The Deflector Selector: A Machine-Learning Framework for Prioritizing Deflection Technology Development

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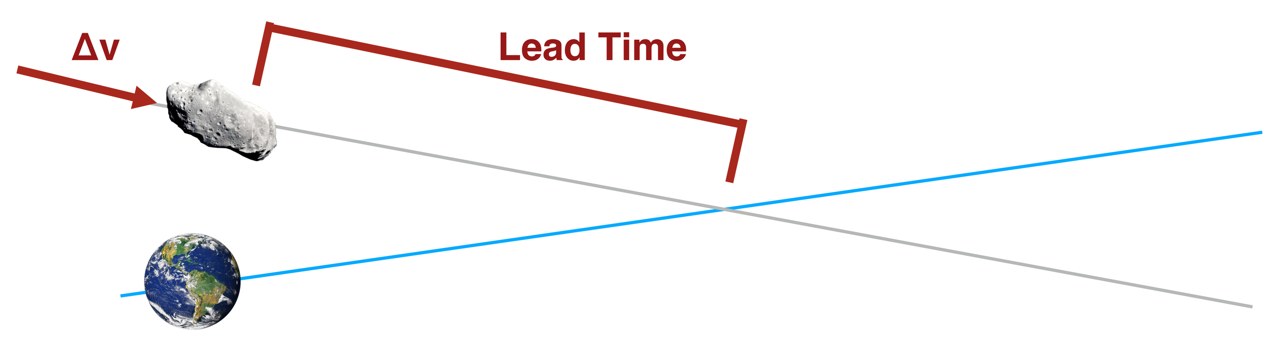
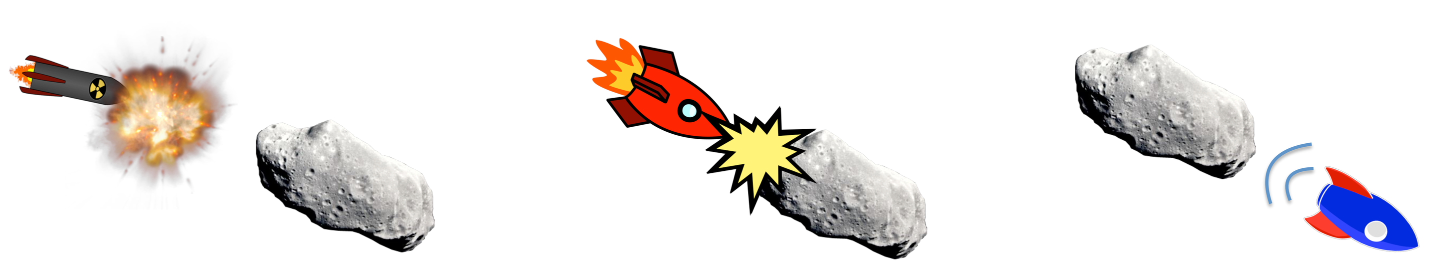
Introduction

Many technologies have been proposed for deflecting an object on an intercept course with the Earth. The technologies act by applying a change-in-velocity (ΔV) along or against the object's trajectory.

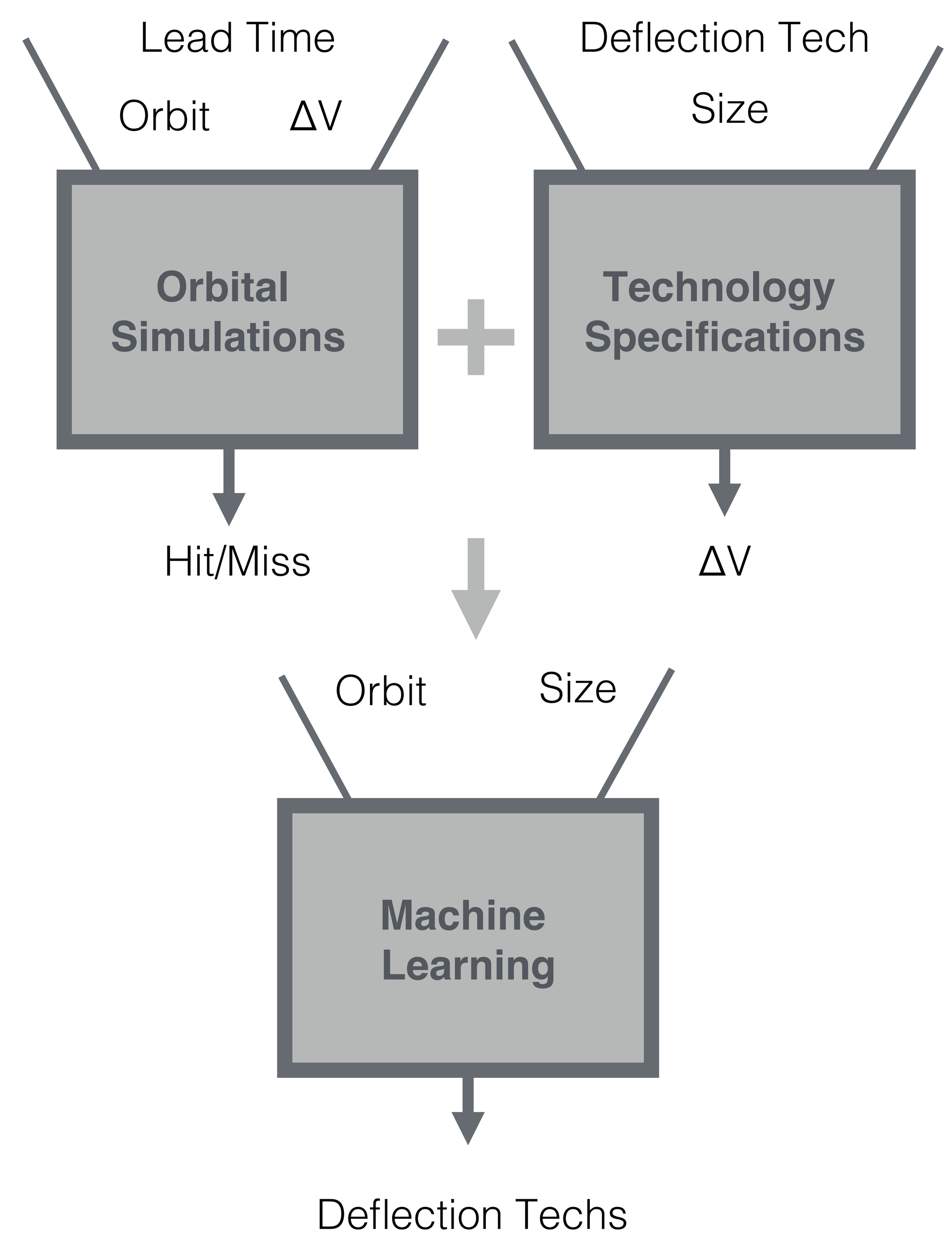


The three most plausible technologies that have been suggested are nuclear explosives, kinetic impactors, and gravity tractors. But the development and testing of all of these technologies should will be expensive and time-consuming. How can we predict which technology will be most effective on the population of potentially hazardous objects, so we can know how to focus our research and funding efforts?

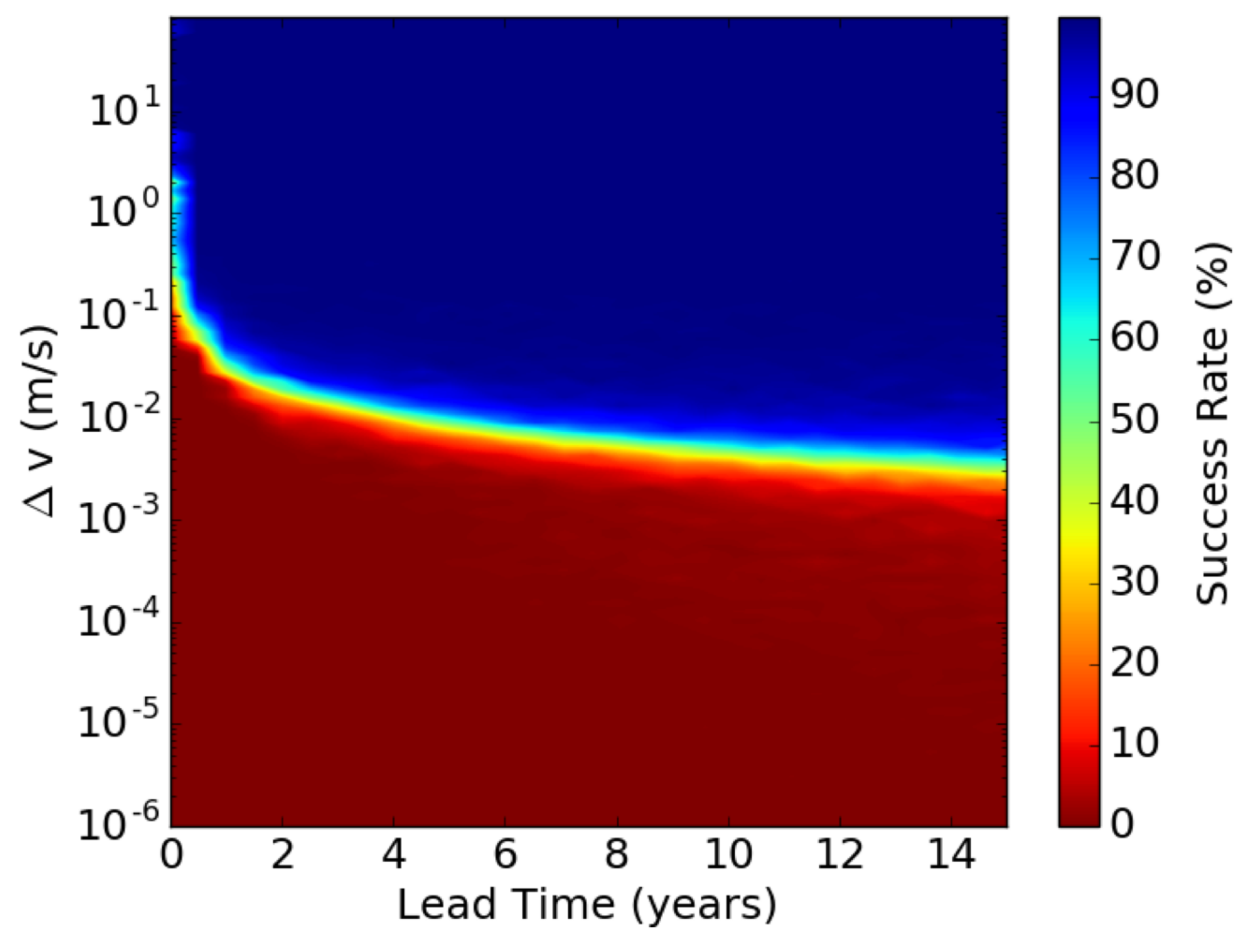
Nuclear Explosion | Kinetic Impactor | Gravity Tractor



The Framework



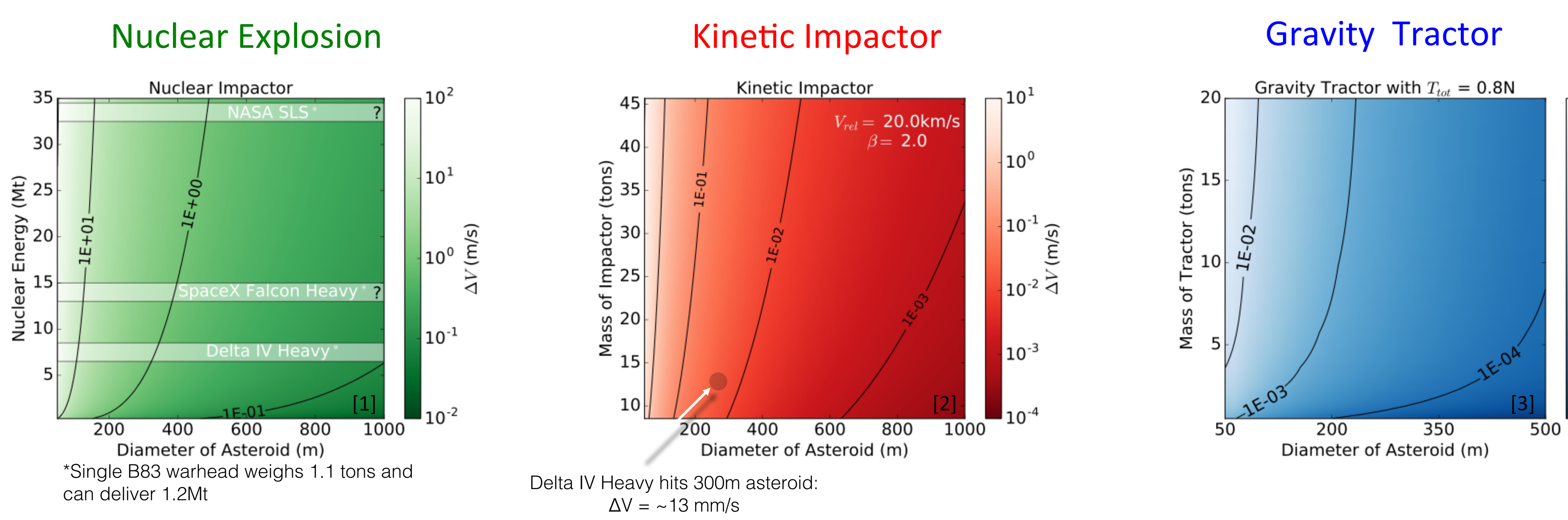
Orbital Simulations



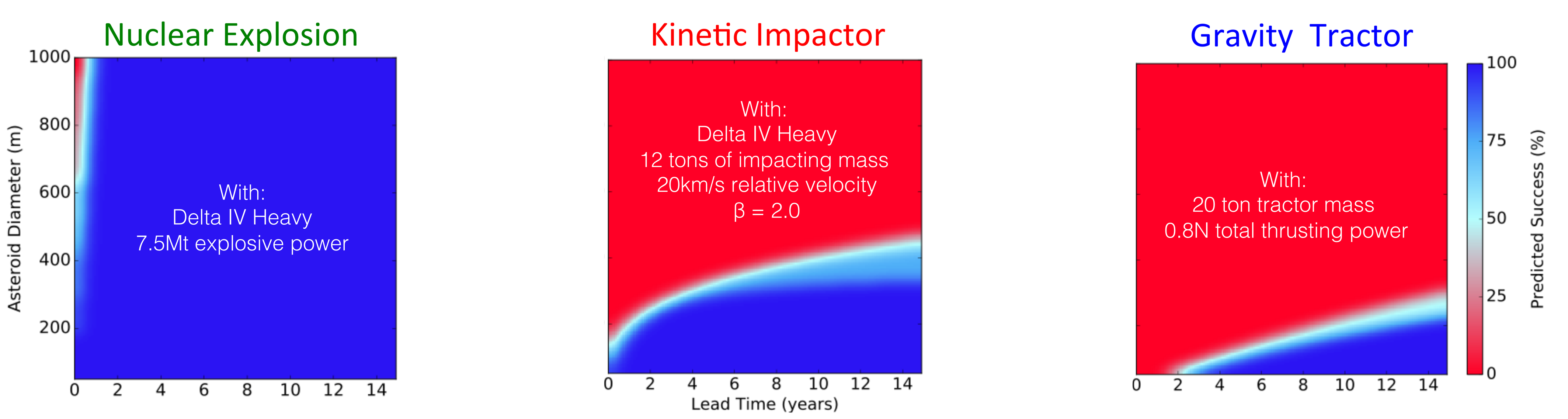
Percentage of orbital simulations in which we applied a given delta-V at a given lead time that resulted in a successful deflection of an object on an intercept course with the Earth.

We first used orbital simulations to test whether applying random ΔVs at random lead time will deflect a near-Earth asteroid on an intercept course. We generated the intercept orbits by rotating known Aten and Apollo asteroid orbits until they intercepted the Earth, without changing orbit shapes. As expected, larger ΔVs and longer lead times are more likely to result in a successful deflection.

Technology Specifications

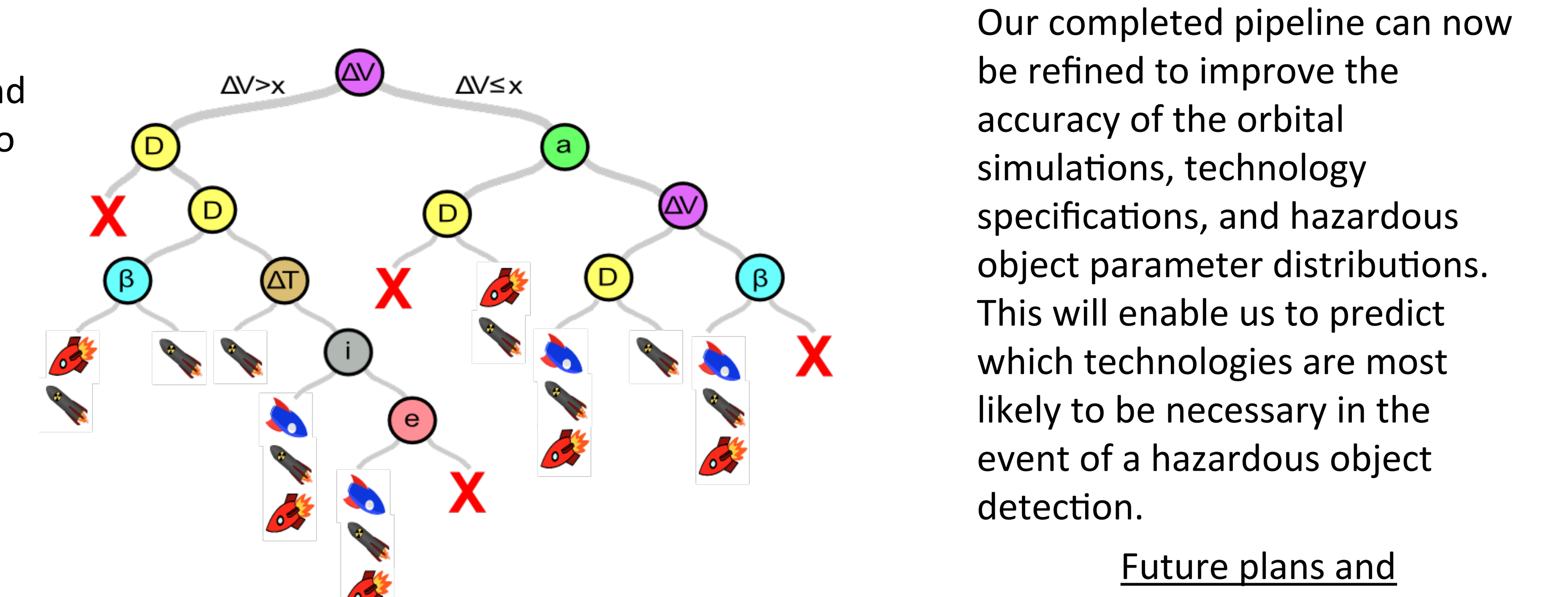


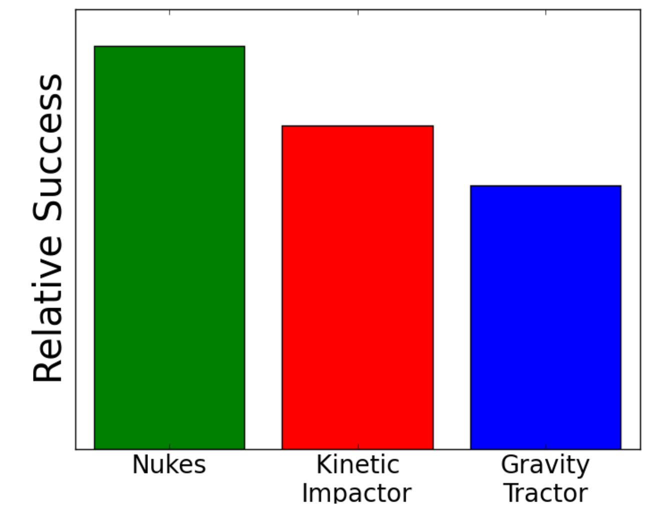
We then analyzed the predicted capabilities of the three most plausible deflection technologies to determine whether they could produce the necessary ΔV values (above). For a given object size and lead time, we can predict the likelihood of success for a given technology (below).



Machine Learning

We used the results from the orbital simulations and technology calculations to train a decision tree to select a set of effective technologies for a given hazardous object. After training the tree on our data, we found it had an accuracy of 98% for determining which technologies would produce a successful deflection.





The most effective technology predicted by our simulations is the nuclear explosive, due to the high ΔVs it can impart and its instantaneous effect. Future improvements to our model will use simulated hazardous object populations to make a more accurate prediction of the most effective technology.

Conclusion

Our completed pipeline can now be refined to improve the accuracy of the orbital simulations, technology specifications, and hazardous object parameter distributions. This will enable us to predict which technologies are most likely to be necessary in the event of a hazardous object detection.

Future plans and implementations:

- Implement detection and travel times
- Add comet population
- Include more object parameters, e.g., spin period, internal structure
- Consider more deflector technologies: thrusters, mass driver, ablation, etc.
- Make Deflector Selector code available for public use

Calculations based on equations from:
[1] P. Hammerling et. al., Acta Astronautica, 36, 337-346, (1995)
[2] J.P. Sanchez Cuartielles, PhD Thesis, (2009)
[3] E. T. Lu et. al., Nature, 438, 177, (2005)

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