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System of Observation of Daytime Asteroids (SODA)

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It is known that the Chelyabinsk meteoroid that collided with the Earth on the 15-th February 2013 was detected by neither any ground-based nor near-Earth space telescopes before it entered the Earth's atmosphere. No ground-based NEO discovery systems are able to detect meteoroids approaching the Earth from day sky. In our previous papers we suggested that the only realistic way to overcome this problem is to use a system of space born telescopes located relatively far from the Earth. We named the system SODA (System of Observation of Day-time Asteroids).

The top-level SODA project goals are:

- to detect "almost all" bodies larger than 10 m entering the near-Earth space (i.e. approaching the Earth at a distance of less than 10E6 km) from the Sun direction;
- to quickly identify a body of special interest (e.g. an asteroid at collisional orbit) and to characterize it, i.e. perform an accurate orbit determination and body mass estimation;
- in the case of a collisional orbit, the system should ensure a warning time of about 4-10 hours and determine coordinates of the atmospheric entry point with the best possible accuracy.

The concept of the SODA system consists of one or two (in optimal configuration) spacecraft (SC) placed into orbits in the vicinity of the Lagrange point L1 of the Sun-Earth system. The SC is equipped with one to three small aperture (25-30 cm) telescopes to observe near space in a conical region around the Earth. It is expected that SODA will be able to detect all decameter-sized bodies coming towards the Earth from the Sun (day-time celestial hemisphere). For objects on collisional orbits the SODA will ensure a warning time of up to 10 hours and the accuracy of coordinates of the atmospheric entry point up to ~10x100 km. Major general system requirements are: usage of existing technologies, and to be a low-cost project.

The optimal variant of the SODA system includes two SC located at a large distance (approximately in antiphase) at a halo orbit around the L1 point. The main advantages of this option in comparison to the one SC variant are:

- increased accuracy of orbit determination since the triangulation method can be used;
- prevention of the possibility of missing bodies at trajectories close to SC (less than 0.4 million km);
- larger detection area;
- improved system reliability.

For the last two years additional research was carried out to make the SODA concept more mature.

Recent progress in manufacturing of CMOS cameras with a small pixel size makes it possible to design a more compact optical system without impacting the efficiency.

The new optical system (30 cm aperture, F:1.5, 3.75 deg field of view) based on the Sonnefeld camera optical design has been proposed. In combination with the pre-aperture slewing mirror (480×340 mm) it provides a 50×120 degree area of observation with a single telescope. SODA SC should have has at least two of these telescopes on board, but for the redundancy and for higher astrometric accuracy, 3 or 4 telescopes options can be considered.

The characteristics of the SODA system can be improved by using a modern off-axis TMA optical design in combination with a small pixel size CMOS detector with enhanced NIR sensitivity. Due to the absence of vignetting and wider spectral range, this option potentially will reduce the telescope aperture down to 20-25 cm without impacting the system efficiency. Further study is needed.

The proposed trajectory design for the SODA mission allows the insertion of 2 SC (~400 kg each) into orbit around the L1 point with a required phase delay using

Soyuz-2.1b medium class launcher with the Fregat-SB upper stage. It takes about 100 days to reach an operational orbit.

The scientific potential of the mission can be enhanced by including instruments for monitoring the activity of the Sun (similar to the DSCOVR space mission).

We believe that the most efficient approach is to combine SODA and ground-based NEO detection systems (e.g. ATLAS). International cooperation is highly desirable. One more argument for closer international collaboration is the necessity of construction of a global network of data receiving stations. These stations should be equipped with low-cost 6 m antennas.