The Threat

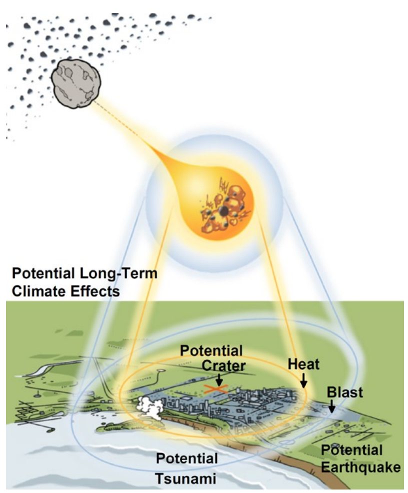
Space rocks larger than approximately 20 m can cut through most or all of the Earth's thin protective layer of air and, due to their extremely high impact speed, cause significant damage on the ground. The extent of this damage depends on the size of the object, its composition, and on the speed and angle with which it collides with our planet.

All such collisions create a **blast wave.** For small objects, this will break windows within a few kilometers of the impact location; for large objects, this will cause complete devastation out to a distance of hundreds of kilometers.

The **heat** generated by an impact can cause burns and fires, out to a distance that again depends on object size. Depending on the material, objects larger than approximately 50 m will also cause a **crater** and could trigger **earthquakes** and **tsunamis.**

Objects larger than approximately 1 km can cause **global effects that could devastate continents** and stress life across the Earth.

Thus, it is critical to the long-term survival of our civilization to prevent such major impacts. This, along with protecting against smaller – but still dangerous – impacts, is the task of Planetary Defense.



Source: NASA/JPL

What Can be Done Now?

Additional telescopes on Earth and in space designed to detect and track near-Earth objects, as well as related processing and analysis capabilities, are needed to detect all potential impact threats.

Maximizing the use of the time between detection and mitigation is also important. This requires both the ability to rapidly design and build reconnaissance and mitigation spacecraft, and the availability of powerful rockets that can launch them on relatively short notice.

Emergency responses on Earth must be prepared, too, including educating the public, contingency planning, and enabling rapid public notification in case of a short-notice threat.

For More Information

In case of a Planetary Defense emergency, the following organizations will be providing authoritative, up-to-date information:

- International Asteroid Warning Network: https://iawn.net/index.shtml
- NASA's Planetary Defense Coordination Office: https://www.nasa.gov/planetarydefense
- ESA's Near-Earth Object Coordination Centre: https://neo.ssa.esa.int/home
- Space Mission Planning Advisory Group: http://www.smpag.net

This draft pocket reference has been reviewed by leading subject-matter experts in advance of distribution for an exercise at the International Academy of Astronautics (IAA) Planetary Defense Conference 2023. It should be considered preliminary. Comments and suggestions can be sent to the author at Jan_Osburg@rand.org.

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An electronic version of this document is available at https://tinyurl.com/Draft-PDPR-2023

Planetary Defense Pocket Reference

What leaders need to know about the threat of an asteroid or comet hitting Earth

DRAFT – 15 March 2023

This document compiles essential information on Planetary Defense. It is designed to be used together with the "Planetary Defense Decisionmaker Guide" which provides more in-depth information. The guide is available at

https://tinyurl.com/Draft-PDDG-2023

Key Takeaways:

- **Space rocks that are large enough to cause major damage on the ground (comparable to the blast and thermal effects of a nuclear weapon) hit Earth on average once per century.**
- Larger objects hit much less frequently, but can destroy whole countries.
- **With enough warning time (years), space agencies can launch spacecraft that change the trajectory of a potential impactor, to keep it from colliding with Earth.**
- However, with current capabilities, not all of these impactors can be identified far enough ahead of time. The less warning time there is, and the longer it takes to get a spacecraft near the object, the harder a mitigation mission becomes.
- Leaders need to understand this threat and be prepared in case of a short-notice impact.

Response Options and Timelines

After initial detection of a potentially hazardous asteroid or comet, **repeated observations** by ground- and space-based telescopes are needed to estimate its trajectory and size. This can take weeks or even months, with estimates being constantly refined as more data is obtained. The precise location of an impact is sometimes not known until a few days beforehand. The approximate time of a potential impact, however, can be predicted relatively early in the process.

If there are several years to a decade before a predicted impact, space agencies can launch a **reconnaissance mission** to obtain close-up views of its size and shape, and characterize its composition. This enables more accurate trajectory and damage predictions, and will also inform the design of any **mitigation missions** that could deflect or destroy the object. However, it can take years to design and build a spacecraft for a reconnaissance or mitigation mission, and flight times from Earth to an impactor are often also measured in years.

The following approaches can theoretically be used for a mitigation mission:

- **Kinetic impactor**: a spacecraft is sent on a collision course with the object to change the object's speed and therefore its trajectory.
- **Gravity tractor**: a spacecraft flies next to the object for many years. The gravitational force between the spacecraft and the object changes the object's orbit over the course of time.
- **Nuclear explosive device**: a nuclear device is detonated within a few hundred meters of the object, vaporizing part of the object's surface which nudges the object into a different trajectory.
- **Ion beam**: a spacecraft aims an ion thruster at the object, which over the course of time pushes it into a new orbit.

Increasing the available warning time expands the amount of response options and the likelihood of a successful deflection.

Terrestrial Preparedness

Even if an object is found years in advance, leaders also need to prepare a terrestrial response to a potential impact, in case mitigation fails. Depending on the time available, this will involve **warning** and informing the public, **evacuating** areas at risk, and **staging** disaster response capabilities to deal with the aftermath of an impact.

Terrestrial response is made more challenging by the **uncertainty** in determining the exact location of an impact and predicting the extent of the damage.

Decision-Making Processes

Every nation should be responsible for protecting its population against the threat of asteroid and comet impacts. However, due to the potentially global scale of the threat, and the need for advanced spaceflight capabilities that only a few countries currently have, **the task of Planetary Defense is by necessity global in scope**.

The International Astronomical Union's **Minor Planet Center (MPC)** collects relevant observation data from astronomers around the world, using it to estimate the orbits of newly-discovered objects. If a potentially-hazardous asteroid or comet is detected, NASA’s **Center for Near-Earth Object Studies (CNEOS)** and ESA's **Near-Earth Objects Coordination Centre (NEOCC)** perform calculations using this data to generate a hazard assessment.

In case of a potential impact, the **International Asteroid Warning Network (IAWN)**, endorsed by the **United Nations Committee on the Peaceful Uses of Outer Space (COPUOS)**, will issue a worldwide notification to United Nations member states.

In addition, space agencies around the world will coordinate characterization and mitigation missions through the **Space Mission Planning Advisory Group (SMPAG)**, an association of space agencies also endorsed by the United Nations.

Informing the Public

Due to the open nature of astronomy, news of a newly-discovered potentially-hazardous object will spread quickly, and leaders must realize that their **initial official statements will likely be distributed well after part of the public is already aware of the threat**.

But **mis- and disinformation will likely start circulating as well**, and thus leaders must be prepared to actively counter that. This should include preemptively addressing potential misperceptions, and will require using clear and correct language and **being open about the significant uncertainties** that will likely exist through much of the post-discovery phase.

Public information statements should include the following key content:

- Impact probability
- Potential impact date and time
- Geographic area at risk
- Estimated impact effects
- All known uncertainties
- What is being done by authorities
- What people themselves should do

Notifications should also refer to authoritative sources such as IAWN, CNEOS, and NEOCC, who will indicate when updated information may become available.

Especially in case of very short notice Planetary Defense emergencies (with only hours of warning), and for disseminating emergency response information after an impact, **wireless alert systems** leveraging the cell phone infrastructure, such as the U.S. "Wireless Emergency Alerts" system or the "EU Alert" used in European countries, could be employed. Since these systems lack predefined event codes for Planetary Defense scenarios, emergency managers should **use relevant existing codes** (like “Shelter in Place”, “Evacuate Immediately”, or “Tsunami Warning”), and/or transmit short **geotargeted free-text messages.**