VERY SMALL ASTEROIDS DETECTION AND RENDEZVOUS STRATEGY

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ABSTRACT

Due to the nature of the errors in the measurements taken of very small asteroid (few meters in size) orbits, the uncertainty region in their position is very elongated in the alongtrack direction. Since the arrival direction of an asteroid rendezvous mission is close to that direction a reasonable arrival asteroid search procedure is to sweep the uncertainty bounding box along the longest axis. The faint asteroid detection challenge shall be solved by dimensioning an optical system and search strategy of appropriate performances, which shall allow finding the small asteroid when arriving to the asteroid orbital region.

For the calculation of the asteroid apparent magnitude, there is a geometrical locus of points with the same visual magnitude which would be the detection boundary for a given optical system. We have called such locus the detection polar and its representation is depicted in Figure 1. Curves are provided for cases where the difference between the absolute magnitude of the asteroid and the visual limiting magnitude of the optical device are respectively 13, 15, 17 and 19 magnitudes and the asteroid slope parameter is G = 0.15 (typical).

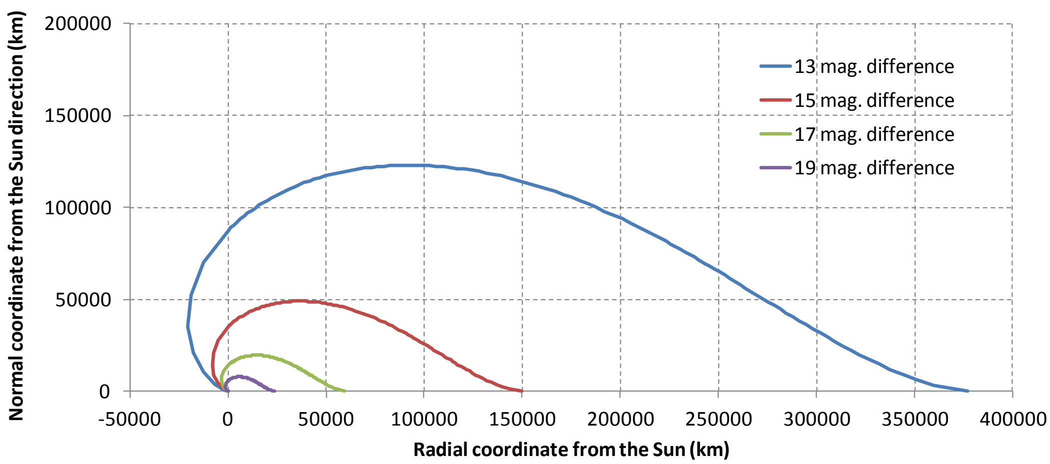

Figure 1. Detection polar for different values of the difference between asteroid absolute magnitude and the camera visual limiting magnitude (asteroid at 1 AU from the Sun, G=0.15)

An effective detection campaign for very small asteroids can be composed of two processes:

1) A search procedure in position, by which the spacecraft sweeps the area occupied by the covariance ellipsoid (see Figure 2)
2) A scan procedure in orientation for a given position, by which the camera subsystem searches for the asteroid within the detection polar (see Figure 3)

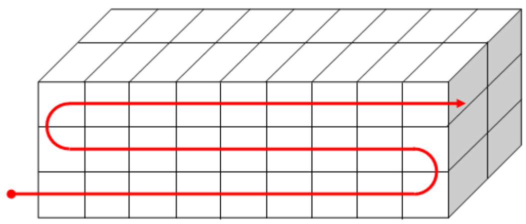

Figure 2: Preliminary sweeping strategy of the asteroid uncertainty cuboid

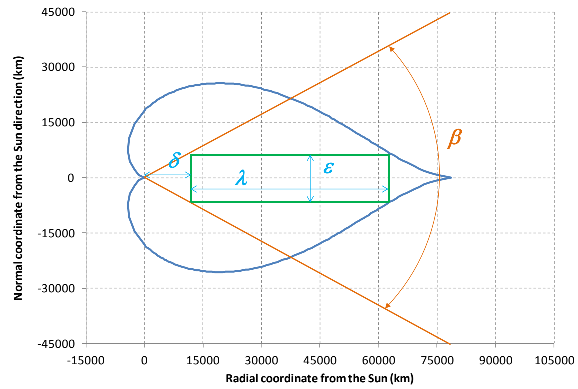

Figure 3: Detection polar for example absolute magnitude and camera limit and detection box for β=60 deg

The proposed sweep strategy to search for the asteroid translates in that the relative motion of the S/C around the average asteroid orbit will need to be such that the S/C is forced to follow the specified path. This implies a limitation on the sweep speed which is the one that can be ensured with the S/C propulsion system and will also imply a certain fuel consumption and search period of time. Those parameters shall be evaluated in order to determine the solution space of application for the design of the arrival phase to the asteroid.

For a forced drift in alongtrack direction, certain initial relative velocity wrt the asteroid can be maintained by pushing in radial direction. It shall be assumed that the satellite possesses the intended relative drift velocity at the beginning of this phase, which can be obtained by proper targeting to this dynamics state at the end of the former transfer phase. The parameters to analyse are then: drift velocity, cost of low thrust profile and maximum thrust needed to keep the intended drift velocity for a given satellite mass.

For a specific mission project managed by Elecnor Deimos, a camera solution has been found suitable for the task of finding defined target asteroids in three months and sweeping an uncertainty region with a maximum dimension alongtrack of 500,000 km, crosstrack of 5,000 km and radial of 50,000 km. It has been assessed that, under such conditions, a camera with a limiting magnitude of 13.5 should be enough to solve the detection of such small asteroids, provided the uncertainty region is scanned in the alongtrack direction in the available amount of time. The resulting constraints are well within the specification of COTS cameras for space applications and propulsion solutions for the S/C sweeping process.