DESTRUCTIVE EXPENDABLE (DE) COUNTERMEASURES (CM) SYSTEM

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ABSTRACT

The idea of kinetic kill as a means of aircraft self protection against anti-aircraft missiles was presented to you at the 1995 conference held in May at the Pensacola Naval Air Station. The concept can be envisioned as building a brick wall in the path of the incoming missile. When the missile strikes the brick wall the missile is destroyed and does no damage to the aircraft. Notice that the brick wall works no matter what the incoming missile might be. It doesn't care if the missile is launched from another aircraft or from the surface. The brick wall also doesn't care how the missile is guided; RF, IR or imaging. The questions of interest about the brick wall are: How big must it be? What building materials must be used? How far away from the aircraft must it be built? How much time is available to build it? How much time is needed to build it? A newly designed expendable, a Destructive Expendable, that would be compatible in size and weight with an MJU-10 flare and that could be launched using an existing dispenser would be the ideal solution. This progress report on the kinetic kill concept will discuss simulation and test results completed since then, which show the promise of the concept. This progress report will also indicate issues where much work remains to be done.

DESTRUCTIVE EXPENDABLE REPORT

The first study to report to you is one completed by a Systems Engineering class at the Air Force Institute of Technology in December of 1995 by a class of five officers. The results of the study/simulation are well documented in a master's thesis.[1] The scenario studied is a KC-135 on takeoff. The threat was a generic, surface-to-air, IR guided missile. The destructive expendable was a spherical container enclosing a deployable net made of DetCord™. When deployed the net had a 20-foot, circular, planar shape. The net was deployed so that the plane of the net was perpendicular to the missile flight path and intercepted the missile at a range of 50 meters. At impact, the detcord exploded causing the missile warhead to detonate. A turreted dispenser accomplished deployment of the expendable. Threats were launched at the KC-135 at all azimuths and ranges. Except for the expendable, all other needed hardware was shown to be off the shelf or modified off the shelf.

The results reported in the master's thesis for this very limited mission scenario are most interesting. The Engagement Model used by the class in this study indicated that using the destructive expendable for aircraft self protection provided the aircraft with a survivability rate is over 90%. The Systems Engineering Model used included eight weighted factors; cost, aircraft impact, operator tasking, effectiveness, mission impact, environmental impact, R/M and installation requirements; with each factor containing sub-factors. Another output of the Systems Engineering Model indicated that the destructive expendable concept was viable and affordable.

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In February of this year, Lockheed Martin Tactical Defensive Systems (LMTDS), under the able direction of Dr. Stavros Androulakakis, finished a study and analysis phase of a program specifically looking at the use of a low-cost, unguided, kinetic kill expendable to defeat the laser beamrider threat. This expendable is to be ejected from the aircraft by some type of rocket dispenser capable of firing the expendable along a selected azimuth. Their simulations and analyses determined requirements, azimuth (2pi)/elevation (~ 0-20 down), on the aiming capabilities of a rocket dispenser. They looked at how close together the missile and expendable would be at the intercept point for errors in the time of ejection of the expendable and in the pointing direction of the dispenser. They looked at how different types of nets and fragmentation warheads might be used to kill the missile. They have parametrically looked at separation range of the aircraft from the missile kill intercept point and the resulting impact on some of the system level requirements. And they have developed a preliminary design of the expendable device. The final report of phase one of this program is now available.[2]

1. Mark C. Cherry [et al.]: A systems engineering approach to aircraft kinetic kill countermeasures technology: development of an active air defense system for the C/KC-135 aircraft.

2. Dr. Stavros P. Androulakakis: New Laser Beamrider Missile Countermeasure Concepts.

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Functionally, the concept of a destructive expendable is broken out at follows: missile warning, acquisition/track, intercept point calculation, dispense expendable and the kill of the incoming anti-aircraft missile. Each one of these functions will be addressed as it relates to a destructive expendable countermeasures system.

Much time and effort has already been spent developing a missile warning capability for our aircraft. Reasons for needing this capability are many. The requirements on missile warning for successful implementation of a destructive expendable will not impose any new requirements on this function and it is most likely that existing missile warning technology will be adequate to accomplish what is needed. Interface requirements of the missile warning function with the needed acquisition/track capability have not yet been established. What has been addressed, both analytically and especially experimentally, is achieving an intercept of the missile and the expendable at the calculated intercept point. This hit to kill intercept capability has been demonstrated by several different programs.

For several years, the U.S. Army has been pursuing the concepts of kinetic kill as a means of tank self-protection, self-protection for ground vehicles and area defense of ground assets. One of these programs is called Small, Low-Cost Intercept Device (SLID). This program, administered by DARPA under the direction of Dr. David Fields, is exploring two different technical concepts of kinetic kill, self-protection systems. One concept by Boeing places a guidance package in the nose of a self-propelled intercept device. Following a launch of the SLID along the correct azimuth and elevation as determined by a threat warning subsystem, minor path corrections are made by the guidance subsystem to steer the SLID to a hit to kill intercept. This technology is similar in many respects to the successfully tested technology used in the Light Weight, Exoatmospheric Projectile (LEAP) demonstrated in a program conducted by the Ballistic Missile Defense Office.

The second SLID concept by Raytheon uses a radar to track both the incoming round and the SLID and achieves a hit to kill through a closed loop, fiber optic, data link. The Raytheon approach also launches the self-propelled SLID along the correct azimuth and elevation using a threat warning subsystem. Both contractors in field tests have already demonstrated critical components of the intercept devices, as well as the intercept devices themselves, during earlier phases of these programs. A system level test, acquisition, track and counter, of the Boeing approach is planned for some time late this year.

A different U.S. Army program, under the watchful eye of Mr. Ken Lim of TARDEC, has demonstrated a radar system capable of acquiring and tracking an incoming missile, dispensing a projectile and achieving a kinetic kill. This program is being conducted by TRW under the direction of Mr. Frank Stoddard. The system works as follows: A millimeter wave radar acquires and tracks the incoming missile. Algorithms calculate the missile flight path and the intercept device flight path. An intercept point of at least 50 meters from the tank is calculated. At the calculated time the intercept device is fired along the calculated flight path. At the intercept point the intercept device deploys thousands of steel pellets and triggers the impact fuse of the incoming round. The intercept test device consists of a rocket boosted, spin stabilized, ballistic round containing a warhead. While the test round warhead dispensed a large number of pellets at the target, the design of the ballistic round is modular so that it can accommodate many different types of warheads.

In six full up, end-to-end tests the intercept device successfully detonated the incoming anti-tank guided missile (ATGM) at the calculated intercept range four times. The misses of the other two tests were caused by improperly boresighted test hardware. It is assumed that the technologies used for this army self defense system can be sized to work successfully on-board an aircraft. TRW has proposed experiments to demonstrate that the radar, algorithms and expendable technologies would work at missile speeds and ranges representative of scenarios for aircraft self protection. Hopefully, SNJW will be able to find the money needed to conduct these experiments.

While this radar technology should be adaptable to aircraft installation, an acquisition/track functional capability specifically designed for use on an aircraft is going to be tested as a part of the Laser Infrared Fly-out Experiment (LIFE) program. This program will be using a laser to acquire and track an incoming anti-aircraft missile following hand off from a passive, missile warning sensor. Tests of this capability are scheduled for the White Sands Cable Car Facility in the Spring of 1999. Both the demonstrated TRW technology and the LIFE technology should be able to satisfy the pointing and tracking requirements of the destructive expendable concept.

The “kill” function of the destructive expendable concept is being explored extensively by LMTDS in the laser beamrider program mentioned earlier. What does it take to “kill” an incoming anti-aircraft missile? Simulation and test results have shown that it may not take much for a “kill”. There are two basic approaches for the kill, physical damage to the missile which will disrupt the missile flight and the detonation of the missile warhead.

For the physical damage approach the effects of the damage on the missile flight path must be known. Hopefully, the damage will cause a significant alteration in the missile flight path so that it will no longer be a threat to the aircraft. For the latter approach, the detonation of the missile warhead must only occur outside the vulnerability envelope of the airplane. A simple analysis of the dynamics of altering the flight path of a high-speed missile leads to the conclusion that the warhead detonation approach will allow the intercept point to occur much closer to the aircraft. This may be important when a thorough, response time, simulation and analysis is completed. What it takes to achieve a kill of the missile is important because it will have a direct bearing on the size and weight of both the destructive expendable and the dispenser.

LMTDS is looking at two different designs of the warhead in the destructive expendable; deployable nets and the fragmentation warhead. Simulations indicate that the impact of an anti-aircraft missile running into a net can “sometimes” trigger the impact fuse. Net parameters that have a direct effect on triggering the fuse are mesh size, cord cross sectional diameter, mass density, Young’s modulus, Poisson’s ratio and tensile stress limit. The effect explored in detail was the ability of the net to impose sufficient deceleration on the missile to trigger the impact fuse before the missile actually would cut through the net. Unfortunately, there is conflicting data on the magnitude and duration of the deceleration pulse needed to trigger these impact fuses. Much simulation and analysis is needed on how these fuses can be activated, as well as tests to support the analysis, so that the “sometimes” trigger the fuse becomes “always” trigger the fuse.

One of the possible net configurations is to make the net out of something called DetCord™. This material generates a blast when the detcord is broken. With proper net construction, fragments can also be added to this net. A DARPA program called EXONET, being executed by Foster-Miller under the direction of Mr. Arnis Mangolds, has conducted static tests using AIM-4 missiles and the DetCord™ nets. In these tests, extensive physical damage to both the external shell and the internal components occurred. It is most likely that the missile will fly no farther if it has suffered this extensive damage, but some flight test data, with a missile containing a live warhead, is needed.

LMTDS has conducted static tests looking at missile damage using AIM-4 missiles and a small fragmentation warhead. Extensive damage was demonstrated at intercept point separations of the missile and warhead compatible with uncertainties in the flight paths of the missile and the expendable. Fragmentation damage is extensive. While the test findings are very preliminary at this point in time, they also seem to indicate that blast effects will cause severe missile damage. If funds hold, it is hoped that tests with a missile flying into one or both of these countermeasures will happen by the end of the year.

Destructive Expendable Countermeasures System level requirements imposed by operational constraints have only been partially studied and analyzed. For example, an operationally derived requirement will be the angular coverage required to obtain acceptable aircraft survivability against the threat. For protection of our aircraft against the SAM threat, simulations have shown that hemispheric coverage is probably sufficient. The required angular coverage is an important requirement since it will have size and weight impacts on the expendable. This requirement will also drive the location of the propulsive capability. Should it be in the expendable, the dispenser or in some combination of the two? Much work remains to be done in establishing the operational constraints and requirements and their impacts on the overall design of a destructive expendable, countermeasures system.

Over the last three years, several independent study, simulation, analysis and hardware test efforts have favorably indicated that many pieces of the technology needed for a kinetic kill self protection system are now available. The planned tests of the laser beamrider, SLID and other programs will provide additional results leading to a better assessment of the viability of the concept of a destructive expendable. As of now, neither a simulation nor any tests have addressed how a missile in flight will react to the physical damage that would be imposed by a kinetic kill expendable. Two major activities are still needed; a thorough and comprehensive systems simulation effort that will address the integration of the various technologies into a concept and the concept into a real aircraft, and the actual design and test of the destructive expendable and dispenser. Hopefully, SNJW will begin to effectively address these issues with a new contract expected to be in place by July 1998.