An Innovative Approach to Estimating Small Arms Reliability
- An acquisition and T&E Efficiency –
Submission Category: Acquisition Reform/Better Buying Power

Small arms typically serve as a soldier's last line of defense on the battlefield. Failure of the weapon could be disastrous; its reliability is of primary importance. In the future, the Army will be able to guarantee small arm reliability to greater and greater degrees by utilizing Dynamic Linear Regression (DLR) methods when evaluating system reliability.

In late 2012, AMSAA was asked to conduct a holistic review of the Army's reliability test and evaluation of its carbines, particularly the M4 and M4A1 while firing M855 and M855A1 ammunition from four different test events starting in the year 2006 and ending in 2012. Analysis revealed that problems facing the previous reliability estimation methods and test designs were manifold. M4 and M4A1s firing M855A1 were not only failing to meet all their Mean Round Between Stoppage requirements, but also individual M4A1 reliability estimates varied significantly between weapons under test. Along with the weapon-to-weapon variability, a non-constant reliability was also observed during the previous testing. This caused problems with reliability estimation, as the method traditionally used assumed a constant failure rate.

A more rigorous statistical model that could be used for assessing small arms reliability and planning future testing was necessary for assessments of reliability. In response to this need, at the request of PM Soldier Weapons, AMSAA's Center for Reliability Growth developed a DLR approach to more accurately and efficiently estimate small arms reliability. This new and innovative reliability methodology has the potential to reshape and optimize how future weapon system testing is planned, conducted, and analyzed.

Until now the method used to estimate small arms reliability could not handle the ongoing

evolution of the overall system components or weapon-to-weapon variability. Crucial components such as magazines and ammunition have undergone significant changes and improvements that affect the reliability of the overall weapon system. The previous method accounted for only the test data from an individual test event when assessing the weapon's reliability. The DLR approach, on the other hand, can account for the numerous physical changes to an overall weapon throughout the years while simultaneously using all data from multiple years of testing to accurately assess the weapon's reliability.

The use of dynamic statistical methods allows updating the reliability estimate of the weapon with each round fired. The DLR framework uses a logistic regression approach to map the linear model inputs to binary results (successful round versus failed round) of the tests. A non-informative prior is first used and then updated to an informative prior as more information is processed, which provides a reliability estimate which is data-driven. An Expectation-Maximization algorithm is also used to estimate the model's evolution of parameters within the DLR framework. These parameters in conjunction with the DLR model inputs are the essential elements to be able to implement the improved analysis procedure.

DLR inputs consist of two separate data structures. The first are the weapons and their failures across multiple tests; the second are the attributes which are suspected to influence the weapon's reliability such as ammunition type, weapon type, or magazine type. Comparisons between weapons' attributes are made via the estimated distribution on the DLR coefficients. With this innovative approach, Army leadership can know with a high degree of certainty whether changes to weapon components are affecting reliability.

The DLR approach can be used to appropriately size future tests by considering any relevant

information available from previous tests along with the intent of the future test. The approach can also be used to compare new and rebuilt weapon reliability, which allows insight into the overall influence of this attribute on overall reliability. This in return may potentially provide decision makers with information needed to perform cost benefit analyses between new and rebuilt weapons with respect to their reliability and dependability.

In general, whenever a system enters into its final mature configuration and operational testing begins, it requires massive amounts of calendar time and money. The previous small arms reliability estimation procedures could not fully account for the vast amounts of data from multiple tests or the ever-changing weapon components and their influence on the overall weapon system. The new DLR method does the aforementioned all while being able to assess the number of weapons and ammunition fired during tests, which is used to demonstrate system reliability. This results in a more rigorously designed test, which could potentially reduce cost during the systems developmental and operational testing. This new approach to testing and analysis, initiated within PEO Soldier, directly supports the Army's efforts to seek out and execute new Test and Evaluation Efficiencies.