# Planetary Defence Decision Tree (Supporting document)

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## I. CONTEXT

"Who decides?" This question is fundamental to any planetary defence action and could have larger consequences for the outcome of a planetary defence emergency than, say, the choice of a deflection mission. This document looks at some of the questions that arise in the planetary defence decision-making process. It is supplemental to the interactive "decision tree" published at https://outerspaceinstitute.ca/planetarydefence.html with an HTML version available at https://outerspaceinstitute.ca/pdtree.html.

From the outset, it is important to recognize that: (1) Decisions are required prior to, during, and after any planetary defence action; (2) Some decisions can only be made by individual states, while others are best addressed in international fora, including within organs of the United Nations; and (3) Planetary defence does not yet have a clear decision-making structure.

## II. PRE-DISCOVERY QUESTIONS

Decisions made *in advance* of any discovery of a threatening near Earth object (NEO) will often determine the choices available after such a threat has been discovered. The details of these pre-discovery decisions are not directly part of our decision tree, although we list some general questions to illustrate their importance. Humanity has more control over these decisions than any other choice in planetary defence, and acting now can increase the options that are available later—when an actual Earth-impact threat emerges.

## III. IDEAL RESPONSE

When designing and debating a decision-tree, it may be useful to consider a hypothetical "ideal" response to an Earth-impact threat. We posit the following for discussion:

1. An international agreement on planetary defence exists before a detection
2. Early detection of the threat
3. Response maintains international cooperation involving all spacefaring states, with near-universal support from other states
4. Rapid reconnaissance mission(s) with redundancies
5. Conventional (nonnuclear) deflection mission with redundancies

Everything else is sub-optimal, rendered necessary by the circumstances—mostly the length of time available, but also the situational facts and the associated physics, engineering, politics and law. A lack or shortage of pre-discovery decisions is also sub-optimal.

The use of "conventional" in the deflection mission refers to any non-NED-based deflection mission, which represents most mission types. This is referred to as "nonnuclear" in the interactive decision tree.

Any international agreement on planetary defence decision-making should include an ideal response and states should adhere to it when possible, including when one of the previous steps has not been taken. Using ours as an example, even if step 3 (international cooperation involving spacefaring states) is not taken, steps 4 (rapid reconnaissance missions) and 5 (conventional deflection missions) will remain – when and where practicable – preferred.

We do not specify the type of deflection other than it being a conventional mission, such as a high impulse kinetic impactor or a low-impulse tractor-type mission. As shown in our interactive decision tree, a NED can lead to some of the worst outcomes when considering the political and social contexts, particularly if there is a failed deflection. Thus, if a non-NED and a NED can accomplish the same deflection, the ideal response will always favour the conventional mission. With this in mind, there may be situations for which a NED is found to be necessary and, thus, their potential authorization and use must be included in decision-making discussions.

## IV. INTERNATIONAL COOPERATION

International cooperation should not be assumed. In previous PDC scenarios, states decide to cooperate, and SMPAG (discussed below) is always centrally involved. Yet decisions within SMPAG are made through consensus, which means one member could interfere with SMPAG's ability to communicate recommendations to member states. In most previous PDC scenarios, the risk of such impediments is glossed over by Russia and China not being explicitly involved in missions, and without mention being made of any effort to involve those spacefaring states, or any refusal by them to be involved.

International cooperation is not a single decision point. It is an ongoing process. Initially, states might decide against cooperation and then change their stance as the crisis progresses, e.g., as the scale of the challenge becomes apparent or their unilateral efforts progress more slowly than planned. In contrast, states may decide to cooperate from the outset, only for this cooperation to breakdown due to irreconcilable differences, such as over the desire of some to use a NED.

A distinction should be made, however, between a breakdown in cooperation and simply failing to agree on an action. In the latter case, cooperation can be maintained provided that other options remain available or there is a pre-determined mechanism for resolving disagreements.

Full cooperation will involve a number of international institutions:

### 1. Space Mission Planning Advisory Group

The Space Missions Planning Advisory Group (SMPAG) was endorsed by the UN General Assembly in 2013 and established in 2014 to "prepare for an international response to a threat by a near-Earth object through the exchange of information, development of options for collaborative research and mission opportunities, and to conduct NEO threat mitigation planning activities."

SMPAG is not part of the United Nations, even though it receives some administrative support from the UN Office of Outer Space Affairs (UNOOSA). Nor is it an "international organization", i.e., an intergovernmental body, created by treaty, with its own "international legal personality". While it has formal processes and terms of reference, it is in practice an advisory group, made up of 18 space agencies, that makes its own non-binding decisions based on consensus. This informal non-binding consensus-based character is well-suited to promote communication, confidence-building and coordination among space agencies, including space agencies of states that might otherwise be hostile or suspicious of each other.

As our decision-tree makes clear, the main decision point that states have concerning SMPAG is: Should states follow SMPAG recommendations or treat them simply as a factor in national decision-making?

### 2. UN Security Council

The UN Security Council was established by the 1945 UN Charter, a multilateral treaty that has since been ratified by 193 states, including all of the spacefaring states. This 15-member body is the principal decision-making body of the United Nations. It offers an existing venue where high level representatives of spacefaring states can gather on very short notice. China, France, Russia, the UK and US are permanent members of the Security Council; the other ten "non-permanent members" are elected for two-year terms. For all these reasons, one can assume that any planetary defence crisis will involve discussions at the Security Council. The question is, what could the member states of the Security Council decide to do when faced with a planetary defence emergency?

The Security Council has the authority, by way of a "Chapter VII" resolution, to assert control over any situation that it decides constitutes a "threat to international peace and security". There is no doubt that this discretionary power, which has already been exercised with regard to an earthquake, extends to planetary defence. The Security Council could thus assert control over a planetary defence crisis, with all major decisions subsequently resting with it as the final authority. A decision to assert control, if done by a Chapter VII resolution, would be legally binding on all UN members, including those not present on the Council.

The Security Council can also use a Chapter VII resolution to legalize what would otherwise be an illegal action, with this power being most visible when it authorizes the use of force against a

sovereign state. In a planetary defence crisis, the situation where this power is likely to matter concerns the use of a NED, which many experts believe would otherwise be illegal.

Since the adoption of a Security Council resolution can be vetoed by any of the five permanent members, any assertion of Council control or authorization to use a NED will necessarily have the support of China, France, Russia, the UK and US.

One should not underestimate the ability of the Security Council to act quickly and decisively. On September 12, 2001, just one day after the terrorist attacks on the World Trade Center and the Pentagon, Security Council Resolution 1368 was adopted. A Chapter VII resolution, it identified the attacks as a "threat to international peace and security," recognized "the inherent right of individual or collective self-defence," and expressed the Council's "readiness to take all necessary steps to respond". Just 16 days later, the Council again invoked Chapter VII to adopt Resolution 1373, which required all states to "prevent and suppress the financing of terrorists," including by adopting new criminal prohibitions in their domestic legal systems. Thus, the Security Council could require states to adopt certain SMPAG recommendations, create its own requirements for states to adopt, or both. And it could do so quickly.

Of course, there are also situations where disagreement among the permanent members prevents decisive Security Council action. Again, international cooperation cannot be assumed.

## V. PARTIAL INTERNATIONAL COOPERATION

It is possible that one or two major spacefaring states might choose not to cooperate with the others. This will have consequences for the institutions that otherwise might have been involved, although several "work arounds" could be used:

### 1. SMPAG minus

As an informal group, SMPAG could continue to meet and operate – in all but name – if one or more space agencies refused to cooperate. SMPAG minus 1 or SMPAG minus 2 would still be able to harness the collective expertise of its members, drawing on all of its previous collaborative work. And it would still be able to issue recommendations.

### 2. Informal group of UN Security Council members and/or spacefaring states

Similarly, if one or more permanent members of the UN Security Council are opposed to the adoption of resolutions there, or even seek to obstruct debate, the rest of the members, or an ad hoc grouping of spacefaring states, could engage in collective decision-making. However, they would not be able to make legal any actions that might otherwise be illegal, such as the use of a NED.

### 3. UN General Assembly

If one or two major spacefaring states decide not to cooperate, the UN General Assembly offers a venue where the rest of the international community could express support for those states that

are cooperating. The General Assembly is where all 193 member states of the United Nations regularly meet. Decisions are made by majority vote, not by consensus, which means that resolutions can be adopted even if they are opposed by some (or indeed all) spacefaring states. General Assembly resolutions are not legally binding, nor can they make legal an otherwise illegal action. But depending on their substance and the distribution of votes, they can sometimes carry considerable political and moral weight.

The General Assembly might also offer a venue for authorizing actions. When the UN Security Council is engaged with a matter, other organs of the United Nations usually defer to it. But in 1950, when Security Council decision-making on Korea being blocked by a permanent member, the General Assembly adopted the first "Uniting for Peace" resolution—deciding that, in the face of Security Council inaction, it could recommend collective measures to maintain or restore international security and peace, including the use of force. It remains debateable whether that or any subsequent Uniting for Peace resolution has carried any legal weight, or whether they remain strictly recommendatory.

If the Security Council was blocked during a planetary defence crisis, one could expect the General Assembly to meet and adopt resolutions. One of those resolutions might express support for SMPAG playing a leadership role. Another might express support (or not) for a deflection mission being launched unilaterally by one or a small group of states. While another still might express support (or not) for the use of a NED. The impact of such resolutions is uncertain.

## VI. LIMITED INTERNATIONAL COOPERATION

Limited cooperation or even unilateral action can still produce positive results. It might also be supported or acquiesced in by other states. For instance, if one or two states decide to attempt a deflection that involved little or no risk, one could expect this to proceed without opposition.

But if one or a small number of states are preparing for a deflection mission that involves unnecessary risks to other states and their populations, such as fragmenting the NEO or achieving only a partial deflection and moving the impact area from one state to another, how will other states respond? Will the states use non-forceful measures such as diplomatic protests, sanctions, etc.? Will the states conduct forceful responses, such as a missile strike on a launch site? The latter option in particular engages international legal issues, including the contested right of pre-emptive self-defence.

## VII. INFORMATION SHARING IN THE ABSENCE OF OTHER COOPERATION

If cooperation between the US and Russia or China proves impossible, some collaborative behaviour should still be possible and probably desirable. The most important collaboration might be the information sharing, including from observations and any reconnaissance missions. Such information sharing, which could help to avoid accidents or unnecessary duplications of effort, is not dependent on reciprocity.

## VIII. RECONNAISSANCE MISSIONS

A reconnaissance mission involves launching a spacecraft to fly by or rendezvous with an asteroid to determine its size, composition, mass, or other information essential to a successful deflection. For this reason, the decision to launch a reconnaissance mission is foreseeable in many potential planetary defence crises.

Time is by far the most important variable here. In previous PDC scenarios, a reconnaissance mission was always launched if time was available. In our view, this is not really a decision-point, since the decision will *always* be in favour of a reconnaissance mission if there is sufficient time for one. Rather, the decision is whether the mission should be a flyby design, which somewhat limits what can be learned from a spacecraft encounter but could result in shorter mission timelines, or whether a rendezvous mission should be pursued, which has the potential for acquiring further information, such as impactor mass, and continuous monitoring, but could require a longer mission timescale. This again highlights the importance of pre-discovery decisions.

Another decision is whether and how to involve multiple reconnaissance missions, since failures are quite possible and there might not be enough time after a failure to send a second spacecraft. This again could require cooperation from many states if planetary defence reconnaissance spacecraft are not prepared in advance.

There is also an important decision to be made about including a deflection option in reconnaissance spacecraft. Due to the high energy density of a NED, its incorporation into a reconnaissance spacecraft may be the most feasible, so we discuss it further here. But there could be other possibilities, for example, integrating reconnaissance spacecraft with conventional deflection missions, such as by launching flyby spacecraft well ahead of a kinetic impactor chain.

While deciding to exclude a NED is a decision against the use of a NED, at least in the reconnaissance stage, deciding to *include* a NED is not strictly a decision to *use* a NED. However, placing a NED on a spacecraft in advance of any decision to use it could still create or escalate tensions with other states that oppose the use of NEDs. Thus, a decision to place a NED on a reconnaissance spacecraft, even as a backup, will likely be treated as similar to a decision to use a NED. This immediately highlights political and even moral complexities associated with this path. But again, we stress that the actual use of the NED, whether as a primary deflection mechanism or as a backup, is ultimately a separate decision.

In previous PDC scenarios, the inclusion of a NED in a reconnaissance mission is usually blocked by an absence of international agreement. However, the *inclusion* of a NED is not inherently illegal; what is illegal for states such as the US, UK, and Russia (because of the Limited Test Ban Treaty), and legally contentious for states such as China and France, is the *use* of a NED. The decision about inclusion is mostly a political question: Can the support of the international community be maintained if a NED is included in a reconnaissance mission? There is further a moral question: Should humanity again tread down the dangerous path of conducting nuclear explosions in space if we are not sure it is absolutely necessary?

## IX. DEFLECTION MISSIONS

The successful resolution of a planetary defence crisis may require a deflection. There are a number of potential methods, each of which offers advantages and disadvantages that will have to be assessed in the particular circumstances at hand. One of the most important variables is, again, the length of time available, since some methods take considerably longer than others. Moreover, the sooner a deflection attempt can be made, the easier it will tend to be. And the lower the impulse, the more controllable the process will tend to be. We consider three broad classes of deflection methods: Low impulse, high impulse-nonnuclear (kinetic), and high impulse-NED.

In addition to time, other major variables could include the size of the asteroid, its composition, the accessibility of the orbit, and the amount of momentum transfer needed for a successful deflection. Other important variables could include (1) the availability of the necessary equipment, (2) the feasibility of construction, and (3) the launch opportunities within the time available. These later variables might depend on pre-detection decisions.

In previous PDC scenarios, kinetic impactors appear always to be considered the first option and preferred over NEDs, if time allowed. Low impulse methods were not explicitly mentioned, presumably because the scenarios did not provide enough time for them to be realistic options.

Then, there are the risks associated with different methods. One risk is asteroid fragmentation, which could increase the number of threatening impactors, or result in an impact on a state that was not previously threatened. Even some kinds of low impulse methods might be riskier than others as any method that requires physically contacting the asteroid could be more problematic than methods that do not. However, low impulse methods take time – time for a failure before the deflection is complete or time for the geopolitical context to change entirely, jeopardizing the mission.

There are also political considerations, especially concerning NEDs, the use of which might cause international cooperation to breakdown.

The use of a NED by a state that would otherwise be impacted does not, in our view, raise serious legal impediments since any state that did so could claim "circumstances precluding wrongfulness" under the customary international law of state responsibility [See the last section of this document, below]. We are also doubtful that a state capable of deploying a NED would, in the face of a potentially existential risk, care about the possible illegality of its use.

There are thus three sets of variables that will always be relevant to the choice of deflection method: time available; risks of potential deflection methods; political factors, especially the maintenance of cooperation among the spacefaring states. To this, we might add a fourth variable: the perception, of national governments and their leaders, as to how best to avoid or mitigate a major threat to their own state. This threat perception variable will depend on whether, and to what degree, political decision-makers are aware of the methods and cooperative mechanisms available in a planetary defence crisis, which will depend, in part, on pre-discovery decisions.

# X. PARTIAL DEFLECTION

In the 2023 PDC Scenario, it might be assumed that NEDs should be used to deflect the asteroid eastward, since the distance to avoiding an Earth-impact is shorter. However, this involves moving the impact location along the track over several countries that would not be directly at risk in the absence of a deflection attempt. Substantial populations, including Maputo, Mozambique (pop. 32 million), are at risk if the deflection is only partially successful. A deflection westward needs to cover more than twice the distance to avoid an Earth-impact, but the track passes over the entire Atlantic Ocean, the south-central United States, and north-western Mexico. The US and Mexican populations along the track are relatively small compared to the populations in south-eastern Africa. We therefore find a version of the "trolley problem" here, with the United States potentially putting large numbers of Africans at risk in order to avoid putting a smaller number of Americans and Mexicans at risk. The ethical dilemma is only complicated (i.e., not eliminated) by the fact that the distance eastward is shorter.

However, there is more than an ethical issue here, since it is possible, perhaps even likely, that countries in south-eastern Africa would object to having the asteroid moved along track over their populations. In the absence of consent, imposing a deadly risk on a country's population would normally be illegal. Sovereign states are not required to make sacrifices to achieve global utilitarian outcomes. And even with state consent, there might well be human rights issues to consider. As a result, a UN Security Council Chapter VII resolution might be the only legal way forward.

Any pre-detection agreement should address these issues, to help states avoid a difficult mix of political, legal and moral decisions.

## 1. Choice of partial deflection

In some situations, a partial deflection might be the only realistic deflection option, with the consequence being a change in the location of the impact, and with that a shifting of casualties and damage from one state (or states) to another state (or states). Ethically, this also begins to resemble the trolley problem, with the further complications of national self-preservation and prioritization of one's own citizens over others.

We again must ask, who decides? States put newly at risk from a partial deflection would be unlikely to consent, and even if they did, difficult human rights issues might arise. Although the UN Security Council could adopt a Chapter VII resolution, provided that no permanent member casts a veto, this would leave 178 states without a role in the decision and could result in widespread backlash.

The UN General Assembly, which includes 193 states—the majority of them non-spacefaring states from the Global South—might seek to take on a decision-making role in circumstances such as these. But could we expect a spacefaring state that wants to protect itself to defer to them? If that state decides to proceed in the face of widespread opposition, how should other states respond? This is another good example of why a pre-discovery agreement is necessary.

### 2. Accidental partial deflection

If a deflection is only partially successful and the asteroid (or a large fragment) is on track to strike elsewhere on Earth, there may be time for a second deflection attempt, albeit with less lead-time. In this case, the facts and context leading up to the accidental partial deflection could strongly influence how states choose to respond.

## XI. DECISION TO NOT ACT

All of the discussion above ignores what could be the biggest decision of all. What if, after a careful assessment of the situation and perhaps one or more reconnaissance missions, it emerges that a deflection attempt carries a greater risk than accepting the impact and treating the situation through terrestrial-based disaster management?

A lack of time is not the issue we are identifying here. Rather, there may be some facts specific to the asteroid, orbit, or overall situation that makes "letting it happen" be the best course of action, and this might include accepting the loss of a city. The 2021 PDC exercise is not a good example of this decision because no deflection was mounted due to lack of time.

Even if inaction is the best option in space, it might be possible to mitigate the consequences on Earth through mass evacuations, the pre-positioning of humanitarian assistance, etc. These mitigation measures are beyond the scope of this paper. Our point is simply that action will not always be the best decision.

## XII. POTENTIAL COMPLICATING FACTORS

### 1. Space agencies or militaries

Will space agencies lead the response in a planetary defence crisis? This decision will be made by each national government, coordinated or not. In the absence of coordination, space agencies might be given the lead role by some states, and militaries by others. Space agencies tend to have more expertise on planetary defence, as demonstrated by the fact that SMPAG is a grouping of space agencies, with no militaries involved. But militaries have more power within national bureaucracies than space agencies and are better funded. They also have responsibility, in most nuclear-armed states, for the warheads that could be adapted for use as NEDs. We cannot assume that space agencies will be allowed to lead in a planetary defence crisis.

This decision could have implications for another decision, discussed above, concerning the lead role of SMPAG in a planetary defence crisis. It is also possible that the UN Security Council could require that SMPAG be allowed to lead. Of course, it is further possible that one or more states (or militaries) might ignore this decision.

The decision on space agency leadership is one that could usefully be made in advance, for example, through a UN General Assembly resolution, UN Security Council resolution, or multilateral treaty on planetary defence decision-making. Note, however, that only a Security Council resolution adopted under Chapter VII or a treaty would be legally binding.

We must note that in all previous PDC scenarios it has been assumed that space agencies would lead the response.

### 2. Threat limited to another state or states

It is possible that the location of the impact and the size of the incoming asteroid are such that the spacefaring states are not directly threatened. In such a situation, those states will have to decide whether to attempt a deflection. This decision point raises ethical issues, including consent, that are beyond the purview of this analysis. It might also engage a duty to rescue in customary international law, as reflected in numerous multilateral treaties on search and rescue in areas beyond national jurisdiction on the oceans and in space. A commitment to come to the assistance of other states during a planetary defence crisis could be part of any pre-discovery agreement.

## XIII. CIRCUMSTANCES PRECLUDING WRONGFULNESS

Sometimes in the international realm, just as in the domestic, lawbreakers are excused for their actions because of the unusual circumstances they found themselves in. If a state chose to violate international law while engaging in planetary defence, for example by using a NED, it is possible that the violation would be excused because it took place under "circumstances precluding wrongfulness". The different circumstances that can preclude wrongfulness are identified in the International Law Commission's Articles on State Responsibility, with "consent" and "necessity" being of greatest potential relevance here.

Article 20 reads: "Valid consent by a State to the commission of a given act by another State precludes the wrongfulness of that act in relation to the former State to the extent that the act remains within the limits of that consent." This means that, if a state facing a NEO threat were to consent to another state using a planetary defence method that violates international law, that act would no longer be wrongful as between those two states.

Article 25(1) reads:

> Necessity may not be invoked by a State as a ground for precluding the wrongfulness of an act not in conformity with an international obligation of that State unless the act:
>
> Is the only way for the State to safeguard an essential interest against a grave and imminent peril; and
>
> Does not seriously impair an essential interest of the State or States towards which the obligation exists, or of the international community as a whole.

Whether these criteria have been met in the case of any NEO threat will depend on the specifics of the threat. Moreover, as the Ad-Hoc Working Group on Legal Issues to the Space Mission Planning Advisory Group explains, the fulfilment of the criteria must be "objectively established and not merely apprehended as possible". In other words, it is not sufficient for the acting state

simply to believe that the criteria for necessity have been fulfilled. We should also note that circumstances precluding wrongfulness are generally considered after action has been taken, when there will be ample time to determine whether the criteria were actually met.

One might also ask whether necessity could justify the use of a NED as a first choice of deflection method rather than as a last resort, for example after kinetic impactors had failed to alter the asteroid's orbit sufficiently to prevent an Earth impact. What if a NED was the most likely method to produce a successful outcome? Again, Article 25(1)(a) specifies that the act must be "the only way for the State to safeguard an essential interest against a grave and imminent peril".

In the 2017 PDC exercise, several states (fictionally) decided to use an NED without UN Security Council authorisation and without having first attempted a kinetic deflection. More realistically, a NEO threat might be identified too late for any deflection method other than a NED. Kinetic impactors will take time to build, and multiple impactors might be needed. Low-impulse methods would take even longer.

Then there is Article 25(1)(b), which specifies that necessity may only be invoked as a circumstance precluding wrongfulness if it does not "seriously impair an essential interest of the State or States towards which the obligation exists, or of the international community as a whole". In other words, necessity cannot excuse an action, by one state, that causes serious harm to other states.

The availability of necessity as a circumstance precluding wrongfulness thus hinges on two different findings of "essential interests": (1) An essential interest of the acting state that is in grave and imminent peril; and (2) The absence of an essential interest of another state or states that would be seriously impaired by the action. The combination of these two requirements sets a high bar for any state that, for instance, is considering whether to use a NED in the absence of consent, a Security Council Chapter VII resolution, or a widely ratified international treaty.