

**Union of Concerned Scientists
Working Paper**

**An Analysis of the
25 January 2002 Test
of the Aegis-LEAP Interceptor
for Navy Theater-Wide**

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The 25 January 2002 Aegis-LEAP Interceptor Test

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The United States conducted a flight test of the interceptor being developed for the Block 1 version of the Navy Theater-Wide (NTW) defense system on 25 January, resulting in an intercept of the target.

Relatively little information about this test has appeared in the press, and some of the information that has appeared is incorrect. This memo describes what occurred during the test and assesses its significance.

A key finding is that the target used in the test was considerably larger than important targets that NTW is presumably being developed to engage, such as a warhead from a North Korean Nodong missile. Using a larger target increases the range at which the Aegis SPY-1 radar can detect and track the target, and provides a larger target for the kill vehicle to impact. In the test, the kill vehicle apparently collided with the booster of the target missile, and would not have destroyed a warhead on the missile.

Moreover, it appears that the planned flight tests will continue to use this large target for the next several years.

The use of a large target may be appropriate at such an early stage of the test program. But the use of such a target limits what conclusions can be drawn from successful intercepts about the capability of the system in operational conditions. The Pentagon has so far not made public claims about the system based on the tests, but others have. For example, a Raytheon press release stated that the January test “demonstrated the capability to provide the country with Sea-based Missile Defense.”² This is clearly not true.

The SM-3 Interceptor

The interceptor used in the test was a Standard Missile 3 (SM-3) interceptor, which has a lightweight exo-atmospheric projectile (LEAP) kill vehicle (also referred to as the kinetic warhead (KW)) as its fourth stage.

The SM-3 interceptor is a modification of the Aegis Standard Missile and is being developed for the NTW Block 1 system. The SM-3 interceptor differs from the SM-2 Block IV booster and sustainer motor by the addition of a third-stage solid-fuel rocket motor (TSRM) and fourth stage kinetic kill vehicle (see Figure 1).

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² “Raytheon STANDARD Missile-3 Destroys a Ballistic Missile Target in Test of Sea-based Missile Defense System,” Raytheon Company press release, 26 January 2002.

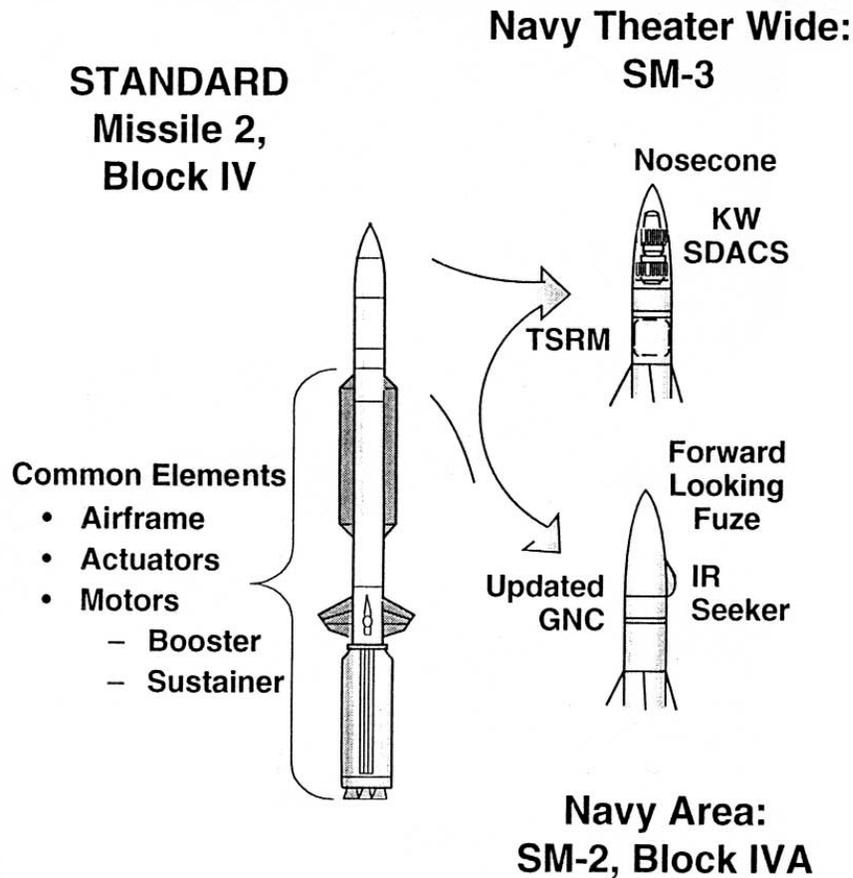


Figure 1: A comparison of the SM-2 Block IV, Block IVA, and SM-3 missiles.

The SM-3 interceptor reaches a speed of 3 km/s.³ The original goal for NTW Block 1 interceptor was 4.5 km/s, but that was reportedly scaled back because modifying the Standard Missile to reach that speed was too expensive. The lower speed means that the Block 1 system falls within the low-speed agreement of the September 1997 Demarcation accords to the Anti-Ballistic Missile Treaty.

The LEAP kill vehicle is designed to operate only at high altitudes where there is minimal atmospheric density, and cannot attempt to intercept below about 100 kilometers altitude. It can therefore only be used as part of a midcourse defense, and not for either boost or terminal engagements.

³ Robert Wall, "Intercept Starts Long Road to Sea-Based Missile Defense," *Aviation Week and Space Technology*, 4 February 2002, p. 34, and Raytheon press release, 26 January 2002.

The Aries Target Missile

The target vehicle used in the test was a one-stage Aries target missile. The Aries missile consists of a solid rocket motor that was originally used as the second stage of the Minuteman I missile. It has a burnout speed of about 2.4 km/s and a maximum range of about 700 kilometers.⁴

The 25 January 2002 Test

This test, designated Flight Mission-2 (FM-2), was intended to “evaluate the fourth-stage kinetic warhead interceptor’s guidance, navigation and control capabilities.”⁵ Intercept was reportedly not a primary goal.

The test was the first using a LEAP vehicle with an operational Solid Divert and Attitude Control System (SDACS).⁶ Development of the system has reportedly been slowed by problems with the SDACS, apparently including difficulties with fabrication and concerns about the possible effect that particles in the exhaust cloud of the divert motors might have on the ability of the LEAP sensor to see the target.

In the test, the Aries target missile was launched from the Pacific Missile Range Facility (PMRF) on Kauai, Hawaii at 9 pm EST (4 pm local time), and reportedly flew in a north-westerly direction.⁷ The Aries missile was detected and tracked shortly after launch by the SPY-1 radar on the Aegis cruiser USS Lake Erie (CG-70), which was reportedly stationed 550 kilometers (300 nautical miles) from Kauai.⁸ A schematic of the intercept geometry is shown in Figure 2.

⁴ The Aries target vehicle is built by Orbital Launch Systems (see www.orbital.com/Missiles/NTW.pdf). The Aries booster (M56A1) has a mass of 5600 kg and carries 4700 kg of solid propellant, and has a burntime of 63 seconds (Environmental Assessment for Exoatmospheric Discrimination Experiment (EDX), 1990; Final Supplemental Environmental Impact Statement (FSEIS) for Proposed Actions at U.S. Army Kwajalein Atoll (USAKA) (US Army Strategic Defense Command (USASSDC), December 1993).

⁵ Raytheon press release, 26 January 2002.

⁶ The previous flight test took place a year earlier, on 25 January 2001. That test was similar to the recent test, but did not have an active SDACS and did not attempt an intercept. The test was reported to be “an evaluation of the SM-3’s airframe stability and control;” in addition, it collected data from the LEAP sensor (Anthony Sommer, “Navy rates Kauai missile test a winner,” *Honolulu Star-Bulletin*, 26 January 2001). Reports state that the SPY radar was able to steer the interceptor so that it passed within 400 meters of the target, and that this accuracy is adequate to allow the kill vehicle to maneuver to intercept (Robert Wall and Bruce Nordwall, “Navy’s Missile Defense Closes In On Intercept,” *Aviation Week and Space Technology*, 5 February 2001, p. 39).

⁷ “Interceptor Hits Target In Navy Anti-Missile Test,” *Associated Press*, 27 January 2002.

⁸ Wall, “Intercept Starts Long Road.”

AEGIS LEAP INTERCEPT

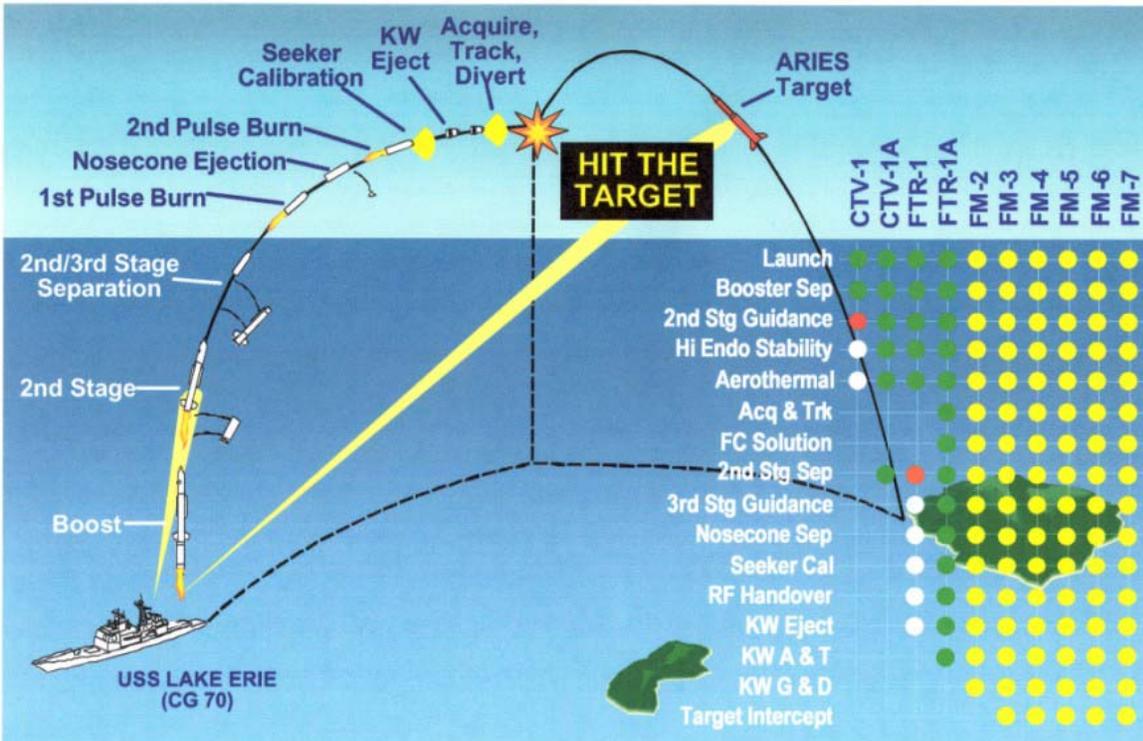


Figure 2: Schematic of test geometry for the ALI tests (from P.M. Grant, “Sea-based Midcourse Defense,” 9 October 2001, www.ndia.org/committees/slaad/pdf/sea.pdf).

At 9:06 the Lake Erie cruiser launched the SM-3 interceptor.⁹

After being released by the interceptor booster, the LEAP kill vehicle reportedly acquired and homed on the target, and intercepted it at 9:08 at an altitude of 160 kilometers.¹⁰ Figure 3 shows an image of the Aries target taken by the LEAP sensor just before intercept during this test.

The closing speed between the target and interceptor in the test was roughly 4 km/s.¹¹ (For comparison, the closing speed in the intercept tests of the ground-based midcourse missile defense system have been 7.4 km/s.) Given the speeds of the target and interceptor and the

⁹ Lt. Col. Rick Lehner, Missile Defense Agency, personal communication, 8 February 2002. The times given in press reports for the launch of the interceptor and for intercept (9:08 and 9:18, respectively) are incorrect and should be 9:06 and 9:08. Given the burnout speed of the Aries missile, its flight time would be less than 10 minutes, so the times reported in the press could not be correct.

¹⁰ Lt. Col. Rick Lehner, Missile Defense Agency, personal communication, 8 February 2002.

¹¹ Wall, “Intercept Starts Long Road.”

reported closing speed, we calculate that the interceptor and target collided at an angle of 107 degrees (i.e., 73 degree from head-on).



Figure 3: The image of the Aries target vehicle from the LEAP sensors just before intercept (US Navy photo).

One report said the intercept took place “more than 300 miles [480 km] northwest of Hawaii.”¹² It is not clear whether “Hawaii” refers to the target launch site at Kauai or to another part of the Hawaii islands.

Computer modeling of the Aries missile shows that if its burnout speed was 2.4 km/s and it flew for eight minutes to an intercept point at an altitude of 160 kilometers, then it flew on a significantly lofted trajectory, with a loft angle at burnout of about 64 degrees. The intercept would then have taken place about 430 kilometers from the target launch site and the target would have had a speed of 1.9 km/s at intercept.

Computer modeling of the SM-3 missile shows that if it flew for two to three minutes to reach the intercept point, the intercept would have taken place 200 to 360 kilometers from the Lake Erie cruiser.

Implications of Target Size

The target in this test was large because the warhead section did not separate from the Aries booster, as is evident from Figure 3. In general, one expects ballistic missiles with ranges of

¹² “Interceptor Hits Target In Navy Anti-Missile Test,” *Associated Press*, 27 January 2002.

interest for Navy Theater-Wide to have separable warheads.¹³ In particular, the North Korean Nodong missile, which could be used to threaten targets in Japan, is believed to have a separable warhead. The same is true for Chinese 600-km-range DF-15 (M-9) missiles, which are reportedly deployed along the Taiwan Strait.

The fact that the target was large has two important implications. First, the large physical size of the Aries booster and the presence of features on the booster, such as the fins, that could give large radar returns, would give the target a much larger radar cross section than the warhead by itself unless it was viewed nearly head-on. This is important because of the relatively poor capability of the SPY-1 radar (see Appendix). This larger radar cross section would make it easier for the SPY radar to track the target accurately so that it could calculate an intercept location and guide the interceptor toward it.¹⁴

The second implication is that the Aries booster presented a much larger target for the LEAP kill vehicle to collide with. The full Aries missile is more than 10.5 meters long and has a maximum diameter of about 1.3 m, while a warhead would be a couple meters long and about a meter in diameter. In this test, the kill vehicle apparently collided with the middle of the missile body, rather than the warhead section of the missile, so that it would not have destroyed the warhead had it been a real interception. Figure 3 shows that the kill vehicle was headed toward the middle of the missile body just prior to impact, since the field-of-view of the LEAP sensor was centered on the middle of the missile body. This image was taken such a short time before impact that the kill vehicle would not have had time to maneuver to strike the warhead.¹⁵

Future Tests

The January 2002 test was the fourth in a planned series of nine developmental test flights (called the Aegis LEAP Interceptor (ALI) series) for the Sea-based Missile Defense (SMD) program.

¹³ For missiles with ranges greater than a few hundred kilometers, the atmospheric forces during reentry are very large, and can break the missile body off the warhead if it remains attached. When this happens, the force of the breakup and unpredictable atmospheric forces on ragged edges created by the breakup can cause the warhead to tumble and swerve significantly. The 500 km-range al Hussein missiles that Iraq fired during the 1991 Persian Gulf war did not have a separable warhead since they were built from parts of short-range Scud missiles. The al Husseins were observed to break up on reentry (see G.N. Lewis and T.A. Postol, "Video Evidence of the Effectiveness of Patriot during the 1991 Gulf War," *Science and Global Security* 4, pp. 1-63). Those missiles reentered the atmosphere at roughly 2 km/s. Since the atmospheric forces increase with the square of the missile's speed, a Nodong missile with a speed of 3 km/s would be subject to forces more than twice as large as the al Hussein.

¹⁴ The radar could continue to track the booster casing after separation of the warhead to get an approximate location of a separated warhead; the accuracy would depend on the speed of separation and the flight time after separation. An attacker could deny such cueing, however. For example, after separation the booster could be programmed to fire its thrusters to divert it away from the warhead (this would be straightforward in the case of liquid-fuel missiles), or could carry an explosive charge to break the casing into pieces.

¹⁵ Given the level of detail that can be seen in the image of the target missile in Figure 4, the image was probably taken approximately a tenth of a second before impact (corresponding to a distance of about 400 meters). The acceleration a required to move the aim point sideways by a distance d in a time t can be found from the equation $d = at^2/2$. This shows that to move the aim point by 3 meters in 0.1 seconds would require a lateral acceleration of about 60g, which is probably ten times the acceleration that LEAP is capable of (Ted Postol, personal communication).

The ALI test series reportedly “consists of repeats of the same engagement to build confidence in the system.”¹⁶ This seems to indicate that all the tests in the ALI series will use non-separating targets. The Navy expects to conduct two more tests this year, and plans to finish the ALI tests by 2003.¹⁷

Following the nine tests in the ALI series, there are plans for six tests called Threat Representative Flight Testing. The first three of those tests will also use “unitary targets” (in which the warhead does not separate from the missile body) flying on different trajectories. The latter three tests will be against “more complex, separating targets.”¹⁸ The Navy reportedly does not currently have enough money for the latter test series; if it feels it is making enough progress in the ALI tests, it may cut that series short and apply the money to the follow-on tests.¹⁹

What Does the Test Show?

Conducting tests with a large target vehicle may be appropriate for early stages of testing, especially given the limits of the SPY-1 radar. However, it appears that such a target will continue to be used for the full ALI test series and the first half of the follow-on test series over the next several years.

Navy Theater-Wide cannot be used to engage missiles with a range of about 400 kilometers or less traveling on standard trajectories, since those missiles never reach altitudes greater than 100 kilometers, below which LEAP cannot operate. (Recall that the target used in the NTW test was flown on a highly lofted trajectory.) A missile like the al Hussein is therefore the shortest range missile that NTW could engage. As noted above, missiles of this range and certainly longer will tend to break apart unless the warhead separates from the missile body after boost phase, which implies that most of the missiles NTW could engage would not present a large target like that used in the test.

Since the test conditions planned for the next several years will apparently be significantly different than if the system were used against a missile with a separating warhead, successful tests cannot demonstrate that the defense would be effective under operationally realistic conditions against a missile with a separating warhead. The Pentagon has not made such claims, and in fact has stated that the current tests are not intended to be stressing. It is important that Congress and others recognize this as they assess the maturity of the technology and its ability to perform important functions.

Appendix: The SPY-1 Radar

The SPY-1 radar was designed for an air-defense role, and is therefore designed to track large objects that are fairly close to the radar, and is not very capable of tracking small objects—such

¹⁶ Wall, “Intercept Starts Long Road.”

¹⁷ Wall, “Intercept Starts Long Road.”

¹⁸ Wall and Nordwall, “Navy’s Missile Defense.”

¹⁹ Wall, “Intercept Starts Long Road.”

as warheads, decoys and missile debris—at long ranges. One estimate of the capability of the current SPY radar suggests that its detection range against a warhead is well under 1,000 kilometers and possibly even less than 500 kilometers.²⁰ Even if detection is possible, the radar may not give very precise track data if the tracking takes place when the warhead is near the edge of the detection range of the radar, so that the signal-to-noise ratio would be relatively low. Thus, the tracking capability of the radar might not be very good against a warhead on even a relatively short-range trajectory, as in this test (in the middle of the target's trajectory, it would have had a slant range of 425 to 500 kilometers from the radar), and could be considerably worse against longer range missiles, which NTW is intended to engage.

Moreover, since the wavelength of the S-band SPY radar is three times that of the X-band radars that are planned as part of the ground-based midcourse system, and because this radar was not designed for missile defense purposes, the SPY radar's ability to discriminate and track is likely to be very poor relative to the X-band radars.

²⁰ George Lewis, MIT Security Studies Program, personal communication December 2001.