System of Observation of Daytime Asteroids: trajectory and orbit design

PDC 19-05-16
College Park, Maryland, USA, 2019 May 1

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Overview

1. Mission objectives
2. Mission concept and constraints
3. Spacecraft
4. Transfer trajectory scenarios
5. Conclusion
System of Observation of Daytime Asteroids

1. Mission objectives

- Detection of potentially hazardous object
  - >10-m size objects
  - approaching from the Sun

- Orbit determination
- Estimation of mass
- In a collisional case:
  - High-accuracy atmospheric entry point determination
  - Warning time > 4 hours

Chelyabinsk, 15 February 2013, 20-meter meteor
2. Mission concept

- Two spacecraft in SE L1 point orbits
  - 3 telescopes on board each S/C
    - small 30 cm aperture optical wide field telescopes
    - 17$^m$ sensitivity
  - 3.5 minutes optical barrier around the Earth observation cycle

→ Almost all > 10m size NEAs will be discovered up to 1 day before possible collision
→ Triangulation observation mode enables precise orbit determination

More details in the poster session
Shugarov et al. “System of Observation of Day-time Asteroids (SODA)” poster
PDC 19-05-P15
2. Mission concept

Constraint 1: «low-cost» mission

Possibilities

- Small spacecraft
- Joint launch of two spacecraft
- Shared platform with other scientific payload
  - Sun, solar wind observation, space weather monitoring
  - Earth observation
- Shared launch with other missions
2. Mission concept
Constraint 2: L1 point orbits

- Exclusion zone of Sun inference
  - quasi-halo orbit does not cross the exclusion zone over the mission

- Unstable collinear point orbits
  - small station-keeping manoeuvres
  - $\Delta V \approx 1$ m/s per year

- Two S/C spaced apart from each other in L1 point orbits
  - transfer trajectory design enables achieving the required positions in the orbits

Rotating coordinate system. Orbit as seen from the Earth.
3. Spacecraft

- Total mass: 400 kg
- Payload mass: 100-150 kg
- 3 telescopes
  - Small 30 cm aperture optical wide field telescopes
  - 17\textsuperscript{m} sensitivity
- Pre-aperture slewing mirrors for fast re-pointing
- Power consumption: 100 W
4. Transfer trajectory

Launch

- Launch vehicle **Soyuz 2.1b**
  - Parking 200 km orbit

- Upper stage **Fregat-SB**
  - From parking orbit toward L1
    - payload mass: **2200 kg**
    - possibility of additional payload

- Launch from **Baikonur**
  - Inclination of parking orbit: **51°**
4. Transfer trajectory

Scenario 1

- **Upper stage**
  - From parking orbit
  - $\Delta V_1 \approx 3.18$ km/s

- **S/C 1**
  - Trajectory correction maneuver
  - $\Delta V_2 \approx 10$ m/s
  - (at separation from the upper stage)

- **S/C 2**
  - Trajectory correction maneuver
  - $\Delta V_3 \approx 10$ m/s
  - (at perigee after phasing orbits)
4. Transfer trajectory

Scenario 2

- **Upper stage**
  - From parking orbit
  - $\Delta V_1 \approx 3.18 \text{ km/s}$

- **S/C 1**
  - Trajectory correction maneuver
  - $\Delta V_2 \approx 10 \text{ m/s}$
  - (at separation from the upper stage)

- **S/C 2**
  - Trajectory correction maneuver
  - $\Delta V_3 \approx \pm 10 \text{ m/s}$
  - (at perigee before lunar flyby)

Rotating coordinate system. Ecliptic plane projection.
4. Transfer trajectory

Advantages

For scenarios 1 and 2

- Possibility of a single launch for both spacecraft
- Required $\Delta V = 10 \text{ m/s}$ on board each S/C for transfer to L1 orbits, while fulfilling requirement on distance between S/C

To compare:

Phase changing manoeuvres when a S/C is already inserted into an L1 point orbit would be $400 \text{ m/s}$ and $40 \text{ m/s}$ for in-plane and out-of-plane $30^\circ$ phase changing
5. Conclusions

- **System of Observation of Day-time Asteroids (SODA)** would enable detecting NEAs coming from the Sun up to one day before possible collision with the Earth and to provide warning time of 4-10h.

- SODA is a low-cost mission: two small spacecraft in L1 point orbits
  - Three 30 cm aperture telescopes on board
  - Total $\Delta V$ budget about 20 m/s on board of each S/C
  - Double launch of both S/C by a Soyuz vehicle
  - Possibility of additional scientific payload on board SODA spacecraft
  - Possibility for other projects for sharing the launch

- SODA project will provide valuable scientific data on statistics about the population of NEAs.
Thank you for your attention!