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On-line

System of Observation of Daytime Asteroids (SODA)

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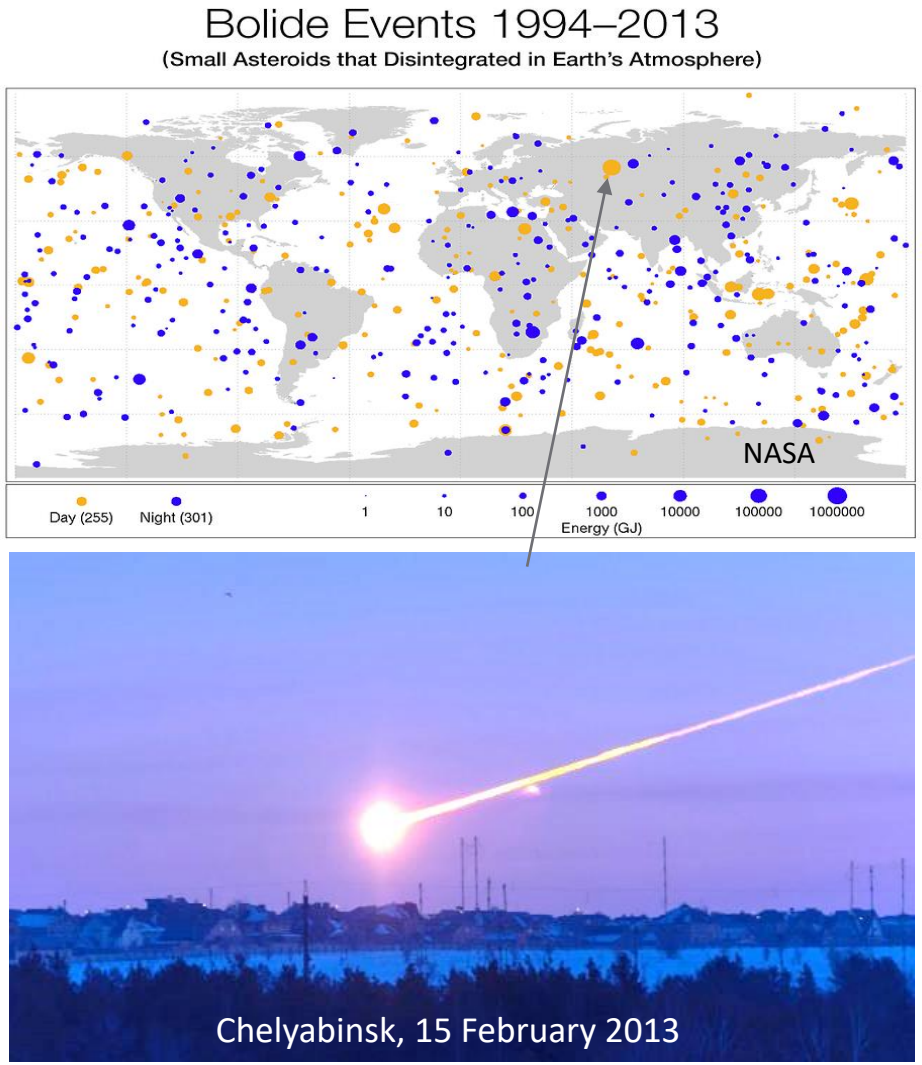
Premises



- Decameter size NEOs (D > 10 m) can be hazardous.
- Nothing could be done to prevent collision of decameter size NEO. Civil defense is the only way to mitigate. Warning in proper time (hours before the collision) is a major action.
- NEOs coming from day sky could not be timely detected by any ground based or near space-based observational facilities. One needs a S/C located far from the Earth.
- There appeared ideas:
  - *Dunham+2013* - to put a 1-m aperture telescope into an orbit around L1 point. The telescope was assumed to survey once per 24 hr an annular region of the celestial sphere around the Earth with an outer radius of about 25 deg.
  - *Shustov+2015, Shugarov+2018* proposed optimized variant of S/C with smaller (30 cm) telescopes and much shorter cadence.

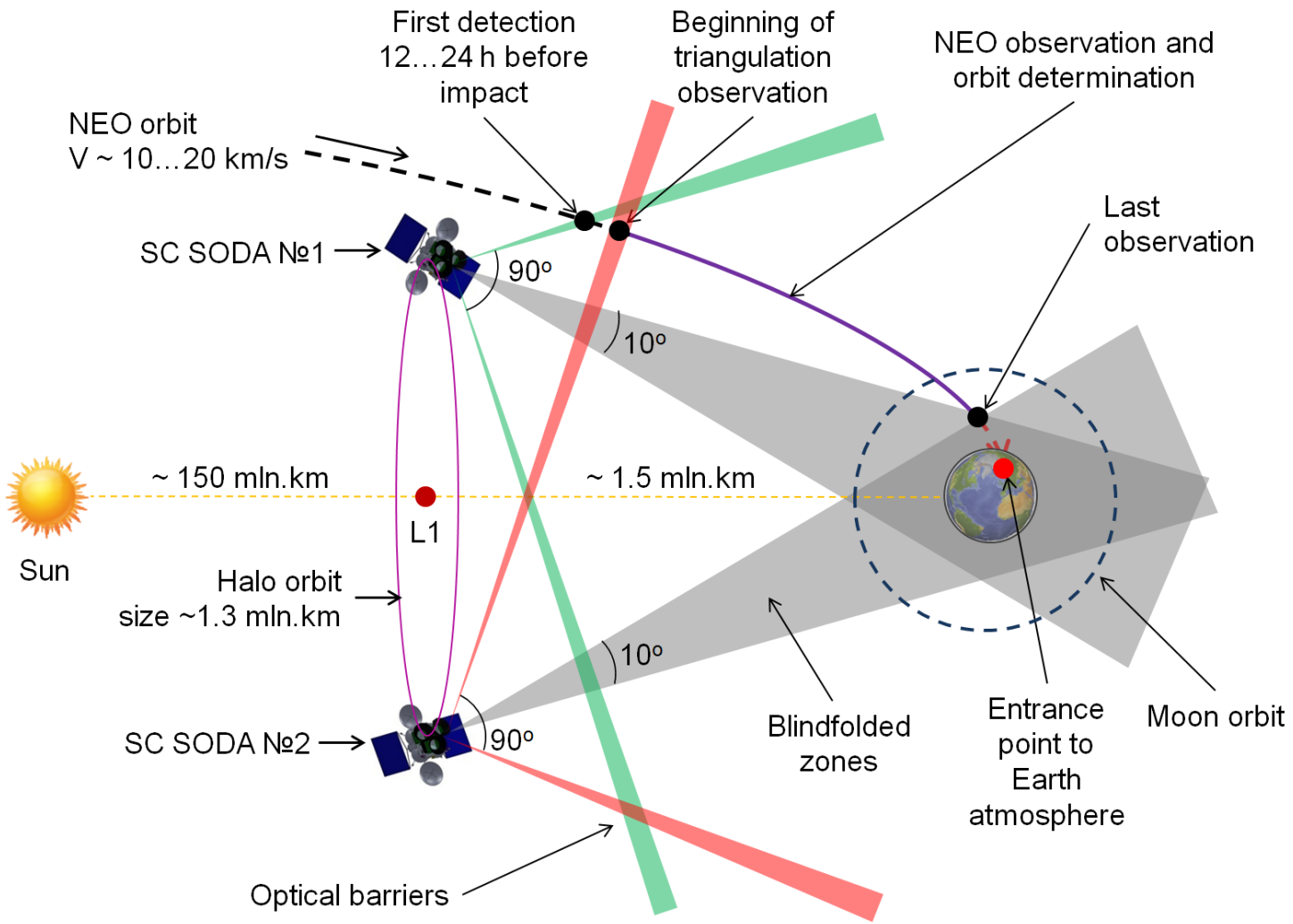
Mission objectives and concept

- Detect ”all” potentially dangerous bodies >10 m approaching from the Sun.
- Characterize objects of interest:
  - Determine orbit and approach velocity
  - Estimate mass and velocity
- In a collisional case:
  - Determine atmospheric entry point with highest possible accuracy
  - Ensure warning time of 4…10 hours
- Low cost mission at L1 (Sun-Earth).
- 2 S/C variant is optimal, 1 S/C still be quite functional.
- Shared platform with other scientific payload (e.g. Sun, solar wind observation, space weather monitoring, etc.).
- A global network of ground stations ensuring 24/7 regime of operation.

Scheme of operation of the SODA S/C

Two modes of operation:
- detection of asteroids coming from the Sun using the conic barrier technique
- target mode to accurately define orbit of the NEO of interest

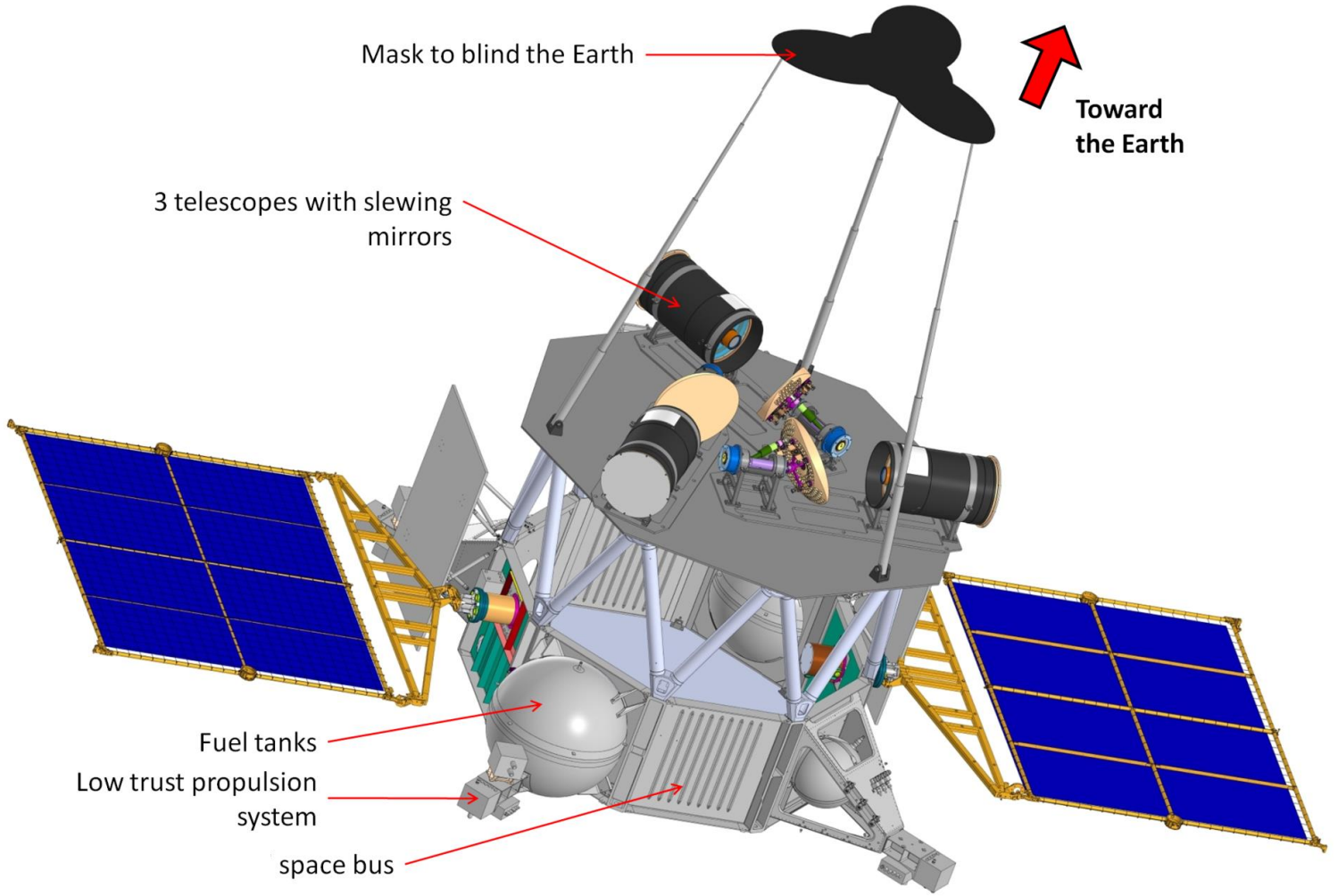
Two S/C variant makes possible a triangulation observation mode, which enables precise orbit determination, helps to avoid missing NEO at close fly-by and provide redundancy.



Spacecraft

Each S/C will be equipped with ≥ 2 telescopes:

- 2 telescope option – minimal variant, no redundancy.
- 3 telescope option – optimal variant: reasonable redundancy.



Telescope with slewing mirror

30 cm aperture optical telescope:
- Sonnefeld camera F:1.5
- 3.75 deg field of view
- 17^m lim. magnitude (4 s exposure)
- 0.5” single observation accuracy
- 2-4 s typical exposure time

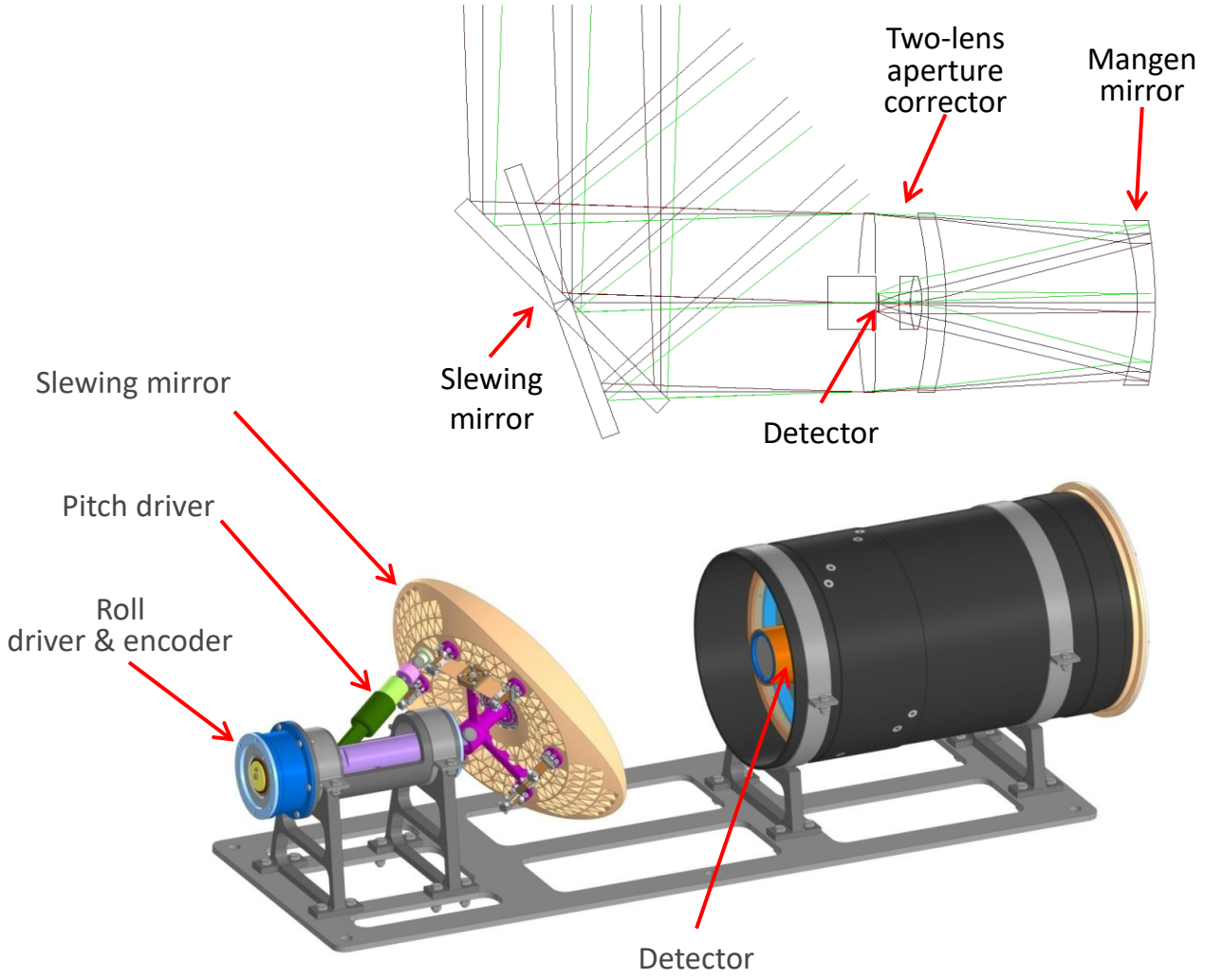
CMOS detector:
- Size of 30×30 mm
- Format of 6×6 k
- 5 μm pixel

Pre-aperture slewing mirror for fast repointing.

Power consumption: 100 W.

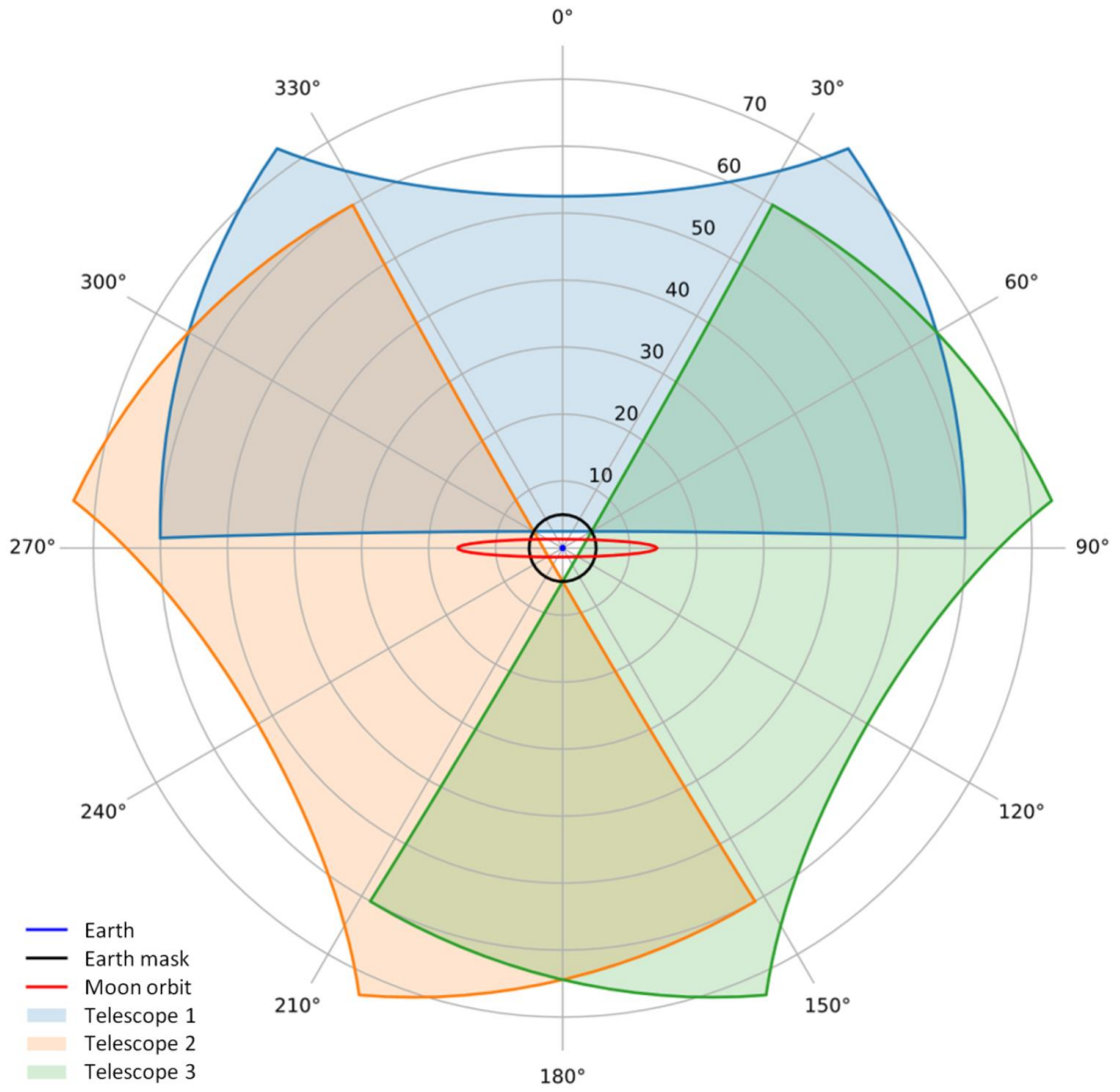
Up to 3.5 min duty cycle of completing optical barrier around the Earth (3 telescopes option).

For more details see poster by Shugarov+



Telescope with slewing mirror

- 3 telescope option provides 100...120 deg overlapped area of observation
- 3 telescope option – optimal variant:
  Improved astrometric accuracy. 50% of the asteroids can be observed simultaneously by two telescopes from one S/C.



A possible scenario of Chelyabinsk event if SODA worked

Chelyabinsk event:

- February 15, 2013
- 17 m size
- 18 km/s

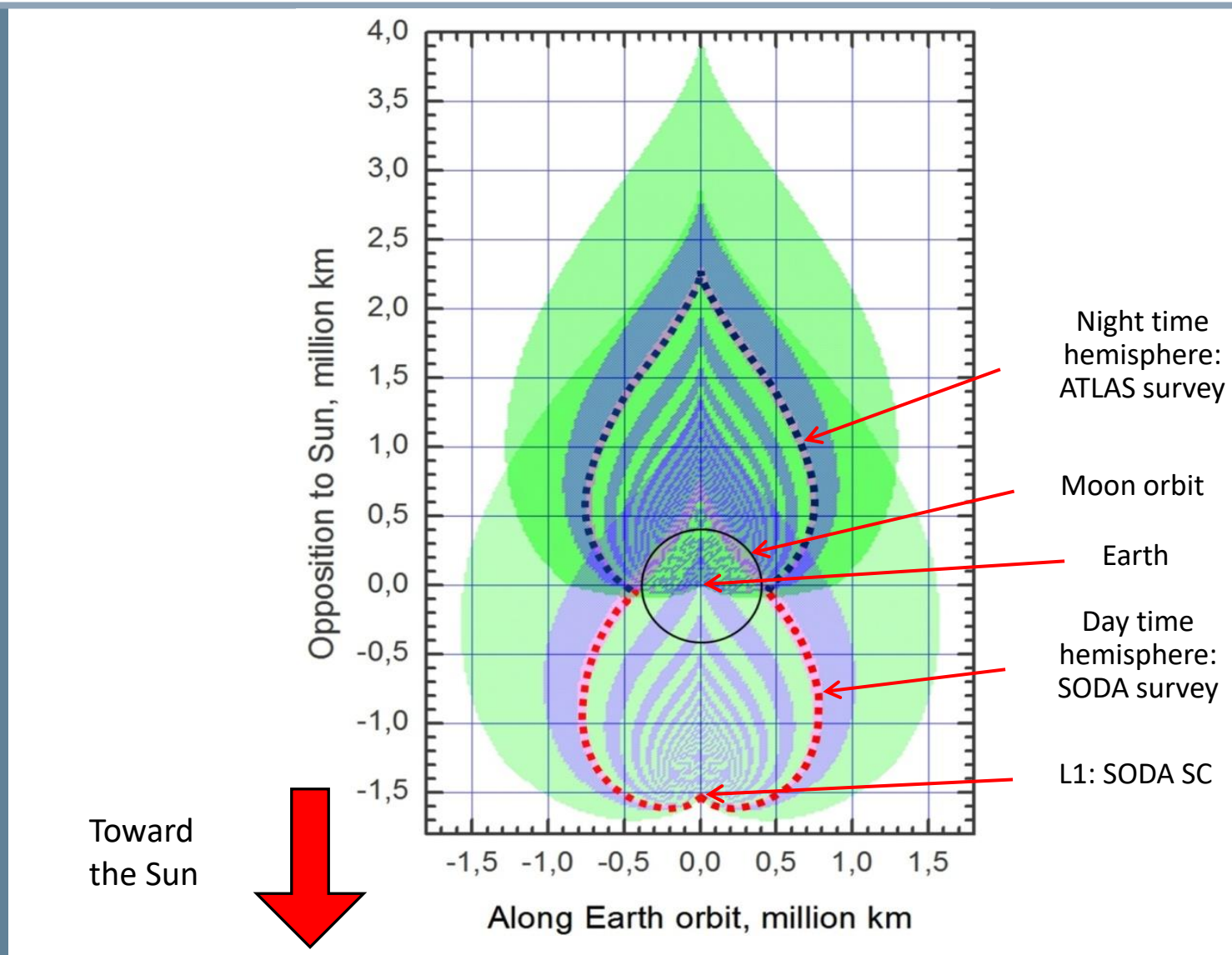
Simulation input:

- 2 SODA spacecraft option
- 0.5 arcsec astrometric accuracy
- Observation every 5 minutes after detection

Time to impact, hours	Accuracy of atmospheric entry point, km	Action
-19	-	First detection of Chelyabinsk's asteroid. Preliminary orbit determination. Data transfer (permanently) to the MPC.
-18	2E4	Start of observation with second S/C in a triangulation mode. First release about possible collision.
-17	5E3×400	First release on the impact region: Russia or Kazakhstan (includes estimated mass of the object).
-16	2E3×200	Updating the forecast: Chelyabinskaya, Kurganskaya, Tumenskaya, Kostanaiskaya region.
-15	5E2× 0	Release of an alert for civil defense of Chelyabinskaya region.
-11	2E2×30	Updated release for civil defense of Chelyabinskaya region.
-4	1E2×20	Final observation and final release.

Cooperation with other survey systems

- A combination of SODA and ground-based survey telescopes (e.g. ATLAS) is a way to provide an efficient all-sky system of detection decameter size NEOs in proper time.
- Combined zone of detection of 10 m body with ground-based telescope (19^m lim. mag.) and the SODA (17^m lim. mag.) is shown in the plot.
- The SNR is marked by color (green and glue) isophotes with 3 unit increments. Blue and pink dotted lines show SNR = 9 (quite reliable detection) for ground-based and SODA telescopes respectively.



Conclusions

- The only realistic way to timely detect daytime asteroids is to use a system of space born telescopes located relatively far from the Earth (e.g. SODA).
- Some years ago, we presented the SODA pre-Phase A study (feasibility and definition).
- Substantial improvements of optical features of the SODA project were made since that. These include a new optical design of the telescope, pre-aperture slewing mirror and new detector.
- SODA uses existing technologies, it is a relatively low-cost project.
- A request for funding for Phase A was submitted to ROSCOSMOS.
- International collaboration is welcome as well as cooperation with other ground-based and/or space projects focused on the detection of 10 m class NEOs.