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Gaia and ESA’s Space Situational Awareness’  
Near-Earth Object programme

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Introduction

In 2008, ESA started a new optional programme called Space Situational Awareness programme. One part of it deals with the impact threat of near-Earth objects for the Earth. This paper intends to inform the Gaia asteroid community about this programme and explores possible synergies.

1. What is Space Situational Awareness?

The SSA Programme Declaration, ESA/C/SSA-PP(2008)2 states: “The objective of the Space Situational Awareness (SSA) initiative is to support the European independent utilisation of and access to space for research or services, through providing timely and quality data, information, services and knowledge regarding the environment, the threats and the sustainable exploitation of the outer space.”

Thus, SSA will provide a service to inform the customers (governments, disaster management, scientists, the public/press…) about the situation of natural and artificial objects in space. This will allow us to better protect our satellites and our planet.

The SSA programme is split in three so-called segments:

(a) Space Surveillance and Tracking of satellites and space debris (SST)  
(b) Space Weather (SWE)  
(c) Near-Earth objects (NEO).

While each of these segments are managed separately and satisfy different communities, SSA will build up a ‘system of systems’ combining all three of these segments.

During ESA’s Ministerial Council meeting in November 2008, the preparatory phase for SSA was approved and is funded with about 50 MHzuro, which is shared between the three segments. During this phase, precursor services are being set up and thorough studies are being performed to assess the architecture and system requirements. At the end of the preparatory phase, all elements for a functioning service shall be in place.

2. The near-Earth object segment of SSA (SSA-NEO)

The Near-Earth Object segment of the SSA programme, hereafter called SSA-NEO, has the following key tasks:

(1) It shall provide information on the impact probability and/or miss distances of NEOs including associated uncertainties. To do this properly, it shall assess impact analyses, results, and perform its own impact risk assessments.
(2) It shall classify the risk of a NEO impact and issue warnings if the risk is higher than the background risk.

To perform these tasks, a network of sensors is being set up for the discovery and follow-up observations of asteroids and in particular also for the characterisation of these objects. It will also set up data centres for processing the information. ESA representatives participate in discussions on the level of the United Nations to set up the political framework for issuing impact warning. In addition, the SSA-NEO team will maintain close links to groups working on mitigation strategies, e.g. ESA’s Advanced Concept Team. SSA-NEO contributes to what the Association of Space Explorers call the Information, Analysis, and Warning Network (IAWN) in a recommendation to the United Nations.

The main building blocks of SSA-NEO will be (Drolshagen et al. 2010):

(a) Network of sensors. This will be mainly optical telescopes, but also radar systems should be involved – in a later phase this can also include space-based sensors. It includes a measurement, coordination and planning function.

(b) Data processing centers to
• Perform impact risk computations;
• Maintain a NEO property database;

(c) Interface to studies on risk mitigation;

(d) Support the decision-making process in case of an imminent impact threat by participating in the Action Team #14 of the United Nations discussing the NEO impact threat.

A graphical view of the SSA-NEO segment is shown in Figure 1.

![Fig. 1 – Block diagram of the SSA-NEO segment.](image-url)
3. SSA-NEO needs for observations

To support the goals of the SSA-NEO segment the following observational tasks have to be performed:

(a) Discovery of new NEOs;
(b) Follow-up of recently discovered objects;
(c) Understand the orbital evolution of asteroids;
(d) Catalogue the physical properties of asteroids.

Ad (a): A large number of asteroids, in particular smaller objects below ~200 m, are not yet discovered. Ground-based survey telescopes try to map the complete sky regularly, however, have limitations due to sky coverage close to the sun, the transparency of the sky, and weather conditions. A space-based telescope has much less limitations in this respect and can contribute to discovering new objects significantly. However, it is expected that most objects which have magnitude of about 20 mag have been discovered already (the currently assumed detection limit for Gaia). Thus it is not expected that Gaia will be a major contributor to new NEO discoveries. In addition, to allow follow-up observations of objects before these have deviated too much from there predicted position, quick data dissemination in the order of hours is important.

Ad (b): When an object is newly discovered by a survey, more observations are required within a few hours and later a few days to extend the observed orbital arc. This is needed to get an orbit solution with accuracy good enough to not loose the object again. Ground-based telescopes can be pointed in the direction of an object in need of observation to perform these so-called follow-up observations. Gaia does not have the possibility to command its pointing. However, one should analyze the possibility of using by chance observations of asteroids in need of follow-up observations as the high astrometric accuracy of the Gaia observations will allow a very good orbital solution compared to ground-based observations. This, in turn, will mean that the objects orbit will be known much better than from ground, decreasing the chance of losing it again. An important point in this respect is that a fast turn-around time of the data is needed – one should be able to assess whether an object was observed successfully within say less than a day to avoid other observatories wasting time on observing the same object.

Ad (c): The orbits of asteroids can be disturbed by non-gravitational forces. One major effect is the so-called Yarkovsky effect, a thermal effect which changes the semi major axis of the orbit of an asteroid. This effect may change an asteroid’s orbit over several tens of years enough to change it from a non-threatening to a threatening object. To better characterize and understand this effect one needs very high accuracy position measurements of the asteroids, something which cannot be done from ground but which would be possible using Gaia (see e.g. Delbo et al. 2008).

Ad (d): A good knowledge of the physical properties of a potential Earth impactor is important to estimate the consequences of an impact and the strategy for a possible deflection mission. The physical properties also influence the non-gravitational forces on the orbit and thus have an effect on the accuracy of the orbit determination. Gaia can contribute precise light curve measurements which would allow the determination of the rotation period of an asteroid. In many cases, the shape of an asteroid can be reconstructed from light curves. Unlike typical ground-based programs for light curves, where one object is followed over
many hours or even days, Gaia will only provide ‘sparse’ observations. Recent studies have shown that these can also be used successfully, in particular if at least one complete light curve has been observed from ground (Durech et al. 2007).

**Conclusion**

The major contribution of Gaia to the field of asteroid science – and the prediction of potential impacts in particular – will be the high-precision star catalogue which it will produce. This star catalogue will reduce the uncertainties in the astrometry and photometry of asteroids dramatically. Even existing data could be reprocessed to improve their accuracy.

Additional contributions from Gaia will be the detection and follow-up of asteroids. The precise photometry can be used for the determination of rotation periods and shape models.

To achieve these goals, the following items should be taken into account:

(a) Data should be available in a timely manner. New asteroid discoveries should typically be available a few hours after obtaining the data. Note that photometric data is less critical, it can be processed after the normal release of the data;

(b) To enable the search for asteroids in historical data *before* the actual discovery of the object (so-called precovery searches), objects which cannot be identified by the pipeline immediately should be stored and not discarded for possible later confirmation;

(c) Coordination between ground-based observers and Gaia will increase the quality of the results;

(d) The exchange of information between the SSA-NEO and the Gaia community should continue to ensure that the synergies of the two projects are maximized.

**References**

