SSA NEO Segment Operation, Maintenance and Enhancement

P2-NEO-I

The Near-Earth Asteroid Risk Communication Days Report

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1.1. Introduction

No question that the Chelyabinsk superbolide event of 15 Feb 2013 has clearly demonstrated that communication skills must be part of the background of those involved in the frontline of NEO impact monitoring activities. Whether addressing the scientific and/or technological community, the journalists and the press or the public at large, communication plays a crucial role in order to guarantee the correctness of information and to avoid the spreading of unjustified alarms. Keeping the tax payers always aware of the latest achievements in NEO impact monitoring is also essential in sustaining the governmental programs devoted to the asteroid hazard.

Therefore within the framework of the NEO Segment of ESA's Space Situational Awareness (SSA) Programme, and in particular of the operations of the NEO Coordination Centre established at ESRIN (Frascati, Italy), a 2-day Risk Communication event was organized.

The audience was not limited to ESA personnel but was open to the participation of professionals in many fields of study where risk communication to the public plays a deciding role (e.g. geophysics) and to media experts in science communication (e.g. journalists, writers).The meeting, which took place on 20 and 21 October 2015 at ESRIN, has recorded a lively participation leading to extremely interesting debates. In what follows a summary of the various presentations (listed in Section 1.5.3) is given (Section 1.2). Detailed study cases are discussed in Section 1.3: they include those presented at the meeting as well as some selected events which happened in the time span between the meeting (October 2015) and the writing of this report (October 2016). In this way it is possible to show how the guidelines developed at the meeting were applied during NEOCC operations (e.g. the "no-reaction" attitude on the alleged first person killed by a meteorite described in detail in Section 1.3.4). The outcome of the Q&A, wrap-up and recommendations sessions is reported in Section 1.4, to be considered as a work-in-progress list of topics which deserve further attention.

A final section (1.5) devoted to all kinds of references suggested throughout the meeting is also provided.

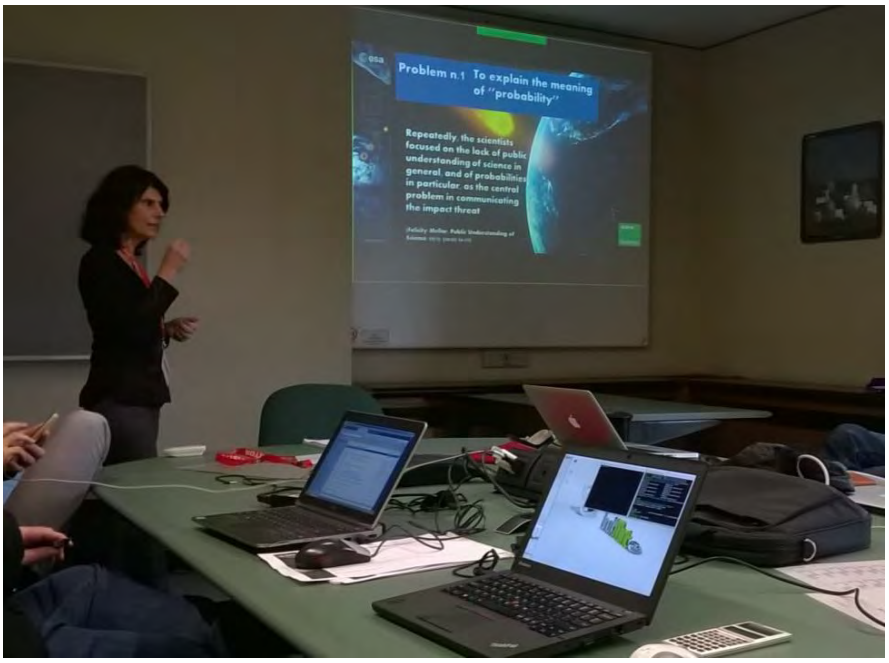

Figure 1 – ANSA journalist Enrica Battifoglia addresses a fundamental issue in risk communication during the meeting.

1.1.1. Participants

The aim of the meeting was to foster the interaction among participants coming from different institutions, working in various fields of study and in different contexts. Therefore a selected audience was invited belonging to governmental institutions (INGV – Istituto Nazionale di Geofisica e Vulcanologia, ENEA – Ente Nazionale Energie Alternative), research institutions and initiatives (INAF – Istituto Nazionale di Astrofisica, the Sapienza University of Rome, the Astronet Network, the EC-funded NEOShield project) and to the aerospace industry (Airbus, Deimos Space, Spacedys). Journalists and science educators either freelance or working for major editorial groups (ANSA - the Italan press agency, The Guardian, ESA Communication Office, Rome Planetarium) completed the audience.

On-site

Alessandro Amato (INGV)
Valeria Andreoni (ESA)
Philippe Bally (ESA)
Enrica Battifoglia (ANSA)
Silvia Bencivelli (freelence journalist)
Andrea Cerase (Università Sapienza Roma)
Matteo Cortese (Deimos Space)
Marta Ceccaroni (Astronet Network)
Paolo Clemente (ENEA)
Paolo D'Angelo (freelance journalist)
Gerhard Drolshagen (ESA)
Stuart Clark (freelance journalist)
Laura Faggioli (ESA NEOCC)
Stefano Giovanardi (Planetario di Roma)
Franca Morgia (ESA)
Erica Rolfe (ESA)
Detlef Koschny (ESA)
Marco Micheli (ESA NEOCC)
Ettore Perozzi (ESA NEOCC)
Daniel Scuka (ESA)
Giovanni Valsecchi (INAF)
Anna Violato (ESA)

Remotely connected

Fabrizio Bernardi (SpaceDys)
Andrea Chessa (SpaceDys)
Alessio Del Vigna (SpaceDys)
Gianpiero Di Girolamo (ESA ESOC)
Linda Di Mare (SpaceDys)
Albert Falke (Airbus Industries)
Pal Hvistendahl (ESA HQ)
Alice Rischer (NEOshield Project)
Federica Spoto (SpaceDys)

1.1.2. Program

The program was designed in order to fulfil two different needs: offering the opportunity to NEO experts to explain the intricacies of the NEO hazard problem and to the media representatives to let the scientists be aware of basic communication principles and of what characterizes the daily work in an editorial environment. Thus the resulting program has been divided into thematic sessions as follows:

DAY 1

Welcome to the SSA-NEO Coordination Centre

into the asteroid hazard

- NEO Segment: an introduction (D. Koschny, G. Drolshagen, ESA)
- How we started (G.B. Valsecchi, INAF)

hazard and the institutions

- Problems in science and risk communication for earthquakes (Alessandro Amato, INGV)
- Prevention and information: a challenge for civil engineering (Paolo Clemente, ENEA)
- The International Charter initiative (Philippe Bally, ESA)
- The EC NEOShield-2 project overview and public awareness activities (Albert Falke, Alice Rischer, Airbus Industries)

DAY 2

Something the air

- Communicating risk: bigging up or dumbing down? (Stuart Clark)
- ESA risk communication plans (Daniel Scuka, ESA)
- The ANSA Science experience (Enrica Battifoglia, ANSA)
- Asteroids at the Rome Planetarium (Stafano Giovanardi, Zetema)
- Freelance journalists contributions (Silvia Bencivelli, Paolo D'Angelo)

Near-Earth asteroid case studies (E. Perozzi, M. Micheli)

Toward a NEO risk communication plan

- Q&A
- Wrap up and recommendations

ESA internal NEO Risk Communication meeting

1.2. Overview

In the following sections the contents of the presentations displayed and discussed in the various sessions of the meeting are summarized.

1.2.1. Into the asteroid hazard

Modern impact monitoring systems were born out of a "media storm". On 11 March 1998 a circular from the Minor Planet Centre claimed that near-Earth asteroid 1997 XF11 would undergo a close encounter with the Earth on 26 October 2028 mentioning that the possibility of an impact, although unlikely, could not be ruled out. The turmoil caused by this statement was worsened by a press release in which with genuine scientific interest it was stated that the object would be visible by the naked eye. Eventually it was realized that the methods available at the time for evaluating the asteroid hazard could not allow such strong statements to be made or dismissed, let alone communicated to the public. This clearly appears from the the reports on the 1197 XF11 affair by C.R. Chapman and B.G. Marsden – then director of the Minor Planet Centre (Section1.5.2).

In his presentation G.B. Valsecchi gave a detailed account on how this event has led the scientific community to realize that a systematic approach in a controlled environment was needed to properly and timely evaluate the hazard associated to every object belonging to the near-Earth asteroid population. This eventually led to the birth, at the very beginning of the new millennium, of the two major NEO impact monitoring systems: *NEODyS/Clomon* at the Department of Mathematics of the University of Pisa (Italy) and *Sentry* at JPL (California, USA).

Basics on the celestial mechanics underlying NEO impact monitoring techniques were also given in order to grasp the intricacies of orbit determination, uncertainty propagation and peculiar geometries such as the "target plane" and the "keyholes" theory. The successful application of this approach to the cases of asteroid 1999 AN10 and Apophis (the most severe potential threat occurred to date) are then discussed covering both, technical and communication aspects.

Within this framework the European Space Agency has started in 2008 the Space Situational Awareness (SSA) programme, whose aim is "to support the European independent utilisation of and access to space for research or services, through providing timely and quality data, information, services and knowledge regarding the environment, the threats and the sustainable exploitation of the outer space surrounding our planet". The programme is divided into segments: SST (Space Surveillance and Tracking) addresses the problem of the space debris, SWE (Space Weather) deals with the consequences of the Solar activity on our planet and NEO (near-Earth Objects) focuses on the asteroid and comet hazard.

The ESA SSA_NEO Segment managers, D. Koschny and G. Drolshagen, have presented the status of the programme and the activities carried out at the NEO Coordination Centre, located at ESRIN and inaugurated on 22 May 2103.

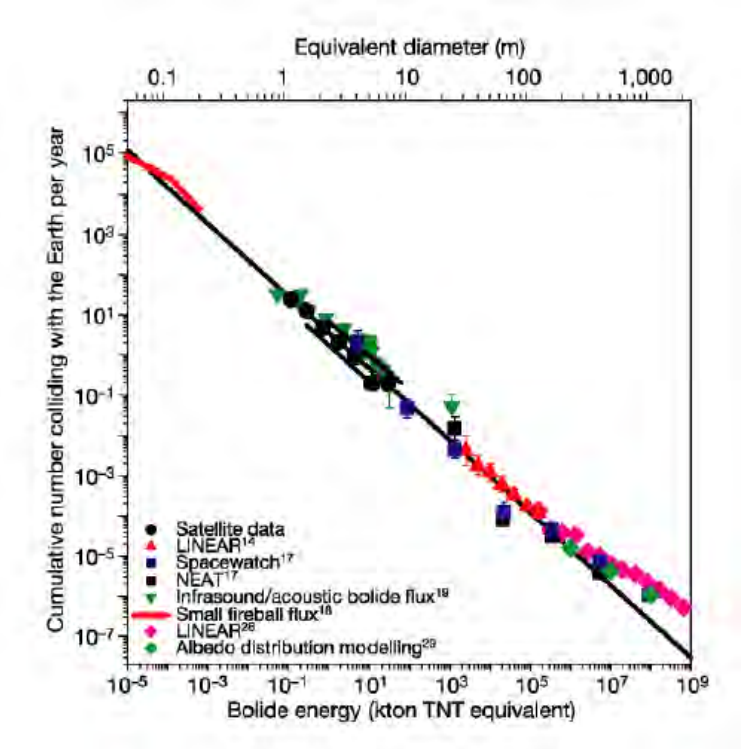

Figure 2 - The flux of interplanetary bodies impacting the Earth (from Brown et al. 2002).

The NEOCC services and operations have two major goals: to maintain a publicly accessible web portal (http://neo.ssa.esa.int/) displaying updated technical information on the NEO population, and to coordinate follow-up observations of potentially hazardous asteroids through a network of collaborating telescopes. The NEO portal is an evolving environment, the system performs daily updates in order to be always aligned with NEO discoveries (about 150 new objects per month) while new software tools and services are implemented on a regular basis.

The observational activity has proven to be particularly rewarding thanks to the onset of fruitful collaborations with institutional partners such as the ESA OGS (Optical Ground Station at Tenerife), ESO VLT (the European Southern Observatory Very Large Telescope) and having been granted access to INAF (National Institute of Astrophysics) facilities, which allowed to perform challenging observations of extremely faint objects. The Centre is also involved in data dissemination by participating to the ESRIN education and public outreach activities, and by issuing a monthly newsletter for keeping the NEO Segment users and stakeholders (from scientists to the public at large) up-to date with NEO-related infromation. The NEOCC operates in close connection with ESA Communication by publishing on the ESA portal and social media reports of interesting events and achievements e.g. when extremely close flybys occur or in connection with peculiar events such as the successful post-launch ExoMars 2016 ground-based observations.

The NEO Segment largely profits of the decade-long outstanding experience developed at the Department of Mathematics of the University of Pisa and at the INAF Institute of Space Astrophysics, where the first NEO impact monitoring SW system (NEODyS) was implemented.

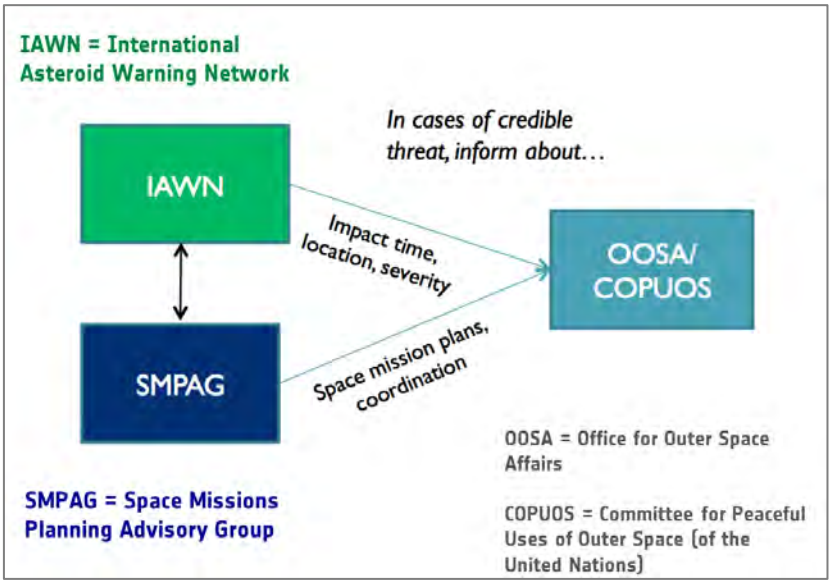

Figure 3 – The international committees responsible for the asteroid threat

The NEO Segment managers are also involved in the high-level decision process that is being set up at an international level to efficiently harmonize the approach to NEO hazard monitoring and establish a shared procedure should a threat become real, thus including communication aspects.

In particular IAWN (International Asteroid Warning Network) is composed by well-known NEO experts in order to " link together the institutions that are already performing many of the necessary functions including: discovering, monitoring and physically characterizing the potentially hazardous NEO population; maintaining an international authoritative clearing house for the receipt, acknowledgment and processing of all NEO observations; recommending policies regarding criteria and thresholds for notification of an emerging impact threat; and developing a strategy using well-defined communication plans and protocols to assist Governments in the analysis of impact consequences and in the planning of mitigation responses.". The purpose of SMPAG (Space Mission Planning Advisory Group' is "to prepare for an international response to a NEO threat through the exchange of information, development of options for collaborative research and mission opportunities, and to conduct NEO threat mitigation planning activities. As shown in the diagram of Figure 3, both committees act and coordinate under UN-mandate on behalf of the Committee on the Peaceful Uses of Outer Space.

1.2.2. Hazard and the institutions

There are several natural phenomena which present potential hazards for the citizens with a long-standing tradition in risk management and public communication. The possibility of closely interacting with representatives of the corresponding governmental institutions was one of the major goals of the meeting.

Being hosted in Italy, a highly seismic and volcanic region, an overview of the activities of risk management and communication carried out at INGV was mandatory. A. Amato has presented an assessment of the technical problems focussing on the difference between events which can

be forecasted (even on the short-term) such as the most energetic meteorological perturbations (e.g. hurricanes) and earthquakes and volcanoes which are not. The intrinsic low capability of forecasting earthquakes both in time and energy is a long-standing problem with non-trivial implications for science, public communication and the law. The study case of the L'Aquila earthquake, which occurred in central Italy, was discussed in detail (see Section 1.3.2) highlighting commonalities and differences with respect to the asteroid hazard.

In seismic and volcanic risk, prevention plays a crucial role and public awareness campaigns are essential in order to teach the population how to safely live in an hazardous area and be ready to properly respond to a "crisis".

The problems connected by a proper use of language, having to deal with conspiracy theorists (social amplification) and the legal aspects of the scientific knowledge have been discussed in detail by Andrea Cerase (Università Sapienza Roma) who also provided a useful list of references on the broad topic of risk communication (see Section 1.5.2.).

Whereas Earthquakes and Volcanoes rely mostly on the statistical processing of sometimes very long time series and the predictions are of a statistical nature, the statistics at the heart of the asteroid hazard can be significantly improved even in the very short term: observation campaigns and mitigation measures can score a 100% success (e.g. deflection missions) leading to a complete removal of the threat. Nevertheless many of the public communication aspects are common and a tight collaboration between INGV and ESA NEO Segment was envisaged for facing together future risk communication challenges.

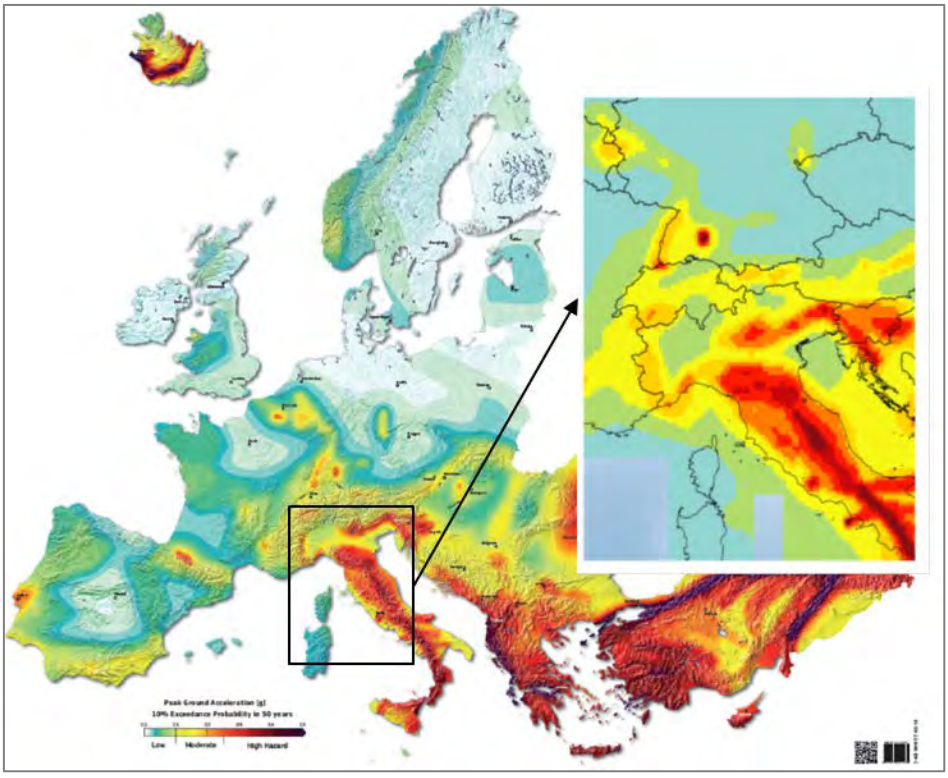

Figure 4 – The European seismic hazard map.

A major Italian governmental institution dealing with the potentially risky situations related to advanced technologies for energy production is ENEA (Agenzia Nazionale per le nuove

tecnologie, l'energia e per lo sviluppo economico sostenibile). The presentation by P. Clemente has provided an engineering approach to earthquake risk assessment by defining measurable quantities such as the "site hazard", the "vulnerability" of the structures and their "exposition". The advantages and drawbacks of the probabilistic vs deterministic approach to seismic hazard assessment were pointed out. The impact of codes and regulations on safety was also discussed as well as the "value" of safety in terms of market and sales. In particular the latter issue has brought an interesting insight into the aftermath of a disaster, which includes the way in which insurances are managed and how the citizens should be refunded and helped to repair the damages. A detailed prevention and public information activity is recommended by direct exposure of the citizens already at primary school level.

Figure 5 – Alert displayed on historical buildings waiting for anti-seismic treatment.

State-of-the art space technology can be fruitfully organized in an operational network for disaster response. In the presentation by P. Bailly the International Charter Initiative is described, whose aim is to create and maintain a unified system for sharing the high resolution images and the data coming from Earth Observation satellites in case of natural or man-made disasters. Due to the peculiar orbit configuration of Earth observation satellites (generally in polar sun-synchronous orbits) it is not possible to provide coverage of a given area on the Earth surface with short repetition times by using a single satellite. Therefore an international collaboration involving satellite owners and operators and belonging to different institutions, from space agencies to the private sector, has allowed to create a "virtual constellation" able to guarantee the rapid response times requested by disaster management. A 24h/7d control centre which is activated on short notice providing key information for disaster relief operations is available since a decade while affiliations are still growing.

Figure 6 – To date the Charter networks links more than 30 satellites

Back to NEO-related projects, an important step for fostering impact mitigation measures has been taken by the European Commission by funding the NEOShield-2 project, approved in the framework of the Horizon 2020 programme. Building on the previous NEOShield experience (an EC FP7 initiative), the objective of the project is twofold:

- to increase the number of NEAs for which physical characterization is available by focusing on objects in the 50-300 m size range and which are potentially accessible for a space mission;

- to compute realistic mission profiles to the near-Earth objects and work out a realistic scenario for a deflection mission in a real case.

A well designed web portal presenting the status of the project, including tools, plots, tables and generic information on NEO science, hazard and mitigation, has been made publicly available. Following the general EC guidelines for data dissemination, the participation to public outreach events and the production of educational material is highly encouraged, as pointed out by the presentation of A. Falke on behalf of the NEOShield-2 team.

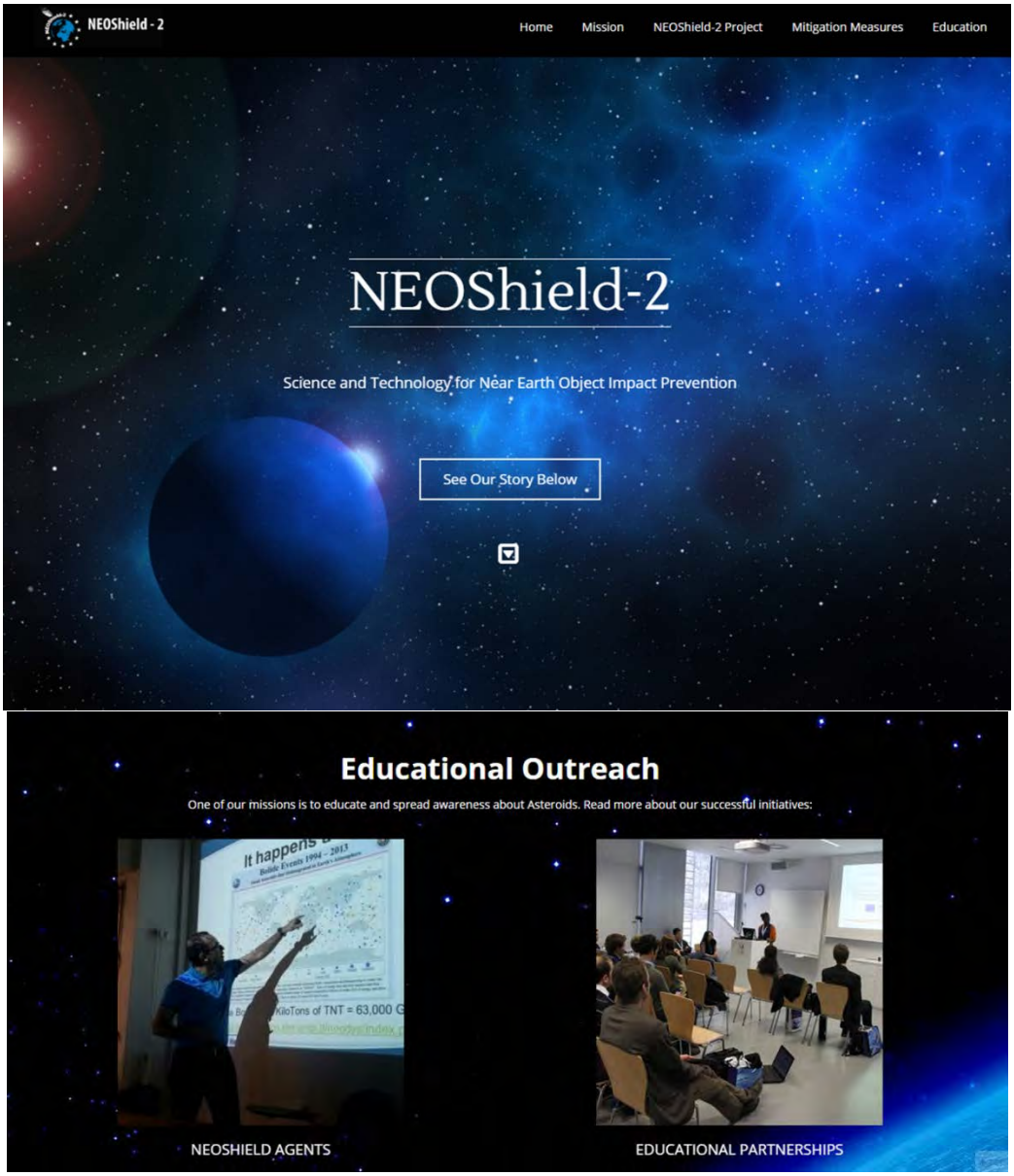

Figure 7 – The NEOShield web site and the outreach section

1.2.3. Something in the air

A whole session has been devoted to presentations by journalists, science writers and media specialist in order to understand the "operational" needs that rule their activities. In particular, as nicely summarized by S. Clark (freelance journalist and editor of The Guardian "Across the Universe editorial – see Figure 8) risk communication to the public is always swinging between two extreme attitudes: spinning up or cooling down a news item. Finding the right balance depends not only on the technical details of the specific event but also on the editorial environment. Pushing on the "wrong side" is not only a matter of infringing an ethical behaviour or a scientific truth but it may pose legal implications when disasters producing large damages and casualties are involved. As shown in Sections 1.3.1 and 1.4.3 one can lose

control of a story even if no incorrect statements are used either by the media or by the scientists, resulting in a wrong public perception of an event. If one adds further perturbations such as the time pressure, the existence of a "grey area" in the scientific knowledge (the subtle difference between "right" and "not wrong") and an audience always at risk of being fascinated by exotic (or worse, esoteric) theories, one gets a full picture of the complexity of the endeavour intrinsic to science communication and, specifically, of the NEO hazard. Language and the tone of communication plays also a crucial role in being correctly understood, entering in practice into all the case studies presented in section1.3.


Asteroids Across the universe

Asteroid 2013 TV135: doomsday again (yawn)

Asteroid 2013 TV135 has a 99.998% chance of missing Earth in 2032. Yet it's the 0.002% possibility that is capturing the headlines

An asteroid plunges towards the Earth. Relax. It (probably) won't happen. Illustration: Getty Images

Figure 8 – An entertaining yet informative news

The experience of the major Italian press agency (ANSA) in establishing in 2010 a web channel devoted to science and technology has been reported by E. Battifoglia. The attention was focussed on two key issues: how to use statistics and in particular the concept of "probability" and how to describe the subtle dynamics between certainty and uncertainty in science.

The contribution of several scientific journalists and writers is also acknowledged. Among them, Silvia Bencivelli gave a detailed account of the media reaction to the Chelyabinsk superbolide event and of her interaction with the NEO Coordination Centre (most of her considerations are included in Section 1.3.1). Stefano Giovanardi explained the initiatives planned for the first edition of the Asteroid Day and of the approach in public communication carried out at the Rome Planetarium.

Figure 9 – Flyer of the "Who is afraid of the Asteroid?" event at the Rome Planetarium

Daniel Scuka, from the ESA Communication office, has explained the Agency policy on risk communication and the way in which the inputs coming from the NEO Coordination Centre operations can be harmonized within it. A procedure has been established where the NEO Web Portal is responsible for publishing technical news on the asteroid hazard, which are then echoed on the Agency social media at various levels which, in turn, provide feedbacks to be answered by the NEO experts, thus closing the communication loop.

1.3. Case studies

Some specific cases presented during the meeting have attracted much of the discussion, and proved to be excellent testing ground for applying in real time what the audience was learning from each other's experience. Moreover in the time separating the NEO Risk Communication Days from the publication of this report, some peculiar NEO events have also happened, which could be relevant for risk communication and therefore have been included too.

1.3.1. The Chelyabinsk Black Swans

In his best-selling book "The Black Swan – the impact of the highly improbable", the economist and writer Nassim Nicolas Taleb refers to the methaphor of the Black Swan, used since ancient times to define an event so improbable that can be safely considered impossible. The discovery of black swans in Australia dismisses the saying and demonstrates that even highly improbable events do indeed happen.

The Chelyabinsk superbolide in itself cannot be considered a "Black Swan" as it falls well within the expectations: an asteroid in that size range (slightly less than 20 meters) would hit the Earth every few decades.

What makes the event exceptional from the point of view of risk communication are the circumstances surrounding the event i.e. an impressing series of low-probability occurrences, namely

1) the incoming direction: the object came from the sunward side of the celestial sphere thus escaping detection from ground-based surveys;
2) the parallel 2012 DA14 encounter: on the same night another asteroid (named 2012 DA14) was scoring the closest approach distance on record and, having been discovered one year before, it had been widely celebrated by the scientists and the media as a proof of our increasing ability to detect in advance potentially harmful objects;
3) the location: the most probable area on the Earth surface for a space object to fall is either the oceans (which occupy about 2/3 of the surface of our planet) or a scarcely inhabited region such as a desert (only about 15% of the land is actually populated). Therefore an event of this energy range is likely to go unnoticed or attracting only a scientific interest. Although Siberia is indeed a very large area with an extremely low population density, the superbolide exploded almost at the zenith of the 1.5 million people town of Chelyabinsk. The consequence is that all of the > 1000 injuries were not due to a direct hit by meteorite fragments but to the side-effects of the in-flight explosion. The delayed arrival of the shock wave caught most people unprepared e.g. standing close to windows which suddenly exploded;
4) the "dashcams" scenario: the citizens of Chelyabinsk are used to install on their cars surveillance cameras for safety reasons; therefore the fireball became by far the most documented event of this kind, more than any fireball professional network could have done; the social media channels contributed to the real-time spreding of images and videos of the event;
5) the impact location: usually searching for the meteorites associated to a fireball represents a real challenge, but in this case a large circular hole was clearly visible on the frozen surface of lake Chebarkul, a few miles north-west of town; the next spring a 500 kg meteorite was recovered from the waters;

6) the 1994 meeting: unlikely as it may sound, in 1994 Chelyabinsk hosted one of the first scientific meetings devoted to the asteroid hazard.

There are many implications out of this chain of consequences: as an example point 3) led the astronomers to struggle for avoiding that the two objects were identified as "one asteroid" and to explain why we knew a lot about 2012 DA14 and nothing of the other. The dangers of having been somehow over-reassuring (as introduced in Section 1.2.3) can be fully appreciated when knowing the legal troubles underwent by the members of the scientific commission in charge of evaluating the risks associated to the seismic swarm which eventually led to the L'Aquila earthquake (discussed in Section 1.3.2).

Figure 10 – A 10 million Italian TV audience was summoned on the asteroid hazard two days before the Chelyabinsk superbolide

Similar considerations can be done on the importance of the social media as an authoritative source of information and on the attention that must be paid in using dangerous wordings and figures when talking about cosmic impacts (to be discussed at length in Section 1.4.3).

It is worthwhile mentioning that an additional "Black Swan" was recorded in Italy. On the 13th of February during one of the most popular TV events (Festival della Canzone Italiana) a journalist known for his TV programs investigating alleged mysterious "happenings", was interviewed live on the risks associated to the 2012 DA14 forthcoming flyby (Figure 10). He correctly dismissed any danger, yet eventually claimed that "if an asteroid has been observed, then certainly it won't hit us; should an impact occur no-one will warn you: you'll know it from the bang!". Even if this sentence was clearly wrong, what happened two days later over Chelyabinsk apparently confirmed his statements giving him a "prophetic" aura.

1.3.2. The 2009 L'Aquila Earthquake Affair

On 6 April 2009 a devastating earthquake hit the town of L'Aquila, in the mountains of Central Italy. There were more than 300 casualties and as it often happens in these cases, the frequent occurrence of illegal or fraudulent behaviour in the construction or the consolidation of buildings according to anti-seismic criteria, was sadly found. But what makes L'Aquila a peculiar case for risk communication is the follow-on legal persecution of well-known scientists, as members of the "Commissione Grandi Rischi" (CGS - Commission on Wide Risks) acting

under the Italian government mandate, of the Civil Protection Department and of the National Institute of Geophysics and Vulcanology.

The CGS was involved well in advance of the 2009 April earthquake, as soon as a seismic swarm started to be detected in the L'Aquila region. The question whether to reassure or to warn the population has been crucial in the debate at court. From a technical point of view a seismic swarm gives no unique predictive clues: it can produce a slow release of the energy accumulated near a fault, thus avoiding it to be concentrated in a single shot, or either it is a sign that a fault system has been activated with no easily predictable consequences. This unavoidable uncertainty can easily give rise to pseudo-scientific claims of people maintaining of being able to predict earthquakes.

The legal action against the governmental experts brought initially to heavy condemnations (including conviction and monetary refunds) to all the 7 accused on the ground that an excess of reassuring statements having no technical justification, had convinced some of the victims not to leave their houses. In 2014 the Appeal Court has cleared 6 of them, eventually mitigating only the condemnation to the deputy director of the Civil Protection Department. Whatever the purely legal aspects of the affair, what clearly emerged from the debate was an extremely faulty approach to risk assessment and communication, in particular through the relationship with the media.

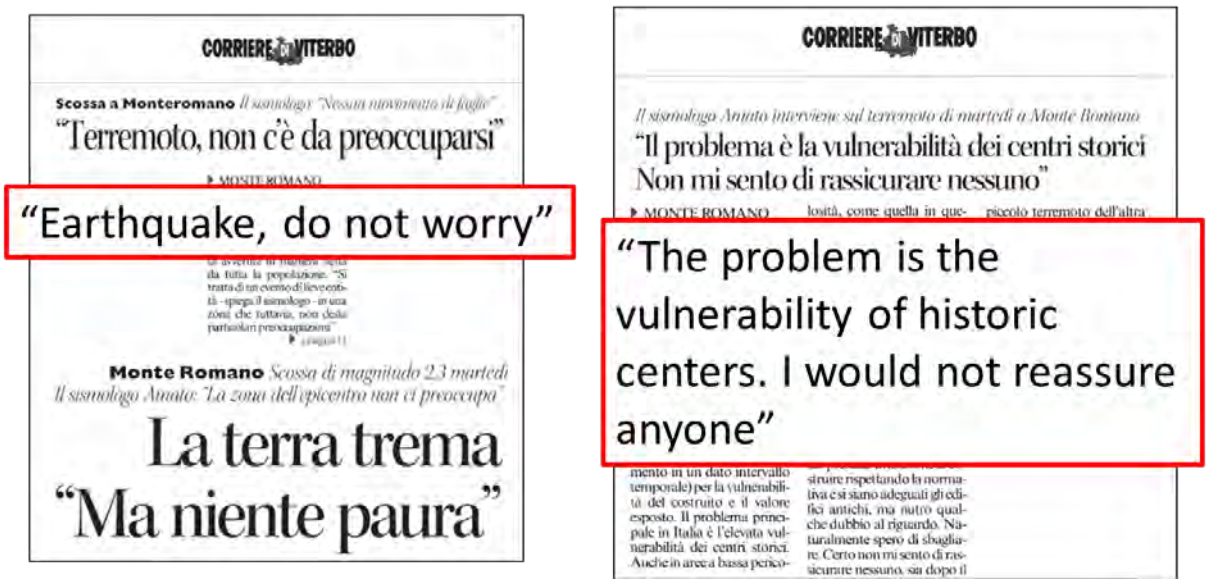

Figure 11 – Contradicting news appearing on the press one month before the L'Aquila earthquake

The technical details of such a complex affair involving technical, scientific and legal motivations can be found in the presentations by A. Amato and P. Clemente and in the References (Section 1.50). For what concerns NEOs, impressive similarities, even if at a much smaller scale, emerged in making comparisons with the public and media reaction after the Chelyabinsk strike. One of the basic questions that was kept on asking was why the scientists had been reassuring everyone the day before the strike that nothing would happen, and then something actually happened. Of course the answer is that the two events – the flyby and the fireball - were independent because they were caused by different and non-related objects: were the 2009 earthquake occurred in Siberia no-one would have charged the Italian scientists

of that. Yet in the public perception scientists are responsible of defending "Earth" from "Asteroids" and even admitting that we do know only a fraction of the NEO population was at risk of being very badly received.

The L'Aquila first degree verdict was issued in October 2012, only months before the Chelyabinsk fireball, the case was very much debated on the media and the Italian public awareness on disaster management was indeed very high. Should Chelyabinsk had been more energetic (due to a slightly larger size, or a steeper entry angle), it wouldn't have been easy to explain the difference.

1.3.3. A meteorite in Uruguay

An interesting news item came out in September 2015, reporting the fall of a meteorite in San Carlo, Uruguay. It is worthwhile reporting the whole text of the announcement as it is representative of the mixed feelings that a potentially threating event may rise.

METEORITE BROKE THROUGH A ROOF, A BED AND A TV LED IN SAN CARLOS, MALDONADO, URUGUAY

On September 19, 2015 a meteorite broke through the asbestos cement roof with a wooden suspended ceiling of a house in the city of San Carlos (Maldonado, Uruguay). It also broke a wooden frame bed and a TV Led.

On the night of Friday September 18, a couple of San Carlos was away from home. Their daughter usually uses the couple's double bed when they are out, but that night she decided to stay in her room. She slept at 2 AM on the 19th; the next morning she waked up surprised because of the sunlight coming from the roof of her parents' room. The surprise was even greater when she found that a rock broke through the asbestos cement roof with a wooden suspended ceiling, it also broke a wooden frame bed, until it rolled and stop beside the wall. The rock was dark with an unusual aspect, but she initially thought that someone stoned her house the night before. Her parents went back home immediately to evaluate the event and to repair the damages. After cleaning the pieces of asbestos cement and wood scattered in the room, they realized a new surprise: when they turned on the TV Led an estrange pattern emerged in the image, indicating that something had knocked it.

Afterwards, the family members started to speculate about the event. They considered that a rock thrown upwards could not impact at a velocity high enough to produce the observed damages. The hypothesis that the rock could come from space (a meteorite) was more promising. After googling about the topic, they found that there were Uruguayan scientists at the Department of Astronomy (Faculty of Sciences, Montevideo) working on asteroids and meteorites. The family sent an email to Gonzalo Tancredi with photos of the event. Tancredi, in collaboration with colleagues of the Institute of Geological Sciences, like Lic. Pablo Núñez, has been analyzing during the last decade more than twenty rocks provided by people from all over the country, suspected to be meteorites. None of the previous cases turned to be meteorites. But this new one presented characteristics typical of a rock coming from space:

- *It has a weak magnetism when a magnet is approached.*
- *It has a black crust all over the surface due to the high temperatures reached after entering the atmosphere at velocities over 11 km/s and the body is slowed down, producing the fusion of the rock.*
- *It presents thumbprint like impressions on the surface, known as regmaglypts, formed by ablation of material from the surface as a rock passes through the atmosphere.*

- *In another side, the fusion crust present a rough surface, known as elephant-like skin, which it is also characteristic of fresh meteorites.*
- *In the areas where the fusion crust peeled off due to the impact, the rock has a greyish color. In these zones, there are microfractures filled with dark material, corresponding to a fragmented structure like a breccia.*
- *The rock is heavier than a terrestrial rock of similar size, implying a higher density. A density of 3.4gr/cm^3 was obtained, a value higher than most of the terrestrial rocks.*

The family gave the rock to the Faculty of Sciences for analysis. ***It was confirmed to be the FIRST URUGUAYAN METEORITE. In addition, it is one of the few registered cases where a meteorite broke a roof (less than 15 cases worldwide in the last 100 years) and the first time that an impact destroys an electronic device like a TV.***

Based on the studies made in the Faculty of Sciences and with the collaboration of international colleagues, the meteorite is initially classified as a stony breccia. The rock weights 712 gr. We are conducting new studies to determine the chemical composition and petrologic type for the classification and registration. We suppose the rock was part of a larger one that fragmented in the atmosphere. Therefore, it is very plausible that there is other fragments scattered in the area of San Carlos. We have been looking for them without success yet.

What makes these news worth analysis is the perfect balancing between the tone of the communication and its content. The opening recalls the "incipit" of a short novel, catching the reader to know more of it. The actual danger of being hit by a meteorite is not hidden but kept in the background (it is clear that if the daughter would have followed her habits she would be hit by the 1 kg meteorite suffering at least bad injuries) thus contributing to positively dramatize the account. The scientific content is detailed and sound exhaustively explaining the origin, composition, and dynamics of a meteorite fall. The "citizen science" contribution is given proper credit: instead of displaying the meteorite under a glass cage at home the family has called the astronomers thus allowing the precious sample to be properly analysed. Finally, the enthusiasm of the discovery, the leading force of science, is kept intact: the writer is proud to announce that what happened has given Uruguay two "firsts": local (first time that a meteorite is recovered within the national borders) and worldwide (first time that a TV set is hit by a space rock). The story represents a good piece of science storytelling on a potentially threatening event.

1.3.4. The Indian bus-driver accident

On 8 February 2016 news spread that for the first time a human being was killed by a meteorite. The reports, originated in a Indian region, claimed that as a consequence of a cosmic impact, a meteoritic fragment pierced the windscreen of a bus hitting the driver to death. The SSA-NEO Coordination Centre received requests of confirmation from all kind of sources, internal to ESA, from the scientific community, the journalists and the public. At a first glance the source of the information appeared reliable (The Times of India) and the news quickly received attention by many major newspapers worldwide. The Indian authorities supported the meteorite hypothesis and went as far as collecting "samples" for scientific analysis. On 9 September very sceptical comments started to appear on the MPML – Minor Planet Mailing List – which links asteroidal experts. It is worthwhile quoting an authoritative posting:

> True?

Unlikely

> Thoughts on this?

No widespread reports of bolide in the sky, sonic booms, etc., just a local explosion and hole in the ground (cf., Peekskill meteorite, which "killed" a car on the ground but was witnessed in the sky by thousands). 11 g "meteorite" looks an awful like the red rocks dug out of the hole in the ground (photo in another news story), suggests the fatality was caused by a flying bit of debris, not a piece of a meteorite. I expect more likely an explosion from some other (possibly illicit) cause that threw enough debris to injure some close bystanders. Blaming a meteorite sounds a bit like "the dog ate my homework".

By the end of the day the possibility that the accident were caused by a dynamite explosion triggered by a small fire gained ground in the Indian Police reports and a in a couple of days the whole story faded away.

The ESA NEO Team decided to follow a low profile approach: ESA communicated that it is unlikely that this was a meteoroid impact.. It is interesting to note that, even if no-one from the NEO community was seriously believing it, a position stronger than "unlikely" would have been inappropriate knowing the statistics associated to the asteroid hazard, and this motivates the need of avoiding risky official statements. Moreover it is also worth mentioning that even within the astronomical community the news gained good ground for some time, demonstrating how focussed are the technical competences in modern science. Risk communication should also consider to properly address an audience having a scientific/technical background.

1.3.5. Asteroid PDC 2015

It is customary for the Planetary Defense Conferences (PDC) to organize "Impact Exercises" during their bi-annual meetings. The audience is split into groups representing different communities (e.g. politicians, civil protection, the public, journalists etc.). An impact scenario is then presented and every day new information is injected thus making the situation evolve.

The 2015 PDC hosted at ESRIN in April 2015 was no exception and an interesting simulation of an impact in 2022 near Dahka, capital of Bangladesh, was carried out. The outcome allowed a better understanding of the complexity of coordinating and implementing a mitigation plan in a region characterized by extreme poverty and social and religious attitudes completely different from those of the western civilization.

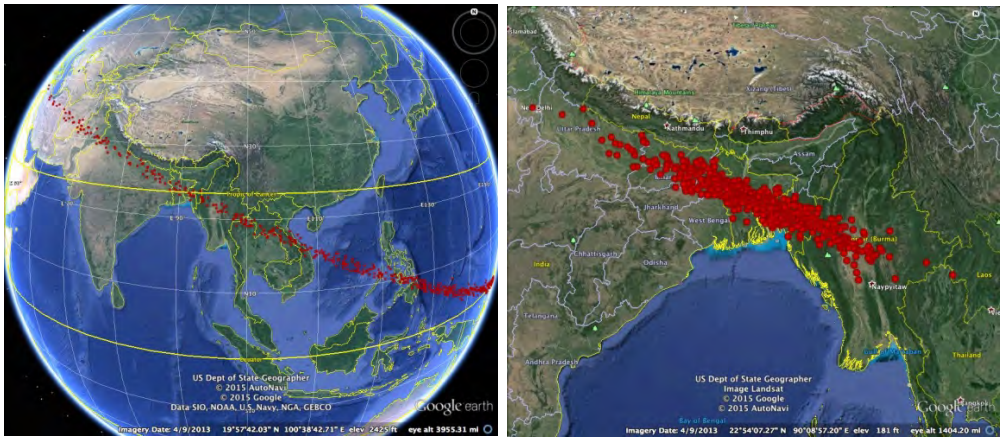

Figure 12 – The impact corridor of the fictitious asteroid dubbed 2015 PDC.

All material used for the impact exercise has been published on the net and it is still available (Section 1.5.3). It includes all sort of "disaster" maps, including plots of the impact corridors and reports of the destructions foreseen in the interested areas. The fact that to date none of this freely available "sensitive" material has been used for the usual "doomsday" announcements clashes with the media storms often caused by a simple, scientifically correct, but may be too naïve wording on the asteroid threat.

1.4. Lessons Learnt and recommendations

The NEO Risk Communication Days have indeed met their primary goal: to allow an open discussion and foster the exchange of methods and experiences among the participants. In what follows some of the subjects which deserved special attention are treated in more detail, together with a short list of recommendations.

1.4.1. Newsletters

A newsletter is the basic means for providing to a wide audience an authoritative source of information. This suits at best to the NEO Segment because of the wide variety of SSA users and stakeholders: the scientific community, governmental institutions, commercial partners, the public and the press. In this respect an acknowledgment is due to the pioneering effort of the Spaceguard Foundation, which edited for many years the on-line journal "Tumbling Stone" (still available, see Section 1.5.3) devoted to asteroid science and mitigation. Therefore since April 2015 the NEO Coordination Centre publishes a monthly newsletter summarizing the status and the achievements of NEO impact monitoring activities. The newsletter makes use of a plain language for easing comprehension (Figure 13). In September 2016 the Minor Planet Centre has started the publication of the "Daily Minor Planet" which recalls both in the title and in the captivating graphics the super-heroes cartoons (Figure 13).

Figure 13 – The NEO Coordination Centre monthly newsletter and the Daily Minor Planet layouts

1.4.2. On risk scales

A striking similarity between the earthquake and the asteroid hazards is the definition and the use of risk scales. They can be a powerful means for helping people to learn how to respond to a threat without knowing any technical detail as well as to help scientists to use an appropriate metrics for measuring the intensity of a phenomenon and its consequences.

There is also a remarkable parallel evolution in the historical and technical background characterizing the adopted scales in both cases. For earthquakes the value of the *Mercalli* scale depends upon the level of destruction recorded, thus being highly dependent on the location and on the logistics (e.g. population density, old buildings, fragile ecosystems etc) – whereas

the *Richter* scale is logarithmic and provides an estimate of the energy of the seismic waves. NEO risk scales have followed a similar pattern: the *Torino* scale was adopted in 1999 essentially for correctly communicating the potential disasters that a given object could produce using color-coded risk levels; the *Palermo* scale is intended as a working tool for astronomers to quickly identify among the growing number of NEOs discovered each night, those who are in more urgent need of being monitored.

In this respect the recent occurrence of another strong earthquake in Central Italy has shown how risk scales can have nontrivial implications for risk management. On the night of 24 August 2016 a sudden earthquake destroyed the historical town of Amatrice, some 150 km north-east of Rome and other neighbouring small towns, causing many victims. In the days following the disaster on the internet appeared several claims maintaining that INGV had lowered on purpose the earthquake magnitude from 6.2 to 6.0 (Richter scale) in order to allow the government not to refund the damages to the citizens. According to these claims the Italian law sets the threshold for refunding to 6.1 Richter. The news escalated until INGV was forced to issue an official statement to support the most important Italian newspapers to help dismissing the claim (Figure 14).

Figure 14 - La Stampa, 26 August 2016

Within this framework it is worth noting that dismissing the claim was not trivial at all: the original information was actually true. A law had been submitted to the Italian parliament in 2012, but during the follow-on discussion the 6.1 threshold was eventually dropped. It also turned out that the US geological survey reported a 6.2 magnitude on his web site while at INGV the displayed value was 6.0 (Figure 15). In his official statement INGV explains that the reason is in the different algorithms underlying the Richter scale with which the numbers are extracted from the seismic signal - but this is a technical consideration that implies some scientific knowledge to be fully understood. A certain confusion arose also between the Mercalli and Richter scales, which were misleadingly mentioned in the articles.

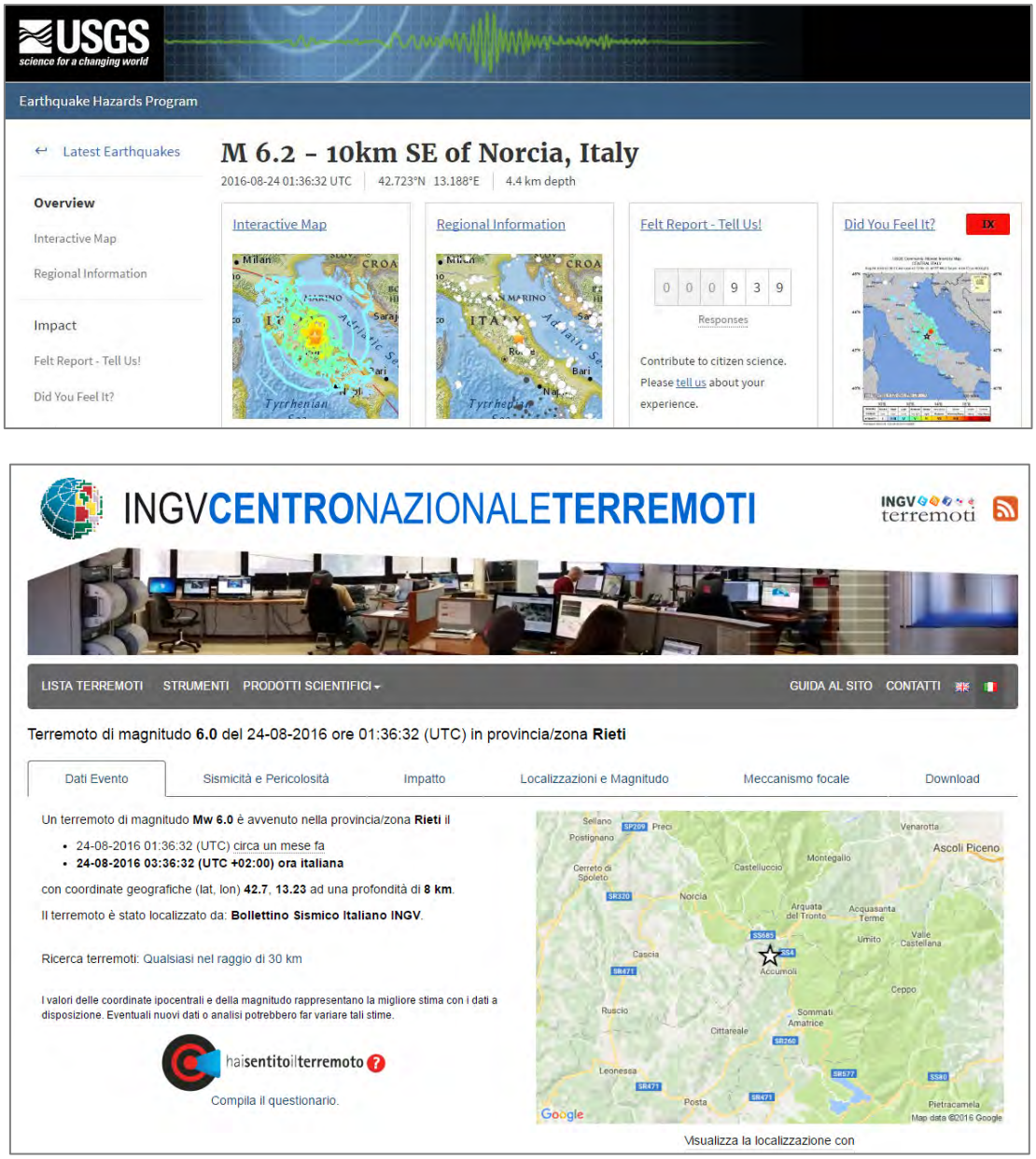

Figure 15 – Comparison between the USGS and the INGV web sites

1.4.3. Probability and all that

A long and interesting discussion has been devoted to how to deal with statistics and probabilities, acknowledging that numbers and percentages once outside the everyday life experience may become meaningless. As an example, the claim that a meteor strike is the most probable cause of death for living creatures, although correct on a geological time scale (ask the dinos!), has no meaning for the average length of a lifetime. To date no humans have been killed by a cosmic strike (see also Section 1.3.4).

Therefore finding appropriate analogies with well-known events surely helps especially when numbers get very small, as in the case of the chances that an asteroid whose orbit is intersecting that of the Earth actually hits our planet, which is of the order of 10^{-5}.

In this respect a possible approach more likely for educational purposes, is to show "how to compute the impact probability with a pocket calculator". This can be done considering that the Earth occupies anytime a segment of its orbital path the full length of its diameter (of the order of 10^4 km); dividing this quantity by the length of the Earth's orbit (10^9 km, assumed circular with radius 1 AU) one obtains a realistic estimate of the chances of hitting the "Earth segment" using a static scenario easier to grasp than even basic celestial mechanics.

The analogy can be brought forwardcomparing the orbital motion of our planet to that of a train repeating its path once per year. From the orbital velocity of the Earth (29 km/s) and from her diameter it can be computed that at an imaginary "crossing" you would have to wait about seven minutes before the green light is given. By recalling a common driving experience, it is easier to understand that crossing the tracks would be dangerous only during a tiny fraction of a day in a whole year time span thus giving a better feeling on the way in which small numbers may (or rather, may not) affect your life.

1.4.4. Communication problems

It is never completely clear how and when an apparently harmless sentence or wording on the asteroid hazard starts escalating toward a false and misleading announcement. Since when NASA was accused of having never flown astronauts to the Moon, providing sound arguments and proofs against false statements has been generally considered useless. Yet also silence is liable of misinterpretations and can be of no help for risk communication. It is also true that scientists and experts, being too much used to technical jargon, tend to forget that communicating with the media and the public requires a completely different attitude and to develop specific skills.

A striking example of this kind is represented by the troubles that NEO experts encountered when appearing on post-Chelyabinsk TV programs. The supposedly reassuring announcement that 95% of NEOs larger than 1 km (i.e. those which are likely to cause a global catastrophe) have been discovered by the astronomers, quickly turned into having to answer that no, we do not know where the remaining 5% is and that yes, it cannot be 100% excluded that one of them may collide with the Earth out of nowhere, as just happened at Chelyabinsk.

When it was computed that asteroid 2016 RB1 would have scored a very close flyby on 7 September 2016 a journalist promptly called the NEOCC. During the telephone conversation the journalist was asked how he got so quickly the news and why he was interested in a relatively ordinary event for an NEO. The answer was that a tweet from MPC was the source and that a well-known scientific writer announced the encounter on his blog using the word "disturbing" (*inquietante*) when remarking that the object had been discovered "only" 24 hours before closest approach. No wonder then: how many serious scientific journalists, that in aday's work are supposed to write about subjects as different as molecular biology, cosmology and robotics, may know that 10m sized asteroids have been passing within the distance of the Moon all the time and that until a few years ago we did not worry just because we simply were not able to see them? In this case a major achievement for a scientist turned easily into a disturbing "only" even for a competent journalist..

Reporting the 2016 RB1 flyby highlights also the game-changing attitude that the social media have introduced in communication as primary sources of authoritative information and as real-time feedback providers. When the news appeared on the ESA social media channels, the

"cottage-size asteroid" wording got enough *likes* to trigger a backstory on ESA's Rocket Science blog eventually leading to link up Jane Austen and the asteroids (Section 1.5.2)

The following example shows instead when a detailed reply does not help to improve communication at all.

Mail received at NEOCC public account

Hi my name is X. It's been floating around that in the next few days their are asteroids on a collision course with earth is it true

Our reply#1

Hello X, thanks for contacting the NEOCC with your question. Fortunately, the news about an imminent asteroid impact that circulated in the past few days is fake, there is no scientific basis to it and no evidence that any asteroid is about to impact our planet.

On our website http://neo.ssa.esa.int/ we provide information on all known asteroids that can impact the Earth in the future (http://neo.ssa.esa.int/web/guest/risk-page). As you can see, there is none with possible impacts this month.

We also issue a monthly newsletter where we discuss various topics related to dangerous asteroids; the next one will briefly discuss these fake news. Let us know if you want to subscribe to it. Thanks for your interest,

A few days later, 3 mails in a row within 24 hours

Hi just wondering if their is any neo going to collide with earth anytime soon

Hi their had been a lot of talk about asteroids going to hit earth with in the next few years . If like to know if we are in any danger of anything going to hit eart soon or in the next 40 or 50 years have we anything to worry about thanks

Hi all this talk about asteroids and comet and meteors are we at risk anytime soon or the foreseeable future. I was looking at the neo table their is some in the risk and some in the priority list could any of them hit or will they definitely miss. And is their anything to protect our planet from these things. Thanks for replying to my e mails I've young kids and they keep asking me about these and I want to put them at ease

Our reply#2

Hi X,

I think you can reassure your kids, as of today none of the known asteroids or comets is certain to hit the Earth in the future. The objects you see in our Risk List are those for which we are not yet 100% sure they will miss, but the probability they will hit is very very small, as you can see in the Impact Probability (IP) column of the table.

New asteroids are still being discovered, and we monitor each of them to make sure none will hit in the future. Discovering them and observing them is right now the best thing we can do to make sure we are prepared if one comes in the future.

Our website is kept updated with all the information we have, and we've also added your e-mail to our monthly newsletter, where we inform the public on any recent update on dangerous asteroids. Thanks again for your interest!

Almost immediate answer

thanks a million for replying to me :-)

but last week…

Hi Why everytime u go on social media or listen to the new you here things like nasa has confirmed a huge asteroid is on its way to earth.

No further replies from our side ended the conversation

As witnessed by these examples there is definitely no simple solution for a successful communication; nevertheless the guidelines drawn by S. Clark in his presentation represent a good starting point:

- Be honest
- Be concise
- Don't caveat statements
- Refer to tangibles: our data suggests… / our analysis shows
- Use statistical analogies where possible

1.4.5. Best of …

A collection of discussion items gathered during the meeting is reported below.

- In general, a cautious approach (up to a no-reaction attitude) appears to be more rewarding in counteracting false statements, which often are likely to disappear by their own;
- Never forget that providing details in dismissing a fake news is likely to provide also additional ground for strengthen it;
- A suggestion for improving impact simulation exercises: why not using "true" roles? (i.e. real civil protection officers, journalists etc.)
- Impact corridors will be more and more available but possibly not publicly disseminated: how to deal with semi-public information without feeding conspiracy theories?
- Learning how to deal with probability (e.g. seismic events,virtual impactors) and certainty (nuclear accidents, impacts) means moving from risk communication to crisis communication.
- Is there the need of better energy and risk scales?
- Is it possible to avoid using probabilities?
- Be prepared at private institutions entering the risk business (e.g. nuclear, asteroid mining)
- Is it really an advantage to try to be more "understandable" to the public at large or is it more liable of misunderstandings?
- Should the fictional movie approach provided by "Disaster Playground" and "Ambition" (described in Section 1.5.4) be further developed?
- It could be useful to compile and share a dictionary of "forbidden words" for risk communication (e.g. lost, fear, death etc)

- There is the need for a broader definition of "risk communication".
- Different media need different communication "tones".
- How good is a low-profile approach?
- Too technical, too short, too informative: establish a common news publication procedure (from preparation to approval)
- Investigate further the synergies between earthquake and asteroid hazards (e.g. table below) for the commonalities emerged in risk communication.

DISCOVERING	MONITORING	PREDICTING	CERTAINTY	MITIGATING
the seismicity of a region	Network of sensors (e.g. seismographs)	Probability of an Earthquake (e.g. seismic swarms)	-	Information Prevention Evacuation
a new near-Earth Asteroid	Network of sensors (e.g. telescopes)	Impact probability (e.g. virtual asteroids)	Impact corridors	Information Evacuation Deflection

1.5. References

Selected readings, links and multimedia text are reported below for keeping alive the discussions started at the NEO Risk Communication Days and for for tracing back the original articles quoted in the present report.

Figure 16 – Books devoted to risk communication and to the asteroid hazard

1.5.1. Presentations

How we started to deal with our sometimes inconvenient celestial neighbours. Giovanni. B. Valsecchi IAPS-INAF, Roma, ItalyIFAC-CNR, Sesto Fiorentino, Italy**.**

ESA's SSA-NEO Segment Overview. Gerhard Drolshagen, Detlef Koschny (ESA), SSA-NEO Segment Managers

Problems in science and risk communication for earthquakes - Alessandro Amato (INGV) with Andrea Cerase (Sapienza University of Rome).

Basic readings in risk communication: a selected bibliography to introduce themes, methods and topics. Andrea Cerase, PhD.

Prevention and information: a challenge for civil engineering. Paolo Clemente, PhD ENEA Research Director.

International Charter 'Space and Major Disasters'. Space technology in support of disaster response. Philippe Bally, ESA.

Communicating risk: bigging up or dumbing down? Stuart Clark, freelance journalist.

An Asteroid is coming… the ANSA Scienza e Tecnica experience. Enrica Battifoglia, ANSA.

Risk communication case studies. Ettore Perozzi, Marco Micheli, SSA-NEO Coordination Centre.

1.5.2. Readings

236 years ago... Giovanni B. Valsecchi. In proc 'Near Earth Objects, our celestial neighbours': opportunity and risk. A. Milani, G. B. Valsecchi, D. Vokrohulicky eds, IAU doi: 10.1017/S1743921307002980, 2007.
https://www.cambridge.org/core/services/aop-cambridge-core/content/view/S1743921307002980

The Asteroid Impact Scare of Mid-March 1998. By Clark R. Chapman, April 1998.
http://www.boulder.swri.edu/clark/fx11.html

1997 XF11 – the true story. By Brian G. Marsden, J. Brit. Astron. Assoc. 109, 1 ,1999.
https://www.britastro.org/journal_old/archive/marsden.htm

Pioggia di meteoriti su Giacobbo, e anche su di me. L'astronomia del rischio. By Silvia Bencivelli, February 2013.
https://silviabencivelli.wordpress.com/2013/02/

Meteorite of San Carlos, Uruguay
https://www.facebook.com/Meteorite-of-San-Carlos-Uruguay-806171216159189/

Meteorite explosion killed Vellore college bus driver, Tamil Nadu government says.
http://timesofindia.indiatimes.com/india/Meteorite-explosion-killed-Vellore-college-bus-driver-Tamil-Nadu-government-says/articleshow/50889270.cms
http://gulfnews.com/news/offbeat/meteorite-kills-man-in-south-india-authorities-say-1.1668619

The backstory: an asteroid over Antarctica. ESA Rocket Science blog, September 2016.
http://blogs.esa.int/rocketscience/2016/09/09/the-backstory-an-asteroid-over-antarctica/

Exomars spotted in space.
http://www.esa.int/spaceinimages/Images/2016/03/Spotted_in_space

On the Title of Moriarty's Dynamics of an Asteroid. Alejandro Jenkins, Escuela de Fısica, Universidad de Costa Rica, 11501-2060,
http://arxiv.org/abs/1302.5855v2

1.5.3. Links

http://neo.ssa.esa.int

http://neo.jpl.nasa.gov/

http://newton.dm.unipi.it/neodys/

http://iawn.net/

http://www.cosmos.esa.int/web/smpag

https://www.theguardian.com/science/across-the-universe

http://www.ansa.it/scienza/

http://www.saperescienza.it/

http://cosmictusk.com/tick-tock-goes-the-clock-anderson-cooper-nails-nasa-on-60-minutes/

http://neo.jpl.nasa.gov/pdc15/

http://spaceguard.iaps.inaf.it/tumblingstone/main.htm

http://www.spacedaily.com/reports/Introducing_the_Daily_Minor_Planet_Delivering_the_Latest_Asteroid_News_999.html

1.5.4. Movies

For a remarkable coincidence the movies *Armagheddon* and *Deep Impact* came out just months away from the 1997 XF11 incident and may well have contributed to raise public awareness (and consequently funding) on NEO monitoring activities. As a matter of fact since then the asteroid threat has been often referred to in the movies – recent examples are the happy ending of *Men in Black III* and the last episode of the *Ice Age* saga.

At the same time fictional movies such as *Disaster Playground* and *Ambition* (an ESA production on Rosetta science) have been realized using more realistic and science-driven plots. In *Disaster Playground* NEO experts play their own role, while in *Ambition* the actors from the celebrated *Game of Thrones* TV series have been involved.

Ambition

http://www.esa.int/spaceinvideos/Videos/2014/10/Ambition_the_film,

Distaster playground

http://disasterplayground.com/

Men in Black III (ending)

https://www.youtube.com/watch?v=fzEIHRbLotA

Ice Age: Collision Course (trailer)

https://www.youtube.com/watch?v=Ohq6NmKMja8

1.5.5. Quotations

Is he not the celebrated author of The Dynamics of an Asteroid, a book which ascends to such rarefied heights of pure mathematics that it is said that there was no man in the scientific press capable of criticizing it?

A.Conan Dyle - Sherlock Holmes, The Valley of Fear

Without leaving your Lisbon subject, concede, for example, that it was hardly Nature that there brought together twenty-thousand houses of six or seven stories. If the residents of this large city had been more evenly dispersed and less densely housed, the losses would have been fewer or perhaps none at all.

Rousseau's Letter to Voltaire Regarding the Poem on the Lisbon Earthquake, August 18, 1756

The question for the media coverage of risk is not so much whether reporting emphasises certainty or uncertainty but how precisely the dynamic between the two is handled

Stocking, S. Holly (1999) 'How Journalists Deal With Uncertainty', in S.M. Friedman, S. Dunwoody & C.L. Rogers (eds) Communicating Uncertainty: Media Coverage of New and Controversial Science, 23-41. Mahwah: Lawrence Erlbaum Associates

Repeatedly, the scientists focused on the lack of public understanding of science in general, and of probabilities in particular, as the central problem in communicating the impact threat

Felicity Mellor, Public Understanding of Science 19(1): (2010) 16-33

Now my plan is as easy to describe as it is difficult to effect. For it is to establish degrees of certainty, take care of the sense by a kind of reduction, but to reject for the most part the work of the mind that follows upon sense; in fact I mean to open up and lay down a new and certain pathway from the perceptions of the senses themselves to the mind.

Francis Bacon, Novum Organum Scientiarum

VI. Comparing Science and the Law

Science and the law differ both in the language they use and the objectives they seek to accomplish.

A. Language

Oscar Wilde (and G.B. Shaw too) once remarked that the United States and England are two nations divided by a common language. Something similar can be said, with perhaps more truth (if less wit), of science and the law. There are any number of words commonly used in both disciplines, but with different meanings.

David Goodstein – How Science Works

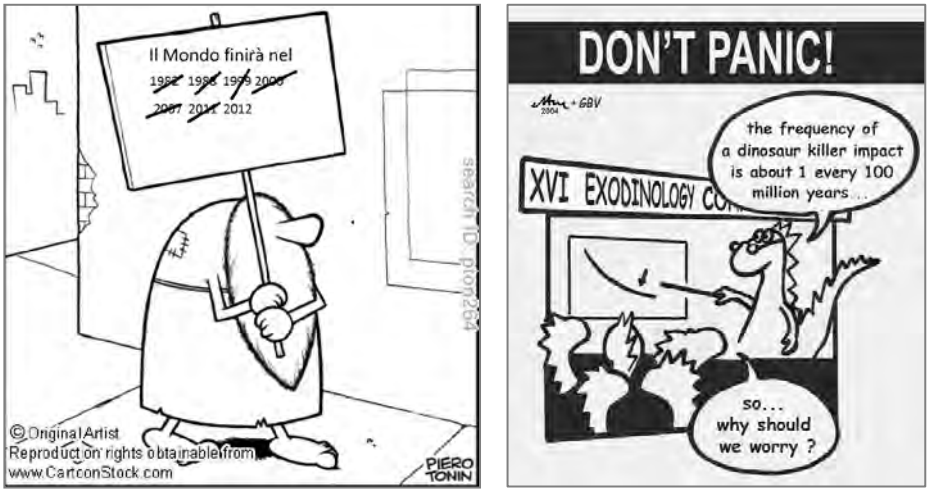

Figure 17 – Just for a laugh!