RELIABILITY SIMULATIONS TO MEET THE NEEDS OF A CHANGING ARMY

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ABSTRACT

Precision Fires Rocket and Missiles Systems Project Office is actively planning to support the US Army transformation to meet a wider range of threats in a set of operating environments. Army transformation necessitates development of a strategically responsive force. High Mobility Artillery Rocket System (HIMARS) is the vehicle in the Multiple Launch Rocket System (MLRS) Family that will meet these requirements. The Precision Fire Project Office is using process simulation as one of the tools to project required resources for HIMARS sustainability. Developed simulation models predict demands caused by failures for Line Replaceable Units (LRUs) that contribute to the total Operation and Sustainment (O&S) cost for the system. Demands are simulated based on the Reliability and OPTEMO of the LRUs. Forecasted demands are used to evaluate alternatives based on Reliability and cost.

1.0 INTRODUCTION

HIMARS, shown in Figure 1, is the next vehicle in the MLRS family systems. HIMARS will replace the legacy M270 MLRS launcher and the interim recapitalized M270A1 MLRS launcher to meet the needs of the Objective Force.

The ARMY is transforming the nature and composition of existing forces into an Objective Force. This Objective force is the plan for the ARMY to meet ever-changing threats. The Objective Force will be a more strategically responsive ARMY, capable of rapid transition across mission requirements, and equipped with significantly advanced systems. The Objective Force results in an ARMY that is responsive, deployable, agile, versatile, lethal, survivable, and sustainable.

HIMARS meets the needs of the Objective Force by its basic design. The HIMARS design consists of a wheeled version of the tracked M270 MLRS and M270A1. Reducing the number of Rocket Pods in half carried by the HIMARS vehicle is another design feature made to meet Objective Force goals. The removal of tracks and rocket pods results in a vehicle that is lighter and has a smaller volume.

HIMARS design feature provides a system that meets the deployable requirements of the Objective force. Unlike previous MLRS vehicles, HIMARS will be C-130 transportable. Systems C-130 transportability will result in greater number of systems being deployed in a shorter period of time.

A key point in the implementation of the Objective Force is the sustainability of the system. Capable systems that cannot be sustained will not meet the requirements of the Objective Force.

The Precision Fires Rocket and Missiles Systems Project Office is currently addressing the issue of supportability for the Objective Force HIMARS system. One of the areas being addressed is the LRUs used in the HIMARS. HIMARS LRUs consist of M270 legacy LRUs and HIMARS specific LRUs. Knowing when and how many LRU failures are expected provide useful insights into sustainability requirements. Sustainability requirements include the number of required number of spares and maintenance resources. Models and simulations are tools used to answer these questions.

Figure 1: HIMARS

2.0 PROCESS OVERVIEW

The process to be studied includes the fielding and operation of the HIMARS system. HIMARS systems are procured and fielded on a set schedule. A time difference is allowed between these stages to allow for the production process. After fielding, the HIMARS system will be in operational units and during this phase, LRU failures will be observed. The LRUs failure is the process that will be simulated.

3.0 MODEL DEVELOPMENT

Model efforts included two different modeling techniques to estimate LRU reliability. Deterministic and Probabilistic models were used to address the same scenario. Both models calculated the probability of success based on the exponential reliability function.

$$R(t) = e^{-.t} \quad (1)$$

Where . is the failure rate or the inverse of Mean Time Between Failures (MTBF) and t is the operating time.

3.1 Deterministic Model

The reliability model was first developed in a spreadsheet application to determine the number of failures by year. Information used by the model number of systems fielded by year, the number of hours operated per year, and the MTBF.

Model development began with the inclusion of a HIMARS fielding schedule. Reliability per year based on yearly operational hours and MTBF were calculated. The number of failures per year is calculated by multiplying the number of fielded for a specific year by its yearly unreliability. The failed LRUs are then added to the proceeding year fielding total. The surviving LRUs are then evaluated in the proceeding year with a reliability reflecting the additional operating hours and the process is repeated. The number of failures is then summed for each year.

3.2 Probabilistic Model

The Probabilistic Model was developed using the ARENA software model. Releasing the defined number of HIMARS systems in the correct year was the first area addressed in the ARENA model. Two separate flows of entities were created in the model. The first represented HIMARS yearly fielding and the other was used to control the fielding schedule.

Once the HIMARS systems begin flowing through the system, they are assigned with variables that record the number of overhauls, same as the number of failures, and the number of accumulated operational hours since the last overhaul. Fielded systems then operate for the duration of a year. At the end of the year, the probability of failure was calculated. This represents a yearly inspection process.

The reliability of LRUs was determined by equation (1) that used operational hours and component MTBF. After calculating reliability, a random number was generated. A generated random number greater than the reliability indicated a failed LRU where the random number is lower than reliability was considered to be operational.

Properly functioning LRUs were routed back to the field for normal operations. Failed LRUs were routed to the overhaul process. In the overhaul process, the overhaul counter variable is incremented up by one and the operational time is set to zero. Upon completion of this process, the system is return to the field for normal operations.

3.3 Model Comparisons

Results from both the deterministic and probabilistic models were generated using the same fielding schedule, yearly operational hours, and MTBF. A comparison of these results can be found in Figure 2. Both curves appear to be similar in shape. The only visible difference between the two curves is that the deterministic model appears to be smoother. This is due to the probabilistic nature of the ARENA model. The ARENA model also deals with whole LRUs and the deterministic model calculates the fraction of LRU failures.

Although the curves appeared similar, the statistical inferences of the values were tested. The Paired t-Test was used to then compare the means of the values. The statistical hypotheses to be proven, null hypotheses, is that the means of the two models are statistically the same. The null hypotheses and the alternative hypotheses show that the means are statistically different, are shown in formula (2).

$$H_0: \mu_1 = \mu_2 \qquad (2)$$
$$H_1: \mu_1 = \mu_2$$

The test statistic for the Paired t-test, formula (3), was calculated to be 0.297.

$$t_0 = \bar{d} / s_d / \sqrt{n} \qquad (3)$$

Since the critical value at 95% confidence interval, .688, is greater than the test statistic, formula (4), we fail to reject the null hypothesis that means are the same.

$$|t_o| < t_{.025,19} \qquad (4)$$
$$.297 < .688$$

Failing to reject the null hypothesis is the strongest statistical inference that we can make.

4.0 MODEL ENHANCEMENTS

Due to the expandability, the probabilistic model was determined to the model of choice. Enhancements to the model will make it a more useful tool.

4.1 Model Updates

Both development models only considered the probability of LRU failures. They both assumed the LRUs were instantaneously replaced with LRUs having the same inherent MTBF. To address this issue, the reliability of replacement LRUs included a 10% reduction in the original MTBF. This models the process of using overhauled LRUs as replacement parts. A comparison between LRU demands using new spares and overhauled spares is shown in Figure 3. The LRU demands using overhauled LRUs becomes dramatically higher during the later stages of system life. After fielding is complete, LRU demands using new spares reaches a steady state. Including the use of overhauled replacement parts produced an upward trend for LRUs demands after fielding completion.

4.2 Future Updates

The current model did not account for maintenance resources consumed by failures, the impact on the logistics supply system, impact on the operation time or consume maintenance requirements. Modeling efforts to address these areas would require the definition of the maintenance concept at the Unit, Intermediate, and Depot levels. Other factors including logistics down time would be incorporated into future versions of the model. The ability for multiple LRUs to fit into a single vehicle will be incorporated.

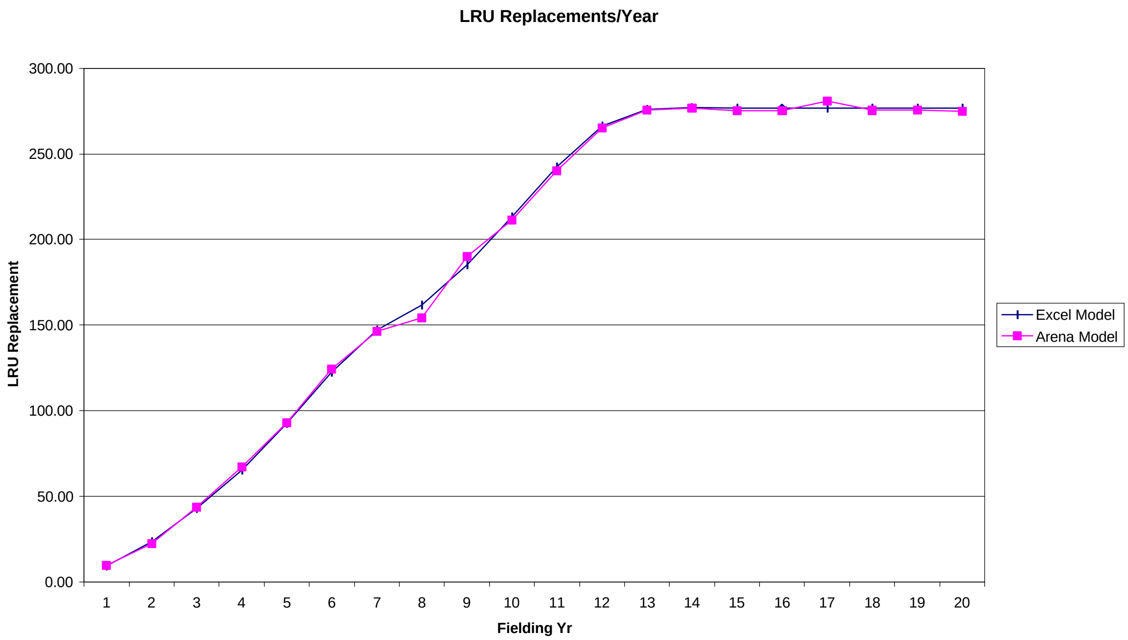

Figure 2 Model Comparisons

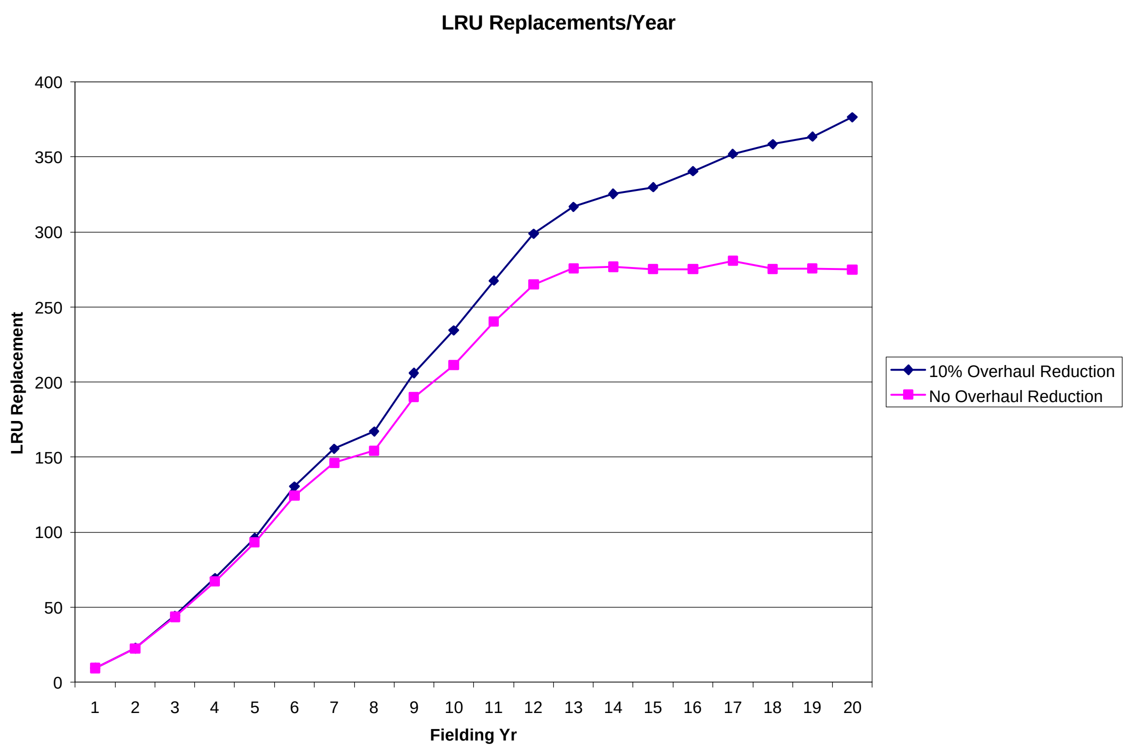

Figure 3 Overhaul Process Comparison

5.0 CONCLUSIONS

Simulation proved to be an effective tool to analyze projected resources required during the operational life of a future fielded system. The versatility of simulation is helpful in answering a wide range of questions.

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