Near-Earth Objects
Space Mission Preparation
ITT AO/1-4137/01/F/IZ

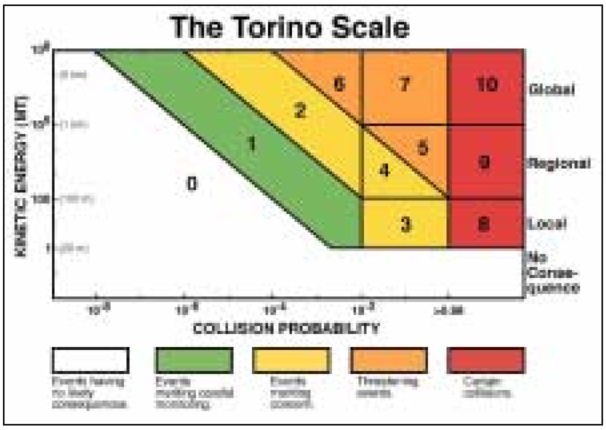
EUNEOS Executive Summary

1. Context of the mission

The NEO hazard

The discovery of 433 Eros in 1898 established the existence of a population of asteroid-like bodies on orbits intersecting those of the inner planets. But it was not until the Apollo program in the 1960s and 1970s that lunar craters were shown to be derived from impacts rather than volcanism. With this evidence in hand, it was finally recognized that the Earth-Moon system has been incessantly bombarded by asteroids and comets over the last 4.5 Gy. In 1980, Alvarez and collaborators presented convincing arguments that the numerous species extinction at the Cretaceous-Tertiary transition were caused by the impact of a massive asteroid. These results brought increasing attention to the objects on Earth-crossing orbits and, more generally, to those having perihelion distances $q<1.3$ AU and aphelion distances $Q>0.983$ AU. The latter constitute what is usually called the near-Earth object (NE0) population. More recently, emphasis has been put also to the putative population of objects that, with $Q<0.983$ AU, are always interior to the Earth’s orbit (IEOs, form inner-Earth objects).

It is now generally accepted that the **NEOs represent a hazard of global catastrophe for human civilization**. Asteroids and comets can impact the Earth at **speeds of tens of kilometres per second**. While the atmosphere protects us from most of the smaller fragments, larger objects (roughly those bigger than 50 meters) are capable of reaching the lower atmosphere or the surface where they explode with an energy greater than that of the most powerful nuclear weapons.



In 1999, a scale has be defined, the *Torino Scale*, which is a sort of “Richter Scale” for communicating to the public the impact danger carried by the newly discovered NEOs. The scale ranges from 0 to 10 and the rating of a specific NEO is computed through an algorithm that convolves its probability of impact due to orbital uncertainty and the potential damage caused in case its collision really occurred.

This rating should be read the following way:

- ✓ A rating of 0 indicates that an object has a null or negligible chance of collision with the Earth or that the body would cause a negligible damage, by exploding in the upper atmosphere. The highest ratings (8, 9 or 10) indicate that the collision is almost certain (>99% collision probability) and that the impact will have notable consequences on the ground.
- ✓ A **rating of 9** indicates that the impact energy is between 100 and 100,000 MT, triggering **damage on a regional scale.** Among these regional scale impacts, the UK Task-Force on NEO hazards emphasized the importance of those with energy larger than 1,000 megaton TNT (MT), which would likely have global consequences on world-wide linked economic system.
- ✓ A **rating of 10** indicates that the impacting object will liberate an energy larger than 100,000 megatons of TNT (MT), triggering **a global climatic disaster**.

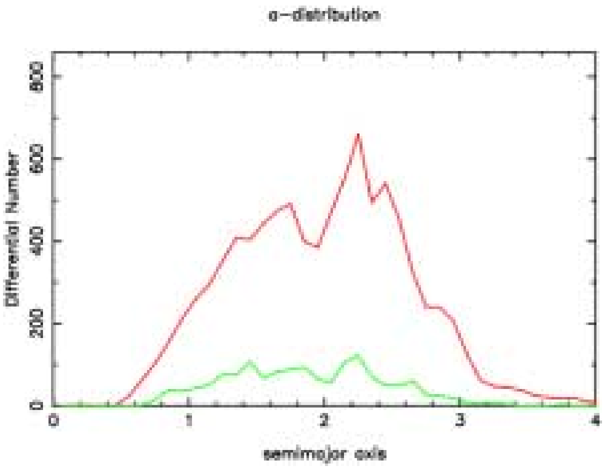
Limitations of the current surveys

The stated *Spaceguard goal* of the current NEO surveys is to discover and determine the orbit of 90% of the NEO population with H<18 in a timescale of a decade. This would essentially ensure protection against impacts in Torino's scale level 10. Currently 598 NEOs with H<18 are known. This number, compared to the total number (1,200) of H<18 NEOs predicted by our model, implies that we are about half-way to the completion of the Spaceguard goal.

At the present time, the most efficient survey for the discovery of NEOs is LINEAR, a MIT-Lincoln Laboratory collaboration, using a pair of 1 m telescopes funded by the United States Air Force and NASA. We have developed a software simulator of the performances of LINEAR that is capable at reproducing LINEAR's detection rate over the last year (after the last upgrade of the system) and the orbital distribution of the detected bodies. Using this simulator we predict that LINEAR will achieve 70% completion on the H<18 NEO population by 2014, and 90% completion (the Spaceguard goal) by 2030.

If the knowledge of the H<18 NEO population is within reach using the current ground-based surveys, the same is not true if the Spaceguard goal is extended up to the H<20.5 objects, in order to protect our planet also from regional catastrophes with world-wide implications on our economic system.

Currently, 1455 NEOs with H<20.5 are known, which, compared to the total number (9150) of H<20.5 NEOs predicted by our model, implies that the observational completion is only 16%.

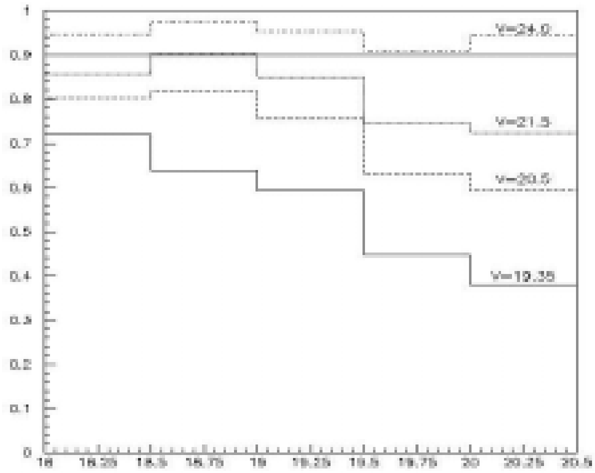


The discovery of a large fraction of the faint (H<20.5) NEO population may be a too ambitious program. For an Earth safeguard purpose, it would be enough to achieve a large observational completeness for the NEO subpopulation that effectively pass close to the Earth's orbit. Most NEOs, in fact, despite having perihelion distance q<1 AU and aphelion distance Q>1 AU do not cross the Earth's orbit in the 3-dimensional space, and therefore they do not carry any collision hazard for our planet. For this reason, the astronomers have introduced the notion of *Minimal Orbit Intersection Distance* (MOID) which is defined as the minimal distance that the asteroid and the Earth can have assuming random position along the respective orbits. NEOs with MOID < 0.05 AU are called *Potentially Hazardous Objects* (PHOs), because these bodies do pass close to the Earth's orbit, and their orbital changes forced by the gravitational interactions with the planets over a century could bring them to collide with the Earth.

Therefore, **the goal of an effective Spaceguard program should be to achieve a large observational completeness of the H<20.5 PHO population**.

Unfortunately, even restricting to the PHO population, the prospects for achieving a better observational completeness with the currently available instruments within a reasonable time are not good.

The figure aside shows the completeness that LINEAR will achieve in 2014 for the PHO population with H>18, according to our simulations. Only 55% of the H<20.5 population will be known, which reduces to 40% if the population with 20<H<20.5 is considered. Increasing substantially the final completeness would require a huge technological effort. A LINEAR-like survey could achieve more than 90% completeness on the H<20.5 PHO population only if its limiting magnitude were increased from V=19.35 to V=24. But this would require to increase the size of the telescopes from 1 to 72 meters (!!) if the exposure time is kept equal to the one currently used.



PHO Completion in 2014 vs. Absolute Magnitude

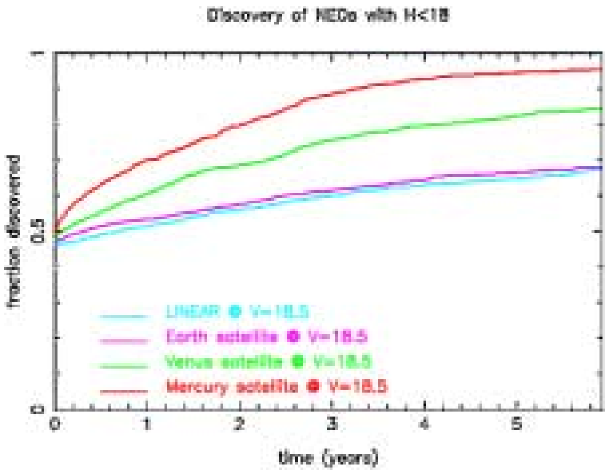
The EUNEOS goal

Given these discouraging prospects for ground-based surveys, we propose EUNEOS, a dedicated NEO survey from space that would **discover a significant fraction (~80%) of the PHO population with H<20.5 in 5 years.**

2. Scientific Mission Requirements

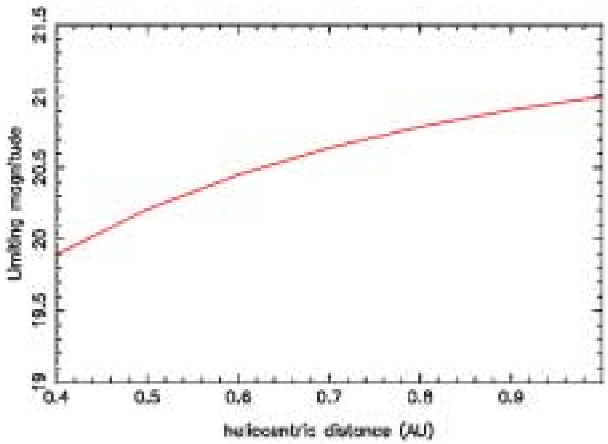
Rationale for the operational orbit

But the key parameter that determines the efficiency of a space survey is the orbit of the satellite, with the survey becoming much more effective as the spacecraft approaches the Sun due to the favourable observing geometry as illustrated on the figure aside.



More precisely, starting from the current observational completeness of ~50% for the H<18 NEO population, this figure shows how the completeness would be improved over the next 6 years by (i) a LINEAR-like survey (cyan) (ii) a geocentric satellite (magenta) (ii) a satellite placed at Venus' orbit (green) and (iv) a satellite placed at Mercury's orbit (red).

All surveys are assumed to have a limiting magnitude V=18, and the space surveys are supposed to observe the entire sky up to 45 degrees of solar elongation every night. This idealistic case illustrates the improvement of the survey efficiency as the observatory is moved to smaller and smaller heliocentric distance.



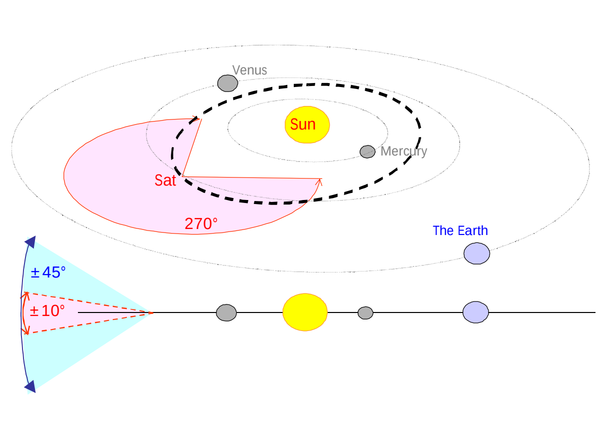
However, this improvement of the survey completeness is tempered by the presence of the zodiacal light, a background luminosity due to the solar light scattered by the interplanetary dust. The dependence of the brightness zodiacal light on the heliocentric distance of the observer is not well known, but it should change as $1/r^{\alpha}$, where α is a positive number between 2 and 3.

The increase of the sky brightness with decreasing heliocentric distance reduces the limiting magnitude of an instrument as it is moved towards the Sun, as shown on the figure aside.

But, even when accounting for this drop of the limiting magnitude with decreasing heliocentric distance, a simulation of the detection efficiency for the H<20.5 PHO population still shows that an important increase in the performance is obtained by moving the telescope from an Earth-like to a Venus-like orbit.

The space observatory should therefore be placed on an orbit that does not penetrate beyond Venus' heliocentric distance (inner-Venus orbit) embarking an optical instrument with a limiting visual magnitude at 1 AU of 21.

Rationale for the observing strategy



The data provided by the survey should allow the computation of high accuracy orbits for the discovered objects. It is therefore necessary that the survey re-visits sequentially a large area of the sky, in order to re-detect the discovered bodies at each scan of the survey area, during a long time-interval.

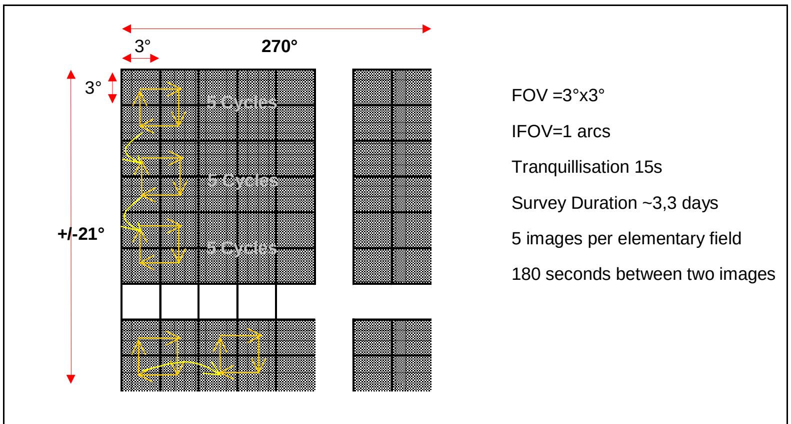
Because all PHOs must pass on the ecliptic plane at an heliocentric distance larger than the satellite position it is suggested that the instrument scans a band of sky around the ecliptic, with height (maximal ecliptic latitude) and width (maximal distance from opposition) as large as possible.

The proposed survey strategy of the EUNEOS missions results in the systematic re-detection of the discovered objects, which ultimately allows a high accuracy determination of the objects' orbits, without any need of immediate follow-up from the ground. For instance, the resulting accuracy on the orbital semi-major axis will be better than 10^{-3} AU for 96% of the discovered objects (better than 10^{-4} AU for 85% of the discovered objects).

Therefore, ***the success of the mission will not critically depend on the effort paid for a timely ground-based follow-up during the EUNEOS mission***. This is an important aspect, because at the moment of discovery by EUNEOS, most of the objects are invisible from the Earth, being too faint or too close to the Sun.

Scanning strategy

The proposed scanning strategy consists in visiting five times the same field of the sky (to lower the false detection probability due to cosmic rays) at 3 minute time intervals, a band of the sky of 21 degrees in declination and 270 degrees in elongation, as presented in a schematic way on the figure aside.



3. System Outline

A possible system organisation for a European NEO Space Observatory Architecture (EUNEOS) is presented on Figure 3-1. It incorporates existing entities to fulfil the mission objectives presented before.

NB: Note that during the envisaged mission duration of 5 years, the interactions with a network of ground-based observatories will be very limited since the proposed space observatory is able by its observing strategy to perform at the same time the discovery and the recovery.

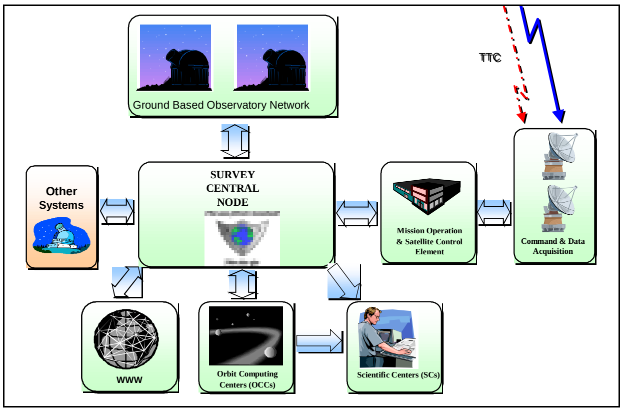


Figure 3-1: Proposed EUNEOS system architecture

Mission Segment

The mission segment consists in:

- A Mission Control Center preparing the observational schedule, collecting the raw astrometric data and handling the interactions with the relevant external entities.
- A Survey Central Node receiving the data from the Mission Control Centre and supervising the generation of all the products made from these data. It is in charge of making available and distributing to the relevant scientific entities these products. The Spaceguard Central Node is proposed to fulfil this role at European level.
- An Orbit Computing Centre exploiting the astrometric data to estimate the orbits of the observed NEO. The Near-Earth Objects Dynamics Site (NEODyS) will primarily be in charge of orbit computation. Other similar centres outside Europe may also receive the astrometric data, for example the Minor Planet Centre of the International Astronomical Union (MPC) and the Jet Propulsion Laboratory (JPL).
- A Deep-Space Network of ground stations to communicate with the satellite on its interplanetary flight. The use of ESA deep-space 15-m stations is the baseline in order to reduce the ground segment operations cost and increase flexibility in the selection of the ground station. For telecommunication sizing, a 6 hours communication window is assumed per day.

Space Segment

The space segment of EUNEOS consists in:

- An optical space observatory totally interior to Venus orbit reaching its operational orbit after a gravity assist by Venus, which allows to keep low impulse velocity budget requirements on the satellite. The
- Deep-space ground stations to communicate with the satellite on its interplanetary flight. The use of the same stations as those activated for the mission telemetry and command is recommended.
- A Satellite Control Centre proposed to be hosted by the European Space Operations Centre of ESA in Darmstadt, Germany.

Products

Two levels of products are foreseen.

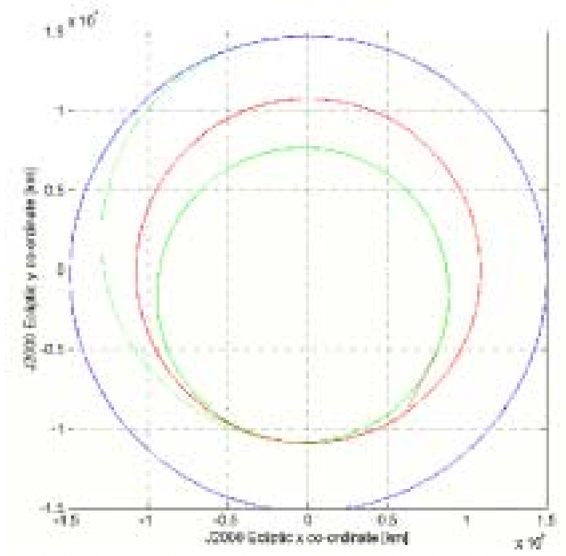
- ✓ Level 1 data which are elaborated on-board the space observatory consist of:
  - ✓ Object Celestial co-ordinates,
  - ✓ Object Magnitude

NB: In case the option of using a polarimetric filter is retained, the Level 1 data would also include the magnitude at polar 1 and the magnitude at polar 2.

- ✓ Level 2 data which are elaborated on-ground consist of:
  - ✓ Observation coordinates Right Ascension, Declination , Solar Elongation,
  - ✓ Ephemeris, including windows of Earth visibility,
  - ✓ Physical properties : Albedo,
  - ✓ PHA estimated class (C,S, M,E …) and composition,
  - ✓ Level of danger.

EUNEOS MISSION ANALYSIS ASPECTS

The EUNEOS trajectory



To reach the EUNEOS operational orbit without intense thrusting after the Earth departure, it is proposed to use a Venus gravity assist.

Venus can indeed be reached with low departure velocities (between 2.5 and 3.4 km/s) as long as the launch date is selected within a one month period around the dates allowing an Hohmann transfer between the Earth and Venus.

This gives launch opportunities for example in May 2007, January 2009 and September 2010, the baseline being probably from a programmatic point of view, January 2009.

With a Soyuz launcher, the mass that can be injected is well above the envisaged EUNEOS satellite mass, which would allow to share the launch (and the cost) with another satellite.

The EUNEOS Mission Phases

The following mission phases are distinguished:

- ✓ Launch phase: The launch phase begins when the spacecraft transfers to internal power on the launch pad and ends when the spacecraft is declared stable, healthy, and the launch telemetry has been played back. The major activities in this mission phase include: the lift-off and ascent phase of the launch vehicle, insertion into a circular parking orbit, a coast period followed by additional launch vehicle burns necessary to inject the spacecraft onto an interplanetary trajectory to Venus, separation of the spacecraft from the launch vehicle, initial acquisition by the DSN and verification of the spacecraft's health.
- ✓ Cruise phase: The Cruise phase begins after the completion of the Launch phase and ends 15 days prior to entry into the sphere of influence (SOI) of Venus. The duration of the Cruise phase is 5-6 months depending on the launch date. The major activities during this phase include: checkout and maintenance of the spacecraft in its flight configuration, navigation activities supporting the design and development of the trajectory correction manoeuvres (above all of the TCM-1, the largest manoeuvre performed during the interplanetary cruise to Venus), monitoring and characterisation /calibration of the spacecraft and payload subsystems, and in particular of the scientific payload
- ✓ Fly-by phase The fly-by phase begins after the completion of the Cruise phase and ends when the spacecraft leaves the Venus SOI. The duration of the Fly-by phase is one month. The major activities during this phase include: the navigation activities supporting the design and development of the last trajectory correction manoeuvres in case of too large discrepancy of the target point in the B-plane, use of the scientific payload to image Venus (TBC).

✓ Operational phase	The operational phase begins after the completion of the Fly-by phase and ends at the end of the scientific mission. This duration of the operational phase is nominally 5 years to achieve a sufficient completion of the discovery. Typical activities include: regular scanning of the sky according to the relevant scanning strategy interrupted from times to times by instrument calibration and observations asked by the ground, navigation activities supporting the scientific exploitation of the data (in particular orbit determination to be able to give observation directions from the Earth).
✓ Decommissioning phase	The Decommissioning phase begins after the completion of the Operational phase and ends with the switch-off of all the spacecraft subsystems. The duration of the Decommissioning phase is typically fifteen days.

The EUNEOS Timeline

Phase/Event	Start	End	Comments
Launch	01-01-2009	01-01-2009	
Cruise	01-01-2009	11-05-2009	✓ TCMs ✓ TCM1: 15 days after launch ✓ TCM2: 50 days before Fly-by ✓ TCM3: 10 days before Fly-by ✓ Calibration of scientific payload
Fly-by	11-05-2009	13-05-2009	Target point for the fly-by rather loose
Operational	13-05-2009	13-05-2014	Mainly discovery but can be asked to performed observations on demand
Decommissioning	13-05-2014	01-06-2014	

The Launch

As baseline, a dedicated launch on Soyuz is proposed. However, a cost saving is possible by using a shared launch on Soyuz with some constraints on the mass of the co-launched passenger and on its operational orbit.

THE EUNEOS SATELLITE

The proposed EUNEOS operational orbit imposes some specific, yet handlable constraints on the EUNEOS satellite design, mainly on the thermal, power generation and telecommunications aspects since the satellite can be as close as 0.5 AU from the Sun and as far as 1.7 AU from the Earth.

Thermal

The main requirement for the spacecraft configuration is the need to have at least one side of the spacecraft that is protected from the sun in all phases of the mission. This is required for the thermal control of both the platform and the instrument (particularly the focal plane). Different strategies have been identified, one of which involves a sun-shield for the protection of one side, and the other two involving 180° spacecraft flips around the optical axis in order to keep the sun in a predefined region in the spacecraft body frame.

Other constraints in the allowed attitude are

- Power generation: one or more solar panels must be pointed at the sun in the various orientations of the spacecraft
- Communication: a high-gain antenna is necessary and must be pointed at the Earth during the overall mission (the Earth position being variable in the S/C body frame).
- Propulsion: a set of thrusters is necessary for orbit corrections and wheels unloading. Those thrusters must be protected from sun illumination, in order to be able to use off-the-shelf equipment, not qualified for the range of solar fluxes that will be encountered on EUNEOS.

A strategy involving two 180° spacecraft flips around the optical axis in three days is preferred.

Power

The solar array sizing for the EUNEOS mission will take advantage of activities performed in the frame of the BepiColombo Definition Study. In particular, GaAs cells are being tested at high temperatures (up to 250°C). It has been shown in theses studies that in order not to exceed this maximum temperature, the solar array has to be tilted away from the sun when the solar flux exceeds about 6000W/m².

The characteristics of the EUNEOS mission are such that the maximum solar flux encountered during the mission will be on the order of 5500W/m², which implies that:

- ✓ the cells envisaged for the BepiColombo mission are compliant with the EUNEOS mission,
- ✓ the same solar array design (including carbon-carbon substrate) can be used,
- ✓ it will not be required to rotate the solar array away from the sun as the limit flux of 6000W/m² will never be exceeded

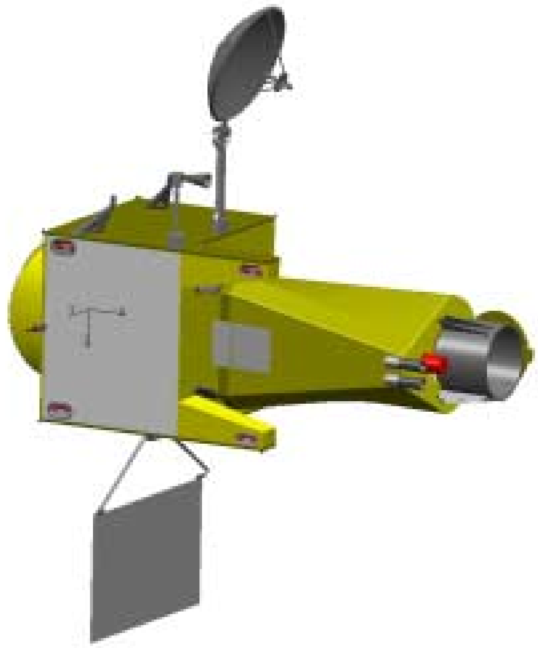
Telecommunications

The large range to Earth during the overall EUNEOS mission is the main sizing parameters of the communication subsystem. The spacecraft will be as far as 1.7AU from the Earth during long periods of time. Considering the requirement that the observation data must be available on ground at most a few days after an object is detected, this means that the system must be able to operate a full capacity at maximum distance (i.e. daily transmit all the required data).

This particularity of the EUNEOS mission, as it is the case with interplanetary missions, imposes the use of equipment capable of variable data rates, in order to adjust the data rate to the capacity of the link at a given date

The use of a 15m ground station is baselined in order to reduce the ground segment operations cost and increase flexibility in the selection of the ground station associated with

- ✓ a communication subsystem based on a 1m diameter HGA,
- ✓ a MGA as backup,
- ✓ two low gain antennas for emergency cases.



The satellite dry mass, including a 20% system margin, is **514 kg**. To this dry mass has to be added the propellant mass of 27kg, which gives a total launch mass of **541.0 kg**.

Mass Budget

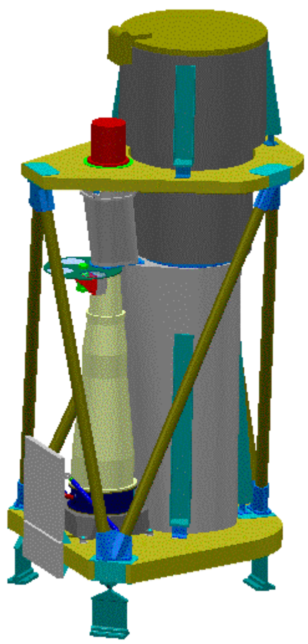
FUNCTIONAL SUBSYSTEM	Total Mass (kg)	Margin (%)	Mass with Margin
1. Structure	55,41	20,00	66,49
2. Thermal Control	20,00	20,00	24,00
3. Mechanisms	25,20	11,25	28,04
4. Pyrotechnics	0,00	0,00	0,00
5. Communications	25,90	12,93	29,35
6. Data Handling System	15,10	11,92	18,12
7. AOCS (incl. prop for SM mission)	32,38	6,70	34,55
8. Propulsion	7,47	5,00	7,84
9. Power	32,01	13,35	36,28
10. Harness	14,00	20,00	16,80
12. Instruments (Payload)	151,70	10,00	166,87
Total EUNEOS	**379,17**		**428,34**

THE EUNEOS PAYLOAD

The main payload requirements are presented in the Table below.

Characteristics	Instrument main requirements	Characteristics	Instrument main requirements
Spectral range	370 nm – 950 nm	Acquisition time	30 seconds
Field of view	3° x 3°	SNR	≥ 3 for an object of 21 magnitude (1 a.u.)
IFOV	$(1.3\ \text{arcsecond})^2$	Brightest targets	16 magnitude

The proposed EUNEOS optical layout is essentially derived from COROT, taking benefit from trade-off studies and design activities performed in the frame of this instrument development, in order to minimise the development risks and costs.



The main structural components are:

- ✓ a primary mirror (M1) based on light-weighted Zerodur glass equipped with three Mirror Fixation Devices (MFD) for isostatic maintain
- ✓ MFDs are made of super invar for mechanical and thermal decoupling from external perturbations, in order to limit the effect of interfaces errors (flatness primary panel) and the effects of differential deformations due to the temperature variations and humidity release of the structure.
- ✓ A secondary mirror (M2) in Zerodur glass equipped with one monolithic MFD for isostatic mount.
- ✓ A dioptric assembly.
- ✓ A focal plane array made of CCD 42-80 detectors butted to form a 2x4 configuration

Comments :

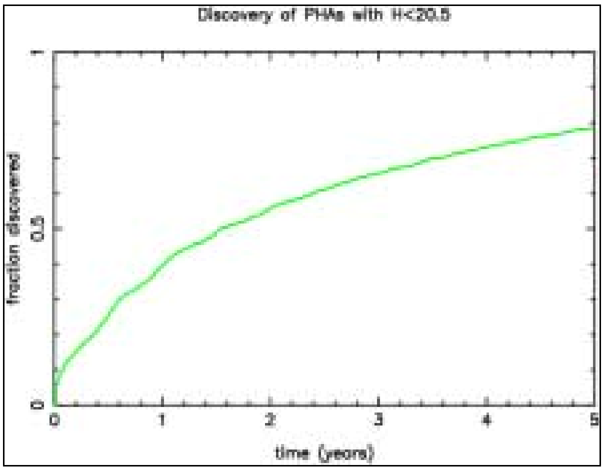
- The shutter / polarizer wheel mechanism is similar to the filter wheel mechanism of POLDER (which is flight proven since ADEOS mission in 1997);
- The focus mechanism is similar to PLEIADES, which will start in 2003 development and qualification;
- Structure : similar to COROT concept, materials and technologies;
- Straylight baffles and vanes: similar to COROT design, materials and technologies;

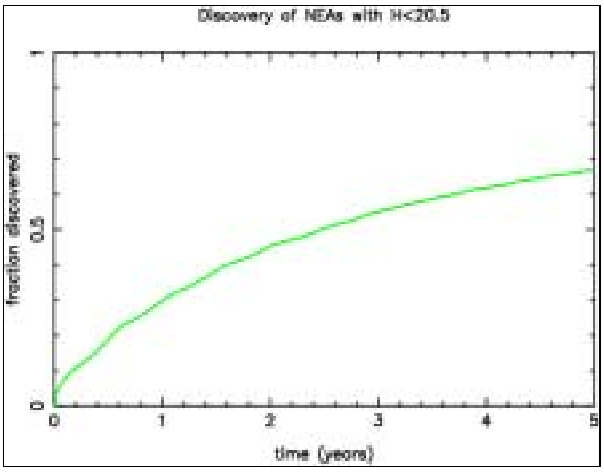
Thermal control : classical concept, hardware and technologies. Concerning the cooling of the focal plane, the concept of dewar, thermal link and passive radiator is similar to COROT, which is currently under development.

4. Mission Performances

The discovery of Potentially Hazardous Asteroids (PHAs) larger than 300m in diameter is the top priority of our program. The model of the orbital and size distribution of Near Earth Objects developed by scientists at the Observatoire de la Cote d'Azur in collaboration with American colleagues at SWRI and LPL under the auspices of ESA predicts the existence of about ~1,000 PHAs larger than 300m in diameter for an overall population of about ~1,000 NEOs larger than 1km in diameter or ~7,000 larger than 300m in diameter.

To estimate the mission performance, simulations are performed accounting for the characteristics of the telescope in terms of limiting visual magnitude, size of the field of view, image resolution scale, exposure time and of the prospected scanning law, and for the expected NEO and PHAs distributions.





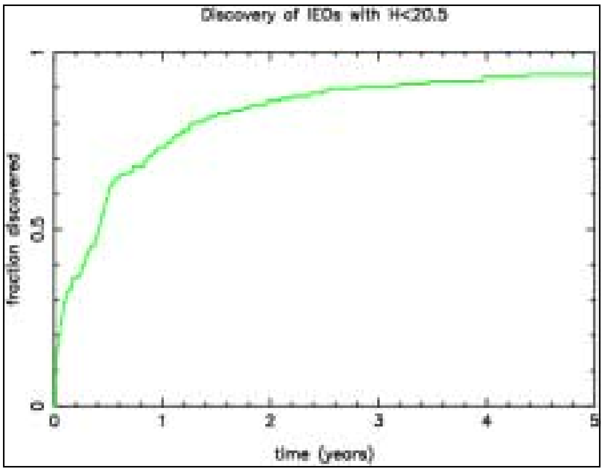
The fraction of the PHA population larger than 300 meters in diameter (more technically defined as the population with absolute magnitude H<20.5) that is discovered by EUNEOS during its 5 years mission, according to our simulator, is close to 80% (which means about 800 objects of this type)

We call "discovered" an object that is detected at least during three consecutive visits of the survey area.

Although the discovery of the PHA is the primary goal of our program, a similar analysis of the EUNEOS detection performance has been done also for the generic NEA population larger than 300 meters in diameter, which -with respect to the previously considered PHA population- includes also bodies that do never come closer to the Earth's orbit than 7.5 million kilometres. The simulation shows that EUNEOS should detect about 68% of the bodies, namely approximately 5000 objects.

The reduced performance of EUNEOS on the generic NEA population with respect to that achieved on the PHA population is simply explained by the difference in the relative geometry between the Sun, the spacecraft and the objects. PHAs must pass close to the ecliptic at about 1 AU, so that they easily fall in the search field of EUNEOS. The same is not necessarily true for the NEAs that are not PHAs.

Another interesting population of objects in the Near-Earth space is that of the IEOs. These are objects whose orbit is completely interior to that of the Earth. None of these objects has ever been discovered from the ground, because their position in the sky is always too close to that of the Sun. Despite the IEOs are not currently dangerous because they do not intersect the Earth's orbit, they could evolve to an Earth crossing orbit on a relatively short time-scale. Being difficult to detect, the IEOs could thus strike the Earth without previous notice. The observational knowledge of the IEO population should therefore be an important goal of any survey program aimed to the protection of the Earth from space collisions.



The detection performance of EUNEOS on the objects of the IEO population larger than 300 meters in diameter is extraordinary. In a 5 year mission, this population – estimated to consist of about 150 objects - is almost completely discovered.

NB: The great performance of the EUNEOS mission is not limited only to the discovery of the Near Earth Objects. The simulations show that the vast majority of the NEOs would be detected multiple times, the observations covering long time-spans. This will allow the data reduction centre to compute high accuracy orbits for the discovered objects. This is an essential point for what concerns the calculation of the impact probabilities with the Earth and the possibility to target ground based observations of these objects after the end of the EUNEOS mission.

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Concerning the requirements for the recovery after the EUNEOS mission, it was shown that a telescope capable of reaching limiting magnitude V=24 at 60 degrees of solar elongation could recover more than 96% of the EUNEOS discovered bodies. The knowledge of these bodies will therefore be secured for the future generations.

The limiting magnitude V=24 is very faint, but should not induce to think that telescopes of the 10m class should be used, as it would be the case if we wanted to discover them directly from the ground. In fact, the availability of a valid ephemeris implies the knowledge of the apparent sky motion of the objects. The telescope can therefore compensate for the NEO motion and avoid the trailing loss, which allows the observer to use long exposure times (much longer than those usable for the discovery of objects with unknown motion) and reach faint magnitudes even with an instrument of the moderate size class.

5. Conclusion

An integrated system including a space-based observatory on an orbit interior to Venus is proposed as a first step to handle the hazard represented by Near-Earth Objects to Mankind by performing a systematic survey of the sky to detect and track the most dangerous of them, the Potentially Hazardous Asteroids.

Compared to existing or envisaged surveys, the EUNEOS survey will detect more fainter objects, yet still able of generating regional disasters in case of collision with the Earth, due to the favourable geometry of the selected operational orbit. This orbit is easily reached from the Earth when taking advantage from a gravity assist with Venus. To keep some numbers in memory, one should retain that the current definition of the EUNEOS mission should allow the discovery of:

- ✓ about ***80%*** of the population of the ***Potentially Hazardous Asteroids*** with absolute magnitude brighter than ***H=20.5*** (roughly of size larger than 300 meters in diameter),
- ✓ about ***68%*** of the ***NEO population with H<20.5***, without restrictions on the minimal orbital intersection distance of the objects with respect to the Earth,
- ✓ about ***95%*** of the population of the ***Inner Earth Objects***, bringing our observational knowledge of this population from the current null level to almost completion.

The constraints imposed on the satellite design by this innovative option – mainly the thermal, power generation and telecommunications aspects - are demonstrated to be within the range of technologies already affordable or in consolidated development in the frame of other ESA financed projects (typically BepiColombo). The margins on the mass and power budgets are very comfortable, which raises no doubt on the satellite design.

The optical instrument requirements are high due to the faintness of the objects to be detected and tracked. Therefore, in order to minimise the development risks and costs, the proposed EUNEOS optical layout is essentially derived from COROT, taking benefit from trade-off studies and design activities performed in the frame of this instrument development. The aspect to be particularly studied in further details is the image quality assessment for the small Instantaneous Field of View, although no unfeasibility is identified at the present stage of the project.

The strength of the proposed mission apart from its intrinsic outstanding performance also lies in the integration of the space observatory in an European system taking advantage of the existing structures in the field of asteroids surveillance to ensure the efficient distribution of the information derived from the EUNEOS observations to the relevant scientific community.

EUNEOS is by far the most optimum NEO survey, it can be seen as a significant contribution of Europe to the hazard represented by NEO in a field where most of the results are obtained in the United States of America. The EUNEOS mission shall not be seen as competing with the future developments of NEO surveys envisaged on the other side of the Atlantic (e.g. PanStarr). At the contrary, each initiative can take advantage of the other, EUNEOS by having a ground observatory with the adequate requirements for sustaining the catalogue beyond the envisaged mission, and PanStarr by devoting less time to detection of NEOs, which frees time for other objectives (the main objective of PanStarr being the asteroids of the main belt).

Currently, no operational survey is capable of achieving results comparable to that of the EUNEOS mission within 2014 (the end of the mission is launched in 2009).