



2013 IAA Planetary Defense Conference

Conference report

Background

The **2013 IAA Planetary Defense Conference: Gathering for Impact!** was held in Flagstaff, Arizona, USA, on April 15-19, and included a special session on Sunday evening, April 14, on the Chelyabinsk Meteor event of February 15, 2013. The conference, which became part of the International Academy of Astronautics (IAA) conference series in 2009, was the fifth in the series of conferences that began in 2004. Previous conference locations were in Anaheim, California (2004), Washington, D.C. (2007), Granada, Spain (2009), and Bucharest, Romania (2011).

As was the case for previous conferences, the 2013 conference brought together world experts to discuss our current understanding of asteroids and comets that might pose an impact threat to our planet, techniques that might be used to deflect or disrupt an oncoming object, the design of deflection campaigns, consequences of an impact, and political and policy issues that might affect a decision to take action. A tabletop exercise on the last day of the conference asked attendees to consider deflection and disaster mitigation responses to a hypothetical asteroid impact threat. The Organizing Committee for the conference is provided in Attachment A.

The Flagstaff conference was sponsored by 23 organizations that are listed in Attachment B and was attended by over 225 individuals (see Attachment C). Both the number of sponsoring organizations and the number of attendees have grown over time, as shown in Fig 1. This increase demonstrates the expanding recognition that defending Earth from asteroids and comets is an important issue for our time.

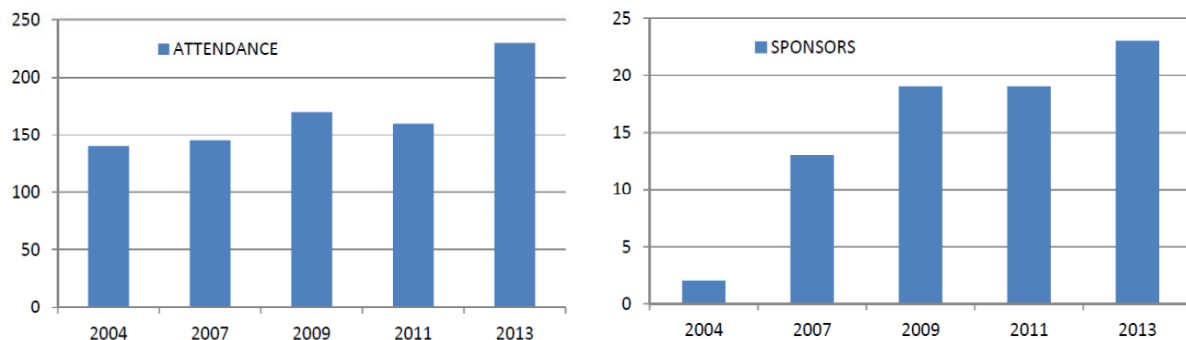


Figure 1. Number of participants at and sponsors for planetary defense conferences.

It is also important to note that the conference sponsors included National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), the Japan Aerospace Exploration Agency

(JAXA), the Romanian Space Agency (ROSA), the United Kingdom Space Agency (UKSA), and the Russian Federal Space Agency (ROSCOSMOS). The involvement and sponsorship of these agencies is particularly important, since planetary defense is an international issue. Should an object on an Earth impact trajectory be discovered, it is possible, and in fact likely, that several space-faring nations would be involved in a deflection/disruption campaign.

Session Summary & Highlights

Special Session on Chelyabinsk

This special session on the Chelyabinsk event was organized by David Morrison of NASA Ames, and speakers provided the most current information on the object that caused the Chelyabinsk event, including its pre-impact heliocentric orbit (forensically reconstructed), estimated atmospheric entry conditions, and the nature of the blast effects felt on the ground. There was no prior warning of the event and the object was not observed before entry. This evening session was open to the public and was attended by several hundred individuals. Speakers described visits to the Chelyabinsk area to document the experiences of witnesses, view the damage, and determine locations where photographs were taken. Photographs were used to develop estimates of the object's entry angle and trajectory, and presenters provided preliminary information based on these efforts. Presenters noted that the effects on the ground would have been much more severe if the object had entered at a steeper angle.

Session 1: Background

The purpose of the first session was to learn about currently funded and ongoing worldwide activities that relate to planetary defense. Presentations included a history and timeline of past planetary defense activities and a summary of activities at the United Nations where Action Team 14: Near Earth Objects is developing recommendations for how the world community will address a potential impact. AT-14 has presented its first recommendations to the Science and Technology Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). The recommendations include the establishment of three coordination groups: the Space Mission Planning Advisory Group (SMPAG), the International Asteroid Warning Network (IAWN), and the Impact Disaster Planning Advisory Group (IDPAG). The SMPAG, which brings international space agencies together to discuss how they will work together should an actual threat be discovered, had its first planning meeting in January 2012.

Other speakers discussed:

- The European Space Agency's activities that support the development and presentation of materials providing information about the impact hazard. The goal is to be aware of and present the positions and physical properties of Near Earth Objects (NEOs) and assess their impact probabilities, effects, and possible mitigation activities. As part of this activity, a "wide survey" will be established to detect all objects down to 40 meters in size in time to give about three weeks of warning. ESA has developed a web portal where authoritative information will be posted (<http://neo.ssa.esa.int>).
- In Russia, an expert group with members from the Russian Academy of Sciences (RAS) and Russian Federal Space Agency (ROSCOSMOS), universities, industry, the Ministry of Defense, and other entities is developing a concept for a national program to integrate efforts to study space debris and near earth objects. In 2012, ROSCOSMOS initiated a program to construct a system for monitoring dangerous space objects (both space debris and NEOs, with ROSCOSMOS responsible for space debris and the RAS responsible for ground-based facilities for detection and studies of NEOs. ROSCOSMOS is in charge of all NEO-related space missions. A mission to Apophis to study physical and chemical properties and attach a tracking

aid is being considered. The RAS is proposing to construct a database of pre-calculated impact consequences to enable quick assessments of land or water impacts.

- The European Commission has approved and funded a 3.5 year study on “Prevention of Impacts from Near-Earth Objects on our Planet,” known as NEOShield. The 5.8-million-euro study was initiated in January 2012, and will investigate the three most promising deflection techniques: kinetic impactor, gravity tractor, and blast deflection. Main themes of the project are: 1) Science-looking at physical characteristics of NEOs, precursor missions, laboratory and computer studies on kinetic impact effects; 2) identifying possible targets and designing space missions to demonstrate deflection techniques; and 3) developing a decision-making tool to aid in response planning, which would include a global response roadmap in collaboration with the UN, space agencies, and others. The effort includes partners from Germany, France, United Kingdom, Spain, United States, and Russia. Details are available at <http://www.neoshield.net/en/index.htm>.
- NASA reported on recent radar observations of asteroid 2005 YU55, a 400-meter diameter object that passed within the Moon’s orbit on November 8, 2011. The United States has provided 98% of the new detections of NEOs since NASA made the commitment to the House Committee on Science in 1998 to discover 90% of more of NEOs larger than 1 km in size in 10 years. A total of 861 NEOs 1 km and larger have been discovered to date, and the rate of discovery for objects larger than 1 km is leveling off. It is estimated that approximately 95% of the NEOs larger than 1 km have been discovered. The discovery program has also found 8909 smaller objects, and the number of known smaller objects continues to climb. Estimates are that less than 10% of objects smaller than 300 meters in diameter and less than 1% of objects less than 100 meters in diameter have been discovered. The observation program has retired two potential threats: the threat of an impact in the year 2040 by 2011 AG5 was eliminated; as was the possibility that 99942 Apophis (2004 MN4) might impact in 2036. The highest remaining threat is an impact in the year 2182 by asteroid 101955 Bennu (1999 RQ36). NASA has signed a Space Act Agreement to support the B612 Foundation’s Project “Sentinel,” which has a launch date not earlier than 2018. NASA is supporting UN COPOUS activities discussed earlier, has provided testimony to the US House Science Committee on threats from space following the Chelyabinsk event, led the Impact Emergency Tabletop Exercise with the US Federal Emergency Management Agency (FEMA), and presented a proposal for an asteroid retrieval mission as part of the US President’s FY2014 budget submittal. Details on NASA’s NEO program are available at <http://neo.jpl.nasa.gov/>.

Session 2: Discovering NEOs—The State of the Art

Presenters discussed current and proposed techniques and missions for discovering NEOs--the first and perhaps the most critical step in planetary defense. Specific topics covered by presenters included:

- Where in the solar system asteroids that became NEOs originated
- How techniques used for discovery of NEOs have evolved from examination of photographic plates to digital images and Infrared telescopes
- Coordination of observation surveys among observers
- Southern hemisphere coverage
- Planned upgrades to discovery resources
- Discovery of 2008 TC3 prior to its entry into the Earth’s atmosphere and the subsequent discovery of fragments at Almahata Sitta in the Nubian Desert

- Lincoln Near Earth Asteroid Research Program (LINEAR), which has discovered approximately 250,000 objects, including 462 potentially hazardous asteroids, approximately 45% of all PHAs to date
- Pan-STARRS 1, which is finding approximately 30 NEOs per month, and upcoming systems such as Pan-STARRS 2 and B612's Sentinel Mission that will enhance discovery capabilities, and
- Asteroid Terrestrial-Impact Last Alert System (ATLAS), a NASA-funded project to find dangerous asteroids, which is expected to provide a three week warning time for objects in the 140-meter diameter class, 1 week for smaller 50-meter-class objects

Session 3: Physical Characterization

Presenters in Session 3 discussed the physical characterization of asteroids and how objects of various types might respond to deflection techniques, topics that are important for estimating the effectiveness of various asteroid deflection and/or disruption techniques. Specific topics included:

- Spin rate and what spin rates say about an asteroid's mass, density, and structure
- What can be learned by flyby of an asteroid
- Strength of small asteroids (less than ~10 km in diameter) based on spin rates and discussion of whether spin rates could be used to distinguish between "monolithic rocks" or "rubble piles"
- Details of the impact hazard for 2011 AG5, keyholes for the February 3, 2023 close approach and possible mission designs for a pre-keyhole deflection should measurements show that such a mission might be warranted. The proposed mission would use a kinetic impactor to provide the required delta-V to the asteroid. The mission would include a precursor spacecraft that would aid in targeting and confirm a successful deflection. The presentation included possible launch options and mission timelines.
- The ExploreNEOs project and the Warm Spitzer Near Earth Object Characterization Study, which has observed 600 NEOs and measured albedo and diameter.
- How radar observations are used to determine physical properties of NEOs. Radar observations can spatially resolve objects with down to 4-meter resolution, better performance than ground-based or space-based optical observations. Radar can also develop 3-D shape models, resolve some surface features, determine spin states, and estimate surface roughness. Orbits determined from radar measurements are very precise; as a result, uncertainties in future orbit tracks and possible Earth impacts are substantially reduced.

Session 4: Mitigation Techniques and Missions

This session examined what might be done to prevent an impact if a threatening object on a collision course with Earth is discovered. Presenters provided overviews of the latest research on deflection and disruption techniques and on missions and techniques that might deliver a deflection/disruption payload to the threatening object. This session had the greatest number of submitted abstracts and a special morning session was added to enable more presentations. Topics discussed included:

- The ISIS mission, which would piggy-back a kinetic impactor payload onto the OSIRIS-Rex mission to asteroid 101955 Bennu (1999 RQ36). The ISIS payload would have a mass of 440 kg and would impact the asteroid at 13.4 km/sec with energy of approximately 9 tons of TNT. The impact and its effects would be observed by the OSIRIS-REx spacecraft. The impact would cause an estimated 0.15 to 0.30 mm/sec change in the asteroid's velocity, which could be measured a few weeks after impact.

- A closed-loop terminal guidance navigation system for a kinetic impactor spacecraft that would be used against relatively small asteroids with short turnaround times from detection to impact. AutoNav, which has been used for several successful missions including the Deep Impact fly-by and impact of comet Tempel 1 in 2005, would require only modest improvements to be used for asteroid deflection missions targeting asteroids 100 meters or less in size.
- A study that examined the asteroid deflection efficiency of the kinetic impactor, which concluded that the momentum multiplier, β , for porous material is less than 2 for impact velocities less than 15 km/sec.
- Nuclear explosives can be used to deflect or disrupt (break-up) asteroids, and models exist that can estimate the effectiveness of both options.
- A spacecraft design that uses a kinetic impactor as a lead for a following nuclear explosive was proposed. The presentation concluded that a 100 meter object could be “safely disrupted” with 15 days of lead time using the device.
- Other presentations addressed target selection and mission design for flight validation missions, both against a single asteroid and using the moon of an asteroid as a target (ESA’s Asteroid Impact & Deflection Assessment (AIDA) concept; GMV’s Binary Asteroid Orbit Modification (BEAST) concept; ADRC’s Hypervelocity Asteroid Intercept Vehicle (HAIV) concept).
- Plans, concepts, and possible targets for human mission to an asteroid and for asteroid retrieval missions and how such missions might benefit planetary defense; OSIRIS-REx, a NASA asteroid sample return mission to the potentially hazardous asteroid 101955 Bennu (1999 RQ36); how the OSIRIS-REx science, platform, and operational concepts apply to the asteroid deflection problem; Marcopolo-R, an ESA sample return mission to the potentially hazardous asteroid 2008 EV5; the Near-Earth Object Human Space Flight Accessible Targets Study (NHATS), a NASA system for automatically monitoring the accessibility of all near-Earth asteroids for future space flight missions (<http://neo.jpl.nasa.gov/nhats>)..
- Asteroid Mission Design Software Tool (AMiDST), which focuses on the launch and terminal phase of an NEO exploration/deflection mission; a CNES proposal for a short (<1 month) crewed mission to asteroid Apophis during its close flyby of earth in 2029; characterization of the thrust induced by laser ablation of an asteroid and a proposed 2025 mission to impart a 1 m/sec delta-V to a 4-meter diameter rocky asteroid.
- Dynamics and control of a spacecraft before and after capturing a small (~7 meter diameter) asteroid and optical navigation and fuel-efficient orbit control around an irregularly-shaped asteroid.

Session 5: Impact Effects that Inform Warning, Mitigation, & Costs

Should a threatening object be detected, the process for deciding the appropriate course of action will include discussions of the possible consequences of an impact. Presentations in this session highlighted existing tools that can be used to predict possible impact consequences, evidence of the nature of impacts from observations of impacts on other planets, and compared the cost of impact to the cost of an effective discovery system. Specific topics included:

- An on-line tool for estimating the damage caused by asteroid impacts (Purdue University and Imperial College, London) - ImpactEarth! (www.purdue.edu/impactearth/)
- Flux of impacts into Jupiter and details of the asteroid that created Meteor Crater
- The value of enhanced NEO surveys for reducing uncertainty about the risk of NEO impacts

- Infrastructure consequences (impacts on population, direct and cascading impacts on infrastructure, economic effects) for a major earthquake to illustrate capabilities of existing consequence prediction tools.
- A presentation noting that emergency managers will usually not deal with NEO deflection, but will instead deal with disaster management, risk management, risk communication, and other disaster mitigation issues. The presentation also noted that recovery from NEO impact resembles recovery from other disasters. A prudent emergency manager should warn the public about a NEO estimated to be in the 5-10 m diameter range and evacuate if the size exceeds 15 meters. Given that deflection may not be an option for short warning time events, evacuation may be the most likely mitigation for such events.

Session 6: Consequence Management & Education

One of the key challenges of managing the consequences of an asteroid event is educating the public on the nature of NEO threats, their evolution, and (in the event of an actual threat) what the public can do to protect themselves. In addition, the organizations responsible for disaster mitigation should understand how they can best contribute to the effort. Key decision makers will need the risk information presented in standardized, easy-to-digest forms. This session provided insights into these topics and probed the following topics in greater detail:

- An international communications response plan needs to focus on educating government officials and the public on the nature of NEO threats. The recommended approach is to use all available media and include documentation from reputable space agencies, planetariums, university programs. A successful approach will take advantage of teaching opportunities during asteroid close approaches and noteworthy meteor events. An effective responsive plan will develop a clear international chain of command for dealing with NEO risks. The plan will also design a communication strategy that makes use of findings from experts in risk communications and will employ “trust agents” that have appropriate skills and credibility to communicate with non-expert audiences.
- Informing the public and decision makers that false alarms are part of the nature of NEO threats. Controversial, inaccurate, or misleading messaging should be expected and handled effectively. In the event of a severe threat, there may be a perception that technologically-advanced nations are imposing their will on others, so geopolitical concerns and perspectives are important; there could be legal challenges to proposed actions and issues of financial responsibility may be raised for losses due to false alarms. In addition to warnings about short term effects of an impact, secondary effects such as earthquakes, fires, weather effects and others must be communicated. A communications plan must anticipate and address controversies and approach communications in phases (general, specific, imminent).
- Challenges facing communication about NEOs include the fact that mass media and, increasingly, social media play key roles in public discourse about science. As a result, communications of information about NEO threats must be open and transparent.
- Findings, results, data are always open to different interpretations. Following conventional scientific practice, scientists should present their data, interpretations, and findings in a qualifying frame of any and all uncertainties relating to the claims. Communications of key findings must be communicated clearly to non-technical audiences.
- Journalists are compelled to clarify, avoid, or eliminate ambiguity or uncertainty, in keeping with long-standing news values and journalistic practices and conventions.
- The U.S. Geological Survey (USGS) has responsibilities for earthquakes, volcanic eruptions, and landslides and is the portal for real-time data including orbital images and GIS products. The

USGS has permanent digital state-of-the-art seismological sensors that will provide first alert that impact has occurred, especially if at sea, has tools to predict extent of damage, and would be part of system that issues tsunami warnings. Landslides could be triggered by impact, there could be long-term impact effects on watersheds and water quality, and distribution of ejecta into the atmosphere could affect aviation.

Sessions 7 & 8: Tabletop Exercise

Session 7 provided an overview and introduction to the tabletop exercise planned for Session 8 the next day. The exercise director noted that the exercise was designed to be a realistic representation of how an actual threat might evolve. The exercise began with the discovery of a hypothetical asteroid 2013 PDC-E, which was discovered on April 16, 2013. Periodic updates provided participants with details on the evolution of the threat consistent with what would be known at the time of the update.

A goal of the exercise was to see how various groups with different perspectives might respond, and to develop these perspectives, participants were invited to join one of the ten groups shown in Table. 1. A spokesperson from each group provided recommendations to the full assembly on actions that should be taken based on that group's consideration of what was known at the time.

The threatening object was a 200 to 300-meter diameter stony asteroid with an initial probability of impact of 0.8% in 2028. The impact velocity, if it were to impact was ~12.4 km/sec and the energy release at impact would be ~300 MT of TNT. There was a 1.2-km keyhole during a close approach with Earth in 2023. If it passed through that keyhole, it would impact in 2028. As noted, the impact probability was 0.8% and not a certainty at this time.

Table 1. Exercise groups.

1	NEO Discovery and Follow Up
2	NEO Characterization
3	Mitigation Techniques and Missions
4	Impact Effects
5	Consequence Management and Education
6	Media and Risk Communication
7	Single nation concerned (to include disaster preparedness roles)
8	UN, International Organizations, and NGOs
9	Space Agencies – launch capability
10	General public

The first update was in 2019, and the impact probability had risen to 28% and the object's size was known to be 300 meters. The risk corridor at that update is shown in Fig. 2. Note that any point in the band defined by the red points shown in Fig. 2, a region that extends from Indonesia to Africa, represents a possible impact point.

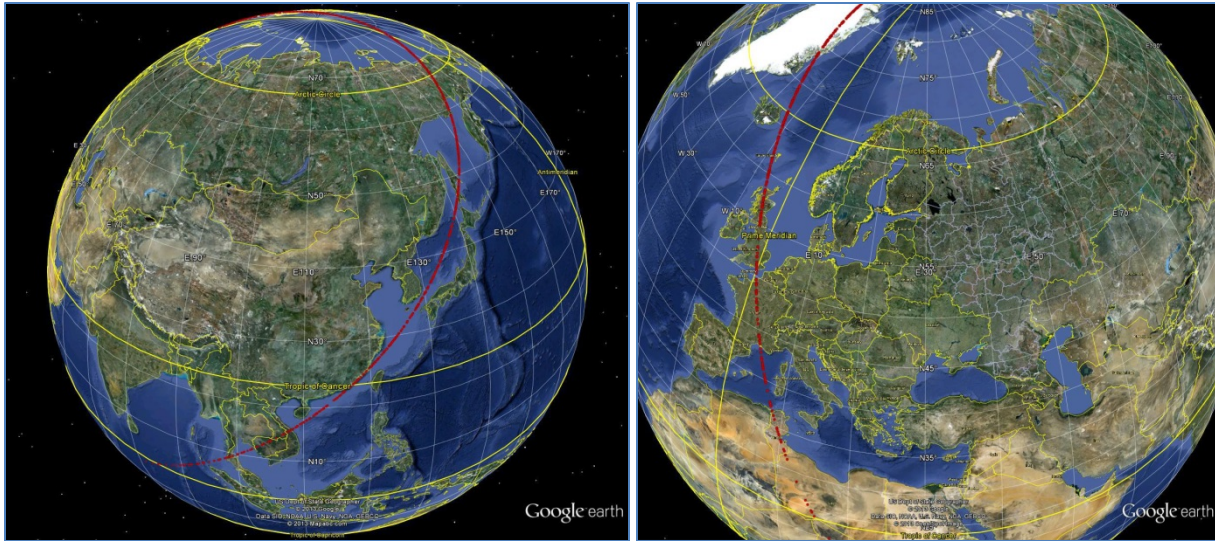


Figure 2. Possible impact points in 2028 based on the best information available in 2019. The probability of impact in 2028 is 28%.

The next update was in 2022, and based on the most recent observations, the probability of impact of impact has risen to 100%--impact is certain and will occur somewhere along the red line shown on Fig. 3.

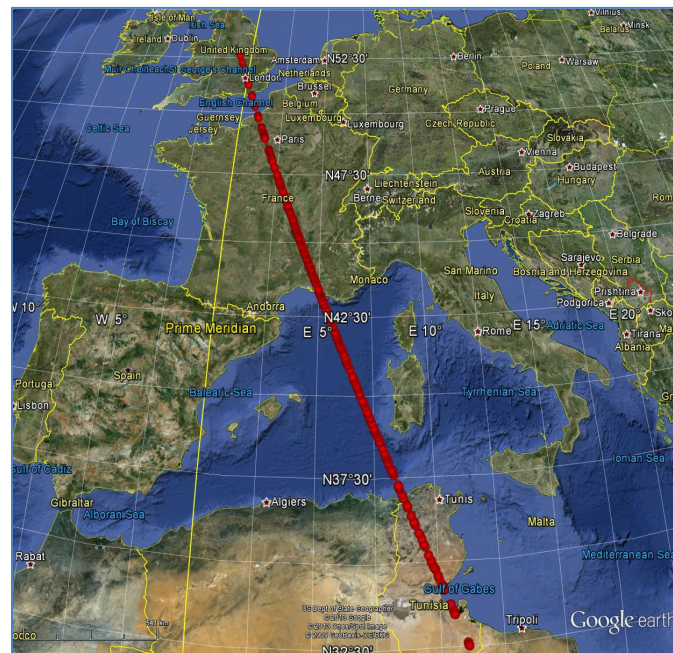


Figure 3. Possible impact locations in 2028 based on the best information available in 2022. Note that the probability of Earth impact in 2028 is now 100%.

The final update, which was presented at the conclusion of the exercise, represented information known in 2023, when radar tracking from Arecibo became available. Impact would occur in the Mediterranean at 07:40:48 on 21 November 2028 (see Fig. 4).

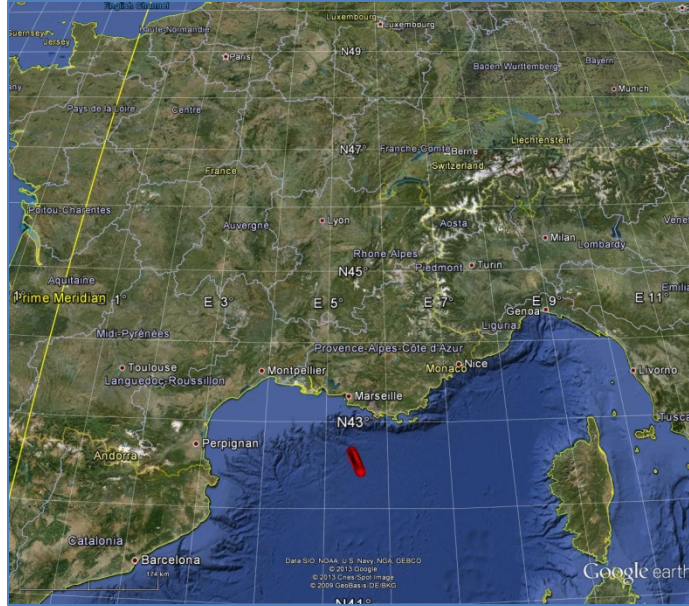


Figure 4. Final impact location.

There was active participation in the exercise, and comments and suggestions captured after the exercise concluded are included in the next section. A report on the exercise is being prepared.

Comments and Suggestions

At the conclusion of the conference, participants were asked to provide their suggestions and recommendations for critical items that need to move forward over the next few years. These were grouped into five categories: communications, discovery and characterization of objects that might pose a threat, measures to increase confidence and cooperation, and general comments.

Discovery & Characterization

- Chelyabinsk was a wake-up call. We need to support the launch of space-based IR survey systems to increase our ability to discover these small objects.
- We should pay due attention to smaller objects that present the most frequent threat.
- Major efforts seem to be 99% American/European. We need to make a real effort to broaden the community. One possibility would be to have a summary session at the yearly IAC.
- We should increase the rate at which physical characteristics of objects are characterized to 1000/year.
- We should upgrade our current radar capabilities to obtain very accurate estimates of the level of threat and basic characteristics of objects.
- Characterization: consider a fleet of low-cost probes that could be sent to asteroids.
- We should support basic science related to characterization of threatening objects.
- We need to reduce uncertainties on the size and other relevant characteristics.
- We need to perform a kinetic impactor flight demonstration.
- It was suggested that new surveys will saturate the current follow up capability, so action will be required to address the shortfall.

Increasing Confidence

- We should find common ground with human missions to improve knowledge of asteroids and reduce uncertainties in the outcomes of deflection actions.
- Should maintain and grow the community while keeping it cohesive.
- Need to have a quick launch/response capability and test new technologies that might improve effectiveness and reliability.
- Should maintain spare parts that are critical to a deflection or disruption campaign.
- Consider use of CubeSats to verify technologies, but note their limitations.
- Place capabilities in orbit that could be refueled and sent on their way.
- Encourage the use of existing missions to test PD-related instruments and technologies (e.g., ISIS).
- We should conduct a study to see what it would take to deflect a short warning threat.
- More work is needed to characterize the beta factor and the directionality of the delta-V on a range of target asteroids.

Cooperation

- We should encourage cooperation among government agencies that will have a role in deflection or disaster mitigation.
- We should branch out to other communities and focus more on these aspects (e.g., Session 6 topics).
- UN COPUOS AT-14: we should encourage support of the SMPAG and the IAWN and bring in disaster management and communication.
- The conference should increase its focus on the policy/legal/political issues.
- Should be a team ready to go to the locations where debris might have survived and recover fragments to improve understanding of asteroid properties.
- We could place a number of small spacecraft in orbit (Sun, Earth) and send them to targets of interest as they are discovered.

Communications

Presentations in Sessions 6 and 7 and those made at the conclusion of the tabletop exercise in Session 8 highlighted communications as a critical component of strategies for taking action against NEO threats and mitigating the effects of both surprise and forewarned NEO impacts.

- Develop a common language for discussing the NEO threat and possible mitigation options.
- Education and communication: should put together accurate graphics and animations; should consider a competition to develop three-minute videos illustrating key points (maybe for next conference?).
- We need to define uncertainty clearly for the public—perhaps have Bill Nye do a short video.
- We should be clear when we say that the uncertainty about the risk is reduced because we now know where some objects are.

General

- We should look outside our current sources for funding—think bigger. See if we can interest large donors in the topic.
- We need an authoritative system for assessing threats quickly (e.g., impact effects).
- Planetary defense is not an offshoot, but its own specialty. University and other programs should focus on planetary defense as a specialty area.
- The SGAC has opportunities available at the 2013 IAC for presentations on planetary defense.

- We should consider establishing “sister cities” where the PDC has been held. Provide a plaque, etc., as a way to spread the word.
- A future PDC should look at the capability and scope of relevant modeling tools as well as the value of an open source policy.
- The Space Generation Advisory Council (SGAC) is organizing a dedicated 2 hour event on NEOs and planetary defense at IAC 2013. Opportunities are available to participate in panel discussion/presentations.

Summary and Recommendations

Over 200 experts from around the world participated in the 2013 IAA Planetary Defense Conference; a meeting that concluded with a tabletop exercise exposed participants to a realistic asteroid warning and impact scenario and asked that they develop responses to the threat from multiple perspectives. Recommendations arising from this experience are below.

Discovery: Discovery remains the most critical aspect of planetary defense. We have discovered only a small percentage of the objects that could destroy a city or cause severe regional destruction, and such an object could enter our atmosphere today with little or no warning. Necessary tools that include space-based survey systems such as that proposed by the B612 Foundation, enhanced ground-based systems such as Pan-STARRS, and upgrades to radars that will improve precise tracking and measurements of an object’s size, rotation, and other factors that inform the design and execution of deflection efforts. UN efforts to formalize cooperative interactions among nations to improve observation and discovery capability should be supported.

Characterization: Research is increasing our understanding of the types of structures and materials that might be encountered by deflection/disruption missions and the responses to kinetic impact and other deflection/disruption efforts. This work will increase confidence in the success of deflection/disruption missions and potentially limit the number of launches required to achieve the desired result.

Verification of our ability to move an asteroid: Missions are being proposed that would use kinetic impactors to move an asteroid, and the impact and motion away from the original path would be verified by observer spacecraft. Designing these missions and developing the necessary tools and payloads for these types of actions would verify model predictions and build confidence in our abilities to deal with an actual threat.

Disaster mitigation: Tabletop exercises for limited audiences are demonstrating the effectiveness of these exercises in making people aware of the unique aspects of asteroid threats and where work needs to be done. Exercises involving disaster response agencies at the local, state, national and international level would help these agencies be prepared for disasters that might be caused by asteroid impacts..

Being Prepared: Atmospheric entries of NEOs of sufficient size to cause serious damage are rare on human time scales, but the need for an active deflection/disruption response could arise at any time. The challenge is to develop response plans and to put cost effective procedures in place to preserve technologies and capabilities necessary for a response. For example, algorithms that can guide a spacecraft moving at 10s of km/sec relative to an approaching asteroid must be made available and tested prior to when they are needed, as must the thruster and other hardware necessary to execute the algorithms’ commands. Procedures should be developed that will maintain a catalog of necessary equipment and tools and assure that these capabilities are tested and verified as part of other missions. Similarly, current procedures for launching spacecraft should be examined to see what can be done to make it possible to reprogram an existing launch

vehicle and mount and launch a new payload quickly. Potentially, a low level build-up of an effective planetary defense capability over time could be done with modest sustained annual investment. Public education and outreach programs also contribute to readiness and preparedness for NEO threats.

International efforts: Planetary defense is an international responsibility and current efforts at the United Nations to provide opportunities for space agencies to begin to plan for shared responsibilities and coordinated actions should be supported. Bi-lateral and multi-lateral agreements will also be necessary as part of the overall coordination of resources and capability.

Communications: The Planetary Defense Conference exercise and the exercise recently conducted by NASA and FEMA helped solidify the importance of developing and moving forward on an overall coordination and communication plan for planetary defense related topics. Information on the nature of a NEO threat, possible deflection/disruption options, the evolution of a threat scenario, risk and uncertainty, and credible tools for simple deflection mission design should be added to currently available authoritative web pages.

The 2013 Planetary Defense Conference started at a point where progress in the area was evident since the last meeting in 2011. After the 2013 meeting it was clear, as noted in this white paper, that real and significant progress is being made in the areas of understanding and dealing with planetary defense. Hopefully, significant progress will be made in the areas highlighted above and reported at the 2015 IAA Planetary Defense Conference.

Co-Chairs:

William Ailor The Aerospace Corporation
Richard Tremayne-Smith

Members:

V. Adimurthy	ISRO/Department of Space
Dave Baiocchi	RAND Corporation
Brent Barbee	NASA Goddard Space Flight Center
Edmund Beshore	University of Arizona
Bruce Betts	The Planetary Society
Mark Boslough	Sandia National Laboratory
Juan-Luis Cano	Deimos Space
Ian Carnelli	European Space Agency
Clark Chapman	Southwest Research Institute
Jean-Michel Contant	International Academy of Astronautics
Richard Crowther	Rutherford Appleton Laboratory
Line Drube	German Space Agency (DLR)
Alan Fitzsimmons	Queen's University, Belfast
Mariella Graziano	GMV
Pedro J. Gutiérrez	Instituto de Astrofísica de Andalucía - CSIC
Alan Harris	German Space Agency (DLR)
Alan W. Harris	Space Science Institute
Dario Izzo	European Space Agency
Andrea Jaime	Space Generation Advisory Council
Rob Jedicke	University of Hawaii
Lindley Johnson	NEO Observation Program Executive
Tom Jones	Astronaut, Member B612 Foundation
Alex Karl	Space Generation Advisory Council
Michael Khan	ESA
Detlef Koschny	European Space Agency
Debbie Lewis	Creative Resilience Ltd.
Nahum Melamed	The Aerospace Corporation
Patrick Michel	Côte d'Azur Observatory
Paul Miller	Lawrence Livermore National Laboratory
David Morrison	NASA Lunar Science Institute
Marius Piso	Romanian Space Agency
Dorin Prunariu	Romanian Space Agency
Boris Shustov	Institute of Astronomy, Russian Academy of Sciences
Michael Simpson	Secure World Foundation
David Trilling	Northern Arizona University
Giovanni Valsecchi	IAPS - INAF
Karel van der Hucht	International Astronomical Union
Frans von der Dunk	University of Nebraska-Lincoln
Brian Weeden	Secure World Foundation
Bong Wie	Iowa State University
Don Yeomans	Manager, NASA Near Earth Object Program Scientist

Major Sponsors

The Aerospace Corporation
European Space Agency (ESA)
International Academy of Astronautics (IAA)
National Aeronautics and Space Administration (NASA)
Secure World Foundation

Other Sponsors

American Institute of Aeronautics and Astronautics (AIAA)
Association of Space Explorers
Astrium
B612 Foundation
Ball Aerospace & Technologies Corporation
GMV
International Astronomical Union (IAU)
Japan Aerospace Exploration Agency (JAXA)
The Johns Hopkins University/Applied Physics Laboratory (APL)
Lawrence Livermore National Laboratory
NEOShield
Northern Arizona University
The Planetary Society
Romanian Space Agency (ROSA)
Russian Federal Space Agency (ROSCOSMOS)
Space Generation Advisory Council
United Kingdom Space Agency
United Nations Office for Outer Space Affairs

ATTENDEES

Attachment C

Paul Abell
 Araba Molly Acquaisie
 Barbara Ailor
 William Ailor
 Robin Alford
 Lorie Allen
 Brent Archinal
 Robert Arentz
 Jacques Arnould
 Erik Asphaug
 Paul Aucoin
 Dave Baiocchi
 Janice Baker
 David Bancein
 Brent Barbee
 Nadine G Barlow
 Antonella Barucci
 Lance Benner
 Fabrizio Bernardi
 Edward Beshore
 Bruce Betts
 Eric Betz
 Shyam Bhaskaran
 Johanna Bible
 Linda Billings
 Mirel Birlan
 Daniel Boice
 Mark Boslough
 Roger Bourke
 Jessica Brown
 Peter Brown
 Marc Buie
 Brian Burt
 Brian Cahn
 Sergio Camacho
 Adriano Campo Bagatin
 Ian Carnelli
 Andrea Caroll
 Joseph Carroll
 Joe Carter
 Clark Chapman
 Andrew Cheng
 Steve Chesley
 Paul Chodas
 Eric Christensen
 Evgeny Chumachenko
 Anne Clasen
 Chuck Claver
 Ursula Collie
 Jean-Michel Contant
 Adam Contos
 William J Cooke
 Andy Court
 Marie-Agnes Courty
 Eric Dahlstrom
 Leonard David
 David Dearborn
 Andrew Deiters
 Richard Demers
 Benjamin Deniston
 Larry Denneau
 Eric Dieterle

Richard Dissly
 Olga Dobrovidova
 Alain Doressoundirama
 Line Drube
 David Dunham
 Steven Eckersley
 Siegfried Eggl
 Martin Elvis
 Davide Farnocchia
 Bret Fitzgerald
 Alan Fitzsimmons
 Jeff Foust
 Victoria Friedensen
 Louis Friedman
 Marcello Fulchignoni
 Roberto Furfaro
 Jose Luis Galache
 Andres Galvez
 Michele Gates
 Nick Genova
 Alison Gibbings
 Jesus Gil Fernandez
 Galen Gisler
 Mark Goergen
 Mikael Granvik
 Tommy Grav
 Mariella Graziano
 Simon Green
 Jim Green
 Jan Thimo Grundmann
 Eliot D. Hariton
 Alan Harris (US)
 Alan Harris (DLR)
 William K. Hartmann
 Matthew Hawkins
 Sonia Hernandez
 Daniel Hestroffer
 Emmanuel Hinglais
 Michaela Honkova
 Fabrice Hoss
 Kevin Housen
 Kirsten Howley
 Ricardo Hueso
 Gary Hughes
 Thomas Humpherys
 Albert Jackson
 Robert Jedicke
 Barbara Jennings
 Ulrich Johann
 Lindley Johnson
 Martin Jutzi
 Brian Kaplinger
 Alex Karl
 Laszlo Kestay
 Michal Kocer
 Detlef Koschny
 Shaunna Kosticov
 Pavel Krasnopolski
 David Kring
 George Kuch
 Vladimir Kulagin
 Hairong Lai

Damon Landau
 Rob Landis
 Stephen Larson
 Anton Ledkov
 Robert Lee
 David Lemarchand
 Daniel Levack
 Chris Lewicki
 Debbie Lewis
 Leviticus Lewis
 Roger Linfield
 Ed Lu
 Devin Lund
 Joshua Lyzhoft
 Claudio Maccone
 Alexander Macdonald
 Amy Mainzer
 Jean-Luc Margot
 Daniel D Mazanek
 Robert McMillan
 Nahum Melamed
 Henry Melosh
 Douglas Messier
 Patrick Michel
 Marco Micheli
 Jacob Miller
 Paul Miller
 Ron Mink
 Darrel Moon
 Dave Morrison
 Nicholas Moskovitz
 Naor Movshovitz
 Jonathan Myers
 Oana Neagu
 Charles Needham
 Jaime Nomen Torres
 Carrie Nugent
 Mike O'Hara
 Dagmara Oszkiewicz
 Steven Overton
 Norbert Pailer
 Davide Perna
 Lyrica Phelps
 Desmond Pilkington
 Marius-Ioan Piso
 Catherine Plesko
 Daniel Pless
 David Polishook
 Jean-Yves Prado
 Dumitru-Dorin Prunariu
 Margaret Race
 Cheryl L.B. Reed
 Harold Reitsema
 Henri Reme
 Carlos Roithmayr
 Jack Rozdilsky
 James Russell
 Eileen Ryan
 Noah Saks
 Agustin Sanchez Lavega
 Dan Scheeres
 Rusty Schweikart

Jianchun Shi
 Andrey Shugarov
 Boris Shustov
 Michael Simpson
 Tim Spahr
 Federica Spoto
 Kjell Stakkestad
 Thomas Statler
 Bringfried Stecklum
 Duncan Steel
 Joseph Stuart
 Yohei Sugimoto
 Gonzalo Tancredi
 Paolo Tanga
 Patrick Taylor
 David Tholen
 Rich Thoma
 Eric Thomas
 Jeff Thrasher
 William Thuillot
 Yang Tian
 Jana Ticha
 Milos Tichy
 John Tonry
 Richard Tremayne-Smith
 Ruth Tremayne-Smith
 John Troeltzsch
 Stephan Ulamec
 Giovanni Valsecchi
 Karel Van der Hucht
 Peter Veres
 Anne Virkki
 Joseph Wasem
 William Welser
 Jack White
 Bong Wie
 Olli Wilkman
 Ray Williamson
 Tim Winkler
 Wolfgang Wittholt
 Maria Womack
 Donald Yeomans
 Alan Zucksworth