Early Gaming at Lincoln Laboratory: The Missile Defense Engagement Exercises of 1966 to 1968

Researchers worked through the operational logic of a complex defense system in the early years of U.S. missile defense research.

What brought Lincoln Laboratory into missile defense research? The Laboratory was established in the early 1950s to develop a continental air defense against Soviet bombers carrying nuclear weapons. The architecture of this air defense system, developed under U.S. Air Force leadership, featured a wide deployment of radars to detect and track attacking bombers, and fighter interceptors to engage and destroy the enemy aircraft. This architecture was essentially a defense of the full area of the United States and Canada.

A different architecture was favored by the U.S. Army and its major development arm, the prestigious Bell Telephone Laboratories. Their architecture, referred to as the Nike Ajax System, featured a localized defense around major cities with radar sensors and guided-missile interceptors. The extreme concern in the United States concerning nuclear attacks led to both architectures being deployed, and by the 1960s the air defense of the United States and Canada comprised a truly massive system.

The late 1950s development of long-range ballistic missiles capable of delivering nuclear warheads to intercontinental distances began to shift the nation's concern away from air defense toward missile defense. The U.S. Army had the lead role in missile defense and, together with Bell Laboratories, conducted a successful intercept of an intercontinental ballistic missile (ICBM) target at Kwajalein Atoll of the Marshall Island in 1962.

In this same era, Lincoln Laboratory became involved in systems to warn of ballistic missile attack, performing architecture work on the Ballistic Missile Early Warning System (BMEWS) that became operational in early 1964. This work naturally led the Laboratory to consider the technological challenges of ballistic missile defense.

Some of the leadership in the Department of Defense thought the Army–Bell Laboratories approach to ballistic missile defense embodied in the Nike-X system was unduly conservative. The technology of ballistic missiles was improving rapidly and the department encouraged projects that were technologically more advanced than the Army's Nike-X program.

The Laboratory entered the missile defense domain in the early 1960s with experiments designed to capture the physics of a missile warhead reentering Earth's atmosphere at hypersonic speeds. This "reentry physics" effort focused on how to distinguish a real warhead from a wide variety of debris from the parent rocket and possibly countermeasure devices such as decoys. Experiments began at Wallops Island, Virginia, then migrated to the White Sands Missile Range, New Mexico, and finally to the Kwajalein Atoll in the Pacific in 1962. This reentry physics challenge was daunting. All we needed to do was weigh objects at a substantial distance (100 km) by "tickling" them with a radar beam! The objects are moving at greater than 20,000 feet per second. They are decelerating at a peak of 60 gs, and they may have an ionized trail attached. We need to do this weighing process in a few seconds, possibly on a number of objects—a heroic challenge, but an intriguing one!

The Lincoln Laboratory Effort

Considerable controversy has surrounded missile defense since its inception: "hitting a bullet with a bullet" was judged too difficult in those early days. A

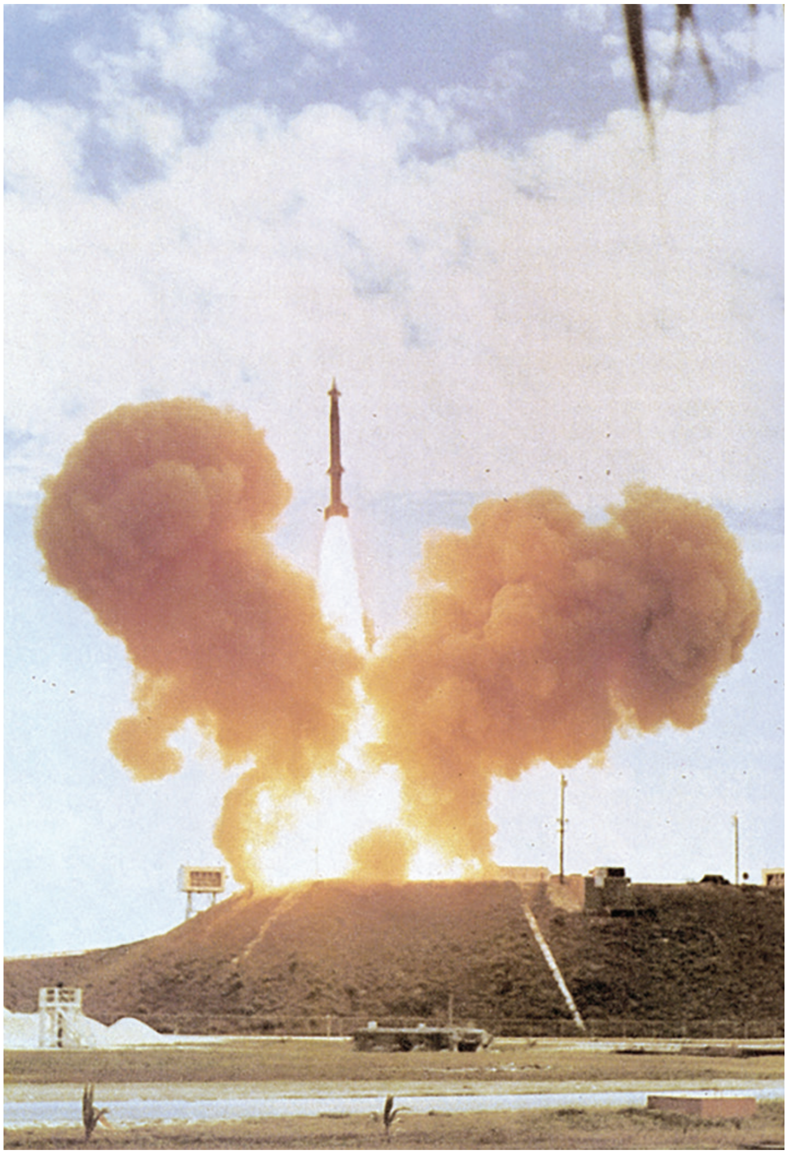

Photo: William Delaney

(a)

Photo: U.S. Army

(b)

The Nike-X interceptors: These two high-performance interceptor missiles (produced by McDonnell Douglas and the Martin Marietta Company) were the backbone of U.S. missile defense research and development in the 1960s and 1970s. They featured high speed and high acceleration, and their launches were spectacular. The author had a box-seat for the first Spartan launch shown in photo (a) at Kwajalein in 1968. The Sprint missile in photo (b) was launched from White Sands Missile Range, New Mexico. These interceptors became major components in the Safeguard missile defense of 1975.

missile defense system must function almost completely automatically; there is not enough time in the engagement of a ballistic missile for a lot of human control and decision making. Skeptics in that era, and even today, believe the necessity for a rapid and flawless execution of an engagement logic is one of the big impossibilities in missile defense.

We researchers at Lincoln Laboratory were intensely curious as to how much of this automated engagement logic had been worked out by Bell Labs for their Nike-X urban defense architecture. The Bell Labs scientists alluded to work on the topic but never presented any results. We suspected that they had not gotten very far on that problem. So, we began to look at the rough elements of a logic that would be needed to launch an interceptor at some incoming ICBM warhead and not launch interceptors at the various pieces of missile hardware junk or countermeasures that could accompany the warheads. These early missile defense systems did their most confident defense in the atmosphere, so there were many reentry physics logic questions to answer. We used models of the Nike-X interceptors in our work but posed new radar models with more advanced capabilities than the Nike radars.

This engagement logic work was done in the Radar Division under the calm leadership of Donald Clark, who was convinced that the engagement logic question was critical to missile defense. The less calm intellectual lead on missile defense systems was Joel Resnick, and the principal system-oriented staff members were John Fielding, Stephen Weiner, and this author.

The Engagement Logic Development and Gaming

Putting together the computer-logic flow for a missile defense system was a challenging task. No one had done it before, but we bravely marched in. How to test one's logic became a prominent question, and we evolved the "Engagement Exercises" as a gaming process to test our logic. An exercise was a bit like our current "red-blue" discrimination games that challenge one set of participants (red team) to devise methods to prevent a defender from knowing which of many objects around an attacking ICBM complex is a real warhead and another set (blue team) to determine strategies to discriminate the missile from decoys or debris. However, our scope was much broader than just discrimination. We featured the whole set of surveillance, detection, verification, tracking, discrimination, interceptor commitment, and guidance processes. We started simple, with simple offense-defense scenarios and built up to more complex games over the course of three years.

The archives show that our first exercise was in May 1966, and exercises followed at roughly six-month intervals for a total of six exercises until the last one in early 1968. We would work for six months preparing the defense logic, which was quite detailed with numerical thresholds for the initiation of some defense process or some defense identification of an object. The setting of numerical thresholds on all processes was a challenge. This "defense team" was opposed by an "offense team" that conjured up a missile threat in gory detail. We were isolated from each other, and the secrecy was tight.

Overseeing both defense and offense teams was the "umpire team" that set ground rules on how much knowledge the opposing teams had of each other (mimicking the information gathered by intelligence communities) and generally inspecting both teams' work for completeness and fairness. The umpire team was a major force in making things proceed in a logical and productive manner, and when we met for the engagement exercise, the umpires were very much in charge. I recall that John Fielding often chaired the umpire team, and that role suited him very well. He assumed a somewhat imperious style, a bit like that of a judge. He coined the phrase "social stigma" as the presumed penalty for overstatements of capability by the defense or offense as we engaged each other. Our group leader Don Clark was often an umpire and his aura of total fairness helped keep things calm.

We were informing ourselves and our sponsor on the complexities of missile defense warfare—and that was good training for the Laboratory's ensuing 50+ years in missile defense.

I was always a defender as was Joel Resnick. The very creative Bob Bergemann of the Data Systems Division and Dave Towle of the Radar Division were professional offense team leaders. A few supporting organization were involved with us. The Cornell Aeronautical Laboratory in Ithaca, New York, and the Kaman Nuclear Corporation of Albuquerque, New Mexico, provided support in threat modeling. A dominant contribution came from the Defense Research Corporation (DRC), later named the General Research Corporation (GRC), of Santa Barbara, California; they were building a huge computer representation of a ballistic missile engagement and had many useful tools, such as trajectory generators and interceptor missile fly-out trajectories.

The DRC team was a collection of very smart "West Coasters" who were intensely interested in our work because Lincoln Laboratory had lots of real-world depth in discrimination, tracking, detection, and false-alarm mitigation. The Laboratory's experience from Kwajalein and many air defense hardware efforts was a great complement to their predominant computer simulation expertise. They became a major player in this work, and we felt a great deal of satisfaction in having two great teams with a shared vision. Jack Ballantine led the DRC team; he was a lot like the Laboratory's Don Clark in calm demeanor. The DRC team's "California cool" was a good offset to the East Coast aggressive styles of Resnick, Fielding, and Delaney.

The Engagement Exercises (Game)

The engagement exercises each took a full three days. They were conducted in a somewhat formal manner, much like a courtroom. The defense team, accompanied by a pile of large paper drawings of the "defense logic," sat in their designated area in a big room. The offense team, armed with their technical documentation of their "threat," did the same.

The umpires sat in a central position. The urban defense system for the United States had been specified well in advance by the defense. The umpires would start with a statement on the world situation, an input on the state of the Soviet Union, and any warning indicators. Then, for example, they might tell us that an Alaskan BMEWS radar was down for repair.

The action would begin when the umpires announced that the BMEWS radar at Thule, Greenland, had received signal return from some object at such-and-such a range and angle and asked the defense, "What do you do next?" Our logic would call for a verify transmission and then a velocity estimate to see if the detection was caused by a satellite or a missile. If the target report passed our missile thresholds, we would send out additional pulses and then follow our logic train of crude impact-point determination, handover to a tracker, track to refine an intercept point, followed by an intercept process. But, things never went that smoothly. At the first engagement exercise, we could not get anything logical to happen in response to our repeated attempts to start a target track or predict an impact point. Eventually, after several hours of tortuous debate and argument with the umpires, they confessed to giving us highly range-ambiguous returns from the moon as our first target (mirroring a real-world event with BMEWS).

Developing a defense logic was a complicated process, even for simple threats, and along the way we noted many shortcomings in our logic. Our leader, Don Clark, would remind us that our goal was to find those shortfalls, and while we intellectually agreed, we defenders wanted to win!

Eventually, our exercises attracted an audience beyond the participants. I recall sometimes acting more like a defense lawyer and doing a bit of showboating along the way. On one such exercise, I had Lincoln Laboratory's Kent Kresa as my cochair on the defense team (Kent went on to a most impressive career, culminating in a position as CEO of Northrop Grumman). On the third day of the exercise, the defense logic was beginning to ferret out the real warheads to be intercepted in a background of countermeasures and interference, and we were launching our Sprint interceptors left and right per our logic. Kent came up and put a Red Auerbach cigar in my mouth, lit it for me, and said, "We beat these guys!" So there was a spirit of winning that kept us on our toes throughout this six-month process we called an exercise.

We continued to conduct these exercises, each with a six-month preparation, over three years, and the game became increasingly complex as we dealt with countermeasures, such as chaff, decoys, jammers, and nuclear blackout generated by the offense or by our own defense interceptor bursts. As defenders, we were learning some tricks of our own, like precommitment of interceptors to provide early intercept options and shoot-look-shoot opportunities. We were finding out which radar capabilities made a big difference. We were also dealing with some nightmare scenarios involving huge enemy warheads that could destroy a city by bursting at very high altitudes, and we invented "the big bomb alarm" and defense logic to thwart that attack.

Overall, we were informing ourselves and our sponsor on the complexities of missile defense warfare. While our work did not appear directly in a system, we were teaching ourselves just how difficult the missile defense job might be, and that was good training for the Laboratory's ensuing 50+ years of work in missile defense. I claim we were the first in the nation to take a hard look at this daunting missile defense engagement logic problem and test ourselves with a gaming process. I am proud to have been part of that fine team of talent.

— WILLIAM DELANEY

Bill is a veteran of 61 years at the Laboratory. He is currently the Director's Office Fellow and is a former Assistant Director. He spent many years in missile defense activities with a tour at the Kwajalein test site and a tour in the Office of the Secretary of Defense with responsibilities for missile defense research and development.