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Do Look Up: A young generation's perspective on Planetary Defense

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Abstract

One aspect of human behaviour that recent events have shown is people's lack of response to seemingly distant or unlikely situations. Nonetheless, this action, or absence of action, results in inadequate planning and policies to deal with high-impact global events like the Covid-19 Pandemic or Climate Change. In this context, the space sector is no exception. Considerable problems such as our unsustainable use of space, resulting in substantial amounts of debris as shown in ESA's Annual Space Environment Report issued in 2021, show our tendency to respond insufficiently to faraway problems even when they might have significant consequences for our future. A space field impacted by this issue is Planetary Defense, which concerns our capabilities to manage the risks associated with Near-Earth Objects' (NEO) collision with Earth. Ideally, a proper planetary defense infrastructure would include adequate technical, societal, and political frameworks to identify and characterize a NEO in a trajectory towards Earth on time and put in place mitigation strategies and emergency procedures. In recent years, the space community has made substantial efforts to strengthen planetary defense capabilities, including the launch of the first-ever planetary defense mission "NASA Double Asteroid Redirection Test (DART)" in 2021. Despite this, the current technological infrastructure and policies in place are still under development with room for improvement. The research presented in this paper is the result of a collaboration between the Space Generation Advisory Council (SGAC) and the NASA Planetary Defense Coordination Office (PDCO). During a three-day workshop at the Space Generation Congress in Dubai (2021), students and young professionals from all over the world were educated on planetary defense and confronted with a hypothetical Earth impact scenario. The paper describes the lessons learned during the workshop, detailing the major outcomes and outlining the proposed recommendations to improve planetary defense infrastructure, policy, and coordination. Furthermore, it provides the results of a survey shared among the young generation to quantitatively assess their awareness about the topic and help improve efforts to educate about planetary defense by identifying the existing knowledge gaps and misunderstandings. Also, the study includes a comparative study of the perspectives of the young generation against the decisions made by the delegates during the simulated scenario. This comparison could provide a better understanding of the young generation's perspective towards handling such a scenario which could help improve our current political framework to be better prepared for dealing with high-impact, low-probability events.

Keywords: Planetary Defense, Statistical Analysis.

Acronyms/Abbreviations

DART	Double Asteroid Redirection Test	HILP	High-Impact Low Probability
FEMA	Federal Emergency Management Agency	PDCO	Planetary Defense Coordination Office
NASA	National Aeronautics and Space Administration	PHO	Potentially Hazardous Object
NEOs	Near-Earth Objects	SGAC	Space Generation Advisory Council

1. Introduction

Millions of years ago, life on Earth suffered a dramatic transition after an asteroid collision. An explosive yield estimated at over 100 trillion tons of TNT wiped out 80% of life on the planet, leaving behind a crater with a depth of more than 185 km. [1]

NASA estimates that Earth is hit by more than 100 tons of dust and sand-sized particles every day. Similarly, every year, an automobile-sized asteroid hits Earth's atmosphere, creating an impressive fireball, and burning up before reaching the surface. Additionally, every 2,000 years or so, a meteoroid the size of a football field hits Earth, causing significant damage. However, it is only every few million years that an object large enough poses a significant threat to Earth. Nevertheless, impact craters on Earth, the moon, and other planetary bodies prove these occurrences. [2]

Like many things in the universe, humankind does not have control over comets or asteroids orbiting the sun. Therefore a space infrastructure can be considered an essential tool to help humanity manage such a potential scenario. To do so, humanity needs additional technological and political development to be able to face an asteroid collision. However, the motivation to advance in the field has barely appeared in recent years. Nevertheless, planetary defense is gaining momentum as more people start addressing the topic and activities in the area increase. The year 2021 saw the first ever planetary defense mission launch to space as a way to evaluate our current capabilities and make new technological demonstrations. The Double Asteroid Redirection Test (DART) is an on-orbit demonstration of asteroid deflection, using a kinetic impact to adjust the speed and path of an Asteroid, becoming the first-ever space mission of its kind. This event occurred only four years after the creation of NASA's Planetary Defense Coordination Office (PDCO), demonstrating the outstanding results that quick action can create. [3]

1.1 What is Planetary Defense?

Planetary Defense encompasses all the capabilities required to manage a potential asteroid or comet impact with Earth. [4]

Fig 1. Planetary Defense overview. (Credit: NASA)

NEOs are comets and asteroids that have been moved by the gravitational attraction of nearby planets into orbits that allow them to enter the Earth's neighbourhood. [5] Therefore, protecting the Earth requires being capable of preventing or mitigating the effects of an impact after a Near-Earth Object (NEO) has been identified and found to be in a trajectory of collision with Earth.

As our technology has improved, so have our observational capabilities. Scientists have been able to observe and record Near Earth Objects exponentially faster, and the record of such objects continues to grow. These objects hold the potential to cause devastation on unprecedented scales, which is why Planetary Defense has grown to be extremely significant in the space industry. For this reason, it is important to know how and when to alert the involved actors (such as governments, scientists, military people, etc.) about potential impacts to allow timely intervention, developing frameworks to be implemented in case of a potential asteroid collision and lay out the path to be followed for decision-making bodies.

Several options exist to prevent an asteroid impact, with different overall performance, cost, failure risks, operations, and technology readiness. Some techniques foresee, for example, destroying the object in orbit before it reaches Earth (called fragmentation) or changing its trajectory at a calculated distance (deflection). Despite this, even if all solutions were available at the moment of discovery of a potential impact, the final decision among the different techniques would be dependent on other factors concerning the asteroid, such as its size, composition, and distance from Earth. This is particularly important if the best mitigation strategy for dealing with an asteroid impact would be to let it hit the Earth. This decision would be acceptable only if handling the consequences of the collision was the most cost-effective and efficient strategy. However, another reason for such a decision could be insufficient time to perform a collision avoidance mission. In either case, disaster management efforts would be needed on the ground to focus on mitigating the effects of the impact. In this case, the experience in preparing and handling emergencies that pose regional and global threats, such as natural disasters and other situations (pandemics, droughts, food crises, etc.), is of much value. While such situations are entirely different from an asteroid impact, they all need similar types of coordination efforts to address the issue at hand. These emergencies are known as High-Impact Low Probability (HILP) events, and an asteroid impact fits well under such a category.

1.2 High-Impact Low-Probability Events

High-Impact Low-Probability refers to a situation with significant economic, social, and humanitarian consequences that is unlikely to occur or be predicted. Nevertheless, such emergencies have left their marks in

history books because of the magnitude of their repercussions, which resulted in consistent changes at different societal levels to better the efforts to be ready to face such events in the future.

Preparing for HILP events usually implies complex risk analyses by leaders and decision-makers at different geographical levels, with different perspectives and understanding of the threats and their consequences. This often results in the low development and implementation of effective response frameworks.

The truth is that despite the recent, considerable efforts to improve risk management techniques, governments and businesses remain insufficiently prepared to confront such crises. Current contingency planning often assumes a return to normality after a crisis. However, this approach is inadequate in a world of complex economic and social risks, especially when dealing with slow-motion crises like climate change or varying factors such as virus mutations during a pandemic. Therefore, proper contingency measures shall consider the full range of preparedness and response capacities and establish clear frameworks for crisis decision-making. [6]

1.3 NASA Planetary Defense Coordination Office

NASA established the Planetary Defense Coordination Office (PDCO) in January 2016 in response to the Office of Inspector General's 2014 report [7] with the hope that the PDCO [8]:

- Provides early detection of Potentially Hazardous Objects (PHOs), a subset of NEOs estimated to come within 5 million miles of Earth's orbit and of a size large enough to damage Earth's surface.
- Tracks and characterizes PHOs and issues warnings of the possible effects of potential impacts.
- Studies strategies and technologies for mitigating PHO impacts.
- Plays a lead role in coordinating U.S. government planning to respond to an actual impact threat.

Besides its many technical efforts to improve the way we detect NEOs and develop technologies and techniques for deflecting asteroids, the PDCO is also responsible for informing the government, the media, and the public on close approaches to Earth by PHOs. Furthermore, the PDCO works with other government agencies on a NEO Preparedness Strategy and Action Plan and provides expert input to the Federal Emergency Management Agency (FEMA) [9] to ensure adequate emergency response in the event of a PHO impact impossible to avoid. Finally, the PDCO also works with other space agencies as a member of the multinational International Asteroid Warning Network [10] and the Space Missions Planning Advisory Group [11], under the endorsement of the United Nations Committee on the Peaceful Uses of Outer Space [8].

2. NASA PDCO Workshop SCG 2021

The PDCO is also active in the sensibilization of people about the topic of HILP events. Their efforts include running workshops and supporting events where they can address Planetary Defense Awareness, such as the Space Generation Congress (SGC).

The NASA PDCO collaborated with the SGAC to sponsor a working group during the Space Generation Congress 2021, to educate students and young professionals on the main concepts of Planetary Defense. In addition, this working group had to go over a hypothetical impact exercise that allowed the participants to compile multiple recommendations to deal with the current technical and political issues that are yet to be solved from their point of view.

2.1 The Space Generation Congress (SGC)

The Space Generation Congress (SGC) is the annual meeting of the Space Generation Advisory Council (SGAC), always held in conjunction with the International Astronautical Congress (IAC) in the same hosting country. ¬150 delegates, consisting of university students and young professionals, come together for three days to gain exposure to fresh perspectives on space issues and brainstorm on the same. This is facilitated through Working Groups, where delegates discuss selected issues and topics relevant to the role of space. One such Working Group in SGC 2021 was Safeguarding Earth, collaborating with the PDCO.

2.2 SGC 2021 Workshop Objectives

With this workshop, delegates were expected to devise solutions during a fast-paced ‘choose your own adventure’ impact exercise where their actions would determine the consequences during a simulated planetary defense mission. The PDCO sought to educate the delegates on key concepts and requirements of Planetary Defense and provide a podium to express their recommendations. This working group focused on planetary defense discussions around the hypothetical impact exercise and allowed the delegates to develop policy recommendations that would encompass this generation’s view of the planetary defense area.

NASA PDCO laid down the following objectives for this particular workshop:

1. Educate the SGC delegates on key concepts and requirements of Planetary Defense
2. Understand the SGC delegate's decision-making process and response plan during the mission
3. Enable SGC delegates to recommend prioritized future courses of action in Planetary Defense to UNOOSA based on their discussions and the simulation exercise outcome.
4. Increase public awareness and engagement with Planetary Defense concepts.

During the workshop, the delegates were expected to discuss the technologies, resources, and regulations available to study, understand and possibly prevent and impact. They were asked to debate the merits and demerits of focusing on prevention or mitigation or neither situation in case of a potential impact. They were asked to identify the main concerns of the affected people across the globe and come up with the steps to provide accurate and timely information to the media, public, and decision-makers. This had to be done by maintaining the right perception of the situation and avoiding panic and chaos. Furthermore, the delegates were asked to justify whether taxpayer money should be used for planetary defense if the odds of an extreme event occurring are relatively low.

2.3 SGC 2021 Workshop Results

At the beginning of the workshop, delegates were separated into groups representing the different parties of people that would be affected by such an event. These groups included scientists, disaster relief, policy, media, and the public. Starting from the presumption that an asteroid would hit Earth within six months, and given the context of the Tunguska event that occurred on 30th June 1908, impacting over 2150 sq km in central Russia, the delegates assessed the active research, steady international efforts, and awareness campaigns for the real threat that an incoming asteroid poses. For three days, the delegates gathered information on all aspects of the society affected, which led to multiple concerns about how this information would be communicated to the general public and their reaction to the news. They recognized a wide range of possible impact scenarios affecting various stakeholders, making it a technological problem to solve and highly complex in terms of politics and society. Various perspectives had to be considered given the potential impact zone, cost of mitigation, and the number of involved parties. The delegates acknowledged that currently, we have limited capabilities for detecting and preventing the impact of an asteroid. Most mitigation efforts would require long-term planning on a scale of 5-10+ years. Nuclear Explosive Devices (NEDs) were discussed as an option but were found to be usually more detrimental than helpful.

They identified that current policies and guidelines do not consider the human factors at stake, such as the psychological impact of the news to the public. To prepare better for such an event, there's a need for better-defined plans and policies that would allow people to properly manage the situation and give a sense of security to the general public.

At the end of the workshop, the delegates provided recommendations to both the UN COPUOUS and SGAC. The UN-COPUOS needs to address the investment required for asteroid early detection systems. It became apparent during the NASA PDCO hypothetical exercise that the current emphasis on 'ten years' is long enough to address technological development, while for worst-case serious threats under the mentioned periods, governments measures would be challenged by social unrest. Science communication needs to be disclosed on all scientific data related to an imminent outer space threat in a timely manner, allowing the general public and scientists to study, analyse and evaluate the merit of policy decisions. Transparency in data sharing can be acquired through creating an inclusive science communication portal with real-time updates.

Along with well-established citizen science projects, such as the Hubble Asteroid Hunter, the working group recommended sessions of learning and training of SGAC members on what Near-Earth-Objects impacts mean and the multitude of implications that arise subsequently, from asteroids detection methods to policy holders and decision-makers. Taking into consideration the development of IAWN and SMPAG, SGAC delegates were recommended to actively participate in action teams, forums and workshops to increase addressing the serious threat and the level of early prevention required, as well as creating collaborations with other institutions, universities and governments, for various mitigation strategies in the event of NEO disasters.

2.4 Planetary Defense Recommendations

The working group proposed further investment into and development of deflective and disruptive technologies - such as kinetic impactor, gravity tractor, and laser ablation. They proposed having readily deployable in-orbit spacecraft to redirect asteroids. Further research on the effects of nuclear disruption/deflection was suggested along with increasing the launching capabilities of NEDs. They advocated for improved infrastructure to accelerate the speed in which a mitigation mission can be launched as well as additional reconnaissance mission technologies to study the properties of the incoming asteroid in advance. More awareness campaigns in collaboration with government authorities and space agencies need to be created to focus on individual responsibilities in the event of outer space threats. With Planetary Defense, the considerations have to go towards transparent information, decision making, creating a dedicated governing body at each country level, responsible for international collaboration and contingency plan development, despite the cultural and religious differences. Sharing data with multinational organisations was also deemed to be essential to promote constant innovation for the industry. This should be a continuous and collaborative effort that requires support from space agencies.

3. Survey

3.1 Methodology and Demographics

The quantitative method used in the study was an online survey that was shared via social media and other types of electronic communications. Prior to participating in the online survey, all the participants were informed about the study, and their consent was obtained. The participants were informed that their participation was voluntary and that all the data collected through the online survey will be kept strictly confidential. They were informed to take their time, and respond to the questions based on their personal experiences. All the participants consented to participate in the online survey, by checking the online consent forms.

The survey questionnaire was developed by the researchers of this paper, with the aim of understanding the level of global awareness around the topics of planetary defence and Near Earth Objects. The questions were drafted up, keeping in mind the concerns and the recommendations that arose during the SGC 2021. Microsoft Excel and Google Sheets were used for the data analysis. The results of this questionnaire are discussed in detail in sections 3.1, 3.2 and 4.1. Section 4.1 dives into a comparison of the recommendations from the SGC 2021 and the public opinion obtained via this study.

The sample population were people working in and interested in the space sector - students, young and experienced professionals within the space industry and research. The survey was circulated among various space-related organisations, student organisations and space-related online forums.

Data gathering via the online survey took place from 23 June 2022 to 11 August 2022. The age range of the sample was 18 and above. The sample consisted of 209 responses. All 209 participants filled out all the necessary questions in the survey.

Of the 209 participants, 37.8% identified as female while 60.3% identified as male. Around 1% of the participants identified as gender non-conforming while another 1% preferred not to disclose their gender identities. 24.4% of the participants were of the age group 18-23, 28.2% were between 24-29, 15.8% were between 30-35 while a majority of 31.6% of the participants were 36 years and above. It was observed that a majority of 36.4% of the participants were from the North and Central America (NCA) region. In comparison, 31.1% were from the Asia-Pacific (AP) region, 29.7% were from Europe, 1.9% were from the South American region and ~1% were from the African region. We could observe an almost equivalent distribution among the participants in the 3 areas - NCA, AP and Europe. It was observed that 34.4% of the participants were students, 23.0% of the participants were young professionals, 28.7% of the participants were experienced professionals, and 12.4% of the participants were retired. For ease of analysis, Students from all levels (including PhD) were considered as Students, Professionals with 0 - 5 years of experience were considered as Young Professionals and Professionals with more than 5 years of experience were considered Experienced Professionals.

3.2 Survey Structure

The survey is composed of a total of 21 questions organised into three main sections: 1) Demographics (6 questions), 2) Level of understanding about Planetary Defense (6 questions), 3) Asteroid Collision Scenario (9 questions).

As the survey was conceived to be completed by the respondents in only a few minutes, the authors decided for multiple-choice questions with predefined options (mostly 1 to 5 options of choice) as the main format for the survey.

The first section “Demographics” served the purpose of gathering general information about the respondents, to derive demographic information to be later applied during the analysis of the results. Questions such as gender, age range, nationality, residing country, highest degree obtained and professional status were included.

The second section of the survey focused on the real core of the research, allowing the authors to further inspect the level of understanding of the topic of planetary defense among the respondents. The questions addressed not only the general knowledge on the topic, but also their perception and the likelihood of impacts of outer objects on Earth, as well as our capabilities to currently track and identify asteroids.

The third section “Asteroid Collision Scenario” had two different purposes: the first part inspected the perception of the respondents about the preparedness of their home countries and of the world to face potential collision scenarios both from the technological and the resource, mitigation and damage control strategies point of view. The second part inspected instead which would be their choices in case such a collision scenario would become a reality. Here questions evaluating mitigations strategies such as nuclear solutions, the quality of the measures in place, the countries’ responsibilities, the involvement of the United Nations, the amount of taxpayers’ money to devote to the development of mitigation infrastructure as well as the sources of information to trust were included. This final section of the survey was interesting to compare the respondents’ answers to the decision taken by the authors of this paper during the workshop that was held in Dubai on similar topics, and whose comparison is reported in paragraph 4.1 of this document.

3.3 Survey Results

The survey results were initially examined with regards to the distribution of the responses to each

question, providing an overall understanding of the survey pool.

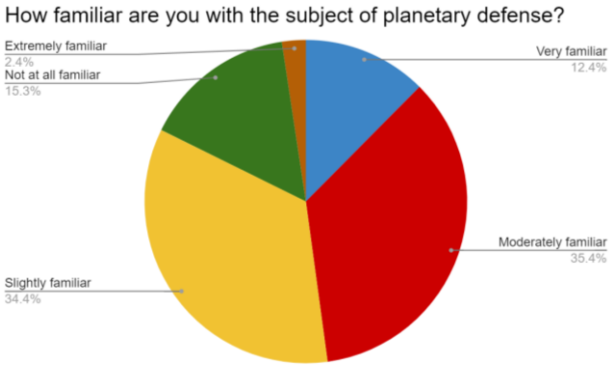

Fig 2. Familiarity with the subject of planetary defense among the participants.

The respondents to the survey admitted to an overall lack of familiarity with the concept of planetary defense. Almost half of the answers revealed that the respondent was either "Not familiar at all" or only "slightly familiar" with the topic. However, most of the respondents believed they were "moderately familiar" with the topic (35.4%) and only 2.5% felt they were "extremely familiar" with it.

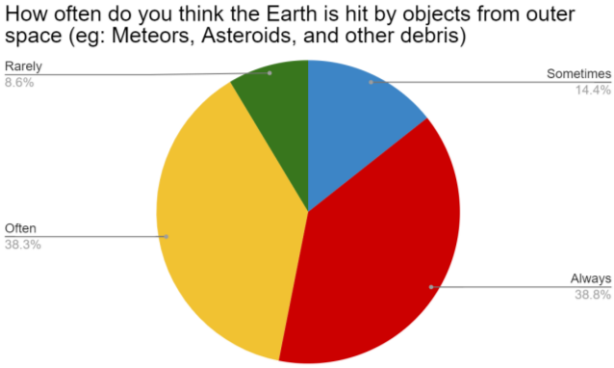

Fig 3. Knowledge of participants regarding the possibility of Earth getting hit by outer space objects.

Most of the respondents (77.1%) believed that the Earth was "often" or "always" hit by objects from outer space, and no respondent believed that it was never hit. This widespread agreement points towards the fact that the younger generation is, in general, aware of the existence of Earth-impact objects.

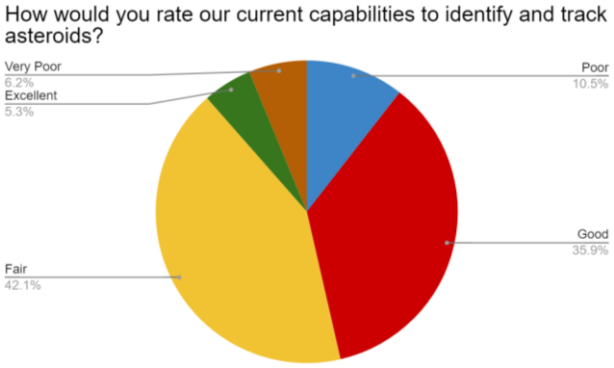

Fig 4. Current capabilities to identify and track potential near earth asteroids.

When asked about their opinion of our current capabilities for identification and tracking of asteroids, 41.1% believed we had "good" or "excellent" capabilities. 42.1% of respondents were less optimistic, believing that our capabilities were "fair", while 16.7% believed they were "poor" or "very poor".

When asked in particular about asteroid impacts, respondents again tended to believe that these events were "likely". 31.6% of the respondents believe an impact was moderately likely, while 26.8%5 percent believed it was either "very" or "extremely" likely. Only 7.2% believed the event was "not likely at all".

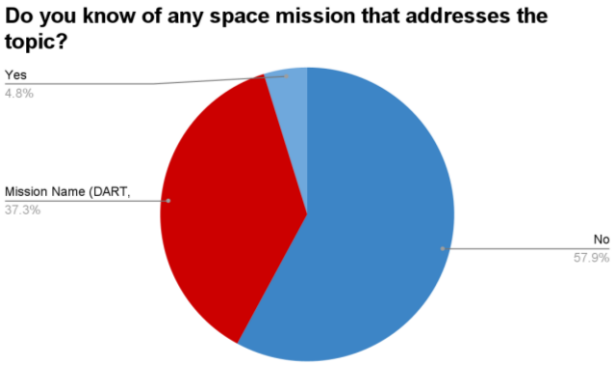

Fig 5. Knowledge of participants regarding any space mission that addresses the planetary defense topic.

Despite acknowledging the possibility of an asteroid impact, most of the respondents were not aware of the current development for planetary defense in the form of space missions. 57.9% of the respondents admitted to not knowing any space mission that aims to improve our planetary defense capabilities. Among those that knew of at least one mission, 37.3% mentioned HERA or DART by name.

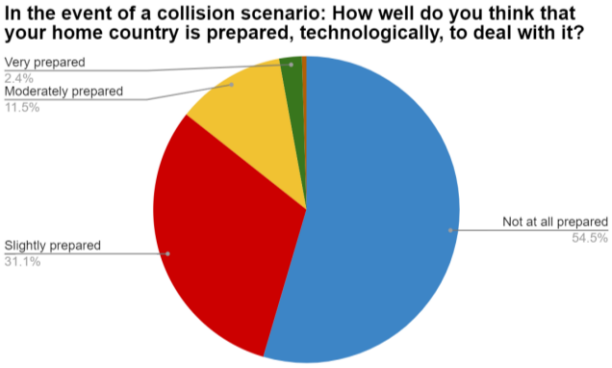

Fig 6. Technological preparedness of the participant's home country in the event of collision scenario.

Respondents were, in general, less optimistic about our capacity to handle a collision. In particular, 54.5% of respondents believed that their home country was "not at all technologically prepared" for this scenario. Only 14.4% believed their country was "moderately" or "very" prepared.

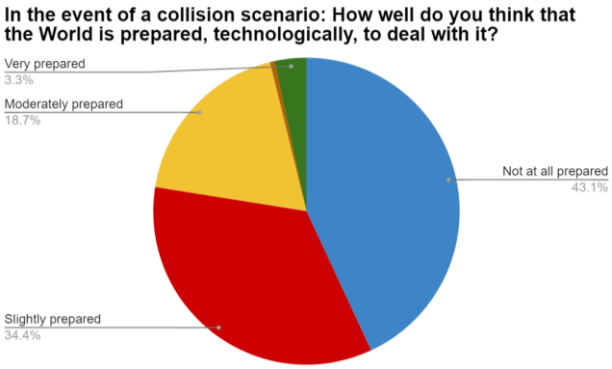

Fig 7. Technological preparedness of the world in the event of collision scenario.

Respondents felt slightly more optimistic about the capabilities of the world in contrast to the capabilities of their home country. 43.1% felt that the word was "not prepared at all", in contrast to the 54.5% who believed their country was "not prepared". Similarly, 22.5% believe the world to be either "moderately" or "very" prepared, 8.1 points higher than for the same preparedness in their home country.

3.4 Comparison of the results

In this subsection, the survey results were examined based on the distribution of responses to each question, giving a comprehensive insight by comparing the responses. Familiarity with planetary defense among the respondents from different geographical regions suggests that at least 30% are unfamiliar or slightly familiar with the concerns regarding planetary defense strategies. It is also similar to the case with respondents who are familiar with the topic. Interestingly the respondents from NCA are much more familiar with the planetary defense subjects than other regions of the world as can be seen from the Figure 8.

Figure 9 compares the familiarity level among students, young professionals, and experienced professionals. It is found that more than 40% of unfamiliar cases are students, and only experienced professionals are 10-15% more familiar with the subject of planetary defense.

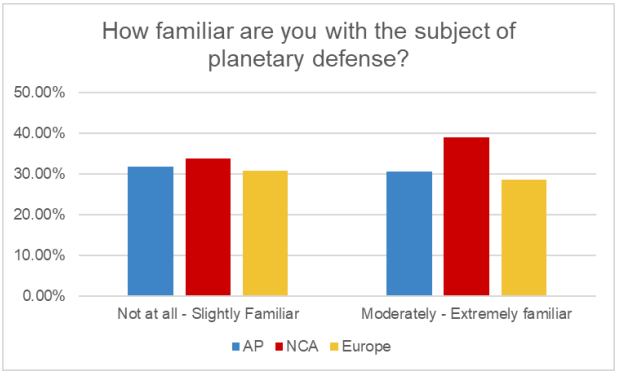

Fig 8. Familiarity on the planetary defense subject based on geographical region.

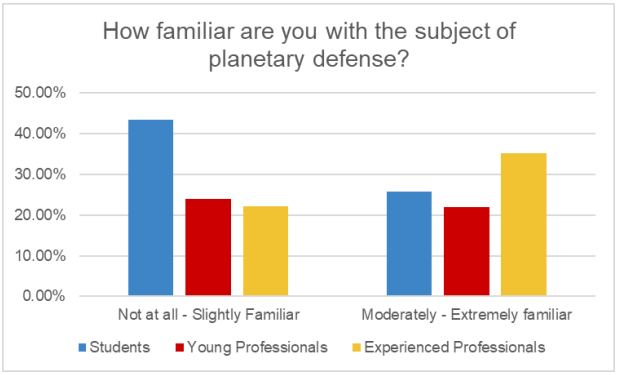

Fig 9. Familiarity on the planetary defense subject based on profession.

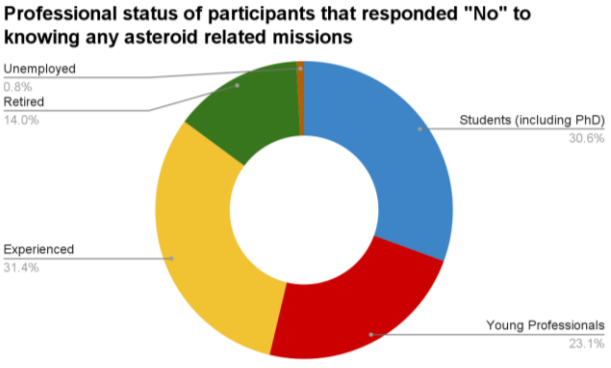

Fig 10. Professional status of respondents unfamiliar with asteroid missions.

Study suggests that among the participants, 31.4 % of

experienced professionals, 30.6% of students including PhD candidates, 23.1% of young professionals were unfamiliar with the asteroid-related space mission. These survey results are illustrated in Figure 10 suggesting the participants' professional status.

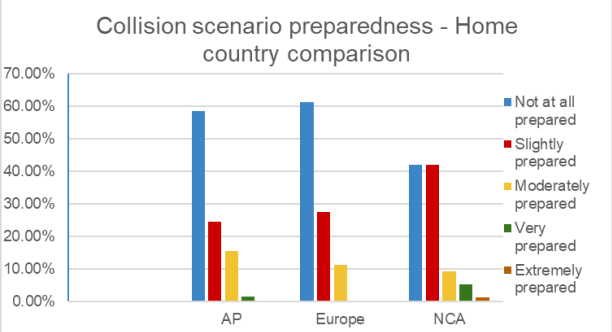

Fig 11. Collision scenario preparedness comparison.

Finally, this study also highlights and compares geographical home country preparedness for any collision events. 60% of respondents who participated with their home countries from the Asia-Pacific and Europe regions believe they are not prepared for any collision scenarios, and 25% of slightly prepared cases. Participants around 82% in this survey from North and Central America believe they are not at all prepared or prepared somewhat. In conclusion, the survey responses suggest that more than 80% of the participants believe their country is either slightly unprepared or completely unprepared, offering lower confidence in times of collision crisis scenario.

4. Perspectives Comparison

Between the workshop participants and survey respondents, there were some common themes that arose. Unlike the SGC participants, it is important to note that survey respondents did not have the benefit of the lectures from experts in planetary defense. Moreover, survey respondents were only looking at a very specific snapshot of a scenario and were not asked to play a role. That being said, the survey responses discussed in the previous section of this paper, provide context for the responses received and a better understanding of their comprehension of the topic.

4.1 Workshop vs Survey

Specifically, to compare the awareness of planetary defense in a targeted application, a series of questions were developed for section 3 of the survey. The scenario and its particulars were described prior to participants completing section 3 of the survey. These questions were designed to mirror those undertaken by the workshop attendees.

After being presented with the scenario, the survey respondents were asked about mitigation strategies. More specifically, whether they would consider the use of nuclear solution. Using nuclear warheads has the potential consequence of nuclear fallout, which would not only impact those in the affected region, but would likely affect the rest of the world, potentially contaminating even more of the Earth's ecosystems. Thus, the nuclear option is not a guaranteed solution. Therefore, it becomes a question of weighing the risks and potential rewards. During the SGC workshop, it was pointed out that for some individuals, it wouldn't matter if it was guaranteed to work, the use of nuclear weapons in any scenario is unacceptable. In the workshop, this opinion seemed to be more prevalent in older individuals and those from axis powers from the second World War.

Figure 12 displays the results from the survey participants. The responses were yes, no, and maybe. There was an equal division between those who had a definite mind-set and those who were unsure. Only 23.4 % were in favour of using nuclear weapons, while 25.8% were firmly against. 50.7% of respondents were uncertain. This matches the uncertainty in the workshop participants, which generated discussions around what consequences the individuals involved in making the decision were willing to live with.

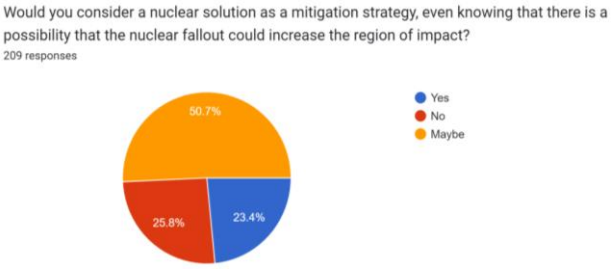

Fig 12. Choice of mitigation strategies for the given scenario.

Survey participants were asked thereafter to evaluate whether they thought current policy measures and any current international legal framework would be enough to effectively deal with a collision scenario. The results displayed in Figure 13 show that the vast majority of respondents were unaware of any such policies in place, with just under ¼ saying that the plans in place would not be enough. Not a single participant responded that the current plans in place were enough to deal with such an event. This result was similar to that obtained by workshop participants, in that not one delegate believed there existed a current policy to deal with such an event. Delegates with legal and policy experience were quick to indicate that any such plans would be insufficient to deal with a collision event and the aftermath. The rest of the delegates were unsure as to whether any plan existed.

This result demonstrates an overall lack of awareness in the area of space related policy and it's a knowledge gap that should be addressed. Awareness of planetary defense and the potential threats to life on Earth is the first

step in improving our ability to mitigate, however the need for policy and legal framework to be in place prior to such an event occurring quickly follows. In order for such policies to be developed, motivated national parties are required to cooperate with each other, aside self-interest, to ensure that agreements and resources can quickly be enacted in the event of humanity threat. Insofar as making national parties and governments invested in cooperating with other nations and establishing a legal framework, requires that the citizens be aware of planetary defense and the implications of a lack of policy. If the issue is not known and is not one made aware of, then politicians and policy advocates will continue to fixate on more immediate issues and the status quo in the area of planetary defense policy will remain unchanged.

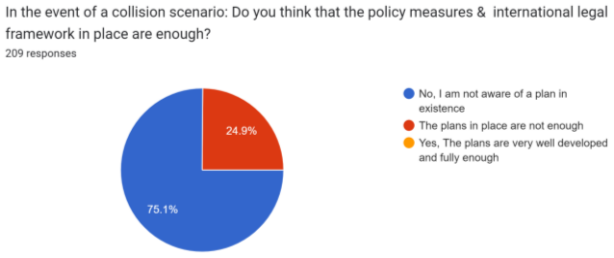

Fig 13. Results of asking whether current policy measures and international framework are enough to handle a collision scenario.

During the SGC workshop, those delegates role-playing as policy makers were quick to identify these issues and discuss the complicated nature of developing policy in this area.

Furthermore, the delegates on the policy team recognised that if world leaders were not also educated on planetary defense, they would not feel the need to take action and establish a framework to help any country in the affected region of impact. Plans developed would need to have international agreement as it is unlikely that an impact would remain in one's borders. Likewise, there likely would need to be a relocation of people and resources. Workshop delegates recommended that there would need to be a special refugee status to help expedite the transfer of people and resources.

Continuing on the policy matter, survey respondents were asked about where the responsibility should lie in dealing with an impact event. Similar to the delegates of the SGC workshop, survey participants overwhelmingly indicated that they believe it to be a global responsibility, with less than 4% of respondents suggesting that the responsibility lies elsewhere or depends upon the severity of the impact.

Despite the shown lack of trust on current global technological and policy capabilities, the great majority of respondents (95.2%) believe the entire globe shares in the responsibility of dealing with asteroid impacts, not only the regions potentially affected.

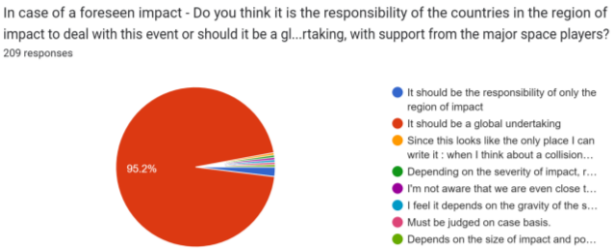

Fig 14. Survey results on where the bulk of the responsibility rests.

The emphasis on global cooperation and that the responsibility of dealing with such a scenario should be a global undertaking, led SGC workshop delegates to consider what that framework could look like and what external body could be in charge. During the workshop, it was suggested that the United Nations Office for Outer Space Affairs (UNOOSA) would likely be the best candidate for such an undertaking, given that establishing a new independent 3rd party that would have the authority and respect of other nations to develop and enact such policies, in addition to leading discussion on potential prevention strategies (i.e. use of a nuclear solution), would be a long and probably inefficient endeavour. That being said, delegates were quick to point out that the UN is not without its bureaucratic issues and that some would consider the organisation as fairly limited in its ability to enforce measures, especially through UNOOSA. Results from the survey appear to reflect a similar view regarding the need for a global independent body to be highly involved in the event of an impact scenario. As depicted in Figure 15, the majority of participants, at 41.1%, think the UN needs to be very involved, and almost a third was of the opinion that the UN should be extremely involved. Overall, over 93% of respondents indicated that the UN should be moderately - extremely involved.

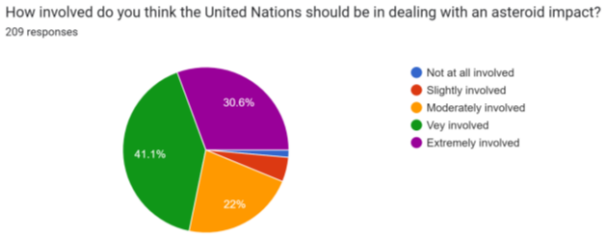

Fig 15. Survey respondents' opinions on United Nations involvement.

Likewise, the simulation undertaken by SGC delegates generated discussion about the resources required in the event of such a scenario, both in terms of early detection and disaster mitigation. Particularly in an impact scenario, people would need to be relocated and

resources to help support them, etc. Furthermore, those emerging space nations would not necessarily have the same access to detection methods. In addition, global situations such as the recent COVID-19 pandemic have highlighted inequities which have contributed to extending the pandemic (ie. access to vaccines).

Establishing national and global funds to develop planetary defense infrastructure along with a disaster fund would be a critical step in achieving readiness. Delegates at the SGC workshop determined the easiest method would be for nations to set aside a portion of taxpayer money to pay into the fund. With this idea, the survey asked whether participants would approve of the designation of some taxpayer money to be used in planetary defense. Figure 16 illustrates the distribution of opinion.

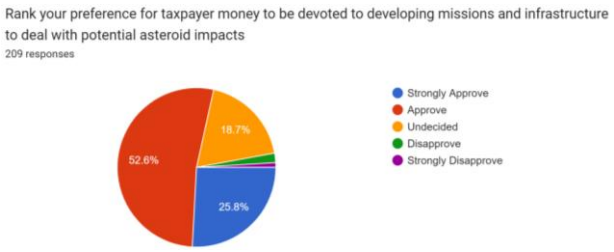

Fig 16. Preference for use of taxpayer money in planetary defense infrastructure development.

Examining Figure 16 shows that over ¾ of participants agree that taxpayer money should be assigned to a planetary defense fund. Only 2.9% of survey participants said they disapproved of using taxpayer money, whereas 18.7% were undecided.

During the SGC workshop, it became clear that the relationship with the public was another critical aspect to consider. Those tasked with the role of representing the policy makers initially decided to withhold information about even a possibility of an impact, until it became more certain, in the interest of preventing widespread panic. Reflective of real life, by not informing the public immediately, the relationship between the policy and public would easily be damaged, making all further communication subject to suspicion. Therefore, one recommendation that arose was to maintain transparency whenever possible.

When asked about how soon the public should be informed about a potential impact, the responses from the survey were more varied and fairly close in proportion, with the exception being the 2.8% that did not want to be informed until it's too late, which is more reflective of the individual, whilst 50.7% of respondents wanted to be informed once impact was confirmed.

The data from the survey suggests that there is no correct or better time to inform the public, other than not waiting until it's too late to do something, and they will never be able to satisfy all the different personality types.

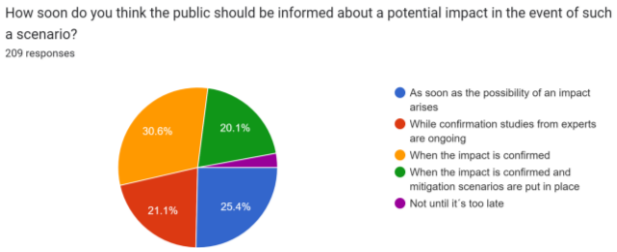

Fig 17. Preferred time of initial notification.

However due to the internet and the global village, if one population receives the news as soon as the possibility arises vs another population waiting until it's confirmed, it would not be long until that population is made aware and it would weaken the trust of the public in their government officials, making it harder to ensure public cooperation of government measures. This was witnessed in various countries around the world during the COVID-19 pandemic, with access to a wide range of information and various countries' measures and recommendations.

The source or method of communication also played an important role. In the SGC workshop, the public became distrustful of the government officials and policy makers, in part due to the delay in admission of the circumstances. They were more inclined to trust the scientists when they got access to them. Members of the public refused to believe anything that came from the government or scientific community, echoing the trend seen during the COVID-19 pandemic and the rise of fake news. Therefore, another recommendation from the delegates was to ensure that everyone, including the public, could have direct access to the latest information through a regularly updated portal, allowing others to independently review the data. Additionally, being able to have access to the scientists and ask questions without having to relay them through a government official can go toward establishing and maintaining trust. Figure 18 shows the results of which sources the public holds in the highest trust.

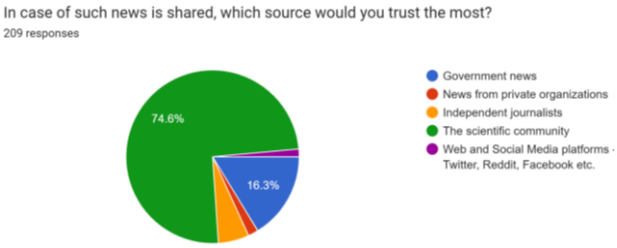

Fig 18. Most trusted source of communication.

Examination of Figure 18 shows that the majority of participants, at 74.6%, trust the scientific community above other sources for such information. 16.3% would likely trust the government news, whereas only 9.1% would only trust independent or private journalism. This

result is fairly promising in that it shows there's still a high level of trust for scientists despite all the "fake news" claims circulating (i.e., COVID-19).

Overall these results add further weight to the recommendation of transparency and public education awareness campaigns. This will not only help reduce panic in the event of a potential impact scenario, but also keep the issue at the forefront of citizens and their governments, hopefully with result being the funding of related planetary defense infrastructure and policies.

5. Final Recommendations and Conclusions

The aim of our study was to present the SGC2021 workshop recommendation on Planetary Defence and assess the young generation's perception and awareness of what actually an asteroid impact would mean, preparedness level and how best this could be communicated toward the general public. Addressing the survey data in comparison to the workshop recommendations we bring forward a new set of points that highlight the importance of creating outreach and awareness campaigns. International space missions have visited 16 minor planets and comets as of 2021 [12], and through DART and HERA space missions we assist the first international collaborative project for asteroid exploration and impact research.

Given the young generation answers regarding planetary protection infrastructure, global awareness and radical collaboration for humanity protection must be addressed. And for it, scientists have been considered the main and trustworthy source for information sharing; however, in the current times, taking the COVID-19 situation, there were no scientists communicating about personal health and hygiene subjects in a structured and proactive manner.

We therefore highlight the requirement for creating Science Communication projects related to asteroids, orbital parameters studies, asteroids and comets trajectory simulation and laboratory-based computer numerical modelling projects.

Radical collaboration and development of new space exploration missions to highlight planetary protection are in need of policy development to support national and international efforts in novel technology development and humanitarian support in the event of impactful collisions. More work in these areas will allow for a suitable level of preparedness for such events and also ensure that should resource and assets need to be mobilised, the tools and mechanisms necessary to do this are already in place.

To conclude our study, in light of the space missions for planetary defence, participatory challenge resides with the need for increased knowledge about local or distant space environments that only through citizen science and outreach projects could be achieved.

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