Enhanced Tracking Capability Using Multiple Stations and Doppler Radar

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Theme

THIS study provides a prototype for the comprehensive evaluation of the tracking capability of a complex tracking system. The computer program generated for this analysis differs from the previous studies in that it permits an evaluation of 1) the random error, 2) systematic errors introduced by uncorrected tracking errors, and 3) systematic errors introduced by the failure of the tracked object to conform to the modeled dynamics.[1-4] Selected results are presented for the Air Force missile testing range safety problem upon which the study was based.

Contents

The realtime Air Force range-safety task is to identify and abort in a timely manner errant test vehicles, while controlling the risk of aborting normal vehicles. This is accomplished by monitoring an instantaneous vacuum impact point trace based on edited and filtered data from a single radar selected from the tracking network. For most vehicles, this fails to provide an adequate discrimination criterion outside of the extended launch vicinity.

This study demonstrated the improvements that might be achieved by using range rate data and simultaneously using information from more than one tracker. Although the coherent signal processing (CSP) of C Band radar data were not highly reliable systems at the time this study was performed; it was demonstrated, for a mission for which data were then available, that satisfactory results were achievable for that mission. Unfortunately, because of security classification, the results for this mission cannot be presented here.

The Simulation: Fig. 1 illustrates the flow of data between the key modules in the simulation. Two preprocessors were used. The first generated a trajectory in the Earth Centered – Earth Fixed (ECF) coordinate system. This provided a reference trajectory for processing real data and provided the basis for the simulations. The second preprocessor edited measurements from the history tape that had been flagged when they were taken as being bad measurements. The tracking function generator determines the appropriate measurement variances for each measurement and in the simulation mode generates tracker measurements. It also sets up tracker misalignments and measurement biases as directed.

The filter estimator employed the Ho-Schur form of a Kalman type filter.[5] The state variables employed are the vehicle postion and velocity and the deviations of the vehicle acceleration from a reference acceleration profile. The ECF coordinate system is used. The model is a simple kinematic one. No attempt was made at the time of the study to choose an optimum state vector. The one chosen has the advantages of computational simplicity and low systematic error. Before a realtime range-safety version of this filter is implemented, it would be appropriate to determine if system accuracy requirements can be met with the simpler filter resulting from employing only vehicle position and velocity. A direct measure of the filter induced systematic error was achievable in the simulation mode by comparing the input ECF trajectory with the estimated trajectory.

The impact predictor implements the Keplerian equations and a linearization of these equations to determine the vacuum impact point corresponding to the estimated state vector and the statistics of the estimated vacuum impact point. By solving these same equations using the original ECF trajectory as the initial conditions, the overall systematic error of the system is determined. The vacuum impact point statistics were used for comparative purposes in this study for historical reasons and for the ease of comparison afforded in contrast to the six-dimensional vehicle state vector. The statistical evaluator model transforms the data regarding systematic and random error to a prescribed coordinate system and calculates the dimensions of the 95% confidence ellipse of the vacuum impact point.

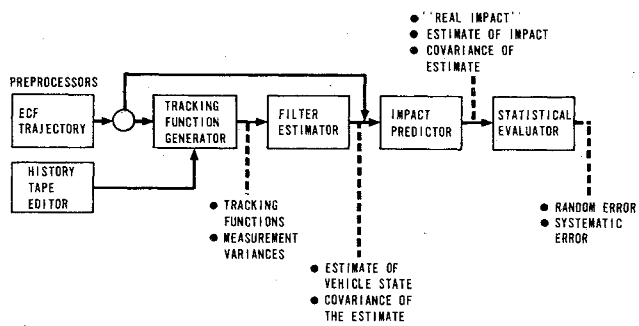

Fig. 1 Simulation flow diagram.

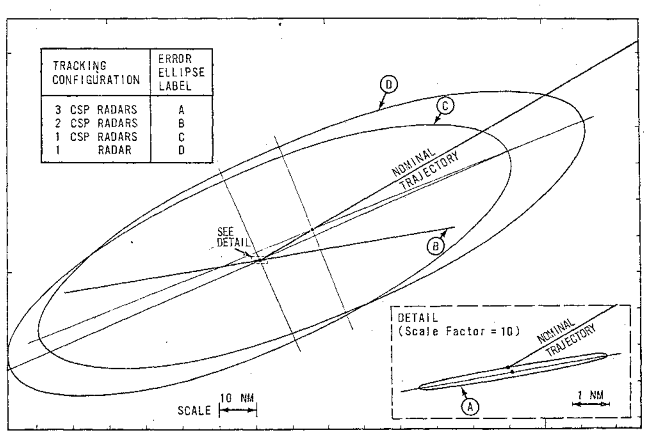

Fig. 2 Comparison of impact point estimation errors.

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Index categories: Tracking Systems; Safety; Computer Technology and Computer Simulation Techniques.

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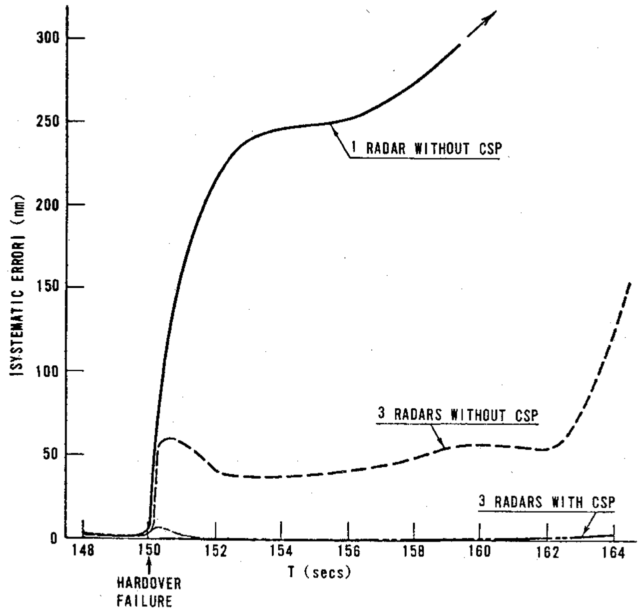

Fig. 3 Comparison of tracking capability through an extreme failure.

Key Results

Probably the most significant result of the study was the establishment of the test bed illustrated in Fig. 1, affording the opportunity to perform complete evaluations of different filter-tracking combinations. Secondly, a number of numerical results were established for a particular filter using existing trackers and representative error characteristics of these trackers. Figure 2 illustrates 95% confidence regions and systematic errors for four tracker configurations tracking an ICBM. In this particular simulation it is assumed that all systematic error introduced by the trackers has been corrected for by preprocessing either at the tracker on site computers or in the main computer. (The effect of systematic measurement error is treated in the backup paper.) The problem of serial correlation has been avoided here by assuming the radar bandwidth settings are such as to effectively eliminate it. Conservative measurement variances commensurate with this assumption has been employed. The subject of modeling serial correlation in a Kalman filter has been treated elsewhere.[6]

Unmodeled system dynamics are most important in the case of a missile failure. Under these conditions, it is important that a rapid, accurate identification of the failure condition be possible to minimize hazards. Systematic error is the principal measure of this capability. One of the most severe failure modes for testing this capability is an instantaneous hardover of the thrust vector. Since details regarding the signal degradation occurring during a failure were not available at the time of the study, this particularly severe failure mode was chosen to demonstrate that even under these conditions multiple trackers and doppler data provide significant advantages for range safety. Figure 3 illustrates the reduction of the systematic error achievable with multiple trackers and multiple doppler trackers over a single tracker in following the missile after a hardover failure at 150 sec.

It should be noted that the introduction of the range rate measurement not only reduces the random error but also the systematic error. Thus, the use of doppler data and multiple trackers affords a significant improvement in tracking normal and errant missiles.

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