A SEMI-PHYSICAL MISSILE SIMULATION FACILITY

Thomas A. Atherton
Office of Missile Electronic Warfare
Electronic Warfare Laboratory
US Army Electronics Command
White Sands Missile Range, New Mexico 88002

This presentation discusses the use of laboratory simulations in support of infrared countermeasures development. The types of simulations used in research and development will be reviewed with emphasis upon laboratory simulations. A review of the key elements required for simulation of infrared countermeasures (IRCM) as applied to anti-aircraft missiles will be followed by a discussion of the US Army's Dynamic IRCM Simulation Facility. The discussion includes delineation of the facility's major components, the means of accounting for the key elements in IRCM simulation, and a discussion of the level of computer usage with this semi-physical simulation.

IRCM for the protection of aircraft can be divided into two basic types: passive and active. Passive techniques include shielding of hot metal parts from view and reduction of infrared emission by cooling of hot metal parts; active techniques include decoys such as pyrotechnic flares and modulated infrared jammers.

Several generic forms are used to simulate ECM environments. One form is the full-scale field simulation in which actual equipment is used. An example of this form is the use of Redeye missile trainers or captive seekers to evaluate the reduction in the acquisition and tracking boundaries resulting from target signature reduction. Another form is the modeling of part or all of the components and environment which will permit evaluation of the effectiveness of IRCM techniques and hardware under controlled, laboratory conditions.

In his paper, "Simulation Methods for Evaluating IRCM," Mr. Neumark at the Eighth IRCM Symposium discussed four laboratory techniques. These four can be classified into two major types: mathematical and physical. Evaluation of IRCM in the context here discussed involves a total system of interest which consists of three major subsystems: the infrared missile, the infrared target, and the countermeasure system. Each of these is a complex system in itself.

The missile is a multiple-loop, highly nonlinear feedback system; the apparent shape and multisource distribution of the target and its signal intensity vary nonlinearly with slant range and often with respect to aspect angle; the signal intensity of the countermeasure device may vary in a similar fashion with respect to slant range and aspect angle and, if an active jammer, may have an infinitely complex pulse train. The success of any simulation is the ability to make the key simulated components or subsystems have their important characteristics; in this case, look like and act like the required missile, target, and countermeasure subsystem.

In the mathematical simulation technique, the entire missile-target-countermeasure system is represented in terms of mathematical relation that can be programmed on an analog, digital, or hybrid computer. The mechanical simulation technique uses computing equipment in combination with real or simulated subsystem hardware. The mathematical technique can be divided into the computer hardware used to implement: analog, digital, or hybrid. The mechanical technique can be divided into two physical methods: electro-optical and opto-mechanical. Each of the methods has relative advantages and limitations.

The primary objective is to provide a realistic representation of the system to be evaluated; i.e., the dynamics and kinematics of an infrared missile deployed against a target aircraft equipped with an active countermeasure device. The simulation method must provide control flexibility, and easy access to system elements in order that system parameters and their values may be varied, and the phenomena associated with jamming may be studied. The simulation must permit a large sampling rate in order that statistical variations may be taken into account. Finally, and this is a very important objective, the result of the simulation study must be practical, not just theoretical. It must relate to the probability of survival of the aircraft to be defended or to the probability of miss of the missile to be countered.

In his evaluation of the four laboratory methods, Mr. Neumark concluded that perhaps the most practical tool for the study and evaluation of IRCM techniques is physical simulation. In such a simulation, components of missile hardware (real or simulated) are connected in a closed-loop with a real time computer. The hardware represents the inherently nonlinear response characteristics of the missile, target, and CM device; the computer simulates the aerodynamic and kinematic responses such as target and missile flight which cannot be reproduced in a laboratory. Typically, an arrangement of optical sources provides target/countermeasure stimuli much like those experienced by a missile in an operational environment.

The electro-optical method of physical simulation uses an oscilloscope to simulate the target and countermeasure sources (figure 1). The simulated sources are detected by the simulated optical tracker. Advantages of this method include accessibility of the reticle which, when placed in front of the oscilloscope, modulates the phosphoresence seen by a photo-detector, excellent display of the modulation process involved in the tracking loop, and ease of changing jamming parameters due to electronic control. The main disadvantage of this method is the inaccuracy introduced by simulating the complex optical infrared seeker.

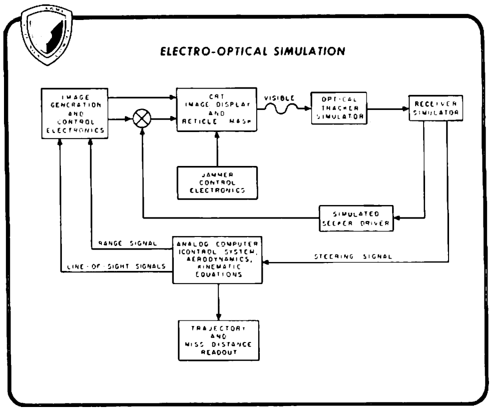


Figure 1.

The chief advantage of the opto-mechanical, or semi-physical simulation method is its realistic and relatively accurate representation of the key elements of the entire simulation system; i.e., the seeker head and signal receiver (figure 2). The actual seeker head and signal processing hardware are in the loop. This eliminates the difficult requirement for modeling the nonlinear characteristics of the multiple-loop missile system, in particular defining these characteristics when subjected to an IRCM environment. The two other subsystems, target aircraft and IRCM, are simulated where this simulation method is used. Basic requirements for simulation of these subsystems include:

Multisource simulation capability

Ability to modulate ir energy from source(s) with varying modulation parameters

Ability to vary intensity and achieve color variations between sources

Dynamic separation between sources

Dynamic variation of target image size

Dynamic intensity changes as a function of closing range

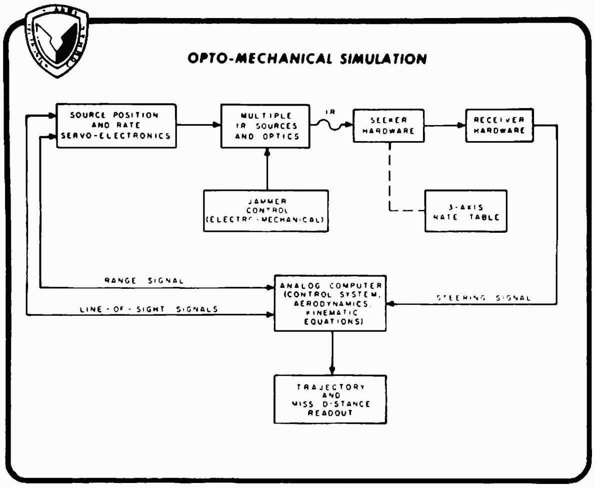


Figure 2.

The US Army's Dynamic IRCM Simulator is a research tool which permits IRCM investigations using semp-physical, closed-loop dynamic laboratory simulation (figure 3). The Dynamic IRCM Simulator consists of a missile flight simulator (MFS) and a computer. The MFS is made up of the line-of-sight (LOS) unit and the missile positioning unit (MPU). The LOS unit contains five infrared sources and optics which collimate the ir energy and establish a continuously varying line-of-sight between each source and the missile seeker. Each source assembly contains an infrared source, a servo-controlled variable aperture used to change the apparent target image size, a servo-controlled circular variable neutral density (CVND) filter used to change the irradiance at the missile, and fixed and interchangeable filters and collimating optics to make the simulated target appear distant (figure 4). Two source assemblies are located in the target bay of the LOS unit; two are located in the jammer bay; one is located in the decoy bay (figure 5). The jammer sources are mechanically modulated where black-body sources are used and electronically modulated when lamps are used as the infrared energy source. A complex optical system of servo-driven mirrors and beamsplitters are used to position the line-of-sight in azimuth and elevation. The infrared energy is detected and processed by the missile. Either the electronic command to the missile's aerodynamic surfaces or a signal corresponding to the actual sensed wing position is put into the computer. The missile hardware is mounted in the missile positioning unit, a separate servo-controlled rate table capable of varying the hardware in yaw (azimuth drive), pitch (elevation drive), and roll.

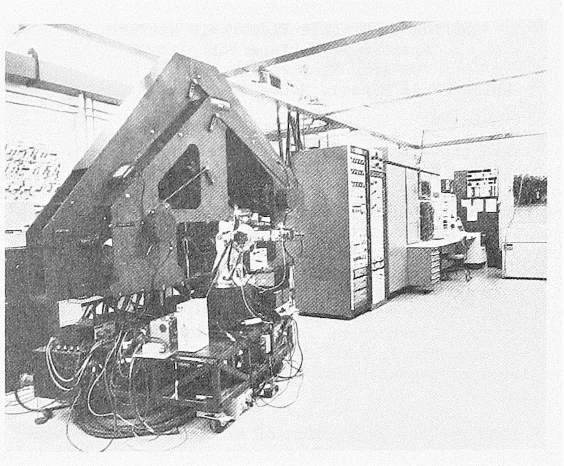


Figure 3.

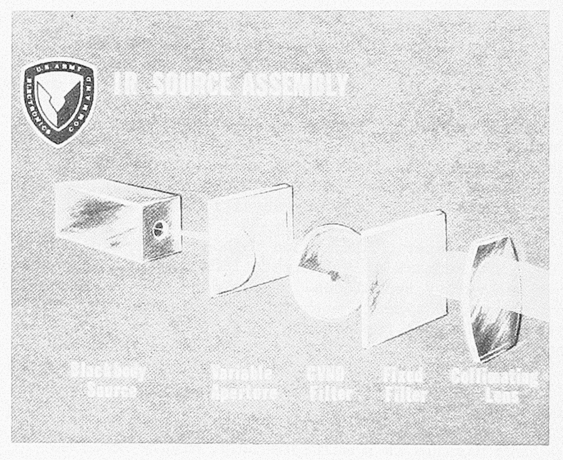


Figure 4.

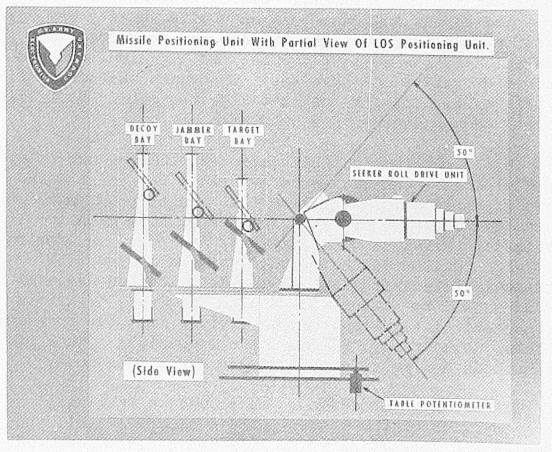


Figure 5.

The computer contains functions for the response of the missile's aerodynamic surfaces, the missile aerodynamics, the target's flight profile, and the target's and IRCM device's effective infrared signatures as functions of aspect, or viewing angles (figure 6). These data are used to compute the missile's flight trajectory, the relative position of the target and missile, the line-of-sight angles, and the target and IRCM effective irradiance. Commands are sent from the computer to control the line-of-sight angles, infrared irradiance of each source, and the missile pitch, yaw, and roll positions. An Electronic Associates Model 7800 analog computer is combined with a 32 K, 16-bit word PACER Model 100 digital computer for hybrid operation.

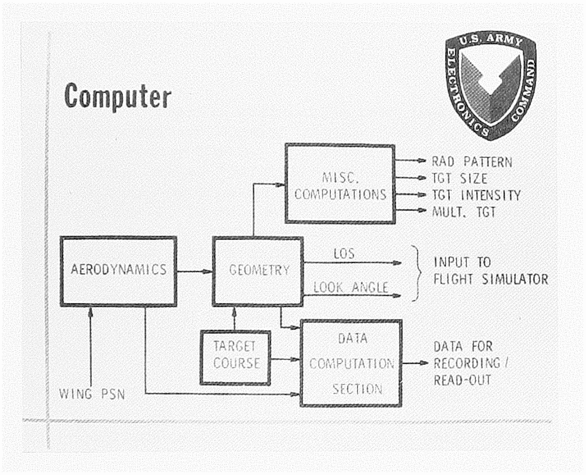
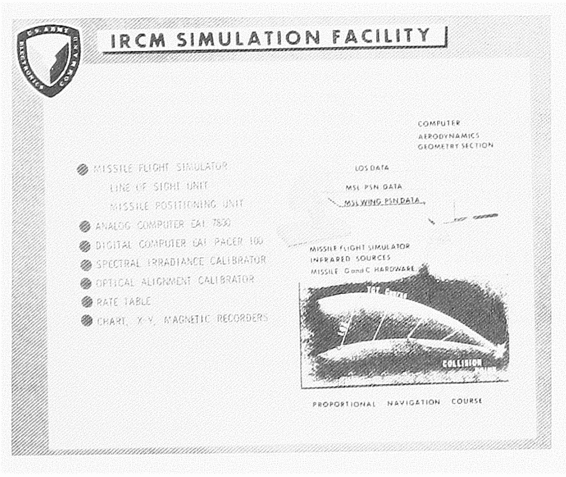


Figure 6.

Teletype, paper tape read and punch, disc, two X-Y recorders, a strip chart recorder, an analog magnetic tape recorder, an oscillograph recorder, and a graphics terminal are used controlling, operating, and recording (figure 7).


IRCM SIMULATION FACILITY

- MISSILE FLIGHT SIMULATOR
  - LINE OF SIGHT UNIT
  - MISSILE POSITIONING UNIT
- ANALOG COMPUTER EAI 7800
- DIGITAL COMPUTER EAI PACER 100
- SPECTRAL IRRADIANCE CALIBRATOR
- OPTICAL ALIGNMENT CALIBRATOR
- RATE TABLE
- CHART, X-Y, MAGNETIC RECORDERS

Figure 7.

This facility has the ability to simulate multiple sources, to modulate the infrared energy from the sources, to achieve dynamic separation between the sources, and with the use of the servo-driven variable apertures and CVND filters to vary the intensities and apparent target size as a function of closing range and/or aspect angle. This facility is a research tool which can be used for evaluating missile performance in an IRCM environment, developing IRCM techniques, aiding the development of ECM equipment, assessing the effects of hardening missiles through infrared counter-countermeasures applications, designing IRCM field experiments, and evaluating results from IRCM field tests.