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National Missile Defense and Early Warning Radars: Background and Issues

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National Missile Defense and Early Warning Radars: Background and Issues

Summary

The Clinton Administration is scheduled to decide by Fall 2000 whether the United States should begin deploying a National Missile Defense (NMD) system. This system could achieve initial operational capability by 2005 and would be designed to protect the United States from a limited attack by intercontinental ballistic missiles (ICBMs). As currently envisioned, the NMD system would operate as an integrated system that would rely on a variety of sensors to detect and track incoming missiles. One key program element is to upgrade the existing Early Warning Radars (EWR) so that they can detect and track the incoming missiles sooner. These upgrades include both hardware and software modifications to the existing radars. The earlier detection and tracking allows a "shoot-look-shoot" strategy, i.e., sequential launching of multiple interceptors at each incoming missile to increase the probability of intercept. This report provides background information and technical details of these planned upgrades as well as their cost and schedule.

NMD remains one of the most controversial national security issues. An in-depth analysis of the NMD program and the debate on it can be found in CRS Issue Brief IB10034. Although the EWR have not yet generated much discussion, their upgrades may also become controversial. Members of Congress could focus on the cost and technical capability of the upgrades, on the legality of these upgrades under the 1972 Anti-Ballistic Missile (ABM) Treaty, or on the international implications of the radars that are located outside the United States. This report will address the issues associated with the planned radar upgrades and the related options for Congress.

The early warning radars planned for the NMD system include the three PAVE PAWS radars at Cape Cod, Massachusetts; Clear, Alaska; and Beale, California; and the two Ballistic Missile Early Warning System (BMEWS) radars at Thule, Greenland (Denmark) and Fylingdales, U.K.. The current mission of these five radars is to provide the North American Aerospace Defense Command (NORAD) with early warning and assessment of incoming ICBMs and SLBMs. The upgraded radars will be designed to support the new NMD requirements without impacting their current NORAD mission.

The Administration argues that upgrading current radars provides effective, low-cost sensors for the NMD mission by reusing about 80% of the equipment at the existing radar sites. Due to the radar operating frequency, the upgraded radars could only provide accurate tracking information for a few warheads accompanied by simple decoys. Thus, the Administration argues that these radar upgrades are for limited defense against limited attacks, not total defense against more advanced ICBM attacks.

Contents

List of Figures

List of Tables

National Missile Defense and Early Warning Radars : Background and Issues

Introduction

Background

The Clinton Administration is scheduled to decide by Fall 2000 whether the United States should begin deploying a National Missile Defense (NMD) system. The system under consideration would likely include 100 land-based interceptor missiles currently planned for a site in Alaska. According to the Administration, this system could achieve initial operational capability by 2005 and would be designed to protect the United States from a limited attack by intercontinental ballistic missiles (ICBMs). The system is intended to protect the United States from emerging threats from nations such as North Korea, which, according to intelligence reports, is seeking to develop an ICBM capability. The current plan also envisions the possible deployment of more extensive systems around the end of the decade for protection against more advanced ICBM threats.

At the present time, the prospective NMD system architecture would operate as an integrated system that would rely on a variety of sensors to detect and track incoming missiles. This concept is shown in Figure 1. Space based sensors, Defense Support Program (DSP) satellites at first and eventually the Space-Based Infrared System (SBIRS) High, would detect the launch, alert the Ballistic Missile Command/Control Center (BMC3) of a potential ballistic missile attack, and then cue an Upgraded Early Warning Radar (UEWR) to the incoming missile. When the incoming missile comes within range, the UEWR would begin tracking the target missile to determine if it is a threat. Upon threat confirmation, the command center would direct the launch of a ground-based interceptor and cue the X-Band radar. The X-band radar would then provide tracking data to the interceptor through in-flight targeting updates (IFTU). This tracking data would be used by the interceptor to maneuver close enough to the target so that the interceptor's sensor could discriminate the warhead from possible decoys. The interceptor's sensors would provide the final course corrections so the interceptor could destroy the target.[1]

Launching multiple interceptors at each incoming missile, a "shoot-look-shoot" strategy, is designed to increase the probability of a successful intercept. Because the UEWR could provide earlier detection, track, and classification, these upgrades would enable the multiple shot strategy. This report will provide background information and technical details of the planned upgrades to the existing Early

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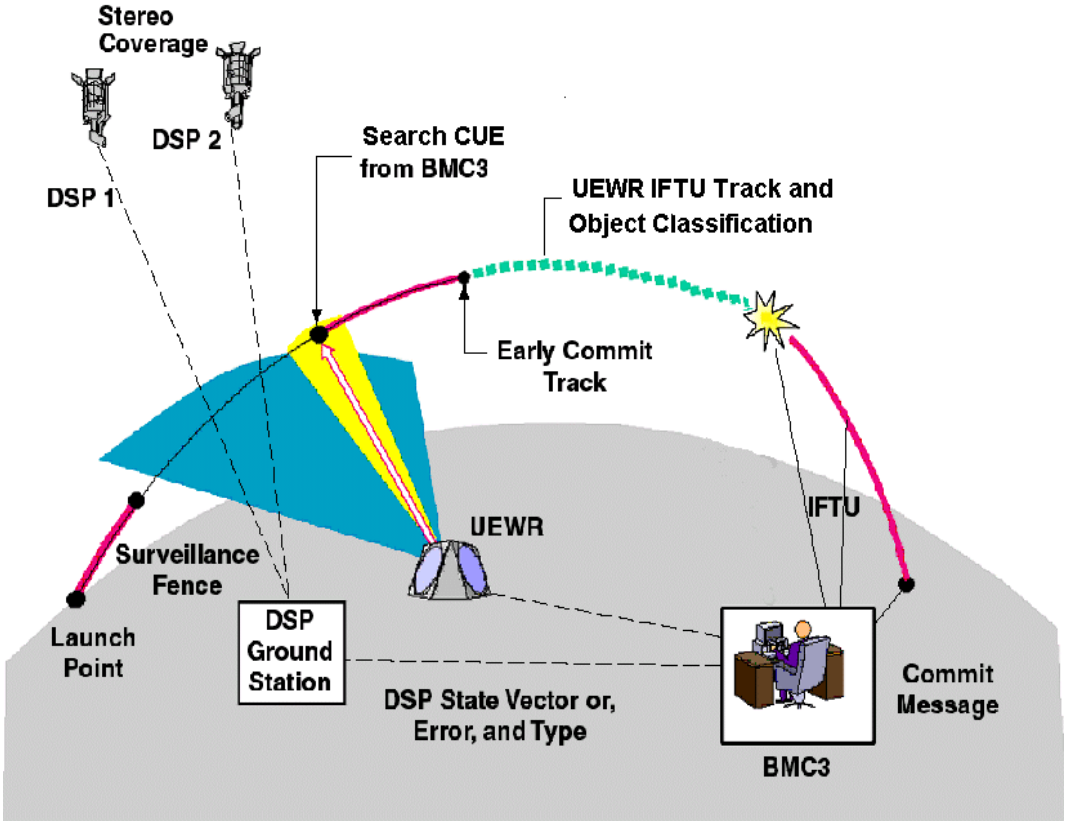
[1] National Missile Defense Program, BMDO Fact Sheet JN-00-05, January 2000.

Warning Radars (EWR). These upgrades include both hardware and software modifications to the existing radars. In addition, new displays would be added to existing interior equipment. There would be no changes to the radar operating frequency, the maximum power output, or the exterior of the existing equipment.[2]

Figure 1. UEWR as an NMD System Element



Issues

NMD remains one of the most controversial national security issues. Details of this program and the debate on it can be found in CRS Issue Brief IB10034. Although the UEWRs have not yet generated much discussion, their upgrades may also become controversial. Members of Congress could focus on the cost and technical capability of the upgrades, on the legality of these upgrades under the 1972 Anti-Ballistic Missile (ABM) Treaty, or on the international aspects of the UEWRs that are located outside the United States. This report will also address these issues associated with the planned radar upgrades.

[2] Early Warning System, BMDO Fact Sheet JN-00-13, February 2000.

Early Warning Radars Upgrades

Current Radars

The early warning radars planned for the NMD system include the three PAVE PAWS radars at Cape Cod, Massachusetts; Clear, Alaska; and Beale, California ; and the two Ballistic Missile Early Warning System (BMEWS) radars at Thule, Greenland (Denmark) and Fylingdales, U.K. These locations are shown in Figure 2. All five radars are solid-state phased arrays. The two BMEWS radars were originally mechanically scanned dish radars but were modified in the late 1980s to phased arrays to improve their reliability.[3] A phased array radar has no moving parts. The Clear radar was originally a mechanically scanned BMEWS system but is currently being replaced with a PAVE PAWS system for increased reliability.[4] The PAVE PAWS equipment came from a non-operational site at Eldorado, Texas. The PAVE PAWS and the BMEWS radars perform similar tasks: long-range, early detection of ballistic missiles. Originally, the BMEWS were for longer range ICBM detection while the PAVE PAWS were for shorter range Sea Launched Ballistic Missile (SLBM) detection. However, the 1980 BMEWS reliability modifications used PAVE PAWS type transmit/receive (T/R) modules and antenna elements so that now both radars have similar performance.[5] The BMEWS radar still has slightly longer range due to its larger size and therefore more T/R modules and antenna elements in each array face.

The current mission of these five radars is to provide the North American Aerospace Defense Command (NORAD) and the U.S. Space Command (USSPACECOM) with early warning and assessment of incoming ICBMs and SLBMs. In addition, these radars track space debris for USSPACECOM.

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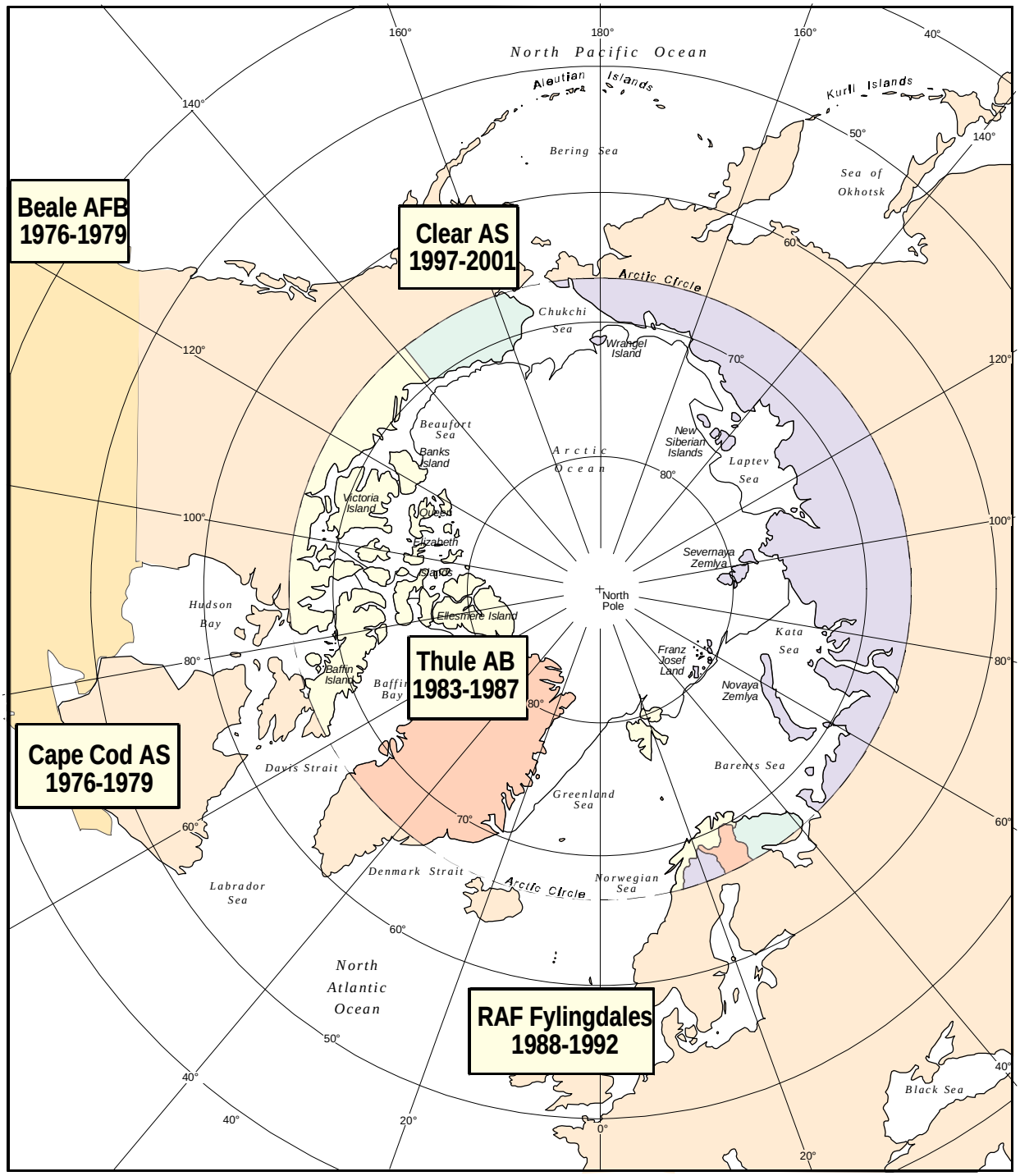
[3] Matthew Bunn, "ABM Treaty and National Security," Arms Control Associates, 1990, pp.100-101.

[4] "Clear Air Station breaks ground on new radar," Air Force News Service, April 21, 1998.

[5] Stanley Kandebo, "NMD Systems integrates new and used components," *Aviation Week and Space Technology*, 3 March 1997, pp. 47-51.

Figure 2. The Five Radar Sites and Installation/Modification Dates



Adapted by CRS from Magellan Geographix.

The BMEWS at Thule and all three PAVE PAWS radars have two array faces. Each array face provides 120 degrees of azimuth coverage and from 3 to 85 degrees elevation coverage in search and track modes. The BMEWS at Fylingdales has three array faces and provides 360 degrees of azimuth coverage.[6] All the radars operate at the ultra high frequency (UHF) band. Figure 3 shows the PAVE PAWS radar and Figure 4 shows the BMEWS radar.

Figure 3. The PAVE PAWS Radar

- **UHF (420-450 MHZ)**
- **Number of T/Rs/Face: 1,792 Elements./Face: 2,677**
- **Number manufactured: 4**
- **Diameter: 72 Ft**
- **Built by Raytheon**

Figure 4. The BMEWS Radar

- **UHF (420-450 MHZ)**
- **Number. T/Rs/Face: 2,560 Elements/Face: 3,584**
- **Number manufactured: 2**
- **Diameter: 84 FT**
- **Built by Raytheon**

[6] "Phased Array: Advances and Future Trends," paper presented by Dr. Eli Brookner at the International Radar Conference, Washington, D.C., May 2000.

Planned Upgrades

The planned NMD system architecture relies on earlier radar detection, track, and classification of targets to enable an earlier launch of its interceptors for the shoot-look-shoot strategy. Upgrades to the existing early warning radars are designed to improve the detection and track range by detecting objects closer to the radar horizon, tracking them with improved accuracy, and then sending the target position and velocity directly to the NMD command system. The upgrades are designed to improve the radar performance in the following specific areas:[7]

- **Acquisition** - Acquire warhead sized objects at longer range
- **Tracking** - Provide precise track estimates to allow earlier interceptor launch
- **Object Classification** - Identify and distinguish between threatening and non-threatening objects
- **Multiple Missions** - Perform the new NMD missions without degrading the current early warning and surveillance missions
- **Command and Control** - Provide real-time communications to the NMD command system in addition to current communication channels

The major hardware modifications planned for the UEWR include replacing the existing computers, displays, and communication equipment with off-the-shelf equipment and developing a new radar exciter receiver. The radar's exciter receiver provides the basic radar transmission signal and then receives and decodes the return signal. The new exciter receiver would provide wider instantaneous bandwidth that allows improved signal processing. This improved signal processing enables the finer range resolution required for improved tracking and object classification.[8] Fortunately, the increased instantaneous bandwidth still lies within the current allocated UHF bandwidth so that additional frequency allocation is not required.

The radar software would be rewritten to include the improved acquisition, tracking, and classification algorithms for small objects near the horizon. The existing software is modular and would be rewritten in seven phases (or builds).[9] The upgraded radar would then be able to search for different types of missiles, distinguish hostile objects such as warheads from other objects, and provide this data to the NMD control system using an improved communications system.

The Administration argues that upgrading current radars provides effective, low-cost sensors for the NMD mission by reusing approximately 80% of the equipment at the existing radar sites. The radiated peak and average power, radar patterns, and operating bandwidth of the upgraded radars remain unchanged from the current radars. Also, there would be no increase in the number of personnel operating the equipment.

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[7] Early Warning System, BMDO Fact Sheet JN-00-13, February 2000.

[8] Discussions with the Raytheon Business Development Office, June 2000.

[9] Discussions with the Raytheon Business Development Office, June 2000.

Table 1 is a summary of the characteristics and measurement capabilities of the current and upgraded radars.[10] As can be seen, the only performance change is the improved instantaneous bandwidth provided by the new exciter receiver that allows the finer range resolution required for improved tracking and object classification. In view of these radar technical characteristics (the UHF operating frequency in particular), the upgraded radars could only provide accurate tracking information for a few warheads accompanied by simple decoys. Thus, the Administration argues that these radar upgrades are for limited defense against limited attacks, not total defense against large scale attacks.

Table 1. The Characteristics and Measurement Capabilities of Current and Upgraded Radars

	Current PAVE PAWS (in Alaska, California, and Massachusetts)	**Current BMEWS** (in Greenland and Britain)	**Upgraded Early Warning Radars**
Frequency	420-450 MHz	420-450 MHz	Unchanged
Antenna Diameter	22.1 m	25.6 m	Unchanged
Average Power (per face)	150 kW	255 kW	Unchanged
Detection Range	5,000 km in search mode	5,000+ km in search mode	Unchanged
Bandwidth	100 kHz (search mode); 1 MHz (track mode)	300-600 kHz (search mode); 5-10 MHz (track mode)	≤ 30 MHz
Range Resolution	1,500 m (search mode); 150 m (track mode)	250-500 m (search mode); 15-30 m (track mode)	≥ 5 m
Angular Beamwidth	0.038 radians = 2.2°	≈ 2.0°	Unchanged
Cross-Range Resolution (for objects at a range of 2,000 kilometers)	75 km	70 km	Unchanged

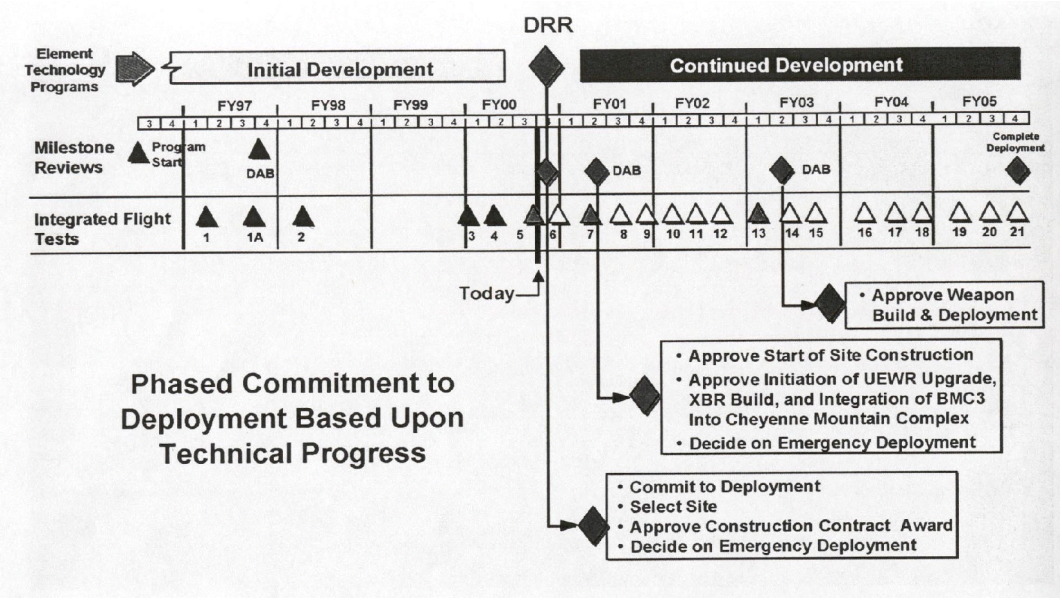
[10] "Countermeasures," Union of Concerned Scientists, MIT Security Studies Program, p. 140, April 2000.

Schedules

NMD Schedule

For perspective, the overall NMD program schedule, as outlined in Pentagon programming documents, is shown in Figure 5.[11] There are three major program milestones, but only the Defense Acquisition Board (DAB) in fiscal year 2001 (FY01) affects the UEWR program. The FY01 DAB approval is required for initiation of the UEWR upgrades.

Figure 5. NMD Program Schedule



UEWR Schedule

Raytheon would perform the majority of the work for the UEWR program. Raytheon also built the PAVE PAWS radars and performed the phased array modifications to the BMEWS radars in the 1980s. Raytheon currently has a contract that continues until April 2001 for the development of the hardware and software upgrades. This development program is on schedule, having completed Phase 1 (Build 1) of the software development and also the Receiver/Exciter preliminary design review (REX PDR) as shown in Figure 6.[12]

The DAB in the third Quarter of FY01 would authorize Raytheon to complete the development and then the deployment of the radar upgrades. Figure 6 shows the total UEWR program schedule, including the software development (7 phases or builds), the hardware development, the testing, and the deployment. As can be seen, the UEWR schedule in Figure 6 corresponds with the NMD schedule in Figure 5. The majority of the UEWR program is after the UEWR critical design review (CDR) and the NMD DAB in the third Quarter of FY01.

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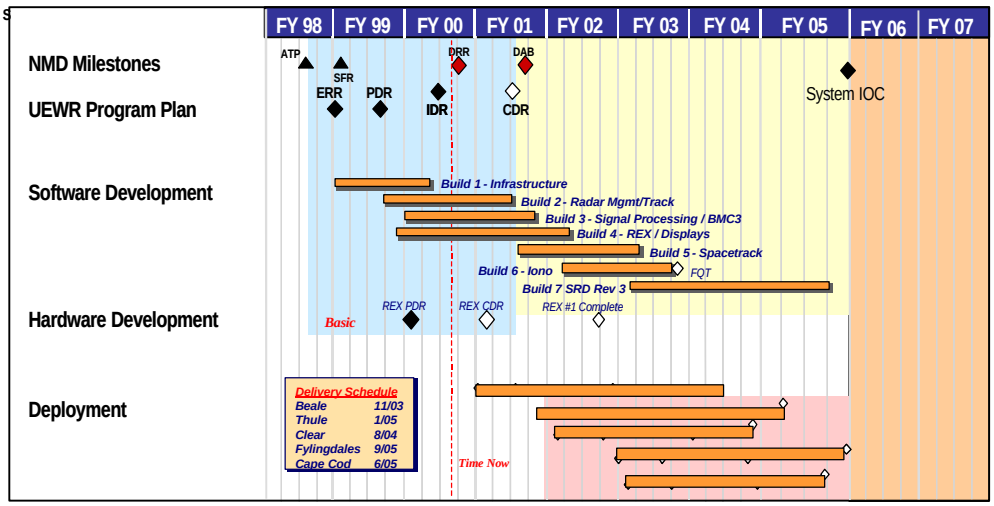
[11] Boeing Briefing Booklet for IFT 5, p. 33, July 2000.

[12] Discussions with the Raytheon Business Development Office, June 2000.

Figure 6. UEWR Program Schedule



Cost

For several years, the Clinton Administration estimated that a limited NMD system would cost $9 to $11 billion to develop, test, and deploy. In January 1999, the Administration included $10.6 billion in the Future Years Defense Program (FYDP) to cover the cost of developing and deploying an initial system of 20 interceptors. In February 2000, the Administration provided a life-cycle cost estimate of $26.6 billion for an initial system of 100 ground-based interceptors, presumably in Alaska. Even more recently, the Pentagon provided a life-cycle estimate of $30.2 billion for the NMD system ($FY1991). As time passes and more detailed assessments are completed, these numbers are likely to change.

Table 2 gives the latest estimates for both the UEWR program and the NMD program. It includes the Administration estimate and the Congressional Budget Office (CBO) estimate.[13] As can be seen, the UEWR program is approximately 4.5% of the total NMD program. Also, the CBO estimate for the UEWR is very close to the Administration estimate which implies that CBO does not believe there is much cost risk or technical risk in the UEWR portion of the NMD program.

Table 2. Cost Estimates for the UEWR Portion of the NMD Program

	Administration Estimate	CBO Estimate
UEWR	$1.2 B	$1.3 B
NMD total	$30.2 B	$29.5 B
% UEWR	4.0%	4.4%

[13] "Budgetary and Technical Implications of the Administration's Plan for NMD," CBO paper, April 2000.

Table 3 shows the planned funding profile for the UEWR program.[14] The funding profile is based on constrained funding in FY01. The funding requirement then increases significantly in FY02 through FY04 to accomplish development and procurement for initial operating capability in 2005. This increased funding would come after the UEWR authorizing DAB in third Quarter FY01. Lesser funding levels after 2005 would be required to sustain additional software modifications as required.

Table 3. Funding Profile for the UEWR Program
(in millions of dollars)

	Priors	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	Total
Development	154	121	131	89	64	18	2			$579M
Procurement		7	152	318	128	22	3	3	3	$636M
Total	154	128	283	407	192	40	5	3	3	$1215M

Issues for Congress

Cost and Technical Risks

As described earlier, the upgrades to the existing early warning radars would require few technical breakthroughs and therefore are considered relatively low risk (both technical risk and cost risk). Raytheon built the original PAVE PAWS radars and performed the phased array modifications to the BMEWS radars in the 1980s. They have developed similar hardware and software upgrades. Raytheon is under contract for the initial hardware and software development. If the upgrades are approved, follow-on UEWR contract funding would be required in April 2001 to meet the planned schedule. The only major cost risk is a break in contract funding, which could delay the program and therefore increase the program cost.

One technical risk area is the available time-line to accomplish both the NMD target tracking requirements and at the same time maintain the current early warning and assessment surveillance for other possible incoming ICBM's. Current analysis shows that both these tasks can be accomplished in the available time-line, but this is an area for continual monitoring.

ABM Treaty Issues

The plans to upgrade the existing early warning radars and to integrate these into the NMD system could raise questions about compliance with the 1972 ABM Treaty.[15] This Treaty draws a sharp distinction between ABM radars, which are

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[14] Discussions with Congressional Budget Office, June 2000.

[15] This report recognizes the debate over whether the ABM treaty remains in force due to the dissolution of the Soviet Union. However, because it remains the U.S. policy to abide by the

radars "constructed and deployed for an ABM role, or of a type tested in an ABM mode"[16] and early warning radars, which simply provide warning of strategic ballistic missile attack. The Treaty states that ABM radars or ABM radar complexes must be located within the ABM system deployment area, which must have a radius of no more than 150 kilometers.[17] It also states that the parties are not to give radars, other than ABM radars, capabilities to counter strategic offensive ballistic missiles, and not to test radars, other than ABM radars, in an ABM mode.[18] Essentially, this means that non-ABM radars, i.e., those located outside the 150km radius of the permitted ABM site, cannot provide tracking and intercept information to the battle-management network for the ABM system and they cannot be tested in conjunction with the other components of the ABM system. But this is precisely what the United States intends to do with the upgraded early warning radars. This issue will have to be resolved at some point if the ABM Treaty remains in force.

A second Treaty issue that might come up as the United States upgrades the radars in Greenland and Great Britain is the Treaty's provision that *future* early warning radars must be deployed on the periphery of the nation's territory and must be oriented outwards.[19] Because the radars at Thule and Fylingdales were in place prior to the signing of the ABM Treaty, they were grand-fathered into the Treaty and are not considered to be a Treaty violation. When the United States modified the radars in the late 1980s, the Soviet Union objected on the grounds that the modifications and new construction altered the facilities enough to create "new" radars, that, according to the treaty, could not be located anywhere except on the periphery of the United States. However, because the modifications were intended to improve the reliability and operations of the radars, and did not alter their capabilities, the United States argued that the radars remained consistent with the terms of the ABM Treaty. The two nations addressed and resolved this issue in the Standing Consultative Commission (SCC), a body established by the ABM Treaty to address compliance issues. The United States could take a similar position this time, and argue that even though the upgrades alter the capabilities of the radars (arguably prohibited by the Treaty), the facilities remain where they were prior to the signing of the ABM Treaty, and, therefore remain consistent with the Treaty. Russia is likely to question whether the upgrades are enough to create "future" early warning radars, and the two nations could, again, address this issue in the SCC.

A third ABM Treaty issue raised by the plans to upgrade the early warning radars comes from the Treaty's provision stating that "each party undertakes not to

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Treaty (neither the Executive Branch nor the Senate have determined otherwise), this report examines the planned radar upgrades in the context of the Treaty.

[16] Treaty between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems (ABM Treaty). Article II, para 1(c). Reprinted in United States Arms Control and Disarmament Agency. Arms Control and Disarmament Agreements; Texts and Histories of the Negotiations. Washington D.C. 1990. p. 157.

[17] ABM Treaty, Article III.

[18] ABM Treaty, Article VI.

[19] ABM Treaty, Article VI.

transfer to other states, and not to deploy outside its national territory, ABM systems or their components limited by this Treaty."[20] If the radars at Thule and Fyingdales are upgraded and integrated into the U.S. NMD system, then the United States will have deployed ABM systems or components outside of its national territory.

The Clinton Administration has recognized that its plans to upgrade the early warning radars so that they can be integrated into the NMD system would be inconsistent with the current terms of the ABM Treaty. It has raised this issue in its discussions with Russia on possible modifications to the treaty. In the Protocol that the Administration presented to the Russians in January 2000, the United States reportedly proposed that the United States and Russia be "permitted to enable strategic ballistic missile attack warning radars in existence on December 1, 1999 to perform ABM radar functions to support the limited territorial missile defense system"[21] In other words, the United States realizes that it would need to alter the treaty's ban on giving non-ABM radars ABM roles, and its ban on deploying these components outside its national territory to accommodate the upgrades to the early warning radars.

Russia has, thus far, refused to discuss specific proposals for modifications to the ABM Treaty, either to permit the United States to deploy an NMD system in Alaska or to include its early warning radars in the architecture for that NMD system. If Russia does not agree to these modifications, then the United States would violate the ABM Treaty if it completed the upgrades to the early warning radars and tested these radars in conjunction with tests of other components of the NMD system.[22] Because other elements of the U.S. NMD program could lead to conflicts with the ABM Treaty at an earlier date than the upgrades to the early warning radars, it is possible that the United States and Russia would have resolved their differences, or that the United States would have decided to withdraw from the treaty, prior to the date on which the radar upgrades violated the treaty. On the other hand, it is possible that Russia might eventually agree to permit the deployment of a limited NMD site in Alaska without agreeing to alter the Treaty's ban on the use of early warning radars in an ABM mode. In that case, the United States would have to decide whether to proceed with the upgrades and violate the treaty, or to cancel the upgrades and accept a less capable NMD system.

International Issues

The upgrades planned for the early warning radars at Fylingdales and Thule not only raise ABM Treaty compliance issues but may also cause some friction between the United States and its allies in Europe. Many European nations have questioned

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[20] ABM Treaty Article IX.

[21] This document was obtained by the Bulletin of the Atomic Scientists from sources in Moscow. The text of the Protocol, along with U.S. analysis and talking points for the discussions were published in the Bulletin of the Atomic Scientists and posted on the magazine's internet site. See {http://www.bullatomsci.org}

[22] It is not clear that the upgrades, alone, would violate the Treaty if the United States continued to use these radars only in an early warning role.

the U.S. plans, arguing that, by undermining the ABM Treaty, the NMD system could undermine the whole U.S.-Russian strategic relationship. Some U.S. allies have also questioned the U.S. assessment of the threat posed by nations seeking to acquire ballistic missiles, and have suggested that diplomacy or arms control, rather than missile defenses, could mitigate this threat.

The United States would seek to reach agreement with the governments of Denmark and Great Britain before it modified the early warning radars on their territories and included the radars in the U.S. NMD system.[23] Some officials in both nations have voiced opposition to the U.S. NMD system. In early August, the House of Commons Foreign Affairs Committee issued a report that outlined British concerns with the U.S. plans. The report stated that the United States "cannot necessarily assume unqualified cooperation" from Great Britain. The report specifically noted that the committee was concerned about the negative effect that NMD deployment might have on arms control efforts.[24] Officials in Denmark have expressed similar concerns. They issued a statement in February stating "the government continues to desire that the use of the Thule radar does not contravene international agreements in force."[25] The challenge in both countries, with regard to the radar upgrades, will be to balance domestic concerns with their U.S. partnership.

The United States continues to press this issue with Great Britain and Denmark. In testimony before the Senate Armed Services Committee in late July, 2000, Secretary of Defense Cohen stated that the United States would need the support of its allies to successfully deploy an NMD.[26] If the U.S. cannot upgrade and integrate the radars at Thule and Fylingdales into the NMD system, the United States might have to accept a system with reduced capabilities until other alternative early warning systems can be developed.

Options for Congress

At present, cost and technical challenges for the radar upgrades appear less controversial than ABM Treaty issues and international issues. The latter two issues could spark more detailed and complex public discussion on the planned radar upgrades.

Congress has not directly addressed the radar upgrades and their implications. Supporters of the ABM Treaty may eventually seek alternatives. Some may seek to suspend the program or eliminate funding for the upgrades until the United States and Russia resolve the issues related to the ABM Treaty. Alternatively, funding for the

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[23] "U.S., Denmark discuss Missile Defense", Washington Post, August 23, 2000, p. 19.

[24] Tom Buerkle. U.K. Panel Questions U.S. Missile Shield Plans. Commons Committee's 'Warning Shot' Puts British Aid in Doubt. *International Herald Tribune*. August 3, 2000, p. 1.

[25] Gopal Ratnam and Amy Svitak. Pentagon Eyes Naval Deployment Of NMD Radar. *Defense News*, August 21, 2000. p. 1.

[26] Hearing before the Senate Armed Services Committee, July 25, 2000.

program could remain in the budget, but the next Administration might be required to report on progress in the negotiations, on possible alternatives if the negotiations fail, or on U.S. intentions to withdraw from the ABM Treaty if the negotiations fail before it permits the new President to spend additional funds on the radar upgrades. Others may argue that Treaty issues should not affect plans to upgrade the radars, either because they believe the United States should withdraw from the ABM Treaty or because they believe that the ABM Treaty lapsed after the demise of the Soviet Union.

If the governments in Great Britain and Denmark remain skeptical about U.S. plans for NMD and continue to question the implications of the upgrades to the radars on their territories, the issues raised by the radar upgrade effort could receive more attention in Congress and could generate discussion in the next Administration on altering the plans for both the radar upgrades and the NMD program. However, the United States could operate the limited NMD system without the radars at Thule and Fylingdales. Many analysts believe that the three UEWRs in the United States would provide adequate coverage for missile attacks from East Asia, although these three radars would not be sufficient to track and identify possible missile attacks from the Middle East. Another option for the end of the decade would be a space-based infrared-radar system (SBIRS-low), which would provide a spaced based early warning, track, and identify capability. While some analysts may believe the United States should delay its NMD program until the U.S. receives approval from Great Britain and Denmark to upgrade the early warning radars on their territories, others may argue that the United States should proceed regardless, and seek alternative technologies to enhance the capabilities of the system if required.[27]

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[27] According to some experts, the Pentagon is exploring the possibility of basing a version of the land-based NMD radar at sea as an early warning radar if Great Britain does not permit upgrades to the early warning radar at Fylingdales. See Gopal Ratnam and Amy Svitak. Pentagon Eyes Naval Deployment Of NMD Radar. *Defense News*, August 21, 2000. p. 1.

Appendix: List of Acronyms

ABM	Anti-Ballistic Missile
BMC3	Ballistic Missile Command/Control Center
BMDO	Ballistic Missile Defense Organization
BMEWS	Ballistic Missile Early Warning System
CBO	Congressional Budget Office
CDR	Critical Design Review
CRS	Congressional Research Service
DAB	Defense Acquisition Board
DSP	Defense Support Program
EWR	Early Warning Radar
FY	Fiscal Year
FYDP	Future Years Defense Program
ICBM	Intercontinental Ballistic Missiles
IFTU	In-flight Targeting Update
NMD	National Missile Defense
NORAD	North American Aerospace Defense Command
PAVE PAWS	Air Force Nomenclature for Phased Array Radars
PDR	Preliminary Design Review
REX	Receiver Exciter
SBIRS	Space-Based Infrared System
SCC	Standing Consultative Commission
SLBM	Sea Launched Ballistic Missile
T/R	Transmit/Receive Modules
UEWR	Upgraded Early Warning Radar
UHF	Ultra High Frequency
USSPACECOM	United States Space Command