ATMOSPHERIC INTERCEPTOR TECHNOLOGY (AIT) STATUS AND TEST RESULTS

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Abstract

The goal of AIT is to revolutionize the development of endoatmospheric interceptors. The technology is designed to perform intercepts from the low atmosphere up through the low exoatmosphere, all at much higher velocities and performance than current and past systems. These technologies not only decrease size and weight of the KV, but also allow for increases in battlespace, coverage or footprint performance and lethality. This provides the warfighter with multiple fire control options in employing the optimum battlefield engagement strategies. Significant AIT technology advancements include: cooled window/forebody, strapdown seeker, solid propellant divert and attitude control system (DACS) and a lightweight integrated vehicle. This paper will provide the status of AIT technology, including results of the ground testing program conducted over the past year.

AIT is demonstrating the advanced lightweight interceptor technologies required to achieve hit-to-kill on a precise aimpoint with the target body, thus ensuring the highest kill probability for all warheads. The AIT technologies, integrated into a modular KV design, incorporate the best ideas from numerous technology programs conducted over the past decade. Planning is underway to fold AIT technology into BMDO system programs and provide the enabling technology for increased mission capabilities.

Introduction

The AIT program is focused on developing the critical technologies needed for high speed endoatmospheric hit-to-kill performance against ballistic missiles. The AIT program is currently BMDO's only broadbased atmospheric technology program supporting advanced TMD and NMD interceptors for all service programs. AIT, managed by the U.S. Army Space and Strategic Defense Command in Huntsville, AL, is a continuation of advanced high speed kill vehicle (KV) technology programs ongoing for the past 25 years.

AIT technology will be providing lightweight high performance vehicles. High velocities and intercepts throughout the endo regime are required to achieve the desired battlespace. This provides expanded options for the warfighter in engaging targets (Figure 1). Harsh flight environments resulting from these engagements drive the optical window and cooling design, and the vehicle airframe structure and thermal protection system beyond the current state-of-the-art technology.

The accuracy required for hit-to-kill provides the requirements for the IR seeker, signal processing, aimpoint algorithm and divert and attitude control system (DACS) performance. Since the AIT strapdown seeker is rigidly mounted to the airframe structure, seeker requirements include isolating vehicle rigid and flexible body motion from corrupting the overall sensor optical track accuracy. The AIT seeker not only meets these requirements, but also provides much smaller and lower cost production seekers (Figure 2). The solid propellant DACS system is being developed to provide responsive and robust velocity and acceleration divert along with meeting insensitive munitions requirements.

AIT Technology Development and Validation

The AIT KV is designed to perform high velocity intercepts from the low endoatmosphere up to the low exoatmosphere. The ultimate achievement of AIT will be to find a precise aimpoint within the target body, thus ensuring total kill of all NBC (nuclear, biological, chemical) and conventional explosives. The aimpoint precision is optimally achieved by balancing the overall vehicle response to seeker tracking accuracy. An overview of the requirements in shown in Figure 3.

Full validation of AIT technology is demonstrated through testing of an integrated KV. Integrating technology components into a total vehicle is essential in transitioning technology out of the laboratory and into the hands of users. Unfortunately, costs for flight testing have reduced the number of possible flight tests

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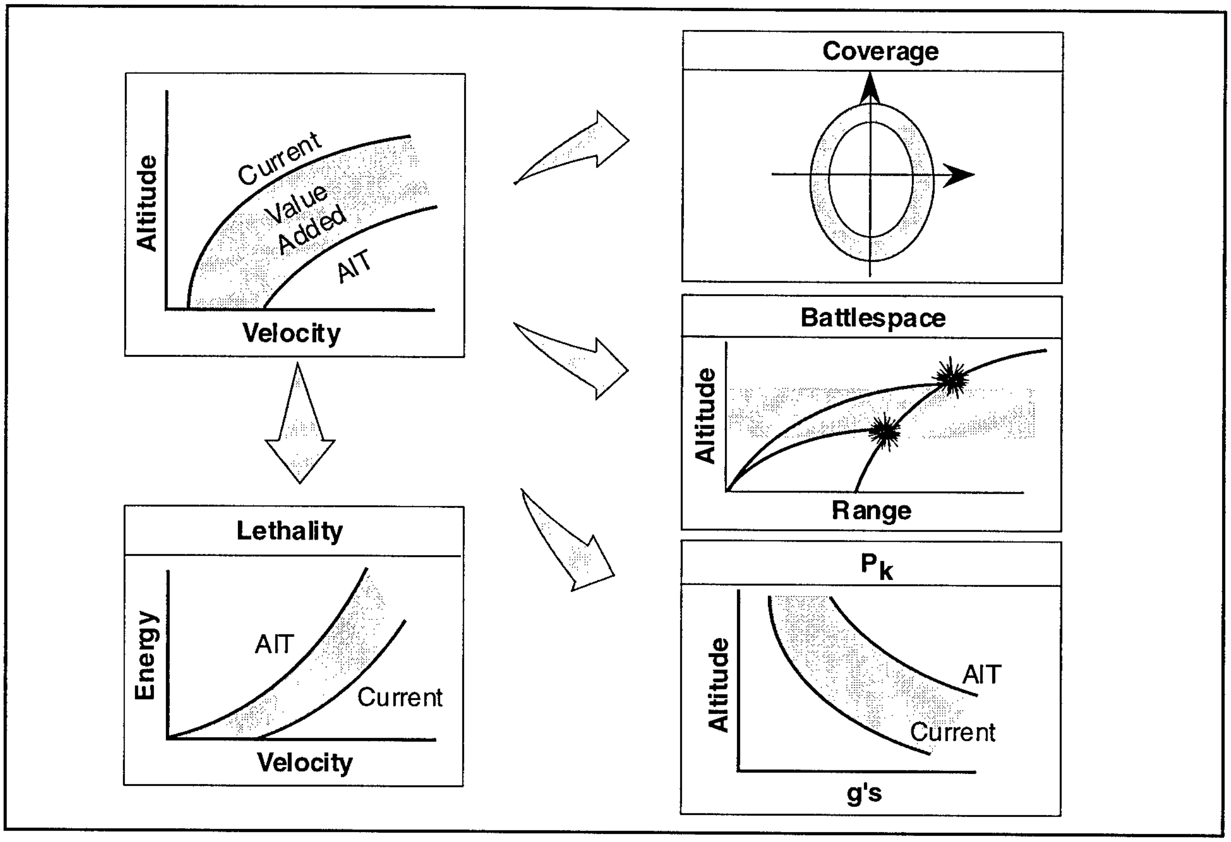

Figure 1. Expanded Options for Sensing and Engagement of Targets

and necessitated unique approaches to validate the technology. The AIT program recognized this from the start and so developed sophisticated simulation and ground test capabilities which allow the design to be tested under stressing flight conditions. Figure 4 shows the AIT technology validation approach.

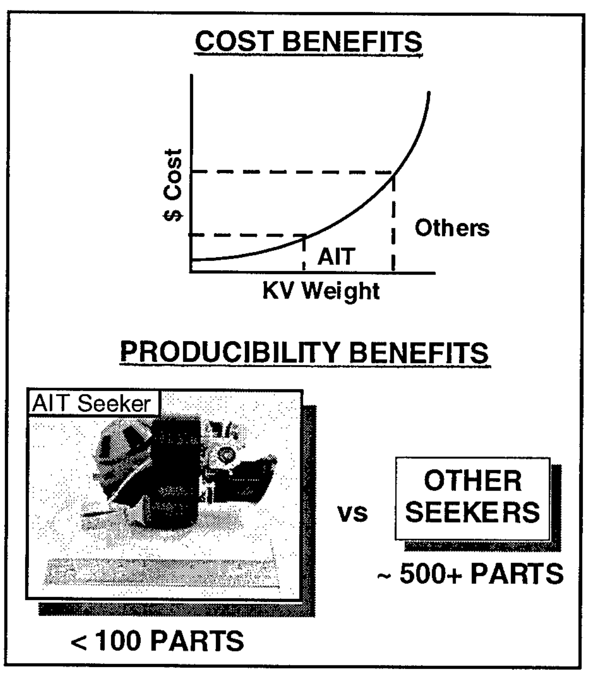

Figure 2. Cost and Producibility Benefits

There are a several significant technology advancements which are incorporated into the kill vehicle that allow for hit-to-kill with aimpoint selection. These components are shown in Figure 5. These technologies incorporate the best ideas from numerous technology programs which have been conducted over the past five years. The insertion of these component and material technologies provide a means to resolve critical issues with a modular vehicle design that yields the necessary performance margins.

The seeker and aperture subsystems have been the primary areas of concentration for AIT during the initial phases since these subsystems drive the size and performance of the entire KV. The only way to achieve the goal of a lightweight endoatmospheric vehicle with aimpoint accuracy is with a high performance strapdown seeker and a small aperture employing an optimized cooling concept to minimize aero-optic degradation.

Cooled Window and Forebody

One of the most difficult issues facing hypervelocity atmospheric interceptors has been aero-optical and aerothermal disturbances due to the bow shock,

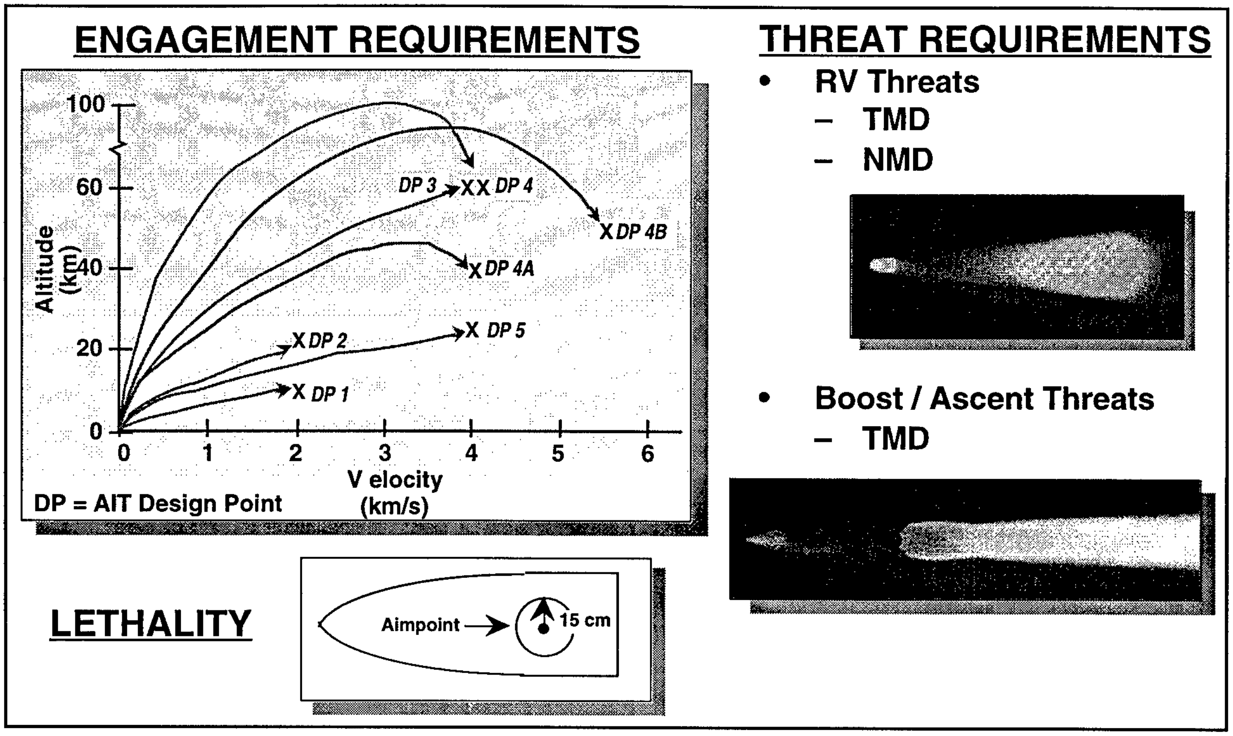

Figure 3. AIT Requirements Developed to Stress Technologies

flowfield radiance, and boundary layer heating. These disturbances can either destroy the window or obscure the target. The AIT program has validated two concepts which are applicable to other vehicles: an externally cooled approach using Helium as the coolant and an internally cooled approach using water as the coolant.

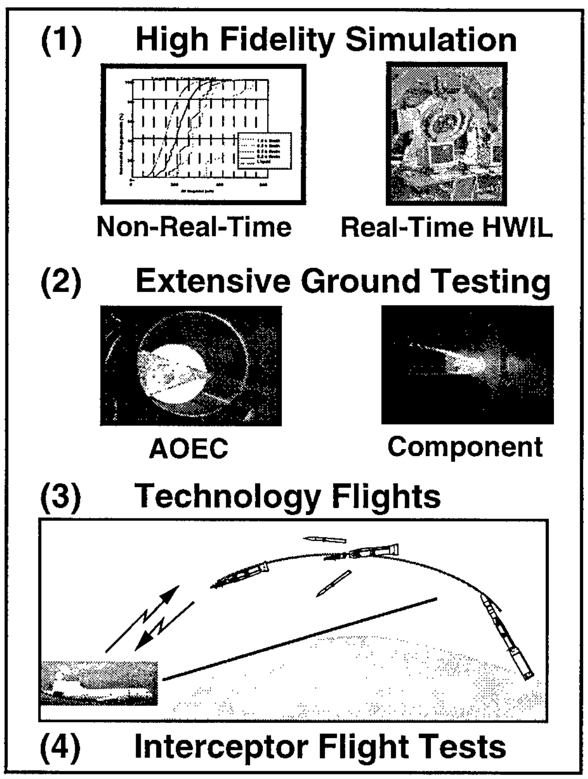

Figure 4. Innovative Approach to Fully Demonstrate Technology

The cooled window and forebody system is designed to allow lower altitude and higher velocity intercepts than current interceptor systems. The current AIT KV design uses a window made of silicon with small cooling channels machined on one surface the then thermally bonded to a second silicon surface plate. The water coolant, in addition to cooling the window, also flows through the window frame, forebody and nose cone to cool the leading edges of the kill vehicle and prevent ablation particles from flowing across the window. One of the advantages of this approach is that all cooling is done internally and does not add any complex external flowfields which might disturb seeker operation.

The AIT window technologies have undergone a significant validation program as shown in Figure 6. The window technologies are currently available for insertion into other missile programs.

IR Strapdown Seeker

The two color strapdown seeker with image motion compensation is one of the major technology issues associated with the AIT program. The seeker embraces a large array of new technologies to address the critical issues and meet the required performance. This strapdown system, in addition to providing improved

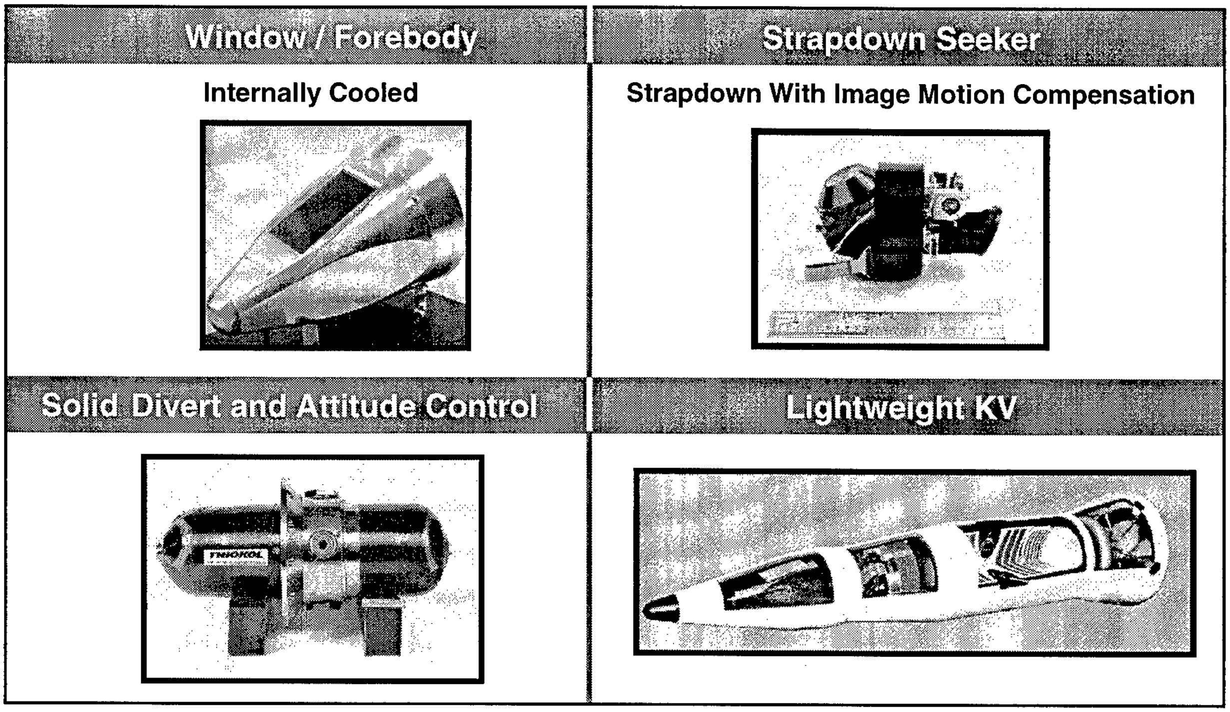

Figure 5. AIT Technology Development

performance, offers the primary method of achieving light weight miniaturized vehicles and the ability to perform aimpoint selection.

The AIT seeker includes a miniaturized, two color, hard mounted strapdown infrared seeker. The focal plane array (FPA) is a 256 x 256 Mercury Cadmium Telluride (MCT) staring array. The FPA is cooled to a steady state temperature using Argon as the cryogen. The FOV is scanned using a two-axis steering mirror to effect an overall field-of-regard of 3deg by 48deg.

The compact folded optical system uses different focal lengths for each color. Acquisition range is maximized by using a longer wavelength, broader spectral band and has a wider FOV to accommodate the target angular uncertainty. The acquisition spectral band is optimized for minimum flow field radiance (the dominant background when AIT operates at relatively low altitude at high Mach number velocities). Window radiance is also a source of significant background. FPA saturation is avoided by using a variable integration time. Endgame track and aimpoint selection uses a shorter wavelength and smaller FOV (longer focal length) to provide higher resolution and thus higher accuracy.

An active line-of-sight (LOS) stabilization control system is used to overcome aerodynamic, rigid body buffeting and propulsive disturbances of the AIT airframe. It uses the two axis mirror in combination with a second, high bandwidth mirror and ultrahigh bandwidth rate sensors in the IMU to achieve subpixel image stabilization. Airframe dynamic bending effects are minimized by hard mounting the seeker directly to the IMU.

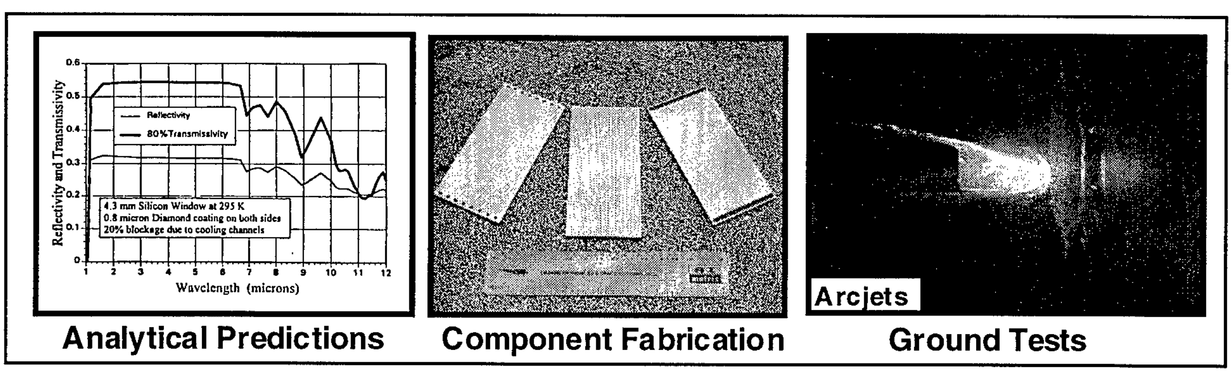

Figure 6. Cooled Window/Forebody is Currently Available

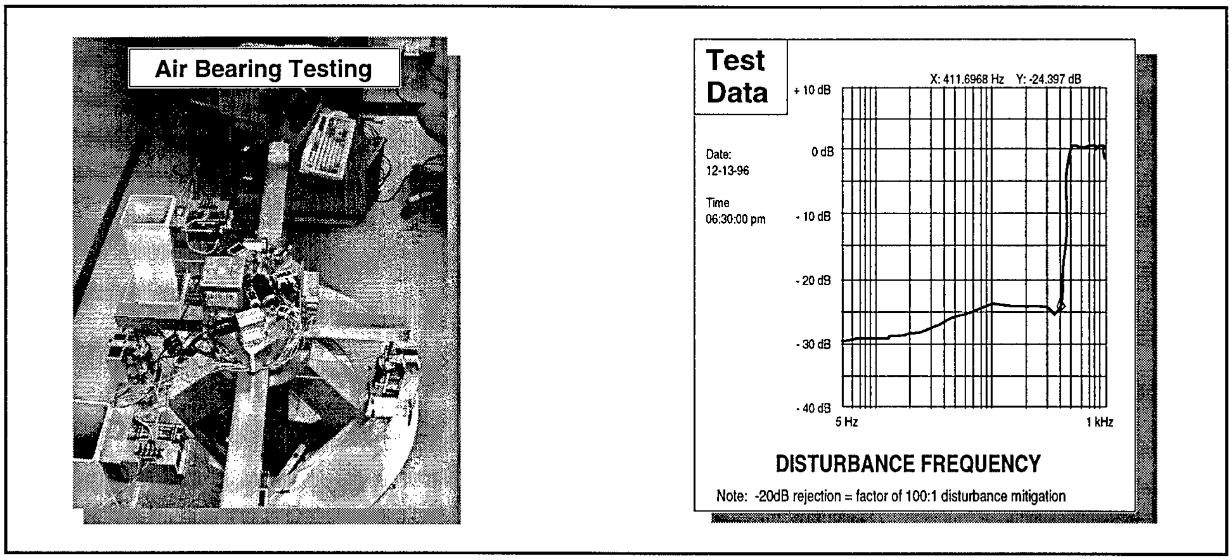

Figure 7. AIT Seeker Demonstrated Active Mirror Compensation

LOS stabilization performance tests were recently conducted in a vibration environment equivalent to that expected on AIT flights (Figure 7). The tests applied 3-axis motion to an AIT equivalent optical train and measured motion of a laser beam projected through the optics. A laboratory setup duplicating the seeker LOS stabilization control loop was implemented. The results confirm the subpixel stabilization capabilities required for AIT operations as errors were reduced to less than 50 microradians rms. The seeker is continuing to undergo integrated testing during FY97.

Solid Divert and Attitude Control System (DACS)

The solid DACS is a technology advancement which provides significant leverage toward developing a common kill vehicle with a true 'wooden round' capability for multi-service applications. The solid DACS provides a robust and temperature insensitive system with the use of insensitive munitions to provide a safer system. The design of the solid DACS builds on a strong technology base from past programs, including LEAP and ASAS.

AIT mission requirements dictate the capability to extinguish and reignite the propellant similar to liquid systems. The AIT approach uses independent propellant wafers with redundant igniters, separated by an insulating material to provide discrete divert and attitude control pressurization pulses. The baseline design produces high divert velocity and divert acceleration.

Thiokol has hot fire tested the large divert thrusters and extinguished after the first propellant burn for several minutes and reignited the second divert propellant grain and fired a second set of divert pulses (Figure 8). In addition, they also have conducted an ACS

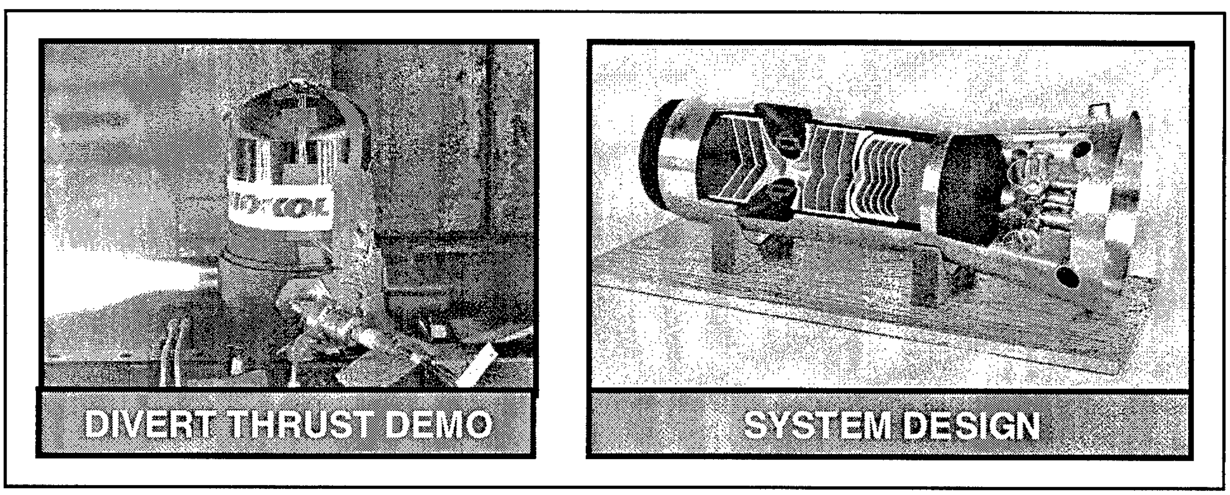

Figure 8. Solid DACS Development for Innovative Munitions

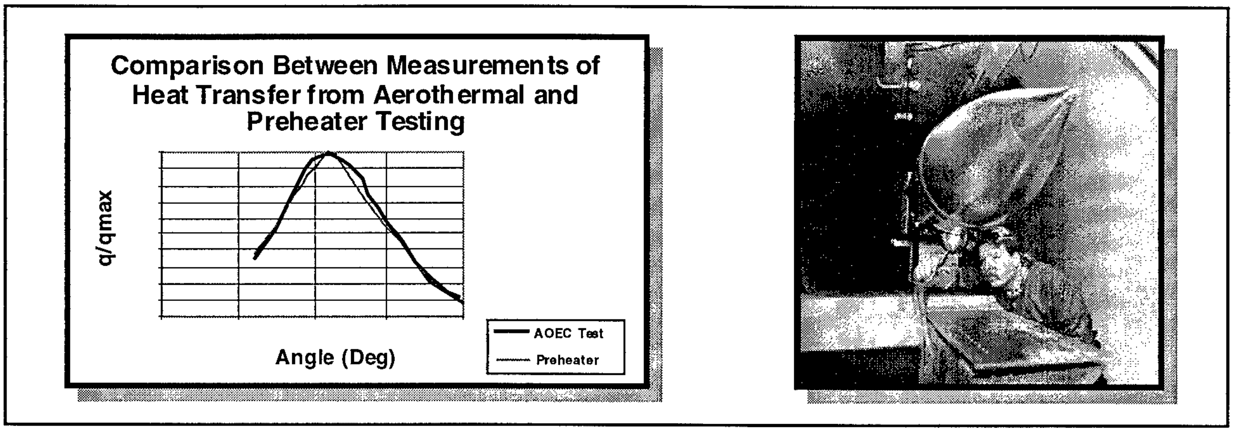

Figure 9. Navy AOEC Testing – SM-2B Block IVA

pressurization test to demonstrate holding ACS pressure over several minutes of a mission duty cycle. These two tests have demonstrated that the design concept is feasible and will meet the mission duty cycle requirements. A full-scale flight weight hot fire test is planned for CY98.

Aero-Optic Evaluation Center

AIT developed the largest and most capable shock tunnel facility in the world, the Aero-Optic Evaluation Center (AOEC) facility. It is the only facility capable of duplicating flight conditions for full-scale atmospheric vehicles at high speed conditions, thus reducing the number of required, and expensive, flight tests. AOEC has carefully isolated the test article and instrumentation from tunnel disturbances to ensure the aero-optic data is not corrupted, which has never previously been accomplished. AOEC also has the extended run time necessary to fully characterize, at flight duplicative conditions, the flow field.

These unique capabilities were successfully demonstrated for the Navy Area Wide missile aero-optics tests (Figure 9). As a result of these tests, the Navy was able to simulate full flight conditions over the IR optical dome and identify and resolve the critical issues associated with the complicated flowfields around the IR seeker dome without flight testing.

AIT plans to test a full-scale model of the vehicle in late 97 to determine the divert plume effects on IR seeker performance. At certain altitudes, the divert thrust creates a flow separation forward of the nozzle which might circulate over the seeker window. The planned tests will determine if this phenomenon occurs for the current AIT design and what effects it will have on seeker performance. In addition, AIT plans to conduct hot fire divert tests at AOEC to determine jet interaction effects (JI).

Hardware-in-the-Loop (HWIL) Simulation

An important facility for any missile program is a HWIL simulation of the missile hardware and software. This is important for integrated testing of the ground test vehicle prior to any flight testing. AIT will use the U.S. Army Aviation and Missile Command's high fidelity HWIL facility which is based on re-use of existing THAAD and government infrastructure for low cost. (Figure 10) Initial testing will be performed using the IR seeker and the avionics software. Ultimately the HWIL facility will be used to test the integrated seeker/avionics, divert valve drivers and all telemetry functions. Currently the AIT models are being updated with more detail as the hardware and software designs mature.

Flight Testing

Following an extensive set of component and integrated vehicle ground testing, AIT is planning to conduct a series of flight tests. This will complete the validation of a highly maneuverable AIT kill vehicle employing strapdown guidance. The AIT flight test approach is

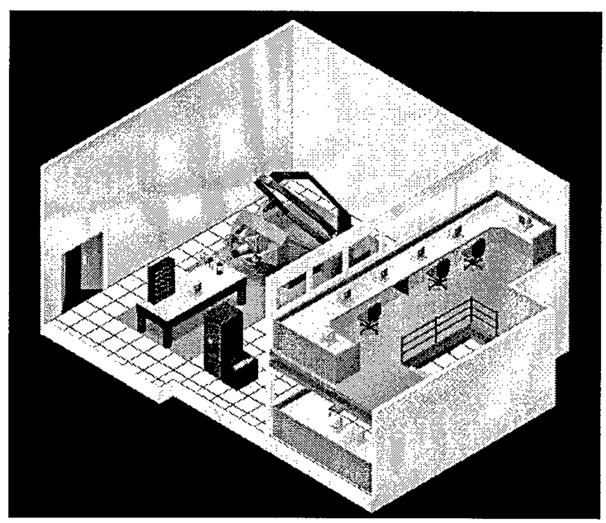

Figure 10. Hardware-in-the-Loop Simulation

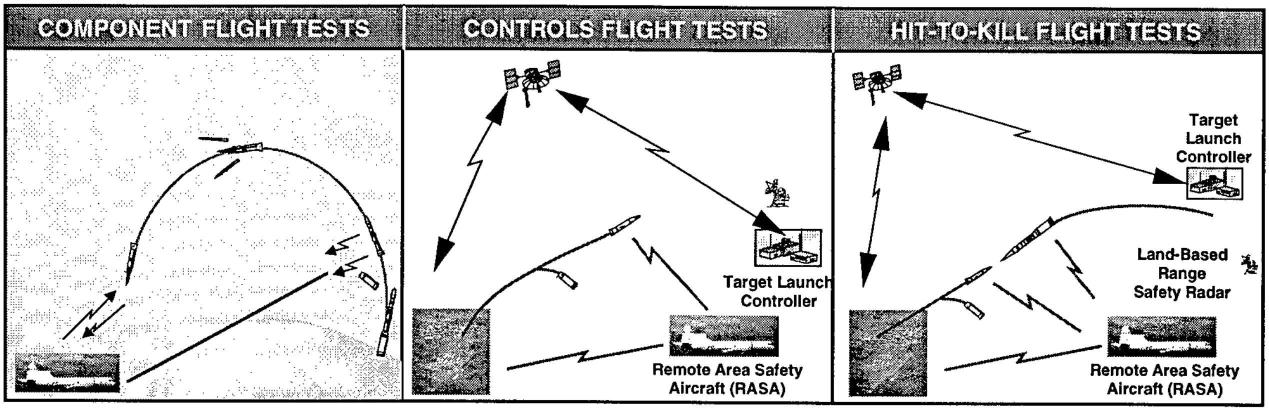

Figure 11. Technology Demonstration Through Incremented Backup

based on an incremental build-up of component demonstrations through hit-to-kill testing (Figure 11). The component flight tests will demonstrate the performance of various subsystems at realistic altitude and velocity environments. The control flights will verify KV/booster operation and establish range interfaces. The hit-to-kill flight tests will demonstrate an integrated KV operation in a series of progressively stressing tests. AIT is currently identifying ranges and booster configurations which can satisfy kinematic and target requirements.

Summary

AIT's primary objective is to demonstrate the critical technologies necessary for high speed atmospheric flights. High velocity intercepts are essential to maintain sufficient battlespace, lethality and coverage/footprint performance. However, such conditions provide severe aerodynamic, aerothermal, and structural requirements. AIT's extensive technology development and ground testing is resolving the critical issues associated with high velocity flight.

AIT has provided significant technology advancements in the window/forebody, strapdown seeker, and solid propulsion systems. In doing so we have established an innovative and affordable set of tools and facilities for testing hardware/software to validate the technologies. Planning is underway to infuse the AIT technologies into BMDO programs and provide the enabling technology for increased mission capabilities.