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GUIDANCE SYSTEM EVALUATION LABORATORY

The APL Guidance System Evaluation Laboratory (GSEL) is a test facility that interfaces missile guidance hardware and real-time computer simulation in a way that closely resembles actual missile flight.

INTRODUCTION

The original APL Guidance System Evaluation Laboratory (GSEL), constructed during 1963-64, was used to evaluate continuously the guidance performance of successive versions of the Navy's Terrier, Tartar, and Standard missiles. During the intervening 15 years, many improvements were made in Naval weaponry to keep pace with corresponding advances in countermeasures and tactics. With the development of Standard Missile-2, resident test capabilities began to fall short of test requirements. Consequently, the Navy approved a major upgrading of the GSEL. This article describes the primary features of the new laboratory, which became operational in February 1980.

BACKGROUND

"Standard Missile" designates a family of surface-to-air missiles deployed on many Navy ships. A common feature is an ability to "home," i.e., guide some or all of the flight by means of target-reflected energy. The source of the energy is a high-power, continuous-wave shipboard radar illuminator. (This type of guidance is called "semiactive" because the transmitter and receiver are not colocated.) To cope with electronic countermeasures, the missile receiver is also designed to home passively on radio frequency (RF) energy emanating from the target.

Figure 1 is an illustration of the many RF signals that can be present at the missile's receiving antenna. Various processing techniques are used to discriminate between those signals, including amplitude, frequency, coherency, and angle-of-arrival measurements. In simplest terms, a guidance evaluation is a determination of how well a missile receiver performs the task of selecting the best available signal to derive steering information. The preferred measure of performance is usually miss distance, although receiver angle error signal quality is used frequently.

FUNCTIONAL OPERATION

Figure 2 illustrates how actual guidance hardware is interfaced with a real-time simulation to model the dynamics of closed-loop homing guidance. The guidance section under test is mounted at one end of the shielded, reflection-free chamber. Its front seeker receives the RF signal(s) emanating from an array of antennas located on the other side of the room. Typically, the RF environment consists of the target skin return combined with on-board jamming, standoff jamming, or both. Considerable care is taken to represent the characteristics of the incident waveforms in terms of their range-

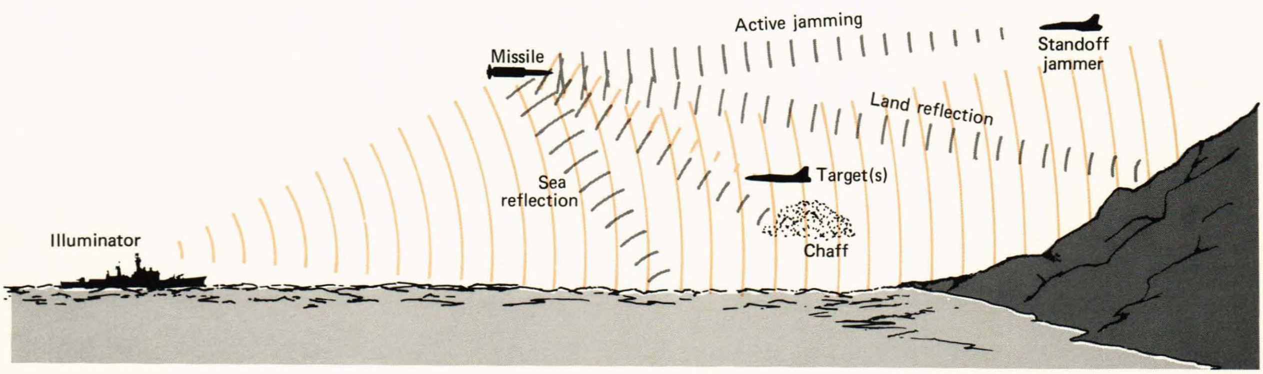

Fig. 1—Typical signals received by the missile in flight. Various discriminants are used to distinguish between the many signals arriving at the missile front antenna. Good steering information can usually be derived from either target-reflected energy or on-board target jamming. Interfering signals, which can exceed the target skin return by many orders of magnitude, must be rejected. Interference derives from natural and man-made environments, both friendly and unfriendly.

dependent power variations, amplitude and frequency modulations, and angles of arrival.

After isolating and processing a preferred RF signal, the guidance section generates pointing commands to update the look angle of the gimballed front antenna. Steering commands are also generated that serve as inputs to a computer simulation of the missile's flight control system. Depending on the trajectory being flown, the modeling of the control system can vary from a simplified to a highly complex representation of the autopilot, propulsion, and aerodynamics. In general, a simplified model is usually sufficient for a low altitude, short range intercept while more sophisticated modeling is required for a high altitude, long range engagement.

In either case, computation of the missile–target geometry and updating of the relative angular position through the RF array permit the homing loop to be closed through space across the chamber. Just prior to intercept, the process is stopped and the characteristics of the end game, including the miss distance, are determined by extrapolation.

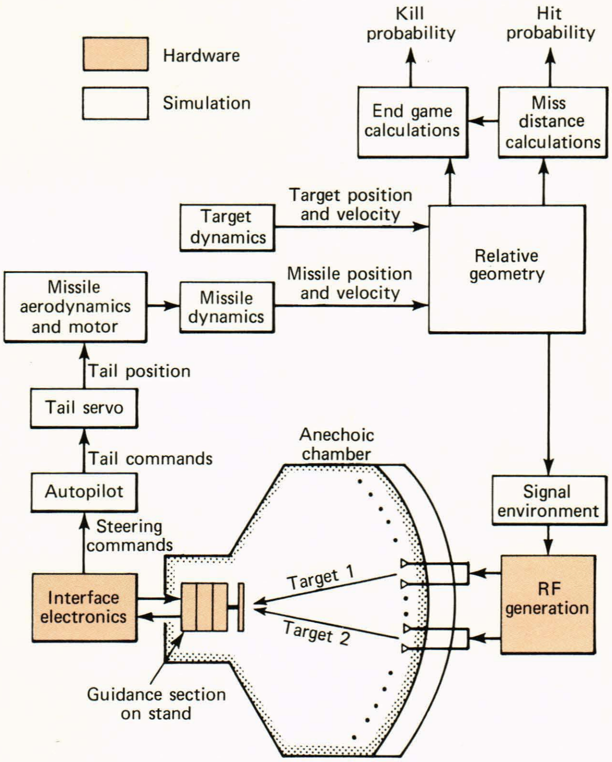

Fig. 2—GSEL hardware simulation interface. A combination of actual missile hardware and real-time computer simulation is used to determine closed-loop guidance performance under carefully controlled conditions. RF signals representing a particular flight environment are transmitted across an anechoic chamber. Missile-computed steering commands, typically based on angle and Doppler frequency measurements, serve as inputs to a simulation of the missile flight control system. The target angle relative to the missile is continuously updated through the array until just prior to closest approach. The geometry of the intercept, including the miss distance, is determined by extrapolation.

UPGRADE REQUIREMENTS

Facility requirements were defined to meet the needs of future test programs. The primary objective was to test an improved version of Standard Missile-2 (SM-2), which is being developed as part of the new Aegis Combat System, with applicable versions for upgraded Terrier and Tartar Combat Systems. SM-2 differs from its predecessors in that it has a midcourse guidance system, including communication links, that extends its effectiveness to longer ranges. In addition, it is designed to operate in more complex threat environments.

The results of the requirements definition studies and the corresponding capabilities of the former GSEL are summarized in Table 1. One of the most striking differences involves angular coverage. Simulations and analyses showed that the new chamber should span ±45° to ensure that miss distance would not be corrupted by room restrictions. Certain formation target tactics, as well as widely spaced standoff jammers, led primarily to this requirement. It is believed that the upgraded facility has the widest angular coverage of any test chamber in the country.

Table 1

GSEL UPGRADE REQUIREMENTS

Parameter	*Upgrade Requirement*	*Previous Capability*
Angular coverage	±45°	±18°
Room length	20 ft	12 ft
Frequency coverage	3-50 GHz	3-18 GHz
Dimensionality	2D + airframe motion*	2D
Target capability	3	2
Polarization	Vertical and/or horizontal	Vertical, horizontal, or circular
Angular rate	≥200°/s	60°/s
Angular acceleration	$\geq 2000°/s^2$	$265°/s^2$

*With future addition of a two-axis table.

Although the former chamber was long enough to test X-band seekers with antenna apertures slightly greater than 1 ft in diameter, an increase in room length to 20 ft was deemed advisable in reconstructing the chamber in order to provide a capability for testing higher frequency seekers. Requirements on both frequency coverage and maximum power output of the RF array are a compromise between the desired capability and what is achievable at reasonable cost. Similarly, the representation of missile/target flight dynamics in a single, arbitrary plane has been retained because of the much higher cost associated with RF generation in two angular coordinates. Three independent kinematic RF sources permit missile performance to be examined in threat situations involving several combinations of penetrating targets and standoff jammers. The simultaneous availability of the two orthogonal polarizations provides the desired degree of flexibility for that parameter.

DESCRIPTION

Figure 3 is a cutaway view of the new facility. The major elements are an anechoic chamber, a fixed-element RF array, RF generators, a hybrid computing system, and monitoring and control equipment. The main anechoic chamber is a screen room in which all interior surfaces are lined with RF absorbing material. A cylindrical wall across the wide end of the chamber supports the target arrays. The guidance section front antenna is located across the room at the focal point of the cylindrical wall (Fig. 4). Both the seeker antenna and the target horns are positioned midway between the floor and ceiling of the chamber. The RF generators occupy a second screen room that effectively shares a common wall with the test chamber. The dual screen rooms protect the guidance equipment under test from possible external interference while confining internally generated radiations.

The array system is one of the more unusual features of the facility. There are two separate interleaved arrays, each consisting of 64 microwave horns. One is equipped with a single set of feeds and the other with a dual set to allow a total of three independently controlled targets to be represented simultaneously. The line-of-sight angle of each target is obtained by varying the relative amplitude of the RF signals supplied to an appropriate pair of horns. Designing the digitally controlled variable power divider that performs this function was one of the more challenging engineering tasks. Under computer control, the target angle can be varied linearly across the array in 0.045° steps.

The RF generators provide: the wide variety of

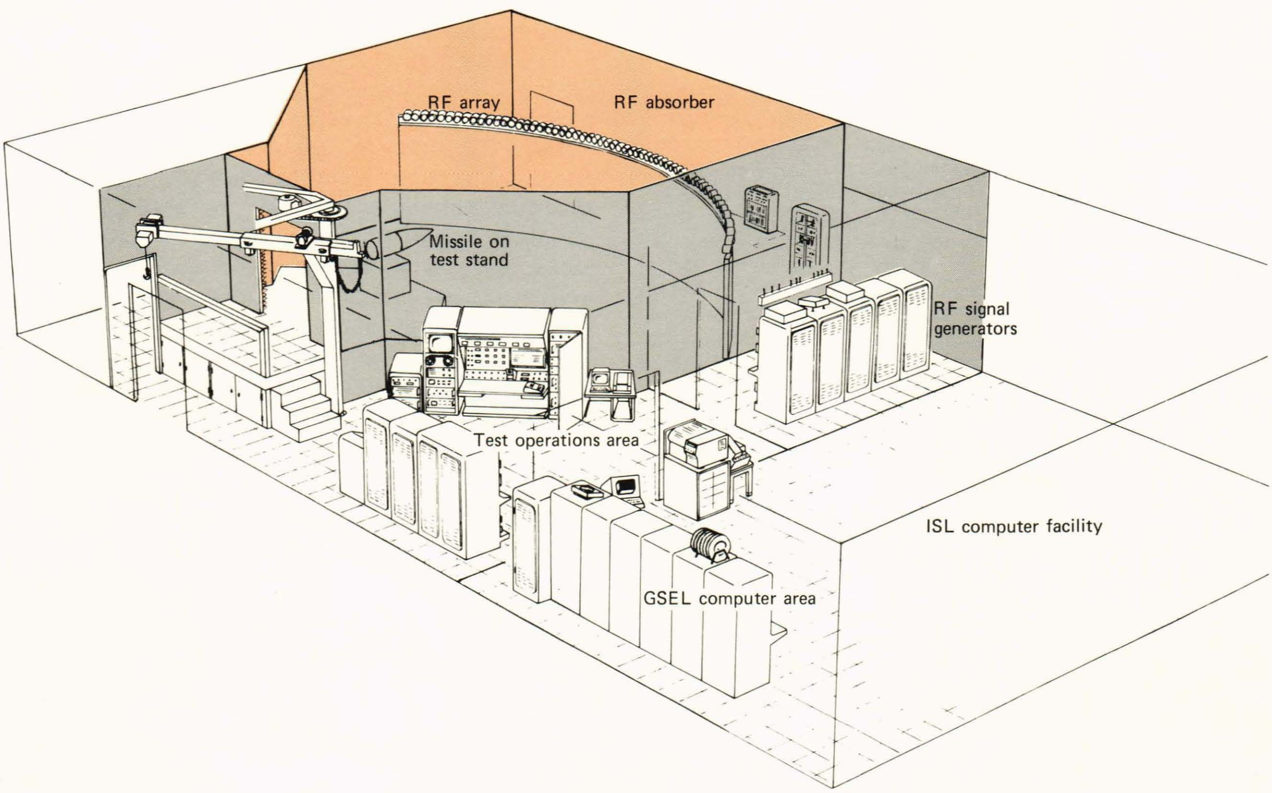

Fig. 3—Cutaway view of the upgraded GSEL. Major features of the upgraded GSEL include a large anechoic (nonreflective) chamber containing a fixed-element RF array, a screen room housing RF signal generation equipment, a test operations area, and a hybrid computer system located in an adjacent room. The new laboratory became operational in mid-February 1980.

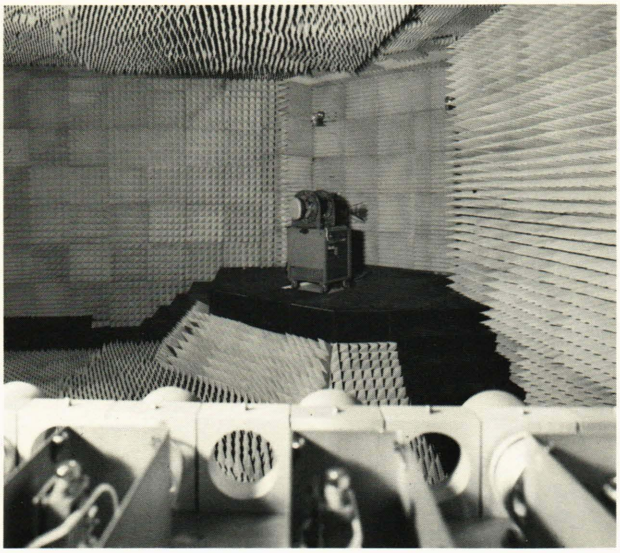

Fig. 4—Guidance section on test stand looking from behind the array. The guidance hardware, an SM-1 unit used for validation purposes, is located 20 ft away at the focal point of the RF antenna array. Absorber-lined interior surfaces suppress reflections, simulating a free-space environment. Mounting holes are for a second, interleaved array capable of representing two additional targets. Circuitry for making final amplitude and phase adjustments is in the foreground.

signals required to test Standard Missile seekers, including a rear reference signal; simulated returns for three targets, each with appropriate Doppler offset from the rear reference signal; and other signals shown in Fig 1. The power level of all signals is controlled to account for range changes. Amplitude modulation is applied to represent target fading. Many of the amplitude and frequency modulations associated with jamming types of interest are preprogrammed; others are easily synthesized.

A Pacer 600 Hybrid Computer System is situated in the adjacent Interactive Simulation Laboratory (ISL). The analog portion of the Pacer system is used to model the missile-target homing loop, including a detailed representation of the missile autopilot and kinematics. The digital portion controls detailed test operations, simulates aerodynamics, and recovers and processes data. Its capability is extended by a suite of microcomputers dedicated to performing specific tasks. The Pacer system has typical peripherals, including a tape recorder, disk storage, a card reader, a printer, and ancillary strip chart recorders. When fully implemented, it will support launch-to-intercept trajectories for all intercepts within the Aegis/SM-2, SM-2, or Tartar/ SM-2 performance envelopes.

The focus of test activities is the test operations area, where the operator's console is located. Other equipment includes a built-in test system to check the operability of the arrays, target generators, and digital communications exclusive of the Pacer computer, and a monitor and control console for interconnecting and monitoring most elements of the system.

CURRENT STATUS

Test operations in the upgraded facility began in mid-February 1980 with the receipt of a guidance section of the next-generation SM-2. Before the former facility was dismantled, closed-loop homing runs were made using an available SM-1 guidance section. When the tests were repeated in the new laboratory, essentially the same results were obtained except that certain second-order guidance effects could be observed that had not been apparent previously.

Much remains to be done before the capabilities of the new facility are fully utilized. However, the objective has been achieved of converting GSEL from a largely manually operated facility that could evaluate missile guidance performance against one or two targets at close range to a largely automated facility that simulates launch-to-intercept trajectories in threat situations involving multiple, widely spaced emitters. It is anticipated that future GSEL operations will continue to contribute significantly to Navy surface missile system programs.