Summary Report
2021 IAA Planetary Defense Conference

EXECUTIVE SUMMARY

The 2021 International Academy of Astronautics Planetary Defense Conference was held virtually on April 26 through 30, 2021 and was hosted by the United Nations Office of Outer Space Affairs (UNOOSA). The conference was sponsored by 13 organizations, over 900 individuals registered (there was no fee), and total attendance included over 700 individuals, with 250 to 300 individuals participating at any given time.

Since the conference was held virtually, it was possible to design the conference program so that individuals in nearly all parts of the world could attend. This plan enabled participation by individuals from 50 nations and 97 technical papers were presented.

This report provides a summary of activities at the conference and highlights the realistic but fictitious Asteroid Threat Exercise, which examined the threat mitigation and disaster management responses to a six-month warning of a potential asteroid impact on our planet.

A highlight of conference was a panel that included of representatives of seven national space agencies, the United Nations Office of Outer Space Affairs, UNOOSA, and two astronautical institutes. Panel discussions demonstrated their awareness and support of Planetary Defense activities.

A primary outcome of the conference was unanimous attendee support for an International Year of Planetary Defense (IYOPD) similar to the 2009 International Year of Astronomy. The 2029 close passage of Apophis is a natural opportunity to hold the event, raise awareness about the hazard, demystify the topic, and connect current and future communities.

In closing, the UNOOSA announced that it will again host the Planetary Defense Conference in 2023 and hopes that the 2023 conference will include in-person attendance at the UN facility in Vienna, Austria. Given the positive comments from attendees at the 2021 conference, it is likely that the 2023 conference will offer virtual attendance opportunities as well.

All session and threat exercise activities were recorded and are available at https://www.youtube.com/watch?v=cXp6WzsnL-g&list=PLaOqa4cng0GF56U0oJMKEjKfLXFBhuxBk&index=1

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OVERVIEW

The 2021 International Academy of Astronautics (IAA) Planetary Defense Conference, the 7th in the series of IAA planetary defense conferences, was a virtual conference hosted by the United Nations Office of Outer Space Affairs (UNOOSA) on April 26-30, 2021. UNOOSA provided support for the virtual aspects of the conference, and administrative support was provided by the European Space Agency. The conference was sponsored by the organizations below:

Association of Space Explorers
B612 Foundation
China Aerodynamics Research and Development Center
European Space Agency (ESA)
The Austrian Research Promotion Agency (FFG)
International Academy of Astronautics
International Association for the Advancement of Space Safety (IAASS)
National Aeronautics and Space Administration (NASA)
Secure World Foundation
Space Dynamics Services (SpaceDyS)
Space Generation Advisory Council (SGAC)
The Aerospace Corporation
The Planetary Society

The conference was organized by the 50-member Organizing Committee given in **Appendix A**, with active assistance from the local organizing committee led by Ms. Romana Kofler of UNOOSA and administrative support by Mr. Peter Kraan of ATPI, the ESA Conference Service Provider.

The virtual nature of the conference and using Vienna time as a basis allowed design of the conference program that could enable participation of presenters nearly worldwide. Table 1 shows the basic format used for each day of the conference and local times for major cities. Keynote speakers, the threat exercise (more on this later), and panel sessions that might be of global interest were included in the "green zone" in the program shown in the table. Technical sessions were held in the 2.5-hour time blocks before and after the Green Zone. The full program for the conference is given in **Appendix B**.

Registration for the conference was free, and nearly 900 individuals registered and over 650 individuals participated (**see Appendix C**), with between 250 and 350 connected at any given time. Figures 1 and 2 show the locations of participants and the number of people who registered from each location (note that the nationalities of registrants were not requested or provided for some, so the figures shown are not inclusive of all participants).

Table 1. Times for major conference activities.

UTC	Sydney	Tokyo	Vienna	DC	LA	
0945	1945	1845	11:45	0545	0245	**INTRODUCTION**
1000	2000	1900	12:00	0600	0300	**TECHNICAL SESSION**
1100	2100	2000	13:00	0700	0400	**BREAK**
1115	2115	2015	13:15	0715	0415	**TECHNICAL SESSION**
1215	2215	2115	14:15	0815	0515	**BREAK**
1230	2230	2130	14:30	0830	0530	**GREEN ZONE ACTIVITIES**
1545	0145	0045	17:45	1145	0845	**TECHNICAL SESSION**
1645	0245	0145	18:45	1245	0945	**BREAK**
1700	0300	0200	19:00	1300	1000	**TECHNICAL SESSION**
1800	0400	0300	20:00	1400	1100	**END**

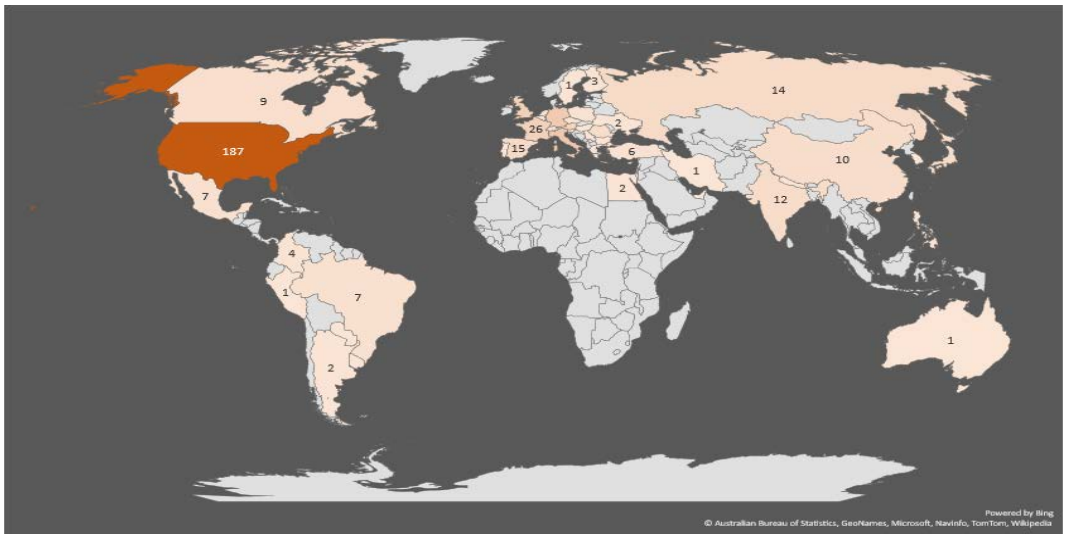


Figure 1. Map showing countries represented and the number of registrations from each country (not all registrants provided their nationality).

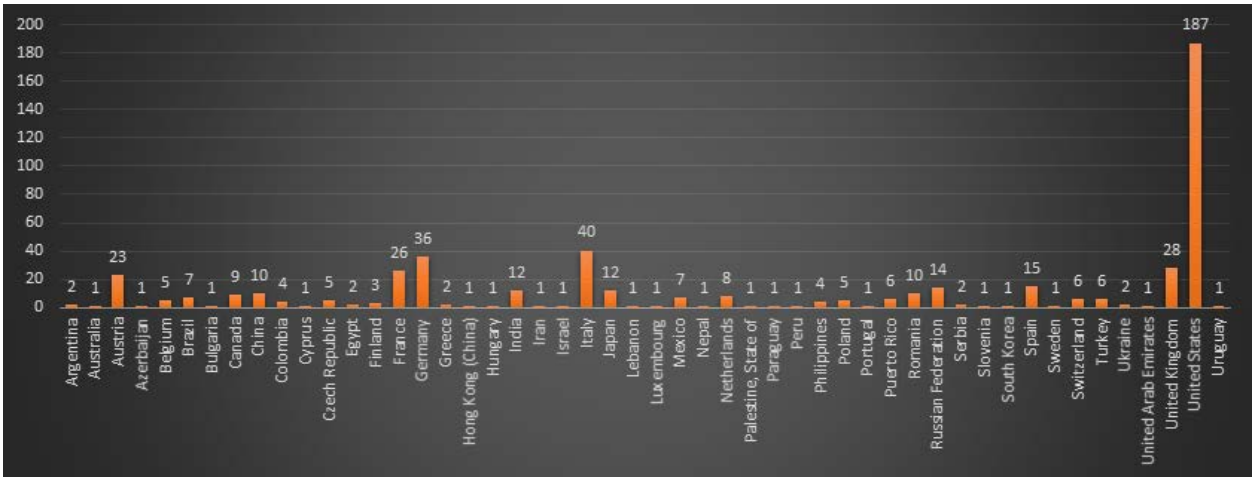


Figure 2. *Bar chart showing countries represented and the number of registrations from each country (not all registrants provided their nationality).*

The following sections provide brief summaries of material covered in each day of the 5-day conference.

DAY 1

DAY 1 GREEN ZONE ACTIVITIES

Welcoming Remarks and Keynote Addresses

Activities in the Day 1 Green Zone included opening remarks from William Ailor, conference chair, who introduced co-chairs Brent Barbee, Gerhard Drolshagen, Alex Karl, and Nahum Melamed, each of whom would chair a day of the conference. Ailor's remarks were followed by opening remarks by Romana Kofler of the United Nations Office of Outer Space Affairs (UNOOSA) and an overview of the International Academy of Astronautics (IAA) by Jean-Michel Contant, Secretary General of the IAA.

Welcoming remarks were followed by keynote addresses by: Simonetta Di Pippo, Director of the UN Office of Outer Space Affairs, and Marius Piso, Chair of the UN Committee on the Peaceful Uses of Outer Space (UN COPUOS).

ASTEROID THREAT EXERCISE

A highlight of the conference was the Asteroid Threat Exercise. As in several previous conferences, the purpose of the asteroid threat exercise for the 2021 conference was to acquaint conference participants and decision-makers with an asteroid threat representative of the type of threat that might be possible given limitations of current discovery capabilities.

On Day 1 conference participants were presented first notice that an asteroid (fictitious, but realistic) had just been discovered that posed a low probability of Earth impact in approximately six months. Should impact occur, impact could include somewhere in a region that covers 2/3 of Earth's surface as shown in Figure 1. The notice was the first of several that would follow as the conference proceeded. The exercise included presentations of details on discovery, mitigation options, and consequences of impact by experts in those areas, followed by panel discussions of next steps that should be taken to prepare for what was disclosed would be an impact.

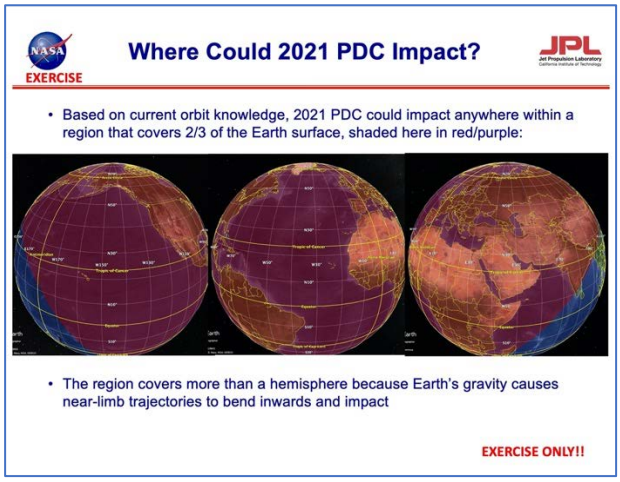


Figure 1. Possible impact locations for newly discovered (fictitious) object.

Updated details on the threat were presented in the Green Zone on the first three days of the conference, and information on each day was based on updated observational data on the threatening object and its orbit. Technical discussions on the feasibility of launching of mitigation or flyby reconnaissance missions and on possible impact locations and consequences preceded discussions by panel members on possible next steps. The exercise concluded on Day 3 with predictions showing the final impact location and date.

More information on the threat and related presentations and discussions are included in **Appendix D**.

DAY 1 SESSIONS

Session 1: ESA Hera mission: planetary defense and science return

Chairs:

Mariella Graziano
Monica Lazzarin
Richard Moissl

Session 1 included oral talks on ESA's Hera mission and its planned data collection efforts and experiments after its rendezvous with binary asteroid 65803 Didymos, four years after impact of NASA's Double Asteroid Redirect Test (DART) spacecraft in 2023 on DIdymos' moon Dimorphos. Hera will be the first spacecraft to orbit a binary asteroid, will deploy two CubeSats, collect information on the physical properties of both objects, and will characterize the impact crater left by DART and land a 6-U Cubesat on Dimorphos.

Session 2: Hayabusa 2

Chair:

Makoto Yoshikawa

JAXA's Hayabusa 2 mission was launched on December 3, 2014 and arrived at boulder-covered asteroid Ryugu on June 27, 2018. During its visit, the mission deployed small payloads, conducted and observed impact of a 2 kg impactor travelling at 2 km/sec via a small, deployable camera, and touched down twice and collected surface material. The mission collected 5.4 grams of material and returned to Earth on December 6, 2020.

Session 3: DART

Chairs:

Dawn Graninger

Andy Rivkin

The goal of NASA's Double Asteroid Redirection Test (DART) is to demonstrate asteroid deflection technology by using a 676-kg kinetic impactor to impact the 160-meter moon Dimorphos of asteroid 65803 Didymos. The impact velocity would be 6.6 km/sec, and the change in period would by measured by observations from Earth. The DART spacecraft will be launched between November 18, 2021, and February 15, 2022, and impact Dimorphos in late 2022. The impact will be observed by the Light Italian Cubesat for Imaging of Asteroids (LICIACube), which will be released from the DART spacecraft before impact, capture images of the impact plume and its evolution, and provide high-resolution images of the surface of Dimorphos.

Session 4: OSIRIS-Rex

Chairs:

Terik Daly

Christian Koeberl

The goal of the Origins, Spectral Interpretation, Resource Interpretation, Security, and Regolith Explorer (OSIRIS-REx) mission is to collect and return a sample of pristine carbonaceous asteroid regolith for analysis, provide ground truth for telescopic data of the entire asteroid population, map the chemistry and mineralogy of a primitive carbonaceous asteroid, measure the Yarkovsky effect on a potentially hazardous asteroid, and document the regolith at centimeter scale at a sampling site. The OSIRIS-REx spacecraft was launched in 2016, arrived at asteroid Bennu in 2018, conducted operations around Bennu, collected samples of the asteroid, and will return the collected samples to Earth in September 2023.

DAY 2

The general topics of Day 2 were NEO discovery and characterization. Session 5 addressed NEO Discovery, while presentations on NEO Characterization were given during Session 6. As was the case for the other

days of the conference, those sessions were split into two parts occurring before and after the midday 3-hour time block devoted to highlight events.

Day 2 GREEN ZONE ACTIVITIES

The highlight events on Day 2 included: a detailed Update on Space Mission Options for the hypothetical threat exercise; a panel discussion of Legal and Policy Issues Related to Mitigation Options; a panel discussion of Disruption & Deflection Options for the hypothetical threat exercise; and the second hypothetical threat exercise inject, which was an update regarding which regions on Earth were threatened by the hypothetical threat object.

PANEL: UPDATE ON SPACE MISSION OPTIONS

Panel Moderator:

Gerhard Drolshagen

Panelists:

Brent Barbee, Aerospace Engineer, NASA/Goddard Space Flight Center
Gerhard Drolshagen, Senior Expert, University Oldenburg

In this panel, SMPAG presented space mission options for the 2021 PDC hypothetical asteroid impact scenario. It was first noted that we do not currently have sufficiently rapid launch capabilities to deploy missions to such a short warning scenario in actuality. Such rapid launch capabilities are important for handling short warning scenarios, such as incoming comets and late detections of asteroids. Although sufficiently rapid launch would not be possible if the hypothetical scenario were real, mission analysis results were presented to show what could be possible if rapid launch were available.

Rendezvous missions are found to be impractical, but some flyby missions for reconnaissance or nuclear disruption could be deployed if extremely rapid launch were possible. However, the range of threat object sizes that could be disrupted is limited and uncertain. The uncertainty regarding the hypothetical threat object's properties make it difficult to define mitigation mission requirements or assess the likelihood of mitigation mission success. That said, deflection would not be practical due to the very short warning time, making robust disruption of the threat object the only practical in-space mitigation option.

Combining the nuclear disruption mission analysis with the Earth impact effects analysis reveals that deploying a nuclear disruption mission in this scenario, even with all the uncertainties, could significantly reduce the risk of impact damage. Similarly, deploying a flyby reconnaissance spacecraft even if a disruption mission is forgone would significantly reduce the uncertainties faced by disaster response planners.

Finally, it is noted that enhanced NEO detection systems such as NASA's NEO Surveyor space-based telescope currently under development, can prevent short warning scenarios in the first place. However, early NEO detection and rapid response spacecraft launch are both key capabilities for an effective planetary defense.

PANEL: LEGAL AND POLICY ISSUES RELATED TO MITIGATION OPTIONS

Panel Moderator:

Alissa J. Haddaji, Lecturer on Law - Space Law, Policy, and Ethics, Harvard Law School

Panelists:

David Koplow, Professor, Georgetown University Law Center
Alissa J. Haddaji, Lecturer on Law - Space Law, Policy, and Ethics, Harvard Law School
Irmgard Marboe, Professor, University of Vienna, Austria

D. Koplow discussed the legal aspects of using a nuclear device in space. After reviewing pertinent international treaties, he finds that the Outer Space Treaty prohibits placing nuclear weapons in Earth orbit, installing them on a celestial body, or stationing them in space; the Limited Test Ban Treaty prohibits any nuclear explosion in space; and Non-proliferation treaties prohibit giving non-nuclear-weapon states control over nuclear weapons and/or assisting, encouraging, or inducing the use of nuclear weapons.

A. Haddaji and I. Marboe both discussed legal aspects of Planetary Defense. A. Haddaji presented the conclusions of the SMPAG Legal Working Group Report, which was prepared by the SMPAG Ad-Hoc Working Group on Legal Issues, which has been operating since 2016 and providing international legal analyses and advice to SMPAG. It is important to note that the conclusions reported are preliminary and do not reflect the positions of national space agencies, ministries, or governments.

The preliminary conclusions include:

- Planetary defense missions must be carried out in accordance with international law
- Each party to the outer space treaty is responsible for the activities of its governmental and non-governmental entities
- Available information relevant to NEO impact prediction should be shared in good faith
- A state would be liable for knowingly releasing false NEO impact prediction information
- A state has a legal obligation to try to protect its territory and population
- A non-impacted state would not have a legal obligation to assist another state who is at risk
- Slow push/pull methods (such as gravity tractors) do not raise any legality issues under international law while using nuclear explosive devices (NEDs) in outer space is prohibited by the Outer Space Treaty and the limited test ban treaty,
- A state is absolutely liable for damage resulting from any space object it launches including insufficient NEO deflections that only shift the NEO impact location,
- Pertinent to planetary defense decision-making processes, the UN Security Council (UNSC has extraordinary power to supersede rules on international law with a nine out of fifteen vote by members and no opposing vote by one of the permanent five (P5) members of the UNSC.

I. Marboe discussed the obligation to inform and to act, liability, responsibility, and international decision-making. This presentation elaborated on and provided detail about many of the conclusions discussed by A. Haddaji. Additional conclusions and recommendations include potential future planetary defense missions need international cooperation and coordination, and instruments could be developed in advance to address problematic issues before action is needed. Such instruments could address issues including NEO impact threat information dissemination, elements of a mandate to carry out a planetary defense mission, draft agreements between potentially affected States and those conducting missions, modalities for cooperation and common procedures when undertaking missions, criteria for selecting and authorizing planetary defense methods, and liability considerations including waivers and modalities for compensating victims.

PANEL: DISRUPTION & DEFLECTION OPTIONS

Panel Moderator:

Alex Karl, Chair, IAF TC on NEOs

Panelists:

Brent Barbee, Aerospace Engineer, NASA/Goddard Space Flight Center
Gerhard Drolshagen, Senior Expert, University Oldenburg
Lindley Johnson, Planetary Defense Officer, NASA HQ - PDCO
Detlef Koschny, Acting Head, Planetary Defence Office, ESA

Panel members provided guidance on the use of space missions, possible use of a nuclear explosive device, messages to the public and UN Member States, known legal and policy issues, activation of disaster response agencies, and other related topics. The following are the key points made during the discussion.

- The matter of how decision-making would work during a planetary defense scenario was discussed, and it was pointed out that IAWN and SMPAG report to a subcommittee of COPUOS, then COPOUS reports to the General Assembly, and then from there it goes to the Security Council. However, when time is of the essence in a planetary defense scenario, the reports might have to go directly to the Security Council.
- IAWN and SMPAG are working continuously, even when a threat isn't present, to better understand the natural disaster of NEO impact and share that information as part of global efforts to become prepared for planetary defense.
- IAWN and SMPAG have ongoing responsibilities to work with space agencies and educate them about planetary defense, and to inform government leaders. That way, there is a basis upon which to build if a real situation occurs. That will help the Security Council reach decisions more quickly.
- Like UN-sponsored humanitarian missions, an international planetary defense campaign would be carried out by a coalition of the willing, i.e., those nations who are willing to address the problem, and the UN would charge that coalition with doing so. Those nations who volunteer would have the responsibility to fund their efforts.
- Regarding the liability associated with things going wrong during planetary defense mission attempts, the Security Council has the power to adjust how liability would be assigned, if warranted, e.g., when there is a significant threat to international peace and security.
- Planetary defense missions can be made reliable in the same ways as other interplanetary science missions, i.e., through robust systems engineering and design the spacecraft to be multi-fault tolerant. Additionally, multiple spacecraft can be launched to provide additional redundancy.
- Efforts such as the development of NASA's NEO Surveyor space-based telescope are underway to improve NEO survey systems to find Earth-impacting NEOs as early as possible. The technology to deploy more effective survey systems is available, and those systems are affordable. Discovering Earth-impacting NEOs farther in advance allows additional mitigation techniques to be considered besides nuclear devices, e.g., gravity tractors or kinetic impactors.
- Space agencies will communicate with the disaster response agencies early on, as soon as an NEO impact threat is known.
- If a nation were to launch a nuclear device for planetary defense without agreements to legalize that action, then the launching state could explain why they did so, e.g., that they had a serious need to defend themselves from the harm of impact, but other nations might not accept that. If the mission were successful in preventing harm from the NEO and caused no physical damage, then there wouldn't be any liability issues, but the unlawfulness of the action would remain. That could set a problematic precedent and so is to be avoided.
- If the nation that would be affected by an NEO impact is not a UN Member State, that affected nation could be invited to make their case to the Security Council, but they couldn't vote.
- Nuclear devices are intended to be used against NEOs when the NEOs are very far from Earth, e.g., several hundred million kilometers away. In those situations, the nuclear devices would have no effect on Earth. However, if there were a situation in which a nuclear device was intended to be deployed against an NEO when near the Earth, then the possible effects of the nuclear device on Earth-orbiting space assets would have to be considered.

- Launch safety would be of paramount importance were a nuclear device to be deployed on a planetary defense mission. Radioisotope Thermoelectric Generators (RTGs) have already been launched multiple times on interplanetary science missions, and the protocols used to ensure safety for those launches could serve as a starting point for developing procedures to ensure safe nuclear explosive device launch in a planetary defense scenario.
- SMPAG was established for international space agency collaboration on in-space mitigation missions, but SMPAG advises rather than making decisions. AIDA (DART, LICIACube, Hera) is an example of international collaboration for planetary defense technique testing happening now. SMPAG should be considering what to pursue after AIDA.
- Correct information must be published as often as possible during a planetary defense scenario, but the possibilities of people misunderstanding or being misled by other sources, e.g., social media, cannot be ruled out.

SECOND EXERCISE INJECT: UPDATE ON THE THREAT REGION

P. Chodas (CNEOS/JPL/CalTech), on behalf of IAWN, provided a brief update on the estimated regions where an impact of the hypothetical 2021 PDC object is possible. Precovery observations of 2021 PDC found in archival images taken seven years ago by the Pan-STARRS asteroid survey in Hawaii enabled more accurate predictions, establishing that the asteroid will impact in Europe or northern Africa on October 20, 2021, with 100% certainty. However, the asteroid's size and impact effects remain highly uncertain.

Day 2 SESSIONS

Session 5: NEO Discovery

Chairs:

Kelly Fast
Alan Harris

B. Shustov began the session with a discussion of the System of Observation of Daytime Asteroids (SODA), which describes a system of two space-based telescopes stationed in the vicinity of the Sun-Earth L1 Lagrangian point to detect incoming NEOs approaching from Earth's daytime sky direction. A request for funding for Phase A was submitted to ROSCOSMOS.

- S. Urakawa described COIAS (COmmon! Impacting ASteroid), which is a software system to be used for detecting asteroids in the Subaru Telescope's Hyper Suprime-Cam data and reporting the detection data to the Minor Planet Center (MPC). The software is intended to have public relations and educational applications as well. Development is ongoing but early tests appear promising.
- New NEODyS Tools were then discussed by F. Bernardi. The EU-funded NEOROCKS (NEO Rapid Observation, Characterization and Key Simulations) Project's primary goal is to minimize the time between an NEO's detection and when its orbit is known well enough for the collection of follow-up observations. The web-based tool set provides several different metrics, helps observers predict NEO locations in the sky and prioritize observation targets.
- L. Conversi discussed the ESA NEO Coordination Centre's observational network, which includes seven observatories and observatory networks that collected over 14000 NEO observations from 2019 to 2020. Their Test-Bed-Telescope 2 is being deployed in Chile and in preliminary tests has reached a limiting magnitude of 20.2 (21.0 with stacking). Their Flyeye 1 telescope, which will be a 1-meter class telescope whose field of view is split across 16 cameras, is currently in development. Installation of the Flyeye 1 telescope at its observatory site is expected to begin in late 2022 or early 2023.

Molotov concluded Session 5a with a presentation about asteroid survey and follow up observations with small telescopes in the framework of the International Scientific Optical Network (ISON). Some of the telescopes perform dedicated NEO survey observations while others detect NEOs as a byproduct of observing anthropogenic space debris. Some of the telescopes perform follow-up astrometric and photometric observations. The network includes 30 dedicated smaller telescopes (0.2 to 0.4 m) and agreements for time on 22 larger telescopes (0.5 to 2.6 meter). The network has produced over 1.2 million astrometric observations and discovered 17 NEOs, 1605 main-belt asteroids, and several other types of minor planets.

- L. Jones opened Session 5b with a description of the NEO discovery and characterization capabilities foreseen for the forthcoming Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST). The LSST survey strategy is being refined and the construction of the observatory and pipelines is ongoing. LSST is expected to be a significant resource for planetary defense and the discovery and study of NEOs and PHAs. Discovery of 50,000 to 100,000 NEOs with absolute magnitude less than or equal to 25 is anticipated.
- A. Mainzer discussed NEO detection and the future of Planetary Defense, describing the need to know when NEO impacts on Earth could occur and how damaging they would be. Towards those ends, NEOWISE data has revealed that nearly a third of NEOs are very dark (very low albedo). The NEO Surveyor space-based infrared telescope system, currently under development and on schedule to launch in 2026, is designed to find 2/3 of PHAs >140 m in size within 5 years. The combination of NEO Surveyor and the forthcoming LSST should be capable of bringing the NEO catalog to 90% completeness within 10 years of NEO Surveyor's launch, fulfilling the US Congressional mandate to NASA.
- F. Spoto then gave a presentation about the new MPC NEO Confirmation Page, which publishes NEA candidates in real-time to help facilitate rapid follow-up observations. Recent improvements include new weighting schemes, error models, and faster code. System tests recently demonstrated the ability to ingest multiple nights' worth of LSST data and produce orbit fits within only a couple of hours using several hundred CPU cores. Work is underway to implement flagging of suspected artificial objects on the NEO Confirmation Page.
- R. Weryk's presentation described NEOs in the isolated tracklet file and efforts to mine the large quantities of unlinked detection data, some of which is over 20 years old. Recent work has produced an "autolinker" software algorithm that has improved the efficiency of linking previously unlinked detections to produce ex post facto NEO discoveries. This has resulted in discovery of several NEOs from data in the isolated tracklet file that range in size from 200 m to 800 m and include 2 PHAs.
- The session concluded with a presentation by M. Kelley about the Comet Asteroid Telescopic Catalog Hub (CATCH), an online tool designed to quickly find asteroids and comets in wide-field time-domain survey data. A key application of the system is precovery from the millions of images produced annually by NEO survey telescopes. CATCH enjoys a substantial increase in efficiency through the use of Hilbert fractal curves. Future work plans include incorporating data from additional surveys and integration with the Minor Planet Center.

Session 6: NEO Characterization

Chairs:

Marina Brozovic, Solar System Dynamics, Jet Propulsion Laboratory
Stephen Lowry, University of Kent
Agata Rozek, Research Associate, University of Edinburgh

The first presentation of Session 6a was by P. Pravec, who described photometric observations of the binary near-Earth asteroid 1991 VH in support of NASA's JANUS mission. Observations and associated simulations indicate that the binary asteroid is in an unrelaxed state with a precessing inclined and eccentric orbit and non-synchronous rotation of the secondary body. However, the secondary spin period and orbit period do appear correlated, suggesting a spin-orbit interaction. More thorough simulations may produce a better understanding of the unrelaxed binary system.

- Next, J. de Leon described efforts to characterize NHATS near-Earth asteroids using the 10.4m Gran Telescopio Canarias. NASA's Near-Earth Object Human Space Flight Accessible Targets (NHATS) system identifies potentially mission-accessible asteroids as high priority targets for follow-up observations. The ongoing observing campaign at the Gran Telescopio Canarias to obtain visible spectra has thus far observed 24 NEAs, of which 59% are primitive and 41% are rocky. 83% of them are less than 100 m in size and some of them also have rotation periods less than 1 hour. Correlations between taxonomic type and diameter have not yet been detected.
- M. Fenucci then gave a presentation about the low thermal conductivity of the super-fast rotator NEA (499998) 2011 PT. Its thermal conductivity was estimated via fitting Yarkovsky effect observations to modeling equations and found to be low, which suggests that the NEA has regolith on its surface. This constitutes the first observational evidence supporting the hypothesis that fast-rotating NEAs can still retain regolith. The authors recommend further study and characterization of smaller NEAs less than 100 m in size to prepare for future deflection missions.
- A. Sergeyev talked about photometry of NEAs in the Sloan Digital Sky Survey. A million observations of 300,000 asteroids, including over 1,600 NEAs and 4,200 Mars-crossing asteroids, were used with new advanced photometry techniques to produce taxonomy results for 420 NEAs with associated probabilities, uncertainties, and linkages to source regions. The authors are considering applying their analysis techniques to data sets from other sky surveys.
- N. Moskovitz described the unique capabilities of the 4.3-m Lowell Discovery Telescope (LDT) for Planetary Defense. The LDT has performed NASA-funded NEO follow-up observations since 2019. Notable examples include providing high-quality astrometry for a virtual impactor at visual magnitude of 25.5, collecting spectroscopy data on Apophis, collecting photometry for the mini-moon 2020 CD3, and collecting photometry for the Didymos/Dimorphos binary NEA system that contributed to an improved estimate of its orbit. Finally, simulated performance of the LDT showed that LDT would be capable of constraining a wide range of orbital and physical characteristics of the 2021 PDC hypothetical threat scenario object during the six months between discovery and impact.
- J. Masiero gave the first presentation of Session 6b, in which he described characterization of NEAs from NEOWISE survey data. The NEOWISE space-based telescope offers a unique capability to provide thermal infrared (IR) observations of NEOs in support of Planetary Defense. NEOWISE is currently capable of estimating NEO diameters with ~30--40% accuracy. NEO albedos can also be derived by combining the NEOWISE IR observations with separate optical observations. NASA has requested that NEOWISE plan to continue surveying through June 2023. NEOWISE performance was simulated for the 2021 PDC hypothetical asteroid threat scenario. Special plans would have to be made for NEOWISE to observe the 2021 PDC hypothetical object and would result in a 3-sigma upper bound of 240 m for the object's diameter by early July of 2021 in the hypothetical scenario.
- M. Devogele discussed polarimetry as a tool for physical characterization of potentially hazardous asteroids. Polarimetry is a measurement of the linear polarization of sunlight scattered by an asteroid's surface, which can reduce uncertainty in the asteroid's albedo. That, in turn, can reduce

uncertainties in the asteroid's diameter considerably. Polarization relationships to albedos for both known asteroids and the simulated 2021 PDC hypothetical threat asteroid were shown. New observations are needed to improve our understanding of the relationship between polarization and albedo and having more polarimeters on large aperture telescopes would be helpful.

- V. Reddy outlined the challenges in differentiating between NEOs and rocket bodies in the context of the 2020 SO study. The object 2020 SO was discovered in September 2020 and temporarily captured by Earth's gravity in November 2020. It's very Earth-like orbit was linked to the Surveyor 2 Centaur rocket booster from the 1960s. Color observations of it were made with the Large Binocular Telescope (LBT) and near-infrared observations were made with the NASA Infrared Telescope Facility (IRTF). Those spectral observations of 2020 SO were consistent with similar observations made of known Centaur rocket bodies. This demonstrates the power of spectroscopy to differentiate between natural and artificial objects in near-Earth space, in this case with a relatively fast turnaround time of only about two weeks. However, space ageing/weather remains a challenge and the authors plan to attempt spectral mixing models when better end member lab spectra are available.
- D. Dunham discussed obtaining accurate NEO orbit estimates from occultation observations. The history of the International Occultation Timing Association (IOTA) was described, along with the nature of asteroid occultation observations, in which the shadow of an asteroid cast by a star is observed, providing information about the asteroid's orbit and shape. Successful occultation observations were described for Phaeton in 2019, verifying its radar size and shape, and for Apophis in 2021, improving estimates of Apophis' Yarkovsky acceleration. The authors recommend that students be taught to carry out mobile, multi-station occultation observations, as such observations could one day play a significant role in a real Planetary Defense scenario.
- Session 6b concluded with a presentation by J. Roa Vicens about a new method for asteroid impact monitoring and hazard assessment, which is the Sentry-II automatic impact monitoring system at the Jet Propulsion Laboratory (JPL). The first version of Sentry, Sentry-I, is based on the Line of Variations (LOV) technique. Sentry-II combines Monte Carlo techniques, an orbit determination filter extended with impact pseudo-observations, and importance sampling to estimate impact probabilities of virtual impactors. Sentry-II has been shadowing Sentry-I for several months, handles non-gravitational parameters systematically, is more robust than Sentry-I in pathological cases, and provides the nominal orbit and uncertainty of each virtual impactor, which is useful for negative observation campaigns.

DAY 3

Day 3 GREEN ZONE ACTIVITIES

Day 3 concluded consideration of the hypothetical asteroid impact threat exercise with the two final injects of the exercise and panels for disaster managers discussions and presentations of heads of space agencies. Information on the two final exercise injects can be found under the dedicated summary section for the PDC 2021 exercise.

EXERCISE SESSION: UPDATED THREAT CORRIDOR & DETAILED OVERVIEW OF CONSEQUENCES

Presenters

Paul Chodas, Manager of the NASA Near Earth Object Program Office
Lorien Wheeler, NASA Ames Research Center

As input for the panel sessions that followed, IAWN presented updated estimates of the region where an impact of the hypothetical 2021 PDC is possible, and experts presented detailed information on possible impact consequences within the potential impact region.

PANEL: DISASTER MANAGERS DISCUSSION

Goal of this panel: disaster response experts saw current best estimates of the region of possible impacts and best-available information on the possible consequences of an impact. Based on that input and discussions with experts, the Panel set directions for responses to the pending disaster.

Moderators:

Leviticus A Lewis, FEMA
Lorien Wheeler, NASA Ames Research Center

Panelists:

Shirish Ravan, Senior Programme Officer, Head of UN-SPIDER Beijing Office, UNOOSA
Tom De Groeve, Representative of COPERNICUS EMS; Deputy, European Commission Joint Research Centre, Disaster Risk Management Unit
Einar Bjorgo, Director, Satellite Analysis and Applied Research at United Nations Institute for Training and Research (UNITAR).
Jose Miguel Roncero Martin, Emergency Response Coordination Centre of the European Commission **(**ERCC)
Richard Moissl, ESA, Planetary Defence Office, Mitigation Coordinator

The panel had a lively and interactive discussion on questions like:

- How does the impact threat fit existing plans for disaster mitigation?
- Given the projected impact area, what plans should be made?
- What guidance should be given to members of the public within and bordering the region of possible impact?
- What are practices at the regional level?
- What are best practices at the national levels (action plans)?
- What are best practices at international levels?

PANEL: HEADS AND REPRESENTATIVES OF SPACE AGENCIES

Goal of this panel**:** Representatives of space agencies share their respective national plans in NEO discovery and mission planning and address cooperation with other space agencies in planetary defense. Addressed as well should be links to disaster management communities and links to decision-makers in case of a potential asteroid impact as well as any gaps in this area.

Panel Moderators:

Lindley Johnson, NASA PDCO
Detlef Koschny, ESA Planetary Defence Office

Panelists:

Simonetta Di Pippo, UNOOSA Director (welcome remarks)
Josef Aschbacher, ESA DG (video address)
Kuninaka Hitoshi, Vice President of JAXA and Director General, Institute of Space and Astronautical Science (video address)
Wu Yanhua, Vice-Administrator, China National Space Administration (CNSA) (video address)
Colonel Carlos Augusto Teixeira de Moura, President, Brazilian Space Agency (AEB)

Steve Jurczyk, Acting Administrator, US National Aeronautics and Space Administration (NASA)
Young Deuk Park, President, Korea Astronomy and Space Science Institute (KASI)
Rolf Densing, Director of Operations, European Space Agency (ESA)
Yoshikawa Makoto, Associate Professor of Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (JAXA)
Klaus Pseiner, Managing Director, Austrian Research Promotion Agency (FFG),
Julio Urdapilleta Castillo, Director of Space Security, Mexican Space Agency (AEM)

Meeting participants were very positively surprised by the large number of high-ranked panelists, who provided a video address or gave a live statement during this panel. It showed the awareness of leading Space Agencies to Planetary Defense Issues. All statements emphasized the importance of Planetary Defense and expressed support for future activities. The rather large number of statements given prevented a more detailed discussion, but this panel was clearly a major highlight of the PDC 2021.

Day 3 SESSIONS

The general topics of Day 3 were impact testing and mission planning. Session 7 addressed Deflection & Disruption Testing while presentations on Mission & Campaign Design were given during session 8. As usual the normal sessions were split into 2 parts before and after the dedicated 3-hour time zone with highlight events.

Session 7: Deflection & Disruption Testing

Chairs:
Patrick Michel
Angela Stickle
Megan Syal

The first presentation of **Session 7a** was given by S. Raducan and addressed the cratering processes on rubble-pile asteroids. SPH simulations of impacts into heterogeneous targets show great agreement with laboratory experiment results. It is concluded that the DART impact is likely to produce morphologies that are dissimilar to cratering and change the global morphology of the asteroid. Impact simulations on rubble-pile asteroids show that both the target morphology and the momentum transfer are affected by the distribution of surface boulders.

- R. Luther showed experimental benchmark results for comparison with the iSale and SPH hydrocode tools for a kinetic impactor. They have run validation tests in the Hera-relevant low strength regime for iSALE & SPH against experimental results for a regolith simulant, including measured values of β. It is found that both codes agree with independent experimental data in terms of diameter, ejection behavior and momentum enhancement.
- Orbital perturbation by the ejecta-collision driven reshaping of Didymos after the DART impact were analyzed by R. Nakano. Didymos is a ~780m dia. top-shaped asteroid, spinning at 2.26hr. It may be structurally sensitive to reshaping from even small perturbations resulting from ejects of the DART impact at Dimorphos. The presented analysis concludes that for a shape change of less than 40m, the reshaping-driven orbital period change is characterized to be linear. The orbital period should always become shorter than the original period for the head-on DART impact scenario.
- P. King and his team studied the late-time nuclear disruption for the hypothetical PDC 2021 scenario. Simulations were conducted with a spherical hydrocode for a 20% scaled model of

101255 Bennu (corresponds to 100-meter diameter). An explosion of a 1-MT device at 15-meter height-of-burst (65 meters from center) at the asteroid equator was assumed. Reported main results were: The nominal disruption model can disrupt the impactor efficiently enough to result in only 1% impacting mass by two weeks. The deflection direction appears to have a modest effect; the strongest performing direction is the radial direction, and the weakest is the ecliptic direction.

- N. Gentile gave an overview of numerical radiation transport techniques in asteroid deflection modelling. Photon transport is necessary to accurately model deflection scenarios using x-ray deposition. Two methods are assessed in more detail: Implicit Monte Carlo (IMC) simulates radiation by computational particles with randomly selected emission positions and directions. S_N or Discrete Ordinates represents the intensity at fixed angles using finite element basis functions in each zone. Pros and cons of both methods are analyzed. The IMC method is finally selected. It is stated that radiation hydrodynamics calculations in 1 and 2D are presently running.
- M. Burkey opened **Session 7b** with a presentation on "Progress on Developing a Simplified Model of X-Ray Energy Deposition for Nuclear Mitigation Missions". A successful mitigation mission could be achieved by either deflection, where the asteroid remains intact and misses Earth, or by disruption where the asteroid is blasted into many small, fast-moving fragments. However, a failure is possible as well: the asteroid breaks into slow-moving fragments that could hit Earth. The presented novel analytic deposition model is progressing quickly and shows promise. It is mentioned that the Planetary Defense community can use the model to explore the vast space of potential scenarios and uncertainties more efficiently.
- Stickle presented results of a working group addressing the DART impact inverse test modelling. Inverse problems can provide information about parameters that we cannot directly observe. One goal is to determine the model parameters that best fit a given deflection observation. Questions to be answered include: What is the expected uncertainty on β estimates following the DART impact from simulations? How do target property choices affect the predicted values? How well can the impact scenario be recreated from limited information? How long do these simulations take to provide answers and how many different simulations need to be run?
- In the related next presentation C. Raskin gave a talk on ´Accelerated Root Finding for the DART Inverse Test Using Machine Learning Decision Trees´. The presented DART inverse test is based on a triaxial, rocky body, a uniform, constant density, and no porosity. The mass of the spherical impactor is 570 kg and the impact is head on. The machine learning algorithm is used at various levels of refinement to obtain a fit to the observations. One result of the exercise is that the synthetic observations are most consistent with a uniform, non-porous, single-density body with $\rho \approx 2.79{-}2.83$ g/cc.
- M. DeCoster addressed the question of projectile geometry effects on momentum enhancement during hypervelocity impacts. Hydrocode simulations were carried out for different projectile shapes like a sphere, a simple spacecraft model and a more realistic model of DART composed of 10 different materials. The 3D DART spacecraft model produces ~3x less ejecta mass than the sphere. The results suggest that a fully dense Al sphere projectile excessively over predicts β for the DART intercept event.
- In the last talk of this session M. Owen studied spacecraft geometry effects on cratering and deflection in the DART mission. The presented work is an extension and improvement of a study presented at the PDC 2019. Simulations are performed with different hydrocodes and with CAD models of DART with several levels of complexity. Analyzed parameters include the crater size

and shape, the ejecta velocities and the momentum enhancement factor. It is found that all these parameters are influenced by the geometry of the CAD model of DART.

Session 8: Mission and Campaign Design

Chairs:

Marco Tantardini
George Vardaxis
Andy Cheng

The first talk of this session was given by Yirui Wang on ´Assembled Kinetic Impactor for Deflecting Asteroids via Combining the Spacecraft with the Launch Vehicle Upper Stage´. The basic concept of such an assembled kinetic impactor (AKI) is to use the upper stage of the launcher as an additional payload to improve the mass of the impactor. As examples the upper stage of the Long March 5 with a dry mass of 6.5 t are used in combination with a normal kinetic impactor for deflecting Bennu and a fictitious NEO of 140 m. It is shown that the AKI concept can greatly improve the deflection efficiency or reduce the launch cost if several launches are required.

- In the next talk, A. Herique introduced JuRa: the Juventas Radar on Hera to fathom Didymoon. JuRa is a monostatic tomographic Synthetic Aperture Radar operating at 60 MHz for backscattering coefficient mapping. The radar should be able to penetrate several tens of meters or even the whole object. Main objectives of JuRa are to analyze the moonlet interior structures and to study the average permittivity and its spatial variation. A secondary objective is to apply the same characterization to the main body.

- G. Di Girolamo presented ESA'S Planetary Defence NEO Coordination Centre DevOps Model Based Operations. First, he gave an overview of the development and operation heterogeneity. The variety of required different activities include software development, Service Level Agreements for data sharing/acquisition, consultancy cooperation with external scientist and many others. The complex DevOps environment includes development, testing and operation of software and the underlying IT infrastructure. The NEO operation complexity requires sometimes hectic interaction with software and data. In future increased functionality, data volume and heterogeneity of tools is expected.

- In the 4th talk of this session P. Tortora gave an overview of Hera radio science experiments through ground-based and satellite-to-satellite Doppler tracking. The objectives of the Hera Gravity Science Experiment are: Measure the asteroids' gravity to constrain their interior structure, characterize the post-impact mutual orbit and rotational states, estimate physical parameters by reconstructing the trajectory of Hera and the Cubesats released by Hera. From the simulations it is concluded that the Hera gravity science experiment at Didymos is feasible, using realistic assumptions on the technological capabilities of the space and ground segment.

- A. Falke presented an assessment of the feasibility of modifying a commercial spacecraft platform to perform asteroid kinetic deflection in the shortest possible time. As example he used a potential NEO impact about 3 years from its detection. It is concluded that such a Fast Kinetic Deflection mission (with 6 months launch readiness) for short warning time asteroid threats is feasible. The study of this FastKD activity identified the pre-requisites needed and required modification activities to "hijack" and re-purpose a commercial telecoms platform.

- The first presentation of the second part of this session on Mission & Campaign Design (8b) was given by D. Perna. He presented the planned Cubesat mission: Asteroid Nodal Intersection Multiple Encounters (ANIME). Main objectives of ANIME are to visit multi-targets including

ultra-small asteroids. The ANIME concept was developed in response to the ASI call for "Future CubeSat missions" and it successfully passed the technical and scientific screening.

- Another small class mission, called Janus, was presented by D. Scheeres. Janus is a dual spacecraft NASA SIMPLEx mission to explore two NEO Binary Asteroids. Janus could provide the first high resolution, scientific observations of NEO binary asteroid systems that have significant diversity. It can provide insight into the mechanics of rubble pile bodies, and into microgravity geophysical processes in general. In addition, Janus defines a new S/C and mission profile that can provide a responsive scientific and planetary defense capability for NEO characterization.
- In the next talk S. Sonnett provided detailed information on the planned survey regions and pattern of the upcoming NEO survey space mission. Simulations show that ~75% of NEOs ≥ 140 meters in diameter could be observed in the first 5 years, and ~85% within 10 years. The total number of observed objects by the NEO Survey Mission could reach 300,000 NEOs, 10,000 comets and millions of Main Belt Asteroids.
- B. Barbee presented an analysis of a risk-informed spacecraft mission design for the 2021 PDC hypothetical asteroid threat. This risk informed mission design considers NEO properties uncertainties and the mitigation mission performance. It addresses the level of damage reduction of a space mission and the potential benefits of just a reconnaissance mission. For the hypothetical NEO 2021 PDC deploying a nuclear disruption mission appears to be the only realistic mitigation possibility (if launch were possible). Should a nuclear disruption attempt be foregone, it is recommended to at least deploy a flyby reconnaissance spacecraft because the data it would provide about the asteroid's properties would significantly reduce the uncertainties faced by disaster response planners.
- The last oral presentation of this session is given by J. Bell on an initiative of the MILO Space Science Institute to enable new, science-focused Deep Space Smallsat missions to Near Earth Objects. Two proposed Smallsat missions are presented in more detail: Apophis Pathfinder uses a pair of small spacecraft to perform the first ever close flyby of the 370-meter diameter NEO (99942) Apophis, before that body's extremely close flyby of Earth in 2029. The second mission, NEOShare, will launch a cluster of six Smallsats that will each perform a close flyby of a different NEO close to Earth. Interested parties are invited to contact MILO to get involved.

DAY 4

Day 4 GREEN ZONE ACTIVITIES

PANEL: RELIABLE COMMUNICATION AND DEALING WITH MISINFORMATION

Goal of this panel: Offer insights to the planetary defense community on challenges in science and risk communication relating to planetary defense.

Panel Moderator:

Linda Billings, Ph.D., consultant to NASA's Planetary Defense Coordination Office

Panelists:

Lea Nagel, MSc, graduate student, Department of Communication, University of Vienna

Katherine E. Rowan, PhD, Professor Emerita, Department of Communication, George Mason University, Fairfax, VA, USA

Sarah Scoles, freelance science writer, contributing writer at WIRED Science, contributing editor at Popular Science.

The panel had an interesting and insightful discussion on questions such as:

- How to deal with misinformation.
- How to establish who and what are reliable sources of information.
- How to discuss probabilities in a way that is understandable to non-statisticians.
- The role of storytelling in effective communications.
- Warning messages: what works, what doesn't, and why.

The panel was accompanied by a very active discussion on the chat among the conference participants. Some key takeaways were:

- Clear, concise, correct, consistent, timely communication can be done, but it requires planning.
- It is important to listen to the affected population and to acknowledge any fears
- Resources with good information as well as availability of experts are important for journalists and translation will be crucial to cover large regions of the world.
- Involving more communication experts as well as interdisciplinary communication will benefit future efforts to prepare good communication strategies and products.

PANEL: LESSONS LEARNED FROM PAST DISASTERS: RECOMMENDATIONS FOR A REAL NEO THREAT

Goal of this panel: Discuss how responses to past low-likelihood, high-consequence disasters might inform actions should a real NEO threat be discovered.

Moderators:

LA. Lewis, FEMA

Shirish Ravan, UN-SPIDER

Panelists:

Shirish Ravan, Senior Programme Officer, Head of UN-SPIDER Beijing Office, UNOOSA

L.A. Lewis, FEMA Joint Operations Advisor, DHS JIAG

Einar Bjorgo, Director, Satellite Analysis and Applied Research at United Nations Institute for Training and Research (UNITAR).

David Schuld, Deputy Director of Preparedness Programs, Hagerty Consultants-Disaster Management Consultants

Katherine Rowan, Professor Emerita, George Mason University

Lara Mani, Research Associate- Cambridge University-Centre for Study of Existential Risk (CSER)

Topics discussed were:

- What has the COVID-19 experience taught us about how the public and decision makers might respond to an impact threat?
- Is there relevant experience from planning for and responses to hurricanes, earthquakes, tsunamis, and other natural disasters?

- Is there relevant experience from disasters at man-made equipment (e.g., nuclear power plants, chemical plants, oil/gas facilities)?
- How has the public reacted in case of past disasters?

Key takeaways were:

- Much can be learned from countries and communities who have already experienced and dealt with a disaster.
- It is important to not forget lessons learned.
- Different disaster response services need to practice and work together.
- Exercises are important; the next step is to actively involve decision makers.
- A Chief Risk Officer position was suggested as part of a standing group to give advice to changing governments on long term risk.
- Governments need to follow through on recommendations by experts for preparations to respond.
- There is currently a lack of incentive and lack of accountability.
- There is not one public, there are many different publics.
- Vulnerable people need to be included in evacuation plans to avoid situations where only people with resources can evacuate.
- It was suggested that risk and responses be localized so communities can better respond.

SPECIAL EVENT: EARTHLINGS VS ASTEROIDS: WHAT'S THE SCORE?

A special virtual event (open to the public) was hosted by **The Planetary Society** and held on April 29, 2021. The session focused on the state of humanity's planetary defense efforts.

Moderator:

Mat Kaplan, The Planetary Society

Panelists:

Kelly Fast, Program Manager for the Near-Earth Object Observations Program in NASA's Planetary Defense Coordination Office

Gerhard Drolshagen, Chair of the Space Mission Planning Advisory Group, University of Oldenburg

Paul Chodas, Manager of the NASA Near Earth Object Program Office

Masaki Fujimoto, Deputy Director General of JAXA's Institute of Space and Astronautical Science (ISAS)

Nancy Chabot, Coordination Lead for the Double Asteroid Redirection Test (DART), Johns Hopkins University Applied Physics Lab

Bruce Betts, Chief Scientist for The Planetary Society

Watch the event here: https://www.youtube.com/watch?v=WqxJQ8vb4Ng&feature=emb_imp_woyt

Day 4 SESSIONS

Session 9: Impact Effects

Chairs:

Michael Aftosmis
Mark Boslough
Jessie Dotson

David Morrison

Olga Popova

The first talk of this session was given by Anna Losiak on 'Studying Bodies of Organisms Killed by an Asteroid: Environmental Effects of Very Small Crater Formation'. She presented the analysis of impact charcoal of two small craters and the environmental conditions present to form it.

- Next was Sun Haihao's presentation 'The Melting Ablation Analysis of Meteorites in High Temperature Flow' in which he presented experimental results on mechanism and ablation of meteoroids.
- Siyao Su's presented the 'Numerical Analysis of Aerodynamic Heating on Asteroid During Entry to Earth's Atmosphere' and the results obtained.
- Dmitry Glazachev introduced the 'Impact Effects Calculator' and applied it for shock wave effects on Tunguska, Chelyabinsk and PDC2021 cases.
- Olga Popova used the 'Impact Effects Calculator' to study thermal radiation and other effects of the same cases as in the previous presentation.
- The first presentation of the second part of this session on Impact Effects (9b) was given by Jason Pearl. He presented 'SPH Simulation of Atmospheric Effects on Bolide Entry' using PDC2021 as example to model its atmospheric entry.
- Next was Marsha Berger who presented 'Towards Adaptive Simulation of Dispersive Tsunami Propagation from an Asteroid Impact' by combining different models on a test case.
- Timothy Titus presented 'Asteroid Impacts – Downwind and Downstream effects' to investigate possible effects displaced in distance and time from the initial impact.
- Cem Berk Senel presented 'Environmental Consequences of Asteroid Impacts by GCM Simulations' by focusing on the long-term potential effects of impact-induced aerosols.
- Then Jessie Dotson presented 'Bayesian Inference of Asteroid Physical Properties: Application to Impact Scenarios' which can be used to constrain the range of likely impactor properties and thereby reduce the uncertainty in modelling results.

Session 10: Disaster Management

Chair:

Leviticus A Lewis

Session 10 started with Deepak Chandra Chandola presenting 'Key Aspects of Disaster Management' in which he identified the main pillars of disaster management and encouraged collaboration among all involved stakeholders.

- Next, Jonathan Lim advocated for 'A Human Rights Based Approach to Disaster Management and Response'.
- Akanksha Marwah outlined 'Prevention, Mitigation and Preparedness for Disasters – Role of UN COPUOS in Disaster Management and Indian Progress' and suggested steps as way forward.
- Ana Lucia Pegetti researched existing mechanisms of information exchange related to NEO disaster risk management and suggested a communication protocol for the case of Brazil in 'Communication Protocol on PHO for Disaster Management by Legitimate Brazilian Institutions'.
- The first presentation of the second part of this session on Disaster Management (10b) was given by Jagannatha Venkataramaiah. He presented 'Real-Time Community Enabling to Care for Planetary Disaster Risk Reduction' to teach students about Planetary Defense and Disaster Management to empower communities to be aware of the topic and come up with creative responses for disaster risk reduction.

- Rudolf Albrecht presented 'Towards Plans for Mitigating Possible Socio-Economic Effects due to a Physical Impact of an Asteroid on Earth' and attempted to quantify the socio-economic effects, not only because of an asteroid impact but also due to the uncertainty before the actual impact. He concluded by suggesting mitigation strategies to prepare for such scenarios.
- Tomas Kohout talked about the 'Rapid Evacuation of the Viipuri (Vyborg City – Experience from the Finnish Winter War 1939-1940', during which all 86.000 inhabitants had to be evacuated within one week during winter. Evacuation details and logistical choices were examined, leading to the presentation of lessons learned for similar evacuations during an asteroid impact threat scenario.

DAY 5

Day 5 GREEN ZONE ACTIVITIES

Activities in the Day 5 Green Zone included panel discussion on proposal for creation of an **International Year of Planetary Defense**, a conference wrap-up discussion, next steps, and recommendations for the 2023 conference.

PANEL: PROPOSAL FOR AN INTERNATIONAL YEAR OF PLANETARY DEFENSE (IYOPD)

Moderator:

Doris Daou

Panelists:

Sergio Camacho
Catherne Cesarsky
Kevin Govender
Romana Kofler
Pedro Russo

The panel first discussed the background of the 2009 **International Year of Astronomy** that celebrated 400 years of astronomy.

- Planning for the 2009 year-long event started in 2003 and was a collaboration between the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Astronomical Union (IAU) involving 148 countries, 40 international organizations, and 28 global projects. It was considered the largest network in science at the time with an outreach of 815 million people worldwide.
- A coordination office was established in 2007, over a year before the event, to prepare implementing the program.
- The main ingredients contributing to the success of the event were a great idea, a strong case, a UN Body recommendation, a UN Proclamation, Global participation, exciting activities (global, regional, national, and local), and enthusiasm, engagements, and excitement at all levels. Funding was problematic in some countries.
- Event execution and coordination succeeded by defining common goals and branding, supporting national and local activities, creating a central coordination framework for people to work with and share resources, and providing seed funding.
- Country-by-country event findings are available in a final report available on the event website.
- A strategic plan was prepared to maintain continuity and link the technological, cultural, and societal aspects of the astronomy field in the decade after the event.

- Four regional offices were established recently under the auspices of the IAU in Japan, South Africa, Germany, and Norway to capture lessons learned and maintain the legacy of the project, inspire STEM education, and coordinate and sustain the momentum through the 2020-2030 decade. The Italian delegation to UNESCO initiated the project and prepared the proposal
- The UN then applied established criteria and guidelines for proposing international events.

Since the two areas are similar in nature and share the goal of global participation, the protocols followed, budget sources, management, networks, activities, and communities created for the international year of astronomy can be activated and leveraged for implementing an International Year of Planetary Defense.

Proposals for a UN-designated international year can be brought up by a UN member state or a group of member states. For a proposal for an International Year of Planetary Defense to be considered, it should demonstrate to UN COPUOS and the UN General Assembly its global scope and local benefits. It was concluded that the Planetary Defense Conference is a fitting entity that should be represented in the proposal and should participate in the organization and declaration of the International Year of Planetary Defense.

The 2029 close passage of Apophis is a natural opportunity to hold the event, raise awareness about the hazard, demystify the topic, and connect current and future communities. To advance the project, it is critical that active advocacy and local lobbying by the planetary defense membership identify stakeholders and communicate the message. The global trusted source of information should be the International Asteroid Warning Network (IAWN), in addition to a national trusted source in each country in the local language.

DAY 5 SESSIONS

Session 11: The Decision to Act

Chairs:

Alissa Haddaji
Rudi Albrecht

Discussion topics included:

- The **Good Samaritan Principle** as it relates to liability waivers associated with Planetary Defense Missions. Differences in liability versus responsibility in international law may apply to consequences of a planetary defense mission going wrong. Hence, the Good Samaritan Principle in domestic law is proposed as an alternative to liability exoneration and waivers for planetary defense missions that may require the creation of new international treaties.
- **Application of the international *jus cogens* norm in Law of Treaties** was proposed to establish an obligation to participate in Planetary Defense. It was argued that Planetary Defense obligations meet all the *jus cogens* criterions, and UN Charter provisions were formed with the aim to compel international participation in the Planetary Defense action. Because planetary defense actions affecting the territory and population under the jurisdiction of another state would be contrary to international law, it was argued that a state's right and obligation to react to an impact threat to protect its territory and population are exceptional circumstances justifying non-compliance with the law when authorized by a time-limited resolution of the UN Security Council.
- A proposed **multi-stage entrepreneurial Planetary Defense policy framework** sought to overcome an imperfect cost-benefit balance associated with the low likelihood/high consequence nature of the NEO hazard. The current majoritarian policy approach to mitigation

is limited in effectivity due to a collective action problem while the absence of concentrated benefits discourages investment. The Wilson-Lowi Matrix was employed to describe steps and tools for moving away from the majoritarian status quo via constituency-building and concentration of benefits to raise policy support, or alternatively, via coalition-building through dispersed costs to assuage potential budget-minded opposition.

- **Lessons learned in natural disaster management** increase our understanding of social-anthropological aspects of an asteroid impact threat and assist with overcoming social challenges such as social inequalities, resistance to displacement, and loss of faith. These apprehensions can be alleviated by attaining a good grasp of how the three main Socio-Anthropological attitudes associated with natural disasters: optimism, pessimism, and fatalism, may apply to the asteroid threat.
- Some of the challenges facing Planetary Defense come from recognizing that very rare events by their nature defy generational memory, and the means to fight them and adapt to them tend to fade over the centuries. This deficiency could be alleviated by educating populations on the topic of Planetary Defense through **joint academic research projects** that could help prevent the mental shock associated with unpredictable low probability, high consequence events. Any intervention that would be taken, which could be multinational, should be locally rooted because top-down-only systems tend to be poorly adapted to local needs or do not know or take into consideration local practices.
- **Preemptive deflections** are precautionary Planetary Defense means and thresholds that could involve multiple state and non-state actors. Aspects considered include proactive establishment of threshold level for moving a hazardous asteroid, management of deep space traffic, and addressing the possibility of mission failures. It important to understand the motivation and jurisdiction of nonstate actors to become involved, and the potential conflict between restraint and active management that may arise by such activities.
- **ESA's Planetary Defence Office** roles and goals include situational awareness, impact and consequence prediction, and technological and political preparation for risk mitigation. The NEO Coordination Center is part of the European center of excellence for exploitation of Earth observation missions in Frascati, Italy, which distributes information on orbits and physical properties via web-portal risk list and close encounter fact sheets and participates in Space Mission Planning Advisory Group (SMPAG) mitigation planning.
- **Space Mission Planning Advisory Group (SMPAG)** is a technical/scientific advisory group formed to prepare international NEO threat mitigation planning and activities by exchange of information and collaborative research on options and mission opportunities. SMPAG was endorsed by the UN in 2013 and it was officially established in 2014. Its activities and status are described in a published workplan that includes criteria and thresholds for impact threat response actions and nuclear device mitigation options. SMPAG performs exercises and workshops and recommends conducting demonstration missions.

Session 12: Public Education & Communication

Chairs:

Linda Billings
Alissa Haddaji
Alex Karl

Presenters discussed:

- **Inspiring the next generation of scientists and engineers** through investigation of world-class problems beyond their immediate environment is an Aerospace Corporation K-12 outreach

initiative. Activities include classroom visits, online tutoring, and virtual mentoring to provide cost-free experiences for students and schools. These activities utilize the NEO Deflection App, a physics-based web application developed jointly by NASA's Jet Propulsion Laboratory and The Aerospace Corporation to estimate deflection impulses imparted to simulated Near Earth Objects on a collision course with Earth. Aerospace has implemented collaborative educational teaming context in the App that is applied in asteroid deflection exercises. In those workshops, teachers, students, or public participants are grouped into teams and competitively solve an increasingly challenging hypothetical asteroid deflection scenario.

- The COVID-19 school lockdown presented an opportunity to **create a roadmap for youth-led do-it-yourself asteroid astrometry** and reach out to kids, families, and citizen scientists by remotely training them on a mix of telescopes, equipment, and techniques. Images taken by the 2-meter Faulkes Telescope South in Australia were able to locate Apophis twice and calculate its motion.
- A **5-tier close approach frequency index** is proposed to evaluate the relative importance of a close approach and communicate objective risk information to the public and the media. The proposed index expands from estimation of impact frequency alone by using the asteroid's absolute magnitude and close approach data based on current NEO population models. The method yielded five infrequent events and one rare event in one year and classified the Apophis close approach in 2029 as a very rare event.
- The **Space Generation Advisory Council (SGAC)**, a global non-governmental, non-profit organization and network that represents university students and young space professionals ages 18-35 to the United Nations, space agencies, industry, and academia. The group provides a youth perspective to planetary defense through annual reports, competitions, and public outreach projects related to Near Earth Objects. Activities include webinars, a "Find an Asteroid" campaign, a "Move an Asteroid" challenge, a NEO renaissance initiative, collaboration with technical committees, and participation in international conferences. SGAC has a permanent observer status at United Nations Committee on the Peaceful Uses of Outer Space.
- A **special interactive session** organized at the 70th International Astronautical Congress titled "Get ready to protect Earth from asteroids – Planetary Defense in your hands" aimed to inform and educate and engage the IAC audience about and derive feedback and insights from a PDC 2019 based simulated exercise scenario. Audience Polling suggested that risk perception should be considered in communications with the public and the potential effects of asteroid warnings on mental health should be considered and addressed. Most of the audience favored preparing in advance to act, although the use of nuclear explosive devices was controversial.
- **Public engagement and outreach in Italy** involve observations of near-Earth asteroids at the Astronomical Observatory of Castelgrande. Activities include interviews with regional and national media, publications in local daily newspapers, participation in Asteroid Day 2020, and conducting lectures for visitor groups at the observatory.
- **Recommendations formed from communication experiences with the public** during the COVID-19 Pandemic advocate being apolitical in an asteroid scenario, presenting a single, simple message, showing graphics rather than words, and using frequencies to explain the threat instead of percentages. It is advised to establish working relationships with social media companies in advance and monitor their activities to fight misinformation, and exercise caution when asking the public to make long-term sacrifices.

Session 13: Apophis and Others, Far and Near: Future Characterization Opportunities from NEO Close Approaches

Chairs:

Gerbs Bauer
Larry Denneau
Michaela Blain

Six oral talks on Apophis and other characterization opportunities associated with NEO Close Approaches discussed:

- **Frequencies of observed close encounters** for Apophis-scale objects have much lower rates than models predict. This apparent disagreement between theory and observations associated with the smaller NEOs is not well understood and may be traced to observational biases. Specifically, the Apophis encounter in 2029 appears to be a once-in-20,000-yr event based on observations versus a predicted frequency of Apophis-like encounters of once per 1000 years.
- The International Asteroid Warning Network (IAWN), with participation of international amateur astronomers, has led a **planetary defense campaign involving 99942 Apophis' close approach** by the Earth on 6 March 2021 to exercise the Planetary Defense System ranging from observations to impact modeling and prediction, and communication.
- **Minimized trailing of reference stars** accomplished from short exposure observations of asteroid (99942) Apophis with the Subaru telescope detected Yarkovsky acceleration corresponding to a semimajor axis drift of about -170 meters per year. The new results shifted the probability distribution peak a little farther away from the 2068 keyhole and refined the impact probability in five other impact scenarios through 2121, eliminating the impact risk by the asteroid over the next century.
- **An intercept and rendezvous mission lasting less than a month with Apophis on the incoming leg** a few days before its Earth flyby in April 2029 with a possible sample return option is proposed to characterize its interior, a feat not achievable from purely terrestrial remote observations. This characterization mission would provide essential data and experience for mitigation planning of this potentially hazardous asteroid should it become necessary in the distant future. Additionally, information provided in the proposed mission could be generalized to develop defense from other PHAs.
- **Potentially hazardous asteroid 153814 (2001 WN5) will make a very close flyby of Earth** within the orbit of the Moon on June 26, 2028. Because this close approach occurs one year prior to the extremely close Earth flyby of 99942 Apophis on April 13, 2029, asteroid 153814 is of interest as a possible rehearsal target for an Apophis radar and infrared based observation campaign.
- **An estimate the mass and some physical and orbital parameters** of an asteroid or a comet is proposed by measuring the modification in a spacecraft trajectory caused by gravitational interaction between the two objects during a flyby. A promising example of this approach is the Spectrum-Roentgen-Gamma mission which could be extended by using propellant left in tanks of the spacecraft after the main mission to redirect it away from a bounded orbit around a Sun-Earth libation point to a close approach with a suitable object.

CONFERENCE WRAP-UP SESSION

The final session began with closing remarks by conference chair William Ailor, who reviewed the five days of the conference just concluded and discussed next steps and recommendations for the 2023 conference. Ailor noted the over 700 total participants, averaging 250-300 during the various sessions, and added that all attendees will receive a certificate of participation. The larger than usual participation from all continents expanded engagement of international leadership as well as remote low budget

participants, especially students. It was asserted that the hybrid model will likely be the new normal at international conferences in general and that future PDCs may proactively adopt a hybrid format to maintain an increased global attendance. The UNOOSA announced it would be happy to host the 2023 conference in Vienna in person and/or virtually, in cooperation with its partners and the host country.

Ailor thanked:

- Romana Kofler of the United Nations Office of Outer Space Affairs and her team of professionals and volunteers, in particular Jenny Epstein, graduate student at the University of Vienna and Daniel Grösswang from the Austrian Space Forum, for taking an active part in the planning and for ensuring the conference was run very smoothly.
- The general organizing committee and the local organizing committee led by Peter Kraan for sharing guiding experiences in shaping the conference structure, topics, and mechanics.
- Co-chair Brent Barbee for pulling sessions together and ensuring that all sessions are designed to run with no issues and according to plan
- Co-chair Alex Karl for introducing interactive and informative intersession polling.
- The sponsors received special appreciation from Ailor for providing moral and material support to the conference and for enabling continued planetary defense research through the student grant project.
- Ailor congratulated Phil Groves and IMAX on the superbly produced Asteroid Hunters movie for introducing planetary defense to the masses and greatly expanding global awareness of the hazard.

Ailor expressed gratitude to the exercise designers for the detailed realistic analysis performed, presented, and smoothly weaved into the general panel discussions. Active engagement of local disaster managers to promptly provide feedback could be considered and preplanned in parallel to the main 2023 PDC exercise component. A comet scenario could be added to future exercises to account for its unique threat characteristics.

Common segments were organized around Vienna time each day, surrounded by two early and two late sessions to accommodate participants from around the globe. This conference structure was reported to have worked well, attendees attended from 50 nations, and Ailor thanked all the panel and session chairs for the excellent time management of their segments.

The daily panel discussions provided in-depth coverage of key topics, but poster talks were not supported in this conference due to time constraints. The 8-minute time limit for talks was felt too short by some presenters and adequate by others. It was considered adequate for topic highlight rather than in-depth discussion and generally accepted as necessary to stick to the program. The 20-minute Q&A time block at the end of each session was felt to be effective for time management. The strict session time management could be maintained in a future hybrid format.

To keep the conference single track while enabling global participation, it was proposed to consider stretching the conference to more than a week, schedule sessions in opposing time zones, and encourage after-session local or virtual gatherings. Preplanned multiple breakout rooms were also proposed to foster expanded interactive discussion in the next conference. In addition to live breakout rooms, usage and capture of chat interactions, and posting of all daily recordings were the recommended mechanisms for expanded engagement.

A special journal issue and student paper competition were not supported in PDC 2021. Participants who developed full research papers are encouraged to submit their work for journal publication on their own. Professor-led student research grants will be solicited, and projects will be selected by the end of 2021 for presentation at the 2023 conference. Participation by several young students was highly

noticed and praised for inspiring local and global future scientists. Engagement of local K-12 communities could be considered in future PDCs through a series of lesson plans and videos produced and posted on conference and space agencies websites.

The wrap-up session and the conference concluded with concurrence by all co-chairs and on-line participants on the proposed **2029 International Year of Planetary Defense** concept, celebrating the 25th anniversary of the PDCs, account for its accomplishments and give tribute to the contributors. Planning and organization of the event would leverage on networks, experiences, and commonalities developed in the International Year of Astronomy project and would take into consideration conflicts and opportunities associated with the passage of Apophis in that year.

To keep the community engaged during even years and perhaps encourage southern hemisphere participation, a virtual PDC-light version or workshop is proposed between formal PDCs. These events could be organized and managed by the next generation of planetary defenders, 35 years and under, and presented at the full PDC the following year.

In place of the traditional conference group photo, individual attendees posted their screenshots to a virtual group photo album on a public webpage created for this purpose.

APPENDIX A: CONFERENCE ORGANIZING COMMITTEE

William Ailor**	The Aerospace Corporation
Rudolf Albrecht*	Austrian Space Forum
Brent Barbee**	NASA/Goddard Space Flight Center & The University of Maryland
James (Gerbs) Bauer	University of Maryland
Randy Bell	The Aerospace Corporation
Bruce Betts	The Planetary Society
Linda Billings	Consultant to NASA's Planetary Defense Coordination Office
Marina Brozovic	Jet Propulsion Laboratory, California Institute of Technology
Mark Boslough	University of New Mexico, Los Alamos National Laboratory
Ian Carnelli	European Space Agency
Nancy Chabot	The Johns Hopkins University Applied Physics Laboratory
Clark R. Chapman	Southwest Research Institute (retired)
Andrew Cheng	The Johns Hopkins University Applied Physics Laboratory
Paul Chodas	Jet Propulsion Laboratory, California Institute of Technology
Jean-Michel Contant	International Academy of Astronautics
R. Terik Daly	The Johns Hopkins University Applied Physics Laboratory
Doris Daou	NASA Planetary Defense Coordination Office
Fabrice Dennemont	International Academy of Astronautics (IAA)
Jessie Dotson	NASA Ames Research Center
Gerhard Drolshagen**	University Oldenburg, Germany
Michael Egan	NASA-HQ
Kelly Fast	NASA Planetary Defense Coordination Office
Dawn Graninger	The Johns Hopkins University Applied Physics Laboratory
Mariella Graziano	GMV Aerospace and Defence
Phil Groves	Documentary Filmmaker, ASTEROID HUNTERS
Alissa Haddaji	Harvard Law School
Joshua Handal	NASA-HQ
Alan Harris	Jet Propulsion Laboratory (retired)
Curtis Iwata	The Aerospace Corporation
Barbara Jennings	Sandia National Laboratories
Lindley Johnson	NASA Planetary Defense Coordination Office
Thomas D. Jones	Association of Space Explorers
Alex Karl**	IAF TC on NEOs
Andrea Kleinsasser*	Austrian Federal Ministry for Innovation & Technology
Christian Koeberl*	University of Vienna
Romana Kofler*	United Nations Office for Outer Space Affairs (UNOOSA)
Detlef Koschny	European Space Agency, Chair of Astronautics, TU Munich, Germany
Peter Kraan*	ESA Conference Bureau Service Provider
Michael Kratzer*	Austrian Permanent Mission to the UN (VIENNA).
Rob Landis	NASA Johnson Space Center

Leviticus Lewis	DHS/FEMA
LIU Sen	China Aerodynamics Research and Development Center
Ed Lu	B612 Asteroid Institute
Irmgard Marboe	University of Vienna
Stephan Mayer*	Austrian Research Promotion Agency
Amy Mainzer	University of Arizona
Nahum Melamed**	The Aerospace Corporation
Patrick Michel	Univ. Côte d'Azur; Observatory, Cote d'Azur, CNRS
David Morrison	SETI Institute
Lea Nagel*	University of Vienna
Jan Osburg	RAND
Ryan Park	Jet Propulsion Laboratory, California Institute of Technology
Gisela Poesges	Geopark Ries e. V., Nördlingen, Germany
Andy Rivkin	The Johns Hopkins University Applied Physics Laboratory
Cordula Steinkogler*	University of Vienna
Angela Stickle	The Johns Hopkins University Applied Physics Laboratory
Megan Syal	Lawrence Livermore National Laboratory
Marco Tantardini	Consultant, former Space Policy Officer in the Office of the Italian Prime Minister
Karel A. van der Hucht	SRON Netherlands Institute for Space Research
George Vardaxis	The Aerospace Corporation
Lorien Wheeler	NASA Ames Research Center
Makoto Yoshikawa	Japan Aerospace Exploration Agency (JAXA)

*Member, Local Organizing Committee

** Chairs of the 2021 PDC

APPENDIX B: CONFERENCE PROGRAM

Day 1 Program

Sydney	Tokyo	Vienna	DC	LA	DAY 1: Highlights	
19:45	18:45	11:45	5:45	2:45	**Introduction (Drolshagen, Kofler)**	
o, Monica Lazzarin, Richard Moissl ; Volunteers:					**Session 1: Hera**	**Presenter**
20:00	19:00	12:00	6:00	3:00	Planetary defence and science	P. Michel
20:10	19:10	12:10	6:10	3:10	Payload update	M. Küppers
20:20	19:20	12:20	6:20	3:20	Milani Cubesat	F. Topputo
20:30	19:30	12:30	6:30	3:30	Juventas CubeSat For the HERA Mission	Ö. Karatekin
20:40	19:40	12:40	6:40	3:40	Q&A	
21:00	20:00	13:00	7:00	4:00	Break	
Chairs: Makoto Yoshikawa ; Volunteers:					**Session 2: Hayabusa2**	**Presenter**
21:15	20:15	13:15	7:15	4:15	Summary of Hayabusa2 Mission	Y. Tsuda
21:22	20:22	13:22	7:22	4:22	Hayabusa2's kinetic impactor	T. Saiki
21:29	20:29	13:29	7:29	4:29	Artificial impact crater on Ryugu formed in the gravity dominated regime	M. Arakawa
21:36	20:36	13:36	7:36	4:36	Physical properties of Ryugu revealed by proximity observations with Hayabusa2 science instruments	S. Sugita
21:43	20:43	13:43	7:43	4:43	Thermal Imaging to Reveal the Highly Porous Nature of C-type Asteroid Ryugu in Hayabusa2 Mission	T. Okada
21:50	20:50	13:50	7:50	4:50	Hayabusa2 Extended Mission to rendezvous with Asteroid 1998 KY26: Investigations of an extremely small fast rotator for planetary	M. Hirabayashi
21:57	20:57	13:57	7:57	4:57	Q&A	
22:15	21:15	14:15	8:15	5:15	Break	
22:30	21:30	14:30	8:30	5:30	**Welcoming Remarks (Kofler, Ailor)**	
22:45	21:45	14:45	8:45	5:45	**Keynote Address**	
23:15	22:15	15:15	9:15	6:15	Break	
23:30	22:30	15:30	9:30	6:30	**Exercise: Inject #1 (IAWN, SMPAG, & Consequence Overview) (Chodas, Wheeler, Drolshagen, Ailor)**	
0:15	23:15	16:15	10:15	7:15	Break	
0:30	23:30	16:30	10:30	7:30	**Panel: Leaders Discuss Next Steps (Kofler)**	
1:30	0:30	17:30	11:30	8:30	Break	
airs: Andy Rivkin, Dawn Graninger ; Volunteers:					**Session 3: DART**	**Presenter**
1:45	0:45	17:45	11:45	8:45	Overview of the DART Mission, 7 Months to Launch	T. Statler
1:55	0:55	17:55	11:55	8:55	LICIACube	E. Dotto
2:00	1:00	18:00	12:00	9:00	DART Mission Status	E. Adams
2:10	1:10	18:10	12:10	9:10	DART: How will we know what we've done? Observations and Dynamics	A. Rivkin
2:20	1:20	18:20	12:20	9:20	DART Legacy: Determination of beta, data archive	A. Cheng
2:30	1:30	18:30	12:30	9:30	Q&A	
2:45	1:45	18:45	12:45	9:45	Break	
hairs: Terik Daly, Christian Koeberl ; Volunteers:					**Session 4: OSIRIS-REx**	**Presenter**
3:00	2:00	19:00	13:00	10:00	Overview and Highlights of the OSIRIS-REx Mission	A. Simon
3:10	2:10	19:10	13:10	10:10	Constraining the strength of 100-m scale asteroids through craters on Bennu's boulders and NEO population estimates	R. Ballouz
3:20	2:20	19:20	13:20	10:20	Bennu craters in the context of planetary defense	B. Bierhaus
3:30	2:30	19:30	13:30	10:30	Observations of Bennu's increasing rotation rate, YORP, and implications for Bennu's evolution	M. Nolan
3:40	2:40	19:40	13:40	10:40	Q&A	
4:00	3:00	20:00	14:00	11:00	**End of Day 1**	

Day 2 Program

Sydney	Tokyo	Vienna	DC	LA	DAY 2: Discovery and Characterization	
19:45	18:45	11:45	5:45	2:45	**Introduction (Drolshagen, Kofler)**	
ast, Alan Harris, Luca Conversi ; Volunteers:					**Session 5a: NEO Discovery**	**Presenter**
20:00	19:00	12:00	6:00	3:00	System of Observation of Daytime Asteroids (SODA)	B. Shustov
20:08	19:08	12:08	6:08	3:08	DEVELOPMENT OF ASTEROID DETECTION APPLICATION "COIAS" FOR THE SUBARU HSC DATA	S. Urakawa
20:16	19:16	12:16	6:16	3:16	New NEODyS Tools for the EU funded NEOROCKS Project: Observations support and Priority Lists	F. Bernardi
20:24	19:24	12:24	6:24	3:24	ESA'S NEO COORDINATION CENTRE OBSERVATIONAL NETWORK	L. Conversi
20:32	19:32	12:32	6:32	3:32	Asteroid survey and follow up observations with small telescopes in framework of ISON network	I. Molotov
20:40	19:40	12:40	6:40	3:40	Q&A	
21:00	20:00	13:00	7:00	4:00	Break	
, Marina Brozovic, Agata Rożek ; Volunteers:					**Session 6a: NEO Characterization**	**Presenter**
21:15	20:15	13:15	7:15	4:15	SUPPORT OF THE NASA JANUS SPACE MISSION - DETECTION OF A SPIN-ORBIT INTERACTION	P. Pravec
21:23	20:23	13:23	7:23	4:23	Characterization of NEAs in the frame of NHATS program using the 10.4m Gran Telescopio Canaria	J. de León
21:31	20:31	13:31	7:31	4:31	The low thermal conductivity of the super-fast rotator (499998) 2011 PT	M. Fenucci
21:39	20:39	13:39	7:39	4:39	Photometry of hundreds of NEOs from SDSS	A. Sergeyev
21:47	20:47	13:47	7:47	4:47	Polarimetry as a tool for physical characterization of potentially hazardous asteroids	M. Devogele
21:55	20:55	13:55	*7:55*	*4:55*	Q&A	
22:15	21:15	14:15	*8:15*	*5:15*	Break	
22:30	21:30	14:30	*8:30*	*5:30*	**EXERCISE: NEO Mission Options (Barbee, Drolshagen)**	
23:15	22:15	15:15	*9:15*	*6:15*	Break	
23:30	22:30	15:30	*9:30*	*6:30*	**SESSION: LEGAL & POLICY ISSUES FOR DEFLECTION (Haddaji)**	**Presenter**
23:32	22:32	15:32	*9:32*	*6:32*	*Legal aspects of the use of a nuclear explosive device in space*	D. Koplow
23:40	22:40	15:40	*9:40*	*6:40*	*Q&A on the use of NED in space*	
23:48	22:48	15:48	*9:48*	*6:48*	*The Legal Aspects of Planetary Defense: Conclusions of the SMPAG Ad-Hoc Legal Working Group Report*	A. Haddaji
23:56	22:56	15:56	*9:56*	*6:56*	*Obligation to Inform and to Act, Liability, Responsibility, and International Decision-Making*	I. Marboe
	23.04	16.04	10.04	7.04	*Q&A on Legal Aspects of Planetary Defense*	
0:15	23:15	16:15	10:15	7:15	*Break*	
0:30	23:30	16:30	10:30	7:30	**PANEL: DISCUSSION OF DEFLECTION/DISRUPTION OPTIONS (LEADERS) (Karl)**	
1:25	0:25	17:25	11:25	8:25	**EXERCISE: INJECT #2 Update on Threat Region (Karl, Chodas)**	
1:30	0:30	17:30	11:30	8:30	Break	
ast, Alan Harris, Luca Conversi ; Volunteers:					**Session 5b: NEO Discovery**	**Presenter**
1:45	0:45	17:45	11:45	8:45	(LSST)	L. Jones
1:53	0:53	17:53	11:53	8:53	NEO DETECTION, AND THE FUTURE OF PLANETARY DEFENSE	A. Mainzer
2:01	1:01	18:01	12:01	9:01	The new MPC NEO Confirmation Page: improvements and results	F. Spoto
2:09	1:09	18:09	12:09	9:09	NEOs in the Isolated Tracklet File	R. Weryk
2:17	1:17	18:17	12:17	9:17	CATCHing Near-Earth Objects in Survey Data	M. Kelley
2:25	1:25	18:25	12:25	9:25	Q&A	
2:45	1:45	18:45	12:45	9:45	Break	
Marina Brozovic, Stephen Lowry ; Volunteers:					**Session 6b: NEO Characterization**	**Presenter**
3:00	2:00	19:00	13:00	10:00	Characterization of near-Earth asteroids from NEOWISE survey data	J. Masiero
3:08	2:08	19:08	13:08	10:08	Unique Capabilities of the 4.3-m Lowell Discovery Telescope (LDT) for Planetary Defense	N. Moskovitz
3:16	2:16	19:16	13:16	10:16	Challenges in differentiating NEOs and Rocket Bodies: 2020 SO Study	V. Reddy
3:24	2:24	19:24	13:24	10:24	Accurate NEO Orbits from Occultation Observations	D. Dunham
3:32	2:32	19:32	13:32	10:32	A New Method for Asteroid Impact Monitoring and Hazard Assessment	J. Roa Vicens
3:40	2:40	19:40	13:40	10:40	Q&A	
4:00	3:00	20:00	14:00	11:00	**End of Day 2**	

Day 3 Program

Sydney	Tokyo	Vienna	DC	LA	DAY 3: Testing and Mission Planning	
19:45	18:45	11:45	5:45	2:45	**Introduction (Drolshagen, Kofler)**	
Michel, Angela Stickle, Megan Syal ; Volunteers:					**Session 7a: Deflection & Disruption Testing**	**Presenter**
20:00	19:00	12:00	6:00	3:00	Cratering processes on rubble-pile asteroids: insights from laboratory experiments and numerical models	S. Raducan
20:08	19:08	12:08	6:08	3:08	Kinetic Impactor Technique: Benchmark and Validation Studies with iSALE and SPH	R. Luther
20:16	19:16	12:16	6:16	3:16	NASA/Double Asteroid Redirection Test: Orbital perturbation by the ejecta-collision driven reshaping of Didymos after the impact event	R. Nakano
20:24	19:24	12:24	6:24	3:24	Late-time Nuclear Disruption in the PDC 2021 Scenario	P. King
20:32	19:32	12:32	6:32	3:32	An Overview of Numerical Radiation Transport Techniques in Asteroid Deflection Modeling	N. Gentile
20:40	19:40	12:40	6:40	3:40	Q&A	
21:00	20:00	13:00	7:00	4:00	Break	
rdini, George Vardaxis, Andy Cheng ; Volunteers:					**Session 8a: Mission & Campaign Design**	**Presenter**
21:15	20:15	13:15	7:15	4:15	Assembled Kinetic Impactor for Deflecting Asteroids via Combining the Spacecraft with the Launch Vehicle Upper Stage	W. Yirui
21:23	20:23	13:23	7:23	4:23	JuRa: the Juventas Radar on Hera to fathom Didymoon	A. Herique
21:31	20:31	13:31	7:31	4:31	ESA'S Planetary Defence NEO Coordination Centre DevOps Model Based Operations	G. Di Girolamo
21:39	20:39	13:39	7:39	4:39	Hera Radio Science Experiments through Ground-Based and Satellite-to-Satellite Doppler Tracking	P. Tortora
21:47	20:47	13:47	7:47	4:47	Hijacking a satellite for Short-Warning Asteroid Deflection – FastKD Mission, Design and Implementation	A. Falke
21:55	20:55	13:55	7:55	4:55	Q&A	
22:15	21:15	14:15	8:15	5:15	Break	
22:30	21:30	14:30	8:30	5:30	**EXERCISE: INJECT #3 (Chodas & Wheeler) (Melamed)**	
23:00	22:00	15:00	9:00	6:00	Break	
23:15	22:15	15:15	9:15	6:15	**EXERCISE PANEL: DISASTER MANAGER'S DISCUSSION (Melamed)**	
0:10	23:10	16:10	10:10	7:10	**EXERCISE: Final Impact Area (Melamed, Chodas)**	
0:15	23:15	16:15	10:15	7:15	Break	
0:30	23:30	16:30	10:30	7:30	**PANEL: HEADS OF SPACE AGENCIES (Koschny, Johnson)**	
1:30	0:30	17:30	11:30	8:30	Break	
Michel, Angela Stickle, Megan Syal ; Volunteers:					**Session 7b: Deflection & Disruption Testing**	**Presenter**
1:45	0:45	17:45	11:45	8:45	Progress on Developing a Simplified Model of X-Ray Energy Deposition for Nuclear Mitigation Missions	M. Burkey
1:53	0:53	17:53	11:53	8:53	The Double Asteroid Redirection Test (DART) Impact Modeling Working Group Inverse Test	A. Stickle
2:01	1:01	18:01	12:01	9:01	Accelerated Root Finding for the DART Inverse Test Using Machine Learning Decision Trees	C. Raskin
2:09	1:09	18:09	12:09	9:09	Understanding Projectile Geometry Effects on Momentum Enhancement During Hypervelocity Impacts	M. DeCoster
2:17	1:17	18:17	12:17	9:17	Spacecraft Geometry Effects on Cratering and Deflection in the DART Mission	M. Owen
2:25	1:25	18:25	12:25	9:25	Q&A	
2:45	1:45	18:45	12:45	9:45	Break	
, Marco Tantardini, George Vardaxis ; Volunteers:					**Session 8b: Mission & Campaign Design**	**Presenter**
3:00	2:00	19:00	13:00	10:00	The "Asteroid Nodal Intersection Multiple Encounters" (ANIME) CubeSat Mission: Science and Planetary Protection	D. Perna
3:08	2:08	19:08	13:08	10:08	Janus: A NASA SIMPLEx mission to explore two NEO Binary Asteroids	D. Scheeres
3:16	2:16	19:16	13:16	10:16	NEO Surveyor Cadence and Simulations	S. Sonnett
3:24	2:24	19:24	13:24	10:24	Risk-Informed Spacecraft Mission Design for the 2021 PDC Hypothetical Asteroid Impact Scenario	B. Barbee
3:32	2:32	19:32	13:32	10:32	The MILO Space Science Institute: Enabling New, Science-Focused Deep Space Smallsat Missions to Near Earth Objects	J. Bell
3:40	2:40	19:40	13:40	10:40	Q&A	
4:00	3:00	20:00	14:00	11:00	**End of Day 3**	

Day 4 Program

Sydney	Tokyo	Vienna	DC	LA	DAY 4: Impact Effects & Disaster Management	
19:45	18:45	11:45	5:45	2:45	**Introduction (Drolshagen, Kofler)**	
ugh, Jessie Dotson, David Morrison ; Volunteers:					**Session 9a: Impact Effects**	**Presenter**
20:00	19:00	12:00	6:00	3:00	Studying Bodies of Organisms Killed by an Asteroid: Environmental Effects of Very Small Crater Formation	A. Losiak
20:08	19:08	12:08	6:08	3:08	THE MELTING ABLATION ANALYSIS OF AEROLITES IN HIGH TEMPERATURE FLOW	S. Haihao
20:16	19:16	12:16	6:16	3:16	NUMERICAL ANALYSIS OF AERODYNAMIC HEATING ON ASTEROID DURING ENTRY TO EARTH'S ATMOSPHERE	S. Liu
20:24	19:24	12:24	6:24	3:24	Impact Effects Calculator. Shock wave effects from impacts of cosmic objects with diameter from a few meters to 3km.	D. Glazachev
20:32	19:32	12:32	6:32	3:32	IMPACT EFFECTS CALCULATOR. RADIATION AND SOME OTHER EFFECTS	O. Popova
20:40	19:40	12:40	6:40	3:40	Q&A	
21:00	20:00	13:00	7:00	4:00	Break	
Chairs: L. A. Lewis ; Volunteers:					**Session 10a: Disaster Management**	**Presenter**
21:15	20:15	13:15	7:15	4:15	KEY ASPECTS OF DISASTER MANAGEMENT	D. Chandola
21:23	20:23	13:23	7:23	4:23	The Decision to Act – A Human Rights based approach to Disaster Management and Response	J.Lim
21:31	20:31	13:31	7:31	4:31	Prevention, Mitigation and Preparedness for Disasters- Role of UN COPUOS in Disaster Management and Indian Progress	A. Marwah
21:39	20:39	13:39	7:39	4:39	COMMUNICATION PROTOCOL ON PHO FOR DISASTER MANAGEMENT BY LEGITIMATE BRAZILIAN INSTITUTIONS	A. Pegetti
21:47	20:47	13:47	7:47	4:47	Q&A	
22:15	21:15	14:15	8:15	5:15	Break	
22:30	21:30	14:30	8:30	5:30	**PANEL: PROVIDING CLEAR, CONCISE, CORRECT INFORMATION TO THE PUBLIC (Billings)**	
23:30	22:30	15:30	9:30	6:30	Break	
23:45	22:45	15:45	9:45	6:45	**PANEL: LESSONS LEARNED FROM PAST DISASTERS: RECOMMENDATIONS FOR A REAL NEO THREAT (Lewis)**	
0:45	23:45	16:45	10:45	7:45	Break	
1:00	0:00	17:00	11:00	8:00	**PUBLIC EVENT: THE PLANETARY SOCIETY (Betts)**	
2:00	1:00	18:00	12:00	9:00	Break	
tson, David Morrison, Olga Popova ; Volunteers:					**Session 9b: Impact Effects**	**Presenter**
2:15	1:15	18:15	12:15	9:15	SPH Simulation of Atmospheric Effects on Bolide Entry	J. Pearl
2:23	1:23	18:23	12:23	9:23	Towards Adaptive Simulation of Dispersive Tsunami Propagation from an Asteroid Impact	M. Berger
2:31	1:31	18:31	12:31	9:31	Asteroid Impacts – Downwind and Downstream effects	T. Titus
2:39	1:39	18:39	12:39	9:39	Environmental consequences of asteroid impacts by GCM simulations	C. B. Senel
2:47	1:47	18:47	12:47	9:47	Bayesian Inference of Asteroid Physical Properties: Application to Impact Scenarios	J. Dotson
2:55	1:55	18:55	12:55	9:55	Q&A	
3:15	2:15	19:15	13:15	10:15	Break	
Chairs: L. A. Lewis ; Volunteers:					**Session 10b: Disaster Management**	**Presenter**
3:30	2:30	19:30	13:30	10:30	Real-Time Community Enabling to Care for Planetary Disaster Risk Reduction	J. Venkataramaiah
3:38	2:38	19:38	13:38	10:38	Towards Plans for Mitigating Possible Socio-economic Effects due to a Physical Impact of an Asteroid on Earth	R. Albrecht
3:46	2:46	19:46	13:46	10:46	RAPID EVACUATION OF THE VIIPURI (VYBORG) CITY – EXPERIENCE FROM THE FINNISH WINTER WAR 1939-1940	T. Kohout
3:54	2:54	19:54	13:54	10:54	Q&A	
4:30	3:30	20:30	14:30	11:30	**End of Day 4**	

Day 5 Program

Sydney	Tokyo	Vienna	DC	LA	DAY 5: Decision to Act & Public Engagement	
19:45	18:45	11:45	5:45	2:45	**Introduction (Drolshagen, Kofler)**	
airs: Alissa J. Haddaji ; Rudi Albrecht, Volunteers:					**Session 11: The Decision to Act**	**Presenter**
20:00	19:00	12:00	6:00	3:00	Liability waivers and Planetary defense Missions: The Good Samaritan Principle	L. V. Ferreira
20:08	19:08	12:08	6:08	3:08	Obligation to participate in planetary defense action as part of international jus cogens	K. Nieweglowski
20:16	19:16	12:16	6:16	3:16	Reacting to Near-Earth Object Impact: Exceptional Circumstances Justifying Non-Compliance with International law	A-S. Martin
20:24	19:24	12:24	6:24	3:24	Planetary Defense as Entrepreneurial Politics: The Case for Policy Optimization	A. Melamed
20:32	19:32	12:32	6:32	3:32	natural disaster management	A. Haddaji
20:40	19:40	12:40	6:40	3:40	Precautionary Planetary Defence: Pre-emptive Deflections and Exercising Restraint	A.Boley
20:48	19:48	12:48	6:48	3:48	ESA's Activities in Planetary Defence	D. Koschny
20:56	19:56	12:56	6:56	3:56	Scope, objectives and first results of the space mission planning advisory group	G. Drolshagen
21:04	20:04	13:04	7:04	4:04	Q&A	
21:24	20:24	13:24	7:24	4:24	Break	
Billings, Alissa J. Haddaji, Alex Karl ; Volunteers:					**Session 12: Public Education & Communication**	**Presenter**
21:39	20:39	13:39	7:39	4:39	Teaming up for Asteroid Deflection	N. Melamed
21:47	20:47	13:47	7:47	4:47	Aiming for Apophis: How we used COVID-19 school lockdown as an opportunity to do asteroid astrometry and teach others	A. Nath
21:55	20:55	13:55	7:55	4:55	Evaluation of an NEO close approach frequency index for public/media release purposes	J. L. Cano
22:03	21:03	14:03	8:03	5:03	Role of SGAC in Global Planetary Defense Outreach	S. Srivastava
22:11	21:11	14:11	8:11	5:11	Engaging the audience - what can we learn from them	A. Karl
22:19	21:19	14:19	8:19	5:19	Observations of NEAs and National Public Outreach at the Astronomical Observatory of Castelgrande	S. Schmalz
22:27	21:27	14:27	8:27	5:27	Public Communication in the case of an Impending Impact: Lessons from the COVID-19 Pandemic	C. Nugent
22:35	21:35	14:35	8:35	5:35	Q&A	
22:55	21:55	14:55	8:55	5:55	Break	
auer, Larry Denneau, Michaela Blain ; Volunteers:					**Session 13: Apophis and Others, Far and Near: Future Characterization Opportunities from NEO Close Approaches**	**Presenter**
23:10	22:10	15:10	9:10	6:10	FREQUENCY OF CLOSE EARTH APPROACHES BY NEAR-EARTH OBJECTS	M. Granvik
23:15	22:15	15:15	9:15	6:15	IAWN PLANETARY DEFENSE EXERCISE: APOPHIS OBSERVING CAMPAIGN 2020-2021	M. Kelley
23:23	22:23	15:23	9:23	6:23	Detection of Yarkovsky Acceleration of (99942) Apophis	D. Tholen
23:28	22:28	15:28	9:28	6:28	APOPHIS Express, a unique opportunity for visiting APOPHIS in 2029	J. Prado
23:33	22:33	15:33	9:33	6:33	Characterization of Near-Earth Asteroid 153814 (2001 WN5) and Prospects for the 2028 Close Encounter with Earth	P. Taylor
23:41	22:41	15:41	9:41	6:41	Extension of the Earth Libration Point Missions by Targeting a Spacecraft to Near-Earth Asteroids	V. Zubko
23:49	22:49	15:49	9:49	6:49	Q&A	
0:10	23:10	16:10	10:10	7:10	Break	
0:25	23:25	16:25	10:25	7:25	**PANEL: PROPOSAL: INTERNATIONAL YEAR OF PLANETARY DEFENSE (Daou)**	
1:25	0:25	17:25	11:25	8:25	Break	
1:40	0:40	17:40	11:40	8:40	**DISCUSSION: WRAP-UP, NEXT STEPS, RECOMMENDATIONS FOR 2023 CONFERENCE (Conference Chairs)**	
2:40	1:40	18:40	12:40	9:40	**Break / End of Day 5 / End of Conference**	

APPENDIX C: ATTENDEES

The following individuals attended the conference via WEBEX:

James (Gerbs) Bauer
Karel A. van der Hucht
Paul Abell
Merna Abumusabh
Raja Acharya
Melissa Adams
Elena Adams
Sonka Adrian
Michael Aftosmis
Harrison Agrusa
William Ailor
Yasuhiro Akahoshi
Rudi Albrecht
Seyed Ali Naghibi Rad
Marilena Amoroso
Mahesh Anand
XY Ang
Simon Anghel
Masahiko Arakawa
Bruna Araujo
Adriana Araujo
Afsheen Arif
Gabriella Arrigo
George Artem
Moin Asdf
Johnny Assaf
Justin Atchison
Almudena Azcárate Ortega
Imelda Bacolod
Laszlou Bacsardi
Ron Ballouz
Ivan Balyaev
Brent Barbee
Terry Barbee
Meghan Bartels
Akos Bazso
Jim Bell
Randy Bell
Harel Ben-Ami
Piero Benvenuti
Marsha Berger
Cem Berk Senel
Fabrizio Bernardi
Bruce Betts
Beau Bierhaus
Linda Billings
Alexandros Binios
Sholehah Binti Ismail
Filmon Birhane
Mirel Birlan
Mirela Bivolaru
Einar Bjorgo
Michaela Blain
Petr Boháček
Aaron Boley
Giulia Bordacchini
Mark Boslough
Ulpia Botezatu
Alice Bourdet
Alexandra Bourlier
Daniel Brack
Louis Brotel
Peter Brown
Marina Brozovic
Melissa Brucker
Jennifer Brüggler
Wojciech Brzeziński
Ryan Bull
Ricky Burcat
Christoph Burger
Mary Burkey
Michael Busch
Yousaf Butt
Nancy C Wolfson
Michael C. Nolan
Piluca Caballo Perucha
Facundo Cabrera
Wendy Caldwell
Sergio Camacho
Diego Cammarano
Adriano Campo Bagatin
Juan Cano
Gianluigi Capo
Joseph Carpinelli
Benoit Carry
Amaury Caruzzo
Anna Casey
Julio Castillo
Marco Castronuovo (ASI)
Ramona Cennamo
Nancy Chabot
Bruno Chagas
Deepak Chandra Chandola
Clark Chapman
Priyanshi Chaturvedi
Andy Cheng
Steven Chesley
Paul Chodas
Eric Christensen
Ilaria Cinelli
Renato Cirelli
Elena Cirkovic
Stuart Clark
Ashley Coates
Marcelo Colazo
Luca Conversi
Bill Cooke
Andrew Cooper
Desireé Cotto-Figueroa
Alan Cross
Roc Cutri
Terik Daly
David Damazzio
Leining Dang
Doris Daou
Tom De Groeve
Leonard de Guzman
Julia de Leon
Dries De Maesschalck
Mallory DeCoster
Joe DeMartini (he/him)
Chi Deng
Larry Denneau
Fabrice Dennemont
Rolf Densing
Ian DesJardin

Josselin Desmars
Young Deuk Park
Maxime Devogele
Alessandra Di Cecco
Ylenia Di Crescenzio
Gianpiero Di Girolamo
Simonetta Di Pippo
Martin Diaz
Eleni Dimokidis
Teja Dobnik
Jessie Dotson
Elisabetta Dotto
Lord Dover
Mélanie Drilleau
Gerhard Drolshagen
Hui Du
David Dunham
Siegfried Eggl
Jenny Epstein
Carolyn Ernst
Nicole Ertl
Esam Esam
Laura Faggioli
Eugene Fahnestock
Albert Falke
Bernard Farkin
Leah Farrar
Kelly Fast
Lori Feaga
Konstantin Fedyaev
Marco Fenucci
Luisa Fernanda Zambrano-Marin
Nicholas Fernandes
Rocio Fernandez
Fabio Ferrari
Luciano Ferreira
Ignacio Ferrin
Alan Fitzsimmons
Angelo Foglietta
Dora Fohring
Thomas Ford
Marc Fournier
Elisa Frattin
Joseph Frisbee
James Frith
Michael Frühauf
Oscar Fuentes-Munoz
John Furumo
Travis Gabriel
Sharafat Gadimova
Jon Gaer
Jose Gambi
Maider Gamero
Raphael Garcia
Gabriela Garova-Mucheva
Peter Garretson
David Gaylor
Andreas Geisler
Nicholas Gentile
Stephan Gerard
Radu Gherase
Renahan Gil
Sarah-Jane Gill
Alejandro Gimenez
Michaela Gitsch
Dm Glazachev
Alessia Gloder
Kevin Govender
Paul Graham
Werner Grandl
Dawn Graninger
Mikael Granvik
Tommy Grav
Mariella Graziano
Dan Green
Sarah Greenstreet
Michael Gregorius
Christian Gritzner
Hannes Gröller
Daniel Größwang
Nicole Güldemeister
Rani Gupta
Vrinnda Gupta
Annika Gustafsson
Adrian Guzman
Gabriela Guzman
Alvaro Guzman
Sabire Hacıömeroğlu
ZHAO Haibin
Sun Haihao
Han Han
Joshua Handal
Charlie Hanner
Ulrich Hans
Katharina Harreiter
Janine Harris
Alan Harris
Alan Harris
Elen Haruyunyan
Haruo Hayashi
Alain Herique
D Hestroffer
Toshi Hirabayashi
Carrie Holt
CHEN Hong
Michelle Howard
Shoucun Hu
Yong Hua Tang
Mark Huber
Kenneith Hui
Marina Huidobro
Simone Ieva
Mukadder Igdi-Sen
Stavro Ivanovski
Anatoliy Ivantsov
Zeljko Ivezic
Alissa J. Haddaji
Samuel Jackson
Cristovao Jacques
Judith Jahnke
Laura Jamschon Mac Garry
Rüdiger Jehn
Peter Jenniskens
Rosa Jesse
Hai Jiang
Wang Jilian
Christopher Johnson
Chris Johnson
Lindley Johnson
Lynne Jones
Thomas Jones
Thomas Jones
Iulian Juhasz
Stephen Jurczyk
Martin Jutzi
Lokdeep Kalaiselvam
Vishnu Kanupuru
Ozgur Karatekin
Alex Karl
Anna Kartashova
Toshi Kasuga
Lea Katharina Nagel
Rei Kawashima

Tufan Kayaci
Suleyman Kaynar
Fatoumata Kebe
Michael Kelley
Jason Kemper
J. Kerner
Lars Kesseler
Andrea Key
Ankit Khanal
Kathleen Kiker
Dong-Heun Kim
Myung-Jin Kim
Patrick King
Andrea Kleinsasser
Konstantin Klenin
Christian Koeberl
Romana Kofler
Tomas Kohout
Svitlana Kolomiyets
David Koplow
Jesse Korpan
Detlef Koschny
Elissavet Koumi
Peter Kraan
Rainer Kresken
Nikolay Krobka
Michael Kueppers
Ken-ichi Kumagai
Kathryn Kumamoto
Juan L. Cano
Fiorangela La Forgia
Michael Lage
Henry Laguna
Aleksandra Langer
Jenny Larson
Michèle Lavagna
Andrea Lazaro
Jasmina Lazendic-Galloway
Monica Lazzarin
Sally Leivesley
Adriana Lenkavska
Gaia Letizia Civardi
Ronald Leung
Ron Leung
L.A. Lewis
Jonas L'Haridon
Chao Li
Javier Licandro
Eva Lilly
Jonathan Lim
Tim Lister
Cate Liu
Sen Liu
Jing Liu
Andy López-Oquendo
Ania Losiak
Stephen Lowry
Ed Lu
Alice Lucchetti
Ana Luica Pegetti
Maria Luiza de Souza
Robert Luther
Josh Lyzhoft
Rosa Ma Ramirez de Arellano
Claudio Maccone
Thomas Maindl
Amy Mainzer
Rahil Makadia
YAMINI MALHOTRA
Alan Mamzer
Rob Managan
Lara Mani
Irmgard Marboe
Franck Marchis
Mohamad Mardini
Kilian Maret
Joel Marks
Julian Marohnic
Marco Marsh
Sean Marshall
Akanksha Marwah
Frank Masci
Joe Masiero
Ron Mason
Donovan Mathias
Hannes Mayer
Stephan Mayer
Monica Maynard
Dan Mazanek
Jaideep Mazumdar
Lianne McGinley
Jane McGonigal
Bob McMillan
Maria McQuaide
Hissa Medeiros
Lucas Meireles
Jaquelin Mejia
Nahum Melamed
Avishai Melamed
Hiran Mexicali
Michael Simpson
Patrick Michel
Jean Michel Contant
Marco Micheli
Claudiu Mihai Taiatu
Olga Mikhalchenko
David Millman
Milica Milosev
Scott Milster
Milton Ramirez
Mrudula Mohan
Richard Moissl
Igor Molotov
Pavel Molotov
Iain Moore
Amanda Moore
Susan Moran
David Morate
Julio Moreno
David Morrison
Nicholas Moskovitz
Carlos Moura
Charles Mudd
Bulbul Mukherjee
Naomi Murdoch
David Musson
Famil Mustafa
Kamil Muzyka
Arushi Nath
Vikas Nath
Ryota Nakano
Azlikamil Napiah
Artash Nath
Samuel Navarro-Meza
Rico Nerger
Martin Nesirky
Dean Newton
Wayne Ng
Krzysztof Niewęgłowski
Marco Nino Sandro Portschy
Bojan Novakovic
Carrie Nugent

Mit Obe
Tatsuaki Okada
Patrick O'Keeffe
Shin-ichiro Okumura
Dario Oliviero
Jan Osburg
Mike Owen
Gerhard Paar
Flora Paganelli
Maurizio Pajola
Madhavan Pallan
Manuel Panchana Moya
Edgar Paolo Violan
Jonathan Parkinson-Swift
Laura Parro
Andrea Pasquale
Patrik Perers
Winfrey Paul
Sagayam Dennis
Jiří Pavlík
Jason Pearl
Anivid Pedros
Ana Pegetti
Ivanka Pelivan
Eloy Peña-Asensio
Pelayo Peñarroya
Alexis Perales
Jorge Pérez
Anne-Charlotte Perlbarg
Davide Perna
Ettore Perozzi
Elisabeta Petrescu
Laurenz Pieringer
Judith Pipher
Simone Pirrotta
Arman Pishini
Marius-Ioan Piso
Cathy Plesko
Adriana Pliego
Violeta Poenaru
Anton Pomazan
Marcel Popescu
Olga Popova
Gisela Pösges
Allan Posner
Manuel Posso
Jean-yves prado
Antonio Prado
Petr Pravec
Lucas Prieels
Dumitru-Dorin Prunariu
Klaus Pseiner
Maxim Pupkov
Sabina Raducan
Ahmad Raeisi
Pratibha Raghunandan
Emma Rainey
Prof. Rajesh Kumar Dubey
Yudish Ramanjoolooo
Pablo Ramirez Moreta
Cody Raskin
Laurent Rathborn
Shirish Ravan
Martin Reynders
Larissa Ribeiro
Andrea Riley
Birgit Ritter
Andy Rivkin
Javier Roa Vicens
Darrel Robertson
Alejandro ROMAN
Gaia Roncalli
Miguel Roncero Martin
Maarten Roos
Princes Rose Velasco
Alessandro Rossi
Giuliana Rotola
Katherine Rowan
Agata Rozek
Regina Rudawska
Alberto Ruiz
Leonardo Russo
Pedro Russo
Mary Ruth Velasco
William Ryab
Eileen Ryan
Andre Rypl
Takanao Saiki
Stephen Salmon
Julio Sanchez
Toni Santana
Luisa Santoro
Nancy Sardone
Bruno Sarli
Dhanisha Sateesh
Akash Satpathy
Anastasia Savchukova
Carolyn Sawyer
Christoph Schaefer
Felicia Schartner
Dan Scheeres
Dan Scheld
Rebecca Schembri
Sergei Schmalz
Nikola Schmidt
Peter Schneider
Estelle Schnitzler
David Schuld
Ruben Schulte-Hillen
Alexander Schuster
Marc Schwetterle
Sarah Scoles
Mehdi Scoubeau
Rob Seaman
Ray Sedwick
Marvin Seegert
Fabienne Seibert
Hasan Seida
Olivia Seidel
Tony Sephton
Alexey Sergeyev
Mahir Shah
Haibin Shang
Sajal Sharma
Aaditya Sharma
A. Shelton
Jianchun Shi
Michael Shoemaker
Andrey Shugarov
Boris Shustov
Bernd Sierk
Salim Sigales
Gabriel Simion
Amy Simon
Lisa Singh
Derek Smale
Simonny Soares
Stefania Soldini
Guangming Song
Sarah Sonnett
Damya Souami
Alexander Soucek (ESA)
Tim Spahr
Federica Spoto

Wade Spurlock
Smiriti Srivastava
Matthew Stasiukevicius
Tom Statler
Cordula Steinkogler
Angela Stickle
Stephanie Stipsits
Mark Stokes
Jinyuan Su
Meng Su
Cecily Sunday
Jessica Sunshine
Jason Surace
Victoria Sutton
Megan Syal
David Tabernero
Mina Takla
Hristina Talkova
Gonzalo Tancredi
Paolo Tanga
Marco Tantardini
Josh Tapley
Paula Tartari
Patrick Taylor
Orkun Temel
Giulia Tempo
Jan Thimo Grundmann
Swati Thirumangalath
Dan Thisdell
Dave Tholen
Cristina Thomas
William Thuillot
Jana Tichá
Milos Tichy
Navin Timilsina
Timothy Titus
Cecilia Todeschini
Giacomo Tommei
Jasper Top
Francesco Topputo
Paolo Tortora
Darin Traff
Madalina Trelia
Robert Trembley
Josep Trigo-Rodriguez
Nair Trógolo
Bart Tsang
Yuichi Tsuda
Linde TUSCHER
Stephan Ulamec
Michael UMD Kelley
Muzaffer Ünsaldı
Seitaro Urakawa
Gianmarco Valletta
Giovanni Valsecchi
Stefaan Van Wal
George Vardaxis
Theodora Varelidi Strati
Ljubisa Vaskic
Tony Vaughn
Dmitrii Vavilov
Sai Vempati
Flaviane Venditti
Jagannatha Venkataramaiah
Sergio Ventura
Dimitri Veras
Peter Veres
Rodrigo Vesule
Salvatore Vicinanza
Arjun Vijaykumar
Adrian Vilchez
Shez Virani
Anne Virkki
Alberto Vodniza
Richard Wainscoat
Ulrich Walter
Yirui Wang
Yueer Wang
Wang Xiaobin
Dietmar Weinzinger
Thomas Weissenberg
Rob Weryk
Lorien Wheeler
Aidan Whyte
John Wimarsson
James Winsley
Daniel Wischert
Wolfgang Wittholt
Ireneusz Wlodarczyk
Edward Wright
Ben Wright
Yanhua Wu
Xinhong Yang
Quanzhi Ye
PO Yen Liu
Don Yeomans
Gan Yong
Makoto Yoshikawa
Tianhong Yu
Si Yuan
Marco Zaccaria Di Fraia
Syed Zaheer Hussain
Yun Zhang
XJ Zhang
Jerry Zhang
Pengfei Zhang
Haibin Zhao
Qi Zhou
Zhuo Xiao
Angelo Zinzi
Michal Zolnowski
Roman Zolotarev
Vladislav Zubko

APPENDIX D: ASTEROID THREAT EXERCISE

As in several previous conferences, the purpose of the asteroid threat exercise for the 2021 conference was to acquaint conference participants and decision-makers with an asteroid threat representative of the type of threat that might be possible given limitations of current discovery capabilities. For the 2021 conference, the threat is an example of case where an object believed larger than 50 meters and has a small, but non-zero possibility of impact is discovered a relatively short time before possible impact. This case highlights our current capabilities to reduce the risk of impact and also prepare for possible impact should that be the eventual outcome.

Should astronomers actually discover such a threat, it would be evaluated by the International Asteroid Warning Network (IAWN), and if found to be credible, IWAN would present the threat to the United Nations Office of Outer Space Affairs (UNOOSA). Kelly Fast, coordinator of IAWN, presented the charts In Figure A-1 to introduce the IAWN.

If the possibility of impact exceeds 1% and the estimated size is greater than 50 meters, a second UN-authorized body, the Space Mission Planning Advisory Group (SMPAG) would be activated to examine possible missions to collect refined information on the object and its orbit and to consider possible mitigation options. SMPAG was introduced by the chair of that group, Gerhard Drolshagen, and his charts are given in Figure A-2. These options might include deflecting or possibly disrupting the object to reduce the possible consequences of impact.

The 2021 asteroid threat was developed by a team at NASA's Jet Propulsion Laboratory led by Paul Chodas, Director of the Center of Near-Earth Object Studies (CNEOS) at JPL. A team led by Brent Barbee at NASA's Goddard Spaceflight Center examined possible mitigation mission options, and Lorien Wheeler led a team at NASA's Ames Research Center that considered possible consequences of an impact as the threat evolved. Details of the threat are posted at the CNEOS webpage at https://cneos.jpl.nasa.gov/pd/cs/pdc21/.

Updated details on the threat were presented in four Injects in the Green Zones on the first three days of the conference, and information injects on each day was based on updated observational data on the threatening object and its orbit. Technical discussions on the feasibility of launching of mitigation or flyby reconnaissance missions and on possible impact locations and consequences preceded discussions by panel members on possible next steps.

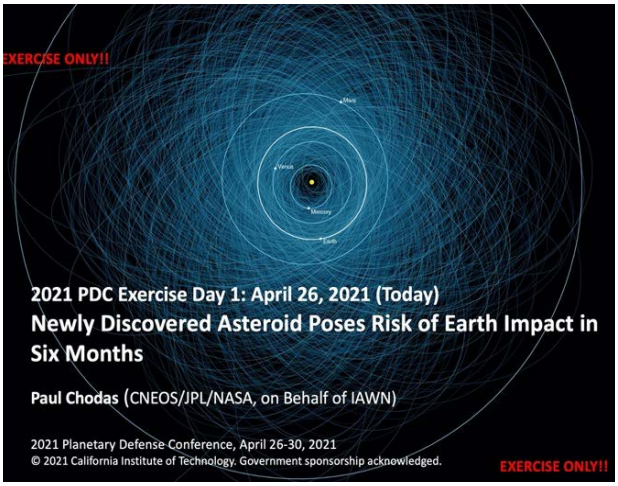
After each day's inject (except for Inject #3 on Day 2), panels of selected conference attendees consider the details of the possible threat and what actions and/or options for mitigating the risk might be available. Inject #3 provided an update on the threat based on new information. There was no further discussion of this update.

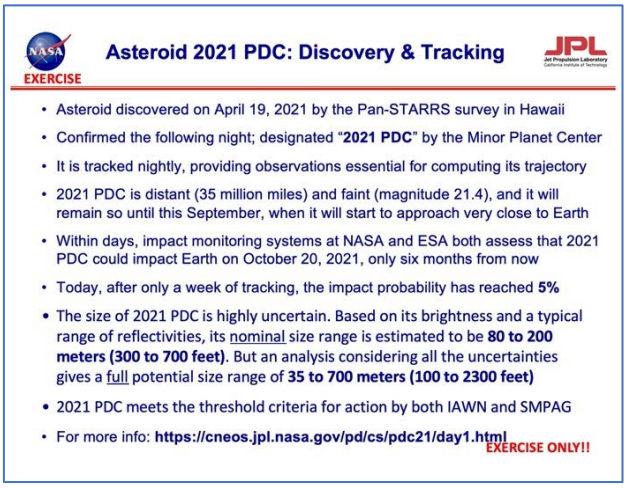
The exercise concluded on Day 3 with predictions showing the final impact location and date and possible consequences of impact.

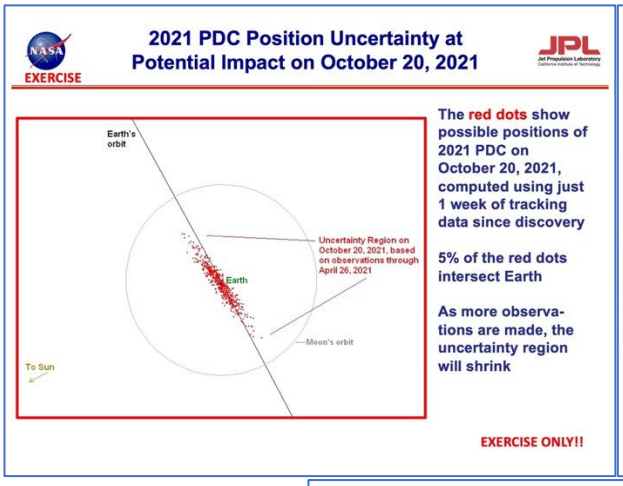
THREAT EXERCISE: DAY 1

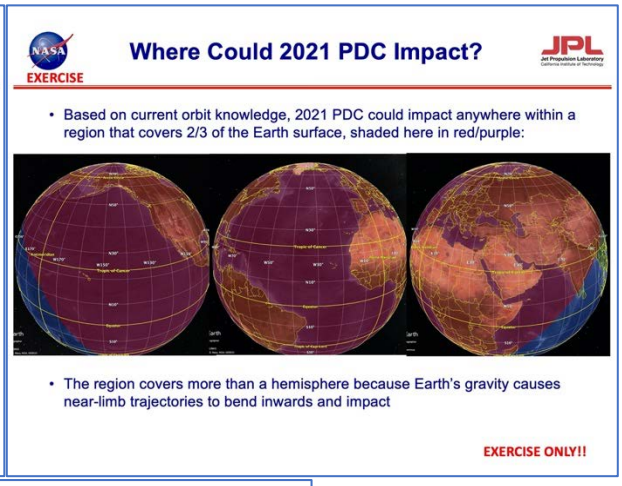
INJECT #1: FIRST NOTICE OF (HYPOTHETICAL) THREAT

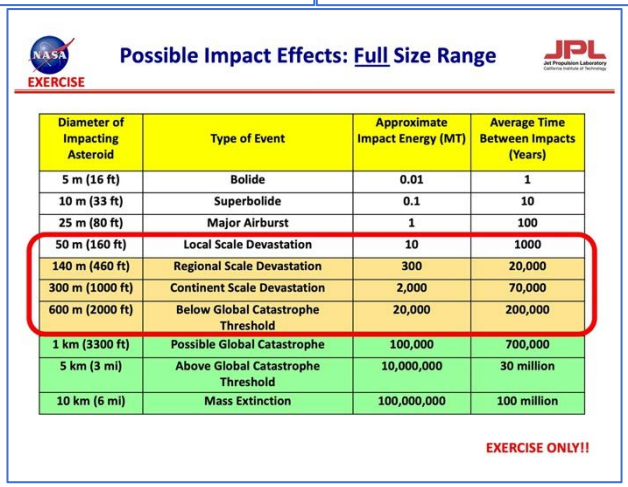
Paul Chodas of JPL, representing the International Asteroid Warning Network (IAWN), presented the fictional threat. His full presentation is available at https://cneos.jpl.nasa.gov/pd/cs/pdc21/day1.html. The excerpts below from that presentation give a quick overview of the threat.





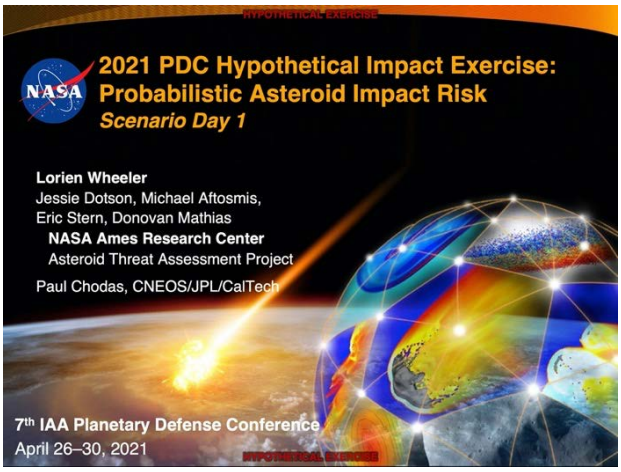


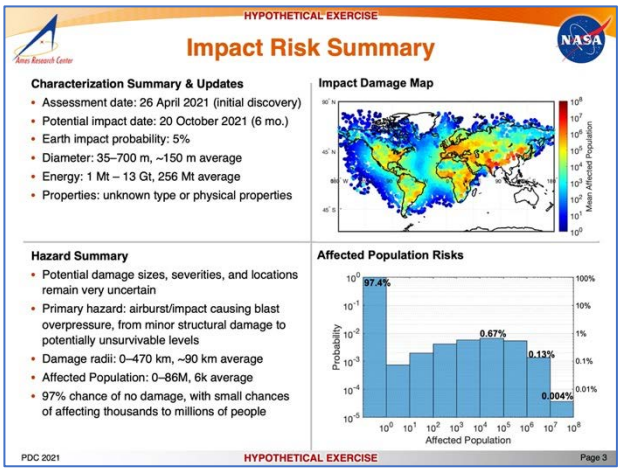


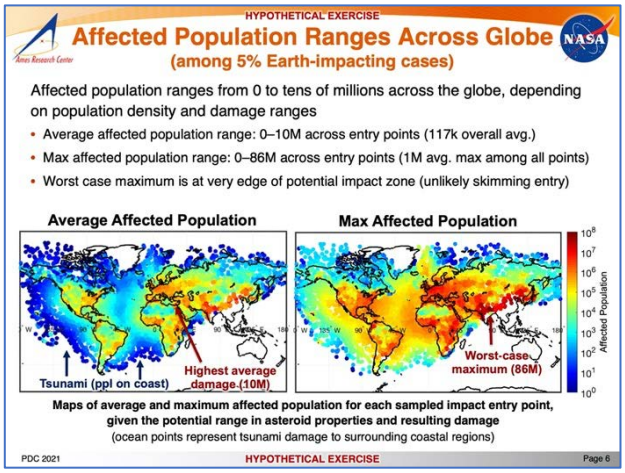


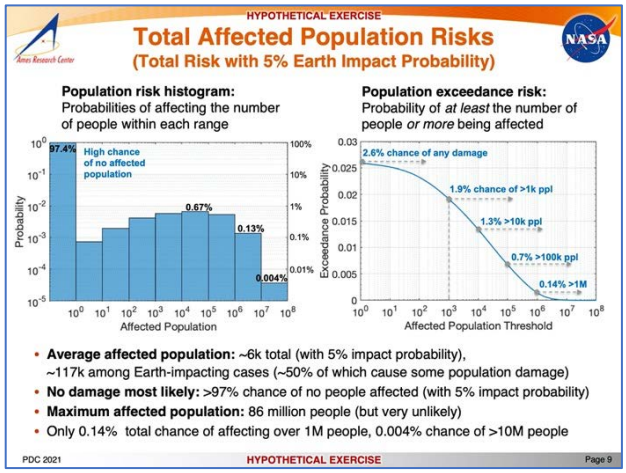
Diameter of Impacting Asteroid	Type of Event	Approximate Impact Energy (MT)	Average Time Between Impacts (Years)
5 m (16 ft)	Bolide	0.01	1
10 m (33 ft)	Superbolide	0.1	10
25 m (80 ft)	Major Airburst	1	100
50 m (160 ft)	Local Scale Devastation	10	1000
140 m (460 ft)	Regional Scale Devastation	300	20,000
300 m (1000 ft)	Continent Scale Devastation	2,000	70,000
600 m (2000 ft)	Below Global Catastrophe Threshold	20,000	200,000
1 km (3300 ft)	Possible Global Catastrophe	100,000	700,000
5 km (3 mi)	Above Global Catastrophe Threshold	10,000,000	30 million
10 km (6 mi)	Mass Extinction	100,000,000	100 million

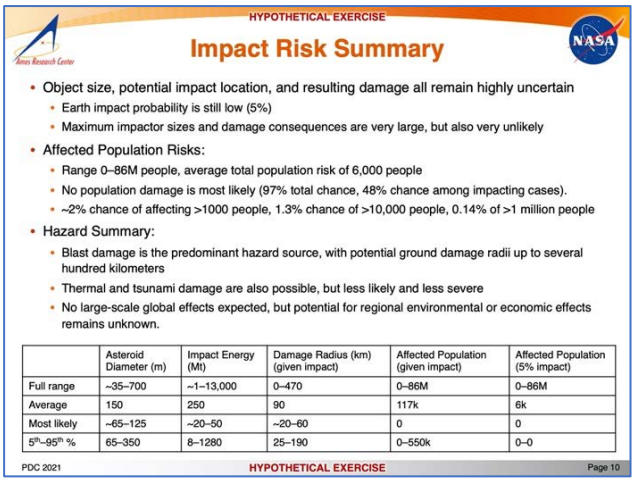
Next, Lorien Wheeler of NASA Ames gave first estimates of the potential consequences should the object impact Earth.





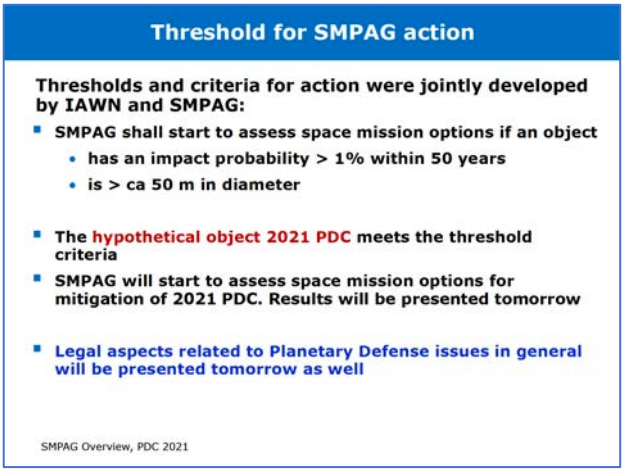






	Asteroid Diameter (m)	Impact Energy (Mt)	Damage Radius (km) (given impact)	Affected Population (given impact)	Affected Population (5% impact)
Full range	~35–700	~1–13,000	0–470	0–86M	0–86M
Average	150	250	90	117k	6k
Most likely	~65–125	~20–50	~20–60	0	0
5th–95th %	65–350	8–1280	25–190	0–550k	0–0

Following the details on the threat presented by Dr. Chodas and possible consequences should the object strike Earth by Dr. Wheeler, Gerhard Drolshagen, Chair of the Space Mission Planning Group (SMPAG), presented a short overview of that group's role and responsibilities. His charts follow.



Should astronomers discover such a threat, it would be evaluated by the International Asteroid Warning Network (IAWN), and if found to be credible, IWAN would present the threat to the United Nations Office of Outer Space Affairs (UNOOSA). If the possibility of impact exceeds 1% and the estimated size is greater than 50 meters, a second UN-authorized body, the Space Mission Planning Advisory Group (SMPAG) would be activated to examine possible missions to collect refined information on the object and its orbit and to consider possible mitigation options. These options might include deflecting or possibly disrupting the object to reduce the possible consequences of impact.

PANEL: NEXT STEPS

Moderator:

Romana Kofler, United Nations Office of Outer Space Affairs

Panelists:

Simonetta Di Pippo, UNOOSA Director
Gerhard Drolshagen, Chair, Space Mission Planning Advisory Group (SMPAG)
Kelly Fast, Representing the International Asteroid Warning Network (IAWN)
Martin Nesirky, Director, United Nations Information Service

The panel considered information presented by IAWN and SMPAG and:

- Discussed the role UNOOSA might play in disseminating information of the threat to all member nations as well as to member states with space launch capability.
- Stressed the need for communicating with the public and translating technical information on the threat into language appropriate for non-technical leaders and individuals
- Stressed the importance of a coordinated international response to the threat and noted that the UN has agencies that have experience in developing such responses,
- Encouraged IAWN to getting data from more sensors to refining the threat and asked SMPAG to develop and report back information on possible coordinated plans for both flyby and disruption missions should they be warranted.

A video of the exercise presentations and the panel discussions is included at:
https://www.youtube.com/watch?v=cXp6WzsnL-g&list=PLaOqa4cng0GF56U0oJMKEjKfLXFBhuxBk&index=1

THREAT EXERCISE: DAY 2

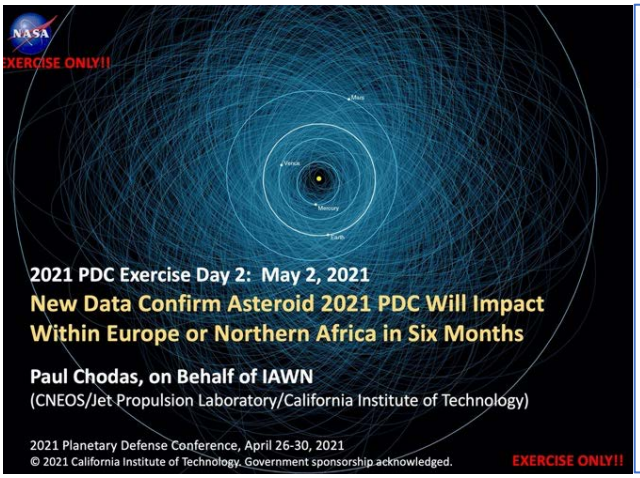
In the session following the presentations on the threat and possible consequences, speakers in Alissa Haddaji's session "Legal and Policy Issues for Deflection" and presentations focused on:

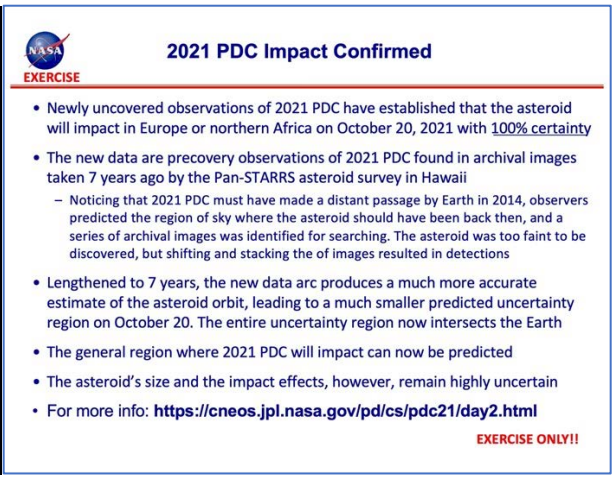
- Legal aspects of the use of a nuclear explosive device in space,
- Legal Aspects of Planetary Defense: Conclusions of the SMPAG Ad-Hoc Legal Working Group Report, and
- Obligation to Inform and to Act, Liability, Responsibility, and International Decision-Making

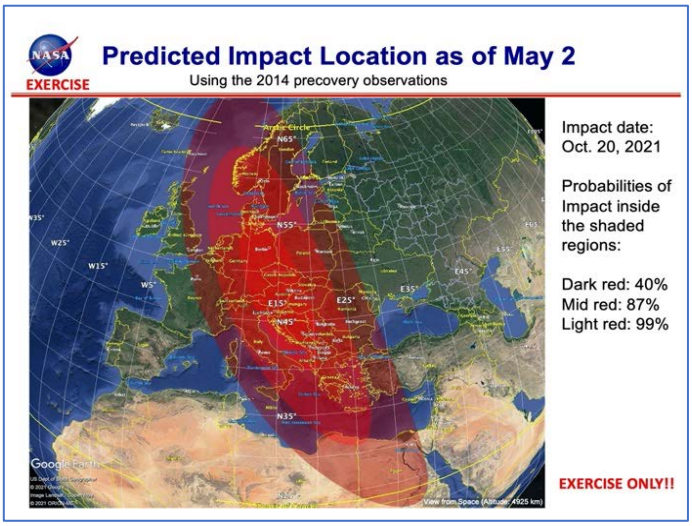
INJECT #2: **UPDATE ON SPACE-BASED MITIGATION OPTIONS**

Day 2 presentation charts on the asteroid threat and possible deflection or fly-by missions are available at https://cneos.jpl.nasa.gov/pd/cs/pdc21/day2.html.

Selected charts from briefing by Paul Chodas follow:

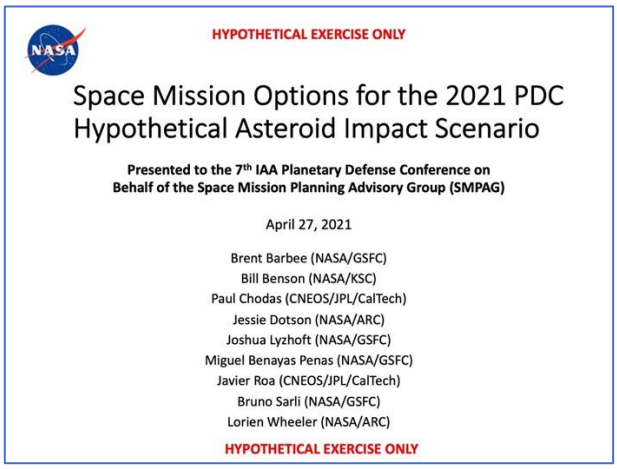


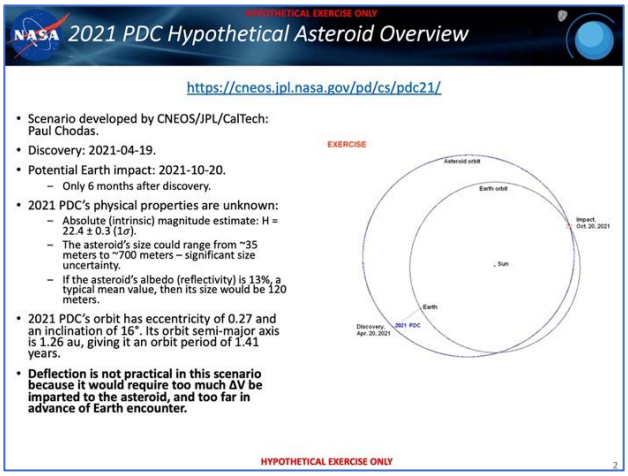


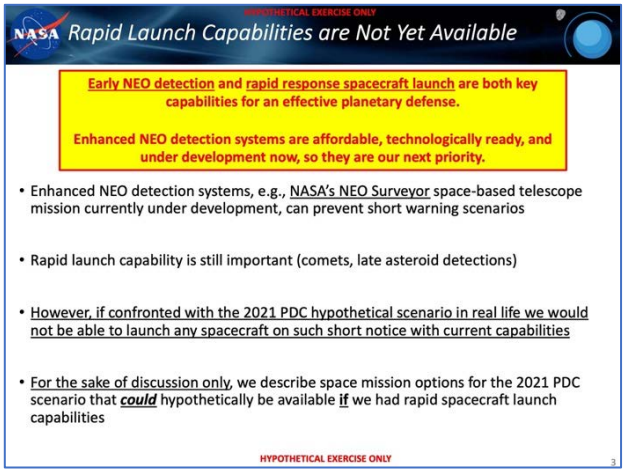


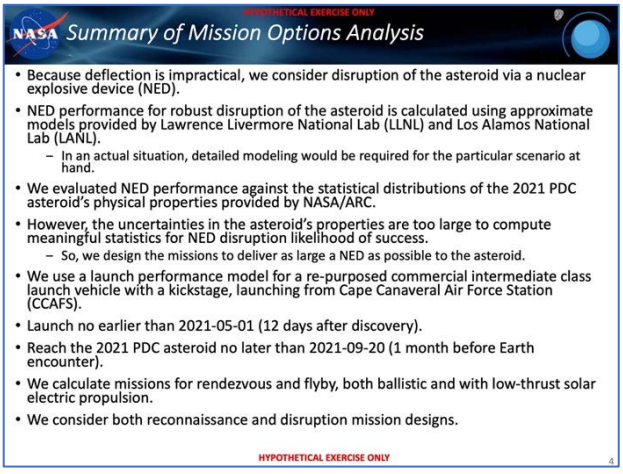
EXERCISE SESSION: UPDATE ON SPACE-BASED MITIGATION OPTIONS

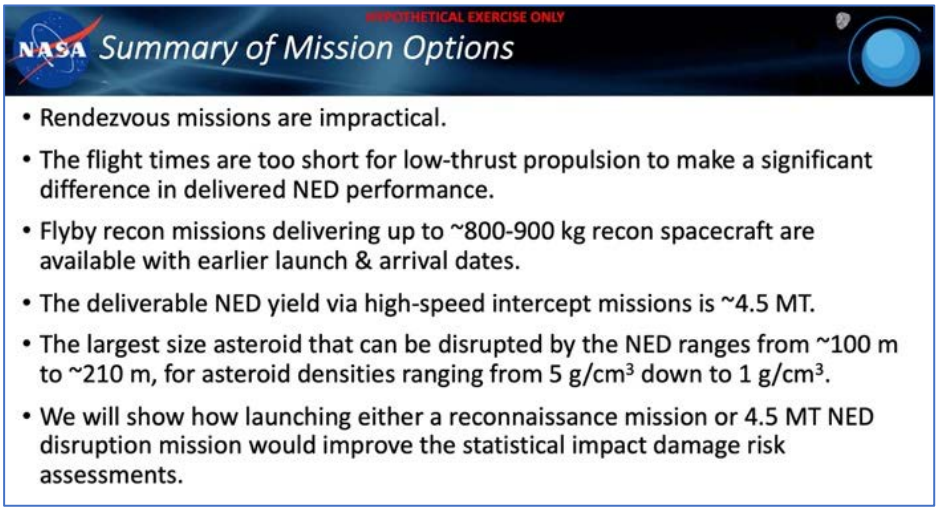
Brent Barbee discussed mission options that might be available, including fly-by reconnaissance and deflection and disruption missions. Selected charts he presented are below.



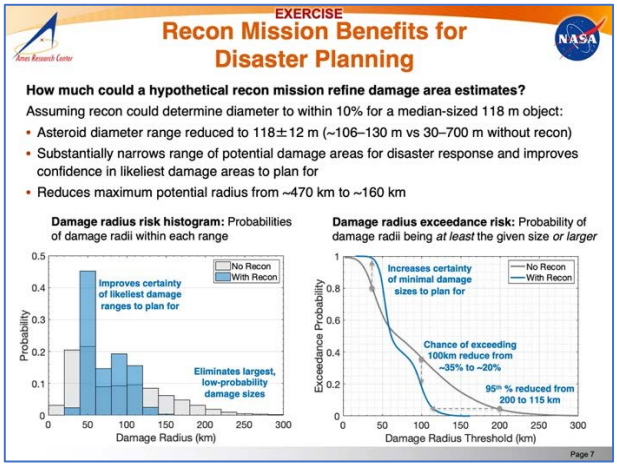


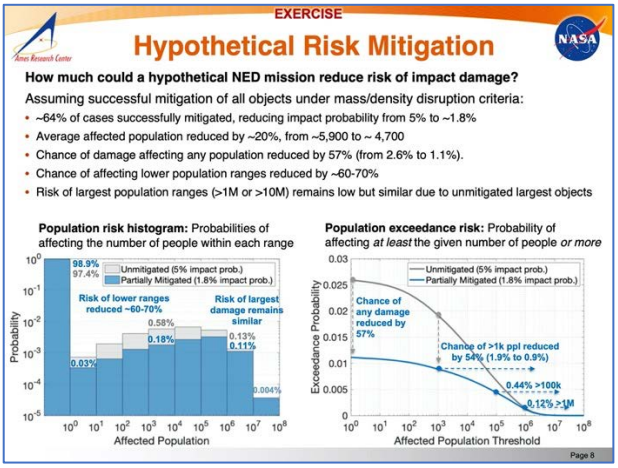


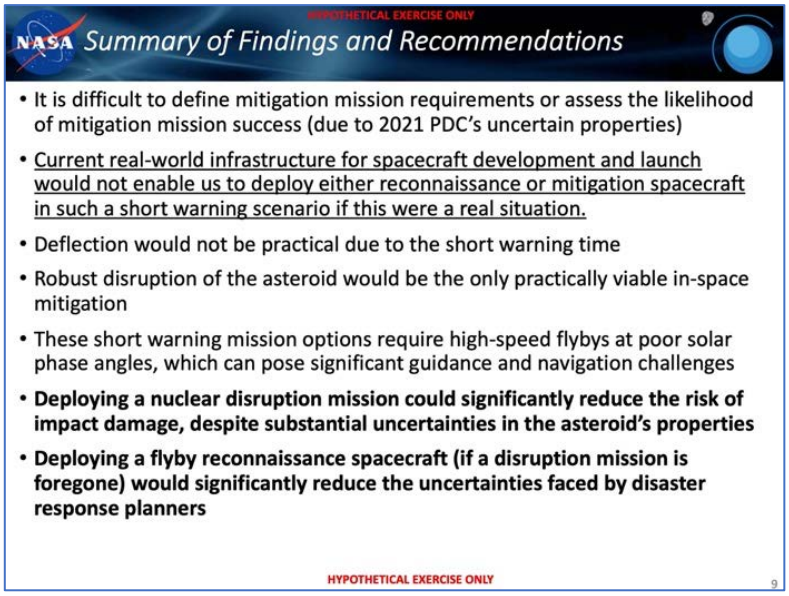




Following information on the threat and the feasibility of a reconnaissance mission to refine characteristics of the object, Lorien Wheeler presented details on the value of a reconnaissance mission relative for refining estimates of the risk and the threatened impact area. Selected charts from her briefing follow:







EXERCISE SESSION: LEGAL AND POLICY ISSUES RELATED TO MITIGATION OPTIONS

Chair:

Alissa Haddaji

Presenters:

Alissa Haddaj

David Koplow

Irmgard Marboe

Cordula Steinkogler

In this session, speakers focused on:

- The role of the SMPAG Ad-Hoc Legal Working Group
- Legal aspects of the use of a nuclear explosive device in space,
- Legal Aspects of Planetary Defense: Conclusions of the SMPAG Ad-Hoc Legal Working Group Report, and
- Obligation to Inform and to Act, Liability, Responsibility, and International Decision-Making

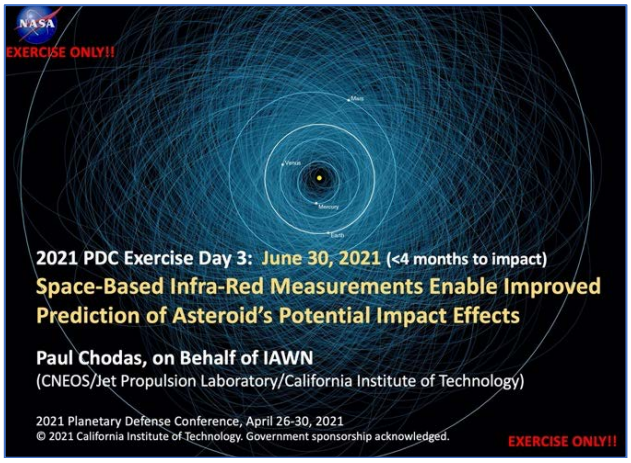
PANEL: **DISRUPTION & DEFLECTION OPTIONS**

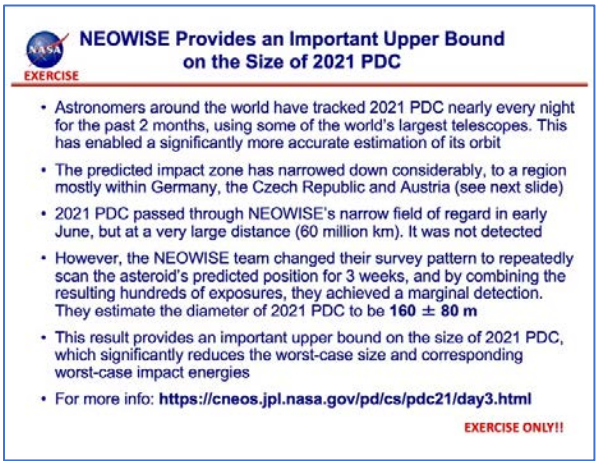
Following that session, Alex Karl led a panel discussion of deflection and disruption options. Details on the panel discussion are provided on Day 2 (page 6 if the main body of the report).

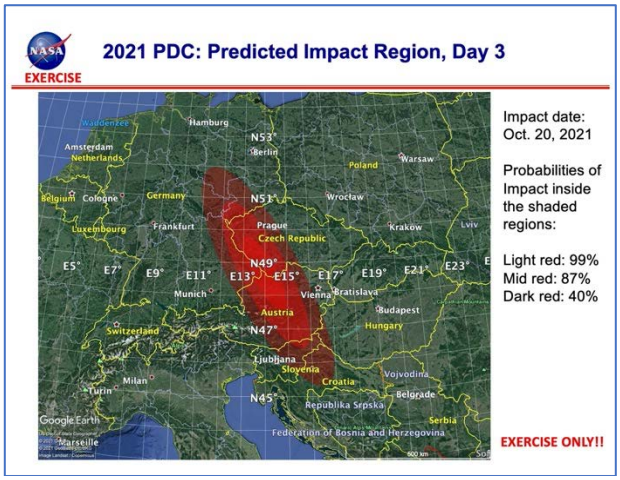
THREAT EXERCISE: DAY 3

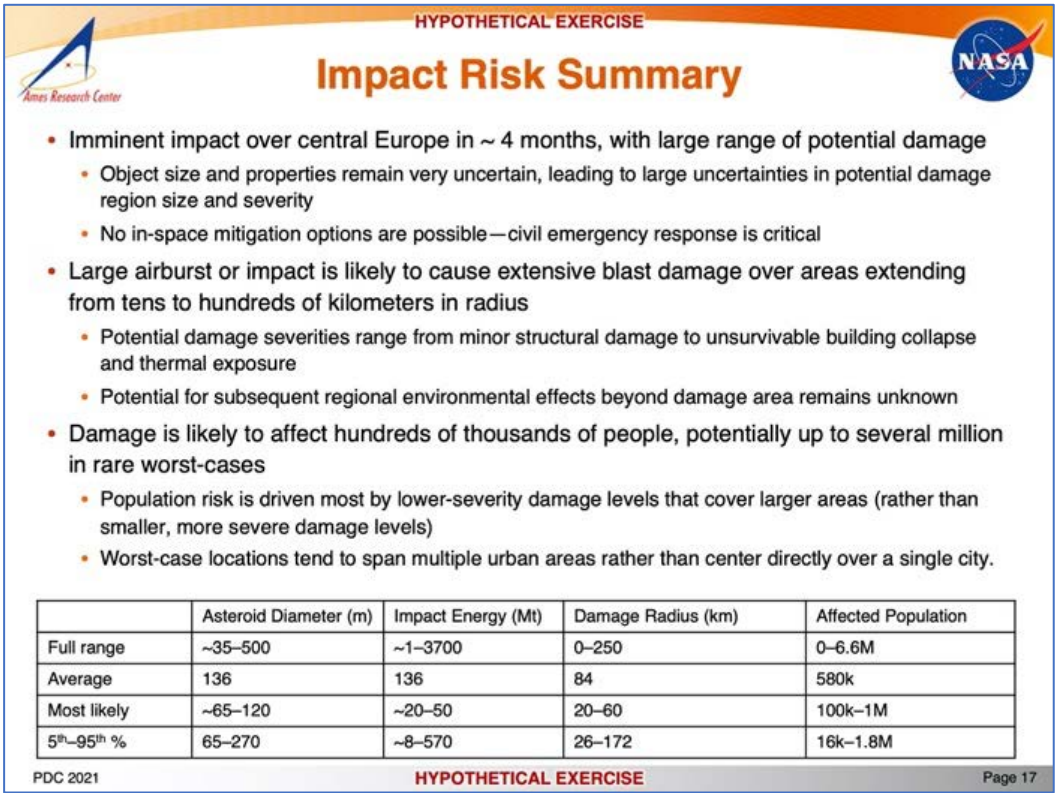
INJECT #3 UPDATE ON THREAT REGION

Paul Chodas presented the latest information on the asteroid threat and Lorien Wheeler gave estimates of the potential consequences of impact given the revised information on potential impact location. Briefing charts for both presentations and detailed background information is given at https://cneos.jpl.nasa.gov/pd/cs/pdc21/day3.html.









	Asteroid Diameter (m)	Impact Energy (Mt)	Damage Radius (km)	Affected Population
Full range	~35–500	~1–3700	0–250	0–6.6M
Average	136	136	84	580k
Most likely	~65–120	~20–50	20–60	100k–1M
5th–95th %	65–270	~8–570	26–172	16k–1.8M

PANEL OF DISASTER MANAGERS

Goal of this panel: disaster response experts saw current best estimates of the region of possible impacts and best-available information on the possible consequences of an impact. Based on that input and discussions with experts, the Panel sets directions for responses to the pending disaster.

Panel Moderators:

Leviticus A Lewis, FEMA
Lorien Wheeler, NASA.

Panelists:

Shirish Ravan, Senior Programme Officer, Head of UN-SPIDER Beijing Office, UNOOSA
Tom De Groeve, Representative of COPERNICUS EMS; Deputy, European Commission Joint Research Centre, Disaster Risk Management Unit
Einar Bjorgo, Director, Satellite Analysis and Applied Research at United Nations Institute for Training and Research (UNITAR).
Jose Miguel Roncero Martin, Emergency Response Coordination Centre of the European Commission **(**ERCC)
Richard Moissl, ESA, Planetary Defence Office, Mitigation Coordinator

As input for the panel IAWN presented updated estimates of the region where an impact of the hypothetical 2021 PDC is possible. Experts presented detailed information on possible impact consequences within the potential impact region.

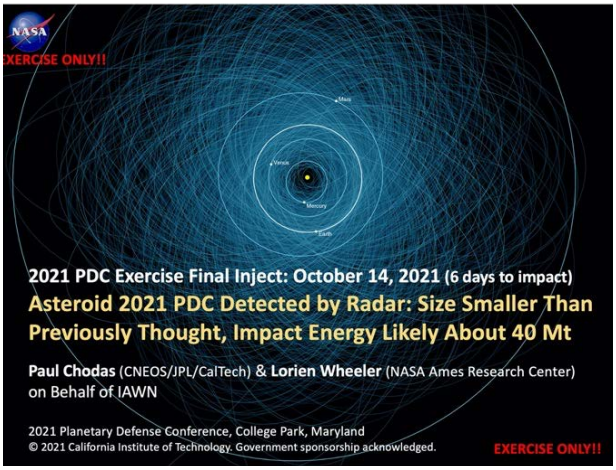
The panel had a lively and interactive discussion on questions such as:

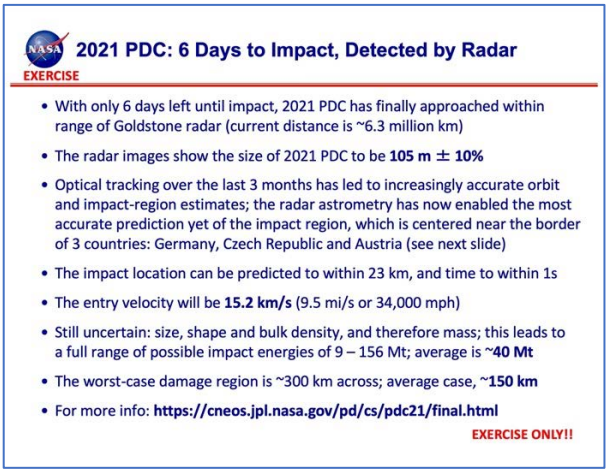
- How does the impact threat fit existing plans for disaster mitigation?

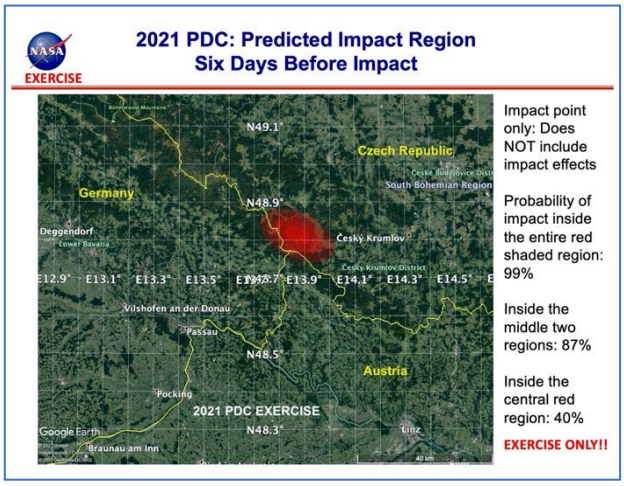
- Given projected impact area, what plans should be made?
- What guidance should be given to members of the public within and bordering the region of possible impact?
- What are best practices at the national levels (action plans)?
- What are best practices at international levels?
- What are practices at the regional level?

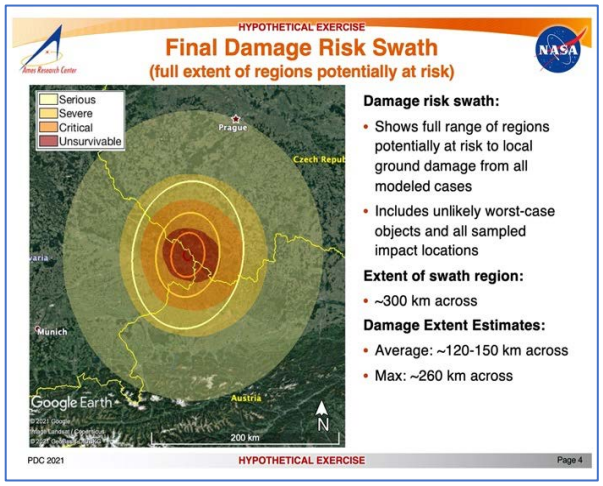
FINAL INJECT (presented after conclusion of exercise discussions)

Drs. Chodas and Wheeler presented predictions of the impact location and consequences at six days before impact:









EXERCISE

2021 PDC: A Few Take-Aways

- A short-warning scenario poses extreme challenges for in-space mitigation
- Had a more sensitive asteroid survey such as NEOSM or Rubin Observatory (LSST) been in place in 2014, it would almost certainly have detected the scenario object, and the 7-year warning of potential impact would have opened up a host of different possible outcomes. In particular, space missions would have been feasible for reconnaissance or simple kinetic-impactor deflection
- Precoveries could play a major role in assessing the impact probability of a threatening object, and in helping to constrain the impact location
- The large end of the estimated size range becomes the dominant factor in a scenario: capabilities that can put an upper bound on the size would be invaluable (space-based IR, planetary radar and recon missions)

EXERCISE ONLY!!

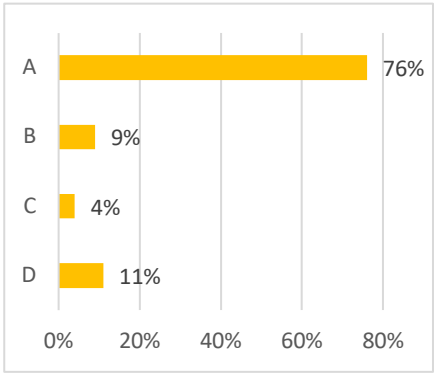
APPENDIX E. POLL RESULTS & CLOSING COMMENTS

Conference attendees were polled to collect opinions on various topics each day and to collect comments and suggestions for then202 conference. The following are results of this polling.

Day 1

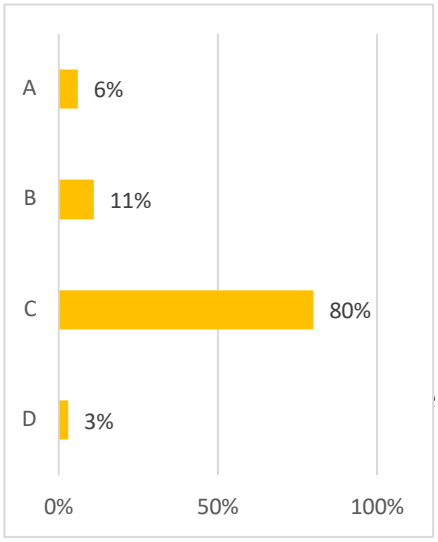
Poll #1 - 15:15 after Welcome and Keynote

	What is your reason for attending the PDC?	Results*	%
A:	I work in the field	149/196	76%
B:	I want to get involved	18/196	9%
C:	I'm just curious	7/196	4%
D:	To see what the risk really is and what we can do	22/196	11%
E:	No answer	95/291	(33%)



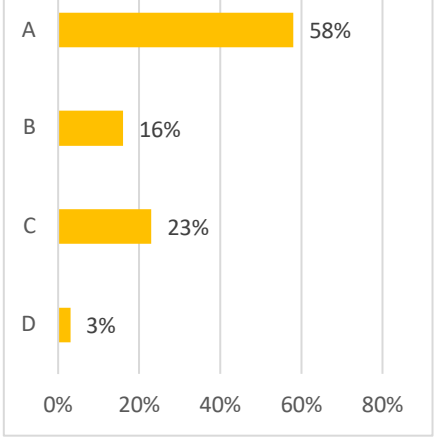
Poll #2 - 16:15 after Exercise Inject #1

	What is your reaction to the scenario?	Results	%
A:	5% chance of hitting us is pretty low. Nothing to worry about.	10/175	6%
B:	Even if it comes our way, we'll just send Bruce Willis, right?	19/175	11%
C:	6 months is soon. We need to act now!	140/175	80%
D:	I'm really worried and losing sleep!	6/175	3%
E:	No answer	138/313	44%
	Had you heard about IAWN and SMPAG before?	**Results**	**%**
A:	Yes, and I was aware of their roles and functions.	104/180	58%
B:	I heard the names before but was not sure what they were doing.	28/180	16%



rs

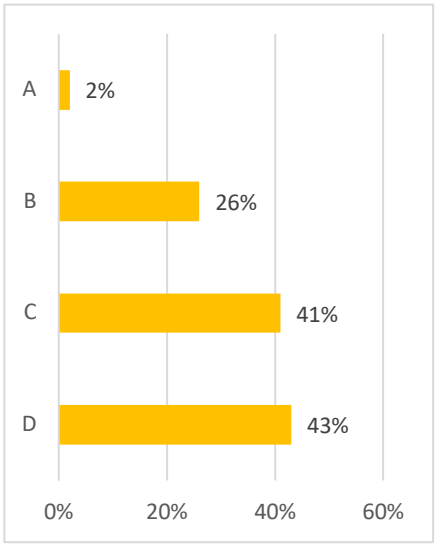
C:	No. First time I heard about it.	42/180	23%
D:	I'm glad nations are working together.	5/180	3%
E:	No Answer	122/302	40%



Day 2

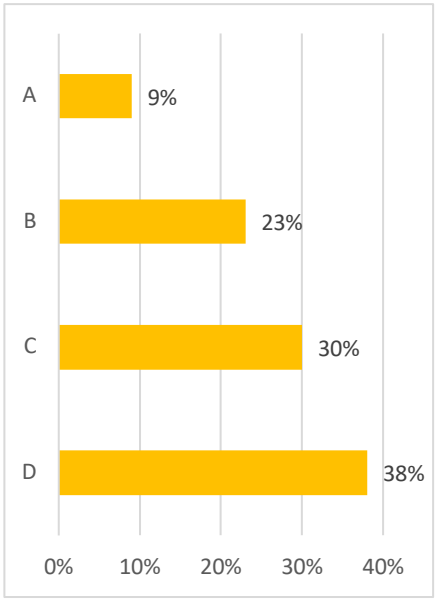
Poll #4 - 15:15 after Exercise NEO Mission Options

	What do you think should be done given the current information?	Results	%
A:	The risk is low. We should wait a bit longer to decide what to do.	3/128	2%
B:	The risk is low. Wait for more information but send a recon mission as soon as possible.	33/128	26%
C:	Time is short. We should get to work on a deflection mission.	52/128	41%
D:	Even though the risk is low, time is short and we should plan to launch a nuclear explosive to disrupt the object as soon as possible.	55/128	43%
E:	No Answer	139/267	52%



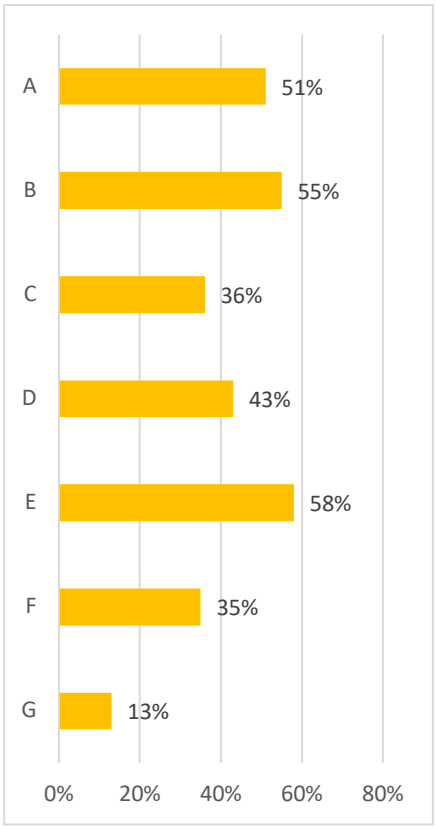
Poll #5 - 16:15 after Session: Legal and Policy Issues

	Is use of a nuclear explosive to deflect or disrupt the object something we should consider given the current risk level?	Results	%
A:	We should never launch a nuclear explosive. The risk of an accident is too great.	10/113	9%
B:	We should only launch a nuclear explosive if it's legal to do so.	26/113	23%
C:	We should launch a nuclear explosive as soon as possible, no matter what the law says when it's the best technical solution.	34/113	30%
D:	We should wait until there's no other option.	43/113	38%
E:	No Answer	140/253	55%



Poll #6 - 17:30 after Panel on deflection options + Inject#2

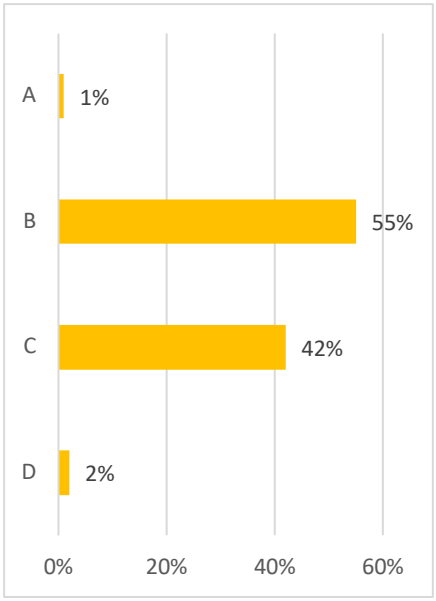
	If you lived in the affected area, what would you like your decision makers to do in order for you to feel they have your interests/safety at heart?	Results	%
A:	Appoint a trustworthy spokesperson who can keep us informed about what's going on.	77/152	51%
B:	Get disaster managers working on a response plan just in case.	84/152	55%
C:	Take action and send a recon mission.	55/152	36%
D:	Take action and send a deflection mission.	65/152	43%
E:	Prepare emergency services for the worst.	88/152	58%
F:	Tell us what we can do if the situation gets worse.	53/152	35%
G:	No matter what they will do, I will move to Australia!	19/152	13%
H:	No Answer	114/266	43%



Day 3

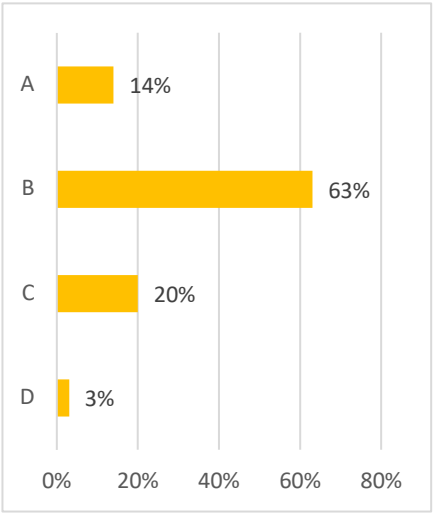
Poll #7 - 15:00 after Exercise Inject#3

	What is your reaction?	Results	%
A:	I have nothing to worry about, it will hit far away.	1/130	1%
B:	While I won't be directly affected we need to do something to help.	72/130	55%
C:	That's right here! We need to act now and prepare for disaster response asap.	54/130	42%
D:	I'm really worried and losing sleep. Best I move abroad.	3/130	2%
E:	No Answer	93/223	42%



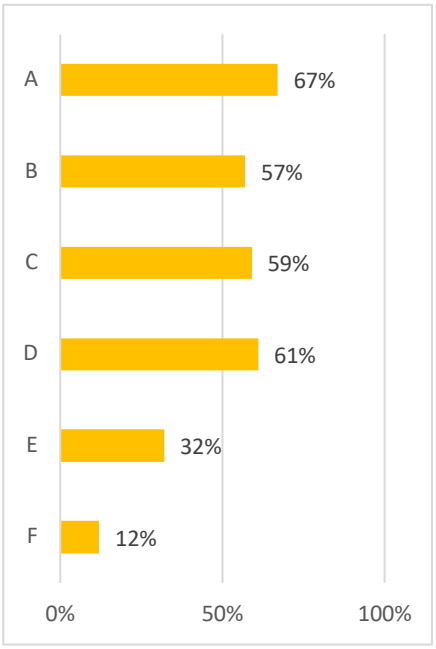
Poll #8 - 16:15 after Panel on disaster Managers + Final Impact Area

	Do you think we would be able to manage such a scenario?	Results	%
A:	Yes, I'm confident in the teams on Ground.	14/101	14%
B:	I think a lot more work is necessary.	64/101	63%
C:	It will be chaos, too many people involved.	20/101	20%
D:	No, I better take my fate into my own hands.	3/101	3%
E:	No Answer	140/241	58%



Poll #9 - 17:30 after Panel Heads of Agency

	What should space agencies do more about NEOs?	Results	%
A:	Build more space observatories to detect them early.	83/124	67%
B:	Test Deflection Techniques.	71/124	57%
C:	Support preparation of mitigation efforts.	73/124	59%
D:	Work towards agreement on a global policy.	75/124	61%
E:	Communicate more with the public.	39/124	32%
F:	other	15/124	12%
G:	No Answer	100/224	45%



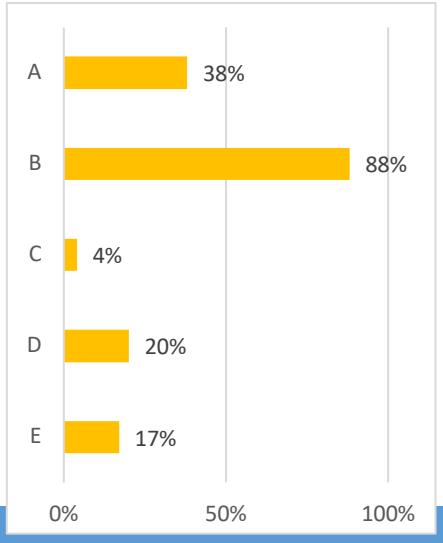
Other
rapid r&d advanced space hardware & propulsion, isru, moon based planetary defense, ...
First of all, do fly frequently! - Practice makes perfect; a lively space sector, scientific and commercial, is the basis for safe action in close calls like this scenario or the 2019 PDC scenario after the fragmentation causing to hit NYC. Missions can be small and many, the only bad thing is to have very few very big missions, _only_ because every generation starts anew (like in the 70s-90s).
Rather send more science missions for in-depth studies instead of doing too much stripped-down" impact/deflection experiments alone."
Build more space AND ground-based observatories to detect them early.
Enhance planetary radar capabilities
The above needs to be more than space agencies and must also be reflected in national policies (an international agreement would further be best). Moreover, highly capable commercial entities disrupt the space agency" model and must be included through some direct process. Pointing to Article VI of the OST is entirely insufficient. "
Support more radar observatories
build more radar facilities and medium-sized optical telescopes that could be used for NEO follow-up

Work together on Planetary Defense!
Build more space and ground-based observatories to detect them early.
All of the above.
Provide more funding for radar, spectroscopic and polarimetry measurements
Take Civic Bodies and Professional bodies for dialogues
support preparation of *reconnaissance* missions (not only mitigation)
Rebuild Arecibo and new and more powerful radar telescopes.

Day 4

Poll #10 - 15:30 after Panel Communications

	Who's information do you trust?	Results	%
A:	Traditional news agencies (newspaper, TV)	35/93	38%
B:	Official sources, such as government, space agency	82/93	88%
C:	Social media	4/93	4%
D:	I trust no one	19/93	20%
E:	Other	16/93	17%
F:	No Answer	104/197	53%

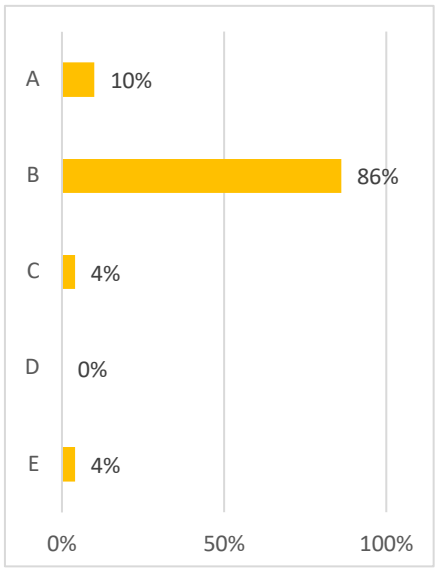


Who's information do you trust?
Explain why the most obvious conspiracy theories are not possible in practice. E.g., a potential asteroid impact cannot be a secret, because all asteroid astrometry is public from the discovery onwards (when the impact is much less than 100% certain) and there are a non-negligible group of amateurs and professionals spread across the globe who compute orbits for these objects on a daily basis. I did this with our national broadcasting company and it was well received. Laymen aren't stupid, just explain it.

Panic is inevitable but doesn't have to be disastrous
Be careful when talking to communicators. They will try to get you to say something controversial. The media thrive on controversy!
Getting out clear information in the heat of the moment is an unwinnable war. Sadly, all sources have been compromised by either malice, agenda, or ignorance. Educating the public in advance of crisis is our best bet, so multiple sources can be referenced/cross-checked. Many lessons to be learned from the Pandemic...
I also trust what might be called science journals" - still journalism, but where stories are more carefully researched and written, have proper citations and reference many different studies/papers/etc. These are usually more interesting than sort of "up-to-the-minute" news of the day, whether that is newspapers or TV shows."
Suggest use of more cross domain / cross discipline lessons learned" in this area and other PD areas should likely prove useful. R. Leung"
There needs to be some strategy for dealing with a leader of a powerful country who is also an influencer dealing with disinformation. We have seen recently that some are willing to annotate charts for their own reasons. Or what if a leader thinks it is advantages to call an asteroid the X-asteroid, where X is an adversarial scapegoat? BTW, trust but verify is not an option for #1.
Sharing data and technology is the key to prove the information you shared.
Being able to triangulate data from multiple sources is important.
I think all three sources of information are valuable as long as there is a proper level of discernment. All three can be sources of misinformation and disinformation. Corroboration among the three and for other independent sources is a good indicator of the voracity of the information, but still not perfect if the three are serving as echo chambers.""
Find a way to inform the public more broadly about planetary defense. perhaps using the examples of well know natural events such as hurricanes or cyclones. The new science of PD may be the problem with regard to public understanding
only because I'm in the industry. if I wasn't, I'd be looking to my peers, social media, and perhaps certain Media celebrities (like YouTube stars) for advice. and, thanks to the broken algorithms, I'd probably go down a wrong, algorithm curated, path...
I typically rely on multiple sources to corroborate a fact
I am curious to see how pre-bunky works with unknown unknowns and how that plays a role when officials deliver some pre-bunking on very important unknown unknowns but get them completely wrong. How does one inform the public about unknown unknowns?
Let's keep learning about the logistical challenges of vulnerable communities. Hosting deliberative forums among them is one systematic approach. See Fishkin and Lushkin on deliberative polls and meetings at scholar.google.com
Official" sources (traditional news media, government agencies) are not trusted by large parts of the populations, due to too many blatant lies and misrepresentations in recent years."

Poll #11 - 16:45 after Panel Lessons Learned from past disasters

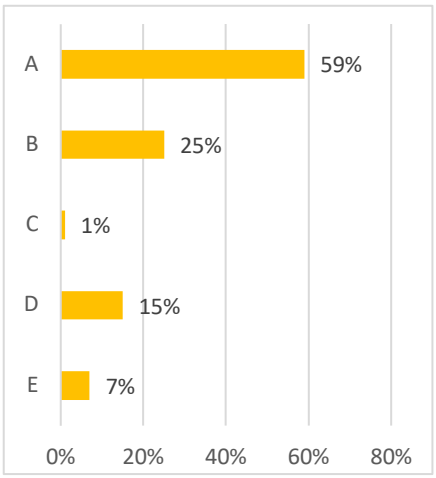
	Do you think we can transfer the lessons learned (LL) to a NEO threat?	Results	%
A:	Yes, the response will be very similar regardless of the situation.	8/79	10%
B:	Partially - it is one thing to identify a LL, another to actually implement it	68/79	86%
C:	I'm pessimistic, there are too many people involved.	3/79	4%
D:	I don't think the LL are applicable to a NEO threat.	0/79	0%
E:	Other	3/79	4%
F:	No Answer	99/178	56%



Do you think we can transfer the lessons learned (LL) to a NEO threat?
We need an international, public-facing, supranational agency for this. It needs to have its own independent public brand.
It is key, at least in the US, to get politicians involved and informed. They need to be convinced of the risks and consequences so they can help with the public.
Most actual consequences of impacts will resemble other natural hazards, so the all-hazards" approach will apply. The problem is that people will *fear* other attributes of asteroid impacts that almost certainly won't happen, thanks in part to bad movies (e.g. radioactivity, a stream of precursor and follow-on impacts). So the problem will be managing communication and developing credibility. "

Poll #12 - 18:00 after Public Event

	How did you like the public event?	Results	%
A:	It was great!	45/76	59%
B:	It was okay.	19/76	25%
C:	I didn't like it.	1/76	1%
D:	I did not watch it.	11/76	15%
E:	Other	5/76	7%
F:	No Answer	104/180	58%

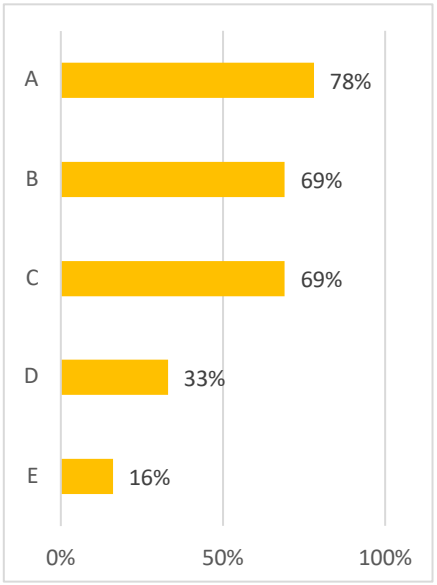


How did you like the public event?
well done! :)
Keep up the good work!
Unsure as to how to send any comments or questions for the streaming session.
I understood the need not to cause panic among the populace, but the facts should not be distorted in the process. For instance, saying that the risk of a large impact has been retired "is not true to reality. It also explains why NEOSM can't get accelerated or Arecibo not get replaced ASAP. -- no sense of urgency."
I hope they had a lot of viewers from the general public""

Day 5

Poll #13 - 16:10 after Session 13

	What should be done for major NEO close approaches?	Results	%
A:	Radar observations (if it comes close enough)	70/90	78%
B:	Space recon missions	62/90	69%
C:	Public education campaigns (esp if they will be visible)	62/90	69%
D:	Use an Earth-Moon bullseye chart (Earth in the center) to show how close it came.	30/90	33%
E:	Other	14/90	16%
F:	No Answer	107/197	54%

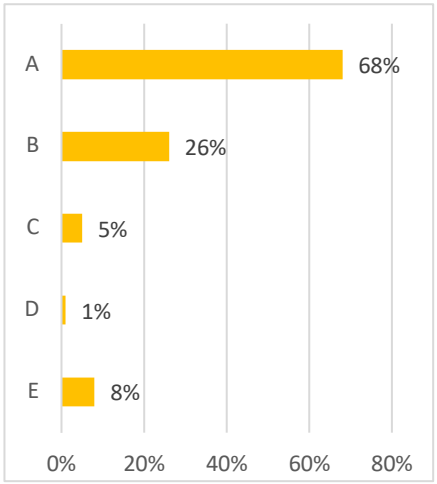


What should be done for major NEO close approaches?
Multi-wavelength observations, sample return missions,
Citizen science campaigns, school team competitions for astrometry & outreach by observations
Livestream as much of this as possible on SM platforms to raise awareness
of course perform all kind of possible optical, spectroscopic and polarimetry observations
coordinated facilities' campaigns
Public viewing through telescopes, if bright enough for visual observations, or streaming video from an observatory if too faint for visual observations.
All of the above
Coordinated observing campaigns
Occultation campaigns for the object
For Apophis consider a bullseye chart comparing to geosync satellites

A, C and D
All of the above. Any major NEO close approach should be used to test/utilize techniques for gaining knowledge of the asteroid as well as interacting with the public and civil defense resources.
Conduct Ground-based and Space-based observation campaign Re: IAWN exercises. Simulate disaster management exercises on the object in question. Plan for effective communication strategies for use with general public.
Simultaneous tabletop exercises around the world- with decision makers (gov agencies, private industry) and science/eng representatives. If it hits one country or region, how will it get help from its neighbors and international community? Recognize what is the maximum capacity for evacuation. i.e. to evacuate Puerto Rico we would need almost a year with >50 flights per day to evacuate the island. We have plenty of lessons learned form many natural disasters (e.g. Hurricane Maria). :)

Poll #14 - 17:25 after Panel IYPD

	What do you think of an IYPD?	Results	%
A:	Great idea!	58/85	68%
B:	It's a good idea, but needs more thought.	22/85	26%
C:	I'm not so sure about it.	4/85	5%
D:	Not a good idea.	1/85	1%
E:	Other	7/85	8%
F:	No Answer	98/183	54%

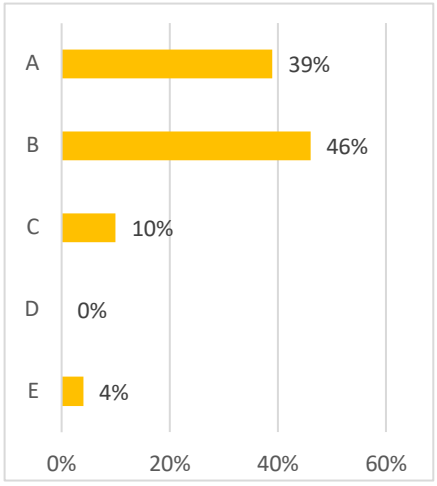


What do you think of an IYPD?
be more inclusive, have D stand at the front (it's spectacular to deflect asteroids) but make it a year for all asteroid matters & interests wide and far
In line with IYPD. We must make it more participatory with other stakeholders., Civic Societies and Professional organizations along with voluntary Space Education Out Reach groups must have a role and be considered from the planning stage itself. JV e mail : jagsiobbindia@gmail.com
I think 2029 is the perfect year for it
That's really great idea especially we can have it in the year of Apophis. Then, please be careful enough about the issue of nuclear device, considering the world public opinion.
Would prefer a name more like the IY of Asteroids and Comets

This is a fringe topic, relative to climate change and pandemics.
Important to keep it focused on Planetary Defense (but in a positive we can do this" way rather than "we are doomed". No mission creep (asteroid year, near-Earth space year, year of global harmony, ...)."

Polls #15+16 - 18:40 after Discussion wrap-up, next steps, recommendations for 2023 PDC

	Did the PDC 2021 meet your expectations?	Results	%
A:	It exceeded my expectations! Well done!	30/78	39%
B:	Yes, fully. I learned a lot.	36/78	46%
C:	Yes, but it could have been better	8/78	10%
D:	Not really.	0/78	0%
E:	No, I'm disappointed.	3/78	4%
F:	No Answer	106/184	58%



	Wrap-up questions	Replies	%
A:	What did you like about this PDC?	51/158	32%
B:	What did you not like about this PDC?	46/158	29%
C:	What can we do better for 2023?	39/158	25%
D:	Are you in favor of a hybrid conference for 2023?	77/158	49%
E:	Please provide additional thoughts and comments	31/158	20%

What did you like about this PDC?
online format
very interesting talks

everything
the virtual format was surprisingly good; informal zoom breakouts & poster sessions
Large attendance enabled by people being able to join at no cost.
Huge range of experts - wonderful breadth of issue coverage.
Everything. Amazing presentations! Excellent speakers!
Great variety of disciplines. Really interdisciplinary, which is quite rare.
I have learned a lot (particularly in terms of social/economical/law implications of impacts) and the exercise was very cool.
diversity of speakers and topics
EVERYTHING!
Most presentation from NASA community and UNOOSA
Specially the Asteroid Info parts and defense
Easy to participate
The availability to attend this conference, where I might not have been able to - and the great content from this.
Timekeeping plus Q&A
The access to the presentation slide in advance and be able to watch the sessions afterward.
Loved it! Multi-disciplinary focus with legal and communications aspects was fascinating to me as an engineer
worked quite well! I liked the discussion on legal issues. The organization per session was just perfect all along with presentation and questions gathered, all so well in time !
Success of hybrid meeting
The opportunity to be online
Presentations about many different topics
I liked the panel discussions in the green" zone of the schedule"

great venue
Opportunity for people new to the subject to attend and learn, and to broaden awareness of the issues.
The green block allowing attendees from USA to watch the sessions live in almost normal hours, and the recorded sessions so we could catch up later
accessibility to those less able to attend in person
No registration fee! Frequent breaks. A quality presentation from 6th/9th graders.
Recording of the virtual presentations is useful for being able to see talks independent of time and be able to refer back to them later.
Great content as usual - always nice to see other aspects of Planetary Defense aside from my niche.
The exercise was very well done. Think the amount of time spent on the exercise was good. (Not too much, not too little.)
The wide range of topics covered
I learned the most from scenario injects and simulation panels!
Very positive the online version
Excellent!
On line very helpful
The global participation and the organization.
The exercise was great.
This has been a very engaging and interesting conference. The best part was the hypothetical asteroid impact scenario.
sidebar discussions once the chat opened up to everyone
I like the sessions and the nature of one track. And the no cost for the meeting.
Fantastic overview of the field - I felt fully immersed in the material
Talks/posters available online all week
The format and content!

topics, exercise, breakout sessions
brings all the important relevant disciplines together
Well done, some little issues are absolutely normal. It's my first PDC and I can't really compare but it feels awesome.
Breakout rooms
I liked everything where I participated as a listener. Great sound and great video quality. I especially liked the absence of a registration price for online participation. I liked that the United Nations is interested in the issue of planetary protection
great conference
diversity of talks

What did you not like about this PDC?
Webex
small number of oral presentations - many interesting presentations were in e-lightnings and posters
eposters , elighting talks not being on stage""
few things, maybe the (necessarily) strongly scripted exercise. Would be nice to have one with wildcards again :)
I was lacking the direct contact with colleagues.
Very short breaks - had to scramble for lunches.
That it was online :(
In some panels, the chairs were also presenters. This should be avoided.
Lack of breaks (because I wanted to participate in the informal meetings). Maybe dividing it to two weeks with less hours every day would make it easier to sit in front of the computer.
Nothing to complain
Very hard to connect to others (as an early stage scientist), no (real) poster session
Nothing!

for a first virtual edition, nothing.
Lack of time/attention for the posters and lightning talks
the Q/A then chat discussion was not easy to follow or sometimes disturbing. The added discussions for posters wasn't easy to attend Missing the discussions in groups with attendees during the exercise (shorter here) missing you !
Needs for one or two longer breakout time
Nothing to comment
During the week of the conference, it was hard to keep up with all of the ePosters and lightning talks. Posting them earlier would have been helpful.
I disliked having to deal with the difference in time zone. I also wish that there had been dedicated time for posters or e-lightning talks
e-poster not exactly allowing interaction
Contributed papers on policy seemed superficial and disconnected from practical issues.
Midnight to 8 a.m. in Hawaii. Questions to presenters sometimes got buried in all the chat.
Times were very difficult for folks in Pacific time zone. Especially for parents with kids. Splitting the technical sessions between earlier and later sessions to accommodate the different time zones helped enable international presentations, but then made it difficult to have interchange between the two halves of the session... each time was somewhat less inconvenient for one group, but trying to bridge both times was even harder. So it sort of siloed.
Difficult to interact with other participants. I couldn't even see who was attending other than panelists and presenters. Zoom rooms open only during 15-minute breaks weren't adequate. Straddling two platforms (webex and zoom) was awkward. Webex itself had strange behaviors - requiring access to mic to allow audio, unable to mute conference audio, so had to close conference connection to listen to Planetary Society presentation or zoom rooms, etc (I was using webex in browser).
The lack of in person interaction greatly reduced the ability for interchange. Also, the green zone was painful from US west coast. Trying to juggle the conference and home duties was basically impossible.
The chat was too hard to follow along with questions and answers. Slack would have been much easier
I did not find something that I did not like
None

Initial inability to provide feedback to ALL. Sometimes the stalling" of presentations."
Missed a 30-45min break in the middle of the program.
I was not able to attend the early morning sessions, but I understand the difficulty in accommodating all the time zones.
fully remote
hard to network/socialize during breaks but the zoom breakout rooms were better than nothing
Lack of consistency of connectivity across the presenters.
I didn't like the virtual nature of the meeting. Still hard to interact in real time with colleagues and new people.
Missed the sidebars and mixing with others on the same mind frame to explore the field
Limited networking opportunities, difficult time zones
the on-side format is much better than the online-format, but because of Corona ...
lack of longer breaks, the conversations in the breakout rooms were very interesting but only 15 min for multiple people's discussions.
some weird business offers or strange mentions in the chat
Representation of e-Posters and e-Lightning Talks was a bit weaker than I expected. It is not a big issue but a way to become better I think.
People should use the social part more
late start

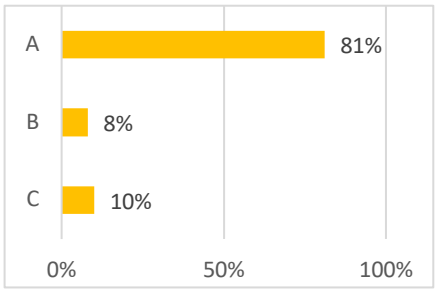
What can we do better for 2023?

depends on how will it take place
cant think of anything , however thanks for doing what you are doing
hybrid: 2023 = 2019 + 2021 would be perfect ;)
Engage yet another layer that will possibly be involved in the disaster management, as commented during the conference.

In person conference!
I think it would be better when we can actually meet and exchange information. I learned a lot, but I hope I can actually contact the speakers. I would feel weird to email them because they don't know me.
Legal and policy issues could have a bit more time. Though I liked this time the format of having one panel with presentations on legal and policy issues, and then a real interactive discussion. Also thanks to the great moderation by Alex Karl.
Shorter program per day, more days. Some peripheral workshops - e.g., on outreach.
No specific suggestion, everything has been managed well
MORE FASCINATION
Things are good, I like the enthusiasm
Online as now
to be able to do a hybrid conference.
Posting the recordings faster (and piecemeal) might help - e.g. so US participants could catch up on the morning sessions before the afternoon sessions start, especially in the case of sessions like mission design which had a part 1/part 2 split
if virtual/hybrid improve the organization of the exercise to have more exchange, don't ask me how!!
More deep and matured arguments in social aspects including laws
Maybe keeping the main room really closed during the Breaks
if hybrid - allowing short talks and e-posters better exposure
The day-by-day reveal" of the exercise is not constructive. If the exercises are to continue, publish the complete scenario well in advance of the abstract deadline, give people other than the exercise developers a chance to think about it, and encourage papers on aspects of the response. This could improve the quality of contributed papers, as well as focus the discussion."
perhaps have breakout sessions (those are virtually possible)
Keep conversation between attendees separate from questions to presenters. I now understand why Webex has separate Q&A and chat functions.
Better, clearer communication about submission and attendance is needed. There was a lot of confusion and lack of clarity about submission requirements (particularly for the 'e-lightning' material), and how to attend the conference (the Friday before the conference, colleagues had no idea how to connect to the conference or that webex invitations were going to be sent out daily, etc).

virtual-only format is challenging! Look forward to in-person conference.
do it in person
Include a chat option that is separate from the Q/A that is accessible for all participants and panelists
Let's do more with the simulation. Work with a participatory futures group like the Institute for the Future iftf.org to simulate economic, psychological, misinformation, etc aspects - the social side the simulation.
Everything is fine
Make it face-to-face
Use Hybrid mode. A bit more video interactions
better setup of the interactive features (Q&A, chat, etc.) starting on Day 1
Explore hybrid option. I think something like gathertown would help with interaction.
hybrid would be great for those who can make it
More thought should be put into timing if there is a virtual component. The majority of the world does not live in Europe. Where do the majority of participants reside?
More States!!! have representation at the decision maker level. Include military, and private industry with capabilities on the fields.
meet in person
Go back to a real meeting
The meteor section
attract more students
as mentioned in the wrapping session, perhaps the way posters are discussed

	Are you in favor of a hybrid conference for 2023?	Corrected Results	%
A:	Yes	63/78	81%
B:	No	6/78	8%
C:	Don't know	8/78	10%
D:	No Answer	80/158	51%



Please provide additional thoughts and comments
Special Issue or 'block of papers' in Acta Astron is a good idea, submission >3 months after PDC for networking & starting coop
updated paper / ext. abstract submission option by T_conference+14 days was always great to network by up-to-date referencing, to have that go into the proceedings (.zip all submissions and distribute to participants and put on website indefinitely)
make a permanent website for all PDCs since 2004, maybe with the earlier 'famous' workshops in the 1990s
Thank you for having me.
All the best. It was wonderful!
I am good with the community members satisfaction :)
PDC is the one event to get in touch with all the relevant people of the field and very important for networking. Please think about potential problems and solutions in case of a Hybrid. On-site and remote attendees need to be connected somehow in an easy way, in particular for meeting for the first time.
Like Alex Karl's suggestion of a 'lite' version in the intervening/'even' years.
My personal, sincere gratitude to the organizers & speakers for the quality of the whole conference.
I'm already very much looking forward to the next PCD - plus a lot of international positive action to move things forward for world governments to take the potential threat(s) more seriously.
I am very much hoping that we can have at least a couple of speakers from this conference to attend and present papers at our British Interplanetary Society's Reinventing Space Conference, and to
Face to face meetings can hardly be compared to on-line discussions. Also in-person meetings will be a lot more memorable. On-line has the benefits for those who cannot participate in person. Thus, hybrid is the way to go.

May be to add a share platform that can be accessed during and after the conference for further exchange and discussions.
be able to form a team with other attendees for the persons that want to improve learning with the exercise.
green zone was good idea indeed (I'm in Europe), will it work as efficiently when conference is held in other (longitude) locations ? maybe yes i.e. it is early morning or late evening for someone but one can afford a 3h conference ? I guess the most problematic places are Australia and Hawaii
some poster and presentations can be proposed *before* (e.g. one week) the conference for display, (in a zone where questions can be asked), and later for discussions during the conference in dedicated slots
For the impact exercise, the chart on page 3 of this document appears to have been confusing for the public: https://cneos.jpl.nasa.gov/pd/cs/pdc21/pdc21_factsheet3.pdf . It is easy to confuse this is the area possibly at these levels of risk" with "all of this area is at risk"."
Many thanks for panelist and organizers
while a hybrid model is preferred, i worry that civil servants will be disproportionately less likely to attend and take advantage of in-person communications because funding agencies will decide that the availability of virtual attendance will mean they won't allow those federal employees to attend. i'm not sure how to reconcile this - perhaps a stated preference for in-person attendance from each relevant u.s. organization?
Much like a new ticker scrolling on the bottom of a television screen, I found the chat to distract my attention from the presentation.
While there are advantages in having hybrid capabilities, there are also huge benefits to in-person interactions. If the conference is hybrid, it may decrease the potential for in-person attendance. For example, it may be hard for NASA participants to get approval to attend in person if there is a hybrid option). In person interaction enables a much better level of engagement and interchange.
The webex chat was very difficult (e.g., no way to find comments that are sent to you privately or that are directed to you, no way to respond to specific comments that are further up the thread, etc)
Not having any time dedicated to the poster or e-lightning sessions short-changed those submissions. There should have at least been a summary by the session chairs highlighting what topics were available (something more specific than vaguely encouraging people look on their own). Maybe have those authors send a one-sentence summary and thumbnail image, and have the session chair give a few minute intro of the topics there. At least for the e-talks, if there are too many posters.
There is a lot of emphasis on the 'number' of attendees that the hybrid format enabled. However, the LEVEL of that participation is significantly less. People don't necessarily pay much attention to a webex that's on in the background, and other work duties, email, family duties, etc. all detract from the amount of focus that can be given to the conference.
Having the 'green zone' always dedicated to panels and having technical sessions split between more extreme times skewed the conference more toward the very high-level vague discussions, and compromised the technical conference aspects, which are critical. The PD community is fairly

small, and this is one of the few conferences for PD-specific technical interchange. This format really severely inhibited that critical component of the conference.
Excellent conference! Congratulations to everybody for their hard work.
Will be challenging to integrate virtual attendees w/ in-person attendees. The risk is having two parallel conferences. But opening the conference to virtual attendance will definitely increase participation particularly amongst developing countries and under-served populations, so worth the effort.
Attending in person is key for technical interchange, but if there's an online component it's extremely likely my employer would not allow me to travel to the conference.
Thank you very much for the opportunity to learn more about PD.
Include more cross discipline interactions
Ronald Leung POC; rsmailtemp-buying@yahoo.com; ronald.y.leung@nasa.gov
More thoughts than possibly summarized via webform/poll, even with multiple spaces to provide..
Hybrid is really an interesting idea. But it has to be designed so that people in person are not meeting at weird times to accommodate other time zones and also so that there are opportunities for those watching from remote locations to actually participate. Trying to make it work" for everywhere in the world simultaneously does not work."
Please do not make it longer than 1 week. That is not doable for in person and also makes it really difficult to schedule around other responsibilities if you are virtual.
The polls were a great idea but sometimes the questions could have been worded better. Plus it should be made clear whether the polling is anonymous or not
Thanks again to all involved in making this happen!!
A hybrid allows many more participants, It is particular helpful for those who can't attend due to conflicts or funding restrictions. It also helps those whose interest is much more limited in scope such as civil defense managers.
We should have some time devoted for the younger participants perhaps ice breaker type of events for virtual attendees.
Have a dedicated member track the chat for questions so that the active chair doesn't have to scramble a bit at the end.
I would make sure that there is lots of time to discussion. There are still some people feeling a bit left out of discussions.
Face to face meetings are still superior to virtual. But having a hybrid to allow others in virtually to participate are a good idea to have more interactions with others in the community.
I think leveraging the Apophis is a good idea, but if we have observing activities or missions to this object, a lot of the attendees will not have time to focus on a PDC meeting at the time of the flyby. I would suggest timing it carefully to make the most of the Apophis encounter.

I benefited from this conference and hope to participate more in the field in the future
Thanks to all the presenters, coordinators, panelists, and chairs and everyone else who put this together - it was a great event for me!
And many, many thanks to Peter Kraan for his patience with my many coordination questions on my first eLightning Talk :-)
Hybrid has benefits, but I have concerns about missed networking opportunities, etc., that are considerably more difficult in virtual settings.
on the internet side there is tab for searching keywords, for example 2019OK.
Fantastic to include the young students. Maybe a selected few more.
Promotion of more table-top exercises during the next two years.
Excellent content, and organization. Thank you very much for all the hard work!
Hybrid is tricky though - works best if all participants are also logged in, whey they speak they should be visible and audible also to the remote participants.
Thank you very much to the scientific and organizing committees, everyone who provided the event organizing committees, everyone who provided the event.