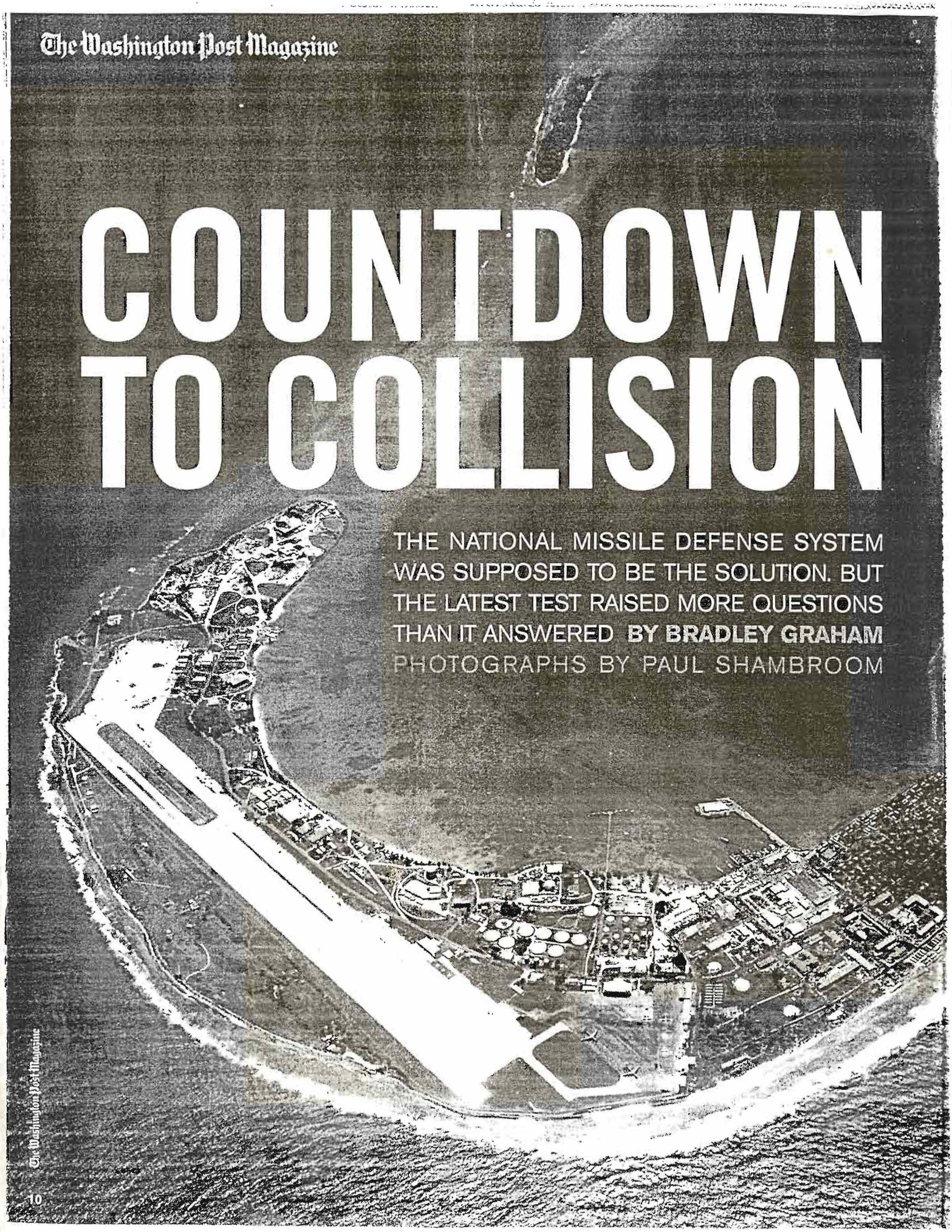
The Washington Post Magazine

COUNTDOWN TO COLLISION

THE NATIONAL MISSILE DEFENSE SYSTEM WAS SUPPOSED TO BE THE SOLUTION. BUT THE LATEST TEST RAISED MORE QUESTIONS THAN IT ANSWERED **BY BRADLEY GRAHAM**

PHOTOGRAPHS BY PAUL SHAMBROOM



THE COUNTDOWN was proceeding toward the most expensive 30 minutes in the military testing business.

In the middle of the Pacific, on a fly speck of an island in the Kwajalein Atoll, a team of contractors and military officers had gathered in a windowless concrete control center to fire off one of the most complex weapons systems ever proposed. Back at an Air Force base a few hours' drive northwest of Los Angeles, another crew had gathered to launch a dummy warhead, complete with decoy, out over the ocean. Nearly 22 minutes later, the Kwajalein team would fire a rocket propelling a "kill vehicle"—a 120-pound package of sensors, computers and thrusters designed to home in on the warhead and pulverize it with the sheer force of a high-speed collision.

After weeks of rehearsals and readiness reviews, the top testers in the national missile defense program thought they had uncovered and fixed every conceivable thing that could go wrong. And after mixed results in two previous tests, they were more confident that this time they would succeed.

Like the others, this test drew on the efforts of nearly 600 people; it involved the biggest names in the defense industry; and it would cost about $90 million. The Pentagon's chief weapons tester had flown out from Washington to be in the control room. Other senior defense officials, including the head of the agency that was developing the weapon, were watching a video feed at the Pentagon. U.S. authorities had taken extra security measures, beefing up a force on Kwajalein and running air sweeps over the surrounding lagoon.

About two hours before liftoff, a security camera trained on the kill vehicle picked something up: a fiberglass skiff racing across the lagoon. Inside the control room, incredulous officials stopped their preparations to watch on a giant video monitor. The skiff hit the beach; a man and a woman got out; they started walking up a road toward the launching pad. They carried a banner reading, "Stop Star Wars, Greenpeace."

Bradley Graham covered the Pentagon for The Post for six years before going on leave last spring. He will be fielding questions and comments about this article at 1 p.m. Monday on www.washingtonpost.com/liveonline.

Two program supervisors bolted from the control room and gave chase in a golf cart, overtaking the protesters short of their target.

IN THE AFTERMATH OF THAT TEST, conducted July 8, the security lapse represented by the Greenpeace invasion went largely unpublicized and unexplained. But then, there was so much else to explain—most notably, why the kill vehicle never got close to its target, and what that failure would mean to the development of a national missile defense system.

No one had ever said hitting a missile with a missile would be easy. In fact, ever since the Clinton administration embarked early last year on a revised program to try to build such a weapon by 2005, military and scientific experts had warned that the Pentagon was taking on a mission impossible. The technology wasn't advanced enough, they said; the architecture was ill-conceived; the timetable was much too compressed.

But Republican legislators had championed the project, convinced that more money and greater political commitment would overcome the technical challenges. Then a North Korean missile launch in August 1998 had startled U.S. officials with the suggestion that the threat of attack from hostile Third World states was closer to reality than American intelligence agencies had predicted. Finally, President Clinton put forward a tentative deployment plan and funding for it. The hope had been that by last summer, initial tests would have yielded two or three successes, demonstrating that a new defensive system was within reach.

BEFORE AND AFTER: PROTESTERS JAMES ROOF AND MEIKE HUELSMAN, BELOW, IN CUSTODY; MICHAEL BRIGHT OF LOCKHEED, ABOVE, DELIVERING A POST-MISSION ANALYSIS.

Instead, the tests intensified debate over the feasibility, cost and diplomatic ramifications of deploying weapons to guard against long-range missile attack.

Similar debates have erupted twice before, in the late 1960s and the 1980s, when the U.S. military's principal anxiety was a massive Soviet attack. Under President Richard Nixon, the government actually decided to deploy a missile defense system, called Safeguard. But the number of proposed interceptor sites got whittled down to just one, in North Dakota, to protect nuclear missile silos; that site operated for only five months before shutting down in early 1976 because of cost and reliability problems. The 1980s debate centered on President Ronald Reagan's proposal for a phalanx of space-based interceptors—the proposal derisively nicknamed "Star Wars"—which died of its own weight. The technology wasn't there, and even if it had been, the sheer scale of such a project would have made it prohibitively expensive.

Now, the perceived threat is different. It comes less from Russia than from North Korea, or Iran, or some other potentially hostile Third World country. These nations, once labeled "rogues" by the State Department but now more diplomatically known as "states of concern," may soon have missiles capable of

PAGE 10 PHOTOGRAPH COURTESY BALLISTIC MISSILE DEFENSE ORGANIZATION

MAJ GEN. WILLIE KANCE, ONE OF TWO GENERALS OVERSEEING THE TESTING PROGRAM, AND THE LAUNCH TEAM GATHER FOR PHOTO DAY.

reaching the United States, although they won't have nearly as many as the Soviet Union did. The current view within the U.S. defense establishment is that an attack would therefore consist of relatively few warheads, rather than the waves that had been envisioned coming from the Soviet Union.

At the same time, the sensors and computers used to discriminate warheads from decoys in space have advanced considerably. The idea of using a ground-launched interceptor to shoot an enemy missile out of the sky seems more achievable than it was just a decade or so ago.

These circumstances brought the Clinton administration around, in its final two years in office, to taking the idea of missile defense more seriously and acceding to long-standing Republican pressure. Under the architecture proposed by the administration last year, the first deployment phase would include 100 kill vehicles based near Fairbanks, Alaska, plus a high-resolution X-band radar on the Aleutian island of Shemya to provide precise detection and tracking capabilities, combined with a handful of upgraded early-warning radars spread across the United States, Greenland and Britain. A second phase foresees about 250 interceptors and more radars, plus a new satellite system for warning and tracking.

All these components, while under development separately for much of the 1990s, remain unproven as an integrated system in real-life conditions. And so the Pentagon scheduled 19 intercept tests through 2005. In the first, in October 1999, the kill vehicle scored a hit, discriminating between a warhead and a Mylar balloon decoy. In the second, last January, the kill vehicle's cooling system malfunctioned and it missed its target by about 200 feet. Because of various delays, and renewed skepticism in some quarters, the stakes were growing as July 8 approached.

The Pentagon had hoped that the program's future would not rest on a single test. In fact, one of the truisms in the defense-acquisitions business is never to let a program get into such a position. Originally, plans called for four flight tests by last summer. But the testing schedule slipped, while political considerations kept the Clinton administration locked into a self-imposed deadline for making a deployment decision this year. So, with only one hit and one miss going into the summer, Air Force Lt. Gen. Ronald Kadish, head of the Pentagon agency responsible for developing the antimissile weapon, took to referring despairingly to the July test as a "binary event": If it succeeded, President Clinton would be more likely to authorize preparations to build the radar on Shemya, and if it failed, he likely would not, which in effect would postpone deployment at least until 2006.

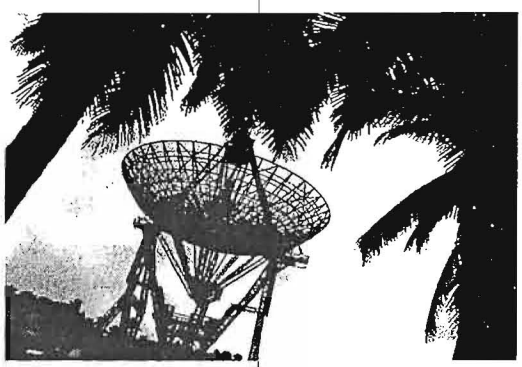
After it failed, Clinton effectively dropped the 2005 deployment deadline. Expressing doubts about the technical feasibility

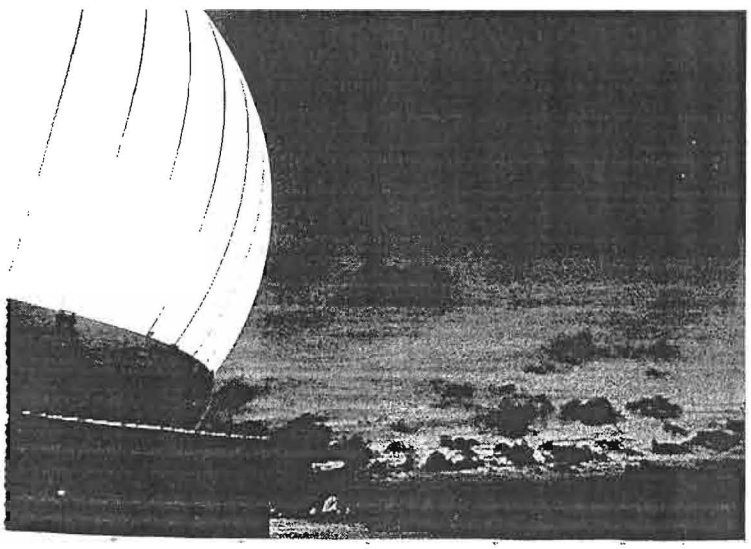
of the Pentagon's approach, he announced in September that he was deferring a decision on the program's future to his successor. The president concluded that taking a chance on the system was not worth rupturing relations with Russia, China or NATO governments, all of which had warned against a unilateral U.S. move to erect an antimissile shield and alter the strategic nuclear balance of the past half-century.

Clinton's action hardly buried the project—it merely postponed the day of political reckoning. During the campaign for the presidency, both Vice President Gore and Texas Gov. George W. Bush expressed interest in pursuing the issue if elected. With Republicans nominally in control of Congress, there may be continuing pressure on the White House to deploy some kind of antimissile system.

But the testing process itself also is likely now to receive a new hard look. The tightly controlled nature of the tests has given rise to allegations in the scientific community of rigging or dumbing down to increase chances of success. Even the Defense Department's chief weapons tester, Philip Coyle, contends that the first three intercept tests have revealed little about the ultimate viability of the planned system. Similar critiques have come from outside review groups, including one requested by the Pentagon and another by the Union of Concerned Scientists.

Still, the two generals overseeing the program, Kadish and Army Maj. Gen. Willie Nance, insist that the early tests have been about as difficult as they should be at this stage. The basic purpose, they say, has been simply to demonstrate the principle of using a missile to obliterate another missile, not the complete operational effectiveness of this "hit-to-kill" technology. Achieving intercept even under these limited and controlled circumstances, the generals argue, has been no small feat.





PARTS OF A COMPLEX SYSTEM: ALTAIR RADAR, ABOVE, AND THE X-BAND RADAR FACILITY, BELOW. OPPOSITE PAGE: BATTLE MANAGEMENT COMPUTERS AND THE "KILL VEHICLE."

Frustrated by what they regard as unrealistic expectations about the testing effort so far, Kadish and Nance granted me unusual access to July's test in the Pacific, starting a week before the launch. Normally, the island is off-limits to journalists during tests, because it is so small and housing is so limited and the testers want to avoid distractions. They granted me an exception because I'm researching a book on missile defense.

From the outside, the run-up to the launch appeared routine, with no glitches. But from inside, the preflight planning looked considerably more frenetic and fretful. Even after all the rehearsals and readiness reviews, after the energetic engagement of all those hundreds of technicians, mission controllers, range safety authorities and other contractors, there still were surprises. And the landing of a pair of banner-carrying protesters was not the last of them.

THE MARSHALL ISLANDS consist of a double chain of 34 atolls that poke out of the Pacific between Hawaii and Guam. One link in that chain is the Kwajalein Atoll, which consists of about 100 small islands and forms the world's largest lagoon—a crescent loop of coral reef enclosing 1,100 square miles. The largest of those 100 islands, also named Kwajalein, is half a mile wide and three miles long. An island-hopping flight from Honolulu takes more than seven hours.

American forces wrested control of the islands from Japan during World War II, and since then the United States has stationed some of its most advanced radar installations on various Marshall Island outcroppings and taken advantage of the chain's isolation to test nuclear missiles and various antimissile systems. On Kwajalein, an old hulking missile control structure stands as a reminder of earlier missile defense programs, with names like Nike/Zeus, Sentinel/Safeguard, HOE and ERIS.

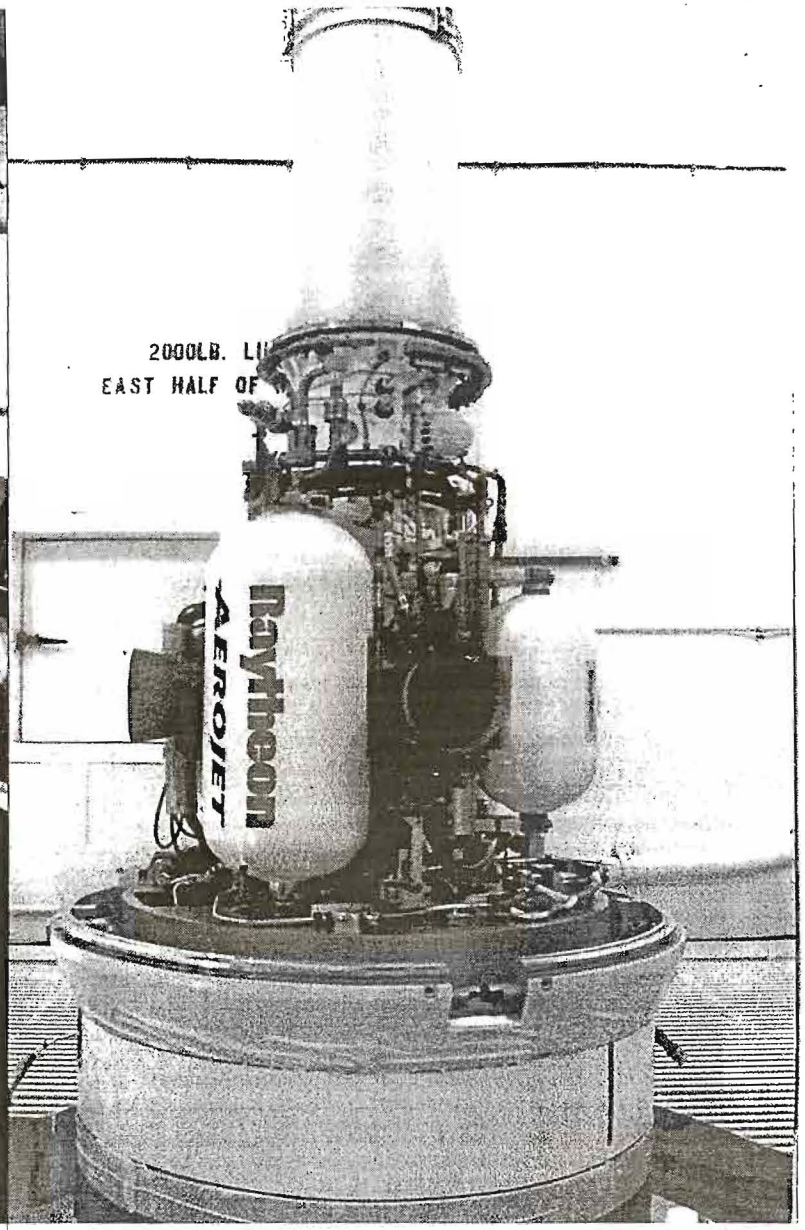
The Marshall Islands have been self-governing since 1979, but the United States has Kwajalein under lease. The island has, in fact, become a distant American outpost, replete with paved roads, TV sports and a general store dubbed Macy's. Over the years, armies of defense contractors have come and gone, pushing the island's population to more than 5,000 at times. Today, about 2,500 live there, all but a few dozen of them civilians working for the Army or for defense contractors and often housed with their families. For a test, the population can swell by several hundred more.

Early last summer, launch crews began returning to Kwajalein with a rebuilt kill vehicle for the July launch. Nearly half a year had passed since the previous test; the January failure prompted a three-month delay as review boards pored over what went wrong. Investigators determined that some kind of obstruction—ice or debris—had choked the flow of the krypton gas that is used, along with nitrogen gas, to cool the infrared sensors that serve as the kill vehicle's eyes. To avoid another plumbing problem, Raytheon Co., which produces the kill vehicle, replaced pipes and valves, modified fittings and revised assembly procedures.

On June 3, a day after the vehicle was filled with krypton and nitrogen gases, measurements revealed another leak.

This time, it was nitrogen. Raytheon officials were incredulous; so were their Pentagon clients. Compounding matters, Raytheon's crew couldn't pinpoint the source of the leak. Without knowing the location or shape of the leak hole, officials could not determine the chances that moisture might be seeping into the system—moisture that might freeze and obstruct the flow of gas in flight.

Concern about the leak continued to shadow launch preparations when, on July 2, senior test managers gathered for a review in Building 1009, a plain, one-story office structure beside the Kwajalein runway that serves as local headquarters for the national



missile defense group. With six days to go, they were reviewing all the problems that had surfaced in preparation for this test.

Leading the team was Nance. Unassuming and soft-spoken, the two-star general had earned his reputation as one of the Army's most skilled acquisitions officers by showing an energetic attention to detail and ability to manage complexity. "He even can remember the serial numbers of parts," said one awestruck aide. A believer in the hands-on approach, Nance tended to spend much more of his time visiting contractors and their production facilities than in his Washington office.

Apart from a handful of colonels, each responsible for a specific part of the system, most of the contingent on Kwajalein under Nance's command was civilian. In 1998, the Pentagon had contracted with Boeing Co. to bring together the system's main components—radars, kill vehicle, booster and battle management computers. The subcontractors included Raytheon on radars and the kill vehicle, TRW on the battle management network and Lockheed Martin on the booster (for the early tests at least, while other firms are designing a new booster for the final system).

The top civilian manager was John Peller, the Boeing team leader. A tall, lanky aerospace engineer with long experience in the Minuteman missile and space shuttle programs, Peller had worked tirelessly on molding what had been a piecemeal Pentagon research and development effort into a single major acquisitions program. But Kadish and Nance were holding him and Boeing ultimately responsible for some of the delays, notably in the new booster design, which was a year behind schedule, and in the delivery of a computer simulation system for running ground tests.

Several dozen problems had arisen in recent weeks, and each one had been written up in a test incident report. Before the launch could proceed, each TIR needed to be certified as resolved or inconsequential. Only a few appeared to be of any lingering significance to test officials. Most of them involved software glitches that were being addressed. Even the nitrogen leak seemed less menacing than it had in June. Based on various structural analyses, Raytheon officials had assured Nance and Peller that the probability of the leak worsening in flight was minuscule.

"The chance of any of these things happening is one in a million," said Dan Testerman, Boeing's deputy director for test evaluation, as the review droned on to cover the most esoteric of issues. But Nance wanted no irregularity left unexamined. A new problem had emerged that very morning, when a Lockheed Martin crew working on the booster discovered a loose power cable on the nozzle control unit.

The cable would have to be replaced, but the spare was in

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Ask Tom

Reader Katherine Vierk of the District is planning a birthday party for her boyfriend–we hope it isn't a *surprise* party, Katherine–and wants to know where in the city she might find a private space that's "a little different, nice, fun, and accommodating 10-15 people." Lucky for her, there's a world of choices. High on my list: Dupont Circle's festive, Latin American-flavored **Gabriel** (2121 P St. NW; 202-956-6690), which can curtain off part of its dining room for a small party, and downtown's **Taberna del Alabardero** (1776 I St. NW; 202-429-2200), a grand Old World restaurant whose regal Aranjuec Room looks as if it had been airlifted from Madrid. In Georgetown, **Bistrot Lepic** (1736 Wisconsin Ave. NW; 202-333-2738) beckons with a French accent and a lovely second-story salon, called Rue Lepic, while the oh-so-Italian **Cafe Milano** (3251 Prospect St. NW; 202-333-6183) offers a choice of three newly refashioned venues: the Garden Room, the Wine Room and the Domingo, which borrows the name of one of the restaurant's frequent visitors (hint: think opera). In Glover Park, **Busara** (2340 Wisconsin Ave. NW; 202-337-2340) can serve its Thai menu in upstairs digs that are as arty as its main dining room. Near MCI Center, if you've got steak and a power scene on your mind, there's the handsome **Caucus Room** (401 Ninth St. NW; 202-393-1300), featuring a series of secluded rooms named for U.S. presidents, and **701** (701 Pennsylvania Ave. NW; 202-393-0701), a tony supper club whose 12-seat private room overlooks the courtyard of the Navy Memorial.

Got a dining question? Send your thoughts, wishes and, yes, even gripes to asktom@washpost.com or to Ask Tom, The Washington Post Magazine, 1150 15th St. NW, Washington, D.C. 20071.

bound in vine leaves and sprinkled with fried onions and more nuts, don't stay for long once they hit the table.

Of the soups, I prefer the lemony broth with shrimp, bites of pineapple and snips of fresh basil to the pho, a timid bowl of beef slices and rice noodles in beef broth. Whole restaurants devote themselves solely to preparing that classic Vietnamese soup, and many of them do it better than Green Papaya.

Vietnamese food makes itself accessible even to people whose tastes run conservative. Its rice noodles are soothing, its slender skewers of grilled chicken and beef seem familiar, and using one's hands to eat a soft rice paper-wrapped roll of pork or shrimp lends a little informality to a meal. While a number of dishes are bolstered with nuoc mam (fish sauce), it tends to be used sparingly, not shouting its presence but enhancing and rounding out a composition. Meat-and-potatoes types will easily recognize bo luc lac, a comforting entree made with cubes of filet stir-fried with onion and potato—and they likely will finish every last scrap. A little excitement comes by way of the optional lemon-pepper sauce.

This is not to suggest that the kitchen waters down its cooking. Ginger noodles blended with chicken, beef and shrimp (or a choice of those) show off plenty of sweet heat; chicken curry, homey with cubed potatoes and carrots and velvety with coconut milk, pulses with its name-sake spices. Lean, thin-sliced beef, enlivened with lemon grass and grilled until its edges have a caramelized crispness, is what I imagine perfumes neighborhoods all over Ho Chi Minh City. On the other hand, I might welcome a little more attention to details in the kitchen: One night the shrimp on my seafood skewer with rice vermicelli were grilled to stiffness. Another time, the admirably crisp skin on the whole flounder, sweetened with a zesty ginger sauce, revealed fish that crumbled from overcooking.

The one thing that never misses at Green Papaya is the service, always accommodating and personable. Phan's attention to aesthetics extends not just to what you see and feel but what you hear: background music that fosters a relaxed mood, and never mind the origin of the notes. It's amusing to be eating decidedly Asian flavors while listening to Spanish classical guitar music, or something French, or what sounds like the score to a Meryl Streep film.

The dining room's pretend fire gets some competition from real flames every time an order of fried bananas is prepared tableside. The cooking demo is entertaining, the flambeed fruit pleasing. From beginning to end, Green Papaya tries to fulfill the promise of its name.

To chat with Tom Sietsema online, click on Live Online at www.washingtonpost.com, Wednesdays at 11 a.m.

MISSILE DEFENSE

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Hawaii. And the Air National Guard C-141 plane that ferries cargo to Kwajalein several times a week had broken down. That night, Nance asked the pilots of a surveillance plane that was in Kwajalein just for the test to spend the next day fetching the spare.

ANOTHER DAY, another review: On July 3, the launch team traveled by large catamaran to Meck Island, over on the eastern rim of the lagoon. Meck is just large enough to host a launch site on a man-made hill at one end, a small dock and short runway at the other, and, in the middle, an aging, five-story, windowless concrete structure that houses a control room and support offices. The building was erected for tests of the Safeguard system in the 1970s, when a computer would occupy an entire room and bear gold-plated circuit boards.

Nance began the review by noting the particular importance of this test, an implicit reference to the decision President Clinton would be making. As the review proceeded, he invited comment from anyone who wished to offer a thought. This open approach was typical of Nance, to the mild annoyance of some associates, because it sometimes resulted in uninformed comments and meandering meetings. But the general did not want to overlook anything that could help the mission.

Between mid-morning and late afternoon, the review covered everything from the condition of the kill vehicle to the weather forecast for launch day. One new problem intruded: A critical communications facility for sending target information to the interceptor while in flight had suffered a power outage during maintenance the night before. The facility, known as IFICS, was making its debut with this test.

A troubleshooting team that morning had concluded that the outage was caused by humid air passing through open panels in the small IFICS facility and blowing across hot computer equipment. Nance ordered that greater care be taken during maintenance; from now on, he instructed, no one would touch anything without a procedure.

Nance had been wrestling with how to get the best handle on all the issues that had come up and their status ahead of launch. Now, he directed staff members to devise charts that would lay out all the critical test events, so they could spot potential glitches in the sequence in which they could emerge. Will the target launch? Will the radars pick it up? Will the interceptor fire? Will the kill vehicle identify

the mock warhead and intercept it?

"What we're trying to get to," he explained to his team, "is whether we have any weak links with single-point failures"—failures that would be caused by any element that lacked a backup or was of overwhelming significance in itself.

On the walk back to the pier for the return catamaran ride to Kwajalein, Peller mused that just scoring a hit was hard enough, but these early tests were even more demanding. There were data to be collected and test-range safety to be maintained. And in real life, the United States would be able to fire a salvo of interceptors against an incoming warhead; in these tests, only one interceptor was being shot. "Testing," Peller lamented, "is actually a lot harder than operating a system."

Senior test team members spent the next day, July 4, compiling the charts that Nance had ordered. The general would use them later in the week in a final videoconference briefing to high-level Pentagon officials. That night, Boeing hosted a beachside party with free-flowing margaritas and a view of fireworks shot from a barge.

With three days to go, it was time for the final full-scale simulation. Tradition called for corporate team photos on the launch hill in front of the interceptor. The photo shoot went smoothly, but sorting out another tradition—the positioning of corporate decals on the booster—wasn't so easy. There just wasn't room enough for all dozen or so decals to go on the missile's "front" side, the one that faces the cameras on launch day. Nance regarded the decal-placement decision as one of the most politically sensitive he had to make. He appointed a group to make a recommendation, then issued his verdict: Put Boeing, TRW, Raytheon and Lockheed Martin on the front, and post the others on the back.

Despite the glitches that had popped up, Nance and Peller were giving this intercept test better odds than they had the first two. Peller put the chances of success at greater than 50-50. Nance pegged them at about 80 percent. But the simulation that day turned out to be more eventful than expected.

About 15 minutes before target launch, a fire alarm went off in the building housing the control room on Meck Island. A 240-amp circuit breaker had burned out, apparently from old age, causing an air compressor to shut down. This in turn allowed humid air to waft into the ductwork and trip the alarm. "A 25-cent circuit breaker is threatening to foil a $100 million flight test," said Jim Ussery, a Pentagon test analyst.

With less than five minutes to go, a new problem arose. Range safety officials declared a "red" condition, halting the countdown, because a UHF transmitter used to send a destruct signal in the event of a misfire had gone down due to a faulty amplifier. Finally, the simulation was run.

With team members in the seats they would occupy on launch day, computers generated mock launches of the target and the interceptor. Mission directors recited in-flight progress reports as if the events were real. A video screen at the front of the control room showed the trajectories of the simulated vehicles converging and, ultimately, colliding.

IN A VIDEO conference call with the Pentagon on July 6, Nance and Peller briefed Kadish and the Defense Department's head of defense research and engineering, Hans Mark. Nance and Peller knew it was Mark who needed the most convincing. Mark was especially proud of his own record—more than 30 spacecraft launches over 40 years, including 14 NASA space shuttle flights, and no failures.

An inveterate memo writer, Mark had kept some of his Defense Department colleagues abreast of his concerns about the national missile defense program. Just before the January flight test, he had issued a memo critical of Nance and Peller for appearing overly confident—"too slick." As the July launch approached, Mark had worried particularly about the nitrogen leak.

During the briefing, Raytheon provided assurances that the leak was under control and likely would pose no threat to the flight. Peller showed the charts listing the critical functions, from launch to intercept, that had to go right for the test to succeed. About 30 potential problems were cited, along with what had been done to address them. Most were given a "low probability" of occurring in flight.

Mark asked what "low probability" meant.

About one chance in 100, Peller replied.

Using a standard probability equation, Mark quickly calculated an overall probability of success of about 70 percent. "If you were selling lottery tickets, I'd buy one," he cracked.

But buying a lottery ticket and recommending an important launch were two different things for Mark. He still had reservations about proceeding with the test, although Nance and Peller came away from the briefing with the impression that Mark had no objection to launching on July 8. Mark knew that the probability calculation he had done was very sensitive to the guesses that were made about the probability of each event occurring, and people had widely different estimates in some cases. He could not put his finger on any single item that would warrant scrubbing the July 8 launch date.

Weeks later, he would say he had continued to worry about the many little anomalies that had cropped up. "You can do all the calculations you want, but you have to depend on your gut," Mark explained. "It can't all be calculation. It has to be to some extent a feeling about whether something might go wrong. I canceled shuttle flights for no good reason other than I didn't feel right that day about a flight." He knew it was all too common in the testing business for judgments to be clouded by an eagerness to get on with any given test. Testers had a term for it: "They had launch fever," Mark said. "I've seen that. And you know what should happen when you have launch fever? You stop, you don't launch. Never mind the calculations."

But that retrospective assessment struck Nance and other senior program officials as gratuitous. In post-flight interviews, they disputed the notion of having been in the grip of any fever. They felt they had been as thorough, deliberate and extensive in their pre-flight checks as they knew how to be.

Even Mark was blindsided by the outcome. During the July 6 review, Mark along with everyone else had glossed over one chart that officials would later wish they had questioned. "Will the kill vehicle separate from the payload launch vehicle?" it read across the top. Only two words appeared on the page below: "No issues."

THE SAFEGUARD missile program conducted 165 flight tests, the Polaris program 125 tests, and the Minuteman program 101 tests. The national missile defense program has scheduled only 19 intercept trials so far. Of course, rocket science has progressed in the past three or four decades, allowing contractors to accomplish much more in a single test. And ground tests and computer simulations have come to play a bigger role in verifying a new system's readiness. Little wonder, too, given the sky-high price of a flight test.

Hit or miss, each test of the national missile defense system now burns about $90 million, according to the latest figures from the Ballistic Missile Defense Organization. The kill vehicle itself costs $24.1 million. The booster—a refurbished Minuteman rocket—runs $11.4 million. What BMDO refers to as "checkout, execution

and post-test analysis" of the mated booster and kill vehicle totals $17 million. The target missile, which includes a mock warhead and decoy packed in a dispersing container, or "bus," comes to $19.1 million. There also are rental charges for use of Kwajalein and Vandenberg Air Force Base in California ($3.2 million) and payments for "radar and battle management support" ($9.6 million). Finally, $4.7 million goes for "system-level planning, analysis and reporting," which covers preflight mission scenarios and post-flight studies.

Given the price, what goes into a test counts for even more than it used to.

Which is where Phil Coyle comes in. Studious and methodical, Coyle has served as the Pentagon's director of operational testing and evaluation for six years, assessing the adequacy of test programs. No stranger to missile defense since his days as test director at the Nevada Test Site in the early 1970s and an associate director at Lawrence Livermore Laboratory in the 1980s, he has emerged as an influential counterpoint to those in the Pentagon pushing for an early-deployment decision. In recent months he has pointedly argued that there is insufficient information to make any judgment about the system's operational readiness, and he contends the testing program itself is flawed.

Coyle was the only senior Pentagon civilian to make the two-day journey from Washington to Kwajalein for the July test. Two weeks earlier, he had sent a memo to Jacques Gansler, the Pentagon's top acquisitions official, saying the test, while the "most significant" so far, contained "significant limitations to operational realism."

Coyle was particularly critical of the use of a large Mylar balloon as the decoy. He described it as "not especially stressing" to the kill vehicle and "not a true decoy" since it could, in fact, help rather than confuse the interceptor by alerting it to the presence of the real target nearby. This happened during the October test, when the kill vehicle got off course and fixed on the balloon at first, without seeing the dummy warhead. Coyle said continued use of the balloon "only invites further criticism from the academic community." Because the kill vehicle had already demonstrated that it could tell a warhead from a balloon in the first test, he observed, it was time for "progressively more challenging countermeasures."

He noted that all major components of the system were still represented in the test by surrogates or prototypes, and the final versions would in some cases differ significantly from these stand-ins. The ultimate booster, for instance, would travel several times faster—and shake more violently—than the refurbished Minuteman missile being used to power the kill vehicle into space in these early intercept tests. Moreover, Coyle pointed out that the test was using the same flight geometry each time—the familiar Vandenberg-Kwajalein scenario. He wanted launches from more operationally representative locations—out of Alaska, for instance—and intercepts at higher altitudes and involving multiple interceptors.

Coyle knew, of course, that early developmental tests were often limited and somewhat artificial. This test program had never been structured to produce operationally realistic test results this early. But that was Coyle's basic point: Even if they succeeded, these tests could not realistically support a deployment decision now.

Coyle had written the memo out of concern that some Pentagon and White House officials didn't fully understand the significance of the tests. He considered it quite unfortunate that the Pentagon had scheduled what it was calling a "deployment readiness review" last summer. It was too early, he thought, to make any assessment of deployment readiness, let alone for the president to make any deployment decision.

At the same time, Coyle thought the tests already had demonstrated considerable progress. They had shown that many of the system's core elements, which weren't even available a decade ago—such as the kill vehicle's infrared sensors or the battle management computers that process data from the sensors and produce a target map for the interceptor—were working. What remained in question for Coyle was whether these elements could work reliably in an integrated system.

Also troubling Coyle—and scientific critics outside the Pentagon—was whether the proposed system could ever adequately discriminate between warheads and decoys. Pentagon officials had insisted that their discrimination technologies—in the kill vehicle and the ground-based X-band radar—would be capable of picking out the right targets by measuring subtle differences in heat, motion and other physical characteristics among objects in space. But the technical wizardry supporting this assertion is classified, and officials had declined to get very specific in public.

Coyle had come to Kwajalein to get better, more precise answers to some questions. "You just get a different story from the guys here than you do in Washington about the way the system is supposed to work," he explained, standing in the control room on launch day. "I don't mean anyone has been trying to mislead us. It's just that they don't have the same detailed information at their fingertips."

Nance welcomed Coyle's presence. The general was troubled by the persistent doubts that Coyle and outside critics had continued to raise about the value of the tests, and looked forward to the opportunity to dispel them. Part of the problem, he felt, was that people were expecting too much too soon. "The first problem is, we're being graded against what the expectation would be for an end-of-the-development cycle, full-operational test," Nance said in an interview later. "This system will go through that, but not until 2004 and 2005. We're not there yet. We're still in the front part of the test program. Our objective is to learn as much as possible about the elements of the system, then move to the next phase and add a little more rigor."

He couldn't disagree with Coyle's argument that the initial tests were not operationally representative. They weren't supposed to be. But he took deep offense at suggestions by others that the tests had been simplified to ensure success. "My disappointment is that we don't put the test in its right context," Nance said. "The message that you get in the media is that this is a rigged test. It's not. We may know where the target is going to launch from and what is in the target array, but it's pretty damn hard to rig a test to ensure we're going to intercept when the test range is nearly 5,000 miles long and the speed is greater than 15,000 mph and we're trying to hit something as small as this target."

ON JULY 8, people started moving into position very early. The launch wasn't scheduled until 2 p.m. local time, but the first ferry to Meck left at 4:30 a.m. The next—and last—left two hours later.

Pre-launch rituals abounded: After arriving on Meck, Nance held to his custom of walking up to the launch site and looking around. The mission control director took his customary launch-day bike ride along a lagoon-side path to the ferry. A Boeing flight test manager rubbed the heads of some guys who worked on the battle management system. A Lockheed Martin marketing specialist kissed the kill vehicle. A Raytheon manager swallowed a few Tums. An adviser to Nance skipped breakfast altogether. Jerry Cornell, Boeing's Kwajalein site manager, brought a palm-size stone engraved with an Indian thunderbird image and a knife that had belonged to J.B. Coleman, a sergeant in the 2nd Texas Cavalry during the Civil War. "He went through

several battles—Antietam, Gettysburg—and died of old age in 1910," said Cornell, who has had the knife for 22 years. "He kind of represents the soldier, the user."

Then there were the team shirts. The kill vehicle crowd wore white with blue trim; the battle management team showed up in green with white stripes; the X-band radar group favored black; the Lockheed Martin booster contingent had bright blue shirts with an island motif of billowy clouds and palm trees. As for the Boeing group, it went loudly against convention—and superstition—by donning bold red shirts. "Historically, red has been a no-no on the range," said Jim Hill, the Meck site manager. "Red means stop, abort. On Kwajalein, it used to be that if anyone wore a red shirt on mission day, he'd not be allowed in the building and would have to go home to change it. Maybe Boeing is trying to do a reverse on us." The Boeing test official responsible for shirt acquisition said red was the only color sufficiently stocked at the Boeing Co. store in Huntsville, Ala.

By mid-morning, about four hours before launch, everyone was settling in for the wait when Vandenberg reported a voltage drop in a battery on the target missile. The battery powered a transponder used to track the container that carries the warhead and decoy. Vandenberg officials quickly determined that the battery still had enough voltage to do the mission, but they decided, without consulting Nance, and to his later annoyance, to recharge it anyway. The action delayed the flight two hours.

The countdown resumed just past noon. Shortly before 2 p.m., the security camera picked up the Greenpeace protesters' skiff. Despite warnings that Greenpeace would try to disrupt the launch, and reports of protest activity in California, no one had anticipated an assault on Meck. Upon getting word of approaching intruders, the handful of blue-suited civilian guards on Meck fanned out to check the shoreline instead of rushing up the hill to protect the missile. The launch site was unfenced.

So there the activists were, closing in on the interceptor, their path unblocked.

Army Col. Earl Sutton, Nance's test director, dashed out of the control room. Michael Bright, wearing a lei with his palm-trees-and-billowy-clouds shirt—he was Lockheed's manager for the booster—ran after him. They were the ones who commandeered the golf cart and caught up with the protesters about 100 feet shy of the launching pad.

"You need to stop right there," Bright recalled saying afterward. They stopped. Sutton was uncertain of his powers of arrest. His basic aim was to avoid a struggle. The protesters—James Roof of Missoula, Mont., and Meike Huelsman of Hamburg, Germany—refused to move at first, saying they wanted to exercise their right to protest. But eventually they were escorted peaceably down the hill, where they were held until after the launch and turned over to Marshallese authorities. They spent nearly three days in jail, then were released and fined $100 each for trespassing.

At the Pentagon, Kadish intently watched the Greenpeace intrusion on a video feed. In the Meck control room, it did not go unnoted that if it had not been for the delay caused by Vandenberg's battery problem, the protesters would have thwarted the launch. They had appeared on Meck at precisely the original start time of the test. "This," Bright announced to the control room, "is probably the only time when a battery problem saved the mission."

At 2:18 p.m., the countdown resumed with two hours remaining. Nance opened a fortune cookie that the battle management computer team had given him earlier in the day. The fortune read, "Time is a wise counsel."

AT 4:18, the target missile lifted off from Vandenberg. The second and third stages ignited, then burned out on schedule. Four minutes into the flight, Vandenberg reported "trajectory nominal," meaning on course. The dummy warhead was confirmed deployed about two minutes after that.

Nance peered at the large video screen at the front of the control room, which traced the target's trajectory over the Pacific. A mission control checklist was on the table in front of him, showing the minute-by-minute callouts for a normal test run.

About eight minutes into the flight, right on schedule, a radar in Hawaii reported picking up the target. But a confirmation that the balloon decoy had deployed did not come.

About 14 minutes in, the unit that monitors the target data being relayed to the interceptor advised, "You will not see large decoy in the target object map." In other words, the balloon wouldn't be in play in this test. It had failed to inflate.

About 18 minutes in, word came that Altair, one of the giant range radars, had reported "a non-nominal complex, a few extra pieces." Evidently, some debris had broken loose from the container that carried the dummy warhead and decoy into space; so even without the balloon, the kill vehicle would be encountering more than just the dummy warhead.

About 20 minutes in, attention switched to conditions on the launch pad at Meck. Safety radars were reported "green," meaning ready to track the interceptor. Then came a general alert: "All stations, stand by for terminal count. For go for launch. We are armed."

The 15-second mark was called out, then the final 10-9-8-7 . . .

The Meck control room began to rumble slightly, and a muffled roar penetrated the concrete walls. A few hundred yards away, the interceptor's booster was firing, shooting off into partly cloudy skies. Bright's hopes soared with the rocket. Nance jabbed his fist into the air, and applause burst out around him.

"Sensor cooldown commanded," intoned the voice of mission control, indicating coolant gases had begun to flow around the infrared sensors, preparing them for their space hunt.

Bright stood in his customary spot in a back corner of the control room. From there he could observe the rush of data streaming into computer consoles. He also could overhear the chatter of technicians monitoring the interceptor's performance.

After about two minutes, the talk suddenly turned worrisome. Transmissions from the missile had become "noisy" with static interference.

"Where's the cover eject?" someone called out anxiously. "We didn't get cover eject." The cover—a giant aluminum clamshell-like device—protects the infrared sensors on the kill vehicle until reaching space. Nor did a signal arrive confirming that the booster's second stage had stopped burning. This signal was necessary before the kill vehicle could separate from the booster and home in on the target.

"We're not going to separate," someone blurted.

Three-and-a-half minutes into the flight, the mission control network crackled with word again from Altair, confirming the technician's gloomy forecast. "Altair reports no separation of KV from PLV"—the kill vehicle was still attached to the payload launch vehicle. Instead of maneuvering toward its target, it would likely tumble back toward Earth.

The control room fell silent. An overwhelming sense of failure struck Bright, a huge deflation, like the air rushing out of a balloon. Second-guesses were streaming into his mind. *What had gone wrong? Where did we make mistakes? What more could we have done?* He just shook his head and walked away.

Nance folded his arms across his chest and stared at the screen, which still showed the target and the kill vehicle arcing toward each other. Perhaps Altair's report was a miscall, Nance thought at first. What if Altair had been fooled, its view obscured because the kill vehicle had separated and somehow gotten behind the booster? Or perhaps the electronic signal that the kill vehicle must receive from the booster before cutting itself loose had been delayed and would still come through? Or maybe the connector between the kill vehicle and booster had been jammed and the kill vehicle would muscle free on its own when its thrusters fired?

For the next five minutes, as a wall-mounted digital clock clicked down to the scheduled moment of intercept, many in the control room simply sat silently, their eyes on the tracking picture. But it was clear that the flight had flopped. No one heard the reports normally broadcast on the mission control network when the kill vehicle closes in on a target. A telemetry indicator on the video screen that signals "valid" when the kill vehicle separates never switched on.

Finally, Nance swiveled around in his chair to address the room. "You've got to take this in context," the general said. "This is the most complex mission that the Defense Department has had since the Manhattan Project or some early strategic system programs, and it is not going to come without flight-test failures. Our job is to evaluate the results of this, learn from what happened today and apply it to the next tests. You've got to remember that our mission hasn't changed. Our mission is to design and develop—and test—a capability to defend the nation against ballistic missile attack. And it doesn't change tomorrow just because of this test."

Staff members, as if welcoming any activity to stave off depression, quickly turned to reviewing the telemetry still pouring in from flight monitors.

IN THE WEEKS that followed, the most likely culprit was judged to be a defective part in the booster's avionics processor, a 10-year-old device with an excellent track record. Some missiles have backup processors; this one didn't. Some senior defense officials wondered whether more attention should have been paid to checking the booster.

Advocates of the system took heart that the malfunction occurred during the routine procedure of launching a payload, not in the much more innovative technology required to knock down a warhead. Moreover, several important elements of the missile defense system had functioned as planned, including the IFICS link and a prototype of the X-band radar designed to help the interceptor find the target.

A week after the president's decision to delay construction of the Shemya radar, Kadish appeared before the national security subcommittee of the House Committee on Government Reform. "In general, there are basically two ways to look at the program to date, and they could be termed the glass-half-full and the glass-half-empty views," he said. "My assessment at the moment is that it is half full. I say this because we have made remarkable and substantial technical progress despite two high-profile test failures."

But given all the controversy generated by the effort so far, the new administration is expected to spend some time now reconsidering just what missile defense design, if any, the United States ought to be pursuing. Should the interceptors be based on land, as the Clinton administration proposed, or fired from ships at sea, as some Republicans have urged? Instead of hitting enemy missiles in their "midcourse phase," as currently planned, is it feasible to go after them earlier, while they still are ascending in their "boost phase"? And anyway, with both North Korea and Iran showing signs of moderation, what's the rush to build a shield?

Even if the decision ends up being to stick with the current approach, missile defense officials recognize the need for some changes. Reflecting concerns about lagging development, the Pentagon prompted Boeing to shake up its management team. Peller was removed as program manager after the July test, and so were several of his deputies. Kadish and Nance, meanwhile, have begun considering ways of overhauling the testing program to add the kinds of targets, decoys and flight geometries that some critics have advocated. Among the proposed changes is a testing approach that would "fly through failure"—meaning no delay in test flights should flops occur. But such a plan would cost more money.

Missile defense officials worry as well about keeping up morale while the future remains in question. And with some reason.

Boarding the first commercial flight out of Kwajalein after the July test, many launch team members looked weary and sounded glum. They reached Honolulu at 3 a.m., only to find a shortage of taxis at the airport. One Raytheon employee cracked, "I can't help bur think that if the test had succeeded, there'd be limos here waiting for us." W

KILBY

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ter part of a decade trying to build a cheap, teliable solar cell that would turn sunshine into electricity; he made some progress, he reports, but "not enough to make the project worthwhile." The Kilby "electronic check writer," Patent No. 3920979, has yet to earn its first dime; ditto for Patent No. 3944724, a "paging system with selectively actuable pocket printers."

Kilby has also spent a lot of time thinking about how to think—or, more precisely, how to get the kind of idea that can solve a global problem or win a Nobel Prize. The first step, he says, is to make sure you've accurately defined the problem you're trying to solve. "A lot of solutions fail," he says, "because they're trying to solve the wrong problem, and nobody realizes that until the patent is filed and they've built the thing." And once you target the right problem, you have to tune out all the obvious solutions. That is, the quick answer that first pops to mind probably won't work. If the problem is of any importance, all the obvious solutions will have been tried already. Instead, you have to find what he calls the "nonobvious" solution: "You only arrive at the invention when somebody develops a method that everybody else has already decided was obviously wrong."

Jack St. Clair Kilby is something of a celebrity in Dallas these days, where the media like to refer to him as "the Texas Edison." But most of his countrymen have never heard of this American who launched a technological revolution. The level of attention given to him was crystallized one fall day in the mid-'80s, when Diane Sawyer flew to Dallas to interview him for "CBS Morning News." Sawyer tossed out peppy questions, and Kilby answered in his slow, laconic way.

"I mean, if you have to think of one thing that kept the United States in the forefront of technology, it was really your invention," Sawyer said. Kilby pondered the notion. "Well, I hadn't thought about it in those terms," he said softly. "Have you made money from this invention?" Sawyer ventured. "Some, yeah," Kilby replied. Sawyer seemed ready to follow up, but then got a high sign from the director. "Coming up next," she said with a smile, "Dr. Jerry Brodie on how to handle the death of a pet."

Somehow, our media-soaked society, with its insatiable appetite for new faces, has managed to overlook a genuine national hero—a man who improved the daily lot of the whole world with a good idea. Will the Nobel Prize finally make us realize who Jack Kilby is, and what he did? W