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THE REAL DEFLECTION DILEMMA

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The term "deflection dilemma" originated in articles in the early 90s by Carl Sagan, Alan Harris, Steve Ostro and others to describe the reciprocity inherent in the capability of humankind to deflect asteroids away from collisions with the Earth. I.e., if one can deflect an incoming asteroid away from a collision with Earth, one can also deflect a passing asteroid toward a collision, presumably a collision with a specific Earth target. While the author considers this historic dilemma to be virtually non-existent there exists a "real" and significant deflection dilemma that cannot be avoided if the Earth is ever to be protected from asteroid impact. The dilemma arises in the Hobson's choice between doing nothing, thereby suffering the consequences of an impact, or pro-actively deflecting an asteroid which will, in the process of "protecting the Earth", necessarily place otherwise non-threatened people and property at risk. As the deflection is initiated the change of impact point (IP) from the original "act of God" IP becomes an "act of humankind" IP-path as the instantaneous IP moves across the surface of the Earth to a point where the asteroid just “misses” the Earth (the "lift-off point"). All points along this IP-path are placed in jeopardy by the possibility of system failure during the deflection operation. Given that the populations and property put in jeopardy will, in the general case, extend across international boundaries the planning and execution of such a deflection mission will necessitate international coordination and perhaps control. Grappling with these daunting issues by an appropriate international body should be undertaken immediately since the development of rational policies will be extremely difficult after an impact is announced and an IP specified.

INTRODUCTION

The term “deflection dilemma” originated in articles in the early 90s by Carl Sagan, Alan Harris, Steve Ostro and others[1] to describe the reciprocal challenge presented by the capability of humankind to deflect asteroids away from collisions with the Earth. I.e., if one can deflect an asteroid away from a collision, one can also deflect an asteroid toward a collision, presumably a collision with a specific target in mind.

While in an academic sense this concept is certainly valid, for many reasons presented below this malicious deflection capability is of so little “practical” use as a weapon that it is of no real concern.

On the other hand in the process of deflecting an asteroid bound for a collision with the Earth, there are substantial legal, political, social, economic, and even military concerns that are introduced. These issues arise independent of the specific deflection techniques proposed. This “real” dilemma arises in that otherwise uninvolved people and property across international boundaries will be put at risk during an asteroid deflection mission. It is therefore critical that the issues raised by asteroid deflection be dealt with by appropriate international institutions at the earliest possible time.

The situation at issue can easily be illustrated by realizing that to deflect an asteroid from impacting the Earth a certain minimum velocity change (ΔV) must be applied to it. Regardless of the technology one chooses to use to achieve this velocity change, should the actual ΔV imparted end up less than this minimum, the asteroid will now impact elsewhere on the Earth. From a legal standpoint the deflection process itself transforms the “Act of God” original impact point into an “Act of Humankind” path-of-risk stretching across the Earth’s surface. This moving point of risk will persist until such time as the applied ΔV exceeds the minimum required to achieve a successful deflection.

In an analogical sense this is equivalent to an armed 100 megaton (MT) bomb being trucked through communities across state after state, country after country, on the way to being safely deposited at a remote disposal site. Of course it could as well be a

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400 or 1000 MT bomb. Nor would there be a choice of not transporting it since it would be timed to go off if not carted to the disposal site.

Each of the various deflection concepts being developed presents its own unique particulars in this consideration, however all fall into two general categories, the continuous or the discontinuous risk path. Continuous risk paths will be formed by deflection systems utilizing slow steady acceleration techniques whereas systems utilizing impulsive means will generate discontinuous and difficult to predict risk paths. In all cases, however, given the possibility of system failure prior to the completion of the deflection program, people and property not initially threatened by the asteroid impact will be put at risk, with all of the legal, political, social, economic and national security implications thereof.

THE "ORIGINAL" DEFLECTION DILEMMA

While counter arguments can certainly be made the risk or threat level posed by the original deflection dilemma can be put into perspective by considering the specifics of the opportunity for malicious use of a realistic asteroid deflection capability.

An operational deflection mission would likely be launched with only enough propulsive capability to deflect the incoming asteroid to a safe miss distance above the atmosphere, accounting for various uncertainties. While different deflection concepts will have greater or lesser precision in applying the required delta V to the asteroid, it would be a wasteful expense if the targeted miss distance beyond the atmosphere were to exceed 1600 miles or so. In other words a reasonable mission capability would be to deflect an asteroid bound for a vertical impact to a miss distance of 1.4 earth radii. In all likelihood most systems that would be considered for operational use would permit a much smaller miss distance while still accounting for all uncertainties and necessary safety criteria.

By way of illustration then, using this specific conservative example the deflection system would be able to deflect either a vertically impacting asteroid out to 1.4 Earth radii, or conversely, if used for nefarious purpose, deflect an asteroid which would otherwise have missed impacting the Earth by 1.4 Earth radii or less to an impact at the "center of the Earth".

How often might a "useful" asteroid of opportunity appear within this radius for someone with malicious intent to take advantage of it? In this example, precisely twice the frequency at which such an asteroid would have impacted the Earth on its own. I.e., the cross sectional area of concern here is double the cross sectional area of the Earth itself (1.4 squared). If then, a "useful" asteroid were to be defined as one between 75 and 150 meters in diameter, such an opportunity might present itself for nefarious use once every 1000 years or so. This is hardly the kind of opportunity that comprises a serious national security threat, or military opportunity.

THE COMPONENTS OF THE REAL DILEMMA

In the event of an actual deflection mission there are essentially two distinct phases of the dilemma, each with distinctive characteristics; the mission planning and the mission execution.

In exploring this subject I will use, by way of example, the particulars presented by a controlled low acceleration deflection technique. While impulsive concepts present slightly different concerns one can fairly easily interpolate from this low thrust example. Since the results of a controlled acceleration are quantifiable and easily illustrated many of the more difficult issues resulting from asteroid deflection become evident for the consideration of public policy makers.

Mission Planning

The mission planning challenge arises in the assumption that there will be a known nominal impact point and known asteroid orbital parameters as much as decades in advance of an impact. A second consideration is that the dominant deflection strategy will be to either slightly speed up or slow down the asteroid in its orbit in order to cause it to miss its rendezvous with the Earth. All other options such as altering the inclination, line of nodes, etc., are very much more expensive provided that the deflection takes place a decade or more prior to impact. Whether one chooses to speed up or slow down the asteroid depends primarily on the angle of the impact from the vertical in the east/west direction. The "default" plan would be to use the minimum energy (and minimum time) to deflect the asteroid safely off the Earth. In simple terms this equates to deflecting it toward the nearest horizon.

The result of these considerations in effect generates a "deflection path" originating from the initial, undisturbed point of impact and terminating at a "liftoff" point where the asteroid passes safely above the Earth's atmosphere. This deflection path lies generally (for the vast majority of NEOs) in an easterly or westerly direction from the initial impact point and its extent is roughly 90 degrees of arc minus the angle off the vertical of the undisturbed impact in the east/west direction. I.e., if the asteroid were to have come in "from the East" 30 degrees off the vertical, then the deflection path would extend approximately 60 degrees to the West of the impact point before achieving liftoff.

The path of people and property put at risk by a deflection mission may therefore extend as much as 5000 miles across the Earth's surface from the initial point of impact.

The precise path, of course, will depend on the specifics of the asteroid orbit and accounting properly for the many uncertainties that will exist when the mission planning actually takes place. Of note, however, is that when the deflection spacecraft arrives at the asteroid, many of these uncertainties will diminish considerably. Since the spacecraft will carry a transponder the precise orbit of both the spacecraft and the asteroid will be known. The deflection path therefore will become known with high precision.

Additional mission planning policy issues arise in the knowledge that by launching an over capable mission one can opt to alter, at least slightly, the lateral deviation of the specific deflection path. Delta V components perpendicular to the asteroid's velocity vector can cause the deflection path to curve slightly right or left of its most cost-effective default path, perhaps thereby avoiding passing over major population centers on the way to liftoff.

Similarly, the avoidance of international borders or key high-value facilities (nuclear powerplants, for example) might factor into the planning process. To dramatically understate it, considerations of this kind will be of great public interest when such a circumstance arises.

<u>Mission Execution</u>

The mission execution phase also raises critical public policy issues. Given that the agency executing a deflection mission will have the capability of controlling the magnitude, direction and timing of the delta V applied, it also controls the actual deflection path achieved, and therefore the people and property put at risk. It is therefore highly likely that strong public demand for oversight and perhaps even independent control will arise. To the extent that, in the extreme, the controlling agency could "drop off" the asteroid anywhere along the deflection path, a variant of the old deflection dilemma re-emerges. However, even absent this extreme consideration, the level of concern likely to arise as the public realizes that a 100+ megaton equivalent bomb will be "trucked" through their community will trigger a demand for the development of a coordinated public policy before any deflection mission can be planned or executed.

POLICY PLANNING

This challenge is, by its nature, international. While there is the exceptional circumstance where the deflection path will lie entirely within the bounds of a single nation state, the general case is one where the path of risk will cross several, or even many, national borders. It would therefore seem appropriate that the many legal and risk sharing issues embedded in deflecting asteroids be addressed by either the United Nations or some other authoritative international policy institution.

The timing for such policy consideration is a challenging issue in itself. The quality of information on a pending NEO impact is highly variable over time. It ranges from a surprise impact with no prior knowledge to the case of 1950 DA[2] where we know today that there is a probability between 0 and 0.33% that this 1.1 km asteroid will impact Earth on March 16, 2880. For all other known NEOs between these two cases we can only state that with the exception of ~ 45 of them the remaining 2700 pose no threat to the Earth for the next 100 years. The residual 45 pose a very small but non-zero threat of an Earth impact at various times within the next 100 years.

The issue then, of what will we know and when will we know it, becomes extremely critical to the timing and development of a coordinated international public policy on the NEO environmental threat.

The natural temptation with such an improbable event is to wait until it becomes either a certainty or near-certainty before addressing it seriously. The price that would be paid for such an avoidance option in this instance will be the wielding of extreme self-serving national influence in the policy making process. If, e.g., it is discovered that a modest NEO will impact in Japan and that the deflection path would take it across Korea and over Beijing and China prior to liftoff, one can easily imagine the difficulty in only then initiating international deliberations on appropriate deflection policies.

Clearly, rational mission planning criteria and risk sharing policies should be discussed and even put into formal treaty documents well before the specifics of a particular impact come to light. Objective evaluation of risk trade-offs and rational mission design will be far easier to achieve in such a pro-active environment than in the power-politics confrontation that would dominate a wait and see alternative.

An even more difficult, though similar, situation applies to the considerations of mission execution. What agency or agencies of any national government will be trusted to "truck" a 100+ MT bomb across the countryside in order to eliminate certain devastation in a neighboring country? Could one seriously imagine today the U.S. DoD being accepted by the world as the responsible agency for deflecting an asteroid from an impact in Afghanistan when the path of deflection would take it directly across Tehran? Of course this is a highly improbable example, but the likelihood that similar political considerations will not exist when we discover a probable NEO impact is dangerous wishful thinking.

CONCLUSION

The Real Deflection Dilemma will arise when the people of Earth awake to discover that a near Earth asteroid is headed for an impact with the planet. It will present itself as a terrible choice; do nothing to prevent it and suffer the consequences, or mount a mission to deflect it from impact thereby, in the process, placing a swath of people and property not otherwise at risk in jeopardy.

In a very real sense, however, we are already ensnared in this dilemma, for we all know that such a moment in time will come. Therefore our own Real Deflection Dilemma is whether to confront the intractable policy choices implicit in protecting the Earth from asteroids now, or to avoid this terrible responsibility and force some future generation to face them in real time when they will become all but impossible to resolve.

References:

1. Sagan and Ostro, Long-Range Consequences of Interplanetary Collisions, Issues in Science and Technology, Volume X, Number 4, 1994.
2. Asteroid 1950 DA, NASA Near Earth Object Program, http://neo.jpl.nasa.gov/1950da/

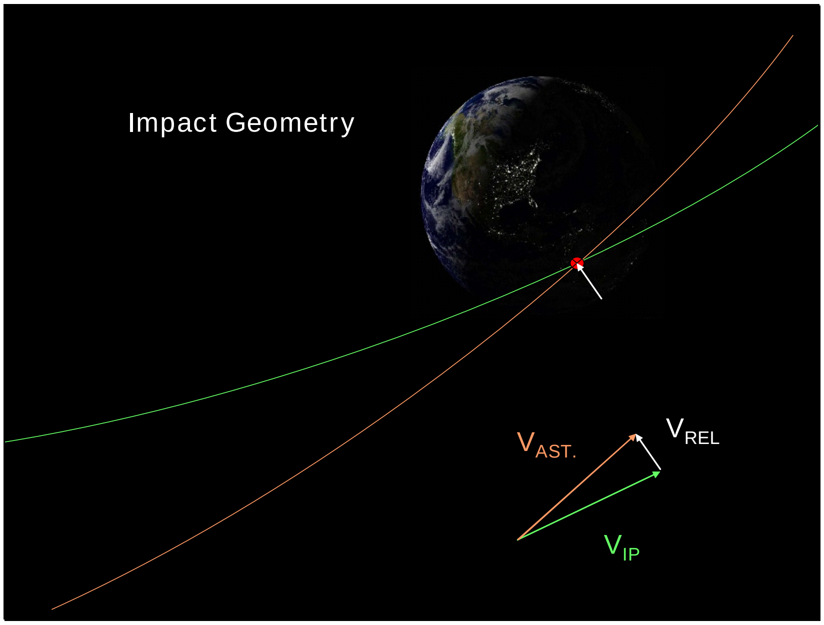

Figure 1.

Impact geometry looking down on the Earth. Impacting asteroid trace in red, Earth impact point (IP) trace in green. The velocity vectors of the asteroid and IP are shown in the lower right with the resultant relative velocity vector Vrel in white. To avoid an Earth impact the asteroid will have to be caused to arrive late for its rendezvous with the Earth.

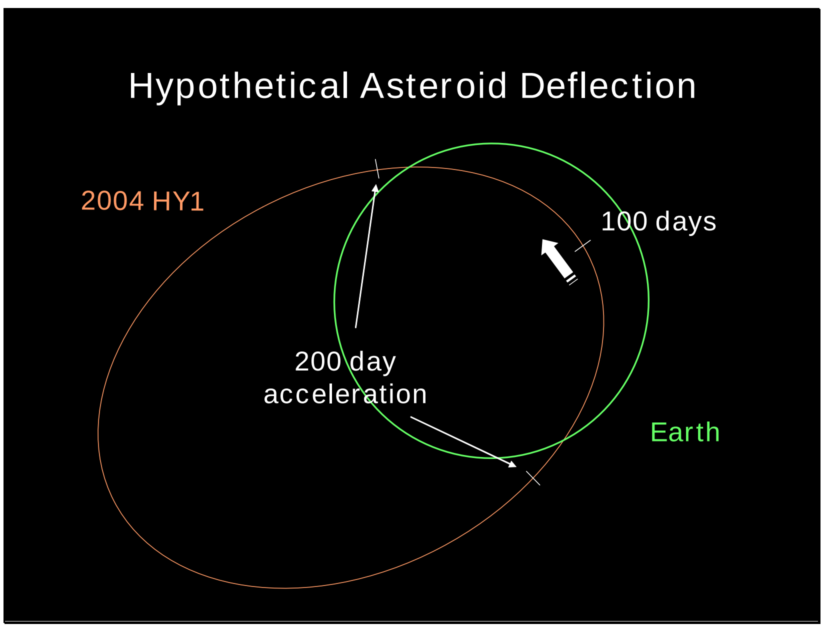

Figure 2.

Orbit diagram of Earth (green) and hypothetical asteroid 2004 HY1 (red) showing the 200 day acceleration phase necessary to increase the period of the asteroid by an amount sufficient to cause it to miss the Earth 10 years later. The specific example is for a ~200 meter diameter asteroid and an acceleration force of 10-12 Newtons.

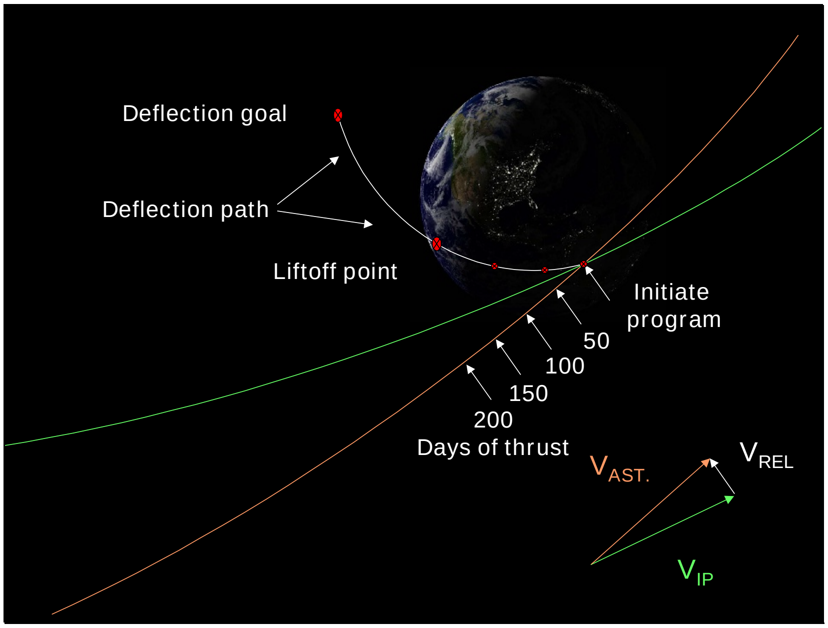

Figure 3.

Trace of “risk path” (white) looking down on Earth. Should the deflection maneuver be terminated for any reason during the 200 day thrusting period the partially deflected asteroid would now impact Earth somewhere along this path. For illustrative purposes new impact points are marked for interruptions at 50 and 100 days. At 150 days the asteroid would reach the “lift off” point, just grazing the Earth. At 200 days the asteroid would reach the planned deflection distance missing the Earth by sufficient distance to safely terminate thrust.