Statement of
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Good morning, Mr. Chairman, Members of the Committee. Thank you for inviting me to testify on the U.S. Ballistic Missile Defense (BMD) testing program. Today, I will address progress to date in critical BMD technologies and in our missile defense testing program. I will also explain some of the constraints we face, and the need for enhancing BMD test infrastructure to enable future progress.

Today, we deploy thin defenses against some short-range missile threats, a capability we will improve this year when we deliver the Patriot Advanced Capability-3 (PAC-3) missiles to our training units. However, we still do not, and will not for several years, have a fielded capability for countering many other existing and emerging ballistic missile threats, especially missiles of medium- to long-range. So there is some urgency behind our missile defense development and test efforts. The deployment of missile defenses requires commitment and focus in our programs over many years. Developing these systems and producing them to be reliable, effective, and affordable is a tough engineering and integration job that requires discipline, patience, and vision, especially in our testing program.

Our BMD testing philosophy recognizes that we must have an integrated, phased test program that comprehensively covers developmental and operational testing. Developmental testing entails conceptual prototype development, assesses the attainment of technical performance parameters, generates data on risk, supports risk mitigation, and provides empirical data to validate models and simulations. Testing of systems, subsystems, and components, especially early in the developmental cycle, helps us to achieve two fundamental objectives: 1) determine performance capabilities, and 2) identify potential design problems to support timely changes. Later operational testing will demonstrate the effectiveness and suitability of missile defense systems in their intended operational environments.

Our test philosophy is to add step-by-step complexities over time such as countermeasures and operations in increasingly stressful environments. This approach allows us to make timely assessments of the most critical design risk areas. It is a walk-before-you-run, learn-as-you-go development approach. These testing activities provide critical information that reduces developmental risk and improves our confidence that a program is progressing as intended.

The consequences of not using a deliberately phased and integrated approach to testing can be very high. If we were to use a less disciplined approach, if we were to rush to add complexity to our flight tests, for example, a test failure would make it very difficult to identify the actual cause of failure, and I would be less certain that I could get useful results for system refinements and subsequent tests. Our test evaluators cannot learn by overloading system components with multiple test requirements and testing them too early under highly stressing conditions. We cannot correct deficiencies if we cannot isolate the variables that affect results. We cannot acquire the data we need to make progress in a methodical way, in other words, unless we use a disciplined, incremental approach.

Our goal of defending against emerging ballistic missile threats by developing missile defense systems on an aggressive acquisition schedule is similar to the way we historically have procured some major weapon systems. Most development programs have problems, especially when pioneering a new military capability. As a rule, we expect problems to emerge during developmental testing. The Atlas ICBM program experienced 12 failures in its 2 1/2 year flight-testing history. And the Minuteman I program suffered 10 failures in a 3 1/2 year testing program.

I also cannot emphasize enough the importance of controlling our expectations and persevering through the hard times as we develop and field a system as complex as missile defense. The once-secret Corona program to develop our country's first photo-reconnaissance satellites is very instructive in this regard. The managers of one of our earliest space programs had to survive 12 failures and mishaps (and a partially successful mission to recover the first object from space) before they successfully orbited the first operational satellite (Discoverer 14).

The Corona program faced many new engineering challenges and failures involving unreliable boosters. The difficulty of this can be put in perspective when we realize that more than forty years later, although we have come a long way, building reliable boosters for our missile programs continues to be a challenge. Other engineering and integration challenges in the Corona program included: designing a technologically unproven satellite payload and marrying it with a booster; launching a multistage rocket and separating from the payload in space; achieving an orbit appropriate for the mission; operating and orienting optical sensors for maximum effectiveness over the operational lifetime of the satellite; sending telemetry for the successful capture of the film capsule by the recovery aircraft; and protecting the film capsule from reentry to return undamaged film to Earth for processing and analysis.

In each of these historical examples, program support by our national leadership persisted despite frustrations resulting from these technical difficulties, and as a result, these national priority programs made profound contributions to our security. Birthing a revolutionary system and making it useful is a tough engineering job. Given the history of such endeavors, it is unrealistic to expect all development and testing activities to be successful, and to expect all successful programs to remain untainted by failures.

As we continue the development of BMD capabilities, especially to counter the longer-range and more sophisticated threats, we will need to invest in additional equipment and infrastructure to test those systems. This is part of our walk-before-you-run approach. The utility of our existing infrastructure will decline over time as our requirements to test BMD capabilities against more stressing targets grow. If we are to continue our plans to proceed with operationally realistic testing, to include testing against increasingly realistic targets, it is critical that we expand the boundaries of our test ranges: 1) to allow for tests of higher velocity interceptors against longer range missiles; 2) to stress our systems using multiple launches or different target and interceptor launch points; 3) and to replicate a more realistic geometric layout that will allow us, for example, to move our radars forward of the interceptor launch positions in order to expand the battle space. No matter how we proceed in the future, we will require ranges that will allow us to do operationally realistic testing in order to demonstrate missile defense capabilities against longer-range theater ballistic missile and intercontinental ballistic missile targets. I will discuss this further below.

New Enabling Technologies

The legacy of technologies employed in our missile defense systems currently under development can be traced back at least to the 1980s. This means that we have been able to build on the investments and hard work of the previous decades. The development of ground-based sensor elements, such as the X-Band Radar (XBR) and the Upgraded Early Warning Radars (UEWRs), may be traced back to the days of the Ballistic Missile Early Warning System (BMEWS) that was fielded in the 1960s. Since that time, we have made significant advances in relevant technologies, including the development of solid-state Transmit/Receive Modules for X-Band Radars, and in electronics for signal and data processing in our sensors and missiles.

Over the years, we have had great success in miniaturizing technologies relevant to the BMD mission and making them more reliable. Our sensors are becoming smaller and more sensitive. Space-based sensors for early warning trace their lineage as far back as the development of the Defense Support Program begun in the early 1970s. We also have capitalized on subsequent space-based sensor development programs, so that today we look forward to the deployment of very capable Space-Based Infrared Systems (High and Low). Major advances in focal plane array technology and computer processing will allow us to deploy extremely sensitive "eyes" in space and on the ground, on our sensors and on our interceptors. We have also had advances in development of longer-life cryocoolers needed for space infrared sensors.

Similarly, our battle management and advanced information processing and handling capabilities have a legacy going back to early computerized command and control systems like SAGE (Semi-Automatic Ground Environment), which was developed and deployed in the 1950s. Computers are critical to all aspects of the BMD mission, but especially for the battle management function and our highly sensitive radars. Using increasingly fast, small, and powerful computers, the battle-management system we have been developing processes large volumes of data in order to integrate operations, sort through and prioritize tracking and cueing information, and control multiple intercepts.

Non-nuclear ground-based interceptor technologies owe a great deal to the successes we have had since the 1984 Homing Overlay Experiment, when we had the first exoatmospheric intercept with the relatively large and heavy HOE kill vehicle, to include the Exoatmospheric Reentry Interceptor System (ERIS) program, and the current Patriot Advanced Capability-3 (PAC-3) and Theater High Altitude Area Defense (THAAD), and National Missile Defense (NMD) programs. We are now able to develop exoatmospheric kill vehicles and endoatmospheric interceptors today that are smaller and more agile. The advances in on-board computer processing capability; larger and more sensitive infrared focal plane arrays; lightweight cryogenic cooling; lighter inertial measurement instruments; lighter, higher capacity batteries; and miniaturized propulsion all synergistically combine to provide dramatic advances in hit-to-kill capability.

Today's exoatmospheric kill vehicles also leverage advances made in lightweight structures. The HOE kill stage weighed roughly 2,500 pounds. This contrasts sharply with the roughly 120-pound Exoatmospheric Kill Vehicle (EKV) that has been developed for the NMD program. This much smaller and lighter EKV can help us to keep the costs of producing down while increasing lethality potential, range, and speed. Even at this lighter weight, the high speed of the intercepts helps ensure lethality.

Larger, more sensitive focal plane arrays can detect warheads farther away and track them more accurately, allowing earlier corrections of the kill vehicle trajectory toward the intercept point. The dramatic increase in on-board processing capability is essential for processing the flood of data from complex target signatures gathered by these larger focal plane arrays. The enhanced on-board processing combined with the advanced inertial measurement instruments and miniature propulsion thrusters enables rapid, precise adjustments of the kill vehicle trajectory toward the selected aimpoint. We have been able to exploit advanced proportional navigation techniques and smaller, more efficient divert propulsion nozzles for our hit-to-kill interceptors. Furthermore, new capabilities for measuring several different colors or wavelengths in a kill vehicle's optical sensor combined with enhanced on-board processing can dramatically enhance our capability to discriminate between debris or decoys and an actual warhead.

We have made significant technology advances. However, we still have a ways to go in areas such as improved target discrimination algorithms, high speed parallel computer processors for multi-color seekers, and automated battle management decision algorithm development. Of course, as we integrate technology into our systems, we will need increased technical fidelity in our testing infrastructure to verify increases in system performance.

Progress in Hit-To-Kill

We have a lot of work to do in the development of missile defenses. Yet we should not overlook the significant progress we have already made, especially in the area of hit-to-kill technology. Indeed, our experience and progress in technology to date argue strongly that missile defense is technically feasible.

Many of the failures we have experienced to date owe more to challenges in engineering and system integration than to an inadequate technology base. Indeed, when evaluating our progress in hit-to-kill technologies against ballistic missile targets, it is important to understand the unique demands placed on the interceptor in the endgame phase of intercept flight-tests. There is a series of events that must take place for a successful intercept to occur. The endgame is the final part of an interceptor's flight, when the guidance system on the kill vehicle acquires the target cluster, executes terminal guidance and divert maneuvers, sorts the real target from the decoys, and then arrives successfully at its aim point and destroys the target by colliding with it.

The endgame is that phase of the test, in other words, where we actually exercise the hit-to-kill components and software and validate their performance. If we do not reach the endgame, we have no way of testing hit-to-kill performance. A botched launch attempt, a failed booster separation, or the delivery of bad commands from the ground means that we did not put the kill vehicle in the region, or "basket," in the atmosphere or in space where it could begin to perform its operations. We also might have a failure in the launching of a target vehicle or in the deployment of the target suite. These kinds of failures make it impossible for us to test our endgame capabilities.

This is important information to keep in mind when I tell you that, across the board in our missile defense program, our overall success rate in those live hit-to-kill tests when we do get to the endgame is very good. Since 1984 we have performed very well in the terminal homing and intercept phase of the endo- and exo-atmospheric intercept tests when we were able to maneuver the kill vehicle into a basket from which it could find and engage its target. When, all totaled, we reached the endgame 17 times, we hit the target 15 times.

While the PAC-3 lineage extends back into the 1960s, critical testing against ballistic missiles dates only from the 1980s. Since then, we have run 10 missile intercept tests with PAC-3 and its predecessor program, Extended Range Interceptor (ERINT). In tests against theater ballistic missiles, we reached the endgame 10 times, and struck the target 9 times. The miss occurred in our early ERINT missile testing. Similarly, in our test programs to demonstrate our ability to intercept an intercontinental-range ballistic missile, when you look at our success-rate when we reached the endgame, we struck the target 4 out of 5 times. This test record includes test events undertaken in the HOE, ERIS, and NMD programs. In the THAAD program, we failed to reach the endgame in six straight tests. But when we did get the interceptor into the proper basket in the following two tests, we destroyed the target.

Consistent with our desire to demonstrate proof of principle early in the testing program and later test technology and capability, in some of these earlier tests, cooperative targets (where we artificially enhanced the capability of the interceptor to initially find the target) were used. However, in the recent series of tests in the NMD and THAAD testing programs, we used non-cooperative targets to test more rigorously the capability of our hit-to-kill technologies.

Focusing on this success in the endgame is not to dismiss out of hand the other failures we have had in testing our missile defense technologies. We fully recognize that if the kill vehicle does not get to the endgame, we are assured of failure. But what success in the endgame does show is that the critical technologies we require to counter the ballistic missile threat, to hit a bullet with a bullet, are in hand.

In other words, we are not awaiting some technological breakthrough in order to proceed with missile defense development. The feasibility of missile defense and the availability of technologies to do this mission should not be in question. On the basis of several decades of experience, I can tell you today that the technology underpinning missile defense is well understood. What we require today and in the years ahead are constancy of purpose and sound engineering discipline to do the mission effectively, reliably, and affordably.

Progress in Missile Defenses

We are working on a number of fronts to develop BMD capabilities to counter ballistic missiles of all ranges. I would like to focus this morning on the progress we have made to date in our PAC-3 and THAAD systems, and in the NMD system, all of which are ground-based systems for countering, respectively, short-, medium-, and long-range ballistic missiles. I will also look at the progress we are making in our sea-based initiatives, Navy Area and Navy Theater Wide, to counter short-range missiles and intermediate-range missiles, respectively. Please note, however, that the programs I will discuss, and the associated schedules and funding levels, may change as a result of the Secretary's strategy review.

PAC-3

When PAC-3 missiles are delivered later this year, they will provide critical operational capability to defend our forward-deployed forces, allies, and friends against short- and some medium-range ballistic missile threats. It is the only near-term active defensive system for local and limited area defense capable of countering short-range and some medium-range ballistic missiles armed with weapons of mass destruction. PAC-3 is designed to counter enemy defense suppression tactics that may include tactical ballistic missiles, anti-radiation missiles, and advanced aircraft employing saturation, maneuver, sophisticated electronic countermeasures and low radar cross-section.

PAC-3 is the country’s most mature BMD system, and it is by far the most successful to date. The program has a proven record of hit-to-kill success, in part because PAC-3 incorporates mature technologies when compared to our other missile defense efforts, and because this program has had the benefit of constancy in purpose. But the PAC-3 testing program is also a fine example of the disciplined "walk before you run" approach I like to apply to missile defense development and testing generally.

For example, beginning early in this program, managers relied heavily on modeling and simulations in an effort to reduce risk in the PAC-3 flight test program. Over 1000 flight simulations are run before each flight to ensure that any technical issues and other uncertainties are identified and resolved. The PAC-3 program also requires three flight readiness reviews prior to each flight to ensure that the missile and system integration pre-mission analysis and flight test procedures indicate readiness for flight-testing. This approach, in part, accounts for our string of flight-test successes.

PAC-3 also has benefited from a long development history. Leveraging the successes of the earlier ERINT program, in roughly 4 years we were able to go from contract award to the first flight test of a significantly more advanced missile capability. The PAC-3 testing program also is proceeding incrementally by testing against increasingly more difficult targets, so that with each test, new ground is broken. This means that when failure did occur, they were not left with a significant analytical problem to determine what went wrong.

PAC-3 interceptor technology continues to show great promise. Since last year, we have extended the string of flight-test successes. We are now 7-for-7 in body-to-body intercepts against ballistic missile targets. PAC-3 missile technology also accomplished 3-for-3 body-to-body intercepts against cruise missiles and airbreathing threats. This past year, we continued to raise the bar for PAC-3. Successes included multiple simultaneous engagements of both short-range ballistic missiles and cruise missiles using PAC-2 and PAC-3 interceptors. As I discussed earlier, we are well on the way to demonstrating that hit-to-kill technology not only performs, but that it performs consistently. PAC-3 will again be tested against multiple targets this July and October. This year we will deliver PAC-3 interceptors to our training batteries and achieve First Unit Equipped, and we look forward in FY 2002 to the Milestone III Defense Acquisition Board Review authorizing transition from low-rate initial production into full rate production.

Navy Area

We also have been working a sea-based terminal defense effort called Navy Area. Navy Area consists of modifications to the AEGIS combat system deployed on destroyers and cruisers and the SPY-1 radar to enable ships to detect, track, and engage shorter-range ballistic missiles using an updated version of the Navy's Standard Missile. Navy Area will take advantage of the Navy's worldwide presence to provide a highly mobile and responsive capability to protect underdeveloped theaters of operation, early entry forces, seaports of debarkation, and other high value sites. The Navy Area missile is designed with direct hit guidance that provides hit-to-kill performance a large percentage of the time. It uses a blast-fragmentation warhead to ensure lethality in stressing scenarios where direct hit may not be achievable and to engage anti-air warfare threats in defense of the Fleet. Ground-based lethality testing has demonstrated blast-fragmentation warhead effectiveness against a broad spectrum of theater ballistic missile and anti-air warfare threats, including unitary high explosive and bulk chemical warheads.

We are continuing execution of a rigorous set of flight tests this year. The first series of eight land-based flight tests began in June 2000 at the White Sands Missile Range, in New Mexico. To date, two Controlled Test Vehicle flights have been successfully conducted. A Fly-By test is scheduled for Winter 2001, to be followed by a series of intercept flight-tests. At-sea testing will begin in 2002.

In 1999, two AEGIS cruisers, USS PORT ROYAL, and USS LAKE ERIE were augmented with appropriate software and the ability to test-fire the new missile. These "LINEBACKER" ships already have influenced tactical design improvements to the AEGIS combat system. Along with the new Flight 2A destroyers, they will continue to conduct a variety of at-sea tests including live fire events to develop core doctrine and tactics and support our flight-testing activities.

THAAD

THAAD is designed to counter short- and medium-range ballistic missiles. It uses hit-to-kill technologies and can operate in both the endo- and exo-atmosphere. Its extended range relative to PAC-3 and Navy Area, which are terminal defense systems, will allow area defense of critical military assets and population centers. THAAD also provides multiple shot opportunities and, in comparison to other terminal defenses, is capable of engagements farther from targeted areas.

We have learned over the years that when we stray from proven principles of testing we are more apt to fail. In sharp contrast to the PAC-3 program, in 1991 we embarked on a more aggressive approach in the THAAD program without imposing proper discipline. The results showed that the risks we took were just too high.

THAAD was initially working to develop a fielded system that would meet all of its operational requirements in one design and development cycle. At the same time, there was great urgency placed on delivering an interim, emergency capability as soon as possible. The original acquisition strategy included a deployable by-product of the early development program — the User Operational Evaluation System (UOES) — that would have provided for an emergency capability in 4 years after contract award if development had proceeded as originally planned. This schedule pressure, combined with cost overruns, led to shortcuts early on in the design, fabrication, and quality control processes.

These shortcuts proved near-fatal later on as we experienced test failures in the program. Continued schedule pressure led to several program restructures, more test failures, and additional delays. This approach brought too much pressure to bear on the THAAD test events and, given the revolutionary nature of the system we were trying to birth, compressed its test schedule well beyond reasonable limits. In the end, we underestimated the difficulty of developing and fabricating a fully integrated developmental missile, which demands stringent quality and reliability. This led to a string of six flight test failures.

An independent review panel led by retired Air Force General Larry Welch issued recommendations to reduce program risk in a February 1998 report. The panel concluded that we violated the disciplines essential to success in developing and testing complex systems. The technical demands of hit-to-kill require a rigorous ground test program, using high fidelity end-to-end system simulations and analysis to reduce known areas of uncertainty prior to flight. This ground-testing should also include hardware-in-the-loop testing of critical flight hardware. Hardware-in-the-loop testing allows us to test actual hardware in a realistically simulated test or operational environment at the system level. System hardware integration and full-up hardware-in-the-loop tests incorporate models and simulations, which represent the complexities of the BM/C3 computer and communications systems, and provide a higher level of confidence in the tested system's performance than can be achieved in a laboratory or at component level of testing. Higher fidelity is usually only attainable through flight or live-fire testing. Simulations and ground testing in the THAAD program were not nearly adequate, and we paid the price in the flight tests.

We were able to achieve successful intercepts in the summer of 1999 through extraordinary measures by the contractor and government. Recognizing the two flight test successes as evidence that THAAD's fundamental design was sound, the Under Secretary of Defense (AT&L) waived the requirement for a third intercept and initiated preparation for THAAD's entry into Engineering and Manufacturing Development (EMD). THAAD is now executing a more conservative development strategy to provide a phased introduction of capability and a test program that accommodates incremental testing, including the rigorous ground-testing and quality control processes recommended by the Welch Panel.

Lessons learned from the Program Definition and Risk Reduction (PD/RR) phase offered critical input into the acquisition strategy and program planning process. With respect to quality control, an extensive ground test program is complemented by strict accountability procedures at all levels (prime contractor, subcontractor, and vendor) to ensure proven, quality hardware is used during EMD flight-testing.

The development effort is proceeding toward a system-level Preliminary Design Review, which has been scheduled for late FY 2002. THAAD system Critical Design Review has been scheduled for early FY 2004, to be followed shortly by the start of EMD flight-testing. The first intercept flight test of the EMD phase is scheduled for fourth quarter FY 2005.

Navy Theater Wide

NTW is another hit-to-kill system that will provide defense in depth from the threat of theater ballistic missile attack for U.S. and allied forces overseas, critical military assets, population centers, and large geographic regions. NTW takes advantage of available sea room and ship mobility to achieve intercepts of the target in the ascent, mid-course and terminal stages of exo-atmospheric flight.

The NTW program focus is successful completion of the Aegis Lightweight Exo-atmospheric Projectile (LEAP) Intercept (ALI) project. As with our other missile defense development programs, NTW has had its share of correctable problems. The FTR-1 flight test, conducted on 14 July 2000, failed due to a software fault caused by an error in the SM-3 GPS Aided Inertial Navigation Remote Processing Unit. As a result, the second and third stages did not separate. A fault analysis was conducted and the faulty software code was corrected prior to the successful Flight Test Round (FTR-1A) mission.

We began the ALI live fire tests, successfully conducting the first Controlled Test Vehicle flight from USS SHILOH in September 1999. We conducted the FTR-1A mission from USS LAKE ERIE in January 2001. The primary objective of FTR-1A was to demonstrate Standard Missile 3 (SM-3) third stage airframe stability and control through kinetic warhead ejection. The primary objectives were met, and the flight test was a success. Two important secondary objectives were to demonstrate performance of the Third Stage Rocket Motor and to collect SM-3 infrared (IR) seeker data against a live ballistic missile target. Our primary and secondary objectives were accomplished. A live ARIES target was launched for this mission. STANDARD Missile-3 fourth stage IR seeker data were collected, validating the intercept mission modeling, simulations and error budget allocations.

NTW has gone to great lengths to learn from the challenges faced by other missile defense programs. The ALI project has been studied and endorsed several times within the Department. The Director of Operational Test & Evaluation (DOT&E) noted that we were applying lessons learned from the Welch Panel review of hit-to-kill missile defense programs. We have used a methodical approach for conducting pre-flight ground tests to reduce risk and inspire confidence and that we have produced a solid PD/RR program.

One of the current challenges with the ALI project is the completion and testing on the Solid Divert Attitude Control System (SDACS). The difficulties encountered with SDACS, which were discovered during scheduled ground testing, involved the use of rhenium in the design and manufacture of certain components. Additional ground tests were then added to the SDACS testing schedule. SDACS testing began with a series of Developmental Unit tests conducted in 2000 and early 2001. The SDACS is being prepared for a Strapdown Integration Test that will verify all outstanding corrective actions. Certification of performance and safety for shipboard use of the SDACS will follow successful completion of this test.

We plan to conduct our next flight tests in the fall of 2001. The primary objective of this flight test, Flight Mission 2 (FM-2), will be to test the kinetic warhead guidance and control functions against a live ballistic missile target in space. We are finishing ground tests on the SDACS and will have all necessary tests completed and technical issues resolved before the flight date. Successful completion of FM-2 will set the stage for the first intercept tests, which will be conducted in FY 2002. The ALI project, which is scheduled for completion in FY 2002, provides the NTW program with AEGIS Weapons System software and validated missile hardware and software that would be the technical and design basis for the continuation of the NTW program into the Threat Representative Testing phase.

The NTW program conducts a wide variety of risk reduction experiments in conjunction with other services and BMD programs. For example, in March 2001, the USS LAKE ERIE (CG-70) participated in the Quick Reaction Launch Vehicle-1 test in conjunction with the Alaskan Northern Edge exercise. The missile track information the LAKE ERIE collected added a great deal to the NTW Program risk reduction efforts.

National Missile Defense (NMD)

The goal of the NMD development program has been to develop, demonstrate, and deploy a midcourse intercept capability to defend all fifty states against a limited attack involving intercontinental ballistic missiles with countermeasures launched by rogue states, such as North Korea, Iran, and Iraq, and accidental launches from major nuclear powers.

The acquisition approach used in the NMD program has benefited from a series of independent reviews led by General Welch. In the February 1998 report, the independent review team pointed out that, under what was then known as the "3+3" program, there were significant schedule and cost pressures and inadequate test assets that led to an intolerable risk of failure. Like the THAAD program, the panel concluded that NMD managers were accepting too much risk in order to develop the program in three years, and then be ready to deploy three years later. The Department restructured the program in January 1999 to more sharply define requirements and milestones, provide more consistent resource support, and execute a more disciplined testing program with more time between tests.

In 1999, BMDO commissioned a second independent panel headed by General Welch to review the NMD program in light of the new program structure. The panel’s charter was to determine the effects of extending the NMD program by two years and to review the adequacy of the resulting test program. The panel concluded that, although the revised NMD program reduced program risk, it remained a high-risk program. The panel made 18 specific recommendations to reduce program risk further. I supported the panel’s recommendations and added funds to augment NMD testing to pay for additional hardware for the NMD Kill Vehicle, additional test equipment and flight-testing.

In June 2000, before our last integrated flight test, the NMD Independent Review Team (IRT) led by General Welch finished another thorough review of the NMD development program. The IRT identified a number of challenges associated with it but concluded that the technical capability was in hand to develop and field the limited system to meet the projected threat. The team also noted with some concern that the flight test restrictions on trajectories, impact areas, and debris in space restricted our ability to test overall system performance limits. I will address these constraints in a moment.

While the NMD testing program experienced delays in development and testing, our analysis last year showed that ground and flight tests to date have demonstrated about 93% of the system's critical engagement functions and shown the ability to integrate the system elements. We have made good progress. The system elements continue to perform at or above expectations. Our major element sensors, which include the existing Defense Support Program (DSP) satellites, provide early warning and cuing data. In all of our tests to date, DSP satellites have provided the necessary alerts to begin the engagement process. The ground-based radars also have performed within design parameters. The Early Warning Radar has shown repeatedly its ability to acquire and classify the targets, and the prototype X-Band Radar based at Kwajalein has demonstrated good detection accuracy and sensitivity.

Communications are managed by a complex Battle Management Command, Control, and Communications (BM/C3) system that updates the engagement plan several times each minute. The BM/C3 system reaches out to all of the elements, passes data and commands throughout the system and meets our human-in-control requirements. It also has met expectations. Future war gaming will further develop the concept of operations to support the BM/C3 and human-in-control tactics, techniques and procedures. An additional element, the In-Flight Interceptor Communications System (IFICS) transmits the target object map to the in-flight Exoatmospheric Kill Vehicle (EKV). During the last integrated flight test, the IFICS sent accurate target updates to the kill vehicle. Given the separation failure in the interceptor missile, the EKV could not receive and process that data. Our ground tests, however, give us confidence that the IFICS-EKV communications and associated data processing will not pose a significant problem. Finally, based on a successful intercept test, we also have confidence that the EKV can discriminate and differentiate the simulated reentry vehicle from other objects in a simple target cluster and execute internally processed commands to guide itself to the target reentry vehicle and collide with it. We expect future tests to demonstrate that the EKV is equally effective against more complex target clusters.

We have been criticized for not making our targets in the NMD program more realistic with the addition of realistic decoys. But, as I described earlier, our testing program is designed to become increasingly realistic. In general terms, our testing approach is to test individual system components, one by one, and then gradually link them for partially-integrated and, later, fully-integrated flight testing. The tests become progressively more stressful, involving, among other things, greater discrimination challenges, longer ranges, higher closing speeds, and day and nighttime shots.

The NMD flight test program is structured to provide targets of increasing threat realism as testing progresses through developmental to operational testing, within range, safety and test asset limitations. The flight test program began with seeker characterization flights. In integrated flight tests (IFT) 1A and 2, we sought to identify the different capabilities of two competing suites of EKV sensors. The testing objectives for these first two fly-by flight tests were different from and, in some ways, much simpler than the testing objectives of the integrated intercept flight tests that followed because they tested only how well the two competing sensor suites could see the dummy warhead and a number of decoys. The target suite was the same in both tests so we could make a comparison of capability. Hit-to-kill was not attempted. We evaluated each EKV performance on the basis of its ability to collect target data to validate our discrimination capability.

The target clusters released in space for these first two flight tests contained the reentry vehicle, nine decoys, and the target deployment bus. This significant countermeasures package contained more objects than the countermeasures packages we employed during IFTs-3, 4, and 5 because the goal in these first two tests was to evaluate sensor performance, not to evaluate the EKV hit-to-kill capability. Those who have criticized us for using only a single large balloon in subsequent integrated flight tests did not understand this test objective.

Consistent with our early flight test objectives, we dramatically reduced the number of objects in the target complex in subsequent flight tests because our testing objective in IFTs-3, 4, and 5 changed from one of simply seeing and discriminating among the objects to one of maneuvering the EKV at very high speeds and ramming into the warhead's "sweet spot." The IRT had advocated removing all decoys from the first few intercept attempts, so as to concentrate entirely on proving our hit-to-kill technologies. We opted to include at least some discrimination requirement. This meant we added the tougher challenges of seeing the objects, discriminating among them, evaluating them, and selecting the warhead instead of the decoy or rocket stage. Nonetheless, in the last three intercept flight-tests, we were primarily testing our ability to do hit-to-kill. These tests were not set up to evaluate the ability of the system to discriminate a full suite of real world countermeasures.

IFT-3, a partially integrated intercept test, demonstrated our ability to do hit-to-kill as well as on-board discrimination and target selection. Integrated Flight Tests 4 and 5 were our first integrated system tests, and our second and third hit-to-kill tests. Although we failed to achieve an intercept in IFT-4, we did test and demonstrate the integrated functionality of the major system elements, the operation and performance of the ground sensors, operation and functionality of the BM/C3 system, and EKV performance up to the last seconds in its flight. The EKV acquired and tracked the RV and decoy but, because of a plumbing failure in the cryogenic cooling system, the infrared sensors were not able to acquire the target objects until it was too late. The disabled EKV was unable to intercept the RV.

The most recent intercept test took place in July 2000. IFT-5 had the same test objectives and scenario as IFT-4, with one difference. We added the IFICS element designed to facilitate transmittal of message traffic to the EKV from the battle management system. Following the launch of the target missile from Vandenberg Air Force Base, the EKV, mounted atop a surrogate booster, launched normally from Kwajalein and headed toward the projected intercept area. Because the booster and EKV failed to separate, the EKV never arrived to its point of destination, so no interceptor objectives were completed. However, in IFT-5, a great deal more data was gathered on the functionality of all of the other elements, including the IFICS, which was able to send information to the boosting EKV.

IFT-5 was a particular disappointment because it did not substantially advance our knowledge of system performance. The test did support what we learned from previous tests and served to validate the integration of the system. For intercept purposes, IFT-5 did not provide us any more information than we would have obtained from any of our risk-reduction flights.

The important point to take away from the high-profile failures in IFT-4 and -5 is that the troubles associated with each were unrelated, and that the problems were fixable. The problems we experienced reflected process problems in basic engineering and fabrication, not underlying flaws in core BMD technologies or design.

Integrated Flight Test 6, scheduled to occur this summer, will give us the opportunity to do what we had hoped to do in IFT-5. Our objectives are to integrate midcourse elements and functions and demonstrate operation of satellites and radars. We also will demonstrate further the effectiveness of our BM/C3 element and fully test, for the first time, the In-flight Interceptor Communications System as well as our ability to execute the endgame part of midcourse intercept. We have another integrated flight test scheduled for Fall 2001.

As I have stated already, this is a high-risk program for the very reason that a significant failure or delay in one element might not allow the program to meet a near-term deployment date. The delays in operational booster production are a cause of some concern and threaten to be that major problem that could significantly impede development progress. While parts of the booster have been used individually in space launchers, they have never been integrated into one system. We discovered design issues with the thrust vector control system and additionally with a reduced burnout velocity that will require us to look at alternate booster solutions to ensure adequate payload margin. We are aggressively exploring ways to restructure the program to fix these delays and reduce program and schedule risk.

Test Infrastructure

In order to meet the challenges of flight-testing, we use an extensive test infrastructure. Collectively, ground-test, range, sensor, targets, and instrumentation assets, as well as our modeling and simulation and associated analytical support activities, provide valuable program-wide risk reduction and test capability. Missile defense test schedules are complex and use a variety of facilities and ranges spread out across the world, and employ threat representative targets. Each range is equipped with precision instrumentation sensors (radar and optical), telemetry capabilities, and flight and range safety systems. Core supporting ranges include both short- and long-range test facilities with multiple launch sites primarily in New Mexico and over the Pacific Ocean.

Additionally, BMDO deploys mobile airborne sensors to the ranges during flight tests. These airborne optical sensors have onboard signal and data processing and collection capabilities. Airborne sensors are able to collect infrared signature data on ballistic missile target trajectories. We are also developing the next generation airborne sensor platform to help gather important infrared data and phenomenology from our test events.

The complexities and economics of BMD programs introduce unique challenges to flight-testing and, hence, our test infrastructure. These challenges will grow over time as missile defenses are developed to counter threats of greater range, higher velocities, and higher altitudes. Independent review teams have noted with some concern that certain flight-test restrictions reduce our ability to test the overall performance limits of our BMD systems, especially against long-range ballistic missiles. Last year, the IRT noted that the BMD testing program was affected by a variety of fact-of-life test restrictions concerning missile over-flight, impact area, and space debris. The result of these restrictions is that we are permitted to test the system in only a limited part of the required operating envelope.

The testing restrictions that we face and the safety concerns we have are tied to the reality that we must use such an expansive test range to test our defenses against long-range ballistic missiles. The boundaries of the range we currently use cover more than 4,000 miles and extend in a southwesterly direction from the west coast of the United States out over the Hawaiian islands and across the Pacific Ocean, ending in the vicinity of the Kwajalein Atoll, located in the Marshall Islands. Within this range, the trajectories of our target missiles fly well over 100 miles in altitude, reaching outer space. Even though the geographic expanses with which we must work are enormous, the speeds at which our target missile and the ground-based interceptor must travel, which are measured in thousands of miles per hour, mean that the engagements we plan take place within a matter of minutes. You can imagine the challenge that this presents for the tester, who must be able to use distributed launch ranges and sensor assets as well as a far-flung network of element prototypes and surrogates to create stressing testing conditions that approximate as closely as possible real-world engagement scenarios.

Yet even this very large test range is not large enough. Given the truncated flight range from Vandenberg Air Force Base on the west coast to Kwajalein, we must restrain our interceptor velocities in order to stay within the bounds of the Kwajalein Missile Range. Added to this are range safety concerns (that is, the safety of ocean vessels and the populations of Hawaii and the Marshall Islands), which restrict us to a limited number of trajectories and intercept altitudes and velocities that are on the low end of how we would like to test. Thus, we are developing air-launched targets to support our objectives of launching targets with different ranges, conducting flight-tests with more flexible geometries, and undertaking multiple simultaneous engagements. Also, an alternative liquid fuel target booster program would allow us to better emulate threats from boost phase through endgame.

Other restrictions on operational realism will never go away. For obvious reasons, we do not want to test our capabilities to counter a live nuclear warhead. However, other areas of operational realism should and can be tested. We can install, activate and utilize much of the operational satellite and fiber optic communication infrastructure at the proposed test sites. We can build and use as test assets the launch facilities under the same environmental conditions as we would expect in the operational environment. This allows us to respond to DOT&E concerns. It also will allow us to gather data validating reliability and maintainability so that we may incorporate important modifications into the system design.

There are some actions we need to take to either eliminate existing constraints or reduce their impact on our testing program. A significant investment in test range infrastructure, especially for our midcourse capability against long-range ballistic missiles, will be required to achieve tactically representative flight test scenarios. Hardware backups for targets and prototype interceptors also would significantly relieve pressure on the test program by reducing delays owing to component failures. The infrastructure that supports analysis archiving and timely and accurate retrieval of data needs improvement in order to apply results from increasingly complex tests in a more efficient and productive manner.

Since production-representative hardware is not now available, the NMD program uses surrogates and prototypes to support early developmental testing to provide a basis for system functionality assessments. As the elements mature, the prototypes will be upgraded to reflect the production configuration and, in some cases, be replaced by the maturing element. The ground-based radar at Kwajalein (GBR-P) serves as the XBR prototype, receiving software upgrades, until we construct an XBR for the initial system. The Early Warning Radar and FPQ-14 radar represent the UEWR in testing and the FPQ-14 radar, which is also required for range safety, serves as a source of midcourse target information for Weapon Task Plan formulation. The Kwajalein Missile Range, however, needs to be capable of sending data to the continental U.S. in order to reduce manpower and equipment requirements on site. Upgrades are also needed to provide more cost effective range safety capability, enhance the range operations center, missile storage and maintenance facilities, and avoid obsolescence in existing instrumentation.

Test range limitations and the use of surrogates are constantly under scrutiny to determine how to maximize our return on the existing investment while leveraging them to meet future operational test requirements. For obvious reasons, the sooner we can get sensors under development on-line or upgraded, the sooner we can test under more operationally realistic conditions. It is our goal to incorporate more realistic scenarios, including long-range intercepts and intercepts with greater closing velocities, and we are currently addressing ways to do so.

We have taken some steps within our existing budget constraints to upgrade the capabilities of our test ranges. The Pacific Missile Range Facility (PMRF), for example, has been upgraded to support testing of missile defense systems designed to intercept short- to intermediate range ballistic missiles. Upgrades addressed test instrumentation (telemetry and range sensors to collect both radio frequency and infrared metric and signature data) as well as housing and logistics infrastructure to support the personnel and materiel that it takes to conduct our tests. Further PMRF upgrades are planned. In particular, the construction of a Missile Assembly and Test Facility at the Naval Magazine, West Loch, Oahu, is required to provide rocket motor testing, missile assembly and ship-loading capability for our future testing requirements. X-band radars at our Pacific Ranges would support algorithm development, help evaluate effectiveness of BMD countermeasures, support kill assessment, provide truth data for test and target characterization, and provide risk reduction for our systems.

Nevertheless, we will still require the use of a geographically expanded test range that will allow the system sensors and battle management software to be exercised against more threat representative long-range flight trajectories and azimuths. An expanded range and mobile instrumentation assets (radars, optics, telemetry and range safety) are needed to overcome restrictions imposed by horizon limitations and to adequately test the ability of the system to execute multiple engagement opportunities.

In light of the restrictions I discussed above, we can look for other flight opportunities to test BMD elements and use different flight geometries and take advantage of "targets of opportunity" to test the BMD system. While facilities are somewhat austere, Kodiak Island in Alaska has been used to benefit our missile defense programs. For example, in FY 1999 the U.S. Air Force launched two test rockets from facilities on Kodiak Island that released multiple objects on a trajectory that ran along the west coast of the United States. We used these launch opportunities to further test the capability of our west coast EWR. We then took that data and ran an analysis as to how the upgraded early warning radar would have responded. Kodiak would need site improvement to support future mission work.

Although not a substitute for intercept flight-tests, rigorous ground-testing provides us performance assessment in a much broader set of conditions and scenarios than can be addressed in flight tests alone and increases our confidence that we can conduct successful flight tests. Ground test facilities complement our use of range assets and flight-testing. BMDO invests in the development and maintenance of facilities critical to testing component, subsystem, and system-level technologies. For example, we have wind tunnels that provide aerodynamic, aero-thermal, aero-optic jet interaction and shroud separation with full flight capability in a Mach 7 regime. We also have hardware-in-the-loop test facilities that employ state-of-the-art computational resources in environmental chambers with target scene projection systems and flight motion simulators. Our sophisticated target scene projection systems are critical to evaluating the performance of our IR seekers against cool targets in the exoatmosphere, for example, or in the presence of countermeasures. We use a unique ballistic missile range facility to investigate real gas effects on aerodynamic shapes above Mach 12 and to test interceptor lethality against high fidelity targets. Ground test facilities to augment the NMD program include end-to-end processor/hardware-in-the-loop facilities, nuclear environment test facilities, and a real-time test bed distributed across current contractor and government test ranges.

Finally, BMD testing challenges dictate the extensive use of modeling and simulation. Some operational scenarios and conditions are impractical, difficult, or costly to replicate in tests, such as operating in nuclear environments and engaging multiple ballistic missile attacks against U.S. forces or the United States. Other constraints–particularly those related to the physical dimensions of test ranges and the location of fixed test instrumentation–limit flight-testing to a small portion of the performance envelope. While flight tests do provide us the greatest opportunity to test the entire weapon system in a controlled environment, they also allow us to gather data to anchor and update our models and simulations. The modeling and simulation program will continue to mature as part of an integrated test strategy to improve confidence levels and provide timely, accurate information.

Our existing test infrastructure meets most of today's flight-test challenges. To meet the challenges of tomorrow, we must upgrade our capabilities to test with flexibility over greater distances. Test scenarios must accommodate multiple intercepts occurring near simultaneously at realistic intercept geometries. Upgrades will be required in our launch facilities, flight hardware, and range tracking and collection assets. Hardware-in-the-loop facilities must be upgraded and made robust enough to be capable of analyzing yesterday's flight test data while simultaneously predicting tomorrow's expected system-performance. We must continue our extensive use of ground- and flight-testing to ensure robust algorithms are in place to address the evolving countermeasures threat. Modeling and simulations will have to be expanded to cover discrimination, lethality, and kill assessment challenges. And we will have to have quicker reaction in our targets program in order to accommodate changes in threat knowledge and to incorporate countermeasures.

Closing

As with any cutting-edge development program, we must expect setbacks and the possibility that a particular approach we are pursuing is not the right one. Our missile defense program is developing complex systems that will employ the most advanced technologies. We expect steady progress toward success, even though we anticipate we will have test failures–failures are an inevitable part of the development process. Given the integrated approach we desire to take with our missile defenses, and given that many technologies can be shared among the different BMD systems, success for one is success for all. And likewise, the failures we experience in one test can provide lessons learned applicable to all BMD development programs. Indeed, from my standpoint, if we do not fail occasionally, we are not pushing the envelope sufficiently.

I believe, Mr. Chairman, that effective missile defense is crucial to meeting our future defense requirements. The missile threats facing our nation, our armed forces, and our allies are immediate and growing. It will take time to prepare to meet these threats, and testing will continue to be an integral part of the process. Each test provides valuable data, data that goes directly into development of effective missile defenses for our country. We will continue to test our missile defenses based upon the disciplined, proven, and scientific methods learned over more than four decades of missile development, deployment, and operations.

Thank you, Mr. Chairman. I would be pleased to answer any questions you or the Committee Members may have.