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SYSTEM OF OBSERVATION OF DAYTIME ASTEROIDS (SODA)

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Potentially hazardous decametre size asteroids are considered as the most probable threat to the Earth in the coming decades. For this reason, close approaches of asteroids larger than 10 m to the Earth, including those coming from daytime sky, are subject to study. In our opinion the only realistic way to detect daytime asteroids is to use a space telescope located relatively far from the Earth.

INASAN has developed a conceptual design of the SODA (System of Observation of Daytime Asteroids) space mission to operate at the vicinity of L1 point. The mission is designed to detect most of the 10 m class bodies coming from the day sky and to ensure a warning time of about 10 h in the case of possible impact. According to our estimation, SODA will detect 2000 decameter asteroids per year coming into a 1 million km vicinity of the Earth. For 10 years of operation several small impactors will be detected by SODA.

We have presented the SODA Project at PDC-2021 (Fig. 1). The 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. The slewing mirror is shielded from the Earth's direct light by a light-shielding mask mounted on the rod at a distance of about 2 m from the telescope.

SODA telescopes should provide two modes of operation:

- complete discovery of new asteroids coming from the sunward hemisphere using a barrier detection technique;
- target mode to accurately define the orbit of a dangerous asteroid.

In order to optimize the SC design, both modes should be implemented by a set of identical telescopes.

Here we briefly discuss possible variations from the SODA baseline design and some new ideas. Several new technical approaches are under investigation.

A new possible design approach is to use a full-reflective off-axis design (TMA) which potentially may reject the scattered light from the Earth using the internal telescope's diaphragms only. In this approach using a mask in front of the telescope to blind the Earth may not be necessary, this makes the spacecraft simpler and more compact. Due to the absence of vignetting and wider spectral range, the telescope aperture may be downsized to 25 cm without impacting system efficiency.

In parallel to studying to build a full-scale SODA project, the concept of a small (~30 kg) and cheap SODA technological demonstrator is being studied. It can be an additional payload for another spacecraft at L1. To fit the SODA payload in the very strict mass budget of the technological demonstrator, we found a way to keep the main functionality of the SODA mission at a reasonable level while only using one small aperture (15 cm) telescope (Fig. 2). A new design includes a full-rotative pre-aperture mirror which provides access to the whole conical barrier using only one telescope (Fig. 3)., and the telescope itself blinds scattered light from the Earth. To compensate for the lack of survey rate and sensitivity, the telescope FoV is increased up to 6 deg and the exposure up to 10 s. Nevertheless, due to the lack of sensitivity (smaller aperture), we expect to have lower completeness of the discovery of 10 m class bodies.

Another problem of the chosen approach is astrometric accuracy. Recent progress in manufacturing CMOS detectors with small pixels (3-5 um) makes it possible to essentially improve the angular resolution of 15 cm class wide field telescopes of the SODA technological demonstrator.

SODA technological demonstrator can be very efficient to verify almost all critical features of the SODA mission, such as:

- to prove the technology of asteroid discovery, coming from the sunward hemisphere, using an optical barrier detection technique,
- to prove the algorithms and technology for potentially dangerous asteroid follow-up observations from L1,
- to prove the algorithms for orbit determination and impact point prediction on the Earth from L1.

SODA technological demonstrator will be capable of beginning scientific operation – discovery of small asteroids coming to the Earth from the sunward direction.

Speaking about possible variations from the SODA baseline design, we are motivated to look for any opportunity to increase the warning time, which is about

10 hours for L1. We consider two variants proposed by other groups aimed to increase the warning time for daytime asteroids.

The first variant is to put the SODA-like spacecraft at a Forced Stationary Point (FSP) beyond L1, say at 3 mln. km from the Earth. We have demonstrated, that increasing the exposure time by 2 or 3, slightly increasing the telescope FoV up to 4 deg and optionally adding the fourth telescope will provide the same detection efficiency of 10 m asteroids from FSP (3 mln. km from the Earth) as for L1. Unfortunately, the current technology of the solar sail and low-thrust ion engine can't keep the spacecraft at FSP for 5-10 years.

The second variant to increase the warning time is to put the telescope on the Earth-leading heliocentric orbit. We have demonstrated that because of a poor phase angle even a 1 m class telescope on such an orbit will not be efficient for the detection of 10 m class day-time asteroids, the reasonable detection completeness is achieved for asteroids larger than 30-50 m. While having a scientific payload mass budget of 1 ton at the Earth-leading heliocentric orbit, we still have no suggestions on how to design a telescope capable of fulfilling our main scientific goal which is to detect 10 m asteroids coming from the Sun. Therefore, at a moment this orbit is fully rejected from further studies.

Now the SODA concept is considered as a part of the conceptual national project "Mlechny Put" (The Milky way) which covers the asteroid hazard problem, observation of the Sun and space weather. In addition to the SODA payload, the spacecraft at L1 will be equipped with many other important instruments to monitor the activity of the Sun. International collaboration is welcome as well as cooperation with other ground-based projects focused on the detection of decameter class NEOs in the Earth vicinity.

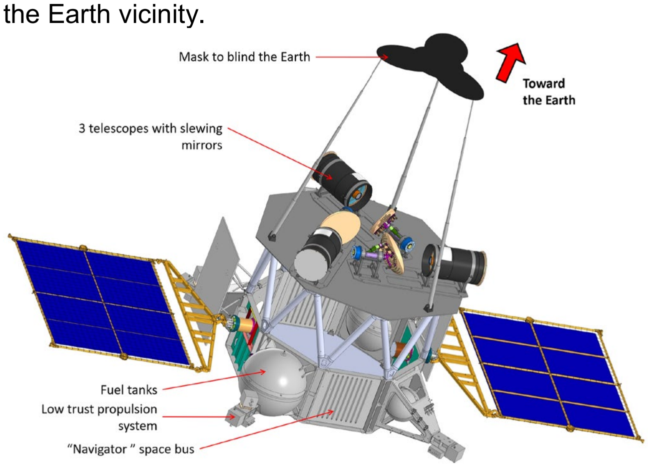

Figure 1. SODA spacecraft concept with "Navigator" spacebus.

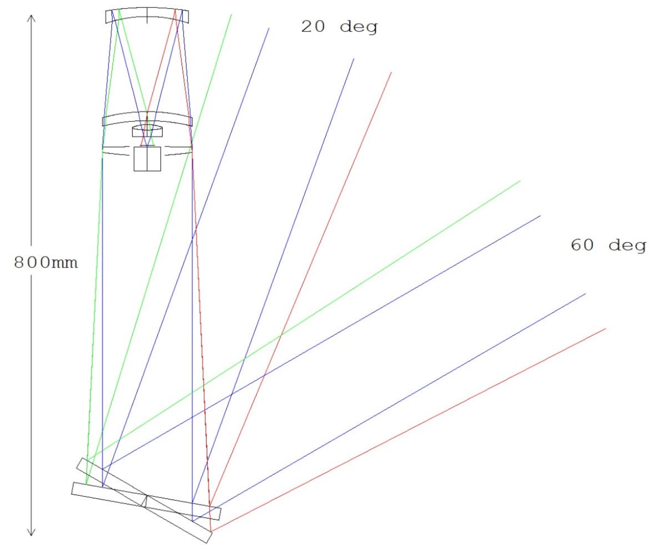

Figure 2. Optical concept of the telescope for the SODA technological demonstrator with full-rotative pre-aperture mirror.

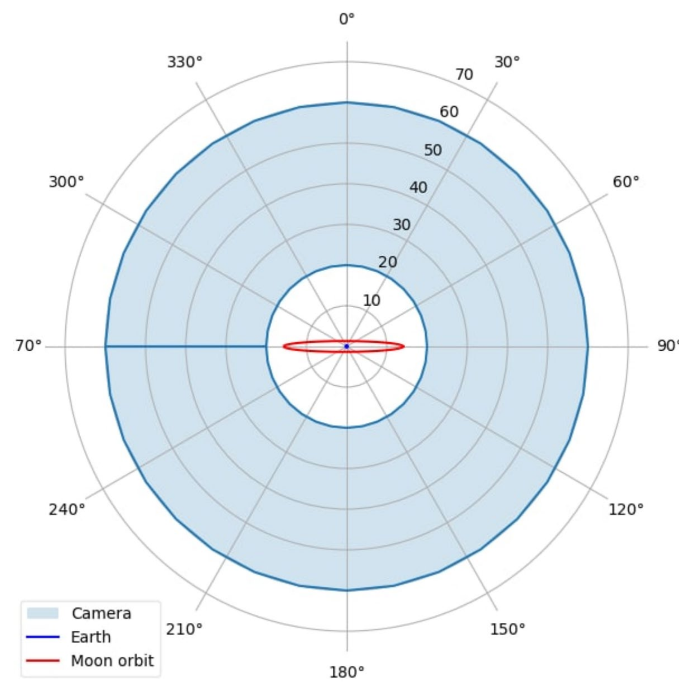

Figure 3. Area of observation of a SODA technological demonstrator with full-rotative pre-aperture mirror.