System Performance Prediction by Modeling Test Data in Digital Simulations

HAROLD L. PASTRICK*
U.S. Army Missile Command, Redstone Arsenal, Ala.
RANDY J. YORK†
Western Kentucky University, Bowling Green, Ky.
AND
ALEXANDER C. JOLLY‡
Code Research Corporation, Huntsville, Ala.

Theme

A SIX-DEGREE-OF-FREEDOM digital simulation was developed to assess alternative guidance and control configurations for a precise weapons delivery system. Several variations were investigated while modeling the system's proportional navigation guidance law and its laser semiactive terminal homing autopilot mechanization. As initial design components were made available, they were evaluated and the test results were modeled for introduction into the simulation. The evolution from models of ideal components through models representing hardware test data is presented within the framework of increasing the validity of the all-digital simulation as a predictor of system performance.

Contents

As part of an exploratory development program, the Army Missile Command began an analysis effort designed to identify potential problems in the mechanization of a weapon system concept. The first step was to develop a full six-degree-of-freedom (6-DOF) digital simulation for evaluation of various autopilot hardware configurations that would enable selection of a guidance system mechanization. To meet the criteria established, the guidance law was developed from those candidates that used only angle or angle rate (no range) information to the target. The techniques considered included attitude pursuit, velocity pursuit, and proportional navigation and guidance (PNG). No combinations of these guidance schemes were evaluated fully, even though some improvement in accuracy was noted by combining proportional navigation with velocity pursuit guidance at the cost of increased complexity. Nevertheless, there was sufficient evidence to indicate that a form of PNG was the only guidance law accurate enough for this system.

In the PNG law the guidance signal is derived from the laser detector which measures the boresight error angle between the detector's electrical null and the target. The information is processed to act as a change in line of sight to the target or line-of-sight rate. The detector is forced to track the target by proper torquing of the gyro which is used as a spatial reference.

A simplified one-axis block diagram of the system is shown in Fig. 1.

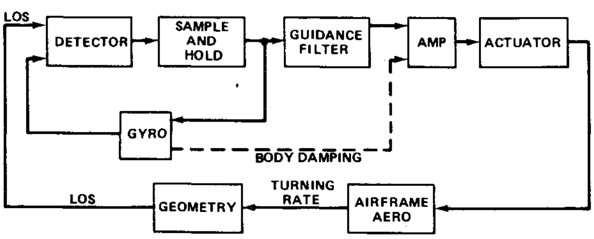

Fig. 1 One-axis block diagram.

The initial digital simulation implementing the PNG law was deliberately kept simple: the seeker was modeled to represent a linear symmetric detector (Fig. 2); the gyro was modeled as a perfect integrator; the actuator dynamics were neglected by modeling them as only a pure gain; and the aerodynamic data were linearized. As hardware development progressed the models were continually updated to correspond more closely to the actual components as described by test data. These data were obtained by a comprehensive test and evaluation program. To verify that the performance of the guidance and control scheme would match the simulation predictions, results of the hardware tests were factored back into the 6-DOF simulation.

Early simulation results indicated that the seeker was the most critical guidance component since it initiated the steering commands for the control surfaces. Thus, it was imperative that the modeling of the seeker be as realistic as possible. The actual laser seeker was found to have large nonlinearities in the supposedly linear region and static boresight shift on the detector null, and the detector null exhibited significant dynamic random shift as a function of closure range. With these inputs from hardware test data, comparisons by simulation were made between the predicted miss distance modeled with ideal components and that obtained with realistic component models.

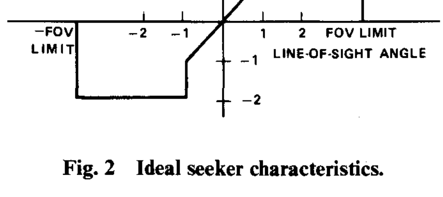

Fig. 2 Ideal seeker characteristics.

Presented as Paper 73-880 at the AIAA Guidance and Control Conference, Key Biscayne, Fla., August 20–22, 1973; submitted September 6, 1973; synoptic received November 26, 1973. Full paper available from AIAA Library, 750 Third Avenue, New York, N.Y. 10017. Price: Microfiche, $1.00; hard copy, $5.00. **Order must be accompanied by remittance.**

Index categories: Lasers; Computer Technology and Computer Simulation Techniques.

* Research Aerospace Engineer, Guidance and Control Directorate. Member AIAA.

† Assistant Professor, Department of Mathematics.

‡ Senior Staff Engineer.

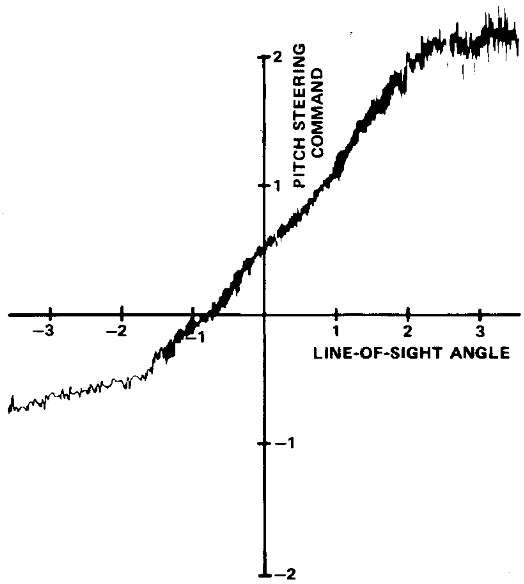

Fig. 3 Seeker output vs line of sight for a given laser intensity.

The seeker is a laser quadrant detector mounted on a 2-DOF gyro-stabilized platform. The idealized model gave seeker output only as a function of the line-of-sight error; however, test data showed that the output of the actual seeker also depended on the laser intensity received by the seeker (Fig. 3), and that the intensity in turn depended on the seeker slant range to target and the laser reflectivity of the target (Fig. 4). The realistic seeker model thus was modeled as a dual-table-look-up subroutine alternating between the intensity vs slant range and

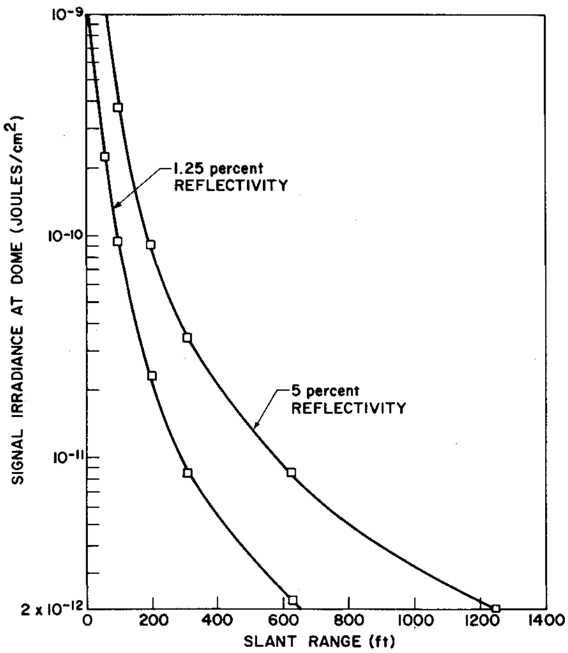

Fig. 4 Laser intensity vs slant range.

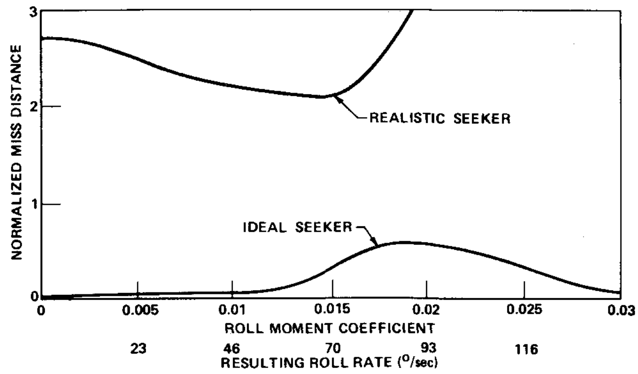

Fig. 5 Roll rate vs miss distance for original autopilot.

the seeker output vs line-of-sight curves without noise. The noise at the seeker output was modeled as a random variable represented by a gaussian probability distribution. The final seeker model was an additive combination of the nominal seeker curve and the gaussian noise (Fig. 3).

The impact of modeling critical components in the simulation by using test data instead of component specification data can be significant. In an early study to determine the effect of roll rate on system miss distance, both fin misalignment and fin aerodynamic blanking were modeled to induce roll rate. Performance obtained using the ideal seeker was compared with that of the realistic seeker (Fig. 5). Miss distance for the ideal seeker was found to be independent of roll rate and acceptable for all rates tested. Miss distance with the realistic seeker, however, was not acceptable at any roll rate, and the autopilot was redesigned in an attempt to improve performance. With the new autopilot the seeker miss distance was no longer independent of roll rate (Fig. 6), but up to a 70°/sec rate, i.e., within the system specification, miss distance was acceptable for both the ideal and realistic seekers.

This case clearly demonstrated the importance of validating simulation models with actual hardware performance. Consequently, other components were updated in the simulation by using test data results. In the case of the simulation developed for this particular weapon system, as is true in general of most such programs, the simulation is representative of the actual system only if it is based on valid test data.

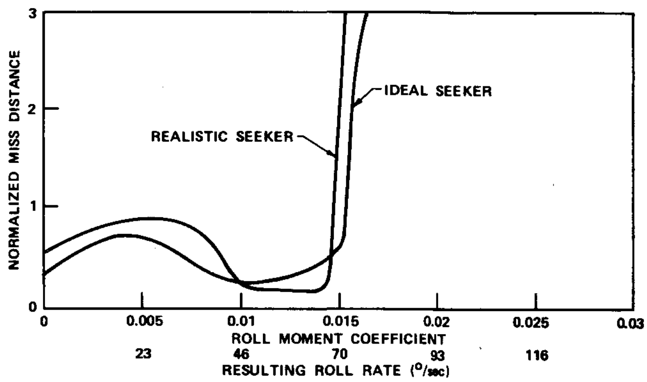

Fig. 6 Roll rate vs miss distance for new autopilot.