Special Report

Potentially Hazardous Asteroids

PLANETARY DEFENSE: THE TIME HAS COME

By Joseph N. Pelton

Shortly after 0900 local time, on a crisp February day in Chelyabinsk, Russia, Marat Ahmetvaleev went to one of his favorite spots to catch some photographs of the rising sun. Instead, he captured this streak of fire, smoke, and stone. At maximum brightness, the burning 17m rock travelled at 18.6km/s.

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For a small percentage of the many trillions of US dollars spent on military systems, the people of Earth could invest in protecting ourselves against one of the great perils to the human race, near Earth objects (NEOs), Potentially Hazardous Asteroids (PHAs), and other space rocks. We have now suddenly become alerted to this danger by a battleship-sized rock that crashed down over Siberia on February 15, 2013. It came down with the force of a nuclear weapon and injured thousands of people and buildings. Yet it was just 15 meters across.

We need a global planetary defense program because these lethal space hazards can kill us all at once, or totally wipe out the infrastructure that allows us to sustain a human population that could reach 12 billion by 2100. A big enough asteroid could also stir up a dust cloud that could block out the Sun and ultimately kill most of the vegetation that sustains us and warms our planet.

A TIMELESS THREAT

Space rocks have the power to damage or exterminate life as we know it on planet Earth. Today we think we know where 90% of all near Earth objects or hazardous space rocks larger than one kilometer in diameter are. Yet that leaves 10% unaccounted for. Perhaps more scary is that 80% or more of the space rocks smaller than one kilometer are still unidentified.

NASA has calculated that if the space rock named Apophis, about 300 meters in diameter, were to hit us at 64,000 kilometers per hour it would cause an explosion equivalent to perhaps a thousand atomic bombs. The amount of damage that could be done is almost impossible to estimate.

Neil deGrasse Tyson, American astrophysicist and TV personality, explains that these space hazards have been threatening to kill life on Earth for eons. He has noted how, some 65 million years ago, an eight kilometer wide space rock hit Earth on the coast of Mexico and left a 160 kilometer (100 mile) diameter crater. The dinosaurs did not have a space program to warn them and no preventive measures in place. Today the dinosaurs are gone, but the so-called K-T event that eliminated about two-thirds of all living species on Earth remains as a warning that it could happen again.

Since 1900 there have been 12 major earthquakes and tsunamis around the world with a total death toll that exceeds two million people. Since 1900 there have been four major volcanic eruptions that have taken lives with an estimated death toll around 105,000. Since 1900 there have been eight hurricanes, typhoons, cyclones, and floods with a total estimated death toll exceeding 6 million. Since 1900 there have been 10 major famines and pandemics that have resulted in some 100 million deaths.

Yet one collision by a near Earth object like Apophis would not only release the equivalent of thousands of atomic bombs, but very likely would result in more deaths than all of these catastrophes combined—by a wide margin.

SMARTER THAN DINOSAURS?

There are a lot of things we need to do smarter and better with respect to ensuring the survival of humans than we are doing. We need a program of planetary defense that could be carried out at much less than 5% of what we are currently spending on space-related activities. This is something we should be doing if we really want the human race and many other species to stick around and survive. Former astronaut Rusty Schwieckart and his B612 Foundation believe that a great deal could be accomplished within a budget of just $250 billion. But what specifically should we do under a Planetary Defense undertaking?

First of all, we need to expose the world community to the Torino Scale, a classification method adopted at Unispace III that explains on a scale from 1 to 10 what the threat level is from potentially hazardous asteroids and the likelihood of their occurrence based on what we know. This needs to be updated as we acquire more knowledge.

Second, we need to up our game to find out what dangers from NEOs are actually out there. NASA's Wide Field Infra-Red Survey Explorer (WISE) space probe provided a much better understanding of the 20,000 to 45,000 asteroids that could impact Earth in very unwelcome ways in coming decades, centuries, or even millennia. New space assets to identified hazards should be a priority. We need more resources like the 16 inch WISE system to track more precisely asteroids like 1999 RQ36. This asteroid is now thought to have a remote chance of actually hitting the Earth at some point before the year 2200, with the most likely impact date being 24th September 2182. The problem with 1999 RQ36 is the crowd that it hangs around with: a cluster of asteroids that are all characterized as NEOs. We need to find not only dangerous asteroids, but dangerous clusters like this one.

Third, we need to better understand phenomena that could impact and change the orbit of NEOs and bring them on a collision course with Earth. The recently discovered Asteroid 2011 AG5 (first noted in January 2011) could clobber us in 2040 if it should hit the so-called "gravitational keyhole" as it circles the Sun, altering course enough to put it on a lethal trajectory. Even the Sun's radiation impacts trajectories via the Yarkovsky effect and we need to study and better understand this effect as well.

THE TORINO SCALE

No Hazard	0	The likelihood of collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bolides that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.
Normal	1	A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.
Meriting Attention by Astronomers	2	A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.
	3	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
	4	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
Threatening	5	A close encounter posing a serious, but still uncertain treat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.
	6	A close encounter by a large object posing a serious, but still uncertain treat of global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.
	7	A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain treat of global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.
Certain Collisions	8	A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per serveral 1000 years.
	9	A collision is certain, capable of causing unprecedented regional devastation for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 10,000 years and once per serveral 100,000 years.
	10	A collision is certain, capable of causing a global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average between once per 100,000 years, or less often.

The Torino Scale is a method for categorizing the impact hazard associated with near-Earth objects (NEOs) such as asteroids and comets.

Finally, we need a well-funded NEO-Shield program to develop the most effective way to divert hazardous space rocks away from an Earth collision or to steer them into the Sun.

To begin this process, the space agencies of the world should form a group like the Inter Agency Space Debris Coordinating Committee (IADC) to coordinate and develop an integrated program to undertake all of the above activities and more. This should include new IR space systems like the WISE probe and more ground-based observations to track PHAs. New research to study aspects such as the keyhole and Yarkovsky effects should be funded, and new targeted ways found to cope with asteroids in killer orbits. This threat, along with other problems associated with solar flares and coronal mass ejections are key cosmic dangers that space agencies and groups like the B612 Foundation, the International Space Safety Foundation, and the International Association for the Advancement of Space Safety need to address seriously.

Dr. Joseph Pelton is Former Dean of the International Space University and Chair of the IAASS Academic Committee.

INFRASONIC DETECTION OF METEORITES

By Matteo Emanuelli

Exploding 32km off the ground with the force of 30 atomic bombs, the Chelyabinsk meteor arrived. Traffic stopped throughout the region as the sky briefly flashed bright white, washing out even the morning Sun. Only after the flash had passed did the sonic boom reach the city: the total impact energy was 440 kilotons of TNT. With the boom came the shattering of thousands of panes of glass, injuring 1200 people. The -17°C cold of the Siberian morning rushed into every building.

In the early morning hours of November 17, 1998, a bright fireball was observed over northern New Mexico, about 150km away from Los Alamos. The bolide was part of the annual Leonid meteor shower. Although the event did not produce any sonic boom reports, it was detected by an infrared radiometer and by an intensified camera located in the state. Los Alamos National Laboratory (LANL) investigated the sighting in its role as a part of the International Monitoring System (IMS) created following the Comprehensive Test Ban Treaty (CTBT). LANL found the presence of an infrasonic signal detected by six infrasound arrays. The signal matched the time and the direction of the fireball seen in the sky. The infrasound recording indicated that the explosion occurred at 93.5 kilometer, matching the measurements from the camera. The velocity obtained for the bolide from the signal was between 920 and 1150km/s. The meteorite was calculated to have a source energy equivalent to about 1.14 tons of TNT, where source energy is the kinetic energy when the shock wave is produced because of the passage through the atmosphere or the fragmentation of the meteoroid itself.

METEORS AND NUCLEAR WEAPONS

CTBT bans all nuclear explosions in all environments for military or civilian purposes. It was adopted by the United Nations General Assembly in 1996 but it has not entered into force as of April 2012, since it has been ratified by only 36 countries of the 44 required. One of the points of the treaty is to establish and operate 337 facilities of the IMS; as of April 2011, the system was 80% complete. To detect nuclear explosions, IMS employs infrasound stations using microbarographs (acoustic pressure sensors) to detect very low frequency sound waves. The investigation conducted by Douglas O. Revelle and Rodney W. Withaker at LANL showed that these detectors could also have been used to detect and measure objects entering the atmosphere. More recently, infrasound detectors were used to study the meteorite that exploded over Chelyabinsk, Russian Federation, on February 15, 2013.

Earth's orbit through the solar system passes through much solid particle debris from both comets and asteroids. These meteoroids can arrive from very different orbits and are composed of different materials such as iron, rocky stones, or carbonaceous compounds. Moreover, they can have a large range of possible sizes and densities as well as a large range of possible entry velocities.

The interaction of these meteoroids with the atmosphere produces shockwaves, partly due to the very high speed at entry and partly due to the compressibility of the atmosphere. The entry speed can typically range from 50 to 300 times the speed of sound (Mach) while, to make a comparison, Lockheed SR-71 Blackbird, the fastest manned air-breathing craft, had as maximum peak speed Mach 3.2. A direct consequence of this high speed is an explosion generated along a cylindrical path on the entry trajectory. The blast wave radius delineates the size of the region in which an explosion has occurred. Large meteoroids, such as the one that exploded above Chelyabinsk, penetrate the atmosphere down to heights where the atmosphere is sufficiently dense to produce a shock wave. While thunder usually produces a sound source with a wavelength on a scale of about 2-3m, the shock wave generated by meteorites can range from 10 meters to many kilometers in length. Sound sources of such magnitude in the atmosphere can have very large amplitudes, enough to break glass windows at close range as observed in the Chelyabinsk region. The frequencies are low enough that they can be characterized as infrasound, meaning the peak energy is below the range of audible sound waves.

As the blast wave radius increases, the frequencies become progressively lower. In the Tunguska event, in 1908, ultra-low sound frequencies of 1/60 Hz were observed at great distances from the entry trajectory.

LISTENING TO INFRASOUND

According to Revelle, an array of low frequency sensors horizontally separated by a few hundred meters to a few kilometers can be used to determine both the direction and the elevation angle of the signals. The determination uniquely locates the infrasound sources in a three-dimensional space within the atmosphere within certain errors.

Such data are also useful to estimate the frequency of occurrence of certain types of meteoroids. Revelle estimates that an event with the energy level of 10Mt, such as Tunguska, is likely to happen once every 120 years. However, data from infrasound measurements reported that 30 ±9 large bolides with an energy level of 0.1kt are likely to enter Earth's atmosphere every year. The data shows that the number of entering debris increases as the source energy decreases and vice versa.

Historically, the primary source of data collection for reentering objects has always been visual or optical observations. However, due to the extensive deployment of ILS infrasound sensors, this mode has shown its relevance along with radar and optical observation for the study of meteor physics. The Los Alamos investigation was one of the first times that infrasound detection has been used to study objects reentering the atmosphere. Revelle's pioneering theoretical work on interaction between meteors and atmosphere led the way for future studies.

Within moments, the sky cleared of any traces of the flaming meteor, leaving the city to gather its wits, begin cleaning up, and ask how such a thing could happen with no warning at all. An asteroid had been expected February 15, with the well predicted record breaking passage of 2012 DA14. Many experts spent the days that followed insisting that their predictions had not been off: the Chelyabinsk Meteor came from another direction entirely.

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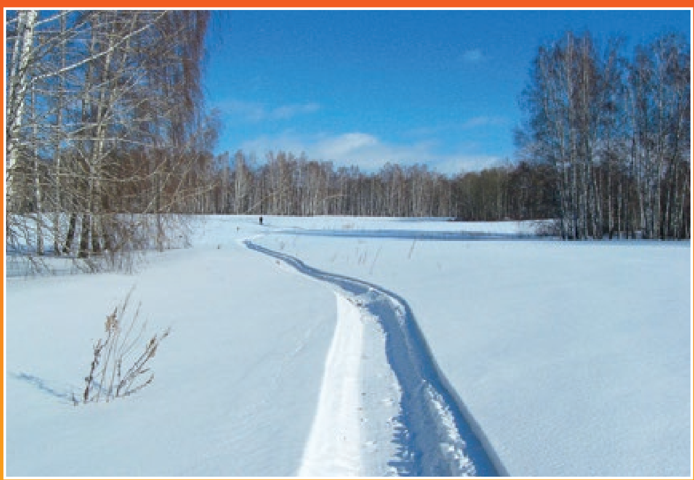
UNITED NATIONS REVIEWS ASTEROID IMPACT IMPLICATIONS

By Leonard David



It did not take long for the scramble to begin. After an unsuccessful search at the bottom of a murky, frozen-over Lake Chebarkul for the stone that created a 6m hole in its icy surface and a 3m crater in its bed, meteorite hunters began scouring the region. These images, taken by a resident of Chelyabinsk on February 28, show the blackened stones standing out sharply against the pristine snow.

It could be considered a cosmic convergence of celestial objects and international politics – but also a wake-up call. The Russian fireball detonation over Chelyabinsk and the close fly-by of Earth by asteroid 2012 DA14 in February came at a moment in time when near Earth object (NEO) experts were convening to scope out international responses to NEO threats to our planet.

Detailed talk about the Russian event and asteroid 2012 DA14 punctuated the agenda of Action Team-14 (AT-14) during the 50th session of the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), held February 11-22 at the United Nations headquarters in Vienna.

The United Nations Office for Outer Space Affairs (UNOOSA) serves as the Secretariat to the Working Group on NEOs of the Scientific and Technical Subcommittee and supports the work of the AT-14 on NEOs. Sergio Camacho, a former UNOOSA Director, serves as the Chair of AT-14.

DELIBERATIONS AND DECISION-MAKING

The multi-year work of AT-14, a group that was established in 2001, is focused on pushing forward on an international response to the NEO impact threat. AT-14 has been deliberating over the years regarding the makeup and focus of an Information, Analysis and Warning Network (IAWN), designed to gather and analyze NEO data and provide timely warnings to national authorities should a potentially hazardous NEO threaten Earth.

In a draft report of the Working Group on NEOs following deliberations in Vienna, it was noted that there are three primary components of threat mitigation: 1) discovering hazardous asteroids and comets, and identifying those objects requiring action; 2) planning a mitigation campaign that includes deflection and/or disruption actions and civil protection activities; and 3) implementing a mitigation campaign, if the threat warrants it.

This meteorite, one of the largest found, was eventually recovered from Lake Chebarkul by Victor Grochowski, the Ural Federal University expedition leader. Compositional analysis showed the meteorite to be a carbonaceous chondrite containing 10% iron. It likely came from the Apollo group of near Earth asteroids.

Photography by Pavel Matsev and Denis Panteleev
http://pavelmaltsev.ru

The Working Group emphasized the value of finding hazardous NEOs as soon as possible in order to better characterize their orbits. This would help to avoid unnecessary NEO threat mitigation missions or facilitate the effective planning of missions, should they be deemed necessary.

ACTION ITEMS

At the February gathering in Vienna, given the output from AT-14, the Working Group recommended that three actions should be taken. First, an international asteroid warning network, open to contributions from a wide spectrum of organizations, should be established by linking together the institutions that are performing the proposed functions, to the extent currently possible. While existing institutions address discovering, monitoring, and physically characterizing the potentially hazardous NEO population, such a network would introduce an internationally recognized clearing house for the receipt, acknowledgment, and processing of all NEO observations. Such a network would also recommend criteria and thresholds for notification of an emerging impact threat.

Second, the IAWN would interface with the relevant international organizations and programs to establish linkages with existing national and international disaster response agencies to study and plan response activities for potential NEO impact events. It would also recommend strategies using well-defined communication plans and procedures to assist governments in their responses to predicted impact consequences. These communication linkages do not limit the possibility of organizing additional international specialized advisory groups, if necessary.

Finally, a Space Mission Planning Advisory Group (SMPAG) should be established by Member States of the United Nations that have space agencies. The group should include representatives of spacefaring nations and other relevant entities. Its responsibilities should include laying out the framework, timeline, and options for initiating and executing space mission response activities. The group should also promote opportunities for international collaboration on research and techniques for NEO deflection.

AT-14 further detailed an Impact Disaster Planning Advisory Group (IDPAG), a body that would be initiated by IAWN. Its duty would be to study past large-scale disasters and develop action plans should an asteroid impact occur. It would be formed by representatives of existing national and international disaster response agencies.

MORE WORK TO DO

Detlef Koschny of the European Space Agency's European Space Research and Technology Center (ESTEC) in Noordwijk, The Netherlands, is an active member in the UN NEO Action Team and working group discussions. In his view, there are a number of items still on the table to be dealt with.

"Well, of course the immediate next steps will be to start implementing what we have proposed," Koschny told Space Safety Magazine; however, he flagged the fact that there are a few things still open. "We need to focus more now on looking outside our direct 'NEO-expert horizon.'"

"The Impact Disaster Planning Advisory Group needs to be established," he added. "We still have work to do in the legal area." For example, just assume the IAWN informs COPUOS about an imminent impact and the SMPAG and IDPAG provide their input on how to react. Suppose it is predicted to hit a country without space capabilities. "How can we ensure that proper action is taken? People have asked what the legal framework for this would be. We have started to address these things, but much more work needs to be done," Koschny emphasized.

In Europe, Koschny pointed out that there is the additional complexity of countries with their own space agencies – plus a European Space Agency. "Often this setup is advantageous, but it also adds another layer into the whole process which we now need to address. So, while I am very happy that we came as far as we did, there is still a lot before us!"

GIGGLE FACTOR: GOING, GOING, GONE

The fireball detonation over Russia, coupled with the very close passage by Earth of space rock 2012 DA14 "certainly underscored the importance of the UN Working Group on NEOs," said Ray Williamson, a senior advisor to the Secure World Foundation and also a member of AT-14.

"The giggle factor…that's gone, over, done with," Williamson told Space Safety Magazine.

"We are in a lot better shape," Williamson added. "There is certainly more awareness of the issue worldwide. And that is worth something…in the sense that now countries are aware that they need to put some expertise into the equation and also resources to provide information that would ultimately protect Earth from these threatening asteroids."