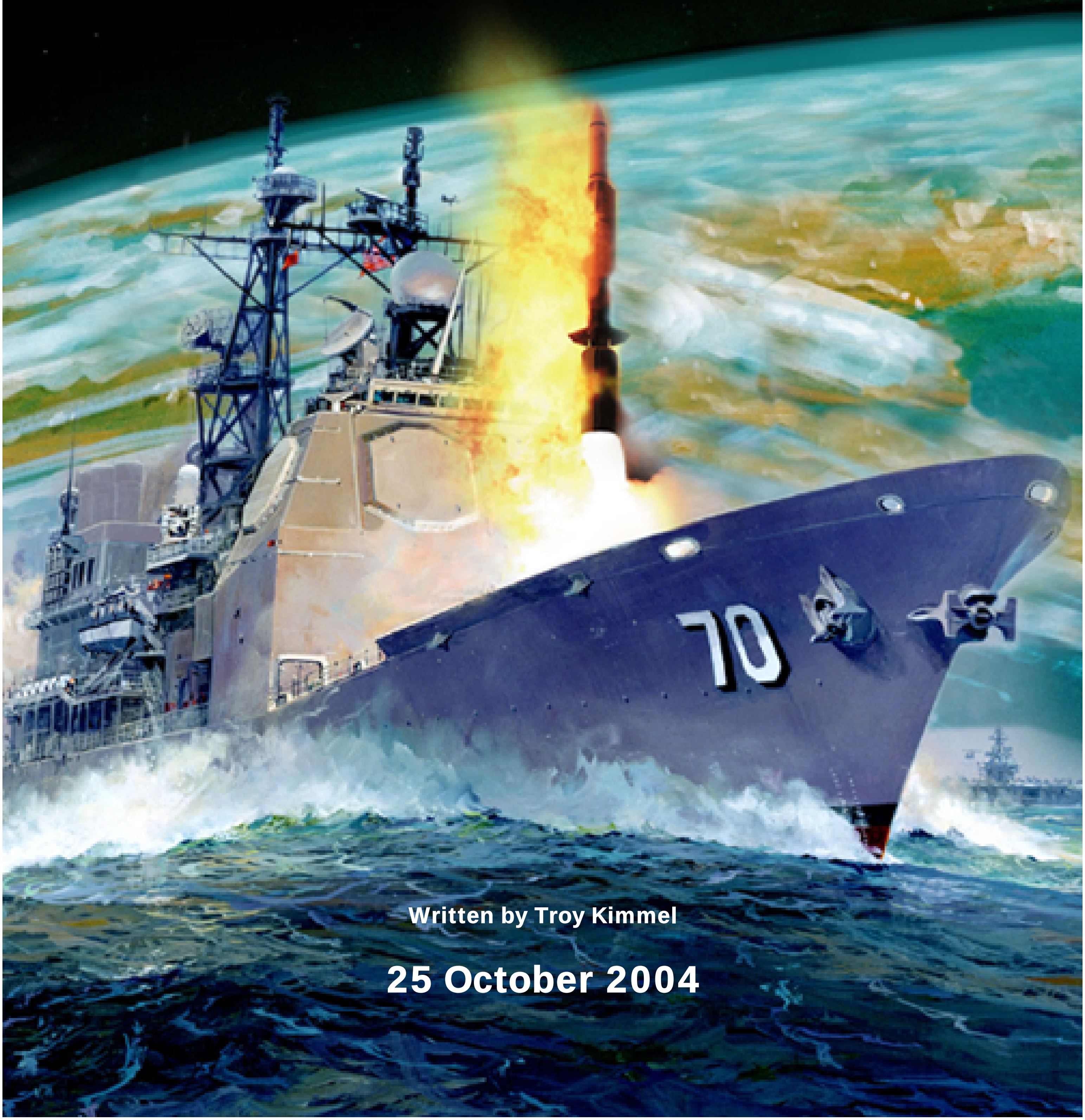
AEGIS LEAP Intercept
A Pioneering and Historic Project

Brought to Closure Under the Leadership of CAPT P. M. Grant III



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25 October 2004

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FOREWORD

This report is a summary of the AEGIS LEAP Intercept Flight Demonstration Project, known colloquially by those involved as "ALI". The ALI project had its origins in 1990 with the first funding of Navy ballistic missile defense studies by the Strategic Defense Initiative Organization. The TERRIER LEAP Technology Demonstration Program followed, but unfortunately was not successful. Following TERRIER LEAP, the ALI project was born, and would attempt to demonstrate the intercept of a ballistic missile using a STANDARD Missile launched from an AEGIS Cruiser. Six years passed from the first official approval for the project until the first intercept test, which fortunately proved successful.

The challenges that the ALI team faced along the way were vast. Funding battles, contract consolidations and negotiations, ground test failures, competition with other programs, flight test failures, reorganizations within both government and industry, manufacturing problems, and Washington politics are but a few. These challenges, when viewed against the backdrop of the project's complexity, provide a true sense of how much time and effort a major weapons systems development requires. Planning for each flight test involved the coordination of hundreds of people and dozens of organizations. Allocating the funding for all of the ALI efforts was a full time job (and then some) for many. Engineering, producing, and testing equipment and computer programs for flight tests required the talents of literally thousands of people.

A project of this magnitude required more than just an experienced manager to make it succeed, it needed a true leader. That leader was found in 1997 when CAPT Peter M. "Mac" Grant III became the Program Manager. A newly promoted Captain at the time, Grant received the equivalent of a doctoral degree in leadership during his five years at the helm of this project. One of the greatest lessons that he learned was that he couldn't do everything himself. To assist him, he recruited LCDR Brian Gannon to be the ALI Project Officer in 1998. LCDR Gannon, later promoted to Commander, proved to be an excellent leader as well, building an organization under him that ultimately achieved three missile intercepts in a row, an achievement unparalleled in ballistic missile defense testing.

What follows is combination of the technical and programmatic history of ALI, not the entire Navy Theater Wide Program. It is impossible to include every important decision or the name of every major participant in the program with only thirty pages, if the text is to remain a readable size. While this is only a summary, hopefully it could provide the skeleton of a much larger work that could someday chronicle the entirety of the project's effort. The story could easily fill a novel, and should be required reading for major program managers within the Department of Defense. It is a story of leadership overcoming adversity, of incredible technical achievement, and of what is required to execute a large, challenging project in a democracy.

Enjoy.

The AEGIS LEAP Intercept Project – How It All Began

January 1991 – The USS Mobile Bay, an AEGIS guided missile cruiser, was on station in the Persian Gulf conducting anti-air warfare operations in support of Operation Desert Storm. Her powerful SPY-1 radar was radiating far into Kuwait and Iraq searching for and tracking enemy and friendly aircraft. An unknown object was detected and tracked, flying a course that no plane, friend or foe, could possibly fly. The cruiser's SPY-1 radar had detected and tracked an Iraqi SCUD ballistic missile in flight, and the geometry of the ship and the missile were just right to allow the AEGIS Weapon System to maintain track, without rejecting the object through its series of velocity and altitude filters.

Magnetic tapes onboard with recorded data documenting this event were removed and analyzed, and soon the event was being briefed to senior Navy and Defense Department officials around Washington. By September 1991, the Director of the Strategic Defense Initiative Organization (SDIO), Ambassador Cooper, asked to be briefed on the ballistic missile defense philosophies of the three military services. VADM J. D. Williams, USN attended this meeting on 16 September as the senior Navy representative, and Deputy Assistant Secretary of the Navy Ned Donalson briefed Ambassador Cooper on how the Navy could contribute to ballistic missile defense. He used the real-world experience of the USS Mobile Bay to punctuate his arguments.

The Navy had already begun to investigate its potential for contributing to ballistic missile defense after the SDIO provided PMS 400, the AEGIS Project Office, $5M for initial Theater Ballistic Missile Defense (TBMD[1]) studies the previous year, in 1990. CDR Stan Groenig was assigned as the first Navy TBMD project manager, and quickly got to work on concept studies. Another boost to Navy TBMD came when the Naval Research Advisory Council released its report "Anti-Tactical Ballistic Missile Requirements in the 2010 Time Frame[2]" in November 1991, confirming the need for the Navy to develop anti-ballistic missile capability for force protection, and possibly self-defense in the future.

In December 1991, the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN(RD&A)), Jerry Cann, decided to move Navy TBMD program management responsibilities from PMS 400 to the Strategic Programs Direct Reporting Program Manager (known as "SP"). His rationale was that SP knew the problems of ballistic missiles (they developed and supported all submarine-launched ballistic missile programs in the Navy), and the current TBMD manager, the AEGIS Project, was too busy building cruisers and destroyers – and TBMD would defocus them[3].

By early 1992, emboldened by the USS Mobile Bay experience and increased SDIO and Navy interest in TBMD, the idea of a technology demonstration was being briefed

[1] Under the terms of the 1972 Anti-Ballistic Missile Defense Treaty between the United States and the Soviet Union, sea-based national missile defense was prohibited, but shorter range "Theater" ballistic missile defenses were not..
[2] Executive Summary of this report available at appendix B.
[3] Worthy of note is that ballistic missile defense had been investigated for AEGIS during the Advanced Surface Missile System (ASMS) Study *in 1965*, but dismissed - ballistic missiles not being a threat to the fleet was the reason.

around the halls of the Pentagon[4] by a visionary Navy Captain assigned to the SDIO named Rodney P. Rempt[5]. The plan was to use a SDIO-developed "kinetic kill vehicle" or KKV called the Light Exoatmospheric Projectile, or LEAP[6], launched into space by a Navy TERRIER missile[7] and 3rd stage "Advanced Solid Axial Stage" or ASAS rocket motor from a ship at sea to hit a ballistic missile target. The Director of SDIO approved the demonstration, and funding was released to begin work on the "TERRIER LEAP" project in 1992.

The TERRIER LEAP Project

CAPT Bill Bassett was the program manager in SP running the Navy side of the TERRIER LEAP Project, while the SDIO-funded ASAS and LEAP development efforts were directed by Mr. Rich Matlock.

In designing the demonstration, a key planning factor was the desire to quickly show an intercept of a ballistic missile. Five flight tests were planned (called Flight Test Vehicles or "FTVs"). The first two would be missile characterization flights, the next two would be KKV characterization flights using a live target, and the fifth and final flight would be an intercept attempt against a live target. Each kinetic kill vehicle characterization flight would use a different design, as there were two separate LEAP designs built by two different contractors, Rockwell and Hughes. The intercept flight test (FTV-5) would use the best LEAP design based on analysis of the two previous FTV tests.

The modified STANDARD Missile II Block III Extended Range (SM-2 Blk III ER), also known as a TERRIER missile, consisted of four stages: the unguided Mk-70 booster 1st stage, the inertially-guided and aerodynamically controlled Mk-30 sustainer 2nd stage, the Global Positioning System/inertially guided/thrust vector controlled ASAS 3rd stage, and the infrared-homing Light Exoatmospheric Projectile Kinetic Kill Vehicle 4th stage. The 1st stage is unmodified from the tactical configuration. The second stage is modified to allow stable flight at high altitudes, with a changed weapon system interface to support different initialization and uplink messages for range safety. 3rd and 4th stages were entirely new – replacing the tactical STANDARD missile homing guidance systems and warhead.

The demonstration utilized a TERRIER New Threat Upgrade (NTU) weapon system modified to utilize target tracking information from a remote location – supplied to the ship via a satellite communications link. Additional modifications to the weapon system tactical configuration were required for range safety considerations. Safety modifications required continuous data uplinks to the missile beginning at 4 seconds after launch.

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4 The beginnings of the Navy Area or Navy Lower Tier program were also occurring at this time – but is not covered in this report.

5 CAPT Rempt was a Surface Warfare Officer and had commanded the USS Bunker Hill prior to being assigned to the SDIO.

6 The LEAP vehicle required ordnance waivers for use onboard Navy ships. Its divert and attitude control system used a hypergolic propellant, which causes shipboard health risks to sailors in the event of leakage (hypergolics are highly toxic).

7 TERRIER Missiles (Also known as STANDARD Missile II Block III Extended Range) are tactical anti-air warfare missiles, and were part of the Navy inventory in 1992.

Several aspects of LEAP operation had already been proven during the SDIO's Minuteman LEAP technology demonstration, including target acquisition and track by the LEAP's infrared (IR) seeker, and attitude control. No target intercepts occurred during these tests, however.

The first test of the series, FTV-1, was successfully executed on 24 September 1992 at the Atlantic Fleet Weapons Training Facility (AFWTF) off of Roosevelt Roads, Puerto Rico. This test flight demonstrated the flight characteristics of a Navy TERRIER missile, launched from the cruiser USS Richmond K. Turner (CG 20), flying outside of the atmosphere – an event never before attempted by the US Navy. It also provided the proof that a tactical Navy missile could reach space, having possible operational uses for ballistic missile defense. This success of this early test made it easier to secure the funding necessary for the next 4 flight tests.

On 28 June, 1993, the ASN(RD&A) Edward C. Whitman officially stood up a new Program Executive Office for Theater Air Defense (PEO(TAD)[8]). The first officer in charge of this organization was Rear Admiral J.T. Hood, a former AEGIS Project Manager. In creating the new PEO, Whitman also transferred responsibility for Navy ballistic missile defense efforts from the Strategic Systems Programs (SP's new name) direct reporting program manager to PEO(TAD). RADM Hood assigned responsibility for both Navy Upper and Lower Tier efforts to CAPT J. J. Nittle, code PEO(TAD)-B. The business of missile defense for the Navy had made an historic shift from an organization with expertise in building ballistic missiles to an organization with expertise in defense against missiles. The new TERRIER LEAP Project Organization is shown in figure 1.

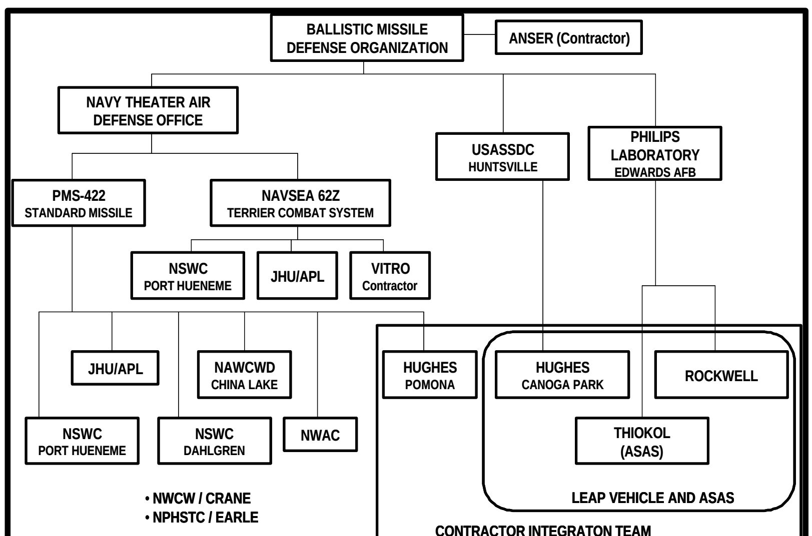


Figure 1: TERRIER LEAP Project Organization, 1993

FTV-2 was launched from USS Jouett (CG 29) in September 1993 at the Sea Range at Point Magu Naval Air Warfare Center, Weapons Division (NAWCWPNS) off the coast of California. This flight test, using TERRIER 1st and 2nd stages and an inactive 3rd stage, demonstrated nosecone ejection and deployment of an inert mockup of the LEAP kinetic kill vehicle in space.

The next test event, FTV-3, was originally planned as a non-intercept flight test to prove third stage separation, guidance and control. However, in October of 1993 due to

[8] PEO(TAD) was formed in part from the previously existing PEO Ship Defense – also headed by RADM Hood. PEO Ship Defense was disestablished at the same time that PEO(TAD) was established.

funding constraints and the desire to accelerate the TERRIER LEAP Demonstration, test objectives for remaining FTV events were accelerated, and both FTV-3 and FTV-4 objectives were changed to include target intercept. Additionally, FTV-5 was removed from the test plan to save money.

The final two flight tests were scheduled for February and March of 1995. This date was little more than a year away, and the nascent PEO(TAD) was eager for success in their high-profile demonstration project. To lend some extra assurance that they were executing as best they could, RADM Hood via his deputy RADM David Altwegg[9], USN (Ret.) enlisted the aid of an independent team in November 1994 (named the LEAP Independent Team or "LEAP-IT") to "...help us (PEO(TAD)) validate our current direction with the LEAP Program and ensure that we have not missed any ideas or significant opportunities to improve." RADM Wayne Meyer, USN (Ret.)[10] chaired the group, which issued its final report on 28 February 1995.

The LEAP-IT found no compelling reasons to postpone the FTV-3 and FTV-4 test events. However, several areas raised concern among the team members, including the following from their 28 Feb 1995 final report:

- Program Management – Lack of a standard management chain of command, and LEAP program team members with little experience managing high risk, high visibility programs.
- Fire Control System – The geographically distributed components affect system connectivity.
- Lack of Engineering Rigor – There is no single system engineer to probe all aspects of the system in-depth.
- Removal of the Control Test Vehicle from flight testing – This critique refers to the decision to make FTV-3 an intercept attempt, vice an engineering test leading to intercept in the final flight.
- Electro Explosive Devices – 40+ one-shot and explosive devices must actuate correctly for mission success.
- Software Changes / Configuration Control – Changes to software are made using the "patching" technique – and sufficient tests are lacking to ensure that these patches inadvertently affect some other part of the system code.
- Lack of attention to risk management / reliability issues. – LEAP program team members seem reluctant to examine data on system component reliability.
- Testing and Verification – Hardware and software components, while tested, were not tested at the extremes – beyond the limits of their nominal operation.

The LEAP-IT also made recommendations on how PEO(TAD) should define mission success in the event that FTV-3 and FTV-4 failed to hit the target. Unbeknownst to the LEAP-IT and PEO(TAD), these specific recommendations were about to become the most valuable part of the report.

[9] Retired Admiral David Altwegg was the civilian Deputy PEO under RADM Hood. Although a retired Admiral, he is known as "Mr. Altwegg" to those in PEO TAD. Mr. Altwegg remained in this position for over 7 years.
[10] Wayne Meyer, a retired 2-star Admiral, was the founding AEGIS Project Officer, a post he held for an unprecedented 13 years. He is a widely recognized expert in Naval weapon systems, ordnance engineering, fire control, and project management.

FTV-3 was originally scheduled for 10 Feb 1995 at the Wallops Flight Facility Virginia Cape Operations Area (VACAPES), using a TERRIER LEAP Missile launched and controlled by USS Richmond K. Turner to hit an ARIES target[11] over the Atlantic Ocean. The Wallops range radar was not operating correctly that day, however, and the test had to be postponed. The test flight was again attempted on 12 February, but this time the target's transponder beacon failed during flight. Consequently, the USS Richmond K. Turner could not maintain minimum acceptable track quality on the target, was unable to compute a valid fire control solution, and a "hold fire" was ordered on the TERRIER LEAP missile. The FTV-3 firing was rescheduled for 4 March 1995, and re-designated FTV-3A.

The FTV-3A flight test was conducted as planned on 4 March 1995 in essentially the same configuration as FTV-3. The missile's physical components, including TERRIER booster and sustainer motors, the Advanced Solid Axial 3rd Stage (ASAS), and the LEAP performed as designed. However, two distinct computer program errors lay undetected in the FTV-3A missile. The first error allowed an alternate waypoint[12] to be in effect at the beginning of 2nd stage midcourse guidance activation (tactical configuration allows for 3 separate waypoints – this test was to use just one) - a waypoint other than that intended for the test. The second error allowed the missile to misinterpret uplinked data messages from the TERRIER Weapon System onboard the ship. The flight test unfolded as follows[13]:

The first error allowed the missile to determine that an alternate waypoint could be in effect at the beginning of midcourse guidance. Memory locations for this waypoint were randomly generated at missile powerup. The second error came into play when the ship began uplinking data to the missile following launch. The uplink data was erroneously interpreted as a new location for the flight waypoint, and overwrote the valid waypoint stored in the missile memory since initialization. Following staging between the first and second stages, the missile detected that both the intended waypoint was wrong (because it had been overwritten unintentionally), and that the alternate waypoint (that shouldn't have been there in the first place) was invalid because it contained random numbers. After determining that the two possible waypoints were invalid, the missile selected a 3rd waypoint (recall that tactical configuration has 3 separate waypoints available) to fly to. Unfortunately – this waypoint was randomly generated at missile initialization – and the point happened to be behind the missile and near the launching ship. After flying to this waypoint, the missile was outside of the possible target engagement envelope. The third stage activated and guided the kill vehicle as close as it could to the target. The kill vehicle, built by Hughes Missile Systems Company (HMSC), then ejected from the 3rd stage and acquired the target at a range of 136km and tracked for 15 seconds, but because of the kill vehicle's great distance from

11 Technically designated the M56A1 vehicle, the ARIES test target is a single-stage missile using a modified Minuteman I Stage 2 motor.

12 "Waypoint" refers to a point in space that a missile is commanded to fly to by the weapon system prior to homing in on a target.

13 Bob Reichert and Don Mitchell of Johns Hopkins University Applied Physics Lab originally wrote this analysis of the FTV-3 failure, on 13 March 1995. It was an e-mail to their JHU/APL colleagues.

the target, it did not have even a fraction of the divert fuel needed to ultimately reach it. A significant number of other test objectives were achieved, however.

The next, and final test flight of the TERRIER LEAP Technology demonstration was FTV-4. This flight test was conducted on 28 March 1995, and incorporated guidance corrections learned from the failed FTV-3A attempt. FTV-4 was essentially the same mission as the FTV-3A test, including launch of the TERRIER LEAP missile from the USS Richmond K. Turner.[14] The ship launched the TERRIER LEAP missile into an acceptable error basket after the weapon system generated a fire control solution on the ARIES target, but battery failure on the Rockwell LEAP prevented its activation after ejection from the ASAS (3rd stage). The LEAP flew within 170 meters of the ARIES target, but did not intercept it. However, as with FTV-3A, a significant number of test objectives were met.

In Crisis – How to Proceed?

With the culmination of the TERRIER LEAP flight test series, the Navy and the BMDO[15] were on uncertain ground. Significant objectives had been met (the most famous of the briefing charts read, "Navy LEAP – 42 of 43 objectives achieved"), but the most significant objective, intercepting a target, had not. In disagreement as to how to proceed in developing a Navy Upper Tier ballistic missile defense capability[16], the Director, BMDO, LTG Malcolm O'Neill, and Principal Deputy ASN(RD&A), VADM W.C. Bowes signed a joint memorandum for distribution on 4 Aug 1995 and 28 July 1995 respectively, chartering a Blue Ribbon Panel to "...review alternatives and recommend the preferred approach to rapidly maturing Navy LEAP with an option for achieving a UOES[17] capability." An advisory group composed of senior BMDO, Navy and ASN(RD&A) personnel was assigned to assist the Panel, as well as two working groups (cost and programmatics/technical risk/schedule) to assist with developing normalized development alternatives for the Blue Ribbon Panel to evaluate.

The Blue Ribbon Panel (know as the BRP) members were:

- Gen Larry D. Welch, USAF (Ret.) – Chairman
- RADM Wayne E. Meyer, USN (Ret.) – Vice Chairman
- Dr. Edward T. Gerry
- LTG C. J. LeVan, USA (Ret.)
- RADM George R. Meinig, USN (Ret.)
- Mr. Marion E. Oliver

[14] Having USS Richmond K. Turner (CG 20) as the firing ship was no small feat – the Secretary of the Navy himself had to intervene to keep CG 20 available – as she was already scheduled for decommission, and was the last TERRIER cruiser in the US Navy. She was decommissioned 3 days later on 31 March 1995 – precluding any further TERRIER LEAP test flights due to the lack of a firing ship.

[15] SECDEF Les Aspin changed SDIO's name to the Ballistic Missile Defense Organization, or BMDO, in May 1993.

[16] By this time, the Navy Lower Tier system (also known as Navy Area Defense) had moved into the Program Definition and Risk Reduction phase of acquisition.

[17] UOES = User Operational Evaluation System. This concept was widely in use at BMDO at the time. It essentially means an advanced fielded prototype of a BMD system that allows accelerated fielding of a capability, as well as "user" input for system improvements before full scale production.

The BRP's tasking required completion of its evaluations not later than 1 October 1995 in order to affect near-term program decisions such as FY 97 program reviews and POM 1998. The working groups immediately formed, with members from PMS-400, PMS-422, PEO(TAD), BMDO, Lockheed Martin, Hughes Missile System Company, Raytheon, Thiokol, STANDARD Missile Company, NSWC Dahlgren Division and JHU/APL. Three development options emerged from the working groups; 1) AEGIS LEAP, 2) Hybrid LEAP, and 3) Hybrid LEAP + AEGIS LEAP.

Hybrid LEAP was an option designed to show some integration with the AEGIS Weapon System (target track would be performed using offboard data, as in TERRIER LEAP), and the missile would be a STANDARD Missile-2 Block IV 1^{st} and 2^{nd} stage, with the 3^{rd} stage rocket motor and 4^{th} stage kinetic kill vehicle essentially unchanged from TERRIER LEAP. The Hybrid LEAP configuration would be used for an initial intercept demonstration and UOES, but a tactical system would be AEGIS LEAP to meet Navy performance requirements.

The AEGIS LEAP option was designed to use the AEGIS Weapon System to track the target, and a new 3^{rd} stage rocket motor (solid and dual-pulse instead of TERRIER LEAP's liquid hypergolic single pulse) and improved 4^{th} stage kinetic kill vehicle atop a STANDARD Missile-2 Block IV 1^{st} and 2^{nd} stage. The AEGIS LEAP system would be developed to improve the missile's burnout velocity and divert distance over the Hybrid LEAP option. Missile lethality, discrimination, and aimpoint enhancements were also possible with the AEGIS LEAP configuration.

The Hybrid LEAP + AEGIS LEAP Option used the Hybrid LEAP option for the initial proof-of-concept flight tests, and the AEGIS LEAP configuration for an eventual deployed system (including UOES).

The Blue Ribbon Panel delivered its final report in October 1995. Evaluation of the options presented was as follows:

<u>Option 1 – Hybrid LEAP</u> – Allows the lowest cost and quickest path to an intercept demonstration and UOES, but the longest path and the highest cost to a tactical system (which would be the AEGIS LEAP configuration). Development risk would be deferred to tactical system development, thus keeping the program in the experimental mode vice the engineering and development mode. Additionally – UOES performance would be substantially less than stated Navy requirements, and require the shipboard use of hypergolic, toxic fuels.

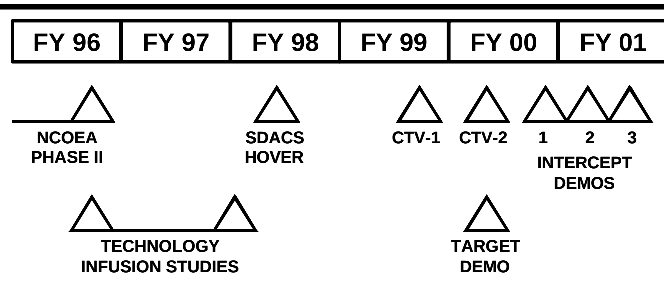
<u>Option 2 – AEGIS LEAP</u> – This alternative offers the lowest cost and shortest path to a UOES that meets Navy performance requirements. However – the first intercept flight test would be 13 months later than for Hybrid LEAP. AEGIS LEAP allows the earliest transition from experimental, largely "throw-away" engineering to engineering and development focused on the development of an integrated weapon system on the road to a tactical system. This option also allows the risks of AEGIS LEAP to be discovered

sooner rather than later – which would save money if there were engineering issues too great to overcome.

Option 3 – Hybrid LEAP to First Intercept – AEGIS LEAP to UOES – This option combines the short path to initial intercept afforded by Hybrid LEAP with the higher performance of AEGIS LEAP for UOES and a tactical system. While this approach gets to initial intercept quicker than AEGIS LEAP – the high program concurrency and dilution of management attention between two different engineering efforts adds great risk to reaching UOES. Both Hybrid LEAP options (1 and 3) would still require a demonstration of the AEGIS LEAP system before a tactical system was to be deployed – adding cost and risk to the development path.

Option 2 was the BRP's recommended development approach for the Navy Theater-Wide Ballistic Missile Defense program. An intercept demonstration was recommended as a program milestone on the route to UOES, and items such as lethality and discrimination enhancements were recommended for deferment until the intercept demonstration was complete. PEO(TAD) was advised to begin preparing a plan to execute Option 2, and submit budgetary requirements for a robust program to achieve UOES as soon as practicable.

RADM Hood, from his post as PEO(TAD) and RADM Rempt from his new post as the Chief of Naval Operations' Director of Theater Air Defense (OPNAV N865) began to work the Pentagon to get funding support and a plan to continue the Navy Theater Wide[18] program, in coordination with the BMDO. By January 25, 1996, RADM Hood was briefing the Assistant Secretary of the Navy for Research, Development and Acquisition, Mr. John Douglass, on a program consisting of 5 test flights starting in fiscal year (FY) 1999, ending in FY 01, with the first intercept flight test in FY 2000. This program conformed to the Ballistic Missile Defense Review's[19] proposed funding level of \$604M over the 5 years of the Future Years Defense Plan (FYDP). The technical composition of the program would resemble the Blue Ribbon Panel's AEGIS LEAP option – save for UOES and tactical development - which were not funded at this time. The Deputy Secretary of Defense approved Program Budget Decision 224 on 10 February 1996 – which funded the 5-flight test program (with first intercept flight test in FY 2000) as presented by PEO(TAD)[20]. Admirals Hood and Rempt now had the



	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01
EXECUTION	160	100	100	150	150	175
BUDGET	200	60	100	150	150	175

Figure 2: 10 Feb 1996 PBD 224 Directed NTW Program Schedule and Funding

18 The name of the program being proposed was dubbed "Navy Theater Wide", a change from the previous "Navy Upper Tier" designation.
19 The BMDR was a Secretary of Defense-level review of ballistic missile defense programs in 1995.
20 Note that the BMDO and the Navy were directed to spend a FY96 Congressional plus-up of \$170M over two years, FY96 and FY97, accounting for the difference between budget and execution in figure 2.

funding and the approval for an AEGIS LEAP intercept program, however, funding was for the flight demonstration only. The second half of the Blue Ribbon Panel's recommendation, development of an AEGIS LEAP system for UOES and tactical deployment, would have to wait until the outcome of the AEGIS LEAP Intercept Demonstration became clearer.

The Maturation of AEGIS LEAP Intercept

The 1996 Program Budget Decision 224 provided the funding and legitimacy for the Navy Theater Wide Program. It was now up to the program managers of the executing organizations to develop the program strategy and engineering detail needed to move forward with the program.

PEO(TAD)-B, headed by CAPT Jim Barron (CAPT Nittle's relief after his retirement on 1 Aug 1995), was the program manager for Navy Theater Wide and the Navy Area Program. While CAPT Barron was in overall charge of the program, he executed through three other program managers within PEO(TAD) who actually controlled the contracts to do the work. Product program managers included PMS 422 (STANDARD Missile), led by CAPT Robert Wilson, PMS 400B (AEGIS Weapon System), led by CAPT Daniel Meyer, and PMS 410 (Vertical Launching System), led by Mr. Rhett Spencer. Each executed their NTW tasking according to direction and funding from PEO(TAD)-B. Prime contractors included Lockheed Martin Government Electronic Systems (AEGIS Weapon System), the STANDARD Missile Company (SM-3)[21] and Lockheed Martin Launching Systems / United Defense Limited Partnership (Vertical Launch System).

In January 1996, an AEGIS Weapon System / STANDARD Missile working group convened to begin to formalize their system concepts – and to receive direction to bound their analysis. Direction was as such, abbreviated here[22]:

1. Conduct an at-sea demonstration (no tactical development)
2. Blue Ribbon Panel recommended schedule – under revision
3. Missile Baseline
    a. Missile Velocity at Burn-Out (Vbo) 3.5 km/sec
    b. Dual-Pulse 38-inch length Third Stage Rocket Motor
    c. Total Missile length 4" greater than SM-2 Block IV
    d. Must fit in VLS
    e. GPS used on 3rd stage for guidance
4. Kinetic Warhead baseline
    a. Defer aimpoint selection capability
    b. Defer enhanced lethality capability
    c. Defer discrimination capability
    d. Use a Solid Divert and Attitude Control System
5. No hardware changes from initial intercept to UOES, only software changes

[21] The STANDARD Missile Company was a joint venture of Raytheon and Hughes to collaborate instead of compete for decreasing Navy purchases of STANDARD Missiles. It was rendered obsolete when Raytheon purchased Hughes in 1997.
[22] Complete list of direction available at Appendix D, pages 5-2 and 5-3.

6. Flight testing required
7. ARIES target
    a. Trajectory based on TERRIER LEAP FTV-3 and FTV-4 scenarios
    b. Test range is assumed to be the Pacific Missile Range Facility
    c. Descent phase intercept
    d. Intended not to stress the NTW system design
8. Guidance Concepts
    a. AWS will command guide first and second stages as in SM-2 Block IV
    b. AN/SPY-1 tracks both the missile and the target.
    c. Concept allows system to operate if GPS is not available, but with reduced accuracy.

Even before the official DoD approval for the NTW program was given, Navy program managers and their associated contractors and laboratory personnel had begun to organize into Integrated Product Teams to support NTW development. Key design drivers were identified during this early planning. The NTW system, due to a number of factors (limited funds, the nature of the mission, the program's heritage as a PMS-422 led effort and CAPT Bob Wilson's will) was to be a "missile-heavy" design. This meant that the missile would perform a sizable portion of the functions needed to do the mission, with the AEGIS Weapon System doing less[23]. CAPT Wilson, PMS-422, lobbied hard to ensure that the developmental missile's physical design was as similar to the UOES and Tactical missile as possible. This became known as the "M1 = M2[24]" philosophy. CAPT Wilson, a very experienced missile engineer, had witnessed numerous problems develop when developmental missiles and production missiles had too many design changes between them. His philosophy was to gain extra functionality in the future via computer program changes (functions such as discrimination and aimpoint selection), rather than a redesign and test of physical components. His philosophy won out, and the ALI missile design, then known as the STANDARD Missile-X, reflected this.

To consolidate NTW program planning, approval, and execution, PEO (TAD) RADM J. T. Hood designated CDR A. J. Cetel (PEO(TAD)-BA) as the Navy Theater Wide Flight Demonstration Project Officer (FDPO), effective 25 March 1996. CDR Cetel[25] was to report directly to Admiral Hood, and program execution was to be through CDR Cetel to the AEGIS Program Manager (PMS 400) the STANDARD Missile Program

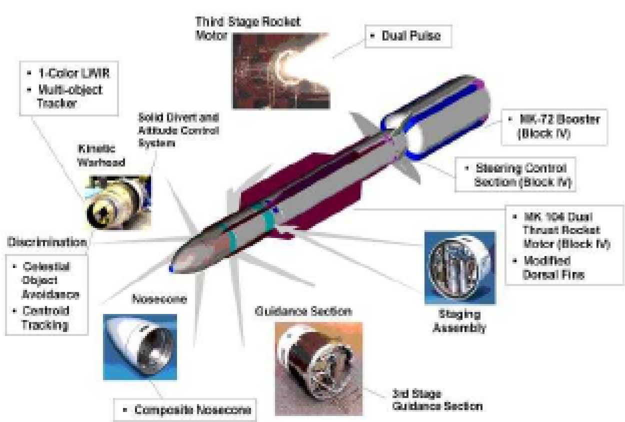


Figure 3: SM-X Round and Components

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[23] For those in the know – the STANDARD Missile is technically a part of the AEGIS Weapon System. What is meant here is all AWS components besides the STANDARD Missile.

[24] Meaning Missile 1 (ALI FDP) = Missile 2 (UOES – later referred to as "Block I")

[25] CDR Cetel had been working with the NTW program since 1994, but reporting to CAPT Nittle, and later CAPT Barron. His job as FDPO was a direct report for ALI to RADM Hood – but still reporting to CAPT Barron for all NTW matters not relating to ALI (a somewhat confusing arrangement).

Manager (PMS 422), and the VLS Program manager (PMS 410). NTW issues beyond the scope of the flight demonstration were still the responsibility of CAPT Barron, including UOES and tactical development[26]

CDR Cetel's first major action as the ALI FDPO[27] was to develop and gain consensus with PMS 400 and PMS 422 on the ALI FDP Project Requirements. A Joint Memorandum of Understanding between the Program Executive Office, Surface Combatants-AEGIS Program (the successor organization to PMS 400) and PEO(TAD) was drafted, and ultimately signed on 7 June 1996. The enclosure to this memorandum was a 15-page document, signed by CAPT (Select) Cetel[28] that outlined the requirements for ALI, including objectives for each of 5 flight tests (CTV-1, CTV-2, GTV-1, GTV-2, and GTV-3) plus a target test mission named "TTV-1". The top-level objectives for the FDP are simply stated as such in the document:

Figure 4: CAPT A. J. Cetel

Flight Demonstration project performance objectives are to:

- Intercept a ballistic missile target in exo-atmospheric flight with the SM-X launched by the AWS.
- Demonstrate critical TBMD interceptor technologies in the SM-X.
- Acquire data for further tactical system engineering development.

The document also provided mission control, AEGIS Weapon System (including the SPY radar, Command and Decision, Weapon Control System, and Vertical Launch System), target and test range requirements.

In late June 1996, RADM Hood retired from active duty. RADM Rodney Rempt, then the Director of Theater Air Defense in OPNAV, code N865, was selected to relieve him of duty as the Program Executive Officer for Theater Air Defense.[29] RADM Rempt, never content with the pace or funding of the Navy's ballistic missile defense programs, immediately directed CAPT(S) Cetel to undertake a "Navy Theater Wide Program Assessment" – the goal of which was to determine how to accelerate the deployment of the Navy Theater Wide system. The study working group, known as the SETAT or System Engineering and Technical Advisory Team, was supported by four oversight and advisory boards, comprised of Navy and DoD officers, civilians, retired flag officers, and industry executives.

Figure 5 – RADM Rodney P. Rempt

[26] Although UOES and tactical development were unfunded at the time, funding became available in later fiscal years.

[27] AEGIS LEAP Intercept Flight Demonstration Project Officer

[28] CDR Cetel screened for promotion to Captain in the spring of 1996.

[29] A waiver was required to allow this – as the PEO position was supposed to be filled by an Engineering Duty Officer. RADM Rempt is an unrestricted Line Officer.

The SETAT worked throughout the summer and fall of 1996 to execute RADM Rempt's NTW Assessment. Key to the effort was the chartering direction to, "practice the proven build a little, test a little," process used throughout AEGIS development, and to "...plan on a sufficient number of missiles and intercept demonstrations."

The results of the assessment were briefed to the four advisory and oversight teams in the fall of 1996. The SETAT-recommended NTW program included a more robust, 12-mission flight test schedule, an initial flight test in August 1997 versus the then-planned September 1999 date, and a number of "Technology Assessment and Risk Reduction Activities" to begin work on system improvements to ALI that could prove valuable in a UOES or tactical NTW system.

Due to RADM Rempt's relentless pursuit of increased program funding and visibility, as well as outstanding support from Congress, the Director of the BMDO approved an extra CTV flight test, and moved the initial CTV flight to August 1997 during a 28 October 1996 meeting[30]. This option was known as the "PB 97+" option, and while not the preferred 12-flight test schedule that RADM Rempt really wanted – it was a step in the right direction. The meeting also resulted in the Director, BMDO designating NTW as a BMDO "Core Program", giving NTW more visibility within DoD. Furthermore, as a direct result of the 28 October meeting, the Undersecretary of Defense for Acquisition and Technology, Dr. Paul Kaminski, signed a memorandum[31] for Lt. Gen. Lyles and RADM Rempt on 3 December 1996 designating NTW as a "pre-MDAP" or pre-Major Defense Acquisition Program. The memo also directed BMDO and the Navy to establish Integrated Product Teams (IPTs) to determine what phase of DoD acquisition the NTW program would enter, necessary documentation for that phase, and a schedule for the program (ALI and the follow-on UOES and Tactical systems). The DoD Overarching IPT (OIPT) was directed to report back to USD(A&T) no later than April 1997 with the required information, to determine NTW's readiness for a formal Defense Acquisition Board Review.

Elevation of the program to a "BMDO Core Program" was a significant milestone. The NTW Program was now poised to become a Major Defense Acquisition Program, with the possibility of fleet deployment and a life beyond the ALI Flight Demonstration Project. Of course, the progress of the ALI FDP would have great bearing on the NTW program's evolution.

As is his style, RADM Rempt was building a coalition of Navy TBMD boosters. His personal efforts prompted the CNO, Admiral Jay Johnson, and the Secretary of the Navy, John Dalton, to sign out a joint memo[32] calling for ASN(RD&A) and OPNAV N8 to conduct a:

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30 See the 18 Nov 1996 Memorandum for the Record, Subj: Navy Theater Wide Options Briefing to Lt. Gen Lyles, Dr. Schnieter, and Mr. Lamartin of 28 October 1996 (location: Appendix B)

31 See Appendix B

32 Ibid.

> "...comprehensive review of Navy TBMD programs. Within 90 days, report to the Secretary of the Navy and the Chief of Naval Operations with a plan to accelerate the fielding of credible sea-based AREA and THEATER-WIDE TBMD systems."

RADM Rempt directed CAPT(Select) Peter M. Grant by memo[33] on 4 Dec 1996 to lead a Comprehensive Program Review (CPR[34]) Team to affect this review. CAPT(S) Grant responded the next day by memo[35] with a list of team members and oversight / advisory group members, approved by RADM Rempt on 6 December.

Meanwhile, CAPT Cetel and the Navy Theater Wide Team were busy preparing for the first major flight test of ALI, named Control Test Vehicle (CTV)-1. This flight test, consisting of a modified STANDARD Missile Block IV launched from the USS Lake Erie, operating a modified AEGIS Weapon System computer program, was to have three main goals:

1. Demonstrate SM-LEAP CTV-1 missile performance at high altitudes
2. Demonstrate AWS tracking and control of the SM-LEAP CTV-1 missile.
3. Gather engineering data to support future AEGIS LEAP at-sea tests.

LCDR Marty Williams, code PMS 400B49A, was assigned duty in May 1997 as the Test Officer for the CTV-1 test event. Under a new 9-flight test plan, CTV-1 was planned almost 2 years earlier than it was in the previous 5 or 6 flight test plans. While one reason for this was to gather engineering data earlier than previously planned, another reason was to show project progress earlier, thereby maintaining support for the project within DoD and the Congress.

CAPT P.M. Grant relieved CAPT Cetel of his duties as the AEGIS Theater Ballistic Missile Defense Program Manager[36] on 27 June 1997. CAPT Cetel was detailed to the Office of Naval Research, where he managed several special projects. CAPT Grant had served in PMS-422 as the SM-X Project Officer in 1995 and 1996, and for the previous 7 months directing the previously mentioned "Comprehensive Program Review". Soon after assuming his new post, CAPT Grant gained full control of Navy Theater Wide when RADM Rempt reorganized the PEO into a number of "mission program managers" and "product program managers". NTW (including ALI) now had a dedicated program manager, and the related Navy Area Program office was created as well. The office's new name was PMS 452, and would officially be recognized on 23 December 1997[37].

Figure 6: CAPT P.M. Grant

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[33] See Appendix B.
[34] Many have suggested that RADM Rempt picked this acronym for its dual-meaning, symbolic of his desire to restart the heart of Navy TBMD.
[35] Ibid.
[36] AEGIS Theater Ballistic Missile Defense was a short-lived name for the NTW program, whose name would change several times over the life of the program.

Knowing that he would need wisdom beyond his own to make ALI a success, CAPT Grant chartered a Senior Advisory Team (SAT) in November 1997, consisting of retired admirals, civil servants, and industry executives. All members had decades of experience in the design and testing of air defense systems. The chairman of the group, RADM (Ret.) Wayne E. Meyer, had participated in two prior reviews Navy TBMD, and knew the players and the program intimately. He and many of the SAT members had invested a considerable portion of their life solving the problems of air defense, and considered ballistic missile defense to be its ultimate evolution. Throughout the many briefings and program meetings that the SAT attended, they began to realize that the fire control problem for ALI was unlike the traditional air defense problem, as the SM-3 missile is not controlled by AEGIS during its last stage of flight. The SAT recommended to CAPT Grant that a rigid definition of the fire control loop for ALI be undertaken, to ensure that: 1) All organizations involved in ALI development understood the fire control loop and their equipments' / computer programs' role in closing it, and 2) that the ALI system design could, in fact, close the fire control loop as currently designed.

This daunting task was given to three engineers at the Johns Hopkins University Applied Physics Laboratory[38] (JHU/APL): Doug Eng, Mark Landis, and Bob Reichert. They worked for months to define how ALI fire control worked, how it differs from air defense fire control, and how to measure system accuracy and response to prove that ALI was accurate enough to do its mission. They coordinated with the SAT throughout their work, and presented their findings to CAPT Grant and others in PMS 452 in November 1998. Their initial findings were that ALI appeared able to close the fire control loop, and that this loop had five major components ("The Five Pearls to Closure" as coined by RADM Meyer). This loop is represented graphically in figure 7.

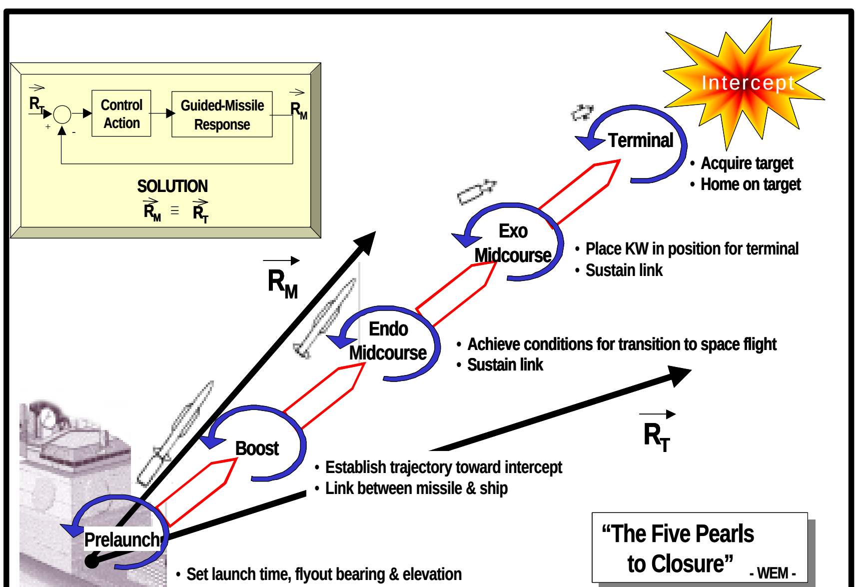

Figure 7: AEGIS LEAP Intercept Fire Control Loop

The three engineers continued their work, integrating ALI component models into JHU/APL simulations of the SM-3 kinetic warhead. They also helped establish the process by which pre-flight fire control predictions were conducted and presented to the many senior-level review boards that convene before ALI flight tests. This process continues to be a valuable pre-flight indicator of system performance.

[37] Although RADM Rempt reorganized the PEO and designated CAPT Grant as PMS 452 on 1 July 1997, the approval for the program office's billets was not received until 23 December 1997.

[38] The Applied Physics Lab has a long history assisting the AEGIS Program, and is the Technical Design Agent for STANDARD Missile.

CTV-1 - A False Start

The CTV-1 Flight Test occurred on 26 September 1997 at the Pacific Missile Range Facility. The test was originally planned for 25 September, but "range foulers" - a Japanese fishing boat - disregarded their Notice to Mariners and entered the hazard area. The boat took quite a while to motor away once notified, and the day's launch window expired. The test was rescheduled for the next day. At 7:30 p.m. local time the minimally modified STANDARD Missile-2 (SM-2) Block IV was launched from the AEGIS Destroyer USS Russell, DDG-59, and self-destructed soon after. A "Failure Analysis Red Team" was established by PMS 422, CAPT Mathis[39], to evaluate this event. After 3 months of reviewing data from the flight, the Team isolated the problem to an existing flaw in the design of the SM-2 Block IV's Steering Control Section (SCS). The SCS contains a "flexprint" or ribbon-type connector that, under resonance conditions experienced during missile flight and pre-flight tests, breaks. This phenomenon occurred during CTV-1, causing a short in the power controller electronics for fin #3 on the missile. The result was a 17 degree deflection from what would otherwise be the zero degree position for the missile fin (straight up and down). With the fin deflected 17 degrees, the missile began to roll. As the speed increased, the roll force became greater than what the thrust vector nozzles on the 1st stage MK-72 booster could compensate for, and control was lost, with subsequent self- destruction (as designed in such an event).

Due to the fact that the mishap in CTV-1 was not due to any modifications made for the mission, but rather by an existing defect in tactical ordnance, the Navy, with BMDO's concurrence, decided to characterize the event as a "No-Test" rather than a failure. The Director of BMDO, Lt. Gen. Lester Lyles apparently received some negative criticism from Members of Congress and staffers over this characterization of the flight (calling it a "No-Test" rather than a "Failure"), and wrote to RADM Rempt (PEO(TAD) saying:

> "We must remain consistent in categorizing the success / failure of our highly visible flight test programs. To do otherwise jeopardizes our credibility and risks far more than we might gain by being "cute" with our words!!!"[40]

It was not the first time, nor the last that RADM Rempt and Lt. Gen. Lyles would have a difference of opinion. The decision now confronting the Navy and BMDO was whether to repeat the CTV-1 mission, or to move ahead with the flight test program – incorporating new mission objectives (and system designs) into the next flight test. Initially, the decision was made to repeat the CTV-1 flight (as CTV-1A) with the addition of a mockup of the Kinetic Warhead to the missile. However, in January of 1999, numerous factors led to the "re-baselining" of ALI, and the configuration of the missile in CTV-1A changed significantly. Rather than use valuable time and talent to repeat the CTV-1 flight test with a similar missile configuration (a modified SM-2 Blk IV), CTV-1A would incorporate many features of the SM-3 design. The new ALI AWS Computer Program, rather than a modified tactical AAW computer program would be used as well. Features such as an inert 3rd stage would allow testing of the 2nd/3rd stage separation,

[39] CAPT Mike Mathis relieved CAPT Wilson, who retired in MONTH YEAR, as PMS 422

[40] October 8, 1997 Memorandum from D, BMDO to PEO(TAD). See Appendix B.

an inert kinetic warhead (4th stage) would allow for environmental instrumentation to validate design models, and use of the guidance section from the SM-3 would allow for risk reduction and validation of guidance algorithms. Additionally, the new VLS canister would be used that accommodated the increased length of the SM-3 as well as the missile strakes that the SM-2 Block IV lacks.

While incorporating more risk (more missile features would be tested in the rebaselined CTV-1A vs. the old CTV-1A missile) and introducing a few months of delay, it was decided that the program could afford it at this point, and the benefits of early testing of the new flight hardware outweighed them. CTV-1A was now expected to fly in July 1999.

Nosecone Development Issues

The SM-3 nosecone covers and protects the KW during endoatmospheric flight. As with all SM-3 missile components, low weight is crucial to achieving the highest velocity at burnout (V_{bo}) possible. Composite materials and titanium were chosen to provide the needed thermal, pressure, and contamination protection during missile flight. Initial testing of the design looked promising, but the first wind tunnel tests at JHU/APL in 1997 showed "outgassing[41]" of the interior composite to be significant enough to affect the KW's operation[42].

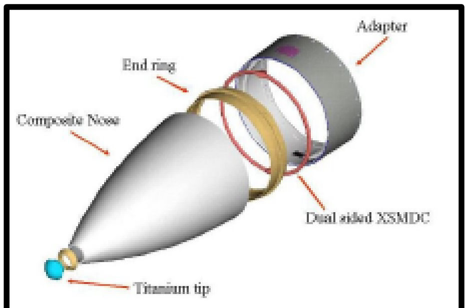

Figure 8: SM-3 Nosecone 3D Rendering

Several processes and designs were changed as a result of the test results and subsequent analyses. The titanium nosecone cap was enlarged, the post-cure temperature of the internal composite was raised to reduce outgassing in flight, and a contamination cover was added to the KW to ensure the cleanliness of the optics. This cover is attached to the nosecone by a lanyard, and is removed with the nosecone during flight. Instrumentation to quantify outgassing was developed for future wind tunnel and ALI flight tests.

Third Stage Rocket Motor (TSRM) Problems

Even though the TSRM design was promoted as a "scaled up" version of the TERRIER LEAP ASAS Motor, its development and testing required significant engineering effort. Engineers at Thiokol set out on a "2-pulse" motor design, meaning that the motor could burn either 1 or 2 pulses (in sequence) depending on the requirements of the specific flight mission. The rocket motor design had two separate propellant masses separated by a barrier, with a separate igniter for each mass. Attitude control for the motor is

[41] Outgassing is the production of volatile gases and particulates by composite materials at high temperatures. The concern is contamination of the KW seeker optics to a degree that could affect mission performance.

[42] Contamination was significant enough to leave a tarry substance on test fixtures. Its discovery was significant – if outgassing had been less visible, but still enough to affect KW performance, the problem could have gone undetected, only to be discovered through flight tests.

provided by a hybrid warm gas / cold gas[43] Attitude Control System (ACS), similar to that proven in the TERRIER LEAP flights.

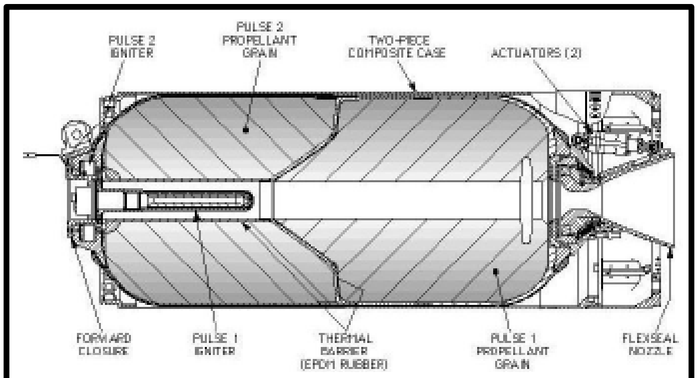

Figure 9: TSRM Engineering Drawing

Many ground tests for the TSRM were planned to verify the performance and safety of the design. These tests, as early as November 1997, revealed several flaws in both the motor and ACS designs. Failed joints, insufficient barrier and case insulation, and pulse ignition delays were discovered. Concern from BMDO and Navy officials over the adequacy of the TSRM design resulted in an investigation by Mr. E. Throckmorton and a panel of propulsion experts from the Navy's Strategic Systems Program Office (formerly known as "SP" – the same organization that briefly ran the TERRIER LEAP program). Additionally, Thiokol headquarters chartered a Senior Engineering Team to assess the design, and the government / industry TSRM IPT conducted their own investigation. All groups concluded that the basic motor design (as modified through engineering changes driven by test results) is the simplest technical approach to a dual-pulse rocket motor, and that the right team was in place to continue its development.

Design changes to fix the test problems were made, and the next test, named BEM-3[44], showed promising results. Unfortunately, a new problem – insulation failure during Pulse 1, was revealed by the failed TSRM-4 ground test in December of 1998. A diagram of the design validation tests for the Third Stage Rocket Motor is shown in figure 10.

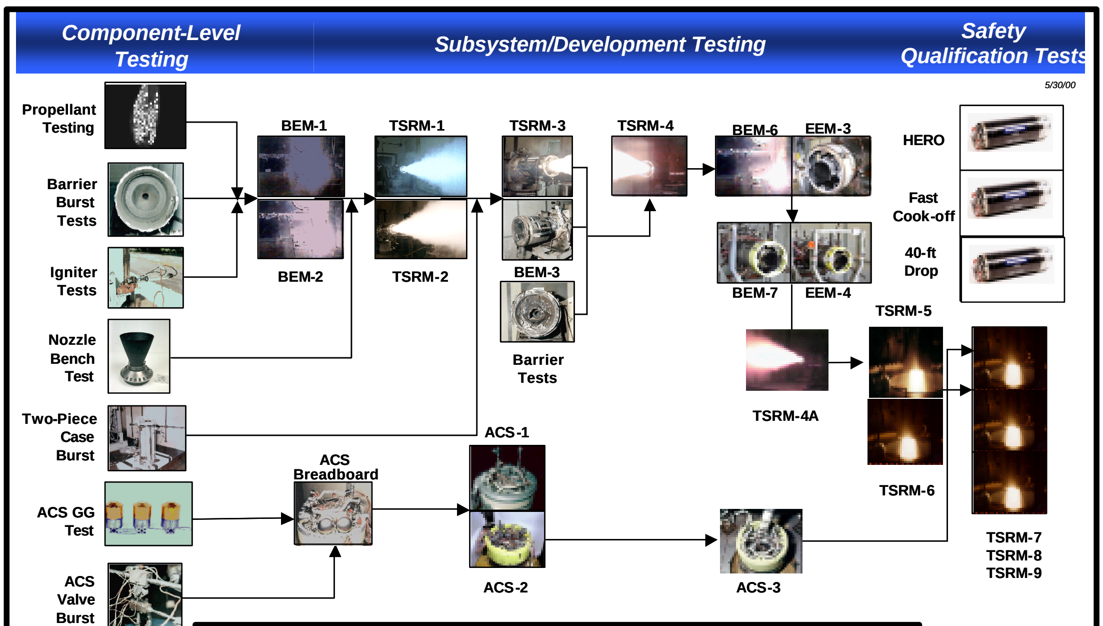

Figure 10: Third Stage Rocket Motor Ground Testing

[43] Cold gas (pressurized nitrogen) is used for pitch, roll and yaw corrections during flight. Warm gas, with higher thrust levels, is used briefly for the large "pitch to ditch" maneuver when the nosecone is ejected.
[44] BEM = Barrier Evaluation Motor

CAPT Grant and his staff began investigating the idea of a back-up plan should TSRM design problems become too time-consuming or expensive to overcome. The most feasible back-up would be to inert the second pulse of the TSRM. This would eliminate many problems discovered in ground tests as of that time, but would require additional ground tests and modification to the AEGIS Weapon System computer program requiring 6+ months. Additionally, this plan would violate the "M1=M2" philosophy of ALI missile design, meaning that a new motor would have to be built and qualified for UOES and Tactical configurations for NTW (costing money and time – and giving critics ammunition for not going forward with NTW). Fortunately, the next 2 ground tests (named BEM-5 and BEM-6) showed resolution of previous issues. However, the Engineering Evaluation Motor (EEM-3) test on 17 June 1999 had a burn-through of the motor case 8 seconds into the planned 10-second burn of pulse 2. The next test, BEM-7, was successful (no catastrophes), but there was an anomalous 1-second delay in activation of the 2nd pulse.

While the TSRM was still far from perfect, test results were good enough to warrant continuation with the present 2-pulse motor design without a back-up plan. This was CAPT Grant's ultimate decision, and he informed the Director, BMDO of it via memo on 30 July 1999.

ALI Gets a Dedicated Project Officer

By the summer of 1999, CAPT Grant had been running both ALI and all related Navy Theater Wide activities for two years. His System Engineer, CDR Jeff Mormon, was also double-hatted as the ALI Project Officer. CAPT Grant realized that just the technical execution of ALI had become enough to consume an officer's entire schedule (a schedule of very long days plus weekends). He needed a project officer dedicated full-time to ALI, and requested that such a billet be created within PMS 452. RADM K. K. Paige, the Deputy Program Executive Officer, Theater Surface Combatants[45] approved the request, and the search for the project officer began. The most promising candidate, LCDR Brian Gannon, then CSSQT[46] officer at Port Hueneme, was interviewed by RADM Paige and Mr. Altwegg at a restaurant in Florida during a lull in Cooperative Engagement Capability (CEC) system testing that brought them all together. LCDR Gannon was later offered the job, and reported to PMS 452 in September 1998.

Unlike his predecessor CDR Mormon who was both the ALI Project Officer and the NTW System Engineer, LCDR Gannon's sole responsibility was the execution of ALI, and he reported directly to RADM Paige. This essentially meant that he was directing the 2 captains and one GS-15 (PMS 400B, PMS 422, and PMS 410) in charge of the ALI system elements, not exactly the most comfortable position for a lieutenant commander to be in. His survival would require tactful diplomacy combined with firm resolve to ensure that ALI succeeded. The ALI Project Organization is shown in figure 11.

[45] PEO(TAD) had reorganized into PEO(Theater Air Defense / Surface Combatants) and then into PEO(Theater Surface Combatants).
[46] Combat System Ship Qualification Trials

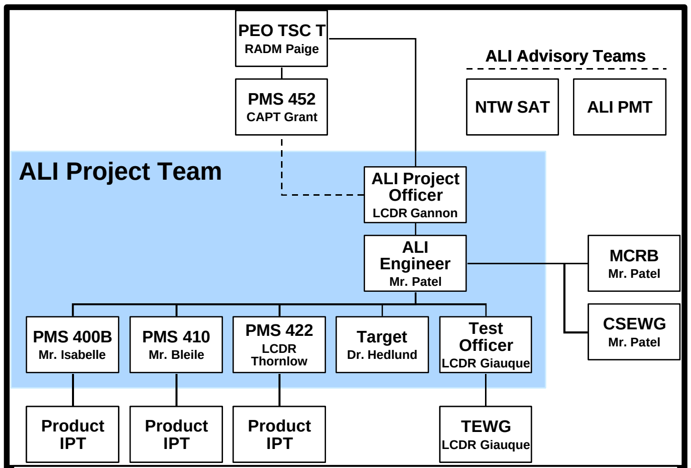

Figure 11: 1999 AEGIS LEAP Intercept Project Organization

Target Flight Test Success

A critical part of the ALI flight tests was the target missile. Ensuring the reliability and predictability of the target's flight characteristics was crucial to ensuring that the flight missions went smoothly. The target chosen, and ARIES target, is essentially a Minuteman second stage (M56A1 motor[47]) with attitude control thrusters, a navigation and instrumentation section, and a "dummy" warhead. The target has up to a 500km range and 325 km altitude. This missile is representative (in infrared and radio-frequency signatures) of the medium-range threats that the NTW system is designed to counter.[48]

The TTV-1 target test took place on 20 Nov 1998. The target was rail-launched from the Barking Sands launch range at the PMRF. The test was a success, and the RF and IR signatures were comparable to what computer models had predicted for the ARIES. As with any test flight, design and procedural improvements were generated, with many being approved for implementation. Improvements such as air conditioning and styrofoam insulation of the target to prevent overheating on the launch pad, a redesigned launch lug ring, incorporation of miss distance instrumentation on the target, and the addition of a video camera to film an incoming SM-3[49] were all to be added for the next target test.

Figure 12: TTV-1 Launch

CTV-1A Flight Test Success

The CTV-1A mission occurred on 24 September 1999 at the Pacific Missile Range Facility. The SM-3 missile was launched from USS Shiloh, CG-67 against a simulated target generated by the AEGIS Weapon System. The missile remained under powered, controlled flight up to the 2^{nd} / 3^{rd} stage separation event, as designed. All primary and secondary test objectives were achieved, including test range instrumentation checks.

Almost 2 years from the first flight test attempt, ALI flight testing was back on track, raising the spirits of all involved, and reassuring the boosters of the program in the Navy, DoD, and Congress that the program could be successful. The next flight test,

[47] These motors (refurbished) come from decommissioned Minuteman I Intercontinental Ballistic Missiles.
[48] While threat representative – the flight trajectories for ALI are designed to maximize RF and IR signatures.
[49] In honor of the Program Manager, CAPT Grant, Dr. Eric Hedlund (the Test and Evaluation manager for ALI / NTW) named the camera on the target missile the "GrantCam".

designated FTR-1[50], would occur in 2000, and planned to include a fully operational SM-3 third stage and mock fourth stage.

It is worthy to note that CTV-1A, as with CTV-1 and all future flight missions, was executed from an AEGIS ship at sea with an all-Navy crew. This was due in no small part to RADM Meyer's persistent pleas to CAPT Grant, for a number of reasons, to ensure that sailors execute all tests on board a Navy ship.

Kinetic Warhead Divert and Attitude Control Problems

While the ALI team was enjoying the success of the CTV-1A flight test, some troubling results were reported regarding the first full-up or "flightweight" ground-test of the 4th Stage Kinetic Warhead's Solid Divert and Attitude Control System (SDACS). The test, named Development Unit-1, or DU-1, had two problems: the Main Thrust Dome Gas Inlet Assembly (where the hot gases from the rocket motor collect for distribution to the divert thrusters) destructively failed, and intermittent switching of the Attitude Control Assembly ball valves (which direct attitude control thrust) showed intermittent switching (not as designed). Pilot tube wall leaks to the Attitude Control Assembly and Main Thrust Assembly were discovered after the test as well – but did not affect the KW performance during the test.

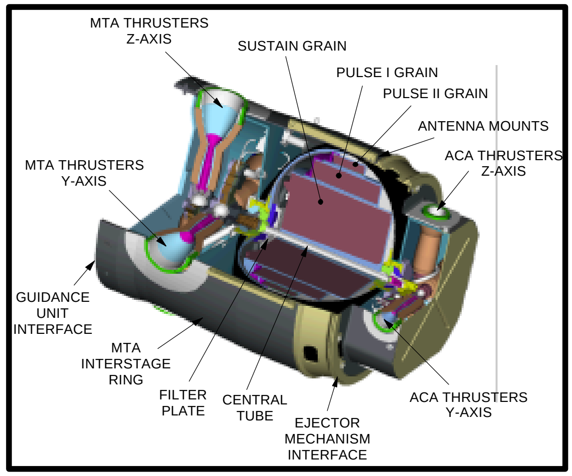

Figure 13: Kinetic Warhead Solid DACS

Corrective actions were implemented by the next ground test in March 2000, DU-2, partially solved the problems. However, four new problems were revealed, plus a reoccurrence of the previous DU-1 pilot tube wall cracking problem in the DU-2 test that would introduce significant delays into the DACS development. Figure 14 shows analysis results as of May 2000.

The Navy leadership and the Director of the BMDO were very focused on the delays that the SDACS problems would bring to ALI. A series of meetings in April, May, and June of 2000 between CAPT Grant and CAPT Bourne (PMS 422), their staffs, Admirals and SESs in the Navy and MDA (including the Director, General Kadish[51]), and OSD officials - most notably the Undersecretary of Defense for Acquisition and Technology (Dr. Jacques Gansler) and the Director of Defense Research and Engineering (Dr. Hans Mark). During this time, 3 of the SDACS problems were traced to their root causes, and 2 problems were given probable root causes. A plan to correct the problems was developed by PMS 452 and the subcontractor that builds the Main Thrust and Attitude

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50 FTR = Flight Test Round. The names of the flight rounds changed over time for various reasons from the original Control test Vehicle (CTV) and Guided Test Vehicle (GTV). Nomenclature.

51 Lt. Gen Lester Lyles was promoted to General and assumed duty as Commander, Air Force Materiel Command on 27 May 1999. Lt. Gen Ronald Kadish, USAF, assumed duty as Director, BMDO on 14 June 1999.

Control assemblies, Honeywell[52] of Tempe, Arizona. Unfortunately, the schedule impact to the ALI program was estimated at 4-6 months delay to the initial intercept flight. PMS 452 executed a proactive information campaign directed at Congress and the press to make sure that the reasons for the delay and program impacts were not left to rumor.

SDACS ISSUE	FOUND IN	KW PERFORMANCE CONTROL AUTHORITY	KW PERFORMANCE STRUCTURAL INTEGRITY	DESIGN ISSUE	PROCESS ISSUE	ROOT CAUSE KNOWN	CORRECTIVE ACTION COMPLETED	CORRECTION IMPLEMENTED
Main Thruster Assy Gas Inlet Assy Structural Failure	DU-1		X	X		X	X	DU-3
Intermittent Ball Valve Switching	DU-1	X			X	X	X	DU-3
Pilot Tube Wall Leaks	DU-1/2		X	Partial	Partial		QA Screen in Use	
Attitude Control Assy Gas Inlet Assy Weld Fail	DU-2		X		X	X	X	DU-3
Pilot Valve Gas Seal Leakage	DU-2	X			X	X	X	DU-3
Pilot Valve Flapper Linkage Warping / Breaking Free	DU-2	X		X		X	Partial	Possible in DU-3
Main Thruster Assy Switching Ball Fail	DU-2	X		UNK	UNK			
Pulse 2 Uncmded Ignition	DU-2		X	UNK	UNK	X		DU-3 Pulse2 Inert

Figure 14: SDACS Issues and Corrective Actions as of May 2000

Two teams were chartered to resolve SDACS problems and to investigate alternative designs. The SDACS Review Team (SRT), led by Dr. Throckmorton[53] of SP, focused on review of the current design, analyzing manufacturing processes to ensure sufficient quality control and providing recommendations to mitigate risk. The Alternative Design Analysis Team (ADAT), led by retired Rear Admiral George Meinig, focused on near-term alternatives to the current divert and attitude control system designs that meet flight test requirements and also reviewed longer-term solutions that could provide enhanced producibility and affordability. When the final report was issued in March 2001, no immediate alternatives to the ALI SDACS were found. However, the possibility of a toxic-hypergolic DACS based on TERRIER LEAP was suggested as a longer-term backup solution, and a pintle-valve design by Aerojet Corporation as a mid to far-term backup.

FTR-1 Flight Test – Another Setback for the Team

The ALI team experienced another setback on 13 July 2000 with the failure of the FTR-1 flight test. The test, conducted at the PMRF, against a simulated target[54] created by the AEGIS Weapon System, consisted of the USS Lake Erie launching a SM-3 that contained an operational 3rd stage and an inert 4th stage. The SM-3 was to operate up to, and including the 4th stage separation from the TSRM.

The SM-3 1st and 2nd stages flew as expected, but the 3rd stage mission sequence was not executed at all. The Mission Review Team (MRT) determined that after launch, no further navigation data uplinks from the AEGIS Weapon System were received by the 3rd stage GPS-Aided Inertial Navigation System (GAINS). The cause was a software error initiated by an incomplete message transfer over the VLS-GAINS fiber optic

52 Honeywell is a subcontractor to Thiokol, who is responsible for developing and producing the TSRM and the SDACS. Thiokol is a subcontractor to Raytheon, the prime contractor for the SM-3.
53 Recall that Dr. Throckmorton also headed a review team after the Third Stage Rocket Motor encountered technical problems.
54 An inert target was used on the ground at PMRF for training purposes, but no target missile flew in this test.

interface, caused during SM-3 egress from the VLS canister. The incomplete message receipt by the GAINS initiated an error-checking routine from which it could not exit, causing deadlocking of the logic in the unit. Post-flight ground testing replicated the error, and a correction to the GAINS computer program was made.

As a result of the FTR-1 flight test, the Director of the BMDO challenged the ALI team to aggressively reduce risk prior to flight tests that include intercept attempts[55]. Rather than repeat the FTR-1 test objectives for the follow on mission, the FTR-1A flight test, several objectives were added. Use of an actual target (known as TTV-2), the addition of an active KW seeker (but not the DACS), and operation of the KW seeker while still attached to the 3rd stage were three of the risk-reducing objectives added to the FTR-1A mission. These new objectives would also serve to greatly increase the amount of engineering data collected that could influence AWS and SM-3 design before the intercept tests.

Anxiety levels were running high in PMS 452 after the FTR-1 mission failure. In February 1999, USD(A&T) had directed D, BMDO by memo to prepare the NTW and THAAD[56] programs for a decision, by him, "...on which of the programs to focus," in the November 2000 timeframe. This would have put the NTW program at a distinct disadvantage over THAAD, as only two of five intercept flights for NTW were scheduled to complete by Nov 2000, versus seven or more for THAAD. RADM Rempt, now the Assistant Chief of Naval Operations for Missile Defense, rallied the Navy to fight against the November 2000 date, including a hand-written note on a memo to the ASN(RD&A) on March 8, "We cannot let Nov 2000 stand without comment." The November 2000 decision date was ultimately set aside, due in this author's opinion to the colossal efforts of RADM Rempt, RADM Paige, CAPT Grant, and his staff.

FTR-1A – Back in the Saddle

The FTR-1A flight mission scenario included the launching of a SM-3, fully operational save the 4th stage DACS, from the USS Lake Erie[57]. The mission occurred on 25 January 2001 at the PMRF. Target Test Vehicle 2 (TTV-2) was launched from Kauai, and acquired by the Lake Erie's SPY Radar during boost[58]. The SM-3 flew a nominal trajectory, and the 1st and 2nd stage performed as expected. The TSRM ignited as expected, and performed the "pitch to ditch" maneuver to eject the 4th stage nosecone as designed during the interpulse delay. The IR seeker on the KW activated and calibrated itself during the burn of the 2nd pulse of the TSRM. Ejection of the kinetic warhead was as expected, and the KW passed within 774 meters of the target, well within the design limits.

[55] Certainly the numerous intercept test failure that the Theater High Altitude Area Defense (THAAD) program, run by BMDO and the Army, influenced the Director to ensure that the same problems would not occur with ALI.
[56] THAAD = Theater High Altitude Area Defense, a competing BMD program run by the Army under BMDO's direction.
[57] All future ALI tests would use the USS Lake Erie. The Lake Erie was later (in 2003) transferred to the MDA (previously BMDO) for use as a dedicated BMD test ship.
[58] Of note was that SPY used only high energy (HE) waveforms to track the target throughout flight – not the more resource-consuming programmable energy (PE) waveforms usually promoted as the best way to track TBMs.

All mission objectives, primary and secondary, were met. The stage was now set for the addition of another objective to the next flight test – intercepting the target. However, the technical problems being experienced with the SDACS would make preparing for the next tests truly “rocket science”.

FM-2 – “Stellar Eagle” - Success Amidst Setbacks

ALI Flight Mission 2 (FM-2) was planned to be the first test of a complete ALI system against a live target. The previous FTR-1A flight test provided important engineering data – proving that the AEGIS Weapon System was capable of guiding the SM-3 to well within the predicted divert distance[59] of the kinetic warhead. FM-2 would prove that the kinetic warhead was able to track and divert itself towards a target, although the FM-2 mission would not include hitting the target as an objective[60]. Engineering advanced technology into a weapon system always presents unforeseen problems, as CAPT Grant had witnessed during his more than 3 years in charge of ALI and NTW. The plan to get the SDACS back on track had run into more problems by the fall of 2001. While several of the previous problems identified during ground testing had been remedied, the latest tests, named “SIT” and “Q1”[61] were showing missed switches in the attitude control assembly (ACA) Y-axis thrusters. To correct the problem as quickly as possible, a team of engineers from Thiokol’s Elkton, Maryland division (Raytheon’s main subcontractor for SDACS development) planned to fly to Honeywell’s Tempe, Arizona facility. They vowed not to return until they and Honeywell engineers solved the current DACS problems. Unfortunately, they were due to leave right after the September 11th terrorist attack, when the entire country’s air travel system was shut down. Undeterred by the September 11th chaos, they rented a charter bus and drove to Arizona, determined to keep the ALI program moving forward. Their initial analysis showed that incorrect ratios between the amplification stages of the fluidic amplifiers[62] (see figure 15) was the cause of the latest test failures. Further analysis suggested that the best remedial action would be to remove the Y valve flow director, as well as to increase the opening in the thruster throats (shown in Figure X as the narrowest point in the output nozzle) by a slight (<10%) amount. Removing the flow directors would be relatively simple and quick, but reworking the thruster throats would take a long time.

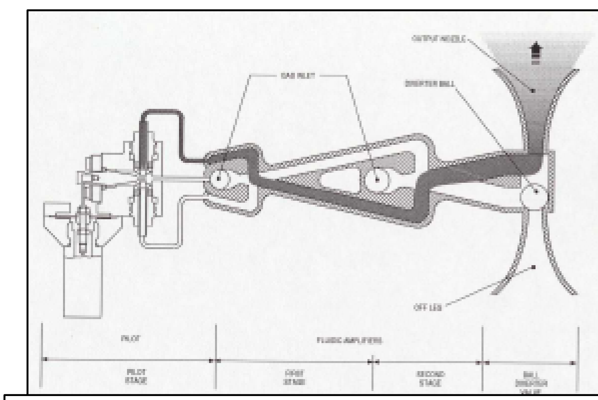

Figure 15: ACA Fluidic Amplifier Diagram (not to scale)

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[59] The closest approach distance between the target and the kinetic warhead without using the DACS is known as the “ZEM”, or “Zero Effort Miss” distance. Guidance corrections derived from FTR-1A data enabled this distance to be reduced to almost 1/3 of the previous distance (300 meters vs. 774 meters).

[60] The configuration of FM-2 was such that target intercept could occur, but this was not made a formal objective. Managing the expectations of the Navy, OSD, MDA & Congress played a role, as well as the engineering goal of building and testing in small increments to prove capability.

[61] SIT = System Integration Test Q1 = Qualification Test 1

[62] Fluidic amplifiers allow a small input stimulus to affect a highly energetic fluid flow.

The remedies for the latest DACS problem were not prohibitive in terms of cost, but the effort, and tests to prove its effectiveness would take enough time to delay the FM-2 flight date significantly. This meant that FM-2, if it stayed on schedule, could not be an intercept attempt if the DACS were to be fixed. The idea of using the DACS in a "sustain-only" mode was floated. By not using the high-pressure pulses within the DACS, only the lower pressure "sustain" pulse, ACA switching errors could (it was theorized) be avoided even if the thruster throats weren't bored out. CAPT Grant prepared the analysis to brief to Navy leaders and Lt. Gen Kadish, and got approval to proceed with the FM-2 "quick-fix" and the thruster throat enlargement for the next two follow-on flight missions. Lt. Gen. Kadish directed that "sustain only" SDACS be flown for FM-2, 3, and 4, unless there was an opportunity to use a high pressure pulse SDACS with a high probability of success. Ultimate approval for the flight missions would be contingent upon successful ground testing of the proposed DACS remedies. CAPT Grant was apprehensive about flying a less than perfect missile, but resigned himself to the fact that the program had to do so to remain alive. General Kadish also directed CAPT Grant to create a formal DACS resolution plan to present for his concurrence by the end of 2001, and to plan for completion of the FM-2, FM-3, and FM-4 flight missions by the end of 2002.

The December 2001 qualification-2 or "Q-2" test to verify the switching of the ACA with removal of the Y-valve flow director was a success, and the FM-2 mission was now proceeding towards a late January 2002 execution date.

After the usual pre-mission sequence of Weapon System Explosive Safety Review Board, Scenario Certification, Range Readiness Review, Mission Review Team, Mission Control Panel, and Mission Readiness Review was completed, the FM-2 mission was declared ready to fly. On the morning of 25 January 2002 the target missile was being checked out on the launch pad at PMRF, the USS Lake Erie was steaming off the coast of Kauai towards its assigned station, and the test range crew was monitoring a significant portion of the Pacific Ocean to ensure that no ships or planes were near the hazard zones calculated for the mission. The mission countdown was progressing towards the target launch time when a MEDEVAC emergency necessitated transit of a USNS ship through the hazard zone to get a sick crew member to a hospital. A helicopter from Hawaii picked up the crew member, and the USNS ship quickly departed the hazard zone. The target launch time was pushed back four hours, moving the target launch time to the very limits of the FM-2 launch window, and the countdown resumed.

At T=0, the ARIES target was launched from PMRF on Kauai. At T+43 secs, the target was detected and tracked by the USS Lake Erie's SPY Radar. One minute into flight, the target's motor burned out, and 30 seconds after that the AEGIS Weapon System had generated a fire control solution. The "good target" call came a few seconds afterwards, and three minutes later the target had reached the apogee, or highest altitude of its flight. The SM-3 was launched one minute later at T+6 minutes, and the assembled crowds at PMRF, the Pentagon, and Raytheon's[63] facility in Crystal City collectively drew in their breath and leaned forward in their chairs.

The SPY radar acquired the SM-3 2 seconds after egress from the ship, and the first stage burned out and separated at around 6 seconds. Second stage activation and burn was as expected, and burnout occurred after leaving the atmosphere. Booster separation was as expected, and third stage (TSRM) ignition and 1st pulse burn was nominal. The "pitch to ditch" maneuver was executed after pulse 1 burnout, and the second pulse carried the SM-3 to an even higher velocity and altitude. After burnout and 3rd stage separation, the kinetic warhead "opened its eyes", and the seeker began scanning the space ahead of it for the target, now headed rapidly back to earth. The seeker locked onto the target, and the SDACS, operating only on the thrust provided by its "sustain" pulse, began to make the minor corrections needed to ensure a collision with the target.

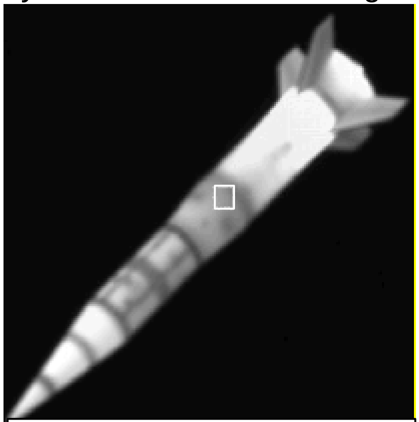

Figure 16: Final KW Image of TTV-2 Target During FM-2 Intercept

The design of the ALI system is such that IR imagery from the kinetic warhead is telemetered to the ship, and from there it can be transmitted wherever it may be needed. This imagery was fed directly to the displays in front of the crowds at PMRF, the Pentagon, and Raytheon. About 4 seconds after ejection from the SM-3, the display clearly indicated that the KW was tracking an object. This object appeared to viewers to be only a pixel on the screen, however. 15 very long seconds later, the image appeared to grow slightly, and by 19 seconds after track was first established, an image of the target grew suddenly huge, filling the seeker's field of view, and then the signal was lost. The Lake Erie's SPY radar and range radars tracking the target and KW recorded numerous objects where there had only been two before – with the conclusion being that the KW HAD SCORED A DIRECT HIT ON THE TARGET.

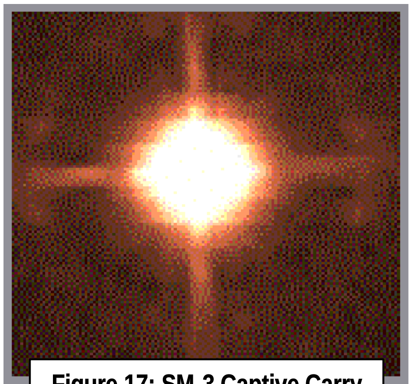

Figure 17: SM-3 Captive Carry Image of FM-2 Intercept

The assembled spectators back on land (and onboard the USS Lake Erie), many having toiled a decade or more to realize this moment, were ecstatic. Even RADM Wayne Meyer, USN (Ret.), present at PMRF, was jumping up and down with excitement – behavior quite uncharacteristic of the 75 year old! The sense of accomplishment by all involved in the project was truly breathtaking. Almost 12 years had passed since SDIO had sponsored the first Navy TBMD study, and on 25 January 2002, CAPT Grant and his industry / government / laboratory team had proved its feasibility beyond a doubt. To prove that ALI was truly a success, however, would require them to hit a target in space at least one more time.

63 The FM-2 mission was "simulcast" to the MDA and Raytheon's Crystal City, Virginia offices, providing the same images and data that the VIPs and program office staff at PMRF were seeing.

FM-3 – "Stellar Impact" – Score 2 for ALI

The mission scenario for FM-3 was designed to be similar to FM-2, showing that the ALI system could reliably intercept a ballistic missile in its descent phase of flight. PMS 452 had hoped to be able to provide a complete SDACS capability demonstration in FM-3 (both sustain and high-pressure divert pulses used), but fate would intervene yet again to prevent this.

The Demonstration Unit 4 (DU-4) test of the SDACS culminated in the structural failure of a weld connecting an interface tube to the Attitude Control Assembly Thrust Dome. This failure occurred during Pulse 2 operation, and was almost identical to the DU-2 failure witnessed almost 2 years previously. Insufficient weld penetration (87% vs. the required 100%) was determined to be the cause.

As part of the DACS recovery plan, alternative designs were being tested. One of these designs, known as the "monolithic DACS" because of its cleaner look (gas passageways were formed inside a block of solid material[64] vs. routed with multiple tubes in the baseline "tube DACS" design), was beginning engineering evaluation tests in the spring of 2002. One of these early tests, Monolithic Engineering Evaluation 1 (MEE-1), proved the structural integrity of the valves, but unfortunately another problem arose. The Attitude Control Assembly diverter balls, which control attitude correcting thrust split during KW flight, deteriorated during operation, with two cracking and one splitting entirely (see figure 18). An investigation was begun to determine the cause. The good news from the test was that valve switching showed improvement over the "tube DACS" design, and the integrity of the design was proven (although the entire test could not be completed due to the diverter ball failure).

Figure 18: Cleaved Diverter Ball from MEE-1 Test

The problems with both DACS tests would preclude the use of any high-pressure divert pulses in the next flight mission[65]. It was decided that FM-3 would have to fly a SDACS in sustain-only mode, as it did in FM-2.

The FM-3 flight mission was conducted on 13 June 2002. Unlike the previous mission, FM-3 had "intercept the target" as an explicit objective. The scenario was similar to FM-2, with the USS Lake Erie as the launch ship and the target (named TTV-4) launched from PMRF's Barking Sands range on Kauai, HI. SM-3 interception of the target was planned while the target was descending from apogee, its highest elevation during flight.

[64] The gas passageways were actually formed by sintering multiple plates with specific cut-outs together. The final product was to be easier to manufacture and less reliant on the problematic welds that had plagued the "tube" DACS design.

[65] The flight mission could have been delayed to try and solve the DACS problems, but the Director of BMDO had directed that ALI flight testing conclude by the end of 2002, making schedule delays an unacceptable option.

The target (TTV-4) was successfully launched from Kauai and flew its expected trajectory. SPY radar onboard USS Lake Erie detected TTV-4 during boost phase (43.7 seconds after launch). SPY used high energy (HE) waveforms to track the target throughout its flight.

The SM-3 was successfully launched from USS Lake Erie. 1st and 2nd stage missile operation were as expected. 3rd stage activation was as expected – pulse one burned nominally, and during the 1st / 2nd pulse "interpulse" delay, the TSRM rotated from the missile velocity vector, ejected the Kinetic Warhead nosecone, and then realigned with the velocity vector. The kinetic warhead's infrared seeker was initiated just prior to ejection from the 3rd stage. The kinetic warhead ejected, the solid divert and attitude control system's sustain grain began burning, and the KW acquired TTV-4 (4 seconds after ejection). The kinetic warhead diverted towards the target, driving the 575 meters of miss distance to zero, and directly hit TTV-3 at the centroid (see figures X and X). This 575 meters was more than expected due to a number of conditions, and an investigation was initiated for resolution prior to the next flight mission. The SPY Radar onboard USS Lake Erie tracked the intercept fragments using Programmable Energy (PE) waveforms, which allow for tracking of low radar cross-section objects at great distances.

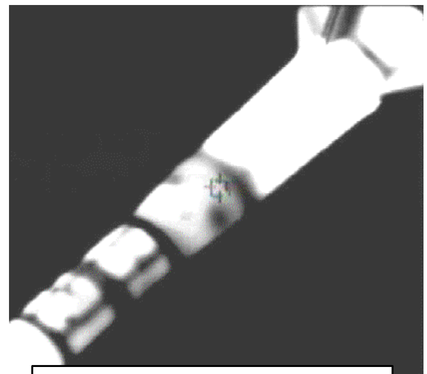

Figure 19: Final Data Frame from KW Seeker, FM-3 Mission

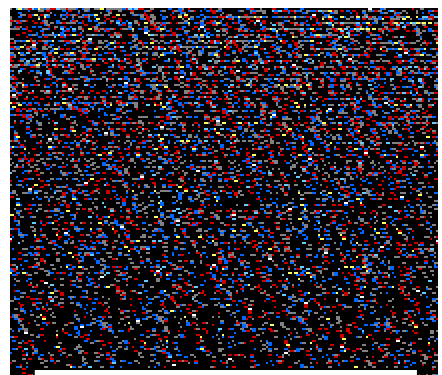

Figure 20: HALO IRIS Image of FM-3 Intercept

The FM-3 Mission was executed as planned – with all primary and secondary mission objectives met. The exit criteria for the AEGIS LEAP Intercept Project, two successful intercepts, were met during this flight mission, but the MDA Director's guidance stood – three intercept tests by the end of 2002. The ALI flight demonstration project would have the chance to demonstrate 3 successes out of as many attempts, which would be a first for any DoD ballistic missile defense project.

FM-4 – "Stellar Viper" – Setting Precedents in Ballistic Missile Defense

With two successes hitting a target in the descent phase in essentially the same scenario, CAPT Grant, CDR Gannon[66], and Dr. Eric Hedlund wanted to prove how robust the ALI system really is. The idea of hitting a target while it was ascending (an "ascent phase intercept") was explored. No ballistic missile defense system in MDA history had ever hit a target while it was still ascending towards apogee. Analysis showed that this objective could be achieved – but they didn't stop with just one unprecedented feat. Modifications to the kinetic warhead's computer program could also allow it to hit a precise location on the target – close to where a warhead would be on an actual enemy missile. This "lethal aimpoint shift" became another objective of the

[66] CDR Gannon had been promoted from LCDR in 2002.

FM-4 mission, one that would stress the system and prove to the Navy and the MDA that ALI had the capability to effectively counter real-world threats.

By the summer of 2002, the Missile Defense Agency had been working for 18 months to realize the President's new, aggressive objective of deploying a ballistic missile defense system as soon as possible[67]. CAPT Grant and his staff had been working seemingly endless drills for the last year to show DoD and the President how Navy Theater Wide (now known by its new name, AEGIS BMD) would contribute to the operation of the Ballistic Missile Defense System (BMDS) that had replaced the MDA's previous concept of both theater and national missile defenses. One part of AEGIS BMD's contribution would be the passing of enemy missile track data from an AEGIS ship at sea to the BMDS. To jump-start the testing of this capability early, passing data from AEGIS to the BMDS via LINK-16 messages became a secondary objective of the FM-4 mission.

During the initial design of the SM-3 in the mid-1990s, the concept of high-pressure pulses in the kinetic warhead's SDACS was engineered into the system design to allow for high-g maneuvers in the last few seconds of flight. These maneuvers were needed to compensate for a maneuvering target, and/or to execute a lethal aimpoint shift in the final seconds before target intercept. With the SDACS still being redesigned and tested due to the problems previously mentioned, the ALI system would have to use only a lower pressure sustain pulse to shift its aimpoint before intercept. Analysis showed that the system design contained enough margin to achieve this objective – another testament to the effectiveness of both the weapon system and missile engineers who designed the system.

With an aggressive set of objectives[68], the ALI Test Team led by Dr. Eric Hedlund prepared for a November 2002 mission date. This test would be different from all previous tests due to the very short timelines needed to ensure an ascent-phase engagement[69]. The range team and the ship's crew would have to train in a slightly different manner to ensure that FM-4 would be as successful as the previous two missions. In addition, the unprecedented number of auxiliary sensors being used to observe this test would require careful coordination.

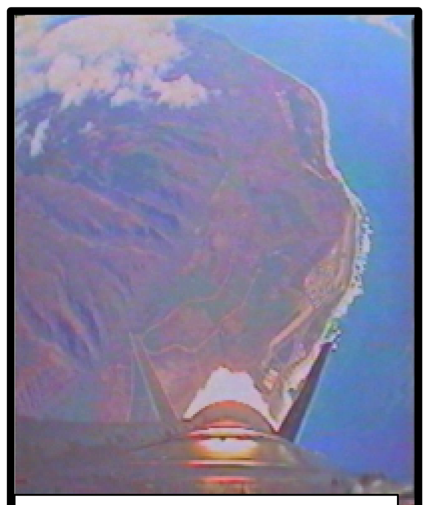

Figure 19: Aft view of Kauai from TTV-5 during FM-4 flight test

The flight mission was executed on 21 November 2002. The target (TTV-5) was successfully launched from

[67] The President's expectations for rapid deployment of missile defenses were later written in National Security Presidential Directive 23, signed 16 Dec 2002. It directs the Missile Defense agency to deploy an initial BMDS by the end of 2004.

[68] Another significant objective was to demonstrate the switching of SPY radar faces (those tracking the missile & target) during flight. This capability had been proven in other tests (QRLV-2), but not an intercept test.

[69] Timelines were so constrained that an SM-3 firing order would have to be given just seconds after a "good target" declaration was made. The target flight time was half of what it had been in FM-2 and 3.

Kauai and flew its expected trajectory[70]. SPY radar onboard USS Lake Erie detected TTV-5 during boost phase, just 2 seconds after breaking the radar horizon (33.6 seconds after launch). SPY used high energy (HE) waveforms to track the target throughout its flight.

The SM-3 was successfully launched from USS Lake Erie 76 seconds after target launch. 1st and 2nd stage missile operation were as expected. 3rd stage activation was as expected – pulse one burned nominally, and during the 1st / 2nd pulse "interpulse" delay, the TSRM rotated from the missile velocity vector, ejected the Kinetic Warhead nosecone, and then realigned with the velocity vector. The kinetic warhead's infrared seeker was initiated just prior to ejection from the 3rd stage. The kinetic warhead ejected, the solid divert and attitude control system's sustain grain began burning, and the KW acquired TTV-5. The kinetic warhead diverted towards the target, driving the 294 meters of miss distance to zero, and impacted towards the front of the TTV-5 target, 206 seconds after target launch at an altitude of 159,000 feet.

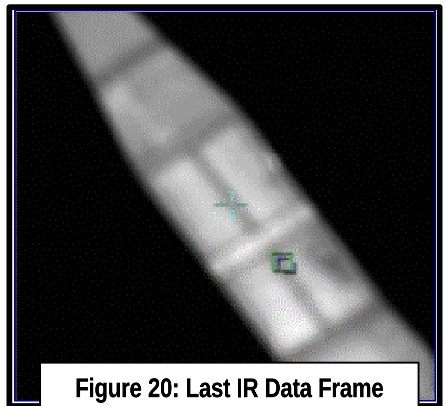

Figure 20: Last IR Data Frame from SM-3 Seeker

The FM-4 Mission was a milestone for both the AEGIS LEAP Intercept Flight Demonstration Project and ballistic missile defense in general. This was the first ascent phase intercept of a ballistic missile ever achieved by a weapon system. Additionally, the ability to hit a specific area on a target was demonstrated, quite an accomplishment when the closing velocities of the kinetic warhead and the target are measured in *miles per second*. FM-4 met all of its ambitious primary and secondary mission objectives. The ALI Flight Demonstration Project was now complete, proving three separate times that an AEGIS cruiser at sea could intercept a ballistic missile in space.

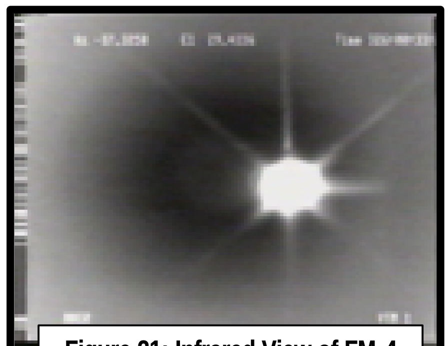

Figure 21: Infrared View of FM-4 Intercept

70 TTV-5 flew what is known as a "minimum energy" trajectory, which gives the longest flight distance (as measured by distance from launch on the ground). Previous TTV flights flew more lofted trajectories.

EPILOGUE

AEGIS LEAP Intercept's overwhelming success has paid dividends to the program and to the nation. As of October 2004, the Missile Defense Agency has deployed an initial version of the Nation's Ballistic Missile Defense System (BMDS). The capabilities proven in AEGIS LEAP Intercept are currently being used to search the skies for enemy missiles in the Sea of Japan. Three destroyers will be available for deployment to provide tracking and cueing to the ground-based component of the BMDS, followed soon after by the initial deployment of a cruiser-based intercept capability using an improved version of the ALI system. Further system improvements are currently being engineered for various epochs through the year 2010.

Following completion of ALI, two of its most important leaders moved on to new posts. CAPT Grant assumed duty in early 2003 as the System Engineer for the Missile Defense Agency, a post of enormous responsibility for a Captain. He was selected for promotion to Rear Admiral (Lower Half) in 2004. He is now charged with engineering the Ballistic Missile Defense System so that the numerous system components communicate and operate effectively, providing the nation and its allies with the first truly global protection from ballistic missiles. CDR Gannon was detailed to SURFPAC in Hawaii early in 2003. Hopefully being in Hawaii will be some compensation for the many nights and weekends he sacrificed to ensure ALI's success.

The PMS 452 program office has been redesignated a Program Directorate (PD), and a field activity of the Naval Sea Systems Command. The command has been elevated to a flag billet, and RADM K. K. Paige has assumed duty as its leader. She has years of experience with Navy ballistic missile defense as the PMS 400 Technical Director (PMS 400B), the Deputy PEO(TSC), and the MDA Technical Director. CAPT Kenyon Hiser is PD 452's first Technical Director, in charge of all engineering and analysis for AEGIS Ballistic Missile Defense. He was the BMDO "Program Integrator" for Navy Theater Wide as a Commander in the mid-1990s, keeping BMDO and Pentagon leadership informed about NTW and ALI during the program's most tumultuous periods. He also led the AEGIS BMD / Japan Cooperative Development program in PMS 452 prior to assuming his Technical Director duties.

As previously mentioned in the foreword, there are too many people that have made major contributions to ALI to even attempt listing them all. Some of the nation's best engineering talent, from industry, government, and associated laboratories has toiled to design and build the ALI system. The sense of dedication and purpose found in these individuals is, I believe, truly unique in today's modern society. As they continue to work towards the ultimate goal of deploying the Nation's first ballistic missile defense capability, they show the same devotion. I stand in awe of their accomplishments, and know that their future achievements will cause the entire country to do the same.

Troy Kimmel, October 2004

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ACRONYM LIST

AAW	Anti-Air Warfare
ACA	Attitude Control Assembly
ACS	Attitude Control System
ALI	AEGIS LEAP Intercept
ASAS	Advanced Solid Axial Stage
ASN(RD&A)	Assistant Secretary of the Navy for Research, Development & Acquisition
AWS	AEGIS Weapon System
BEM	Barrier Evaluation Motor
BMDO	Ballistic Missile Defense Organization
BMDS	Ballistic Missile Defense System
BRP	Blue Ribbon Panel
CDR	Commander or Critical Design Review
CEC	Cooperative Engagement Capability
CNO	Chief of Naval Operations
CSSQT	Combat System Ship Qualification Trials
CTV	Control Test Vehicle
DACS	Divert and Attitude Control System
DU	Demonstration Unit
EEM	Engineering Evaluation Motor
FDPO	Flight Demonstration Project Officer
FM	Flight Mission
FTR	Flight Test Round
FTV	Flight Test Vehicle
GAINS	GPS-Aided Inertial Navigation System
GPS	Global Positioning System
GS	General Schedule
HE	High Energy
IPT	Integrated Product Team
IR	Infrared
JHU/APL	Johns Hopkins University Applied Physics Laboratory
KKV	Kinetic Kill Vehicle
KW	Kinetic Warhead
LCDR	Lieutenant Commander
LEAP	Lightweight Exoatmospheric Projectile
LEAP-IT	LEAP Independent Team
MDA	Missile Defense Agency
MDAP	Major Defense Acquisition Program
MRT	Mission Review Team
NSWC	Naval Surface Warfare Center
NTW	Navy Theater Wide
OPNAV	Office of the Chief of Naval Operations
PE	Programmable Energy
PEO	Program Executive Office

PMRF	Pacific Missile Range Facility
PMS 400	AEGIS Shipbuilding Program Management Office
PMS 410	Vertical Launching System Program Management Office
PMS 422	STANDRAD Missile Program Management Office
PMS 452	Navy Theater Wide Program Management Office
RADM	Rear Admiral (Upper Half)
RDML	Rear Admiral (Lower Half) Note: RADM Was used for both Upper and Lower Half until around 2002
RF	Radio Frequency
SAT	Senior Advisory Team
SCS	Steering Control Section
SDACS	Solid Divert and Attitude Control System
SDIO	Strategic Defense Initiative Organization
SETAT	Systems Engineering and Technical Advisory Team
SM-3	STANDARD Missile – 3
SP	Strategic Systems Program Management Office (also SSPO)
SRT	SDACS Review Team
TAD	Theater Air Defense
TAD/SC	Theater Air Defense / Surface Combatants
TBMD	Theater Ballistic Missile Defense
THAAD	Theater High Altitude Area Defense
TSC	Theater Surface Combatants
TSRM	Third Stage Rocket Motor
TTV	Target Test Vehicle
UOES	User Operational Evaluation System
USD(A&T)	Undersecretary of Defense for Acquisition and Technology
USN	United States Navy
Vbo	Velocity at Burn-Out

APPENDICES

APPENDIX A

TERRIER LEAP / Navy Theater Wide / Sea-Based Midcourse Defense / AEGIS Ballistic Missile Defense Program

Key Program Dates

10 July 1990 – Ambassador Henry Cooper appointed Director of the Strategic Defense Initiative Organization by President George H. W. Bush.

19 Jan 1991 – **USS Mobile Bay (CG-53) detects and tracks SCUD missiles launched by Iraq during Operation Desert Storm**.

1991 – **Naval Research Advisory Committee (NRAC) Issues Report "Anti-Tactical Ballistic Missile Requirements – 2000"**. Laid the foundation for future work on the Navy Area and Theater Ballistic Missile Defense Programs.

1991 – **Defense Science Board Ballistic Missile Defense Summer Study**. Stated that the Navy can make a significant contribution to Theater Missile Defense, and that the recommended path to realize a capability will be to upgrade AEGIS. However, the study focused much more on THAAD, PAC-3, and Corps-SAM systems.

Summer 1991 – **Tactical / Theater Ballistic Missile Defense Study**. The Strategic Defense Initiative Organization (SDIO) sponsored and the Navy oversaw this study. Recommended using the Navy's existing air defense infrastructure as a basis for Ballistic Missile Defense, and pursuit of a dual-track approach (lower tier and upper tier) to Navy ballistic missile defense. Interestingly, the possibility of using a modified SM-2 Blk IV for BMD was investigated, but instead the study team recommended augmenting the Blk IV with an infrared seeker to double the forward reach of the missile against targets. A major conclusion that advanced the concept of Navy TBMD was that building a TBMD capability using AEGIS ships could be done without major equipment upgrades to the AEGIS Weapon System.

18 Nov 1991 – Joint Requirements Oversight Council (JROC) approves Mission Need Statement (MNS) for Theater Missile Defense.

September 1992 – TERRIER LEAP Flight Test Vehicle (FTV)-1 successfully launched from USS Richmond K. Turner (CG 20). This test demonstrated the flight characteristics of a TERRIER missile outside of the atmosphere.

13 Feb 1993 – **CNO approves Sea-Based Theater Missile Defense Mission Needs Statement**.

May 1993 – **Red Tigress.** USS Anzio (CG 68) and USS Vicksburg (CG 69) conduct a detection and tracking experiment at sea named Red Tigress. Both ships demonstrated successful detection and transition to track of ballistic missile targets.

13 May 1993 – SECDEF Les Aspin announces that SDIO's name is officially changed to the Ballistic Missile Defense Organization.

4 Aug 1993 – Major General Malcolm O'Neill, USA, is nominated by President William Clinton to be the Director of the BMDO with a promotion to Lieutenant General. He is later confirmed by the Senate.

September 1993 – TERRIER LEAP Flight Test Vehicle (FTV)-2 successfully launched from USS Jouett (CG 29). This test demonstrated the deployment of a kinetic kill vehicle by a tactical Navy missile in space.

March 1994 – **Concept Evaluation and Integration Study**. Chartered by PEO (TAD). A year-long assessment of operational and technical issues for both Navy Area (called "Nay Lower Tier") and NTW (called "Navy Upper Tier"). Concluded that modifications to AEGIS can fully support the Area and NTW missions, identified NTW development risk areas, and concluded that integrating a THAAD missile for NTW would mean reduced performance and introduce technical obstacles into the program.

May 1994 – Joint Memorandum for the Record between ASN(RD&A) Nora Slatkin, Director, BMDO LTG Malcolm O'Neill, USD(A&T) Deputy for Strategic and Space Systems George Schneiter, and his deputy for tactical warfare systems Paris Genalis signed. This memo specifies what will be reviewed in an upcoming Defense Acquisition Board review of Navy TBMD, and directs ASN(RD&A), the OSD Director of Program Analysis and Evaluation (PA&E) and the Director, BMDO to **develop guidance for a two-phase Cost and Operational Effectiveness Analysis (COEA) for Navy TBMD** prior to 1 Aug, 1994. Phase I is to address Navy Area, Phase II is to address Navy Theater Wide capability.

14 June 1994 – CNO J. M. Boorda signs a memorandum for the VCNO directing him to "...establish a robust TBMD organization within the Navy staff." This included adding 10 billets to the CNO N86 Organization to man the Theater Air Defense (TAD) organization, designated as "...the single officer responsible for all TBMD requirements and policy.". Another 10 Navy billets were provided to the BMDO to increase Navy presence.

Aug 1994 – Navy Area TBMD Program goes to a Defense Acquisition Board (DAB) Review. Program approved to enter the acquisition process in the program definition and risk reduction phase.

28 Feb 1995 – **LEAP Independent Team Final Report** issued – Chaired by RADM Wayne E. Meyer, USN (Ret.), and asked by PEO(Theater Air Defense) to assess the status of the Navy's LEAP Program.

4 March 1995 – **TERRIER LEAP Test Event FTV-3A**. Tested a LEAP atop a STANDARD Missile I Blk III ER launched from the USS Richmond K. Turner at sea vs.

a target launched from Wallops Island, VA. Intercept not achieved – STANDARD Missile autopilot guidance activated during flight and diverted the missile to an unintended waypoint, that was too far from the target to allow the LEAP to intercept. The Kinetic Warhead, built by Hughes Missile System Company (HMSC), did acquire the target at a range of 136km and tracked for 15 seconds, but because of the kill vehicle being out of the error basket, it did not have enough divert fuel to reach the target. A significant number of other test objectives were achieved, however. (note: FTV-3 test event was attempted first on 10 Feb 1995, but Wallops Flight Facility had range radar problems that postponed the test. 2nd attempt occurred 12 Feb 1995, but the target missile transponder failed and a hold-fire was ordered for the TERRIER LEAP Missile. Event was rescheduled for 4 Mar 1995 and redesignated FTV-3A).

23 Mar 1995 – Assistant Secretary of the Navy for Research, Acquisition, and Development (ASN(RD&A)) Nora Slatkin and Director of the Ballistic Missile Defense Organization LGEN Malcolm O'Neill **sign Memorandum of Agreement number A-143**. The MOA outlines the management responsibility and oversight that BMDO and the Navy will share for the development of the Navy Area program and the Navy Theater Wide program. (Note: Need to check this date – could be 23 Mar 1993 or 94.

28 March 1995 - **TERRIER LEAP Flight Test Event FTV-4**. – Essentially the same test scenario as FTV-3A, but with a Rockwell LEAP Kinetic Warhead and corrective changes to the STANDARD Missile second-stage guidance software (correcting the errors discovered during FTV-3). The missile was delivered to within its required error basket, but the Kinetic Warhead's internal battery failed to activate upon separation with the third stage. Therefore, no intercept was achieved during this test.

26, 27 June 1995 – **Extended Tracking and Control Experiment (ET&CE)** conducted at the Pacific Missile Range Facility, Hawaii. USS Port Royal (CG-73) and USS Lake Erie (CG-70) track TBM targets and exchange Link data. Cueing demonstrated via DSP and TRAP messages.

4 August 1995 – D, BMDO LTG Malcolm O'Neill and PDASN(RD&A) VADM W. C. Bowes sign a joint memorandum **authorizing the establishment of a Blue Ribbon Panel** "...to review alternatives and recommend the preferred approach to rapidly maturing Navy LEAP with an option for achieving a UOES capability."

3 October 1995 – **TERRIER LEAP Blue Ribbon Panel** recommendations released. Convened by Direction of D, BMDO and ASN(RD&A) to determine the best path to pursue following the TERRIER LEAP flight test series. Chairman: Gen. Larry Welch, USAF (Ret.), Vice Chairman Wayne E. Meyer, USN (Ret.). Panel

Fall 1995 – **Congress appropriates and authorizes an additional $170M** in Fiscal Year 1996 for the Navy Upper Tier program over the President's budget request.

Feb 1996 – **Program Budget Decision (PBD) 224** adds $604.1M over the FYDP (FY97-01) to the Navy Theater Wide Program. Directs program to "...proceed to a system level intercept employing the AEGIS / Standard Missile / Vertical launching System/LEAP System." Also directs the program to conduct concept definition studies & technology demonstrations, as well as to assess the potential of various alternative kill vehicle technologies (LEAP, THAAD, AIT and EKV). Directs BMDO to select the final NTW kinetic kill vehicle configuration in FY 1998 and conduct the first flight intercept demonstration in FY 2000. Directs FY96 congressional plus-up of $170M to be used across FY96 and FY97. Program funding and schedule set as follows:

	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001
Funding ($M)	60	100	150	150	175
Events:			△ CTV-1	△ CTV-2 △ GTV-1	△ GTV-2 △ GTV-3

(CTV = Control Test Vehicle Flights, GTV = Guided Test Vehicle Flights (Intercept Attempts)

February 1996 – As a result of the end of the TERRIER LEAP flight tests and the start of the AEGIS LEAP Intercept demonstration, **work begins to transition LEAP and ASAS contracts funded by BMDO's Technology Readiness (TR) branch to PEO(TAD)**. Efforts are made to maintain funding of facilities and talent utilized during TERRIER LEAP.

25 Mar 1996 – CDR A. J. Cetel, PEO(TAD) –BA, designated as Navy Theater Wide (NTW) Flight Demonstration Project Officer by RADM J. T. Hood, PEO(Theater Air Defense). CDR Cetel to report directly to PEO(TAD).

18 April 1996 – LTG Jay M. Garner, Commanding General of U.S. Army Space and Strategic Defense Command signs a memo for the BMDO Director. The memo criticizes the draft Navy Theater Wide Report to Congress , stating that the report misrepresents NTW system performance and misinterprets results of the CAPSTONE TBMD Cost and Operational Effectiveness Analysis (COEA).

9 May 1996 – **Phase I of the Theater Missile Defense Cost and Operational Effectiveness (TMD COEA) is completed.** Key findings include the validation of the effectiveness of multi-tier TMD architectures and the benefits of sea-based missile defenses – especially in crisis scenarios when land-based forces have yet to arrive

23 May 1996 – USD(A&T) Dr. Paul Kaminski appoints **RADM Richard D. West Deputy Director of BMDO**. This is the highest position that any Naval officer has held in BMDO to this point.

31 May 1996 – **LTG Malcolm O'Neill, Director of the BMDO, retires from the U.S. Army.**

7 June 1996 – **Navy Theater Wide Flight Demonstration Project Requirements** Joint Memorandum of Understanding signed between CAPT J. Barron (PEO TAD-B), CAPT

Dan Meyer (PMS 400B3) and CAPT Bob Wilson (PMS 422). Designates CAPT (S) A. J. Cetel as the flight demonstration project officer, and puts the flight demonstration project requirements under configuration control, requiring the approval of the three signatories to change the requirements.

26 June 1996 – **Lt. Gen. Lester Lyles, USAF nominated by President William Clinton to be the Director of the BMDO**. He is confirmed by the Senate on 2 Aug 1996.

2 Aug 1996 **– CAPT (S) A. J. Cetel directed to conduct the Navy Theater Wide Program Assessment** by PEO Theater Air Defense, RADM Rodney P. Rempt. From the chartering letter “The intended result of this assessment is to produce a plan to accelerate, to the maximum extent practicable, the deployment of a credible NTW TBMD system....Review programmatic, schedule, funding, technical and organizational considerations. 5 groups formed to conduct the assessment, including a Senior Oversight Board (senior Navy, BMDO and lab), an Assessment Planning Team (mid-level Navy, BMDO and lab), System Engineering and Technical Assessment Team (working-level Navy, lab and industry), a Senior Advisory Panel (retired Flag officers and industry VPs), and a Senior Industry Advisory Group (Senior Industry). Significant guidance included direction to use AWS, SM-2, VLS and LEAP to engage a TBM target, use PMRF as the test range, keep risk under control, and commence test events no later than the end of 1997.

29 October 1996 – CNO Jay Johnson (Actually, ADM Gehman for CNO) and SECNAV John Dalton sign a memorandum directing ASN(RD&A) and DCNO (Resources, Warfare Requirements and Assessments) (N8) **to jointly conduct a “...comprehensive review of Navy TBMD programs**. Within 90 days, report to the Secretary of the Navy and the Chief of Naval Operations with a plan to accelerate the fielding of credible sea-based AREA and THEATER-WIDE TBMD Systems.”

3 Dec 1996 – **USD (A&T) Paul Kaminski memo to D, BMDO (Lt. Gen Lyles) and ASN (RD&A) (Hon. John Douglass)** designates Navy Theater Wide as a “BMDO Core program” as defined in the 1993 Bottom-Up Review. NTW also designated a Pre-MDAP program, with direction to begin IPT process to determine how to transition the program to an MDAP, specifically directing BMDO and Navy to determine the appropriate phase of the acquisition life-cycle to enter, documentation required for that phase, and a schedule for the program.

24 Jan 1997 – Navy STANDARD Missile Block IVA intercepts a Tactical Ballistic Missile target at White Sands Missile Range, New Mexico. This is the first ever Navy intercept of a ballistic missile. This is a Navy Area program event, not NTW.

27 June 1997 – CAPT(S) P. M. Grant relieves CAPT A. J. Cetel of his duties and responsibilities regarding the Navy Theater Wide Program.

26 Sep 1997 – **AEGIS LEAP Intercept Demonstration first flight test** named Control Test Vehicle 1 (**CTV-1**) executed. Mission used a modified SM-2 Block IV, and attempted to fly the missile to an altitude never before reached. Unfortunately, the missile self-destructed soon after launch due to a problem with the SM-2 Block IV Steering Control Section (SCS) that caused a control fin to remain deflected at a 17 degree angle – more than the booster's thrust vector control could compensate for.

29 Sept 1997 – **ASN(RD&A) approves the findings of the Navy TBMD Cost and Operational Effectiveness Analysis (COEA) Phase II**. Recommended the continuation of the STANDARD Missile – LEAP program underway at the time, versus other missile configurations such as THAAD missile integration or a new missile development.

Nov 1997 – CAPT P.M. Grant **charters the Navy Theater Wide Senior Advisory Team**, an advisory team comprised of retired flags and industry leaders knowledgeable in acquisition management and systems engineering, to advise him on the AEGIS LEAP Intercept (ALI) Program.

13 Feb 1998 - RADM Rodney P. Rempt, PEO(TAD) **reassigns Navy Theater Wide program authority and responsibility from PEO(TAD)-B to a new Navy Theater Wide Program Management Office, PMS 452.** CAPT P.M. Grant III is designated the Navy Theater Wide Program Manager (Acting), pending approval by the Acquisition Workforce Oversight Council. PMS 452 is retroactively established, effective 23 December 1997.

6 Mar 1998 – ASN(RD&A) John W. Douglass announces that the Program Executive Offices for Surface Combatants and Theater Air Defense **will merge to become a new PEO(name TBD**). This memo also establishes a new Deputy Assistant Secretary of the Navy for Theater Combat Systems, with responsibility for acquisition issues regarding TBMD and surface combatant combat systems.

20 April 1998 – Joint Letter between PEO(TAD), PEO(Surface Combatants), and PEO(Carriers, Littoral Warfare, and Auxiliary Ships) signed 17 Apr 1998 transfers reporting **authority for Navy Theater Wide from PEO(TAD) to PEO(SC)**. PEO(TAD) disestablished this date as well.

14 April 1998 – **Naval Theater Ballistic Missile Defense Operational Requirements Document (ORD) validated by Joint Requirements Oversight Council (JROC)** to include requirements and Key Performance Parameters (KPPs) for Navy Theater Wide program. This document had previously been validated by the JROC for the Navy Area program.

22 May 1998 – Navy Acquisition Workforce Oversight Council co-chairs ASN(RD&A) John Douglass and VCNO Admiral Donald Pilling **approves CAPT P.M. Grant III as the Navy Theater Wide Program Manager**, PMS-452. USD(A&T) Jacques Gansler concurs by memo 09 June 1998.

29 Jun 1998 – **USD(A&T) approves program decision memo from D, BMDO and ASN(RD&A)** listing the exit criteria for the NTW program's Program Definition and Risk Reduction (PD&RR) phase and documentation required for the upcoming Defense Acquisition Board Review.

31 August 1998 – Japanese AEGIS Destroyer JDS Myoko (DDG 179) tracks North Korean firing of TAEPO DONG-1 missile from North Korea over Japan.

10 Nov 1998 – RADM K. K. Paige designates LCDR Brian B. Gannon as Navy Theater Wide AEGIS LEAP Intercept Project Officer, code PMS 452AL. LCDR Gannon directed to execute ALI through CAPT Grant, PMS 452. The code for LCDR Gannon's position later changes to PMS 452X.

20 Nov 1998 – AEGIS LEAP Intercept Target Test Vehicle-1 (TTV-1) Test conducted at PMRF. Target tracking conducted by Navy Area TBMD Linebacker ships USS Lake Erie (CG 70) and USS Port Royal (CG 73).

25 Jan 1999 – PMS 452 releases "Final Report: NTW Early Deployment Options Analysis". Also known as the "13 options" study.

25 Feb 1999 – USD(A&T) Jasques Gansler directs, by memo, Lt, Gen Lyles, D, BMDO to restructure NTW (and other BMD programs) to reflect Program Budget Decision 224C, and meet a First Unit Equipped date in FY07. Even though funding is only available for either THAAD or NTW to meet a FY 07 FUE, BMDO is directed to baseline both programs for an FY 07 FUE. A decision "...on which of the programs to focus." Is anticipated for Nov 2000, and D, BMDO will begin development of programmatic and technical considerations in coordination with the Services and the Joint Staff to aid in the Nov 2000 decision.

10 March 1999 – Lt. Gen Lyles, D, BMDO directs CAPT P.M. Grant, PMS 452 by memo to structure the NTW program for a FUE of FY 2007 for the "Block I" system. CAPT Grant is also directed to continue the AEGIS LEAP Intercept Flight Demonstration Program (FDP), as well as Block I risk reduction activities..

21 April 1999 – RADM Kathleen K. Paige, Deputy PEO(TSC) directs, by memo, CAPT P.M. Grant to develop a "...comprehensive and robust program strategy for deploying the NTW capability..." to include an assessment fo alternative development strategies. Numerous Navy, OSD and industry participants were named. A main focus of this study was investigation of the "OR" ship concept – an AEGIS ship that could perform TBMD or AAW missions, but not both simultaneously. Report due to RADM Paige 2 June 1999. This effort becomes known as the "Goat Island" study.

04 May 1999 – USD(A&T) **Jacques Gansler signs an acquisition decision memorandu**m (ADM) authorizing continuation of the NTW program in the Program Definition and Risk Reduction phase, and exit criteria for entry into the engineering and

manufacturing development phase. Also approved was the NTW acquisition strategy, acquisition program baseline (APB) and associated Cost as a Independent Variable (CAIV) objectives. Long-lead material authorized after successful completion if initial Threat Representative Testing (DT-1B flight test) and the STANDARD Missile Critical Design Review. The Milestone II documentation set was also stated.

27 May 1999 – Lt. Gen. Lester Lyles promoted to General and assumes duties as Chief, Air Force Materiel Command.

02 June 1999 – RADM William W. Cobb designates Mr. Richard S. Matlock (code PMS 452R) as the Japan / U.S. Cooperative Project project manager contingent upon signature of the "Memorandum of Understanding (MOU) Between the Department of Defense of the United States of America and the Japan Defense agency Concerning Cooperative Ballistic Missile Defense Research". Execution will be through the NTW program manager, CAPT P.M. Grant III.

14 June 1999 – Lt. Gen. Ronald Kadish, USAF assumes duties as Director, BMDO.

2 July 1999 – Deputy Chief of Naval Operations VADM Conrad C. Lautehbacher and D, BMDO Lt. Gen Ronald T. Kadish sign Memorandum of Agreement **No. A-143 Addendum 1**. This addendum to the original Navy / BMDO MoA A-143 of 23 Mar 1995 updates the Navy / BMDO cost sharing and program management agreements for the Navy Area and Navy Theater Wide programs.

16 Aug 1999 – Memorandum of Understanding signed between United States and Japan regarding cooperative development for NTW Block II system. Three tasks defined: 1) System Concept Exploration and Guideline Development 2) Preliminary Design, and 3) Technology Risk Reduction. Both parties' contribution not to exceed $36M.

26 Aug 1999 – USD(A&T) Jacques Gansler directs D, BMDO by memo to do the following WRT Navy Theater Wide by 30 November: "Complete the re-configurable ship feasibility study and provide feedback from OPNAV on operational aspects. Define a program with phased introduction of mission capability as an alternative to the current baseline, a general description of the Block II program, and a strategy on how to best infuse the Japanese cooperative program."

1 Sep 1999 – D, BMDO Lt. Gen. Kadish directs PEO(TSC) by memo to begin assessing feasibility and approaches for a First Unit Equipped (FUE) date for NTW of FY 2007 or earlier. Due to Lt. Gen Kadish by 10 Nov 1999.

8 Sept 1999 – Lt. Gen. Kadish, D, BMDO forms an "Upper Tier Strategy Tiger Team" to assist him with meeting the 10 Nov 1999 deadline for providing USD(A&T) with an evolutionary approach to the Upper Tier of ballistic missile defense.

24 Sept 1999 – **ALI Flight Control Test Vehicle (CTV) 1A** – SM-3 launched from USS Shiloh (CG-67) demonstrated airframe stability and control of SM-3 missile thorugh 2nd / 3rd stage separation event (primary objective). All secondary objectives achieved as well.

12 Oct 1999 – PMS 452, CAPT Grant, signs a letter to OSD Program Analysis and Integration (PA&E) stating that the NTW Program does not concur with PA&E's Upper Tier Effectiveness Analysis. Recommended changes to the analytical methods and conclusions were provided.

??? Dec 1999 – DEPSECEF John Hamre approves PBD 224C2 – adding ????????????Funding to Navy Theater Wide in Fiscal Years 2002, 2003, 2004, 2005

16, 17 Feb 2000 – DoD Compliance Review Group conducts its annual Anti-Ballistic Missile Treaty review of BMDO Programs.

18 Feb 2000 – Chief of Naval Operations Jay L. Johnson writes in a memorandum to SECDEF William Cohen (via memorandum) "...I most strongly recommend that a sea-based Navy Adjunct be included in any policy and/or architectural designs for a NMD system."

24 April 2000 – MGEN Willie B. Nance, Jr., Program Executive Officer and System Program Director for National Missile Defense, in a memo to PEO(TAD/SC) **approves NTW participation in additional NMD Integrated Flight Tests (IFTs) IFT-5 and RRF-8/OSP Demo.** NTW participation is dubbed "Associated Operations", and is designed not to interfere with the NMD tests.

30 June 2000 – Chief of Naval Operations Jay L. Johnson **establishes, by memo, an Assistant Chief of Naval Operations (ACNO) for Missile Defense**. RADM Rodney P. Rempt is named to this post, with CAPT Christopher M. Moe as his deputy. The ACNO MD "...is assigned the specific task of reaching the Navy's full potential in Ballistic and Cruise Missile Defense."

13 July 2000 – **FTR-1 Flight Test** – Primary objective and one secondary objective not met (Primary = demonstrate third stage airframe stability and control of FTR-1 configured SM-3 missile through KW separation, Secondary = demonstrate elements of third stage performance). Problem determined to be a GPS-Aided Inertial Navigation System (GAINS) software error caused when unexpected data was received via the fiber-optic VLS/GPS interface (VGI) after the fiber optic cable severed during missile egress.

11 Sept 2000 – **NTW Program Execution Review** presented to Lt. Gen Ronald T. Kadish, D, BMDO. Several actions and recommendations were issued by Lt. Gen Kadish by separate memo 25 Sept 2000.

SEP 2000???? PDM-1 Study Initiation?

3 Oct 2000 – Lt. Gen. Ronald T. Kadish, by memo, requests the assistance of the ACNO MD and Director, Joint Theater Air and Missile Defense Organization (JTAMDO) to "...review the NTW requirements base and access (sic) the need for modifications." This request is to assist with the ongoing PDM-1 study.

19, 21 Oct 2000 – Lt. Gen Ronald T. Kadish, D, BMDO, and H. Lee Buchanan III, ASN(RD&A) sign Memorandum of Agreement A-143 Addendum 2. This document describes the program management structure and acquisition approach for NTW and the Navy Area Program. Of note, PMS 452, PMS 451, and the Navy US Japan Cooperative Development Program manager are assigned additional duty (ADDU) to the Director, BMDO.

13 Dec 2001 – President George W. Bush announces that the **United States of America intends to withdraw from the 1972 Anti Ballistic Missile Treaty** with the Soviet Union in 6 months time.

14 Dec 01 – **Navy Area Program cancelled** after USD(AT&L) fails to certify the program as "in the national interest" after breaching program cost estimates by more than 25% in accordance with "Nunn-McCurdy" legislation.

25 Jan 2001 – **Flight Test Round 1A (FTR-1A).** Conducted at the Pacific Missile Range facility off of Kauai, HI. Mission was a success, demonstrating STANDARD-Missile-3 first, second, and third stage operation, and successful ejection of an inoperative kinetic warhead.

April 2001 – RADM Meinig Alternative DACS commission reports out.

30 April 2001 – Paul A. Schneider, Acting ASN(RD&A) directs PEO(TSC) , by memo, to enable the Navy Theater Wide Program manager to "...have direct line authority over the execution the execution of all budgets and contracts in this program" by 15 May 2001. This is a departure from the previous execution of the program, in that the NTW PM issued Project Directives (PDs) to those PMs with contract authority (e.g. PMS 400B, PMS 422, PMS 410).

13 June 2001 – President George W. Bush announces that the United States of America **is no longer a party to the 1972 Anti Ballistic Missile Treaty.**

26 June 2001 – RADM Rodney P. Rempt, ACNO/MD, directs PEO(TSC) by memo to begin work on defining the system requirements for an advanced S-band Theater Air and Missile Defense Radar. X-band radar requirements and S-band key performance parameters to be sent under separate cover.

2 Jan 2002 – **SECDEF issues guidance on DoD Ballistic Missile Defense Programs** – including elevation of the Ballistic Missile Defense Organization to agency status as

the Missile Defense Agency and the application of a “capability-based” requirements process for missile defense. Current Service missile defense Operational Requirements Documents **(ORDs) are cancelled.**

25 Jan 2002 – **Flight Mission 2 (FM-2)** Conducted at the Pacific Missile Range Facility off of Kauai, HI. Mission was a success, and the first intercept of a ballistic missile in space by a U.S. Navy warship. SM-3 hit the target while the target was descending. Hitting the target was not a de facto objective of this test, but the SM-3 did it anyway.

15 Feb 2002 – Missile Defense Agency initiates the Missile Defense National Team (MDNT), a team comprised of several large defense contractors to define, design, engineer and build the Ballistic Missile Defense System.

13 June 02 – **Flight Mission 3 (FM-3)** Conducted at the Pacific Missile Range Facility off of Kauai, HI. Mission was a success, and an almost exact duplication of the test scenario of FM-2. This test’s success meant that the exit criteria of the ALI Demonstration had been met.

21 Nov 2002 – **Flight Mission 4 (FM-4)** Conducted at the Pacific Missile Range Facility off of Kauai, HI. Mission was a success – STANDARD Missile – 3 intercepted an ARIES target while the target was ascending (pre-apogee), a first for the Department of Defense. The kinetic warhead also demonstrated an aimpoint shift on the target – hitting it close to the warhead instead of at the target midpoint (as had been done in FM-2 and FM-3). This maneuver is intended to increase lethality against target missiles.

17 Dec 2002 – **President George W. Bush announces that he has directed Secretary of Defense Donald Rumsfeld to “...proceed with fielding an initial set of missile defense capabilities.** We plan to begin operating these initial capabilities in 2004 and 2005, and they will include ground-based interceptors, sea-based interceptors, additional Patriot (PAC-3) units, and sensors based on land, at sea, and in space.”

Appendix B, “Binder of Selected Program Documents” is provided under separate cover.

Appendix C, “Binder of Selected ALI Flight Test Presentations” is provided under separate cover.

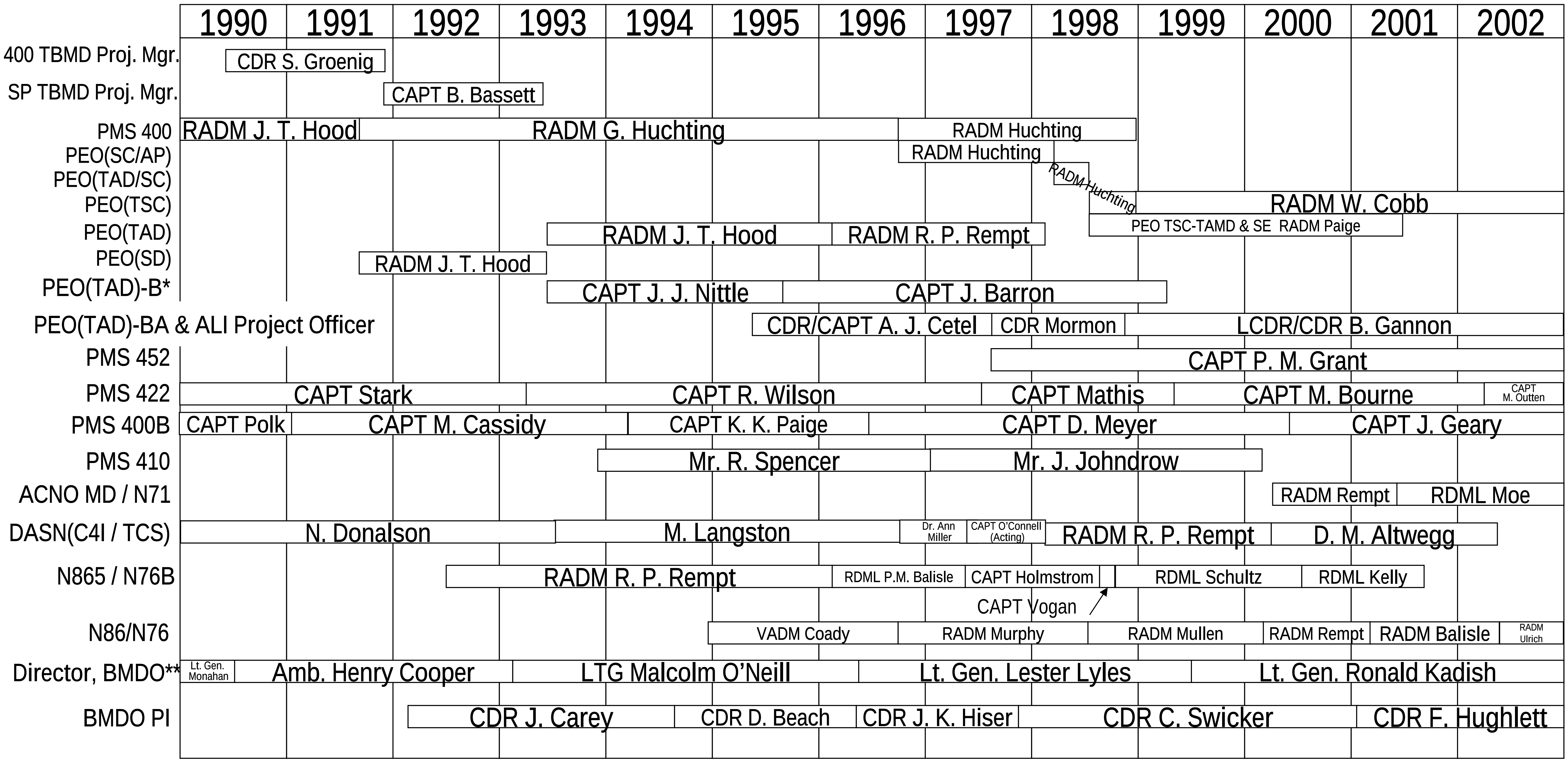
Appendix D, JHU/APL Publication "Overview of the AEGIS LEAP Intercept Program (August 1995 – August 1998)", is provided under separate cover.

Appendix E

NTW Congressional Plus-Up Funding History

1. FY95 - +$58M from Congress to Complete TERRIER LEAP, $75M total for FY05.
2. FY96 - +170M from Congress ($200M total for FY96), +$604M over FYDP by PBD 224 (02/10/96)
   a. Funded ALI (5 test flights, 2 CTVs, 3 GTVs, initial intercept Sep 2000)
   b. No risk reduction activities
3. FY97 - +246M from Congress ($304M total for FY97), +$207M over FYDP by PBD 224 (12/11/96)
   a. Increased ALI to eight test flights, 4 CTVs, 4 GTVs, initial intercept moved up 8 mos. to Jan 2000
   b. Some risk reduction activities funded
4. FY98 - +$215M from Congress ($447M total for FY98)
   a. Increased ALI to nine test flights, initial intercept moved up 4 mos. to September 1999
   b. More extensive risk reduction activities
5. FY98 - $38M from Congress (Emergency Supplemental; H. Report 105-504)
   a. + $18M to AEGIS TBMD design development, including discrimination
   b. + $8M for NTW Block I development team, +$4M for Block I system engineering
   c. +8M for developmental test missile long lead items
6. FY99 - +$148M from Congress ($368M total for FY99)
   a. +$120M for program acceleration
   b. +$28M to initiate a radar improvement competition
7. FY99 - +$30M from Congress (Emergency Supplemental; P.L. 105-277, 10/21/98)
   a. +$20M for Japanese cooperative development for NTW Block II
   b. +$10M for NTW acceleration
8. FY00 - +$50M from Congress to continue NTW Block II radar development
9. FY01 - $441M budget
10. FY02 - $446M budget
11. FY03 - $386M budget
12. FY04 - $664M budget, plus Japanese Cooperative Development budget of $53M in its own Missile Defense Agency line item.
13. FY05 - $1,072M budget, plus Japanese Cooperative Development budget of $72M.

Appendix F: TERRIER LEAP and ALI-Related Organizational Leadership 1990-2002



* Position changed to PEO(TSC)-B when PEO(TAD) became PEO(TSC)

** Position changed to Director, Missile Defense Agency 2 Jan 2002