

A Small Satellite Mission devoted to Mid-Low Latitudes Observation.

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Introduction

The feasibility of a small satellite mission devoted to observe the mid-low latitude regions has been analyzed.

The satellite will be equipped with three optical sensors: a medium-high spatial resolution VIS-NIR multi-spectral sensor, allowing the surface monitoring and land-use and land-cover studies; a medium spatial-resolution 3-bands thermal (MIR-TIR) sensor allowing the surface temperature (LST, SST) estimate and hot-spots (fires, volcanic eruption, etc.) detection; a panchromatic VIS-NIR camera for night-time observation able to reveal artificial and natural lights.

The selected orbit, called multi-sun-synchronous (MSS), represents an innovation with respect to the classical sun-synchronous orbit much suitable for observing tropical regions, allowing an enhanced revisit frequency.

Further, such an orbit allows the observation of the same region of the Earth at different local-time. In this way, the diurnal cycle of surface temperatures can be reconstructed with a 2-hours local-time step.

An analysis of the capability of the selected ground stations to acquire the data gathered by the remote sensing sensors has been carried out.

Orbital perturbations have been taken into account and an estimate of the propellant required for ground track control has been performed in order to verify its compatibility with a small mission requirements.

STK software has been used during the following phases:

- 1) to verify the periodicity and multi-sun-synchronism of the selected orbit;
- 2) to evaluate the minimum swath required to guarantee the full coverage of the area of interest and verify the possibility to have an overlap between adjacent swaths;
- 3) to analyze the quality of satellite accesses on the selected ground stations in terms of number and duration of each contact and select the best ground stations to allow the full payload data downlink;
- 4) to define the data acquisition strategy and compute the instruments duty cycle able to guarantee the full coverage of the target area;
- 5) to compute the orbital decay.

1. Orbital characteristics

A multi-sun-synchronous orbit is defined as an orbit characterized by the condition: $n = Nm$ where n is the time in nodal days needed to re-assume the same illumination conditions, m is the revisit frequency and N is an integer. The sun-synchronous orbit is a particular case of the multi-sun-synchronous orbits family.

Thanks to STK an analysis of the multi-sun-synchronous conditions for the selected orbit has been carried out. A multi-sun-synchronous can be direct and low inclination orbit. In our case, the orbital characteristics are:

$$a = 6958,74 \text{ km}, i = 44.708 \text{ deg}, \Omega_{t=0} = 325^\circ, m = 5, n = 60.$$

The following table shows the time and the longitude of the equatorial crossings from which the respect of the revisit frequency m of 5 nodal days.

Pass	Time (UTCG)	Lon Ascen Node (deg)
1	1 Jan 2008 12:00:00.000	44.581
74	6 Jan 2008 09:59:57.918	44.580
877	29 Feb 2008 11:59:35.044	44.570

Table 1. Longitude and time of the satellite *nodal crossing*, after a periodo of m (5) and n (60) nodal days.

Fig. 1 shows the distribution of the ground tracks covered by the satellite in 5 nodal days.

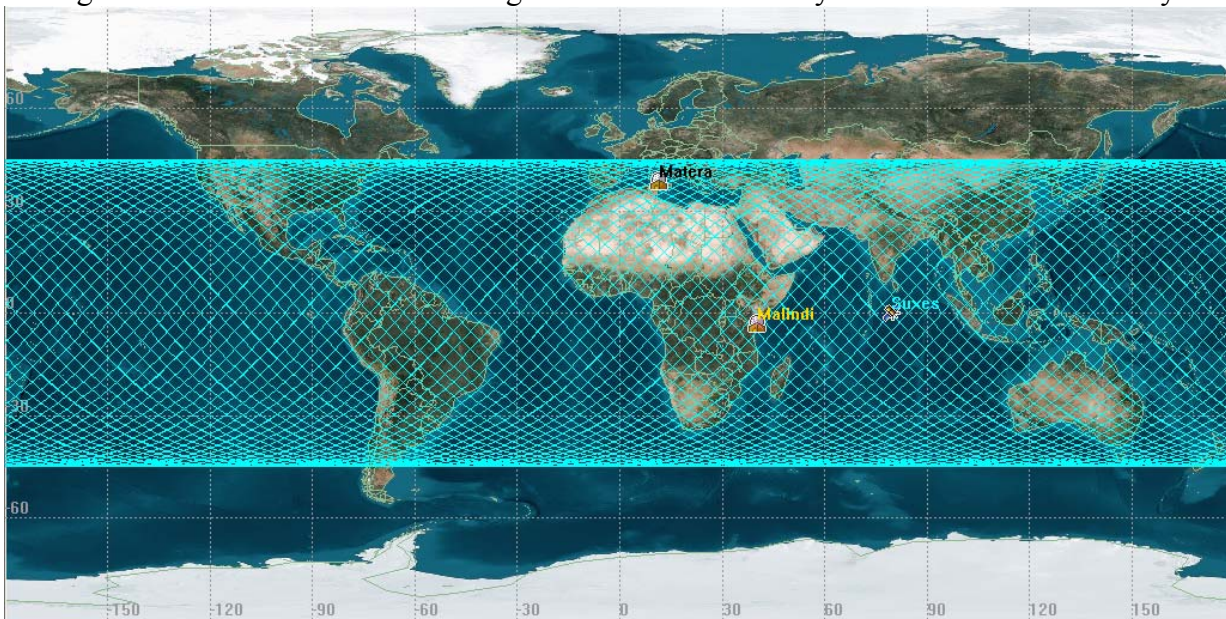


Fig. 1. Ground tracks pattern.

Fig. 2, where the number of each track is shown, allows to verify that the temporal sequence of the track, during the 5 days, agrees with the value given to the k parameter. Let us recall that two spatially adjacent tracks will be covered after k or $m-k$ days according to the k value.

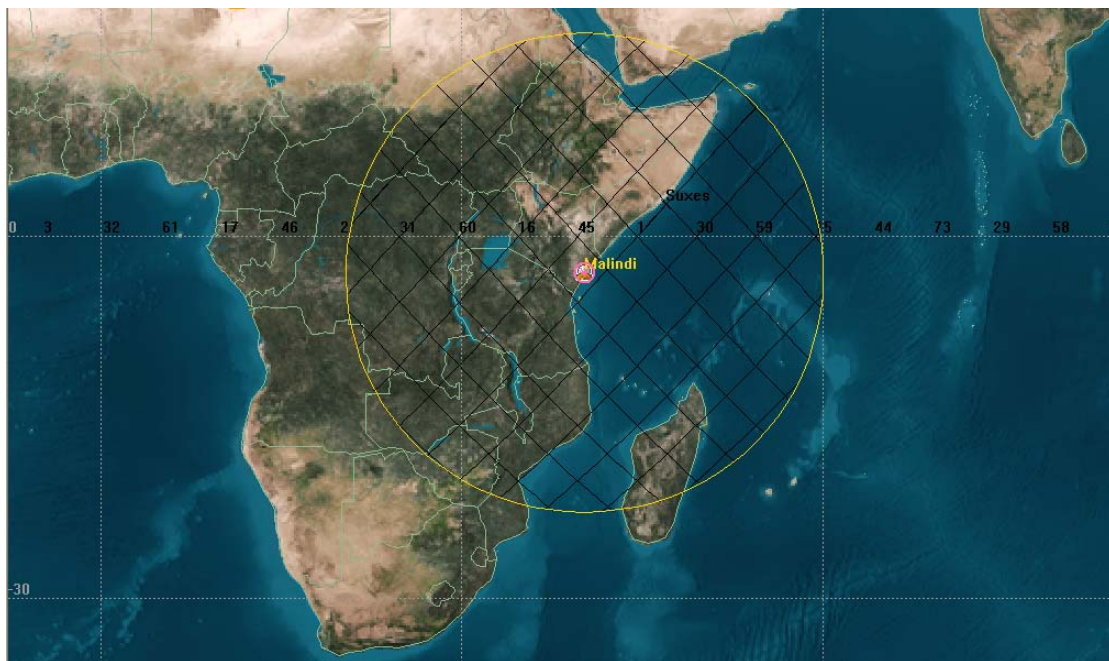


Fig. 2. Ground tracks numbering.

Every 5 nodal days a given area of the earth is observed at a certain local time and two consecutive observations of the same area are obtained with a local time sampling interval of 2 hours. Assuming the mission starts on the 1st of January 2008 the Fig. 3 shows, during the first 5 days revisit interval, which tracks are travelled at sun. As a consequence of the orbital characteristics, the local time of the observation of the same area changes regularly. Fig. 4 shows as, after 30 days the descending part of the orbit will be illuminated instead of the ascending arc.

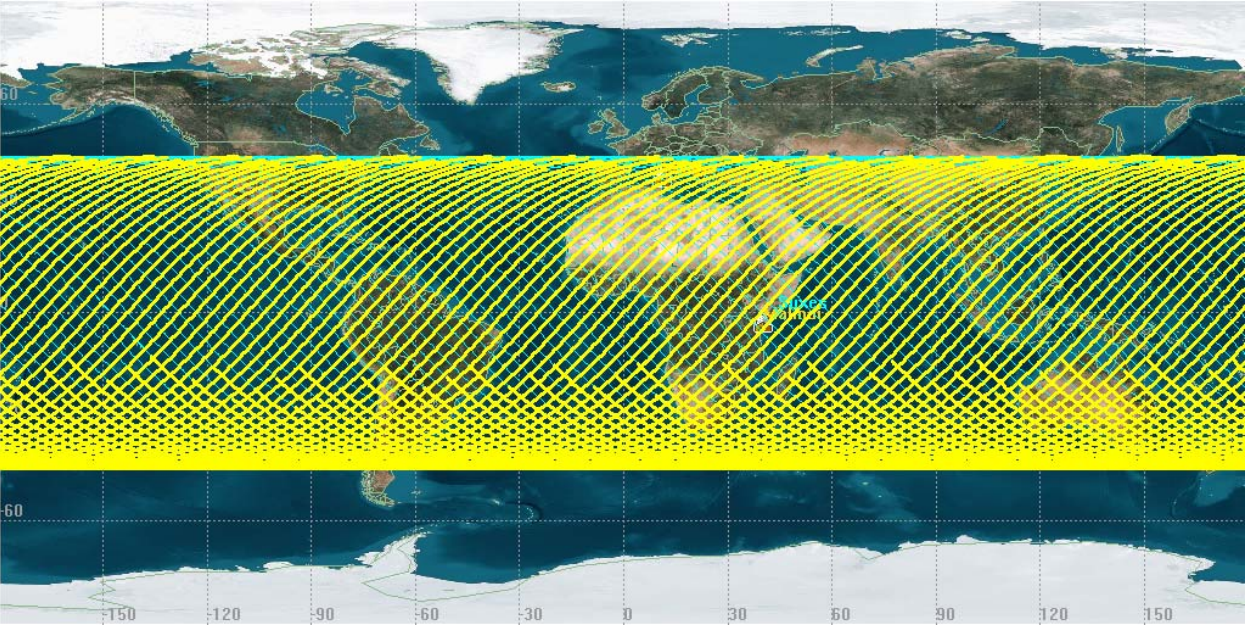


Fig. 3. Ground tracks at sun during a 5 days period from 1st to 6th January.

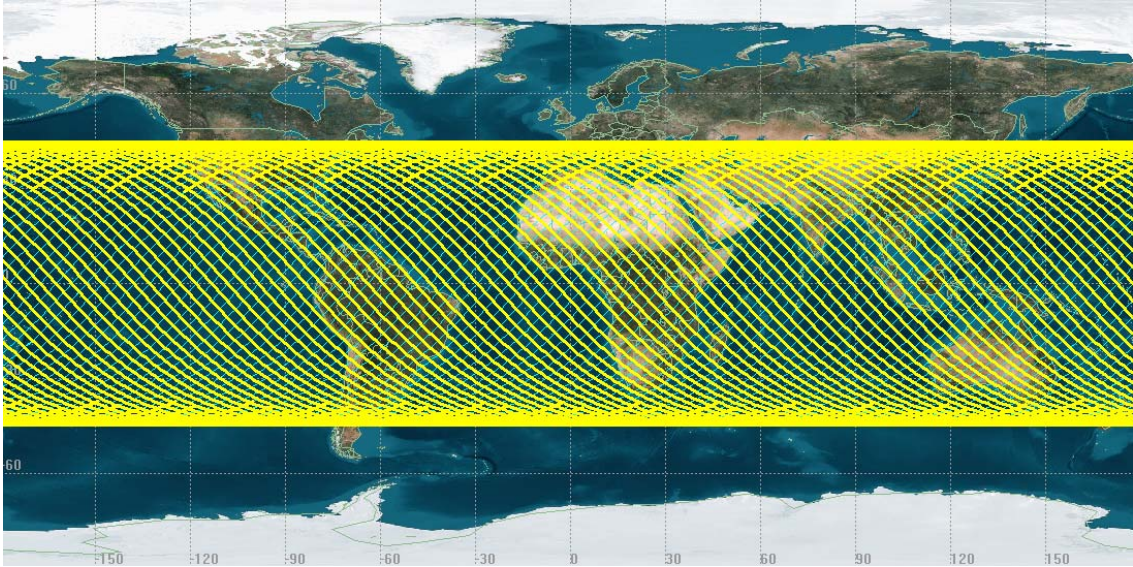


Fig. 4. Ground tracks at sun during a 5 days period from 31st of January to 5th of February.

Since one of the remote sensing sensors can operate only during day, as result of the analysis shown in Fig. 3 and 4 the plan of images acquisition can be established.

2. Sensors characteristics and access times at ground stations

STK tools have been used to verify if the global coverage of the Earth's mid-low latitude regions is obtained in the

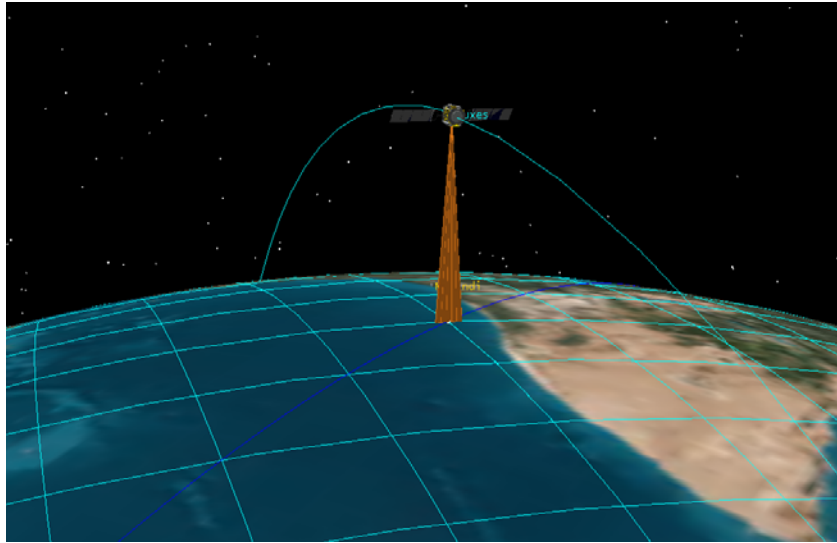


Fig. 5. Swath of the multispectral VIS/NIR sensor looking at nadir

required time and how a sensor tilting angle strategy, if any, can be implemented (see Fig. 5). Further, defining the ground stations (Fig. 6) and computing the acquisition circles the access times (Fig. 7 and 8) can be estimated and the transmission bit-rate to download all the acquired data be evaluated.

In particular, Figs. 7 and 8 show the number and duration of the satellite

contact with the two selected ground stations of Matera (Italy) and Malindi (Kenya). A third station is necessary to maintain an adequate down-link bit rate. The more suitable has been selected by using plots like the one shown in Fig. 9. This Fig. reports the number and duration of the satellite accesses at the considered ground stations.

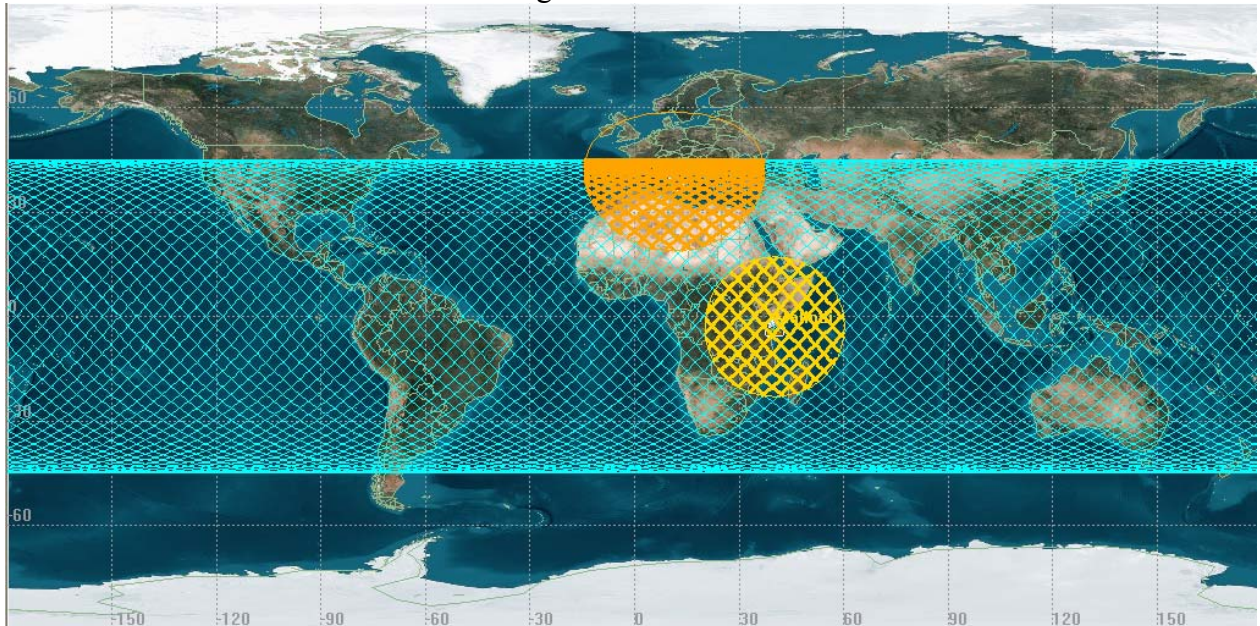


Fig. 6. Ground station acquisition circle.

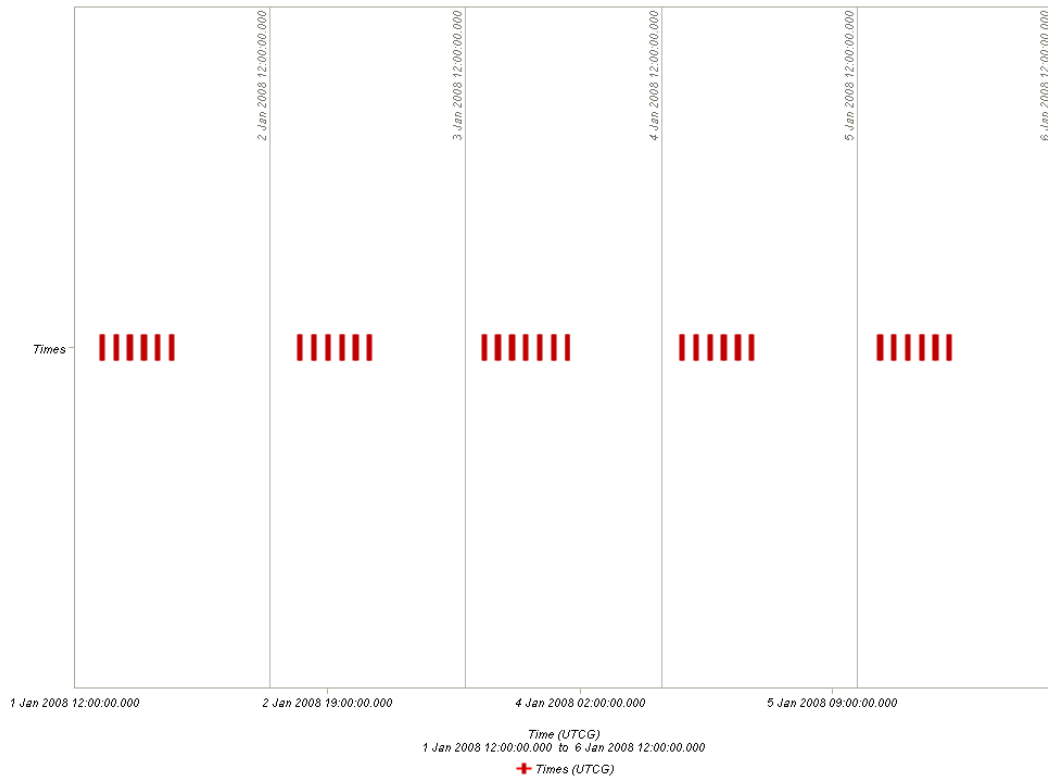


Fig. 7. Satellite accesses at Matera (Italy) ground station during the 5 nodal days repetitivity cycle.

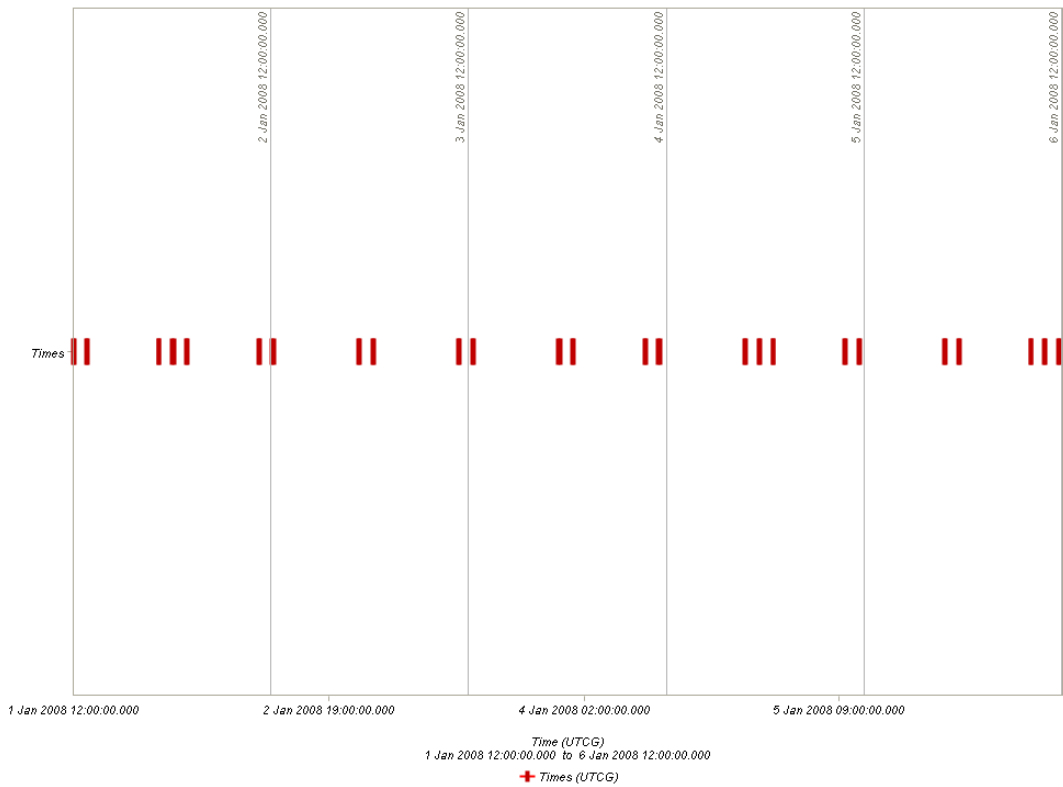


Fig. 8. Satellite accesses at Malindi (Kenya) ground station during the 5 nodal days repetitivity cycle.

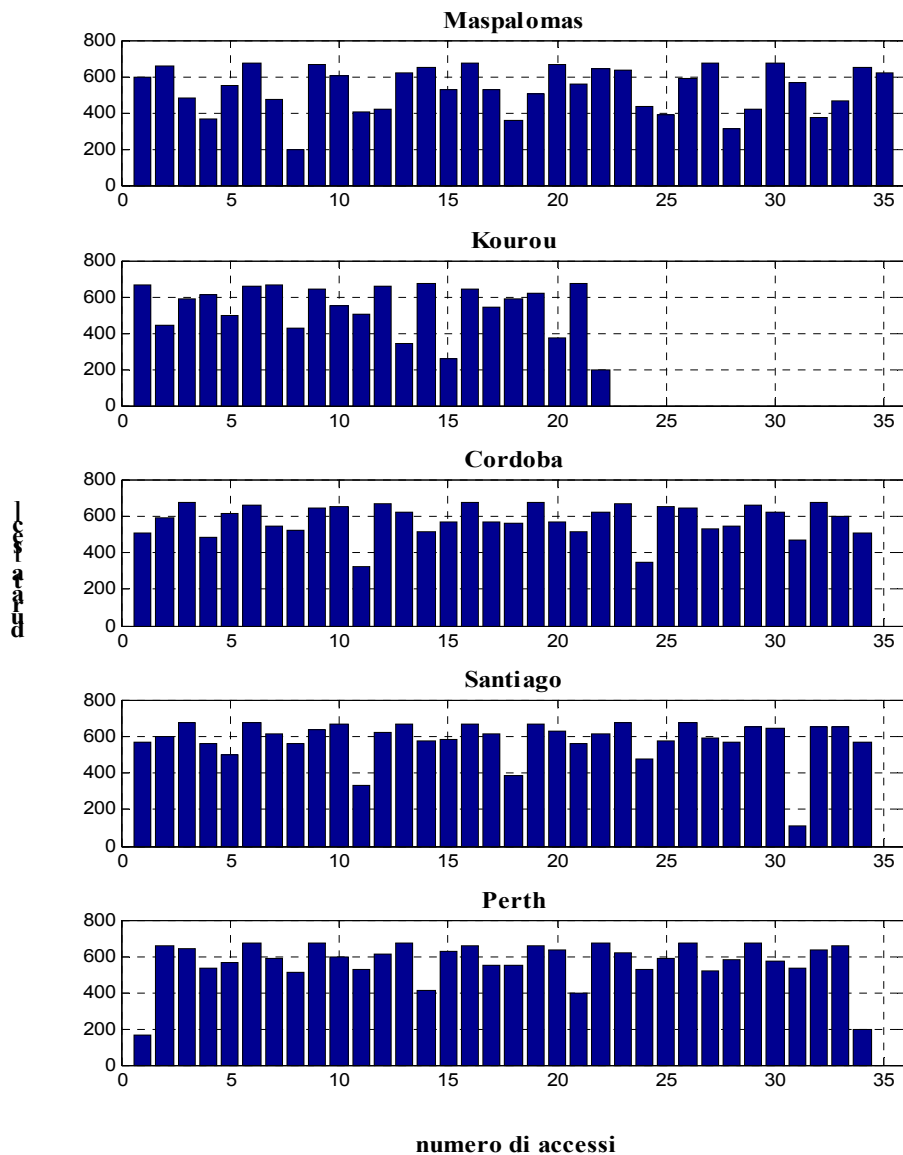


Fig. 9. Ground stations performances in terms of accesses number and duration.

Accesses duration [sec]	Maspalomas	Kourou	Cordoba	Santiago	Perth
Minimum	199.0	196.3	323.1	110.5	162.2
Maximum	674.9	671.2	675.6	676.0	676.0
Average	532.1	536.7	578.7	582.2	568.8
Total in 5 days	18625.4	11807.2	19676.6	19794.1	19339.4
Daily total averaged duration of the contacts including Matera and Malindi			10004.5		

Table 2. Statistical data for the considered ground stations obtained by using STK.

3. Acquisition strategy and instruments Duty Cycle

STK allows to define an area target more or less extended (Fig. 10 and 11). In this way the time needed to observe the assigned area can be computed, thus the acquisition strategy can be implemented and the duty cycle of the considered sensor can be evaluated. In our case the observation is restricted to the land surface comprised between ± 45.0 deg.

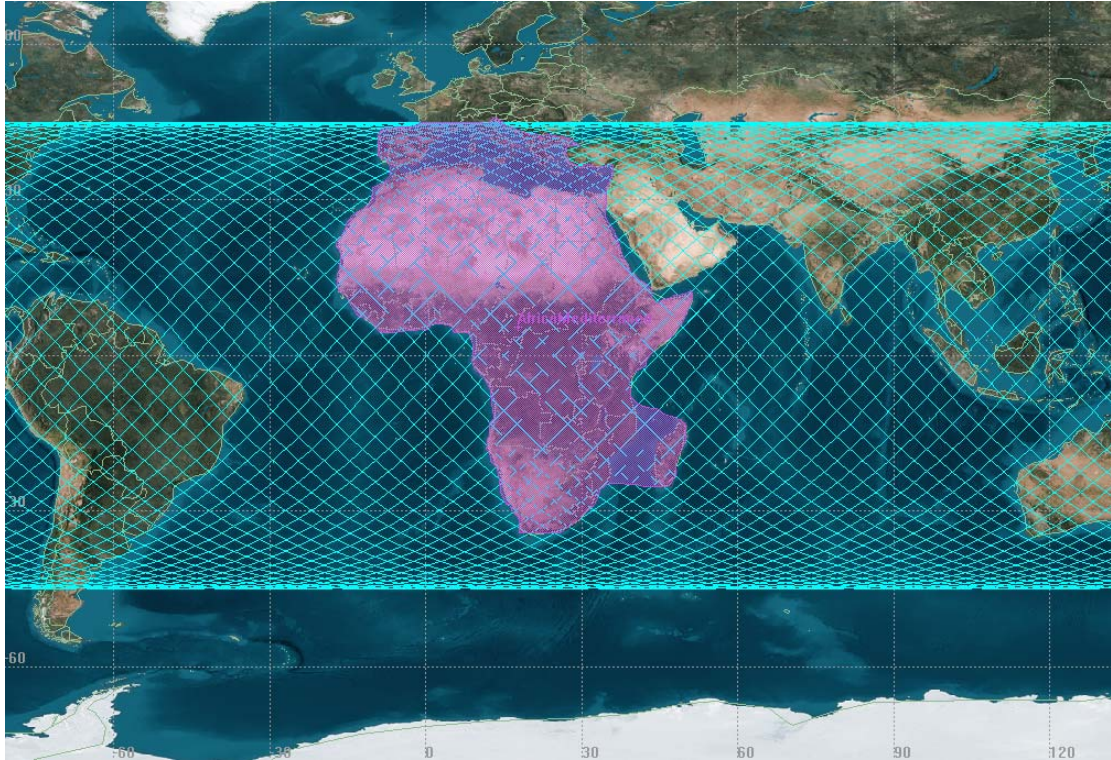


Fig. 10. Satellite tracks on part of the area target comprising Africa and Mediterranean region.

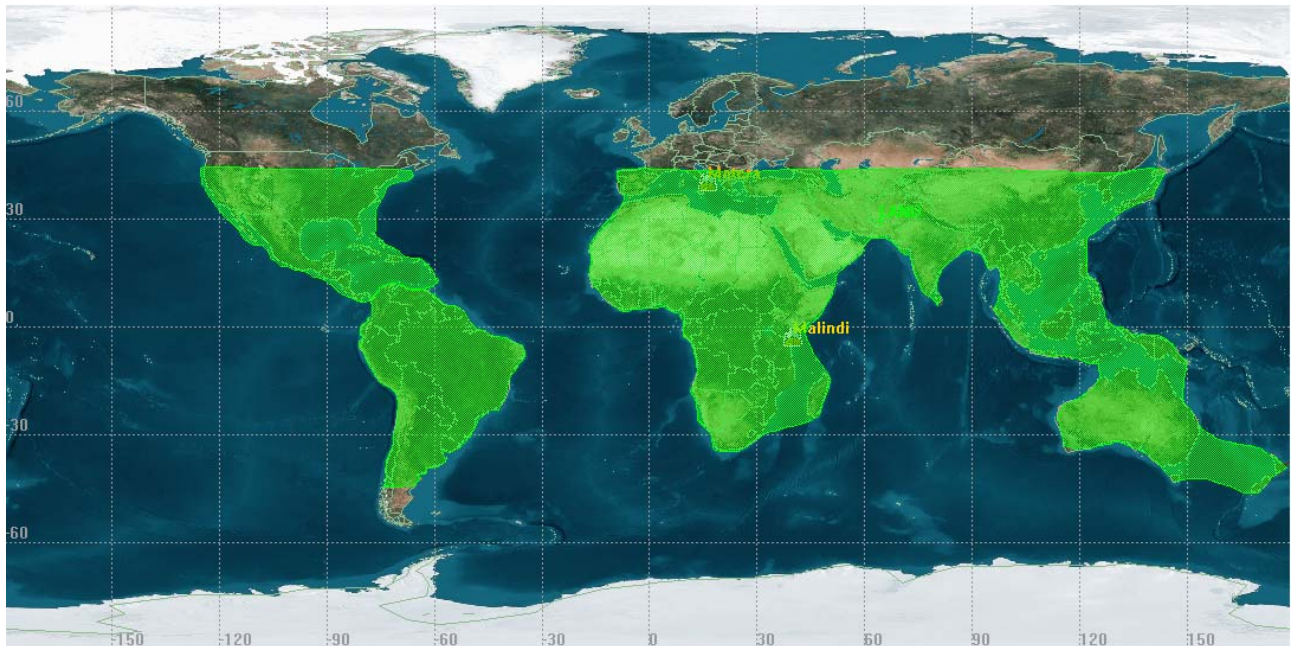


Fig. 11. Area target defined for the mission under study.

Using results like these reported in Fig.12 the duty cycle (DC) can be computed. In fact, Fig. 12 shows the duration of the accesses on the area of interest and their distribution during the 5 days of the revisit period. An averaged duty cycle of the 20% has been computed.

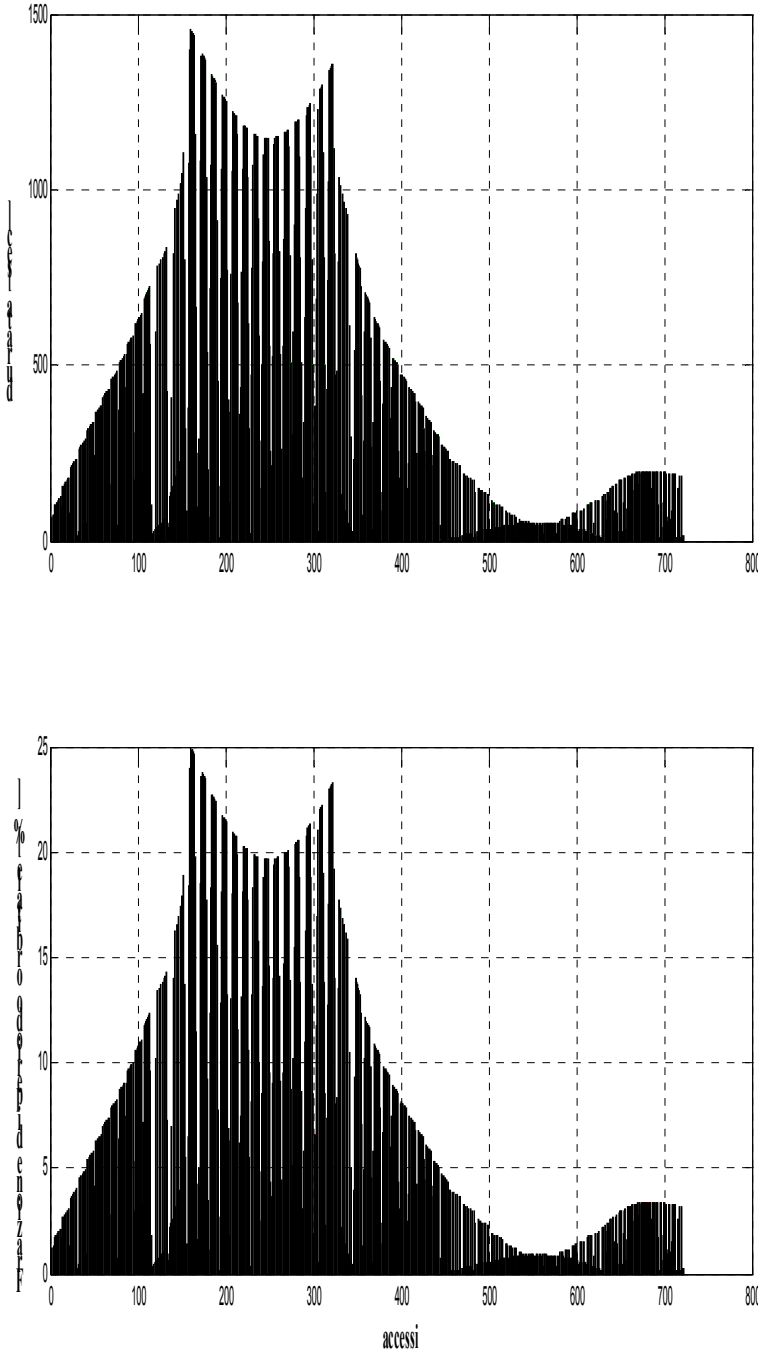


Fig. 12. Access duration on the target area during the 60 days needed to recover the same illumination conditions. On the right the duration has been esprime in percentage of the orbital period.

4. Orbital decay

The Fig.13 shows the decay of the satellite orbit, as consequence of the atmospheric drag effect. Starting from these values, assigned the allowed range of the ground tracks drift the amount of propellant needed during a five years mission can be estimated.

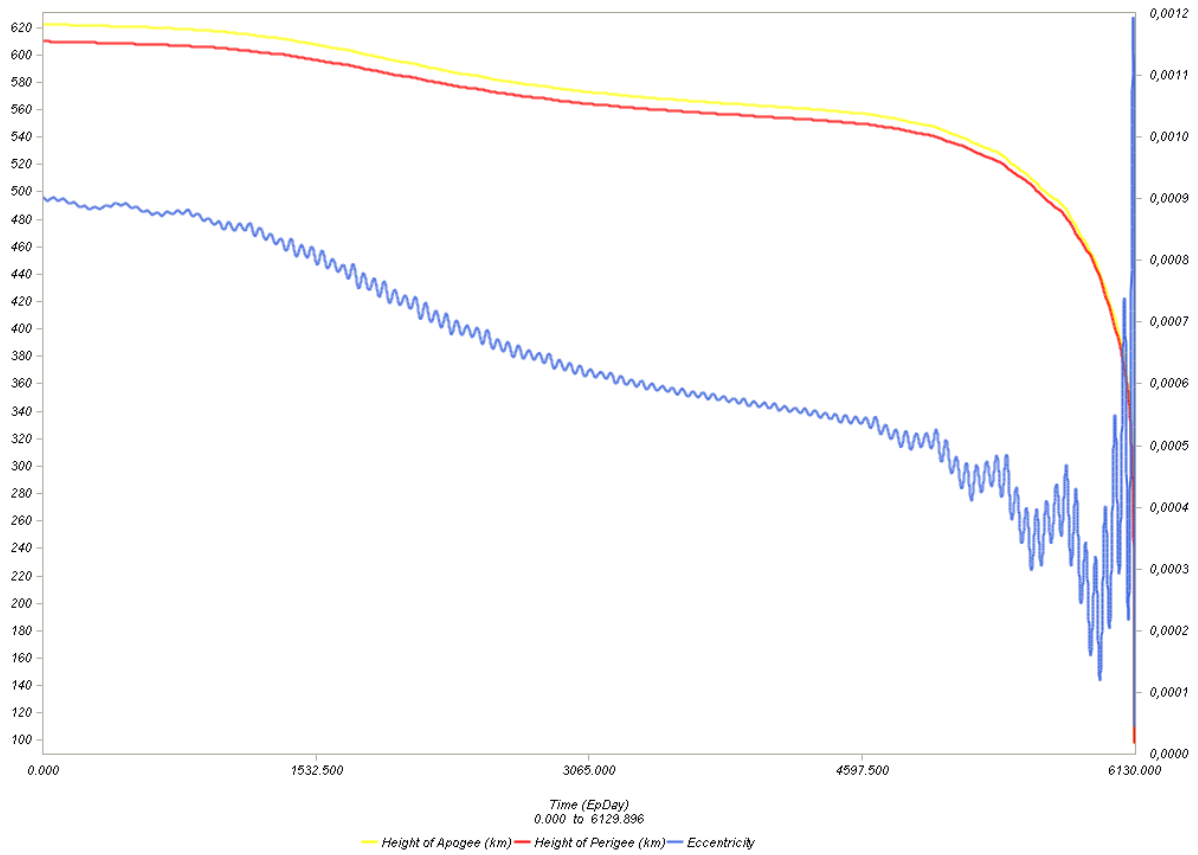


Fig. 13. Orbital decay during the satellite lifetime