Missile airframe simulation testbed: MANPADS (MAST-M) for test and evaluation of aircraft survivability equipment

Clements, Jim, Robinson, Richard, Bunt, Leslie, Robinson, Joe

Jim Clements, Richard Robinson, Leslie Bunt, Joe Robinson, "Missile airframe simulation testbed: MANPADS (MAST-M) for test and evaluation of aircraft survivability equipment," Proc. SPIE 8015, Technologies for Synthetic Environments: Hardware-in-the-Loop XVI, 80150A (13 May 2011); doi: 10.1117/12.884656

Event: SPIE Defense, Security, and Sensing, 2011, Orlando, Florida, United States

Missile Airframe Simulation Testbed – MANPADS (MAST-M) for Test and Evaluation of Aircraft Survivability Equipment

Jim Clements[a], Richard Robinson[b], Leslie Bunt[b], Joe Robinson[c]

[a]US Army Aviation & Missile Research Development & Engineering Center, Redstone Arsenal;
[b]AEgis Technologies, 410 Jan Davis Drive, Huntsville, AL USA 35806
[c]Missile Design, 2503 Southhurst Drive, Huntsville, AL USA 35803

ABSTRACT

A number of techniques have been utilized to evaluate the performance of Aircraft Survivability Equipment (ASE) against threat Man-Portable Air Defense Systems (MANPADS). These techniques include flying actual threat MANPADS against stationary ASE with simulated aircraft signatures, testing installed ASE systems against simulated threat signatures, and laboratory hardware-in-the-loop (HWIL) testing with simulated aircraft and simulated missile signatures. All of these tests lack the realism of evaluating installed ASE against in-flight MANPADS on a terminal homing intercept path toward the actual ASE equipped aircraft. This limitation is due primarily to the current inability to perform non-destructive MANPADS/Aircraft flight testing. The U.S. Army Aviation and Missile Research and Development and Engineering Center (AMRDEC) is working to overcome this limitation with the development of a recoverable surrogate MANPADS missile system capable of engaging aircraft equipped with ASE while guaranteeing collision avoidance with the test aircraft. Under its Missile Airframe Simulation Testbed - MANPADS (MAST-M) program, the AMRDEC is developing a surrogate missile system which will utilize actual threat MANPADS seeker/guidance sections to control the flight of a surrogate missile which will perform a collision avoidance and recovery maneuver prior to intercept to insure non-destructive test and evaluation of the ASE and reuse of the MANPADS seeker/guidance section. The remainder of this paper provides an overview of this development program and intended use.

Keywords: Missile Airframe Simulation Testbed (MAST), Man-Portable-Air-Defense System (MANPADS), Surrogate Missile, Aircraft Survivability Equipment (ASE), HWIL in the Sky.

1. INTRODUCTION

The MAST program was conceived in order to change the way missiles are being developed and tested. By providing a non-destructive testbed for existing and future missiles systems, MAST will allow missile flights to become common, rather than rare. The MAST-M system will first be used to test the response of aircraft defense systems, such as ASE, against existing missile threats, and could later be used to test new missiles in their early stages of development. The testing of ASE has been the justification for a large number of missile flight tests in the last several years. By presenting a non-destructive, high fidelity flight test option, the MAST-M program promises an innovative and highly effective way to test and evaluate ASE. This paper will first describe ASE systems at a high level and will then explain how ASE operation heavily influenced the requirements for the MAST-M program's goal of creating a surrogate MANPADS system for ASE testing and evaluation.

2. AIRCRAFT SURVIVABILITY EQUIPMENT

2.1 ASE Mission

Aircraft survivability can encompass the following measures:

1) Tactics – Proper tactics reduce exposure to enemy weapons.
2) Signature Reduction – Reduces the effective range from which a weapon can engage the aircraft.
3) Warning – Provide a warning to aircrews when they are about to be engaged, allowing time to react. These same systems can be used to cue an active jamming or decoy system described below.
4) Jamming and Decoying (electronic attack) – These systems deploy flares and/or engage the incoming missile with energy to confuse or damage the seeker, driving it off course. This is the heart of the equipment that MAST-M plans to test.

Technologies for Synthetic Environments: Hardware-in-the-Loop XVI, edited by Scott B. Mobley, R. Lee Murrer, Jr.,
Proc. of SPIE Vol. 8015, 80150A · © 2011 SPIE · CCC code: 0277-786X/11/$18 · doi: 10.1117/12.884656

5) Aircraft Hardening (vulnerability reduction) –This approach hardens the aircraft to absorb the punishment of weapon and/or ground impact and reduces the harm to equipment and crew.

While all of these elements add up to a safer existence for flight crews, the area in which MAST-M's capabilities will be most effective is in the testing of measures invoked by ASE: warning, jamming, and decoying.

2.2 ASE Architecture

The aircraft survivability equipment implemented by the United States Army on its helicopter fleet consists of the missile warning system (MWS), computer control system, Directed Infrared Counter Measure (DIRCM), and flare ejectors as seen in Figure 1.

Figure 1: ASE Components

These systems are coupled together so that the warning system not only warns the crew of a launch event and incoming missile track, but also serves as a trigger for the flare dispenser and a cue to the DIRCM. Figure 2 illustrates this operation.

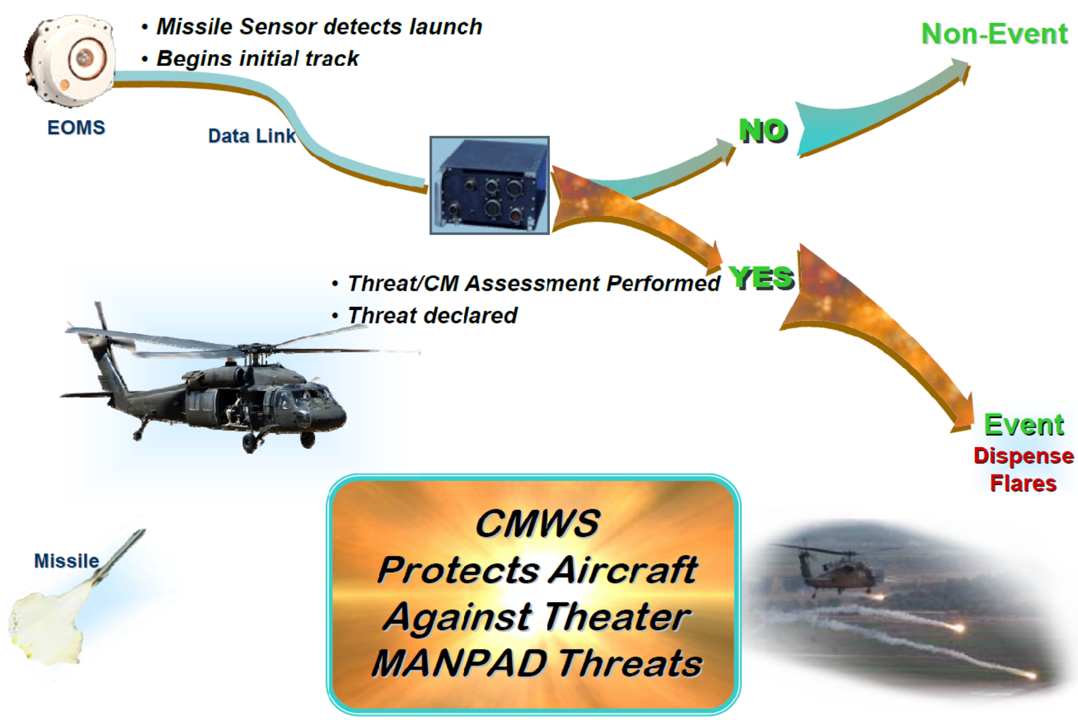

Figure 2: ASE Operation

2.3 ASE Operation

ASE is an arrangement of systems that work in concert to defeat IR guided MANPADS. The MWS electro-optical (EO) sensors scan for launch events. Once an event is detected, the incoming missile it is put under track. If the track has certain characteristics the missile is classified as a threat and a warning is given to the crew. At the proper time, flares are dispensed to spoof the missile away from the aircraft. If it isn't spoofed and the track continues to ingress, then the DIRCM puts the threat under track and very quickly must engage the seeker with a laser that emits the proper energy to jam the threat. This has proven to be highly effective in making our aircrews safer, but it hasn't been easy. Much testing and long hours have gone into fielding these systems and there is always room for improvement when lives are at stake. The current systems are also heavy and fairly large for a flight system, therefore new systems are in procurement. Introducing more lightweight systems will allow weight to be added to the aircraft in other areas, such as more payload and additional crew members. These new systems will have to be extensively tested, and as a result numerous missile firings are in the future for the ASE development community.

2.4 ASE Testing Need

ASE testing has consumed many hours and a numerous missile flights in the past because it is not a simple task. There are many complicating factors when dealing with the actual systems. Missiles are obviously fast, explosive, and dangerous. They are not easily acquired and they are expensive. Perhaps the most limiting factor is that missiles are not reusable. Every test results in the total loss of the asset and any telemetry equipment onboard. Aircraft are also precious to say the least, and expensive. The crew members on board the aircraft are even more precious. The ASE equipment is also rather rare. Destroying or damaging ASE equipment and/or aircraft is generally out of the question. So how does one test them? This testing is obviously not trivial. Testing is generally done via digital simulation, simulated missiles against real aircraft, or real missiles against simulated aircraft. Typically, the least expensive choice is digital simulation, but the validity of this kind of testing has been questioned. Using simulated missiles via ground emitters has some obvious drawbacks. The ASE can easily tell that the ground emitter is not moving in space; therefore it will not classify it as a threat to the aircraft because it does not appear to be a missile in flight. Flying real missiles against simulated aircraft is the option that has expended a lot of missile assets, and where MAST-M's capabilities can help the most.

3. MAST-M

As mentioned earlier, MAST-M has taken on the task of revolutionizing how missiles are tested. Traditional missile testing programs are destructive and high-risk, resulting in a very long and expensive development stage. MAST-M intends to change this by allowing missiles to be tested over and over again without destroying them. Typical missile tests end in one of two ways, either a high speed collision with the target, or a high speed collision with the ground. Even though this kind of result could be considered a success for the program, the prototype missile and all hardware on board are lost. This is an unfortunate demise considering the expense, both in terms of money and time, that goes into building a missile. This kind of destructive testing also significantly limits the number of tests that can be performed. MAST-M offers an alternative approach. With a recoverable missile, a program can fly as many times as needed to collect data and fine tune electronics. Because the missile is retrieved after each test, data can be stored on board rather than transmitted, decreasing cost and lessening avionics complexity and development time. Teams will be able to launch, conduct their test, retrieve the missile, download data, and test again within hours. This may sound like a futuristic solution, yet it has already been done by the MAST-M team, and the roles and applications are expanding all the time. The most obvious use of this technology is to design recoverable surrogate MANPADS missiles to test ASE that is installed on military aircraft.

3.1 Revolutionary Missile Development Approach

Missile development programs are expensive. MAST-M would like to change that. Figure 3 shows a typical air defense missile test program.

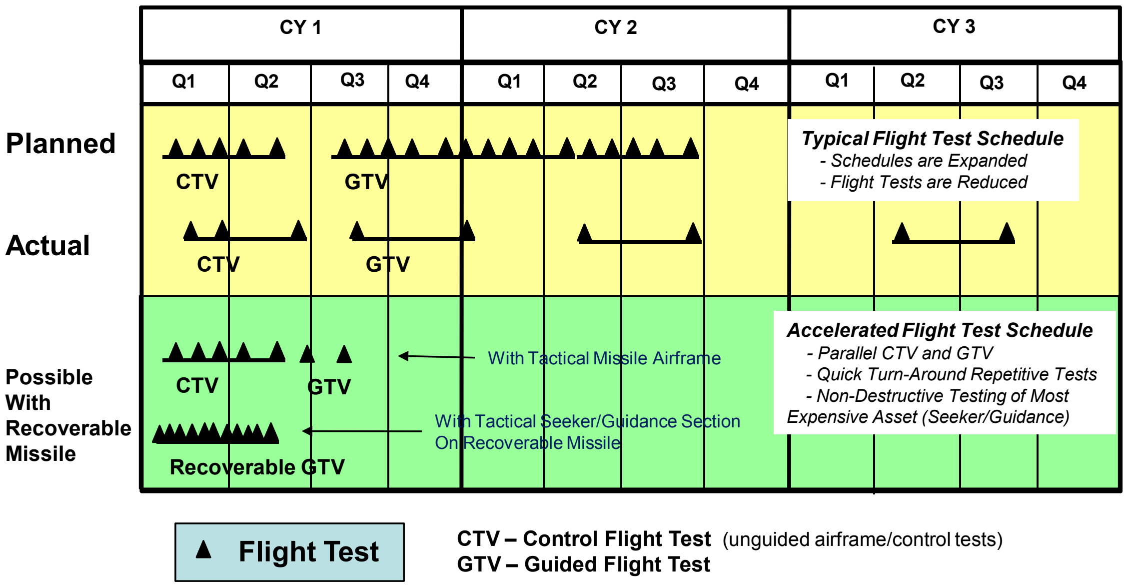

Figure 3: Typical Development Schedule

The top line is what is typically planned out, a two year program flying once a month. No engineer is going to be happy with such a sparse test program, but that is typically all management will allow. The middle line is a typical flight test program execution. Funding hiccups, test mishaps, data anomalies, and prototype development and testing all stretch the test schedule. In reality, the actual expense of creating the prototypes might be more than a program can handle in a particular year and still pay salaries, consequently spreading the prototype development across the schedule. If the engineers were disappointed by the original schedule, they are typically more than concerned by the execution, as it leaves little time and funds to explore and test all possible solutions. The bottom line shows what kind of test program could be executed with a MAST recoverable missile. All the guided flights could be executed in a single month or quarter because, in theory, only one prototype missile is needed. A team can fly the recoverable prototype over and over again in a short period of time until they have collected enough data to analyze the performance of their hardware and build confidence in the design. This approach prevents precious dollars from being spent on travel, multiple launch days and range time, and numerous missile prototypes that are not recovered in the end. Flight testing could become almost as common as HWIL testing, but offer more information. It would not be surprising to find that programs that have previously not been attempted because they were deemed unaffordable could be attempted in the future with the help of MAST-M.

3.2 MAST-M Design

In a typical missile flight test program the warhead is removed and replaced with a telemetry system. This approach allows data to be extracted and recorded, and minimizes damage to the target. Minimizing target damage is important considering that target missiles and aircraft can cost millions to tens of millions of dollars. MAST-M takes a different tactic and replaces the warhead with a recovery system. This system currently utilizes two parachutes and a separation joint. The separation joint maintains airframe stiffness during flight, but then at the end of the flight it splits the missile into two parts, exposing the parachutes and allowing them to deploy into the airstream. This approach mimics the approach used on the Recoverable BAT flight test program and amateur rockets flown by the thousands every year in the US. It has proven to be highly reliable both in MAST-M ground separation testing and flight testing.

To avoid hitting the target and to set up a safe condition to deploy the parachutes, more systems can be required as seen in Figure 4.

Figure 4: MAST-M Design

A MANPADS guidance section is used to guide the MAST-M missile. Packing parachutes will be in vain if the MANPADS seeker guides MAST-M all the way to the target, therefore a collision avoidance system called Guardian is necessary. Guardian consists of parts needed for situational awareness, such as an IMU and GPS receiver, combined into a navigator via a flight computer and software. This allows MAST-M to know where it is in 3D space. It also must know where the target is to accurately avoid a collision. This is accomplished by equipping the target with a navigator (similar to the one on the MAST-M missile) and a radio to send the information to the ground station which then relays it to the missile. With knowledge of where MAST-M is and where the target is, the Guardian software can oversee the test mission and allow it to be conducted safely.

During a test, when it determines that further ingress would pose a danger to the target and MAST-M, Guardian calls off the test mission. It ignores the seeker guidance commands and begins a high G avoidance maneuver. This transition into a steep climb also bleeds off considerable energy until it is safe to deploy the drogue parachute. The small drogue parachute allows high speed deployments followed by a rapid descent to the ground. Near the ground, a larger main parachute is deployed to further reduce the descent speed, greatly lessening the ground impact velocity and shock on the payload. The main parachute is attached forward of the section's center of gravity so that the seeker is pointed up at impact. This parachute recovery approach has been tested and is working well for MAST-M.

For the MANPADS emulation mission to test ASE, even more changes were necessary to implement collision avoidance and recovery. The tactical MANPADS control actuation system (CAS) only has one channel of control. This single channel is rolled into and out of the pitch and yaw control planes at a high rate to achieve control in both planes. This presents a couple of issues MAST-M desires to avoid. This bleeding of control into both planes is not as effective as two channels of control, and is much less effective than a missile flying in the X configuration. Almost all missiles fly in the X configuration to take advantage of the 40% greater lift capability. The other challenge a rolling missile would pose is that the parachute shroud lines are subject to tangling. A rolling airframe would greatly increase the chances of such an occurrence and ultimate loss of the airframe. To execute two channels of control requires a new CAS design unique to MAST-M. It must emulate perfectly the rolling part of the mission and also perform the non-rolling. Fortunately, two suppliers were found who could deliver CAS hardware that could meet specifications and the development schedule.

There are several options for transferring the seeker fin commands that are intercepted by the Guardian flight computer to the CAS. They can be passed through to the CAS as is, scaled, superimposed on a second guidance signal to fly a path that would not actually collide with the target but is close enough to fool the MWS, or they can be ignored altogether. This point of control is what allows a test to be switched on and off easily by the collision avoidance logic within Guardian, yet fly a perfect emulation when desired.

3.3 MAST-M Operation

MAST-M is designed to mimic a real MANPADS almost perfectly. It detects the target just like a MANPADS because the seeker is an actual threat MANPADS seeker. It launches just like a MANPADS because all of the systems, motor, launcher, and grip stock have been designed for perfect emulation. It creates signatures just like a MANPADS. It flies just like a MANPADS, therefore the tracks look identical. It homes in on the target's infrared light emissions just like a MANPADS. It reacts to countermeasures just like a MANPADS. The only thing it will not do is destroy the target the way MANPADS are designed to, therefore providing the highest fidelity emulation without the destruction. The ASE system under test has near perfect stimulation that will invoke a response, and the response of the missile to the countermeasure is also, near perfect. The only limitation is that the missile needs time to execute an avoidance maneuver, so time under test will be lost due to kinematic limits. If a non-rolling missile flying optimally cannot avoid the target, then it is safe to say a jammed missile is not going to be able to miss either. In that case, more mission test time is not likely to be valuable.

4. TESTING

ASE testing with MAST-M could be similar to an actual combat engagement if that is what the test director desires. MAST-M will undergo rigorous testing against unmanned drone aircraft to eliminate all safety concerns before flying against a manned aircraft. The drone (with ASE installed) would fly to a point within the engagement range of a MANPADS. The remote controlled launcher would point the missile at the target and it would acquire and shortly thereafter launch. The MWS would recognize MAST-M as a threat and activate the flare dispenser (if allowed by the testers). It would also cue the DIRCM. The DIRCM would start tracking MAST-M and attempt to jam it. If the jam is successful then MAST-M would begin a pull up to set up recovery. If it didn't get jammed then it would continue to ingress until Guardian determined it was no longer safe. This would also initiate the pull up to set up for recovery. If wind conditions would tend to blow the missile landing to an undesirable location, a waypoint can be set to compensate and keep the missile landing in a favorable location. The parachutes will deploy and the missile will land in a desired area. The missile can be recovered immediately and data can be extracted to assess the test. The missile will then be checked out for damage and to ensure that all systems are operating within given tolerances. This operational sequence can be seen below in Figure 5.

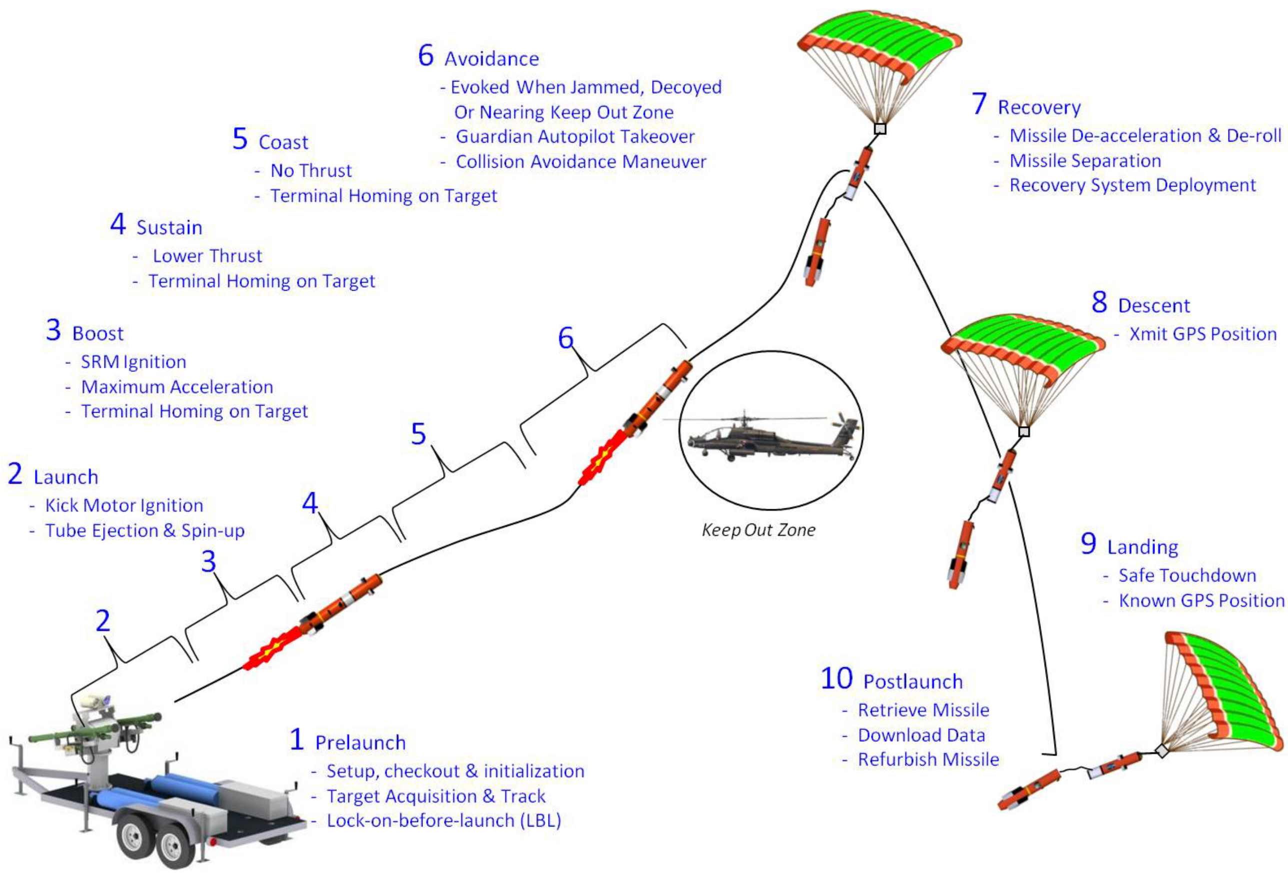

Figure 5: MAST-M Air Defense Scenario

After recover and check out, the batteries will be recharged, the parachutes will be repacked, and other recovery devices such as lanyard cutters and explosives bolts will all be replaced. Finally, a new motor will be attached. The missile will be reloaded into the launch tube, and the tube placed back on the launcher. MAST-M is ready for another test. The requirements are for a maximum turn-around time of 4 hours, but that can be abated by having more MAST-M missiles on hand to avoid testing interruption.

5. CONCLUSION

ASE equipment is important and has already saved the lives of soldiers and pilots. The current systems are heavy and need to be replaced with lighter systems to regain the payload ability of the aircraft. The testing of these systems requires a lot of missile flights. MAST-M has a way to execute those flights cheaply, safely and in a way superior to previous approaches. MAST-M also has a far better way to test new missile developments and change the landscape of missile developments in the future.

REFERENCES

[1] "Aircraft Survivability Equipment (ASE)." Global Security. 2008. <http://www.globalsecurity.org/military/systems/aircraft/systems/ase.htm>

[2] Clements, Jim, Joe Robinson, and Richard Robinson."Non –Destructive Missile Seeker Flight Testing: HWIL in the Sky." SPIE Defense, Security, and Sensing Conference. 2010.