NATIONAL MISSILE DEFENSE (NMD)

DoD ACAT ID Program		**Prime Contractor**
Total Number of Interceptors:	100 (capability expanded)	LSI, Boeing North American
Total Life-Cycle Cost (TY$)	Cumulative Cost	
Capability 1 (Expanded):	$29,500M*	
Capability 2:	$35,600M*	
Capability 3:	$48,800M*	
Interceptor Cost (TY$):	$18M	
Deployment Readiness Review:	August 3, 2000	
Capability 1 IOC (program of record)	FY05	

*Assumes an FY05 Initial Operational Capability. These figures are Congressional Budget estimates taken from: *Budgetary and Technical Implications of the Administration's Plan for National Missile Defense, April 2000.*

NOTE: As of the date of preparation of this report, the NMD program is undergoing a revision in acquisition planning and testing strategy. While this may invalidate some of the verbiage herein, the discussions of test results, testing adequacy and limitations, and technological challenges are still relevant.

SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2020

The mission of the National Missile Defense (NMD) system is to defend all fifty United States against a limited strike of Intercontinental Ballistic Missiles (ICBMs). The initial deployment (Capability 1 (C1)) is intended to satisfy the threshold operational requirements and defend against limited attacks by adversaries from "States of Concern" (formerly known as "Rogue Nations) with a residual capability against small-scale unauthorized or accidental launches by the major declared nuclear powers. C1 will deal with a defined set of simple countermeasures and field 20 interceptors. C1-Expanded will be fielded two years later and will add 80 more interceptors for a total of 100 and upgrade the X-Band tracking radar. The NMD system is intended to perform surveillance, detection, tracking, discrimination, and battle management functions, including engagement planning, intercept, and kill assessment, which requires the integration of multiple sensor, communications, command and control, and Ground Based Interceptor elements. Capability 2 will be an upgraded configuration that is intended to cope with more complex countermeasures. Capability 3 would meet the objective values of the User's operational requirements and result in a total fielding of 250 interceptors and add additional launch sites. The objective capability may take an additional five years after the initial deployment of NMD to become fully operational.

The NMD system is an integrated collection of core "elements" consisting of the Battle Management, Command, Control, and Communications (BMC^3) element, Upgraded Early Warning Radars (UEWRs) and an X-Band Radar (XBR), and an arsenal of Ground Based Interceptors (GBI). The system will also be supported by external space-based sensors (the Defense Support Program and Space Based Infrared System satellites). The BMC^3 at the Cheyenne Mountain Operations Center will perform engagement planning and situation assessment while keeping a "human-in-control" and serves to integrate GBI and sensor operations. The GBI is a silo-based, three-stage, ICBM-class missile that delivers a separating Exoatmospheric Kill Vehicle (EKV) to a "deployment basket" above the atmosphere en route to engage a threat Re-entry Vehicle (RV). The EKV employs visible and infrared sensors to acquire and track the target, performs onboard discrimination to select the RV from associated objects, and fires divert thrusters to steer itself to achieve a direct hit on the targeted RV. After the intercept, ground radars continue to collect data on the engagement so that a kill assessment can be made.

By design, NMD embodies the ***Joint Vision 2020*** operational concept of ***precision engagement***: NMD is an integrated system of sub-system elements that relies on ***information superiority*** to provide responsive command and control to engage attacking ICBMs. It performs kill assessment to evaluate the success of an engagement, and is capable of executing multiple engagements. By providing defense for the nation, NMD also incorporates the operational concept of ***full-dimensional protection***.

BACKGROUND INFORMATION

In early 1996, DoD completed a comprehensive review of its theater and national ballistic missile defense programs. The review shifted the NMD program from a Technology Readiness Program (1993-1996) to a Deployment Readiness Program (1996-2003), with the potential for a deployment decision in 2000. The acquisition strategy for NMD was referred to as the "3+3" program.

In spring 1998, the Ballistic Missile Defense Organization awarded the Lead System Integrator (LSI) contract to Boeing North American. The LSI serves as the prime contractor for NMD system development. The LSI contractor will be responsible for integrating the elements of NMD (sensors, interceptors, and the BMC^3) and for demonstrating system capability through integrated ground and flight testing. In December 1998, the LSI selected Raytheon over Boeing as the EKV contractor.

In January 1999, the Secretary of Defense redirected the acquisition of the NMD program to implement a phased deployment approach, based upon technical progress, leading to an operational system by the end of FY05. The revised strategy retained a 4QFY00 Presidential deployment decision based, in part, on the demonstrated technological feasibility of the system to defeat the C1 threat. Prior to this decision, a senior-level DoD Deployment Readiness Review (DRR) would be the basis for a SECDEF recommendation to the President regarding initial steps toward an FY05 deployment of a C1 NMD system, with an option to deploy C1-Expanded by FY07. That DRR would assess the satisfaction of seven deployment readiness decision criteria approved in June 1999 by the Under Secretary of Defense for Acquisition, Technology and Logistics.

The DRR was conducted on August 3, 2000. The specific decisions addressed at the DRR were element site selection, the authorization to award site-construction contracts, and the purchase of long-lead XBR hardware. Two subsequent decision points had also been added on the path to the 2005 deployment. An FY01 decision would consider the building and/or upgrading of required ground radar systems, the integration of command and control software into the Cheyenne Mountain Operations Center, and the purchase of long-lead interceptor hardware. Due to a slip in the testing of the tactical booster, the long-lead interceptor hardware decision cannot be looked at until FY02. An FY03 decision was to determine if the GBI is ready for limited production and deployment. The program is currently being re-baselined and several different options are being considered. As a result, the program planning and acquisition decision milestones may be changed.

On September 1, 2000, the President announced that, based on the information available to him, he could not conclude that there was enough confidence in the technology and operational effectiveness of the entire NMD system to move forward to deployment. He also asked the Secretary of Defense to continue a robust program of development and testing.

TEST & EVALUATION ACTIVITY

The NMD T&E program aims to incrementally demonstrate progress toward C1 capability through integrated ground testing, integrated (intercept) flight testing, risk-reduction flights, digital simulations, and human-in-the-loop command and control exercises. Integrated Flight Tests (IFTs) and Risk-Reduction Flights (RRFs) are conducted between Vandenberg Air Force Base (VAFB) in California and Kwajalein Missile Range (KMR) in the Marshall Islands. Integrated Ground Tests (IGTs) continue to be conducted at the Integrated System Test Capability (ISTC) facility in Huntsville, AL. Battle Planning Exercises and Command and Control Simulations leverage the Joint National Test Facility in Colorado Springs, CO. Additionally, lethality testing is performed at the Arnold Engineering Developmental Center in Tennessee, and the results are combined with those obtained using physics-based hydrocode computer simulations created and conducted by Department of Energy laboratories.

As laid out in the pre-DRR (Phase I) TEMP, which was approved by OSD in December 1999, testing in FY00 focused on the acquisition of data to support the assessment of the deployment readiness criteria as well as on continued system development. This TEMP is in the process of being updated. The post-DRR (Phase II) TEMP will lay out the T&E program from the present to IOC (2005 according to the program of record, but in the process of probable revision) and will provide a detailed T&E roadmap, to include modeling and simulation, for the development of a C1 NMD system. The Phase II document is expected at OSD in 2QFY01.

The flight test program has demonstrated a very basic functionality of a system of NMD surrogates and prototypes. The configuration of the NMD system during the two integrated system flight tests to date (IFT-4 and IFT-5) was, and will remain to be for some time, a limited functional representation of the objective system. Initially using surrogates to approximate NMD elements (as needed), then progressing to prototypes, IFTs are designed to demonstrate potential overall system effectiveness, collect data that address system issues and key technical parameters, and verify the performance of NMD elements. The following table summarizes integrated flight test results executed to date.

Integrated Flight Tests Executed to Date

EVENT	DATE	OBJECTIVES/RESULTS
IFT-1A	June 24, 1997	Non-intercept flight test (fly-by) to assess the performance of the Boeing-built EKV seeker, collect target phenomenological data, and evaluate (post-test) target-modeling and discrimination algorithms. **Test objective achieved – Boeing was not chosen as the NMD EKV contractor**.
IFT-2	January 16, 1998	Non-intercept flight test (fly-by) to assess the performance of the Raytheon-built EKV seeker, collect target phenomenological data, and evaluate (post-test) target-modeling and discrimination algorithms. **Test objectives achieved – Raytheon was chosen as the NMD EKV contractor**.
IFT-3	October 2, 1999	First intercept attempt of a target RV by the Raytheon-built EKV. IFT-3 was an element test of the EKV, not an end-to-end system test, which relied upon a surrogate booster vehicle and range assets to define the "deployment basket" and deliver the EKV to that location. Once deployed, the EKV operated autonomously to intercept the mock RV. BMC^3 and other elements functioned as planned in a background ("on-line") test in parallel with the EKV flight test. **Intercept achieved**.
IFT-4	January 18, 2000	First end-to-end system test (intercept attempt) using NMD prototype elements (except the IFICS) and range assets to approximate the objective system. The EKV was again successfully delivered by a surrogate booster and separated into the "deployment basket." **Although IFT-4 demonstrated the successful operation and integration of NMD elements, an intercept was not achieved**. The failure is directly traceable to the cryogenic cooling system of the EKV, which failed to cool the IR sensors down to their operating temperatures in time because of an obstructed cooling line.
IFT-5	July 8, 2000	Second end-to-end system test (intercept attempt) using NMD prototype elements and range assets to approximate the objective system. A new feature of the test, as compared to IFT-4, was the participation of the IFICS as the communication link between the BMC^3 and EKV. **Although IFT-5 demonstrated the successful operation and integration of the BMC^3 and ground-based radars, an intercept was not achieved**. The failure is the direct result of the EKV not separating from the surrogate booster due to an apparent failure in a 1553 data bus in the booster. No EKV test objectives were met.

In addition to intercept flight tests that the NMD program plans, manages and executes, the NMD Joint Program Office (JPO) and Boeing leverage a series of Risk-Reduction Flights (RRFs). The majority of RRFs are conducted as associated operations with Minuteman III and Peacekeeper Force Development missions. NMD additions to the planned tests are structured to meet IFT risk reduction requirements. There are no interceptors flown during RRFs. The RRFs provide a flight test environment by which each element, in a system configuration context, examines integration with other elements and interoperability with external systems. The RRFs provide a vehicle for testing IFT setups, provide test team training, verify up-range and downrange element integration prior to the IFT, and verify the real-time test procedures. A total of ten RRFs have been flown to date, the last three in FY00. In addition to reducing risk for upcoming IFTs, RRFs are being used to investigate discrimination and countermeasure issues. RRF-9, for example, deployed a total of 22 objects, including an RV, replicas, balloons, and other countermeasures. RRFs typically fly trajectories similar to IFTs, however, some are flown parallel to the California coastline to examine potential UEWR performance in a crossing trajectory.

Computer modeling and simulation will be employed to efficiently repeat hypothetical experiments in order to determine, with statistical confidence, the values of technical performance measures throughout the engagement envelope. Further, digital simulations provide representations of elements that are not mature enough for the flight test program. The principal simulation tool providing system-level evaluation is the LSI Integration Distributed Simulation (LIDS). Late delivery of LIDS Build 4 precluded its use for making a credible assessment of potential NMD system performance in support of the DRR.

Integrated ground tests performed at the ISTC use a combination of models, software-in-the-loop, and hardware-in-the-loop components to test the NMD system to the extent possible in a simulated operational environment. They are intended to validate system functionality and integration between NMD elements, subject the system to stressing environments and operational scenarios, and evaluate tactical intercept boundary conditions. The only IGT conducted in FY00 was IGT-5, a series of runs that were performed during October 19-29, 1999. IGT-5 demonstrated the successful integration of the BMC^3, GBR-P/XBR, and UEWR simulations, but the capability to demonstrate the integration of the simulated BMC^3 with the GBI was not yet available. That function will not be tried until IGT-6. IGT-5 provided a very limited assessment of NMD performance against a sub-set of C1 requirements. Future IGTs will include improvements to the NMD element representations. The LSI is planning on conducting IGT-6 in 2QFY01.

In 2000, NMD continued tests and analyses to develop and accredit the lethality simulations (Parametric Exo-Endoatmospheric Lethality Simulation (PEELS) and hydrocodes) that will be used to evaluate NMD system effectiveness. Activity included twenty 1/4-scale Light Gas Gun data shots against Medium Sized Re-entry Vehicle targets and a number of other tests at Sandia National Laboratories to develop Equations Of State for RV materials.

On April 4, 2000, PEELS 8.1 was accredited by the Accreditation Working Group for the determination of the following system evaluation parameters:

- RV negation.
- Probability of Kill Single Shot.
- Probability of Hitting Target Within Defined Aim Point Accuracy.

- Probability of the NMD System Meeting its Objective.

- Determination of aim point selection to support DRR.

The LFT&E Working Group, a subgroup of the NMD Lethality IPT, is in the process of modifying the LFT&E strategy for NMD, as currently presented. LFT&E activities are expected to include integrated flight testing, quarter-scale light-gas-gun impact testing, and hydrocode simulation analyses. The integrated flight test program is currently scheduled to conduct three LFT&E flight tests, flying targets with representative "threat packages," for lethality assessment.

TEST & EVALUATION ASSESSMENT

Due to its late delivery, immaturity, and lack of validation, the LIDS high fidelity system-level model has not yet been used to make any significant assessment at this time. LIDS Build 4 has been delivered to the OTAs for training and DOT&E will participate in that training.

The IGTs conducted to date are by design being conducted using current configurations of element hardware and software and do not have all of the planned functionality of the C1 design. This has precluded a true assessment of the potential operational effectiveness of the system that is planned for deployment. Of the seven different scenarios examined in IGT-5, only one scenario had nominal performance. Boeing attributed the off-nominal performance in the other scenarios to a lack of maturity of the NMD element representations used in IGT-5. None of the scenarios in IGT-5 were completely operationally realistic. For example, only one IGT scenario to date, by design, featured any countermeasures at all, and those were limited to unsophisticated countermeasures. Additionally, the simulated NMD system in IGT-5 could not process more than about two dozen objects in any one scenario, so much of the target debris was removed from many of the IGT-5 scenarios (in one particular scenario, almost 90 percent of the target objects was removed). The lack of these objects made these thinned scenarios unrealistic for testing discrimination, radar resource management, and BMC^3 processing capabilities.

The flight test program has demonstrated, as indicated above, the basic functionality of the NMD system. The most notable achievements have been the hit-to-kill intercept of IFT-3 and "in-line" participation by the GBR-P, BMC^3, and EWR in IFT-4 and IFT-5. (Additionally, the IFICS was in-line during IFT-5). However, flight tests during developmental testing necessarily make use of surrogate and prototype elements, so the configuration of the NMD system during both IFT-4 and IFT-5 remains a limited functional representation of the objective system.

While a successful intercept during any future flight test will be a significant achievement in the development of the NMD system, it should be seen in the context of the following limitations:

- **Limited Engagement Conditions**. Test target launches from VAFB and interceptor launches from KMR, along with safety constraints, place considerable limitations on achieving realistic engagement conditions with respect to early warning radar tracking, interceptor flyout range, intercept altitude, and closing velocity, as well as other less significant aspects of an engagement. (**NOTE**: *The JPO is investigating alternative intercept flight configurations, which will attempt to achieve longer range and higher velocity intercepts.)*

- **Artificiality/GBR-P Siting**. The prototype XBR (GBR-P), which is located at KMR, is not sufficiently forward in the test geometry to adequately support weapon task planning by the BMC^3. As a result, GPS instrumentation or a C-band transponder on the target RV are used as the principal sources of tracking and identification data for such functions. (**NOTE**: *The JPO is investigating the location of additional mid-course tracking radar to eliminate this limitation.)*

- **Target Suite Reduction**. In addition to the target deployment bus, the target suites flown in IFTs 3, 4, and 5 each contained only two objects (a Medium Re-entry Vehicle and a Large Balloon). The additional two small balloons that had been called out in the 1999 TEMP were eliminated. This was also a significant reduction in complexity from the 1997 TEMP (ten objects for IFTs 3 and 4 and nine for IFT-5, although it is acknowledged that the objectives changed for IFT-3 and 4). The 1999 TEMP number of target elements will not be flown until IFT-8. The 1997 level is not currently planned for any intercept flight test and it does not appear the JPO intends to change that plan. (**NOTE**: *The JPO is looking to refocus the content and purpose of RRFs to increase the level and intensity of countermeasure flight testing.)*

- **Target Suite Complexity.** The current NMD test program is designed to examine a narrowly defined C1 threat space that includes only unsophisticated countermeasures such as simple balloons. The currently defined, most stressing intercept test plans call for using a collection of such simple balloon decoys that approximate the re-entry vehicle IR and radar signatures. However, the missiles currently deployed by the established nuclear powers employ countermeasures that exceed the C1 definition of unsophisticated. The test program needs to broaden the scope of countermeasure testing if it is to quantify not only the "residual" capability that is part of the NMD operational requirements, but also assess the design margin and growth potential of the system design. (**NOTE**: *The JPO is looking to refocus the content and purpose of RRFs to increase the level and intensity of countermeasure flight testing.)*

- **Multiple Simultaneous Engagements**. NMD system performance against multiple targets is not currently planned for demonstration in the flight test program, although multiple engagements are expected to be the norm in NMD system operation. (**NOTE**: *The JPO is now planning for such flight testing and investigating options.)*

- **GBI Booster Testing**. Developmental delays of the tactical booster have pushed boost vehicle testing back about 18 months. As a result, the first use of the operational booster stack in an IFT will now occur in IFT-8 (scheduled for 3QFY02), vice IFT-7 as originally planned. This will defer the decision on the procurement of long-lead interceptor hardware from the FY01 DAB to some later point in 3QFY02.

VALUE ADDED

DOT&E has voiced significant concern about the limitations of testing to date and the robustness of future testing to support a deployment decision for an effective NMD system. The Department is developing revised plans for the NMD program, which is attempting to address those limitations.

RECOMMENDATIONS

The NMD testing program of record was intended to accommodate an aggressive pace of development. However, the program is not aggressive enough to match the pace of acquisition to support deployment and the test content does not yet address important operational questions. Because ground test facilities and models and simulation for assessment are considerably behind schedule, a more aggressive testing program, with parallel paths and activities, will be necessary to adequately stress design limits and achieve an effective IOC by the latter half of this decade. This means a test program that is structured to anticipate and absorb setbacks that inevitably occur. In our DRR Report, DOT&E made a series of recommendations which are discussed below:

- Target suites used in integrated flight tests need to incorporate challenging unsophisticated countermeasures that have the potential to be used against the NMD C1 system (e.g., tumbling RVs and non-spherical balloons).

- Discrimination by the radar and EKV should be given more weight in performance criteria. All other aspects of the NMD performance requirements appear to be within the state of the art of technology. Discrimination by the EKV, on the other hand, will be the biggest challenge to achieving a hit-to-kill intercept.

- Test range limitations need to be removed to adequately test the NMD system; i.e., use of the FPQ-14 range radar tracking the C-band transponder as the source of weapon task planning by the BMC^3 needs to be phased out. Target trajectories or radar locations (GBR-P and UEWR) need to be changed to permit the organic NMD system to provide early radar cueing and mid-course discrimination with the appropriate degree of position and velocity accuracy. It may require significant funding increases to implement this recommendation; however, since the NMD flight testing program is likely to continue for many years until and throughout deployment, the investment to remove this significant limitation seems warranted.

- While the current disciplined testing approach of not firing any flight test until all anomalies from a preceding flight test are thoroughly understood is good traditional engineering practice, an FY05 IOC of an effective NMD system appears unlikely under this paradigm. Program options should consider a much more parallel approach whereby flight testing can continue at an aggressive pace in the wake of a possible failed intercept.

- An innovative new approach needs to be taken towards HWIL testing of the EKV, so that potential design problems or discrimination challenges can be wrung out on the ground in lieu of expensive flight tests. DOT&E strongly recommends the initiation of an intensive effort to develop a flexible, comprehensive HWIL facility with high fidelity target-scene representation for the design and testing of the EKV. The Current JPO plan to leverage HWIL facilities at existing government sites is a good initial step, but the technology and methodology associated with those facilities need to be advanced to create a challenging, realistic, and interactive environment.

Finally, DOT&E recommends that the growth path from Capability 1 to Capability 2 or 3 be rigorously defined and evaluated. A program to reach C2 or C3 will involve more demanding scenarios in a complex operational architecture than that required of C1. The program office needs to ensure that such growth is realizable.