Cosmic Objects Panel: Perspectives for the defense of human kind against the near-Earth objects hazard in the new Millennium

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Abstract

The presence of a population of small planetary objects that may cross the orbit of the Earth constitutes a danger for the human civilization and more in general for the terrestrial biosphere. This is well known, and the scientific community is currently doing important actions to prevent possible collisions and mitigate the possible effects of such events. On the side of the detection of potentially hazardous objects, dedicated sky surveys are currently operational from ground and from space, and new, more powerful instruments will be made operational in the next years. On the side of the physical characterization of potential impactors, we have available a variety of techniques to be able to estimate the size and composition of these bodies, in spite of their relative faintness. In case of the discovery of an object moving along a trajectory that can lead to an impact with the Earth, different possible techniques can be considered to prevent the collision, depending on the time available between the discovery of the object and its predicted impact. What is still sorely missing is an agreed framework in which any possible activity of defense can be put into existence according to internationally agreed laws and treaties. The defense of the Earth against collisions with celestial bodies is a task that cannot be solved by scientists alone, but it requires actions by well-informed decision makers at an international level. For this reason, we propose in the framework of the New Manhattan Project the organization of an international conference in Erice, with the participation of scientists, engineers, lawiers, top officers of the most important Space Agencies and high-level members of the governments of different countries, as a first necessary step to establish a body of internationally agreed rules to set up a real system of defence against catastrophic collisions with near-Earth objects.

1 Introduction

There are today more than 15,000 small bodies classified as near-Earth objects (NEOs). About 1,000 of them have estimated sizes ≥ 1 km. NEOs are essentially asteroids and comets whose orbits sweep the region of the inner planets. In the past, NEOs have been divided in different orbital categories, including Atens, Apollos, Amors, Arjunas or IEOs, depending upon the values of their perihelia and aphelia (the minimum and maximum distances from the Sun). These orbital classifications can be useful to characterize the current orbital properties of NEOs, but we know that NEO orbits evolve chaotically over astronomically short timescales, therefore any given object can be found to belong to different orbital classes in different epochs. The bottomline is that the whole NEO population is intrinsically dangerous from the point of view of possible impacts with our planet. Objects that are not dangerous today can become a hazard for future generations, so all objects deserve a continuous monitoring. A great effort is currently spent to discover and compute the orbits of NEOs. The most immediately interesting among them are called Potentially Hazardous Objects (PHO) and are defined as NEOs having Minimum Orbit Intersection Distance (MOID, i.e. the minimum distance between the orbit of the NEO and that of the Earth) ≤ 0.05 Astronomical Units[1], and Absolute Magnitude H $\leq$ 22 (a measure of the intrinsic brightness of celestial bodies), corresponding to objects having a size around 150 meters. The number of currently discovered PHAs is close to 1800. Note that it is estimated that a collision with an object having a size of 1 km or larger would produce a global catastrophe in the Earth's biosphere, but even objects with sizes of the order of 100 meters in the case of a collision, both on land or in the ocean, can produce very serious devastations.

When dealing with the computation of the impact risk, it should be clear that the fact that a given NEO can move at the same distance from the Sun as the Earth is not *per se* sufficient to make a collision possible. This is due to the fact that the orbits of the Earth and of other planetary bodies as a rule are not perfectly co-planar, and also the orientation of the orbits in space is crucial to permit a real orbital intersection. In other words, when a NEO reaches the same distance from the Sun as the Earth, it is normally far from our planet and no collision can occur. A necessary prerequisite to make a collision possible is that the Earth's and NEO's orbits really cross each other in (at least) one point, or, more precisely, that the NEO and the Earth, in their orbital motion, can really reach a mutual distance smaller than the Earth's radius. Even when this orbital configuration is reached, however, a collision can occur if and only if both the Earth and the object pass through the orbital intersection point simultaneously. These conditions are extremely rare, and this makes an impact with any given NEO to be a very unusual phenomenon. The probability of one of such events to occur in a given interval of time, however, depends on the number of possible impactors. Due to the fact that NEOs are increasingly more numerous for decreasing size (in technical terms, the size distribution of these objects is well represented by a power law), this explains why impacts with NEOs having sizes larger than 10 meters are rare (about one per century) whereas we can see meteors (produced by the entry in the atmosphere of much more abundant interplanetary dust particles) every night from any given location.

[1] The Astronomical Unit is the adopted unit to express distances at the scale of our planetary system. It is equal to the semi-major axis of the orbit of the Earth, namely about $149,600,000$ km

On the other hand, it is sure that, over long timescales, NEOs of sufficiently large size to produce dysasters, hit the Earth. There are over 150 impact craters currently recognizable on our planet, in spite of their progressive erosion due to atmospheric (wind, rain) and geologic (volcanos, global resurfacing related to continental drift) phenomena. Some craters have been associated to possible events of mass extinction experienced in the past by the Earth's biosphere. Apart from these rare events, that are thought to happen with a frequency of once per 10^8 years (the most recent one having produced the Chicxulub crater about 60 Millions of years ago), much smaller bodies, having sizes of some tens of meters, hit the Earth much more frequently and can cause local devastations over large areas, as in the case of the famous Tunguska event in 1908.

In general terms, it should be observed that the risk due to the possible impact of small celestial bodies has some peculiar characteristics, when compared to other possible kinds of natural dysasters. In particular, NEO collisions are rare, but when they occur they can cause very big devastations and produce huge numbers of victims. This is the reason why since many years the scientific community in the most developed countries has been addressing the NEO impact risk.

2 State of the art

What are the problems to be solved to set up a credible defense against possible impacts by NEOs? The problem can be divided into different, logical steps:

1. Discovery of possible impactors. This means not only to detect them, but to compute their orbits and orbital evolution.

2. Based on the computed orbit, computation of the probability of impact with the Earth over the maximum possible span of time.

3. Confirmation of a non-null probability of collision, based on improved knowledge of the orbit obtained by further observations.

4. Having identified a possible impactor, some basic questions must be answered, including the following: How much time we have to react ? How big is the impactor? What it is made of ? In other words, it is necessary to obtain a decent *physical characterization* of the NEO.

5. Depending upon the available time, identification of the most efficient technique to avoid the impact, taking also into account the available information about the physical properties of the body. In possible cases of very short notice of a very imminent impact, a quick evacuation of the predicted impact area must be organized and promptly executed.

6. Implementation of the most suitable defense action.

In this Section, we briefly summarize the current state of the art regarding the main points mentioned above, and we point out the major existing problems.

2.1 NEO Detection, computation of orbits and impact probabilities

NEO detection is difficult due to a number of reasons, including (1) their faintness; (2) their rapid motion in the sky when they are close to the Earth and thus easier to detect; (3) the geometry of their passages close to the Earth. In particular, NEOs, as all other Solar System bodies, are in the best possible conditions for observation from the Earth when they are close to solar opposition, that is when they are seen from the Earth in a direction opposite to that of the Sun. In these conditions, the objects reach their minimum possible distances from the Earth, and their maximum possible brightness. Unfortunately, there are NEOs that rarely or even never can be seen at solar opposition. In particular, this is the case of objects spending a large fraction of, or all their orbital period around the Sun, moving at heliocentric distances closer to the Sun than the orbit of the Earth. These are elusive objects which are difficult to observe from the ground, They do not constitute a large fraction of the whole NEO population, but they are important, being also characterized by relatively high collision probabilities. This is a reason why space missions like the Gaia satellite launched by the European Space Agency at the end of 2013, can play an important role, being able to observe zones of the sky down to a minimum angular distance of 45° from the Sun, which are hardly observable from the ground.

In spite of these problems, starting from the late ninenties, when the yearly discovery rate of NEAs was very low, the situation has been rapidly improving. In particular, the NEO discovery rate started to increased enormously with the advent of CCD-based detectors, and continues to increase nowadays. According to current estimates, about 90% of the 1 km or larger

NEAs have been discovered so far, although the completeness level at smaller sizes is still considerably lower.

NASA funds all the major ground-based and space-based surveys aimed at the NEO discovery, including the Catalina Sky Survey, the Mt. Lemmon Survey, and the dedicated Pan-STARRS telescope. Europe is currently setting up another independent ground-based telescopic survey that will nicely complement the US surveys. Other countries are also involved in NEO discovery tasks, although their contributions are generally minor.

On the side of orbit determination, one should take into account that the computation of an orbit is always based on observations giving the position of the object observed in the sky at different epochs. The longer the period of time covered by observations, the longer the corresponding arc of orbit sampled by the data, and the more accurate the resulting determination of the orbit. One should never forget, however, that any measurement of position is unavoidably affected by errors, that depend upon many factors, including the instrumental quality of the detector and the weather conditions at the epochs of observation. For this reason, the computation of an orbit is an iterative process, in which the accuracy of the result tends to improve as soon as more numerous data of better quality become available. We also note that, in addition to classical telescope observations, that give the varying position of an object in the sky, in the case of NEOs it is also possible to complement telescope data with measurements of the radar echo of the objects. This provides much needed information about the radial distance of the object, and can improve drastically the accuracy of orbit computation in a much shorter time. Unfortunately, only a handful of radar transmitters and receivers needed to produce radar echo data are currently available, practically only in the United States, and with some pending funding problems.

The same factors that make difficult NEO detection make the initial determination of their orbits problematic. This due to the fact that (1) the faintness of the objects most often implies short observed arcs, covering limited interval of time when the objects are sufficiently bright to be detected by available telescopes; (2) the rapid motion in the sky of most NEOs requires immediate follow-up, that is not always available; (3) in some cases the geometry of NEO apparitions makes the observed positions compatible with orbits of very different nature, while in other cases, as mentioned above, it makes the follow-up nearly impossible from the ground.

For the purposes of orbit determination, NASA funds the operations of the Minor Planet Center (MPC) of the International Astronomical Union, where astrometric data are collected, stored and made available to the astronomical community. The MPC computes orbits and is also in charge to assign official designations to all asteroids and comets. Moreover, NASA operates the Planetary Defense Coordination Office at the Jet Propulsion Laboratory (JPL), where independent orbit computations are made. In Europe, a major orbit-computing facility is the University of Pisa (Italy), whose NEODyS and AstDyS websites will migrate, in the next years, to the NEO Coordination Centre of the European Space Agency (ESA).

The problem of determining the probability of collision with a NEO is obviously based on the knowledge of its orbit. The problem is made more difficult by the fact that NEOs have orbits that evolve chaotically due to close encounters with the terrestrial planets (from Mercury to Mars). Moreover, NEOs are small bodies, and their orbital evolution is also influenced by non-gravitational mechanisms due to subtle mechanisms of irradiation of the received solar light. In practical terms, therefore, there is always some limit to our capability to compute the evolution of NEO orbits in the future. Much depends on the perturbations experienced by these objects when they have a close encounter with a planet. These perturbations are extremely complicated and cannot be accurately predicted over long time scales. For this reason the computation of the impact risk becomes very complex, and some special concepts (including the so-called "key holes", corresponding to domains of possible positions at a given epoch for a NEO to make it possible a future collision with a planet) have been developed and successfully tested in recent times.

Summarizing, the problem of NEO detection, orbit computation and evaluation of the impact probability is not in principle an easy one, but we have currently the technology and we master the techniques needed to successfully cope with it. The situation is generally good and is expected to improve further, as newly dedicated observing facilities are expected to enter into operations in the next years.

2.2 NEO Physical characterization

The development of techniques of defense to prevent possible collisions or at least to mitigate their effects critically depends upon our capability to determine not only the orbit of possible impactors, but also their physical properties. In fact, the energy delivered to the Earth in case of an impact is equal to the kinetic energy of the impacting body, given by $1/2\, m\, v_{imp}^2$, where v_{imp} is the velocity at the epoch of impact, and the mass m of the body is equal to the product $\rho \cdot V$, where ρ is the average density and V is the volume. For sake of simplicity, we can assume the object to be a sphere, so the volume becomes $V = 4/3\pi R^3$, where R is the radius of the object.

The determination of the mass m requires therefore knowledge of the size of the object, of its composition and internal structure. The determination of these parameters is a very challenging task. The easiest parameter to be determined is the size, but this cannot be done in a straightforward way. The problem is that NEOs are simply too small for their apparent angular sizes to be measurable by simple imaging using even the largest existing telescopes. The determination of the size requires therefore a measurement of the brightness (the larger the object, the brighter). Unfortunately, however, the population of small Solar System bodies is very heterogeneous in terms of composition, and as a consequence the surfaces of different objects are characterized by very different reflectivities (in technical terms, albedos), in such a way that a simple measurement of the brightness is not sufficient to distinguish between a smaller, brighter object and a darker, larger one. The difference is important, because NEO albedos vary by a factor of 10 depending on surface properties. The determination of the size of a NEO is therefore strictly related to a determination of its albedo. There are techniques to solve this problem. One possibility is to measure the NEO flux at mid-InfraRed wavelengths, corresponding to the thermal emission of the objects, determined by their temperature and dependent on the size, but only weakly on the albedo. Unfortunately, thermal-IR measuremens are hard to be obtained from the ground, due to absorption of the flux by the atmosphere. The major sources of thermal IR data are measurements from satellites. Unfortunately, we cannot expect that at any epoch there may be IR satellites in operation to promptly perform measurements of hazardous objects of recent discovery. Another possible technique for the determination of the albedos is based on measurements of linear polarization of the scattered sunlight received by the objects. This technique is feasible and is based on ground-based telescopes. Because NEOs are faint, in case of urgent needs it is necessary to obtain observing time at very large telescopes. This is feasible in principle, because all major telescopes guarantee some small fraction of observing time to Targets of Opportunity and to Director Discretionary Time. In this respect, therefore, the determination of the size of a potentially hazardous object of recent discovery is feasible in principle (though not so easy). The same is true for the possibility to carry out spectroscopic observations that are needed to determine also the general composition of the surface, in such a way as to be able to distinguish between different types of surfaces, characterized by different overall compositions. From the point of view of the determination of NEO sizes and compositions, therefore, we can say that the necessary techniques and facilities exist and are in place.

2.2.1 Problems

According to what has been explained above, the determination of the size of a potentially hazard NEO is possible, and this is *per se* a very positive step forward. However, we have also seen that the kinetic energy delivered to the Earth in case of a collision depends upon the mass, and in turn the computation of the mass is based on knowledge not only of the size, but also of the average density. Here, we face a major, and still unsolved, problem.

Even having available some evaluation of the size and surface composition of of any given NEO, this is not sufficient to infer an accurate estimate of its average density. The reason is that this parameter depends on the internal structure of the object. We encounter here a strong limit of our current knowledge. The determination of the internal properties of a small planetary body is a formidable problem. Very different internal structures can be possible, and in particular the existence of possible empty zones (macroporosity in the jergon of specialists) are suggested by a few available data indicating for some asteroids surprisingly low values of density, in disagreement with what should be expected for bodies having a monolytic structure and the compositions inferred from surface properties. The overall internal structure is decisive to determine the average density of a body, and hence its mass. It also plays a decisive role when possible techniques of orbital deflections to avoid a possible impact are considered. Unfortunately, the internal structures of NEOs can hardly be determined by means of remote observations.

The determination of the internal structures of the objects requires the development of *tomography* techniques to be carried out by dedicated space probes. There are essentially two different possible approaches, one being based on electrodynamics, and the other on elastodynamics. Both of them are based on the idea to measure the propagation of (electromagnetic or mechanical) waves in the object's interior, and to derive from them the transmission/reflection properties of the materials. The application of electrodynamical techniques is aimed at analyzing the dieletric properties of the material, and does not require a contact of a detector with the object's surface. The application of elastodymanical techniques is aimed at the determination of the mechanical properties of the materials, and requires a contact with the surface of the object under scrutiny. In terms of practical applications in the framework of an actual space mission, the latter translates into the need of placing one or multiple landers on the NEO surface. The application of electrodynamical techniques requires instead one or more orbiters around the object, equipped with suitable radars and with optical imagers. There is therefore in general terms a wide spectrum of possibilities in terms of different possible options for a tomography mission. These concepts have been preliminarily developed, but not yet put in practise, although we have already available the necessary technology for execution of orbital manoeuvers, data acquisition and geophysical imaging. It is then a high priority task for the development of a NEO defense system to be able to convince the Governments that the realization of a tomography mission is a very high priority for the next years, and an excellent investment of resources also in terms of purely scientific return.

2.3 Possible defence options: pros and cons

In the unlucky case of discovery of an object on a path of collision with the Earth, what we can do? How we can defend ourselves? In practical terms, very much depends upon the available time, namely the time between the discovery and orbital characterization of the object, and the predicted epoch of impact. Depending on this, we have basically three possible main options:

1. "Gentle" techniques of slow and progressive deflection.
2. More energetic options, based on the idea to suddenly deliver a sufficiently energetic impulse to immediately modify the orbit of the object.
3. In cases of short notice, and/or of large impactor's size, the use of very energetic countermeasures based on the use of nuclear devices.

Item (1) in the above list applies to the most favourable cases, namely the situations in which the available time is long (up to several years) and the potential impactor is small. In these conditions, it is sufficient to deliver to the object a very modest, continuous impulse to slowly modify the orbit up to the point that, eventually, no collision takes place. Small NEOs can be so small and light that even very small perturbations, accumulating over a sufficiently long time, can produce noticeable modifications of the orbit. In this respect, different options have been proposed by different authors, including the so-called "Gravity Tractor" or "Space Tug" technique proposed by the Apollo 9 astronaut R. Schweickart, and the B612 Project organization. The main idea is to launch a spacecraft toward the object, and once it reaches the immediate vicinity to keep it in position and use it as a gentle gravitational perturber to slowly modify the NEO orbit. At the same time, the same spacecraft would be also essential to produce a continuous and very accurate monitoring of the position and motion of the NEO, in such a way as to be able to know with high accuracy the exact needs in terms of impulse in the case that a further kinetic impact turns out to be also necessary. The second item in the above list is easy to understand. The idea is to exert a sudden impulse to the object, in such a way as to obtain a desired change of trajectory. This can be done by means of an impact, using a missile or other similar device. An actual application of this technique to a real celestial object has been done in the past by the Deep Impact space mission of the NASA. The purpose of that mission, however, was to study the response of the immediate subsurface layers of a comet to sudden exposure to the surface. In that case, moreover, the target of the mission was a sizeable comet, much more massive and bigger than a typical NEO. The concept of a space mission explicitely devoted to assess the response of a NEO to a sudden impact was submitted years ago to the ESA (the so-called Don-Quijote mission), but no practical implementation of this mission concept has been actually made since then.

It should also be understood that the use of a kinetic impactor to modify the orbit of a NEO should be designed in a such a way as to avoid as much as possible a fragmentation of the NEO target. This is due to the need of spending the delivered momentum to deflect the body, not to break it up. The fragmentation of a given NEO into smaller pieces could lead actually, in many circumstances, to a failure in avoiding a collision with the Earth, and could even make the event even more dangerous, by multiplying the number of impacting bodies. Again, even in this respect, a knowledge of the internal structure of the object is sorely needed.

Another important element to be taken into account is that, for the purposes of obtaining an orbital deflection sufficient to force a NEO to miss the Earth, the imparted momentum should be delivered in such a way to produce a change of the orbital motion along the direction of the motion of the object (by accelerating or decelerating it). The reason is that to produce a change of motion in a different direction is much less efficient, and requires a lot more of delivered momentum.

The final option to be considered in the the case of the discovery of an impacting NEO with too short notice, and/or having a too large size to allow an effective application of the other options described above, is the use of nuclear devices. It is clear that the possible use of such devices, even for the purposes of avoiding a major catastrophe, raises a lot of problems. According to current international treaties regulating the use of the space, the launch of a spacecraft carrying nuclear devices is formally forbidden. Even in the case of urgent, exceptional circumstances dictated by a possible NEO impact, the use of nuclear weapons would raise huge problems, in the absence of an internationally agreed framework for the use of such devices in space to face this specific threat. Specifically, convincing answers should be given to major questions, including:

- Who decides? On what basis? Which are the agreed criteria?
- Using which facility(ies)? Where the facility(ies) is(are) located? Who controls and manages such facility(ies)? Who pays?
- Are we sure that we can reliably and accurately compute the outcomes of NEO disruption attempts using nuclear devices?

The first two items in this list are self-explanatory. As for the last item, we face the problem that any matter related to the use of nuclear weapons is obviously studied in military laboratories in which all the activities are classified and kept secret. However, it would be very useful, in evaluating the possible use of such devices for NEO defence, to make some blind tests to compare the predicted outcomes of such NEO deflection/disruption technique, according to independent calculations carried out by different teams belonging to different Nations. This would be in principle a very useful test to evaluate the real capability to develop robust strategies of defence using nuclear devices in conditions where no other options are viable. On the other hand, the possible existence of significant differences in the predicted outcomes in a standard simulated situation would add another serious element of uncertainty to be taken into account.

Summarizing, we have today the necessary techniques to avoid a NEO impact in favourable circumstances, when the impactor is small and the available time is long. In the most critical cases, an attempt of deflection using nuclear devices could be unavoidable, but we are certainly not ready today to develop a generally agreed defense system making use of these devices.

2.4 The need for International Authority

In spite of the importance of the purely scientific and technical aspects, we think that the most important problems that we have to face today to set up a credible defense system against the NEO hazard are not due to technical issues. There are major aspects that require political decisions to be taken by public authorities at an international level, under the coordination of the United Nations.

In this respect, the UN Committee on the Peaceful Uses of Outer Space (COPUOS) was set up by the General Assembly in 1959 to govern the exploration and use of space for the benefit of humanity. The Committee was tasked with reviewing international cooperation in peaceful uses of outer space, studying space-related activities that could be undertaken by the United Nations, encouraging space research programmes, and studying legal problems arising from the exploration of outer space. UN have also a dedicated structure, the United Nation Office for Outer Space Affairs (UN-OOSA), whose core business is to promote international cooperation in the use of outer space to achieve development goals for the benefit of humankind.

Among some fundamental UN treaties regulate the space-related activies of the Nations there is the Outer Space Treaty (1967, 104 States parties/25 signatories), which establishes internationally agreed rules to regulate: the Exploration and use of outer space province of all mankind (Article I); the Principle of nonappropriation (Article II); the International law and UN Charter (Article III); Weapons of mass destruction (Article IV); the International responsibility for national activities in outer space (Article VI); the International liability for damage (Article VII); Jurisdiction and control (Article VIII); Cooperation and mutual assistance (Article IX); Information and notification (Article XI).

As for the specific management of the NEO impact hazard, a fundamental action was the UN General Assembly resolution 68/75 (2013), concerning the International response to a NEO impact threat. An Action Team on NearEarth Objects, established by COPUOS as a result of recommendations of the third global UN Conference on Exploration and Peaceful Uses of Outer Space (UNISPACE III), produced general recommendations for an international response to the NEO impact threat (document A/AC.105/C.1/L.329). In addition, two entities, whose work is facilitated by the UN, were created at a global level as a result of recommendations, namely the Space Mission Planning Advisory Group (SMPAG) and the International Asteroid Warning

Network (IAWN).

For what concerns the future, 2018 marks the 50th anniversary of the first UN Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE), held in Vienna in 1968. COPOUS decided in June 2015 to use this milestone anniversary to renew and strengthen its mandate as a unique platform for interrelationship between major space faring nations and emerging space nations, supported by the UNOOSA. The official purpose of this conference, UNISPACE+50, is to develop a longterm vision for Space, from a domain of States towards a domain of a commonly shared human experience.

This looks very timely, considering the most critical problems in the development of a reasonable defence system against the NEO hazard, including primarily the need of an International, Decision-Making Authority. This is urgently needed to manage the situation whenever the discovery of a NEO impactor will make it necessary to take actions to avoid or mitigate a possible dysaster. This means being able to manage also the political and financial problems arising from possible situations in which evacuation of a local impact zone may be economically preferable to mounting a deflection mission.

The same Authority must be also in charge of managing situations in which the probability of an impact occurrence increases gradually from the time an object first appears to be threatening. In such a situation, it becomes urgent and necessary to take decisions concerning at which level of impact probability a deflection mission should be planned, using which deflection technique, and at which probability level should a mission be actually launched, and by whom, and which funds have to be used for this purpose.

Moreover, once an asteroid deflection is initiated, the original impact point will necessarily tend to shift across the surface of the Earth until the orbit is modified in such a way as to avoid an impact. There will be therefore a well known, and evolving path of risk involving very specific nations. At this point, competing national interests will dominate the risk trade-offs. This makes tremendously necessary the existence of an International Authority to decide in which direction the impact point has to be shifted, according to clearly established and transparent criteria.

It is critical that an approved International Authority in charge of managing these operations is established before the possible discovery of some actual object moving on an impact orbit with the Earth. We can only hope to have sufficient time.

3 Role of the New Manhattan Project

Many international meetings in which the attendance was limited to scientists and experts of the technical details, have been organized for many years. However, these meetings have proven so far to be not sufficient to translate scientific knowledge into much needed actions. The results of technical studies must be known, understood and taken into account by people who are responsible of taking actions at national and international level.

The Erice Seminars have always had the goal of conveying together famous scientists, technical experts of a wide spectrum of relevant disciplines, officers in charge of important national and international Agencies, high-level legal and policy advisors, decision makers, and the international press. The Cosmic Objects Panel therefore believes that a very timely and useful action for the New Manhattan Project is the organization of a Top Level International Conference in Erice, in which the problems of the defence against NEOs are debated together by scientists and legal and policy advisors, as a first step toward the establishment of an internationally-agreed protocol in which a clear plan of actions, funding and responsibilities are agreed upon by the Nations under UN coordination, and established in order to set up for the first time a real and credible defense system against the NEO hazard. THe main goals of the proposed conference will be:

- To set up a meeting of all the relevant stakeholders to promote a general discussion of the political problems that must be solved to develop an agreed strategy for a global defense system, including also the management of evacuation procedures. To make first steps forward in the direction of understanding whether and up to which level of involvement the international community is willing to participate in a defense system. To produce a first list of possible actions to be undertaken at international level.

- To exert moral suasion to support the development of space missions aimed at performing experiments of radio tomography, to infer the internal structures of the bodies.

- To suggest that qualified Teams of different countries independently compute the outcomes of the use of nuclear devices aganst a NEO in some standard simulated cases, decided by a technical commission, to compare the results and infer uncertainties in the expected outcomes.