COSMIC Objects Panel: Plan of the presentations for the 2016 Erice International Seminars

A. Cellino: General Introduction.
G. Valsecchi: The NEO hazard and how we deal with it.
P. Sava: 3D Interior tomography of comets and asteroids.
A. Zaitsev: Citadel: a Concept for a credible Defence System.
N. Hedman: Global Space governance and Space Security: The role of UNOOSA.
A. Cellino: Presentation of a project for the NMP.
The orbits evolve under gravitational and non-gravitational perturbations.

Potentially Hazardous Objects (PHA): Minimum Orbit Intersection Distance (MOID) ≤ 0.05 AU, and Absolute Magnitude H ≤ 22 → (size > 150 m).

There are currently (Aug.18, 2016) 1726 known PHAs (out of >14,000 NEAs)

(Courtesy of NASA JPL) + Near-Earth Comets!
Sooner or later they hit. There are 150 identified (not eroded) impact areas on Earth.

Wolf Creek Crater, Western Australia
Age = 300,000 yrs, Diameter = 850 m

Manicouagan Crater, Quebec, Canada
Age = 215 Myr, Diameter = 100 km

Tunguska site, 1908
What are the problems to be solved to set up a credible defense against possible impacts by near-Earth objects (asteroids and comets)?

1. Discover possible impactors. This means not only to detect them, but to compute their orbits and orbital evolution (see Valsecchi's talk).

2. Answer some immediate questions:
   - How much time we have to react?
   - How big is the impactor?
   - What is it made of?
The apparent visible brightness of an asteroid depends on two fundamental physical parameters, namely the size and the albedo (reflectivity) of the object.

To solve this problem, flux measurements at both visible and mid-IR wavelengths (usually from space) are needed.

One single measurement of brightness at visible wavelengths is not sufficient to derive an accurate size.

Or, the albedo can be assessed by means of polarimetric measurements.

Note that, among asteroids, the albedo can vary by a factor of 10.
Most technical problems can be faced using current technology. Discovery and orbital computation are effectively carried out by means of dedicated, ground-based sky surveys.

For physical characterization we have at disposal observing techniques (Reflectance Spectroscopy, Polarimetry, Thermal Radiometry) to infer the size, albedo and composition of the objects.

Existing large telescopes can be used, but this requires (at least) an efficient Target of Opportunity policy.

Space-based and radar facilities can also be very useful.
We have also to answer some more complicated questions:

- What is the internal structure of the impactor? (See Dr. Sava’s talk)

- Which are the possible techniques we can use in different circumstances to prevent or mitigate the impact? (see Dr. Zaitsev’s talk)

- Who actually takes charge of the required actions? According to which international Treaties and Agreements? What is the role of United Nations? (see Dr. Hedman’s talk)
In terms of technical problems, two major issues are open:

1. The problem of understanding the internal structure of the potential impactors, which are crucial to assess the performances of deflection and disruption techniques (see talk by Dr. Sava)

2. The problem of being possibly forced to take under consideration the possible use of nuclear devices when nothing else can possibly work (short advice, big impactor). Need of having at disposal public and verified studies of the expected performances and effects of using such last-option devices.
End of the general introduction
General summary and a proposal for the New Manhattan Program
Summary: What Do We Know About the Impact Hazard?

• **How many asteroids and comets** there are of various sizes in Earth-approaching orbits (hence, impact frequencies are known).

• **How much energy** is delivered by an impact (e.g. the TNT equivalence, size of resulting crater).

• How much dust is raised into the stratosphere and other **environmental consequences**.

• **Biosphere response** (agriculture, forests, human beings, ocean life) to environmental shock.

• Response of human **psychology, sociology, political systems, and economies** to this kind of event.
What we can do about impact hazard? What we are actually doing? How we can defend ourselves?

**Sky Surveys:** telescopic search for NEOs. Several dedicated observing stations. Situation quickly improving.

**Physical characterization:** Situation not so brilliant, but all the necessary tools are in place and ready in case of urgent observations (Target of Opportunity policy at the most important telescopes)

**Deflection Options:** If a possible impactor is found, then we could try to deflect the object so that it misses Earth

- Gravity tractor or space tug
- Kinetic energy impactor
  (NASA “Deep Impact”;
  ESA “Don Quixote” mission concept)

**Ultimate option:** Stand-off nuclear blast (if NEO is too big or warning time is too short)
The most important problems that we have to face to set up a credible defense system against the NEO hazard are not limited to technical issues.

There are major aspects that require decisions to be taken by public authorities at an international level, under the coordination of the United Nations.
Need of International Decision-Making Authority: Some examples

(1): If the impactor is relatively small an evacuation of the local impact zone may be economically preferable to mounting a deflection mission. **Questions:** Who decides? On what basis? Who pays for the evacuation?

(2): For any anticipated impact the probability of its occurrence will increase gradually from the time it first appears threatening. **Questions:** At what probability of impact is a deflection planned? Who decides? Using what deflection technique? At what probability is a mission launched? Who pays? Who executes the operation?

(3): Once an asteroid deflection is initiated the original impact point is shifted across the surface of the Earth until the deflection is complete. **Questions:** In which direction is the impact point to be shifted? Based on what criterion? Who is liable for failure?
It is critical that an approved international protocol on asteroid deflection be developed prior to the discovery of some actual, likely impact event.

Once an impact is found to have a high probability to occur, it will have a well known path of risk involving very specific nations.

At this point, competing national interests will dominate the risk trade-offs unless an internationally agreed protocol has already been established.

Since the discovery rate of NEOs is rapidly accelerating, the immediate development of a NEO deflection protocol is urgent!.

2004 VD17 path of risk
(courtesy of R. Schweickart)
The possible use of nuclear devices as a possible option in most unfavorable situations (short notice, big impactor) opens other obvious critical questions:

• An international framework for the use of nuclear devices in space does not exist.

• 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?
International meetings in which the attendance is limited to scientists and experts of the technical details, only, are not sufficient. 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 mentioned in this session are debated together by scientists and legal and policy advisors, as the 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.
Main goals of the proposed conference:

• 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.

• Suggest the execution of independent computations by qualified Teams of different countries in order to predict the outcomes of application of nuclear devices to the disruption of a NEO, in some standard simulated cases to be decided by a technical commission, taking into account different options concerning the possible internal structure of the target. A comparison of the results will be useful to infer existing uncertainties in the expected outcomes.

• 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. 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. Produce a first list of possible actions to be undertaken at international level.
PLANETARY DEFENCE

ORGANIZING EARTH DEFENCE: an International Conference to make first operative steps

NEW MANHATTAN PROJECT - SCIENCE FOR PEACE THE WORLD OVER

Panel for the Defense against Cosmic Objects
Thank you for your attention
Current situation concerning the rate of discovery, the computation of the impact risk and the most relevant aspects of NEO dynamics will be summarized in the presentation of Dr. G. Valsecchi.
The size and absolute magnitude distributions of near-Earth objects according to the 2007 NASA Report to the US Congress
The Torino Scale for the impact hazard

| Events Having No Likely Consequences | 0 | The likelihood of a collision is zero, or well below the chance that a random object of the same size will strike the earth within the next few decades. This designation also applies to any small object that, in the event of a collision, is unlikely to reach the Earth’s surface intact. |
| Events Meriting Careful Monitoring | 1 | The chance of collision is extremely unlikely, about the same as a random object of the same size striking the earth within the next few decades. |
| 2 | A somewhat close, but not unusual encounter. Collision is very unlikely. |
| 3 | A close encounter, with 1% or greater chance of a collision capable of causing localized destruction. |
| 4 | A close encounter, with 1% or greater chance of a collision capable of causing regional devastation. |
| 5 | A close encounter, with a significant threat of a collision capable of causing regional devastation. |
| 6 | A close encounter, with a significant threat of a collision capable of causing a global catastrophe. |
| 7 | A close encounter, with an extremely significant threat of a collision capable of causing a global catastrophe. |
| Threatening Events | 8 | A collision capable of causing localized destruction. Such events occur somewhere on Earth between once per 50 years and once per 1000 years. |
| 9 | A collision capable of causing regional devastation. Such events occur between once per 1000 years and once per 100,000 years. |
| Certain Collisions | 10 | A collision capable of causing global climatic catastrophe. Such events occur once per 100,000 years, or less often. |
Consequences of Land Impact by 200 meter to 2 km Near Earth Asteroid

• **Consequences are well understood from nuclear bomb tests and studies of terrestrial and lunar impact craters.**

• Crater rim ~15 times diameter of NEA; total destruction zone twice as big (4 – 40 km from ground-zero)

• Explosion fireball: 3rd deg. burns 10 – 100 km from ground-zero; firestorm 30 – 300 km from ground-zero

• Air-blast, overpressure destroys all structures 10 – 100 km away; poorly-built structures destroyed (within minutes) by winds, earthquake, falling debris up to 70 – 700 km from ground-zero

• Ozone layer destroyed globally by NEAs >500 m diameter

• Atmospheric pollution (sulfate aerosols, nitric acid rains, injection of dust and water into atmosphere); “year without summer” for NEAs ~1 km diameter, global agricultural disaster (“impact winter”) possible for NEAs >2 km diameter (land or ocean impact).

• Electromagnetic Pulse? Could bring down power-grid and communications just when they are most desperately needed.
To Tell or Not to Tell...

- In 2004, at some point, in the 1/37 computed chance that the asteroid Apophis would hit, extreme destruction would have occurred within the zone between the dashed lines, somewhere along the solid red line.

- You can hardly imagine a line crossing more densely populated areas.

There was hot debate about whether to release the possible impact points after they were calculated on Dec. 24th. NASA officials, scientists argued we should wait for perhaps a year. But withholding information from the public violates risk-communication principles!
First problem:

In spite of big improvements in recent years (availability of new dedicated telescopes and telescope time) many dangerous objects may be difficult to detect from the Earth.

130,000 simulated impactors, their locations 20 years before impact. Veres et al., Icarus 203, 472, 2009
Deflection Options

Kinetic Impact

Deep Impact (NASA)
Successfully impacted Comet Tempel 1 in on July 4, 2005

Don Quijote (ESA mission concept)
Proposed to impact target asteroid while standoff spacecraft gathers data
Gravity Tractor


Pulls the asteroid using mutual gravity as a tow-rope
Extreme Possibility:

Stand-off nuclear blast (justified only if NEO is too big and/or warning time is too short)

Very big question marks concerning the response of NEOs to such attempts to deflect and/or destroy them. Strong dependence of the outcomes upon (poorly known) internal structure.
In the past, there have been many international meetings organized to debate the most technical problems related to NEO hazard, including the 2001 Erice School on Space Chemistry.

Many of these meetings have been organized with the endorsement of UN offices.

These meetings have been attended mostly if not exclusively by scientists and engineers.

In previous Erice Seminars these problems have been presented to a wider audience, but we need to make some steps forward.