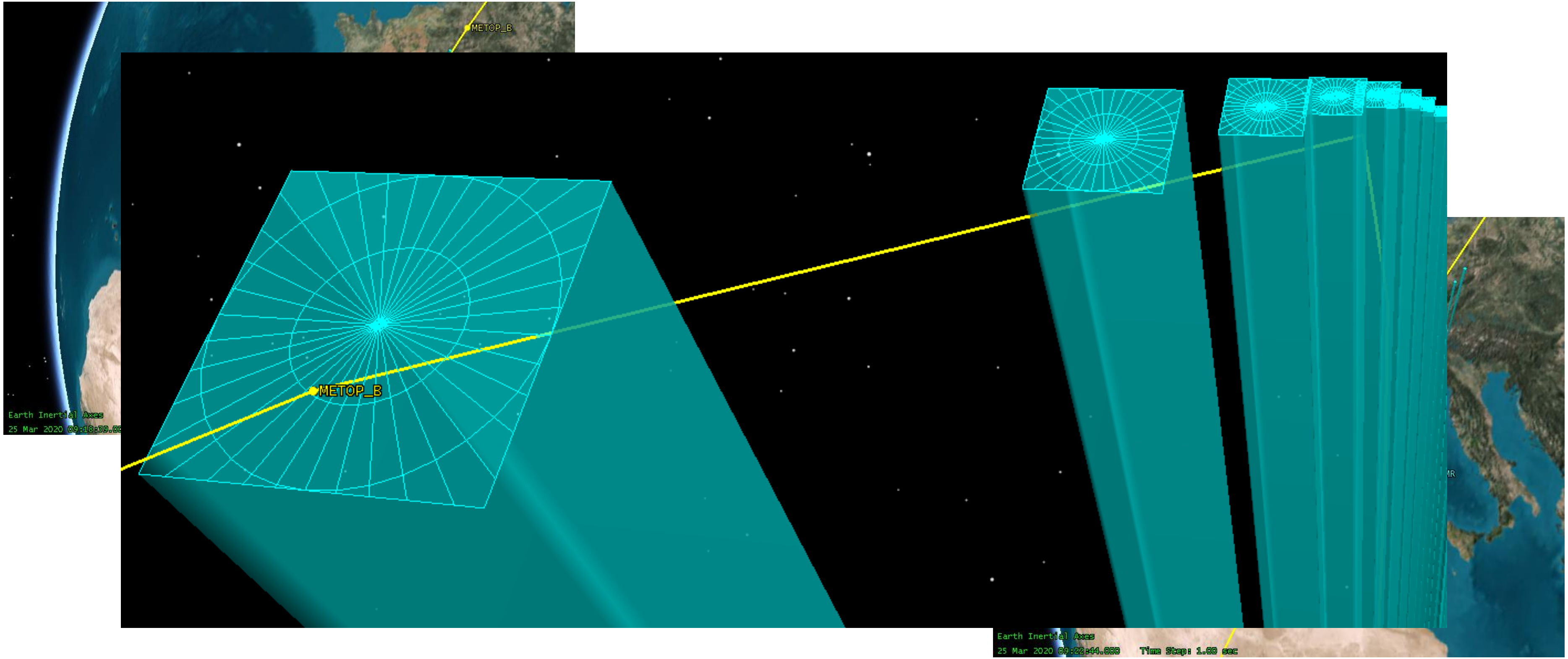
```
CCSDS_OEM_VERS = 2.0
COMMENT PREDICTED ORBIT
CREATION_DATE  = 2020-03-25T09:10:02.931
ORIGINATOR     = OPERATOR

META_START
OBJECT_NAME          = METOP-1
OBJECT_ID            = 2012-049A
CENTER_NAME          = EARTH
REF_FRAME            = EME2000
TIME_SYSTEM          = UTC
START_TIME           = 2020-03-25T00:00:00.000
STOP_TIME            = 2020-04-08T00:00:00.000
META_STOP

2020-03-25T00:00:00.000 -3956.972341  1652.324083 -5791.100821  -4.592720   3.980358   4.275333
2020-03-25T00:03:00.000 -4710.996327  2336.317376 -4926.294724  -3.761092   3.597663   5.306176
2020-03-25T00:06:00.000 -5303.131989  2940.021689 -3891.784253  -2.799062   3.090764   6.155438
2020-03-25T00:09:00.000 -5712.794109  3442.560590 -2723.033401  -1.739412   2.476797   6.793333
2020-03-25T00:12:00.000 -5925.643672  3826.496894 -1460.241250  -0.618567   1.776740   7.197216
```

High quality Ephemeris (reference)

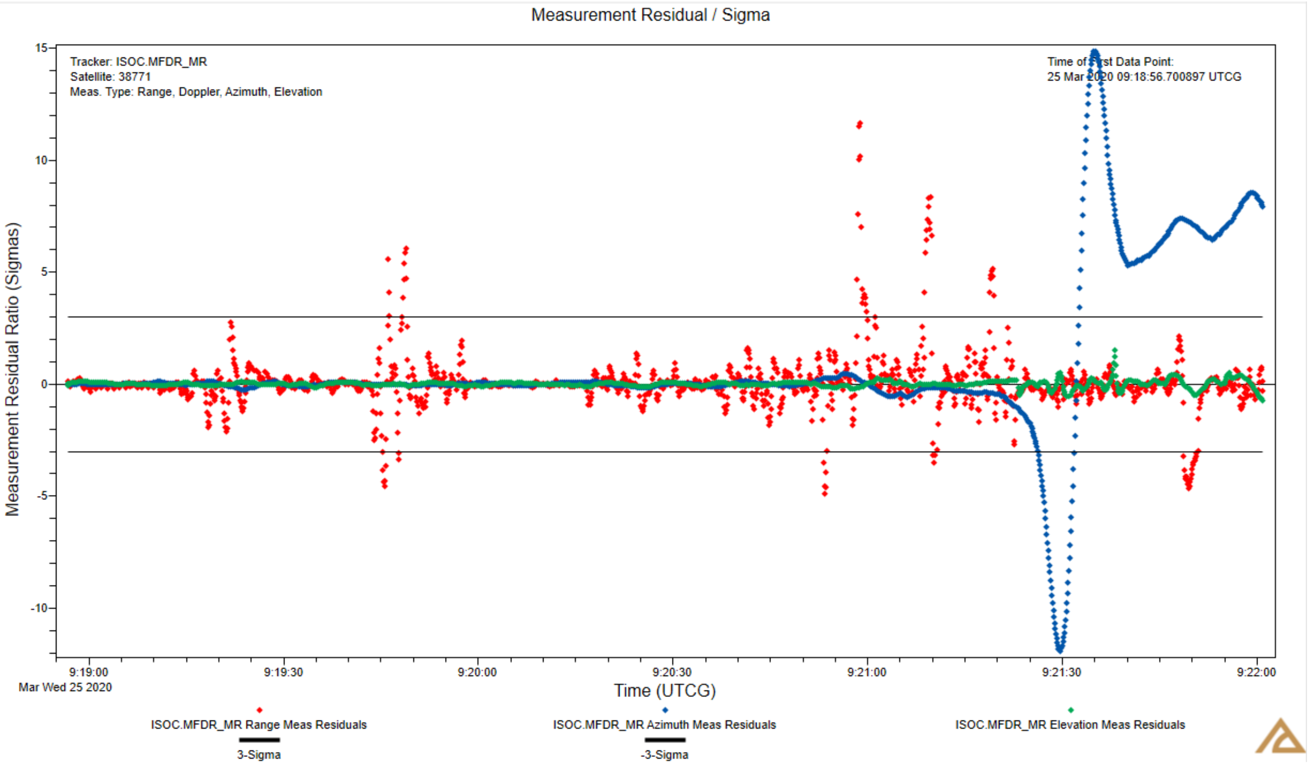
Passage comparison



Measurements Residuals

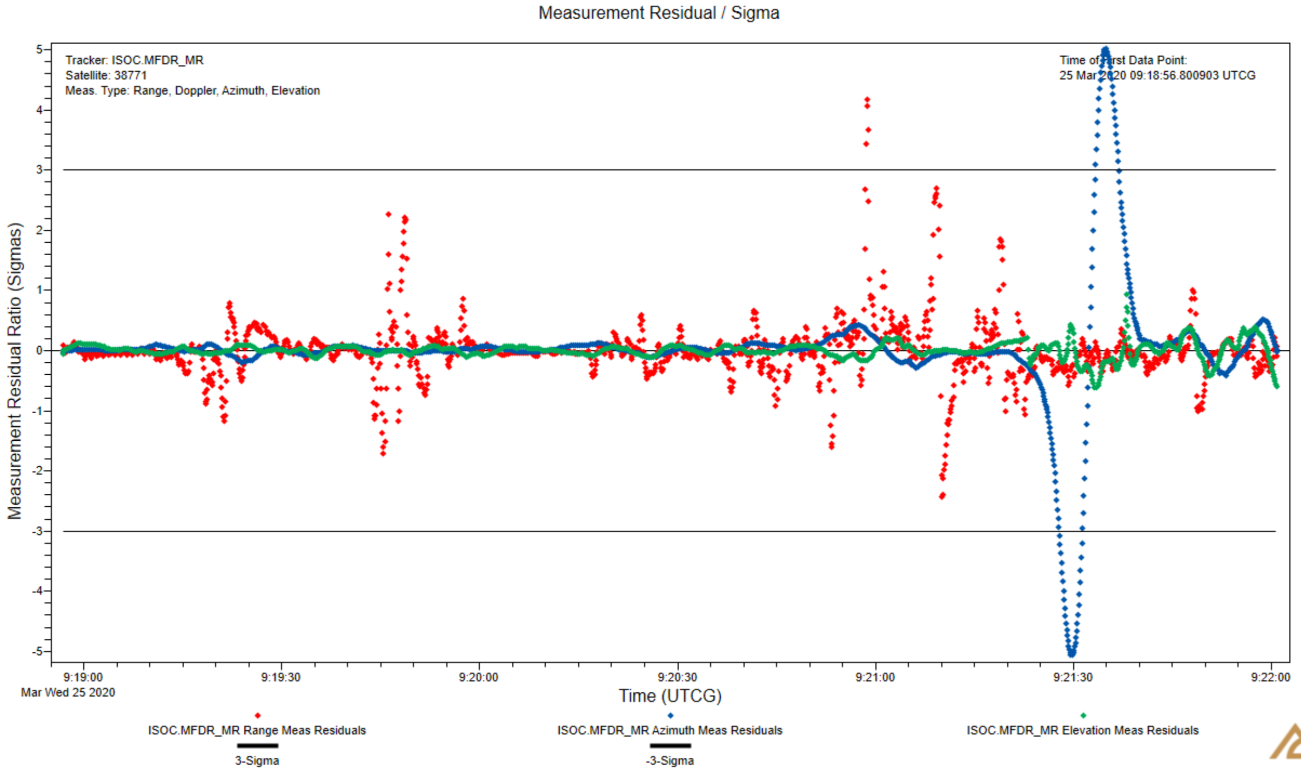
Measurement Residuals shows small dispersion but:

- some problems in azimuth (blue dots) in the last part of acquisition
- white noise, expecially in the range (red dots)



Measurements Residuals

After a filtering process the Residuals shows smaller dispersion



Orbit Determination

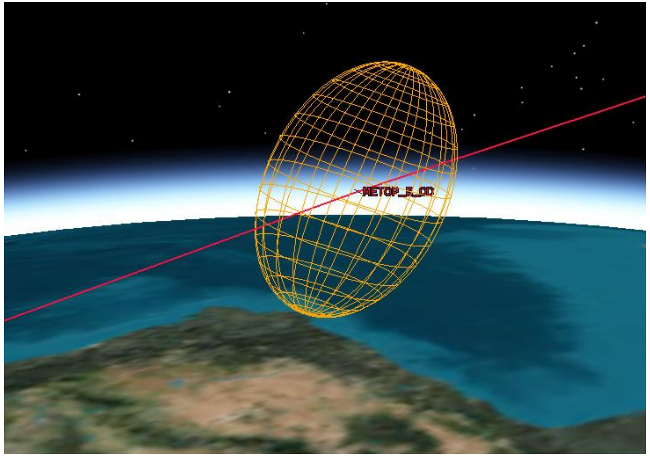
Step 0
measurements

Step 1
Satellite
Initial Orbit Determination

Step 2
Least Square Filter

Step 3
Kalman Filter

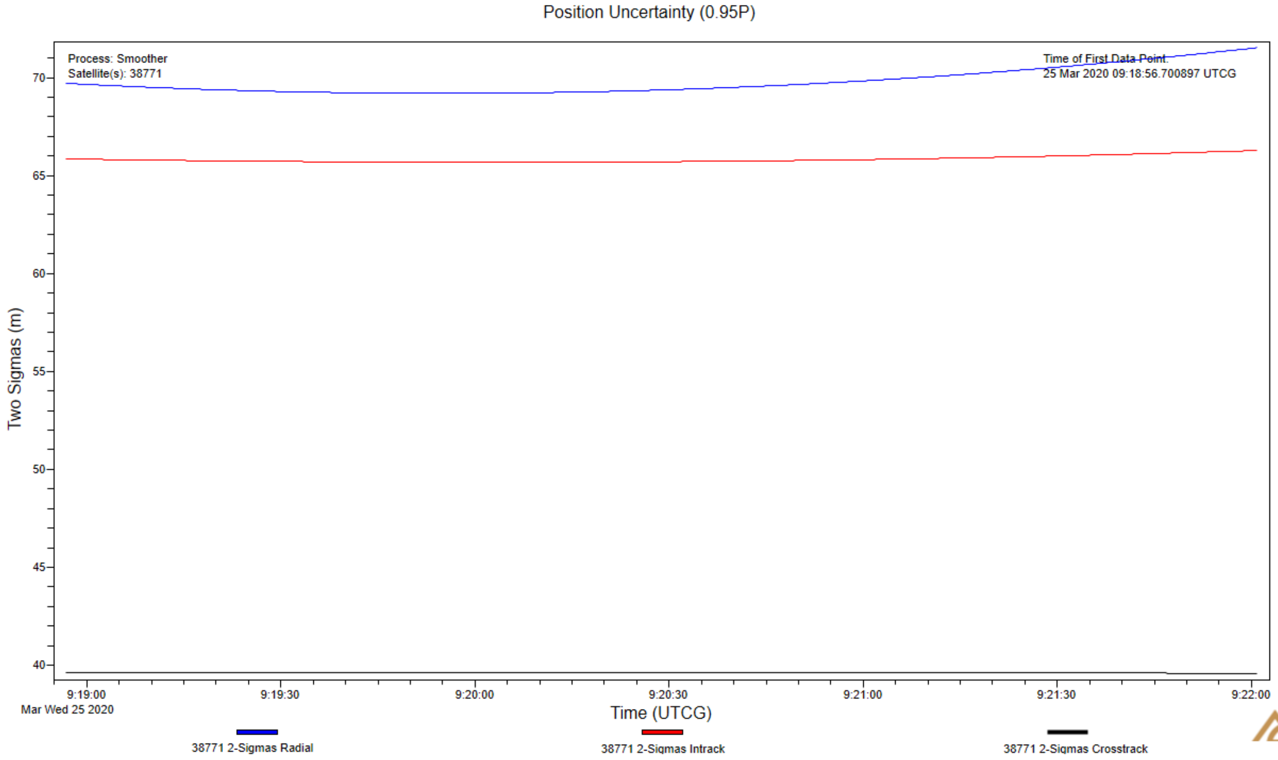
Step 4
Smoother



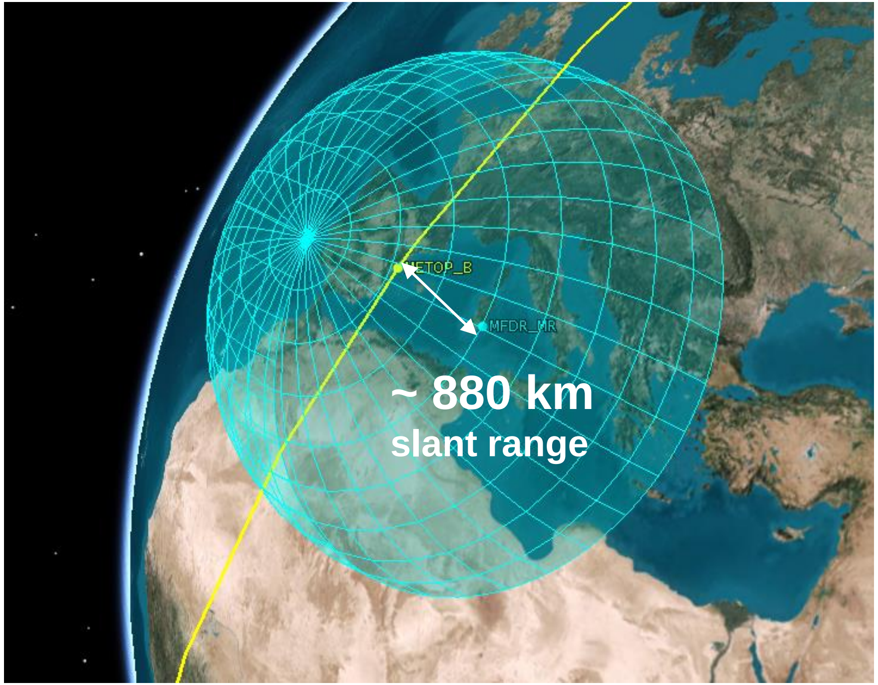
ephemeris file
&
covariance

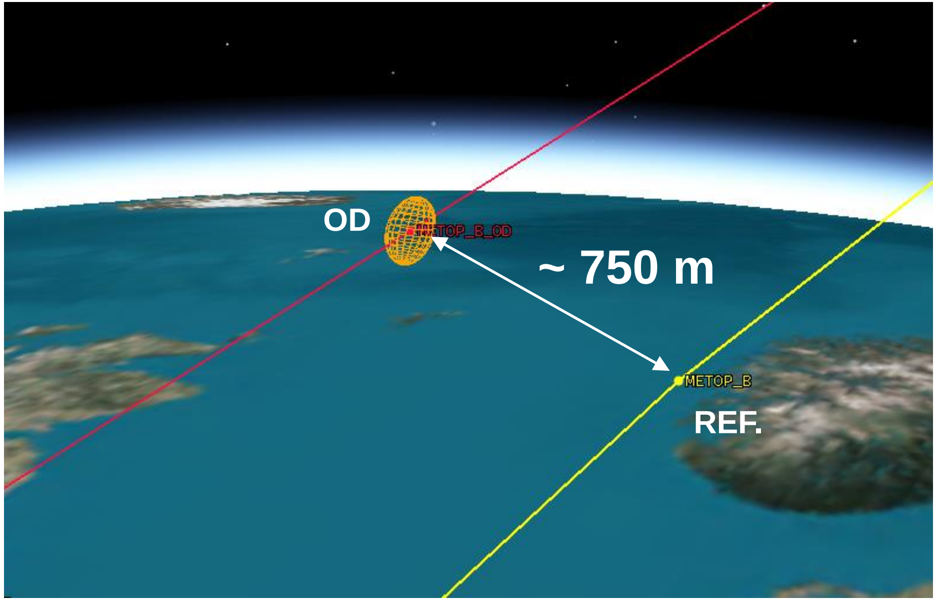
Output & results

Position uncertainty shows small covariance matrix



Output & results





Geometry of observation – Orbit from OD and from reference

Conclusions

- Italian Air Force deeply involved in SST, performing data fusion from optical and radar sensors
- Radars are a fundamental component for SST
- Further tests and analyses are required in order to assess both other systems bias and systems characterization (e.g. ionospheric corrections, RCS vs Range)

Questions?

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