

## 2011 IAA Planetary Defense Conference

### Impact Decision Support Diagrams

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One way to frame the job of planetary defense is to "find the optimal approach for finding the optimal approach" to NEO mitigation. This requires a framework for defining in advance what should be done under various circumstances. The 2D action matrix from the recent NRC report "Defending Planet Earth," can be generalized to a notional "Impact Decision Support Diagram" by extending it into a third dimension. The NRC action matrix incorporated two important axes: size and time-to-impact, but probability of impact is also critical (it is part of the definitions of both the Torino and Palermo scales). Uncertainty has been neglected, but is also crucial. It can be incorporated by subsuming it into the NEO size axis by redefining size to be 3 standard deviations greater than the best estimate, thereby providing a built-in conservative margin. The independent variable is time-to-impact, which is known with high precision. The other two axes are both quantitative assessments of uncertainty and are both time dependent. Thus, the diagram is entirely an expression of uncertainty. The true impact probability is either one or zero, and the true size does not change. The domain contains information about the current uncertainty, which changes with time (as opposed to reality, which does not change).

At any instant, there are probability, size, and size-uncertainty estimates for a given NEO. As these change, the NEO will follow a trajectory in the 3D domain. NEOs with multiple potential impact dates will have multiple trajectories. The decision should depend only on the current position of the NEO in the decision domain, not on its phase-space trajectory. Thus there will be a volume within which a given action is recommended. Uncertainty is included in the size estimate, so the assessed NEO size will change with time (almost always getting smaller as uncertainty decreases) but at any given time we must assume the worst and act accordingly. Decision domains will be separated by surfaces. The diagram is for NEOs that do not pass through keyholes, but the concept is also applicable to keyhole passages.

The NRC action matrix will map directly to the "probability equals one" plane where examples of possible decision domains can be used to generate a notional diagram. This hypothetical diagram could, for example, recommend that NEOs smaller than 100 m not be deflected, define a region where slow-push is optimal, a region where nuclear deflection is optimal, and a region that is beyond any realistic mitigation attempt. As time progresses, the prescribed strategy would change from slow-push to nuclear, so the need for a "back-up plan" is explicit. Virtually every NEO that has been discovered is moving on a trajectory that is within an epsilon of the  $p=0$  surface. PHOs can rise above this surface into a region in which action is recommended. The first-level action could be "characterize and plan." For a given size, there would be some probability threshold above which production of hardware (rockets and warheads) should commence. This would also depend on time-to-impact. The amount of time needed depends on  $\Delta V$  requirements, so a "scaled time" axis would be useful.

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Every plane associated with a given NEO size would have a family of curves separating various action domains. They could be generated from a dense matrix based on expert consensus. The first step should define the action domains and how they should relate to one another, but not define their boundaries.

Finally, the decision support diagram only considers technical/science/engineering issues. Clearly there are political, economic, and diplomatic issues that would also be part of the actual decision making. Decision-makers will make a "go/no-go" decision that is ultimately based on information other than technical. The planetary defense community needs to make "go" an option for them, or else there would be no decision for them to make.

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