Shot Down

The American Physical Society takes aim at the boost phase

by Eliane Trepagnier

An Inter-Continental Ballistic Missile launches from North Korea, arcing through the atmosphere towards the United States. Thirty seconds later, the US missile defense has detected the launch, setting off a pre-determined set of responses. At 45 seconds, they track the enemy missile, determine its path, and calculate a firing solution. At 75 seconds, the US launches an interceptor missile from a boat stationed in international waters off the Korean coast. At 165 seconds the two missiles collide, destroying the enemy missile. This timeline for a successful interception leaves no room for uncertainty or error. Is it a realistic defense strategy, or just a fantasy on the part of the US Department of Defense?

In the fall of 2000, this problem attracted the attention of the American Physical Society, the nation's premiere organization of physicists. In response to the large amount of money and resources being dedicated to boost-phase missile defense systems and the lack of technical information available to the public, the APS launched a project of its own, a two-year study of the technical feasibility of destroying an enemy missile early in its flight path. Destroying a missile during its boost phase—its first stage of flight, while it is actively launching into space—is an extremely attractive idea to the US Defense Department because once an ICBM has reached space—the so-called midphase—it could separate into multiple warheads and decoys, swamping any defenses.

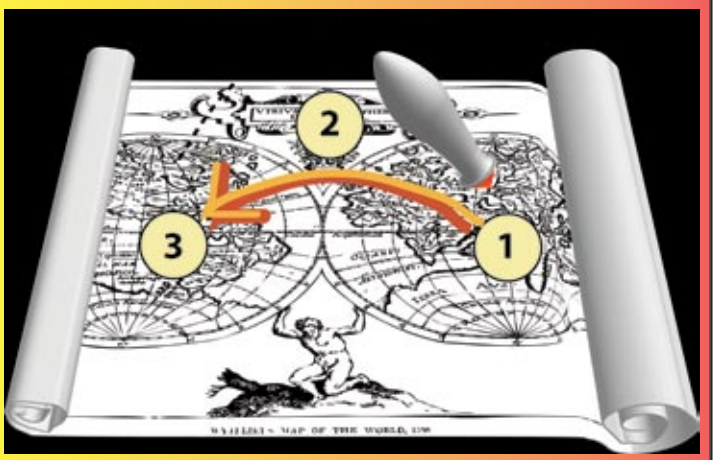
One of the scientists involved in the APS study was UC Berkeley professor Roger Falcone. Falcone studies ultra-short pulses of light as well as the interaction of very high power lasers with matter. It is the latter research area that attracted the interest of the APS study organizers. This area of research fits in well with one of the tactics examined in the study, the Airborne Laser (ABL). Other group members chosen by the APS to participate in the study were experts in rockets, radar, and guidance systems.

In order for the study to be accessible to the public, all information used by the group had to be public knowledge. This brought the challenge of coming up with reliable unclassified estimates of the classified technology held by the Defense Department. So the group avoided classified information by extrapolating from technology developed by the scientific community. With regard to imaging technology, Falcone explained, the group looked at "what the astronomy community had developed for things like Hubble and other space telescopes…we looked at what the most advanced scientific technologies were, extrapolated a little bit on that and said well they can't really do better than this unless they know something that astronomers don't know." The group was also briefed by outside experts on aspects such as detector technology and missile technology. According to Falcone, "we listened to anybody who we thought was knowledgeable…most experts participated quite enthusiastically."

One crucial group did not participate in this study: the Missile Defense Agency (MDA), the Department of Defense agency running the missile defense program. According to Falcone, the MDA repeatedly turned down APS group requests for briefings or meetings. He added, "they decided early on not to participate in our study."

Once, however, these two parties were brought together in the same room. This feat was the accomplishment of Dean Wilkening, the scientific director of the Center for International Security and Cooperation (CISAC), and an expert in missile defense who briefed the APS group during their study. Wilkening organized a boost-phase defense meeting, which included missile defense contractors as well as academics. Wilkening confirmed that the MDA was reluctant to participate in the conference. "In general they are skeptical of academic scientists," he added. This is presumably due to a long history of criticism of missile defense, by academic scientists, physicists in particular. The people trying to develop these systems, he continued, don't find it rewarding to meet with academics because they believe academic scientists are all skeptics or critics.

The Boost Phase



The path of a launched missile is divided into three phases.

1) The **boost phase**, while the missile is launched on a rocket through the atmosphere;
2) The **mid phase**, as the missile arcs through space towards its target;
3) the **terminal phase**, as the missile re-enters the atmosphere.

The Department of Defense's Missile Defense Agency pursues a layered defense system, intended to defend against all three phases.

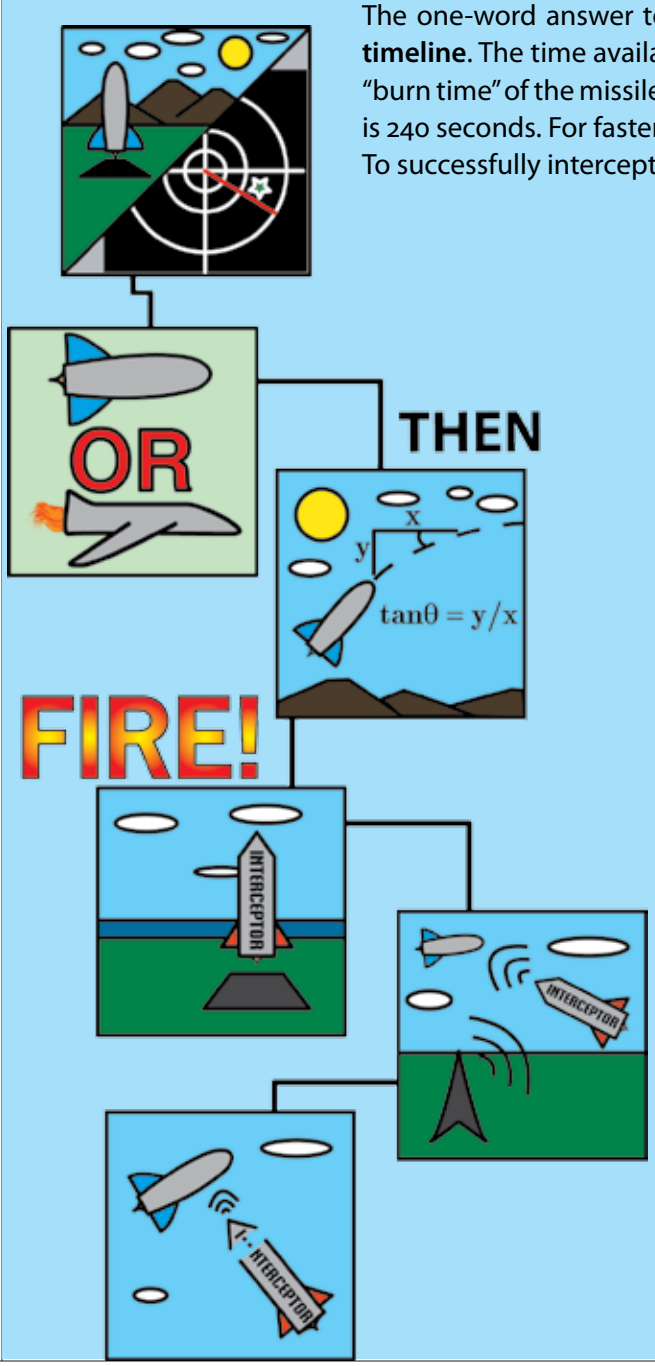
ILLUSTRATION: ANDY DEMOND

According to Wilkening, many of them are.

Perhaps one of the most polarizing debates between missile defense critics and true believers is the debate over the Patriot missile. At the center of this debate, on the critic side, is an MIT physicist named Ted Postol. During the first Gulf War, the Patriot came to symbolize American military might and technical superiority. It was touted by the first President Bush as "proof positive that missile defense works." Official estimates put the Patriot effectiveness at 96%.

Postol did his own studies on the Patriot's performance, estimating the success rate of the missiles by examining US Army data on Patriot-Scud engagements as well as news media video recordings. By analyzing, for example, the speed of falling objects emerging from an engagement and the explosions of these objects on the ground, Postol tallied the number of warheads destroyed. His own estimate of the Patriot's success rate was vastly different. In a 1991 hearing before the House Armed Services Committee, Postol testified that, in comparison to the damage caused

Timeline for an interception



The one-word answer to why boost-phase defense is so challenging, says Falcone, is **timeline**. The time available to shoot down a missile in the boost phase is given by the "burn time" of the missiles. For comparatively slow liquid-propellant missiles, the answer is 240 seconds. For faster-burning solid-propellant missiles, it is only 170 seconds. To successfully intercept a missile in its boost phase, a defense system must:

Detect a launch. The current US tracking system, the Defense Support Program (DSP), cannot detect exhaust plumes of rockets until they have reached an altitude of 10km, and sample once every 10 seconds.

Identify the launch as a hostile missile. This means distinguishing the bright spots of the rockets from bright spots due to aircraft or fires on the ground.

Track the rocket and determine its heading. The group points out that the path of a peaceful space launch would likely be indistinguishable from an attacking missile.

Fire interceptor(s). The group found that the earliest launch times possible were 65 seconds (liquid propellant) and 45 secomds (solid propellant).

Accelerate the kill vehicle. The rockets of the interceptors must accelerate their payload, a "kill vehicle," which is then hurled to the position where it is expected to intercept the missile. The kill vehicle must then home in on and hit the missile. The booster rocket must accelerate rapidly enough to reach a missile launched at least 45 seconds earlier.

Home in and hit the missile. The kill vehicle must track its target and maneuver to hit it. The vehicle must switch from the easy task of tracking the exhaust plume to homing in on the smaller and cooler body of the missile.

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Roger Falcone, a UCB physics professor, was an author of the APS study.

by Scuds before the introduction of the Patriot, the post-Patriot damage was the same or, in some cases, worse. The Patriot success rate dropped from 96% to almost 0%. Most likely, there were no Scud missiles intercepted by Patriots during the Gulf War at all. In this case, at least, the effectiveness of our defense was entirely psychological.

So, is the APS study the axe-grinding of a group of anti-missile defense academics? Probably not. For one, they weren't all academics. As Falcone explained, "we had a group of scientists and engineers, some like myself, who were outside the military complex and some who made their careers at Lockheed or at RAND designing missiles or radar, people who had actually designed weapons systems that are currently operating." Further, the group excluded anyone who might be prejudiced by previous studies done on boost-phase defense. None of the members had come to any conclusions about the feasibility of boost-phase defense before the study began. Finally, according to Falcone, the political viewpoints of the members of the group never came into play. Falcone continued, "I think everybody going into the study knew that the answer [to whether boost-phase defense would work] wouldn't be yes or no, that the answer would be: the system would be subject to the following limitations." As it turns out, those limitations are severe.

The general conclusions of the study were as follows. Against liquid propellant ICBMs, the slower of the two types, the United States has some limited defense capability. Against faster solid propellant ICBMs we have none. The group stressed that all findings reflect "upper bounds" on performance, reflecting "optimistic assumptions" and the "theoretical possibility" of an intercept.

As Falcone put it, "for a large amount of money in missile defense you could get an extremely limited defense system." This would involve surrounding North Korea with interceptors, waiting for a launch. Falcone explained that during APS study group meetings when the members began realizing how close the interceptors would have to be stationed waiting for a missile launch, it seemed an almost ridiculous situation. "It was suggested that, if you are going to be looking right at the missiles, you might as well just go in and shoot [them] up with machine guns."

But the bigger problem, according to the study, is that what limited defense capability we have completely disappears once attacking countries acquire solid propellant missiles. The study states "countries of concern might acquire or develop solid-propellant ICBMs within the next 10-15 years and that it would be imprudent not to consider them in evaluating the feasibility of boost-phase defense systems." The study further notes that, "A boost-phase defense would create incentives to develop or acquire solid-propellant ICBMs." In other words, armed with this knowledge, North Korea would seek solid-propellant missile technology and eliminate our defense capability.

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These considerations are strictly technological. There are also many political issues to consider. One is the destabilizing effect our missile defense development has on our relationship with Russia and China. Another is the problem of shortfall. After a successful interception, the attacking missile falls to the ground short of its intended target, but outside the country that launched it. Falcone sums up this problem as: is it acceptable for us to shoot down a missile to defend ourselves and have it fall on Western Canada? It is possible that a nuclear weapon would not be triggered if it were to crash to the ground short of its target; even so it would scatter radioactivity. What would be the political ramifications of sending such

a weapon crashing into China?

Given that the Department of Defense is pursuing this strategy, the question arises: does the Department of Defense's analysis of boost-phase missile defense lead to more optimistic conclusions? Thanks to the CISAC meeting, the only instance where the MDA was brought together with the APS study group, Falcone has some basis on which to answer this question. While the MDA made no formal response to the results presented at the meeting, they did make oral comments on areas where they thought the group had made some wrong assumptions or had not taken certain technologies into account. Did the APS group and the MDA arrive at the same conclusions? According to Falcone, "there was nothing we heard from the MDA that said we were wrong about our assumptions on rocket sizes, acceleration rates, mass, sensor technology… I think we came to the same conclusions on system design challenges. That was the result of our meeting." Falcone believes that the conclusions of the MDA match up reasonably well with those of the APS. Wilkening agrees. He does not believe there were any serious technical disagreements between the APS study, the analysis by the MDA, or his own work.

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Then why does the Defense Department pursue a program with such limited chance of success? According to Falcone, the difference is attitude. "I think there's a sense in the military… that technological surprises can happen, and advanced research and development, and testing, will pay off… There's a 'can-do' attitude [which says] 'if you give us enough money we will solve what seem to be insurmountable problems of science and technology.'" Wilkening sees the difference not as an issue of optimistic outlook, but a question of, as he puts it, "preferences." "MDA is obviously in favor of building missile defense. They're committed to it."

Whether it is their "can-do" attitude or just a matter of "preference," it is clear that the MDA is in favor of the program. And, as Falcone points out, politicians would like to believe them. Falcone understands that the idea of a missile shield is extremely politically satisfying: a seemingly clear-cut solution to the threat of offensive missiles aimed at us. He adds "and if you're a politician with the responsibility for national defense who doesn't really have a fundamental understanding of physics… you could buy into it because you want it to work."

In fact, missile defense has a long history of appealing to politicians. It was over 20 years ago that President Reagan committed the United States to a missile defense shield known by its detractors as "Star Wars." As Falcone explains, Reagan was told that a nuclear exchange with the Soviet Union would leave a hundred million Americans dead, since the only defense we had against the Soviet threat was mutually assured destruction. "And Ronald Reagan said when he was told that, he considered this to be irresponsible, he couldn't be the president of this country [and be] responsible for defense and believe that the defense is letting a hundred million Americans die. So some scientists offered him the idea of a shield, and he said, we gotta do it, it doesn't matter how much it costs."

As it turns out, the APS studied the feasibility of that project as well. The 1987 Star Wars study, Falcone said, was important in explaining to people how the vast majority of the parts of that program "were just not feasible from a basic physics perspective… it was a vision by the President which ultimately had little basis in reality." Maybe so, but the president's mandate lives on in the missile defense community.

According to Wilkening, the missile shield idea has persisted ever since. He explains that members of the administration have "done battle for 20-odd years with the arms control community. Now they're in the driver's seat and having a heyday."

Wilkening sees a major difference in perceived threat level between some analysts and the Bush Administration. According to him, "The Bush Administration genuinely believes it's important for our security." As a source for this belief, Wilkening points to the Rumsfeld Commission report. In 1998 Congress ordered a study of the missile threat to the United States. The commission was headed by

Donald Rumsfeld, then Chairman of the Board of Directors of Gilead Sciences, Inc. The report states, "A nation that wants to develop ballistic missiles and weapons of mass destruction can now obtain extensive technical assistance from outside sources. Foreign assistance is not a wild card. It is a fact." The report further asserts "nations about which the U.S has reason to be concerned are exploiting a dramatically transformed international security environment… an ever-widening access to technology, information and expertise that can be and is used to speed both the development and deployment of ballistic missiles and weapons of mass destruction." The Rumsfeld Commission concluded that the missile threat is huge and growing.

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With this kind of commitment from the Bush Administration, what impact does a study by the APS have? As a case in point, take the issue of space-based missile defense, putting hit-to-kill interceptors on satellites in low earth orbit. This strategy was examined in detail by the APS study, and determined to be infeasible. Launching the thousands of massive satellites necessary to defend against a single solid-propellant ICBM from North Korea or Iran would require a five to tenfold increase in the current United States space-launch capability. Wilkening, who believes that boost-phase defense could work, says that emphasizing space-basing is "not the way to go." But, according to Wilkening, the MDA doesn't like options other than space-based defense. "It's an article of faith amongst pro-missile defense people." Apparently, such articles of faith are not subject to technical scrutiny. According to Wilkening, the study will have little effect on the Bush administration or the MDA. He continued, "the impact of all of these studies is probably pretty minor."

If the study will have no effect on the mindset of the missile defense community, what about on politicians who make funding decisions? Wilkening thinks that, for a number of congressmen, the study "reinforced the belief" that missile defense, especially space-based missile defense, was not feasible. Unfortunately the study was poorly timed to the Congressional calendar. According to a Congressional staffer, by the time the study came out, in July 2003, Congress had already set the budget for fiscal year 2004 missile defense funding. And by the time fiscal year 2005 budget hearings were going, the study was old news.

According to Wilkening, the threat of missile launch against the United States is less of a concern than conventional terrorism, bioterrorism, or global warming. He adds that missile defense spending is "not a worthwhile allocation of scarce resources." Falcone agrees with Wilkening's assessment. His theory on why the budget is so large is simple: momentum. Falcone explains that once contract money starts flowing out of Congress, it's nearly impossible to shut it off. Missile defense budgets fuel the livelihoods of too many, and the lobby is too strong to shrink them. Today's inflated budget is a reflection of the political climate of an earlier time. Missile defense got its big start under Reagan, and it is his words that open the MDA's Ballistic Missile Defense System overview. The then-president asks, "What if free people could live secure in the knowledge that their security did not rest upon the threat of instant U.S. retaliation to deter a Soviet attack?" For one thing, the threat of Soviet attack disappeared along with the Soviet Union. But more importantly, the United States probably faces far less risk from a complicated, expensive, and risky ICBM launch than from an anonymous untraceable and inexpensive weapon delivered, for example, by container ship. Our exorbitant spending on missile defense, to the tune of several billion dollars per year, is an attempt to solve the problems of a new political climate with the same cold-war era solutions. The world has moved on, but our defense programs and our budgeting are frozen in time.

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Want to know more?
APS study report: www.aps.org/public_affairs/popa/reports/nmd03.cfm
Discussion of the report: www.physicstoday.org/pt/vol-57/iss-1/p30.html and www.physicstoday.org/vol-57/iss-7/p13.html