GUSDON

Global University Space Debris Observation Network

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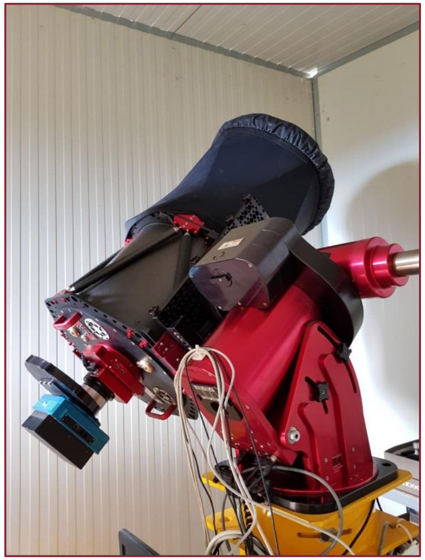
Project Objectives

- **Education**:
  The proposed project allows for space debris education improvement, with benefits for students, Professors and University staff
- **Science:**
  GUSDON can become an invaluable tool for space debris and uncontrolled re-entering objects monitoring
- **Awareness for a larger public:**
  The project will widespread awareness on the pollution of the Earth orbit and its associated risks, stimulating conscious decision making

United Nations Sustainable Development Goals: The project framework

Why Optical Observations?

- Optical observations are able to achieve high quality measurements with “low-cost” passive hardware
- Students can operate the system with no risk of “hurting” or “disturbing” during operations
- These features allow to let students and untrained personnel to operate observatories, while for active systems it would be much more complex



Typical Space debris “low cost” passive optical observatory

Space Debris observation “Active” Infrastructures (RADAR or LASER ranging)

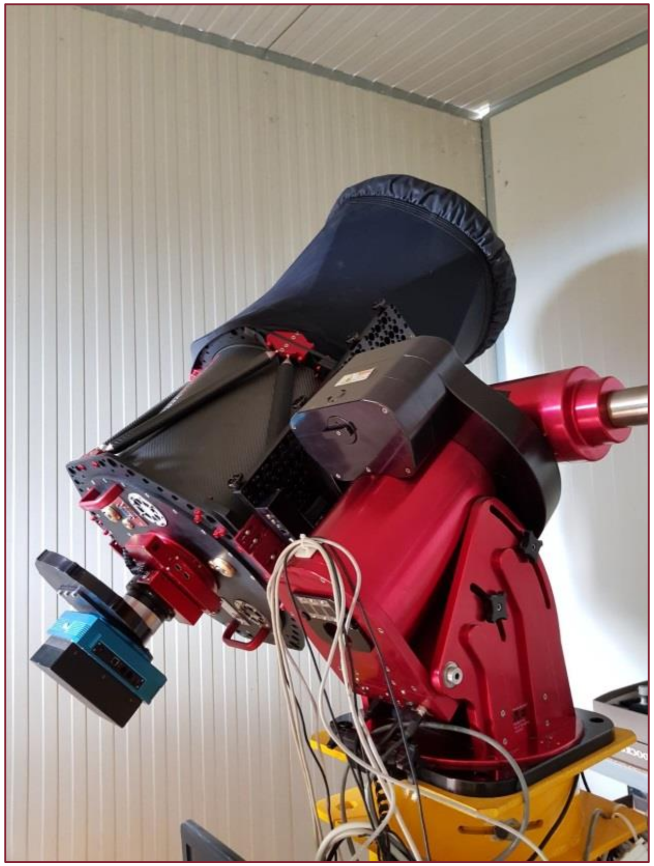
Typical Optical Configuration:

RESDOS (Sapienza University of Rome, Italy)

- **RESDOS**

40 cm optical tube, Field of View: 2 deg x 2 deg

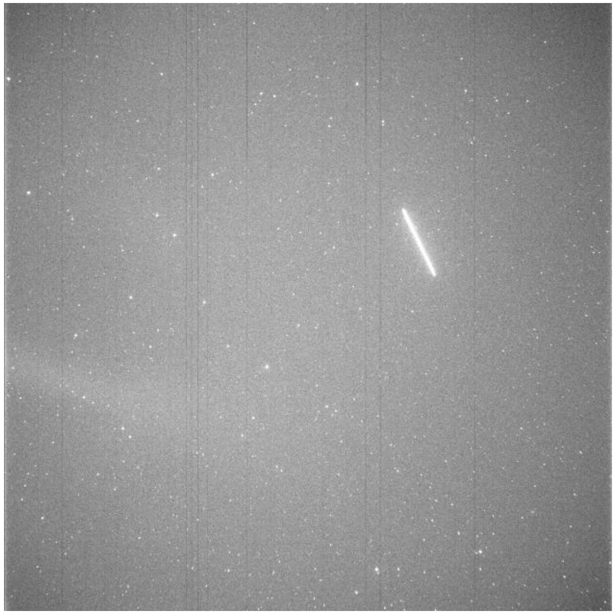
- **Compatible with various CCD models**
- **PC controlled mount**
- **Automatic image acquisition**
- **Observations scheduling software**
- **Shelter**
- **Completely remotely controllable telescope**



Space debris optical observations techniques

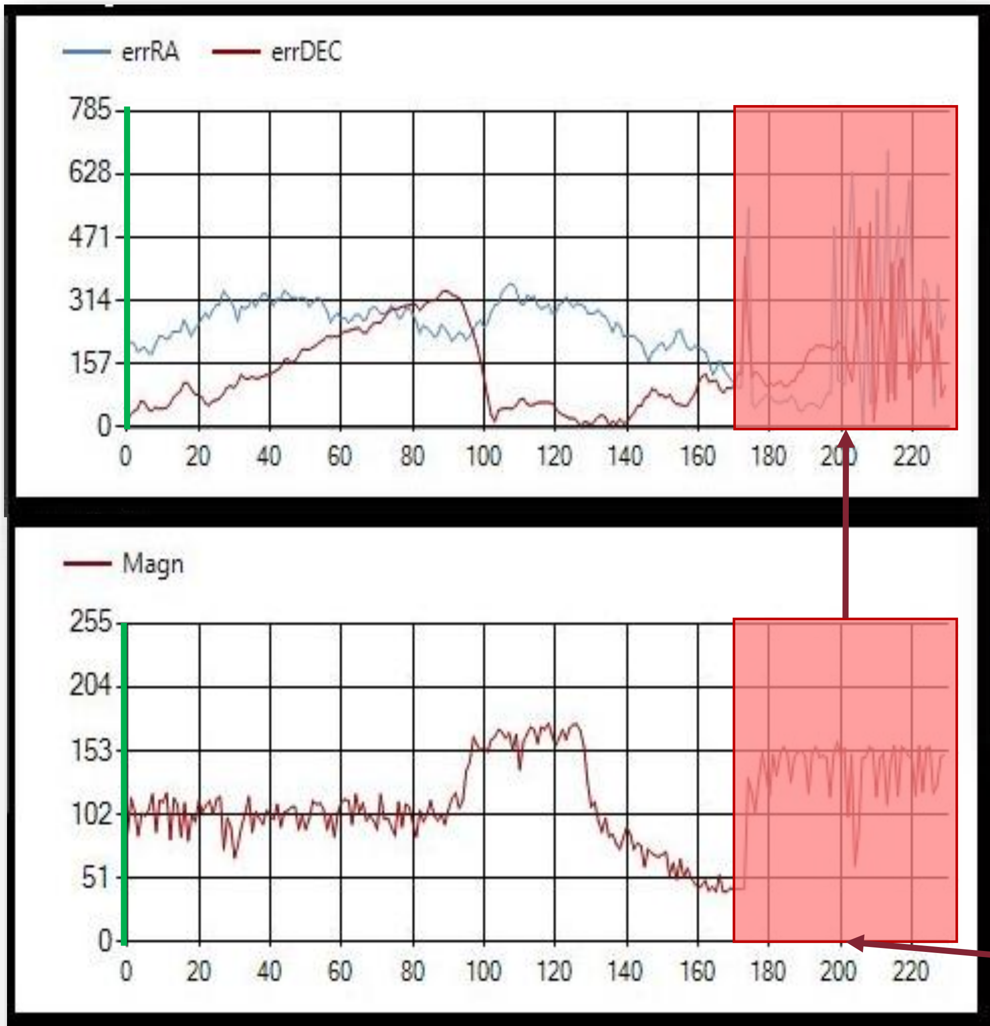
- Sidereal tracking
- Target tracking

SIDEREAL TRACKING: Tiangong1



TARGET TRACKING: two GEO satellites

Real time LEO object tracking



Real time tracking of COSMOS 1340:
- T_{exp} = 0.2 s
- mag_{sat} = 4.0

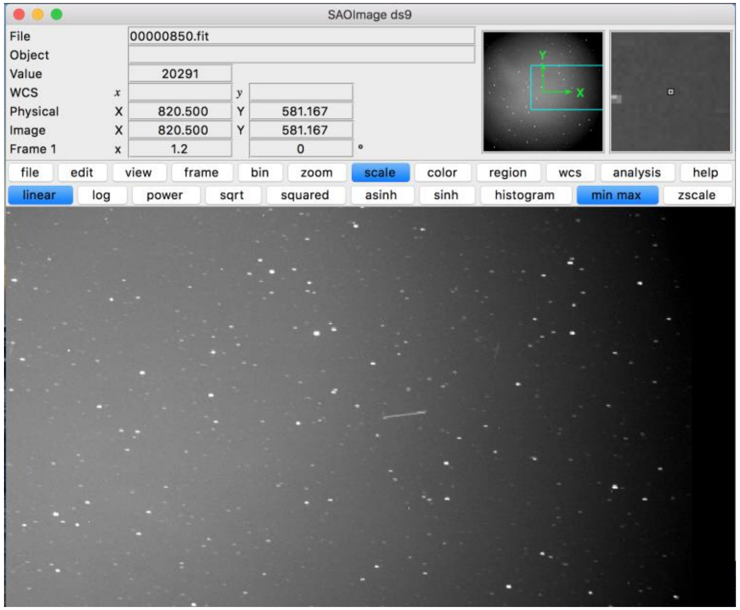
RA error: 230 ± 40 arcseconds

Dec error: 174 ± 21 arcseconds

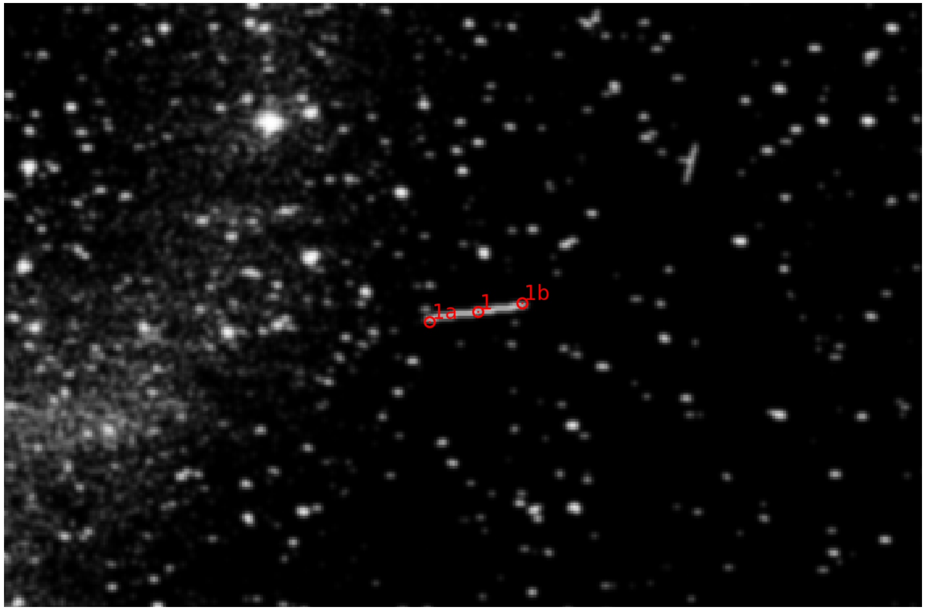
End of passage

Sidereal Tracking - example

- With sideral tracking the objects' light streak can be identified by automatic image analysis tools



RAW IMAGE



Automatic object light streak identification

Stellar Background Identification – Celestial Coordinates determination

- The angular measurement is provided by comparison with the stars' position.
- The measurement accuracy is not related to the mechanical pointing system

Once stars and objects are identified in the image the celestial coordinates of the center of the image are extracted from the header file.

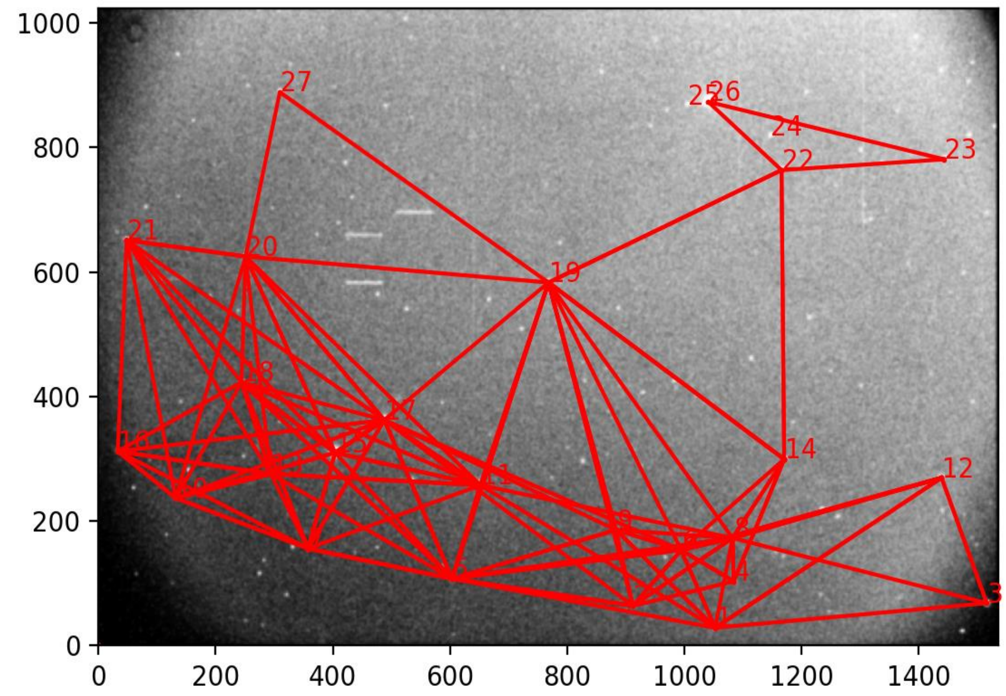
↓

An index file reporting the triangles characteristics is then generated from the star catalogue Tycho2

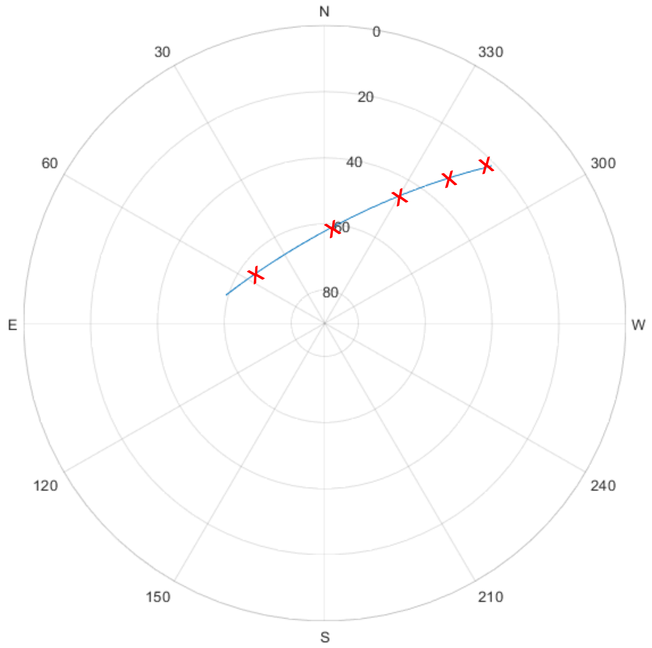
The same file is then generated considering the star positions identified in the image

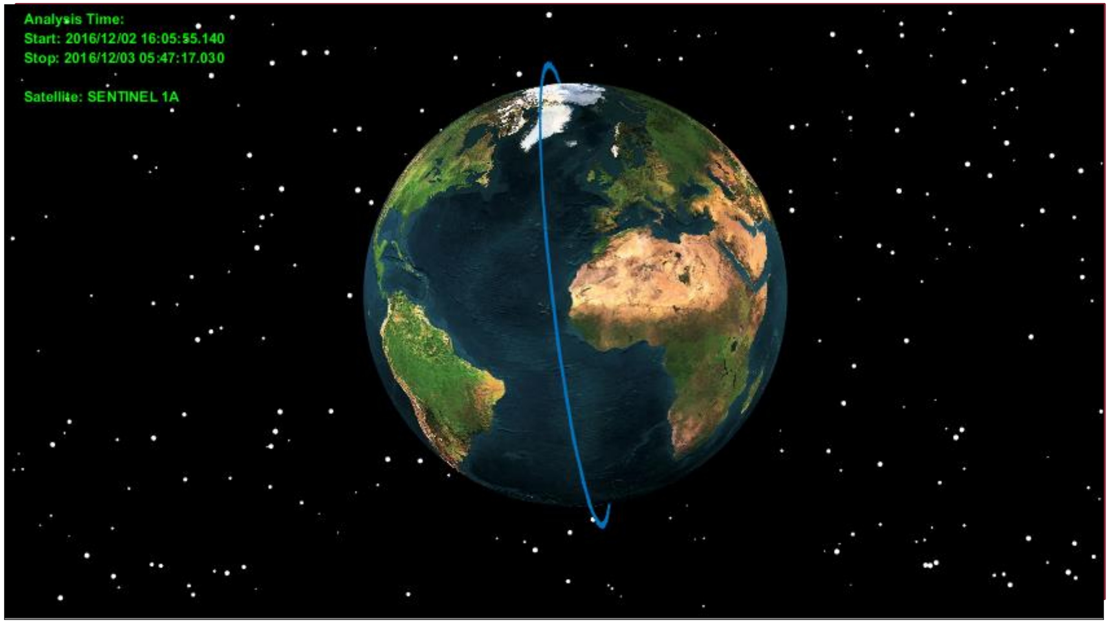
↓

Image and catalogue index are then scanned looking for matching triangles



Orbit determination



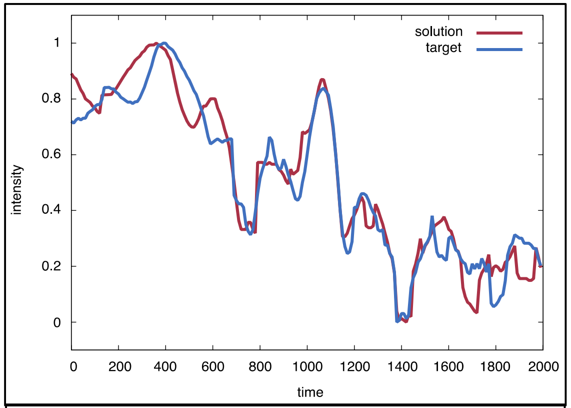


MEASUREMENT ACQUISITION AND INTEGRATION ⇨ ORBIT DETERMINATION ⇨ IMPROVED ORBITAL PREDICTION

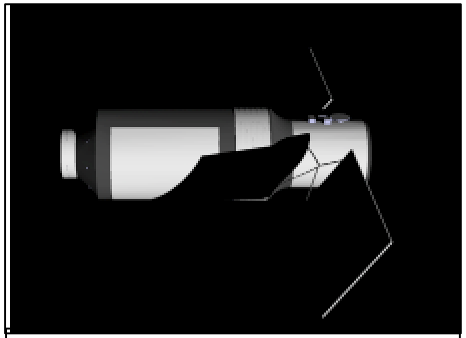
Light-curve analysis

The acquired data can be exploited for analysing the luminosity changes of the identified target. By knowing the observable geometry and materials, it is possible to reconstruct the **attitude motion** of the object.

Acquired data



Analysis of tracklet luminosity



Attitude reconstruction

The attitude reconstruction of an uncontrolled object becomes crucial for:

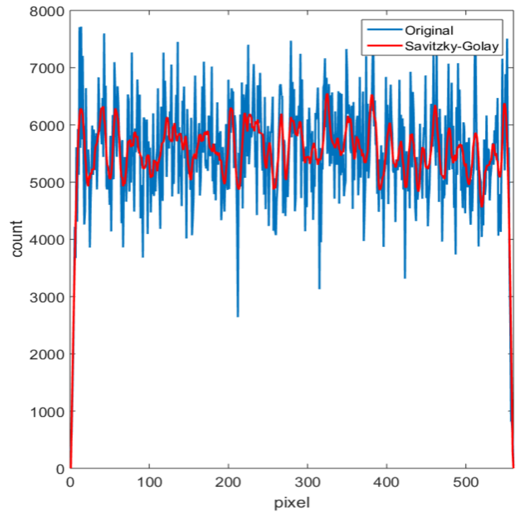
- The final phase of the atmospheric re-entry. The trajectory heavily depends on the drag coefficient, whose knowledge needs to consider the object attitude wrt the along-track direction;
- Future Active Debris Removal missions – an estimation of the attitude status is needed for planning the ADR missions.

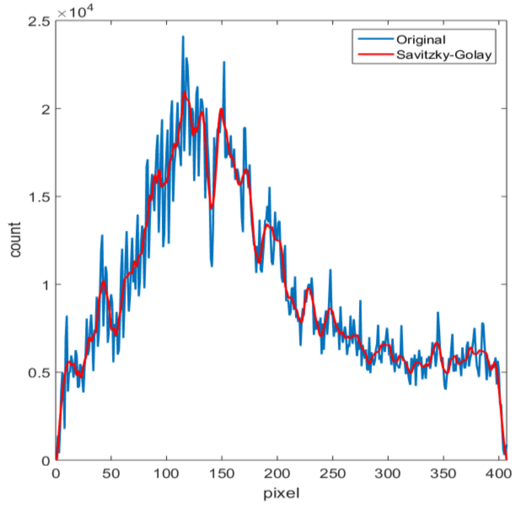
Light-curves analysis examples

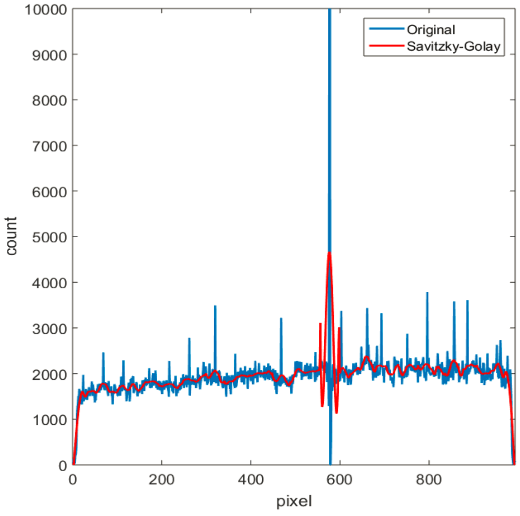
SSN 20491: H-1 R/B

SSN 27386: Envisat

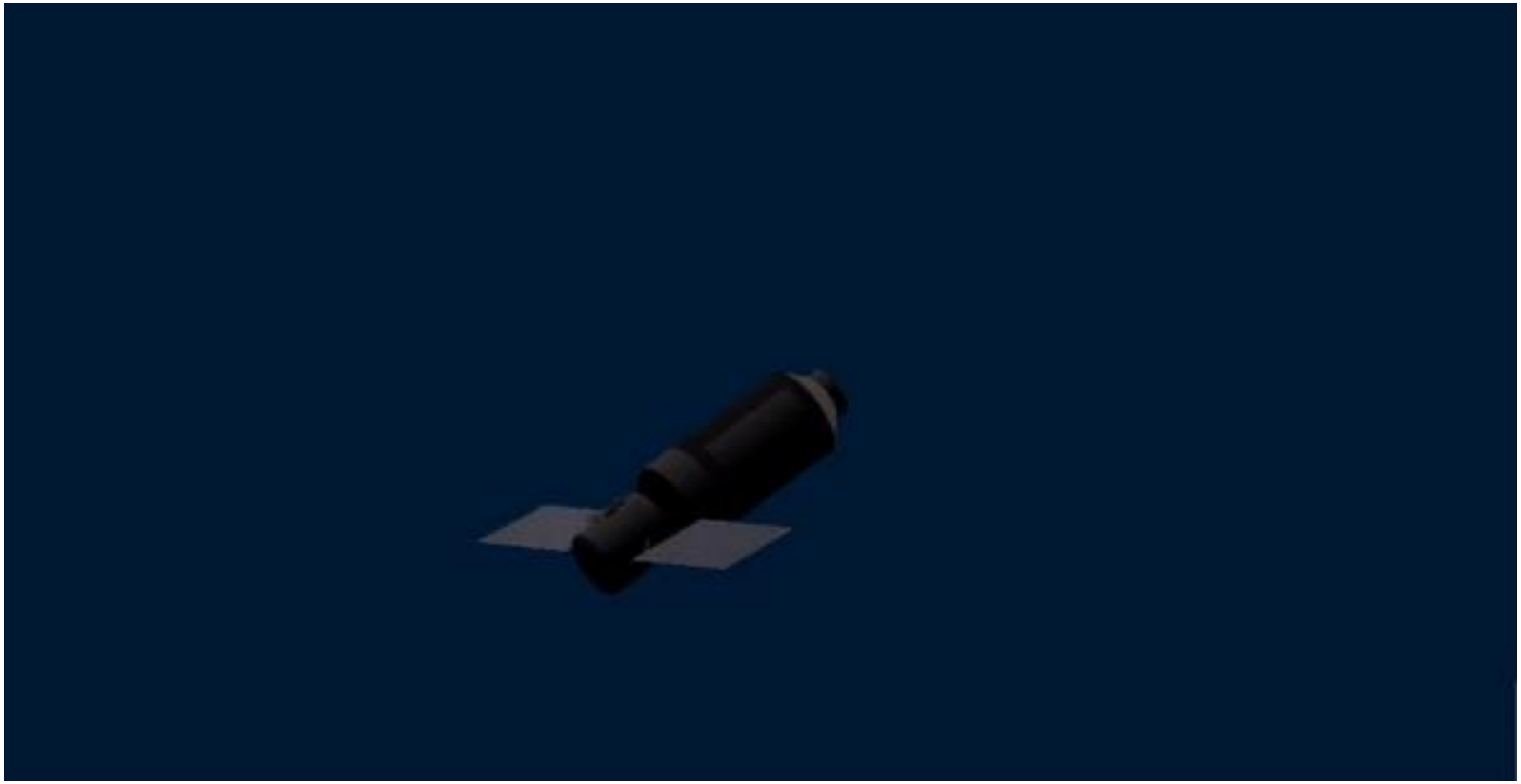
SSN 37820: Tiangong-1





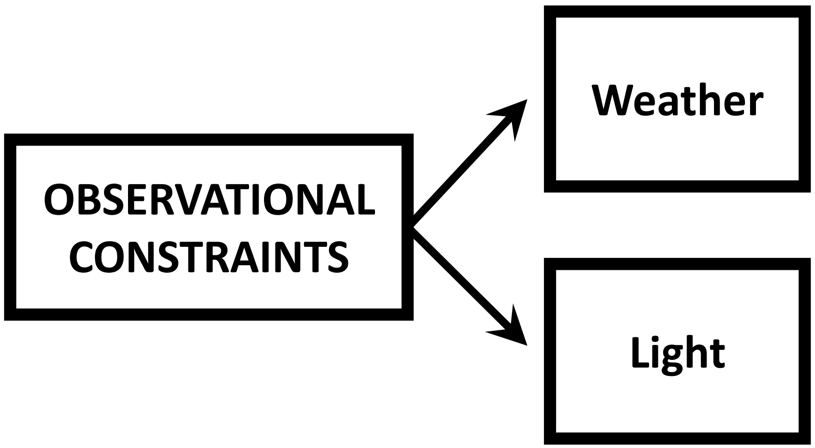


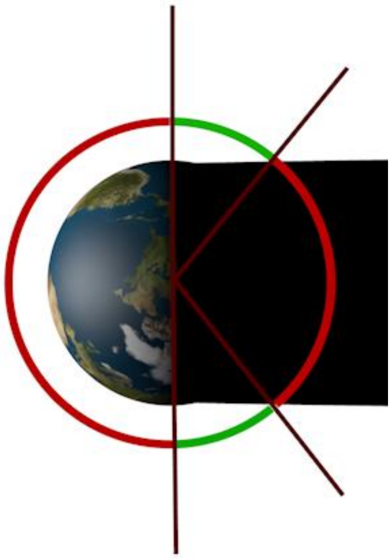
Example of reentry analysis



Why more than a single telescope?

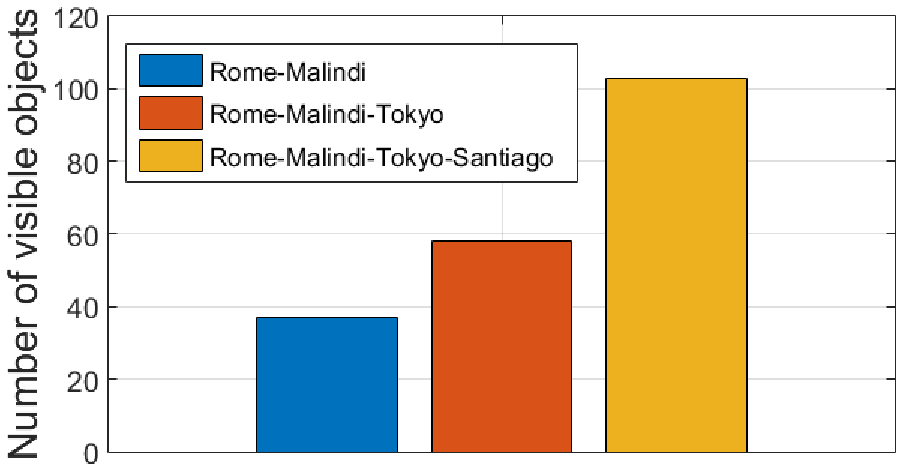
- Optical observations are constrained by weather conditions of the observation site;
- The observations can be performed only when the observational site is in darkness and the target is in Sunlight.
- For LEO objects, the suitable angular range is restrained to small regions at dawn and dusk.





Why more than a single telescope?

- With an observational network of observatories dislocated in multiple continents, the coverage over debris visible passages increases significantly.
- As an example, compare the visible passages number of possible configurations of two/three/four observatories in Europe, Africa, Asia, South America.



The analysis has been performed on the average number of visible passages in a single week of the 100 brightest objects.

Introducing GUSDON

- A Global Observation Network for space debris involving a great number of institutions in all continents
- An invaluable space debris observation infrastructure with a great educational return in the field of:

  - ❖ Hardware installation, operations, control
  - ❖ Data analysis of raw images
  - ❖ Data integration for orbit determination
  - ❖ Optimal observational strategies evaluation
  - ❖ Light-curve and spectroscopic analyses

Introducing GUSDON: Hardware

- A modular, reliable observatory architecture has been identified, for the benefit of Institutions interested in establishing an optical observatory
- It is based on affordable components, allowing to a achieve valuable results in space debris identification and tracking
- Institutions already involved in space debris observation, can easily adapt their system to be shared in the network

Observatory Standard Architecture

The modular architecture for the observing station is composed of:

- A Newtonian telescope combined with a CCD to provide large FOV (approx. 1.5 degrees);
- A PC controllable motorized mount;
- A high resolution VIS CCD;
- Tools for the scheduling of the operations;
- (Optional) Shelter design;

Introducing GUSDON: Data sharing

- As baseline data distribution principle, the entire data set acquired from **all** the observatories should be made available to **all** the involved institutions
- The de-localization will help in increasing the observations
- There is strength in numbers: the larger the network, the more accurate the results of the orbit determination process
- The contribution of the network may be critical in the case of re-entry observation campaigns

Why joining GUSDON?

Space debris research

- An invaluable research tool for identification, monitoring and tracking of space debris
- A potentially critical tool for the observation of re-entering objects

Space debris education

- Students will familiarize early in their University curricula with the space debris issues;
- Students and researchers will be involved in:
  - ❖ Collection of space debris images and observational campaigns;
  - ❖ Angular measurement extraction and raw data analysis;
  - ❖ Advanced space debris determination;
  - ❖ Analyses focused on the space debris attitude determination (photometry, spectroscopy, etc.)

Conclusions

- GUSDON proposes the implementation of a Global Observation Network managed by all the Universities that wish to be involved in the project
- Optical observations are a space debris monitoring technique to match affordable costs, easiness of use and scientific results
- The data acquisition can aim at debris identification, orbit determination, attiitude reconstruction, spectroscopic image acquisition – at different level of complexity
- The results to be achieved are a huge step towards a better monitoring of the Earth orbit environment and for an improved awareness of the space debris problem