GUN WEAPON SYSTEM ERRORS AND THEIR EFFECTS

The concept of “errors” implies something other than truth or intention. Most people will agree that errors are bad. Nobody wants to make an error. Errors cause problems. Errors cost time and money. It is only serendipitous situations where errors are the cause fortuitous events. Consequently, a great deal of effort goes into the worthy cause of the eliminating or reducing errors.

Yet despite all efforts to avoid errors and to minimize their effects, the world is full of errors. Every activity and every system will have its own set of errors and the result of every activity and the performance of every system will be affected by those errors. Therefore, it behooves us to try to understand the errors and their effects. It is through this understanding that we can guide efforts for error reduction and avoidance along a cost effective path.

This treatise will explore the errors that are associated with gun weapon systems and their effect on the performance. The performance of a gun weapon system, whether the system be a soldier with an M-16 rifle or a MK 45 5-inch naval gun controlled by a sophisticated fire control system, is strongly affected by the errors inherent to function of delivering ordinance on target. Most gun systems errors are stochastic, in so far that they often have random components. These are the types of errors cause gun systems to miss their targets regardless of the efforts to correct for their effect.. Errors and gun system accuracy are so intertwined that gun system performance is specified in statistical terms such as the probability of hitting a target of a given size, or the size of the cluster of shots all aimed at the same point.

This treatise also categorizes gun weapon system errors by their temporal domain across firing occasions and shots during each occasion. The relation between the domains are explained Gun weapon system errors are identified by their source and occurrence. The effects of the errors are also given for selected gun systems and calibers.

The analysis of gun system errors and their effect is important for specifying performance. The complexity of the gun engagement and the uncertainty of data used to solve the fire control problem require mathematical models and simulations to analyze gun system performance and effectiveness. The statistical representation of data (primarily input data) for use in mathematical models and simulations of gun systems engagements is collectively called the error budget. The form and fit of the error budget data are defined by the model or simulation used to conduct the analysis. The understanding of error budgets is paramount to credible effectiveness analysis.

General Types of Gun System Errors

Gun system errors are associated with data that are inaccurate or incomplete, procedural mistakes and operator skill. Inaccurate data arise from measurement, latency, or response. Incomplete data occur from assumed characterization of data or processes. Procedural errors relate to the mistakes in the operation of the gun systems. A final type of error is a result of operator skill. Since procedural errors should be preventable, and operator skill levels can be addressed by training, a separate discussion of these types of errors is provided.

Measurement errors. Data that are measured have errors that are caused by the accuracy of the measuring device or equipment and the tenacity of the data collection methods. Any device that measures a physical quantity does so with some degree of precision. When a radar measures the range and bearing to a target, it does so with a degree of accuracy described by the radar equations. When a gun mount sends its train and elevation position back to fire control, it is done to the resolution of the angular resolvers in the gun mount.

Data latency errors. Data are measured because they are unknown, usually because they are dynamic. So, if a datum value is measured at a particular time, it is valid only at the moment of measurement. If it is used at any other time, its error will be proportional to its age and rate of change. Inputs to the fire control system such as target location, meteorological information, and attitude angles are examples of data that contain measurement errors and have latency.

Response errors. Equipments that respond to actions do so with varying degrees of fidelity. When a gun mount is directed to point in a particular direction, it does so with some inherent error. The resultant pointing error is caused by the electro-mechanical control system, the tolerance in the drive mechanism, and the wear of the gun mount components. Additional error-producing effects could include the thermal expansion of gun mount parts, the temperature of hydraulic fluids, and the resolution and transmission of the ordered gun position. In the case where the gun mount position is continuously changing, the derivatives of the gun orders come into play and the response errors may be reflected in the angular rates of the gun mount.

Assumed characterization errors. Assumed characterization errors represent errors proportional to the degree that the assumption is valid. The gun fire control problem is highly complex and challenging and needs to be solved at a high rate of frequency to account for the motions of the firing platform and target. This often leads to fire control designs that sacrifice some fidelity for computational efficiency of the fire control solution. The differences between these sacrifices in fidelity (approximations and assumptions) and reality are the assumed characterization errors. For example, many minor-caliber fire control systems do not include meteorological data as part of their fire control solution. Their solutions are based on nominal meteorological conditions such as no wind, standard air temperature, and standard air density. Therefore, any gun firing occurring outside of those assumed meteorological conditions will have assumed characterization errors. In this example, the actual wind speed and the difference between the air temperature and density from their assumed values represent the assumed characterization errors.

Procedural errors. Procedural errors are caused by operator mistakes and, of course, are preventable errors. Error budgets often distinguish procedural errors from other types of errors, because procedural errors are considered to involve the unknowing use of incorrect data, or using data incorrectly, while other types of errors involve a lack of precision in one way or another. Procedural errors are considered only when measures of effectiveness involve the operational aspects of the gun system. If, for example, an amphibious ready group has a large number of gun systems available to support operations, estimates of operational proficiency based on training can be used as a metric for procedural errors. Procedural errors are often used for error budget analyses that support war fighting planning and weapon allocation studies.

Operator skill. While not specifically an error in the true sense of the word, operator skill must be accounted for to realistically depict and analyze a gun system. Most gun systems have some degree of operator interactions that affect gun system performance and effectiveness. In most systems, the operator has the ability to adjust the aim point to account for unknown sources of errors. Other gun systems rely on the operator's ability to track the target with an optical sight to accomplish its target tracking functions. Crew-served weapons rely solely on the operator to keep the target in the cross hairs. The skill level of the operator should be recognized as a part of the error budget.

Statistical Representation of Errors

The concept of errors for gunnery analysis can be applied equally to either a single firing from a single gun, or to a collection of guns firing many rounds at many different types of targets, over long periods of time, and under a wide variety of conditions. The analysis objectives bound the problem. If the analysis supports article testing of a single gun system, then the error budget used for this analysis is limited to the statistical representation of the uncertainties for that gun. On the other hand, if the analysis supports war planning or equipment acquisition, the error budgets represent the whole set of weapons, conditions, and measures of effectiveness that might be encountered during the deployment of the weapon class.

Fixed bias errors. Fixed bias errors are constant offsets from true data or assumed values. They are signed values (positive or negative) that remain constant for the duration of the analysis. They are not random variables. Fixed biases are useful for analysis of a single system or a unique condition.