

The Bering Mission – Exploring the Asteroid World

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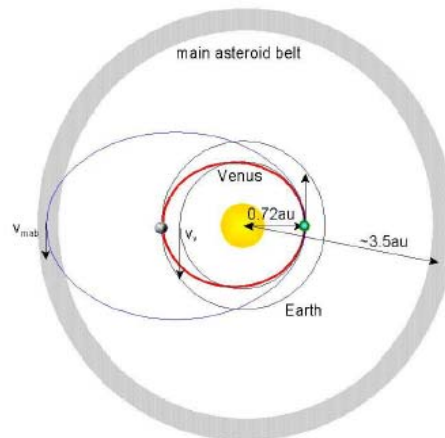
Our present understanding of asteroids and their orbits is almost entirely based on surveys of asteroids larger than 10 km in diameter. The size distribution of the asteroids implies that the presently undetected population of sub-kilometer asteroids, by far outnumber the known larger objects. The smaller virtually unknown sub-kilometer asteroids will most likely provide unique insight into the evolution of the asteroid belt and the meteorite-asteroid connection.

The asteroids constitute a rich, readily accessible sample of the material, from which the planets initially was assembled. Studies from the ground and the very few space missions that has targeted specific Asteroids, so far have shown their geology to be exceedingly complex: They range from primitive, carbonaceous chondrite-like bodies in the outer asteroid belt to whole or fragmented asteroids in the inner belt which, more or less Earthlike, consisting of a metal core, a mantle, and a crust. Meteorites have provided us with samples of approximately 150 of these highly diverse asteroids. Despite the fact that several spacecraft to date, statistically, must have passed by smaller asteroids, the technology employed in these vessels has not held the capability of unscheduled detection. Therefore the encounters have gone unnoticed by. Recent developments in the autonomy of spaceborne imager- and computer technology has changed this, so that it is now possible to detect, classify and observe an encounter of a smaller asteroid and determine its orbit, which is what Bering is intended to do.

In order to obtain an estimate of the object detection rate for Bering, we have developed numerical models that allow us to study the problem in detail. The simulation scenarios include both the NEO and the asteroid Main Belt environments, with the simulated size distributions of these populations matching the current best estimates. Assuming that no or very few asteroids gets so close that they overflow the tracking instrumentations field of view, the asteroids can be simulated as test particles. The simulations involves up to $1.4 \cdot 10^9$ such test particles, covering sizes down to 1 meter. These small objects have strongly confined visibility peaks, and thus the simulations need to have a fine time resolution, in order to allow a close monitoring of the test particles. The outcome of the simulations demonstrates the feasibility of the Bering mission in terms of scientific return, but also contributes to defining the needed technological framework of an autonomous mission.

Two spacecraft flying in a loose formation is proposed for Bering. This has two objectives: Firstly, it allow for generation of distance information to the target using stereo imaging. Otherwise, target distance would be constrained only. Secondly, it ensures redundancy of the main telescope.

In order to accomplish the mission objectives, the Bering spacecraft shall search both the inner part of the solar system and the main asteroid belt with a serendipity philosophy, i.e. it does not target a specific object, but is going to fly out to collect data about objects that are, for the majority, unstudied and unobserved so far. Several possible interplanetary orbits have been studied for Bering. The simplest solution is to let Bering fly into an interplanetary orbit with aphelion at about 3.5 AU (mean semi-major axis of the main asteroid belt) and perihelion at about 0.7 AU (Venus semi-major axis). This orbit can be achieved with a single unpowered gravity assist maneuver from Venus whereas the ΔV required to reach Venus could be delivered directly by the launcher, which may be of the Soyuz class.



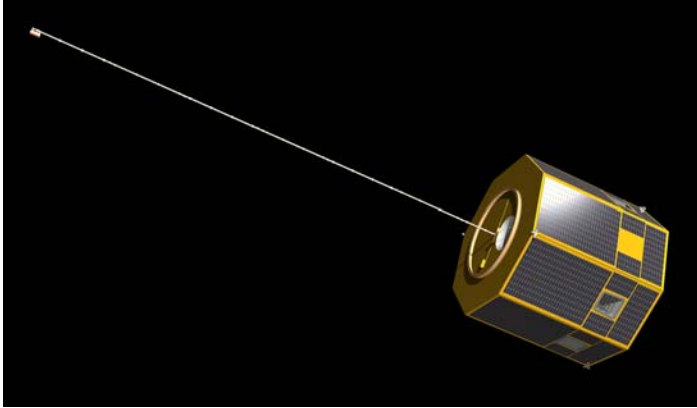
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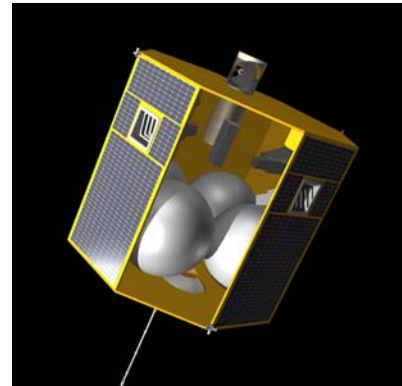
We propose Bering as a slow spinner, which requires a symmetric body. As Bering will bring tanks for its cold gas propulsion system, these tanks need to be arranged symmetrically and depleted at the same rate throughout the mission in order to keep the spacecraft balanced.

A powerful suite of instruments is proposed. Each satellite has an Advanced Stellar Compass (ASC) system with 7 camera heads, a folding mirror based 0.3m multi-spectral telescope imager, a boom-mounted magnetometer and a laser ranger.

The onboard autonomy is centered around two ASC data processing units, each driving 3 respectively 4 camera heads whereby a high sky coverage is ensured. The instrument delivers accurate absolute attitude information from star tracking, accurate absolute position information from planetary triangulation and detects non-stellar objects, i.e. NEO's and asteroids, all fully autonomously.

An ASC camera head, co-aligned with the telescope, facilitates the pointing of the spacecraft. When the ASC has detected a sun orbiting body, the apparent inertial position of the body is measured and passed on to the main onboard processor. The data is processed, the attitude corrected and the telescope is pointed towards the target.

No specific standard platform has been identified at this stage, which can be adapted to the Bering mission. However, Bering bears significant resemblance with the Meteosat Second Generation (MSG) satellites. Throughout the design phase, design concepts, components and subsystems having a flight heritage will be preferred in order to minimize risk. It is important to realize, that the technologies employed are all mature, and available. And, that the double spacecraft mission features a very high level of redundancy. E.g. the ASC's are to a large extent redundant, reducing only the sky coverage should a unit fail. The same is true for the telescopes, the TM/TC link and to some extent the magnetometer and the laser ranger.



The proposed orbit will take Bering out to 3.5 AU where the sunlight intensity is only 8.1% of that in Earth orbit. For reasons of pointing stability it is not desirable to have deployable solar panels. Therefore, Bering is limited to body-mounted panels. All surfaces of the rotationally symmetric body of about 2.0×1.8 m dimension are covered with solar cells to the largest extent possible. In order to maximize available power at aphelion, it is proposed to use triple-junction InGaP/GaAs/Ge solar cells having a 27.5% efficiency at BOL. Worst case available bus power at worst case attitude of 54 W. The Ka band radio link to Earth ensures TM/TC contact with the two Bering spacecraft out to aphelion even using a 5 m ground station. However, for downlinking science data, support from a large ground station of the ESA or NASA Deep Space Network is needed.

A few of the objects detected will be big enough and pass close enough such that a small magnetometer/gravity probe can be ejected and tracked from Bering as it passes close to the object. The deflection of its orbit will allow us to constrain the mass of the object. While in the vicinity of the object, its magnetic signature will be determined by the probe magnetometer. The probe will be tracked by a laser ranger, integrated with the main telescope, while "cats eye" retro-reflector material coating of the probe ensures high detectability. A simple one-way radio link will convey magnetometer measurements. The probe is powered by an un rechargeable Lithium-ion battery.

The study of Asteroids and specifically Near Earth Objects (NEOs) is facing two severe problems which both are related with their initial detection and re-observations. The first is that most objects are faint due to their relatively small size compared to the distances, which bring the majority of these outside the envelope of standard astronomical telescope detection methods. The second is, that when an object eventually gets close enough, and in a pose, that offers high luminosity, it is moving fast which results in high proper motion rates.

Focusing on omni-directionality and high-speed operations, rather than faint objects, the Bering mission will enable a much wider class of objects to be studied. The cruise phase of the planned Venus swing-by will offer excellent viewing conditions of NEOs with orbits inside the Earth, and the mission phase in the Asteroid belt will bring the "observatory" close to the targets, such that more than just the largest objects can be studied.