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Developing a "Planetary Defense Decisionmaker Guide"

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Abstract

How to detect and deflect asteroids and comets that threaten to impact Earth, and how to mitigate the consequences should an impact be unavoidable, is a vital but complex topic that touches on multiple disciplines, involves multiple stakeholders, and presents multiple options to decisionmakers. Related issues have been extensively researched for many years, and a large number of papers, reports, and other references exist. However, key findings, insights, and recommendations have so far not been pulled together into a single document in an easily-accessible format that would allow decisionmakers at all levels and in all nations to "get smart" on the topic quickly in order to save lives and protect assets in case of a Planetary Defense emergency. This paper discusses the goals, design approach, structure, and key content of one such resource: the "Planetary Defense Decisionmaker Guide" that the author has developed over the course of the past several years.

Keywords: Planetary Defense, emergency communication, space education

Introduction

How to detect and deflect asteroids and comets that threaten to impact Earth, and how to mitigate the consequences should an impact be unavoidable, is a vital but complex topic that touches on multiple disciplines, involves multiple stakeholders, and presents multiple options to decisionmakers. Related issues have been extensively researched for many years and a large number of papers, reports, and other references exist, but strategic insights, operationally-relevant information, and actionable recommendations have so far not been pulled together into a single, comprehensive document in an easily-accessible format that can stand on its own, without requiring an accompanying voice track like, e.g., briefing slides prepared for Planetary Defense exercises.

While many senior government officials in the U.S. and Europe have direct access to dedicated Planetary Defense subject matter experts who can answer their questions and inform their decisionmaking, especially in case of a short-notice Planetary Defense emergency, most national leaders around the globe do not have that luxury, and neither do most industry executives, media (and social media) representatives, civil society leaders, and others who will have to "get smart" on the topic quickly in

order to save lives and protect assets. Nor do most of these stakeholders have the time, interest, and/or access required to read through the hundreds of relevant publications in this field.

Decisionmakers in the US and around the world will therefore benefit from having a compact yet comprehensive reference available, written in plain language, that helps them understand the key issues, discusses what can be done now, and outlines what the options are once a specific threat materializes.

This paper provides an overview of one such resource, the "Planetary Defense Decisionmaker Guide" (PDDG), and documents the considerations behind its structure and content. The creation of the initial draft of the PDDG was funded by the RAND Corporation with gifts from supporters and income from the operation of RAND's Social and Economic Well-Being division.

Approach to Creating the Planetary Defense Decisionmaker Guide

Based on the author's observations at several Planetary Defense tabletop exercises, the need for a consolidated resource for decisionmakers who are not subject matter experts (SMEs) became apparent. The first step towards creating such a document was to determine what information national-level decisionmakers need to know regarding planetary defense. For this, the author reviewed the relevant literature, elicited information from subject matter experts, and observed related exercises and planning efforts.

The next step was to create a format appropriate for effectively and efficiently conveying that information to senior decisionmakers. This format was then populated with the required information, appropriately referenced and with clickable hyperlinks as available, to make it easy for readers to access more in-depth information as needed, and to facilitate keeping the PDDG up-to-date.

The initial draft was reviewed by multiple SMEs, and the revised draft was then provided to participants of a Planetary Defense exercise in order to obtain additional feedback on both the format and the content.

This paper documents the process up to that stage. The final steps will involve updating the PDDG and making it available to national and international leaders in government, industry, and civil society, as well as to the interested public. Ideally, the PDDG will be updated every few years as the field of Planetary Defense evolves.

Integration into National and International Strategies and Plans

Several governments[1] and space agencies[2] around the globe have offices dedicated to Planetary Defense. The United Nations Office of Outer Space Affairs likewise is engaged in the Planetary Defense community (UNOOSA, 2025). The PDDG can augment the outreach, public information, and risk mitigation activities of these organizations.

For example, in the U.S., the PDDG directly supports Goal 4.1 ("engage and inform foreign governments") of the 2023 U.S. National Preparedness Strategy and Action

[1] For example, the United States has created a "Planetary Defense Coordination Office" as part of NASA's Science Mission Directorate (NASA, 2023).

[2] See, for example, ESA, undated.

Plan for Near-Earth Object Hazards and Planetary Defense, as well as Goal 5.3 (“develop and share informational material for different audiences”) and Goal 8.2 (“enhance leadership messaging of planetary defense”) of the 2023 NASA Planetary Defense Strategy and Action Plan.

Similarly, the PDDG can augment the public outreach efforts of UNOOSA and of the UN-endorsed Space Mission Planning Advisory Group (SMPAG), through which space agencies worldwide can coordinate their response in case of a Planetary Defense emergency (SMPAG, 2025), and International Asteroid Warning Network (IAWN), which coordinates and communicates detection and tracking of potentially-hazardous asteroids and comets (IAWN, 2025).

Requirements for a Decisionmaker Guide

As mentioned above, the overarching objective of this decisionmaker guide is to provide a comprehensive, yet easily-accessible resource both for senior decision-makers and a wide range of other stakeholders on the topic of Planetary Defense, with a focus on information that is needed in case of a Planetary Defense emergency. This led to the following list of requirements:

- **Information structure**: logical flow of topics from beginning to end, but also a headings hierarchy and user-friendly table of contents that allows readers to “jump” to the topic that they are most interested in; offering multiple levels of detail to accommodate both readers who have only little time & interest and those who want in-depth information; self-contained chapters even if that requires repeating information from earlier chapters.
- **Content**: covering the likelihood and consequences of impacts, what can be done once a threat materializes, what can be done now, who decides on what is done, where to find additional information; focus on information needed by decision-makers with terrestrial responsibilities such as emergency response and disaster communications, since any in-space missions will be conducted by national space agencies and others who already are subject-matter experts. However, experience from the Planetary Defense Conference exercises has shown that terrestrial responders still want to understand the scientific and technical background on the threat, key details of in-space missions, etc., in order to inform their decisionmaking.
- **Communication style**: easily understandable by an educated layperson, without “dumbing down” or omitting key details; conciseness to minimize time investment required by the reader. Lots of references, with clickable URLs, to help interested readers to research topics of particular interest in more depth.
- **Physical layout**: suitable for reading on a screen or printing and putting in a binder, but also suitable for professional print production; hardcopies allowing easy “jumping” to chapters most relevant to the reader.
- **Process**: written using commonly-available software and stored in a commonly-used file format to facilitate collaboration; initial draft field-tested at exercises and reviewed by subject matter experts; final version updated every few years to capture new developments.
- **Dissemination**: available online for free download, on a trusted website, in a common file format; hardcopies available at low cost on demand, and proactively handed out to the most relevant stakeholders; outreach campaign to announce availability of the Guide.

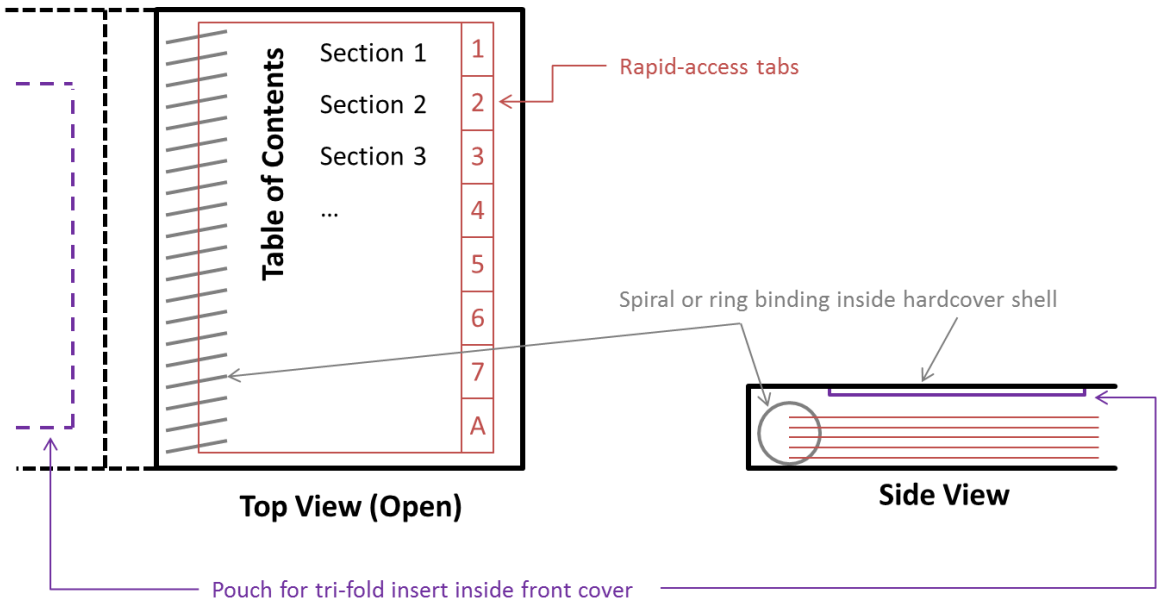
The remainder of this paper discusses how these requirements were implemented for the PDDG.

Structure of the PDDG

The PDDG consists of two separate documents that are mutually supportive, but still viable as standalone products: the main Guide, and a two-page “pocket reference” that captures the basics and also works as an attention-getter for the main Guide.

While the layout of both products is suitable for screen display and localized printing by the reader, it can also be professionally produced, preferably in a spiral- or ring-bound format so the reader can leave it open on a table, and with a hardcover shell to facilitate storage on a bookshelf and increase protection against damage. The inside of the Guide’s cover will ideally have a transparent pouch to hold multiple copies of the Pocket Reference. Rapid-access tabs for the chapters of the PDDG are cut into the outside page margin, and matched to a one-page chapter overview. Figure 1 illustrates the design concept for the PDDG. Both the main Guide and the pocket reference are designed to be printed on U.S. Letter size paper, but can also be scaled to DIN A4 paper. Both documents are meant for double-sided printing.

Figure 1: Design concept for Planetary Defense Decisionmaker Guide hardcopies



Main Document

The main Guide has four major parts to accommodate readers with different levels of information requirements:

- An Executive Summary (11 pages in the current draft) that covers the most relevant aspects of Planetary defense. This is aimed at readers who have only 15-20 minutes to understand the big picture, and then can delegate detailed exploration to their staff. Topics covered include: risk and consequences, timelines, response options, what can be done now, who decides and how, and how should the general public be notified once a specific threat has been detected.

- A main section (75 pages in the current draft) that contains key information for readers that have a few hours to familiarize themselves with the topic. It is divided into seven chapters, each starting with its own detailed table of contents to facilitate rapid access to the information that a reader is most interested in.
- An appendix (39 pages in the current draft) that provides more detail on some of the issues discussed in the main section, in particular: definitions, abbreviations, the most threatening known potential impact events for the next 100+ years, examples for public notification messages, contact information for organizations involved in Planetary Defense, insights from high-fidelity computational simulations of impact effects, examples for the refinement of impact predictions over time, and large-sized versions of key figures.
- An extensive reference section that documents all sources of information used in the Guide, and provides the reader with a starting point for more in-depth research if desired. All sources that are available online include the respective URL as a clickable link.

To help the reader navigate the content of the Guide efficiently, the document starts with a one-page chapter overview table, followed by a detailed table of contents. The content of the main section is described in more detail below.

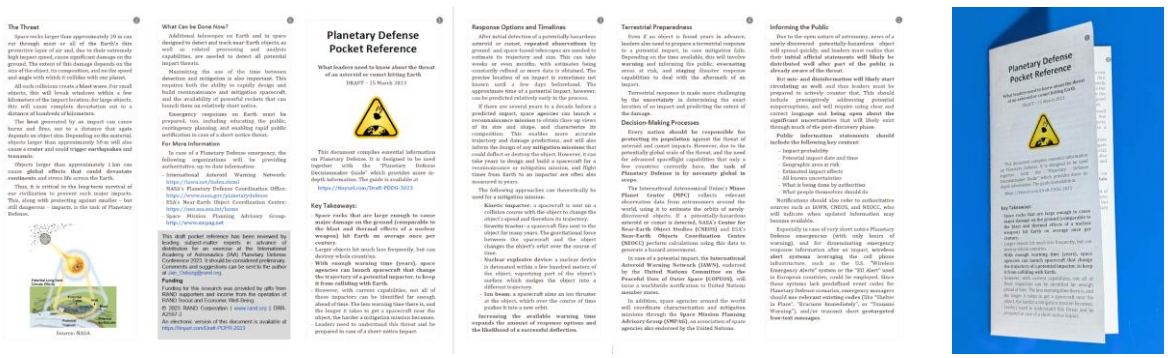
Pocket Reference

The pocket reference is designed to be printed on a single sheet of paper, double-sided, and then folded twice so that it fits into a coat pocket. This tri-fold format allows for six text boxes, each devoted to one topic:

1. Purpose and key takeaways
2. The threat
3. Response options and timelines
4. Terrestrial preparedness
5. Informing the public
6. What can be done now

The Pocket Reference also includes a link to the main Guide. Figure 2 shows the overall layout of the Pocket Reference and how it looks once folded. The current draft is available at https://tinyurl.com/Draft-PDPR-2023.

Figure 2: Planetary Defense Pocket Reference layout (left) and hardcopy (right)



Content of the PDDG

The content of the PDDG was compiled from dozens of authoritative sources, all of which are listed in the “References” section, and peer-reviewed by senior subject matter experts. This content is divided into the following chapters:

1. **What Are the Odds?** This chapter summarizes the probabilities for various categories of impactors, with tie-ins to the subsequent “What Would Happen” chapter and the discussion of decisionmaking under uncertainty in the “Who Decides” chapter. The key insights communicated in this chapter are that major impacts resulting in worldwide devastation have occurred several times during the Earth’s history, and that impacts that would result in severe, city-sized damage are likely to occur approximately every century.
2. **What Would Happen?** This chapter provides an overview of impact consequences by impactor type and size, illustrated by historical examples. Key insight conveyed: even a relatively small object (~100m diameter) would create a blast wave comparable to that of a multi-megaton nuclear weapon over the impact area.
3. **What Are the Timelines Involved?** This chapter discusses possible timelines, from no-notice events to those with decades of warning time, emphasizing how detection capabilities and associated uncertainties drive response timelines, and how timelines drive response options. Key insights highlighted: some potentially hazardous asteroids can be identified and predicted decades in advance. However, some objects can also impact the Earth with only a few weeks or days of advance warning—or no warning at all, if they approach from a part of the sky that is not sufficiently covered by early-warning telescopes.
4. **What Can Be Done Now to Reduce the Risk?** This chapter outlines options for space surveillance, research and testing of deflection methods, and other related topics. Key insight here: investment is needed in the areas of improving detection, preparing for asteroid characterization or deflection missions, and preparing for mitigation in likely impact areas.
5. **What Are the Options Once a Catastrophic Impact Is Likely?** This chapter elaborates on the key advantages and disadvantages of the main deflection options (kinetic impactor, gravity tractor, nuclear, and their combinations), and will also discuss emergency response measures on Earth. Key insights include: potentially hazardous objects can be diverted in deep space if there is enough warning time. If diversion fails or is impossible due to lack of time, potential impact areas on Earth should be evacuated. Uncertainty affects both the technological (diversion) and evacuation approaches: A diversion attempt can have a range of possible outcomes, including complete failure or partial success, and the uncertainty in impact area prediction will likely remain high until a few weeks (or even days) before an impact and thus result in uncertainty regarding which areas to evacuate.
6. **Who Decides?** This chapter outlines which national and international stakeholders are involved in Planetary Defense, and what the associated notification and decisionmaking processes are. It also discusses issues regarding competing national interests in case of global threats and summarize the applicable legal frameworks. Key insights discussed: NASA’s Planetary Defense Coordination Office has the lead in detecting potentially hazardous objects, determining impact likelihood, and notifying the U.S. government if needed. FEMA has the lead in mitigating and responding to impact

consequences at the federal level. Two subcommittees of the United Nations Committee on Peaceful Uses of Outer Space, Office of Outer Space Affairs, play a role in coordinating international warning and response.

7. **How to Inform the Public?** This chapter summarizes best practices in risk communication as applied to planetary defense, illustrated by key lessons learned from past disasters. Key insights: the current U.S. notification process involves NASA informing the U.S. public after first notifying the federal government. However, discussing the associated complexities and uncertainties in a way that average citizens can understand and base their decisions and actions on will be challenging, especially in the face of competing sensationalist reporting.

Figure 3 shows the chapter overview and margin tabs. The current draft of the Planetary Defense Decisionmaker Guide is available at https://tinyurl.com/Draft-PDDG-2023.

Next steps for the PDDG

Initial feedback on the Planetary Defense Decisionmaker Guide and the associated Pocket Reference has been positive. Thus, once funding to finalize the current draft has been secured, its content will be updated, and additional testing with relevant audiences will be conducted, both on the content and on how to best structure it. The revised version will undergo another round of peer review before being finalized.

This final version will be made available online, and, if funding permits, hardcopies will be produced and provided to national leaders, space agencies, emergency management agencies, and other relevant audiences. Regular updates, at least every other year, will ensure that the PDDG always reflects the most recent insights of the Planetary Defense community.

Figure 3: Planetary Defense Decisionmaker Guide chapter overview page with margin tabs

Chapter Overview

Executive Summary Concise summary of key insights, with pointers to relevant chapters.	SUMMARY
Chapter 1: What Are the Odds? Summarizes probabilities for various categories of impactors, with tie-ins to "What Would Happen" chapter and the discussion of decisionmaking under uncertainty in "Who Decides" chapter.	THE ODDS
Chapter 2: What Would Happen? Provides an overview of impact consequences by impactor type and size, illustrated with historical examples.	THREAT
Chapter 3: What Are the Timelines Involved? Discusses possible timelines, from no-notice to decades, emphasizing how detection capabilities and associated uncertainties drive timelines, and how timelines drive response options.	TIMELINES
Chapter 4: What Can Be Done Now to Reduce the Risk? Outlines options for space surveillance, research and testing of deflection methods, and other related topics.	DO NOW
Chapter 5: What Are the Options Once a Catastrophic Impact Is Likely? Elaborates on key advantages and disadvantages of the main deflection options (impactor, gravity tractor, ion beam, nuclear), and also discusses emergency response measures on Earth.	RESPONSE
Chapter 6: Who Decides, and How? Describes which stakeholders are involved and what the associated processes are. Also discusses issues regarding competing national interests and summarizes applicable legal frameworks.	WHO/HOW
Chapter 7: How to Inform the Public? Summarizes best practices in risk communication as applied to Planetary Defense, illustrated by key lessons learned from past disasters.	PUBLIC
Appendix Provides more detailed coverage of key topics, and reference information that may only be of relevance to some readers. Also provides larger-sized versions of key figures.	APPENDIX
References Sources of the content used in this document, and recommended reading for a more in-depth study of the issues.	REFERENCES

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Abbreviations

ESA: European Space Agency
IAWN: International Asteroid Warning Network
NASA: National Aeronautics and Space Agency
SME: Subject Matter Expert
SMPAG: Space Mission Planning and Analysis Group
UNOOSA: United Nations Office of Outer Space Affairs

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