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The Fiscal Impact of Automatic Testing on Fix-Forward Operations

Natasha Chick, Taylor Gordon, Kendall Munsey, Gino Nicosia, Chloë Smith, and Christopher Fisher

Department of Systems Engineering
United States Military Academy, West Point, NY

Corresponding author: Christopher.b.fisher14.mil@mail.mil

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Abstract: This study analyzes how the Next Generation Automatic Test System (NGATS) can decrease maintenance costs for units conducting Multi-Domain Operations by enabling fix-forward operations. Modern warfare requires complex weapon systems, making field-level electronic maintenance a vital Army function. The NGATS, a multi-platform tester, enables units to conduct field-level maintenance rather than sustainment-level maintenance which requires the evacuation of equipment out of theater. The NGATS can test electronic systems for a diverse set of platforms including the Abrams, Avenger, and Blackhawk. This study uses a decision tree model to determine the expected cost savings associated with NGATS fielding and increased field-level maintenance. The results indicate a projected cost savings of approximately $2 billion across all Armor Brigade Combat Teams in the active-duty Army over ten years. This strongly supports accelerated NGATS distribution, as units require testing capability to perform fix-forward maintenance and maintain readiness on the battlefield.

Keywords: Next Generation Automatic Test System, fix-forward, Multi-Domain operations, readiness, maintenance, cost avoidance, automatic test system, electronic maintenance

1. Introduction

The Army Vision for 2028 illustrates the inevitable change in how the United States will have to deal with future conflicts (Milley, 2018). The focus has shifted to near-peer competitors whose technological capabilities have the potential to rival that of the United States. The Army's new operating concept, Multi-Domain Operations (MDO), describes the extension of battle to five domains (land, sea, air, space, and cyber-space) to effectively defeat such adversaries. Since MDO depends on rapid mobilization and further emphasizes the need for high levels of equipment readiness, field-level maintenance (also called "fix-forward") is receiving increased attention. Many weapons platforms currently rely on Contracted Logistics Support (CLS) and use exchange pricing to replace faulty electronic components, often requiring equipment to be evacuated out of theater. This incurs significant costs, both financially and in terms of equipment availability. The Army funded the development of the Next Generation Automatic Test System (NGATS) in 2007 to be a "single source of Automatic Test Equipment" and support the modernization of electronic maintenance, effectively bringing electronic testing to the field and increasing the operational availability of equipment (Moody, 2016). Twelve years later, the NGATS is a fully developed program of record, but currently does not have sufficient funds allocated to achieve full operational capability in a timely manner. To justify an increased rate of fielding, an analysis of how the NGATS can impact maintenance costs is appropriate.

2. Background

2.1 NGATS Overview

This study focuses on the decision between conducting fix-forward operations or sustainment-level maintenance. Fix-forward maintenance allows for decreased repair times and increased efficiency for electronic systems maintenance.

Operating in close proximity to forward deployed elements allows maintenance units to provide immediate and more efficient support for repairs and replacements.

Army platforms such as the Abrams Tank and Bradley Fighting Vehicle have modular electronic components that can be replaced when they fail. These components are known as Line Replaceable Units (LRUs). When maintenance contracts exist with the Original Equipment Manufacturer (OEM) and a unit believes an LRU is faulty, it is sent to the manufacturer for replacement. This applicable cost for the Army is either the original price of that part or a lower pre-negotiated exchange price, depending on the nature of the contract. The main issue with exchanging an LRU with the OEM, is that the full exchange price for the LRU is paid, even if the cost of repairing the LRU is small. Additionally, unit operators typically identify faulty LRUs through platform built-in tests (BIT), which can be inaccurate, and in turn, inaccurately label an LRU faulty.

Automatic Test Systems (ATS) are "computer-controlled suite[s] of electronic test equipment" that allow Army units to test these LRUs, usually at the Brigade Support Battalion (BSB) instead of sending it to the OEM (Baloney et al., 2014). Soldiers are trained to use the ATS to test each LRU to determine whether it is faulty, or if the BIT misidentified the problem. If the LRU is found not-faulty, it is classified as a "No-Evidence of Failure" (NEOF) and replacement of the LRU is not necessary. If an LRU is determined to be faulty, the ATS pinpoints the problem, enabling Soldiers to determine whether it can be fixed at the unit-level or if it truly does need to be replaced entirely.

The current primary ATS in Army inventory is the Direct Support Electrical System Test Set (DSESTS), which is used to test only Abrams and Bradley LRUs. The Army's newest ATS, the NGATS, is a multi-platform tester with the ability to test virtually any electronic system in Army inventory, provided the necessary hardware interfaces and software are developed to connect the NGATS with a given LRU. This hardware and software is collectively known as a Test Program Set (TPS). The NGATS distinguishes itself from previous ATS models with its common architecture that is compatible with previous test equipment, its increased detection rates of false failures, reduced test times, and portability (Clark, 2018).

Figure 1 illustrates the relationship between the NGATS and a platform it has the capability to test. When a faulty LRU is identified on a platform such as the Abrams, it is removed from the platform and sent to the NGATS for testing. The LRU is paired with the NGATS via its TPS. The NGATS then tests the LRU and determines whether the LRU is actually faulty. If it is not faulty, it is reported as a NEOF and the LRU can be returned to the unit. If it is faulty, the NGATS provides instructions to the Soldier on how to repair the LRU or determines that the LRU is not reparable at this station (NRTS) and needs to be evacuated to the OEM for exchange. Unit-level LRU repairs can consist of replacing a modular subcomponent known as a Shop Replaceable Unit (SRU), replacing a knob or other physical repair, or even simply tightening a connection or downloading a software update. Once the LRU is successfully repaired or replaced, it is sent back to the unit to be reinserted into the platform.

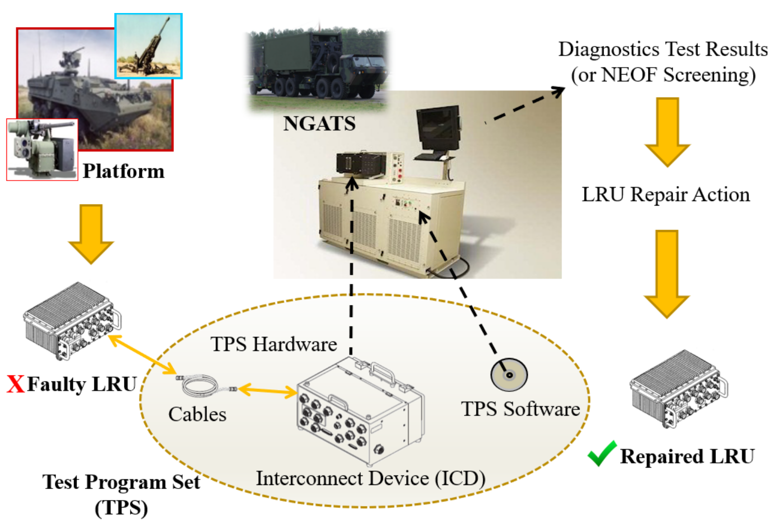

Figure 1. NGATS Activity Flow Diagram (Clark, 2018)

2.2. Problem Definition

The goal of this study is to determine the effects of fix-forward operations on maintenance costs by determining cost savings for platforms using the NGATS. The results of this study will provide ARDEC with a quantitative understanding of the maintenance cost-savings associated with NGATS-enabled fix-forward operations and will inform future NGATS budget allocations.

3. Methodology

3.1 Methodology Overview

Modeling the cost savings of fix-forward maintenance consisted of two parts. The first part was to determine the cost-savings that units already experience by practicing DSESTS-enabled fix-forward maintenance for the M1A2 Abrams. 18 months' worth of Abrams testing data was obtained from the 3rd Armored Brigade Combat Team, 4th Infantry Division (3ABCT, 4ID), including records from both Fort Carson and a nine-month rotation in support of Operation Atlantic Resolve (OAR) in Europe. In total, there were 635 maintenance records available. The second part of the modeling process was applying these cost savings to platforms which are not supported by field-level ATS yet, such as the Stryker. Since unsupported platforms currently rely on their OEMs to replace faulty LRUs, no testing data was available. Therefore, modeling assumptions were made which allowed Abrams model parameters to be applied to these platforms. The following sections provide details on these parts.

3.2 Modeling Abrams Fix-Forward Savings

A decision tree was used to determine the expected maintenance cost savings associated with fix-forward operations for the Abrams. A decision tree is a decision analysis tool that uses a system of different nodes: decision, chance and end nodes. Chance nodes have an associated probability and end nodes have an associated cost. When aggregated together, these nodes produce an expected cost for a decision node. Precision Tree® developed the decision tree software used to model this problem.

Figure 2 shows a portion of the model, for just one Abrams LRU, the Hull Power Distribution Unit (HPDU). There is only one decision node in the tree: whether to conduct field-level maintenance using the NGATS, or sustainment-level maintenance through the OEM. A decision to use sustainment-level maintenance automatically results in a cost equal to the exchange price for the LRU, in this case $66,269. The components of the field-level maintenance decision tree are: the failure and NEOF rates for each LRU, repair costs for different types of LRU repairs, and the unit and exchange prices of both LRUs and SRUs. In the case of the HPDU shown in the figure, the expected cost of conducting fix-forward maintenance using the NGATS is $15,808. The model used prices from the Federal Logistics database to determine the cost of acquiring necessary repair parts. All the probabilities were derived from the maintenance records provided by the 3ABCT, 4ID.

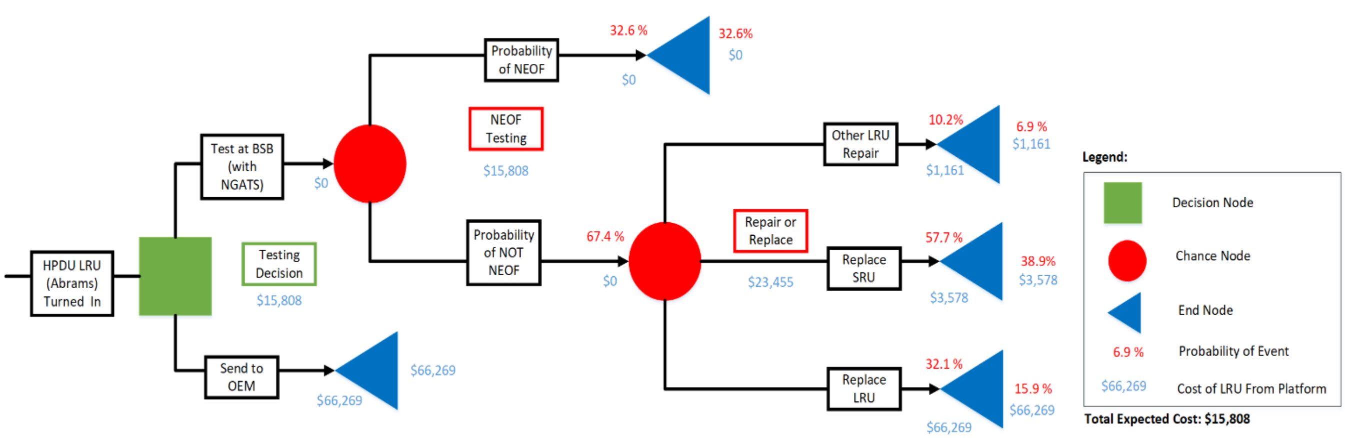

Figure 2. Hull Power Distribution Unit Branch of Abrams Decision Tree

3.3 Application of Model to Other Platforms

After current cost-savings of fix-forward operations were modeled, the model was applied to other platforms that could receive fix-forward support once the NGATS is fielded. To achieve this, average chance node probabilities from the Abrams LRUs were applied to additional platforms when no data was available. The trend in maintenance costs compared to the actual cost of Abrams LRUs was applied to these additional platforms because LRUs are similar in nature regardless of the difference in platforms. The frequency of LRU failure rates per platform per day was also taken directly from the Abrams and Bradley average. The decision trees provided reasonable cost avoidance results as more platforms were added.

4. Results and Analysis

4.1 Expected Cost of Maintenance

The decision tree produced an expected cost of maintenance for a single Abrams LRU that was sent in for repair, as depicted in Figure 3. "Fix-forward" represents the expected cost when the NGATS is used to test LRUs at the BSB-level and includes the likelihood that the LRU was either a NEOF, required an SRU replacement, required a different repair, or required a full replacement. "Evacuate to OEM" represents the exchange price for the LRU, assuming no NGATS is available. The model's overall expected cost of a work order was $5,800 using field-level maintenance, and $35,700 using sustainment-level maintenance. This showed a cost savings of 84% with NGATS use.

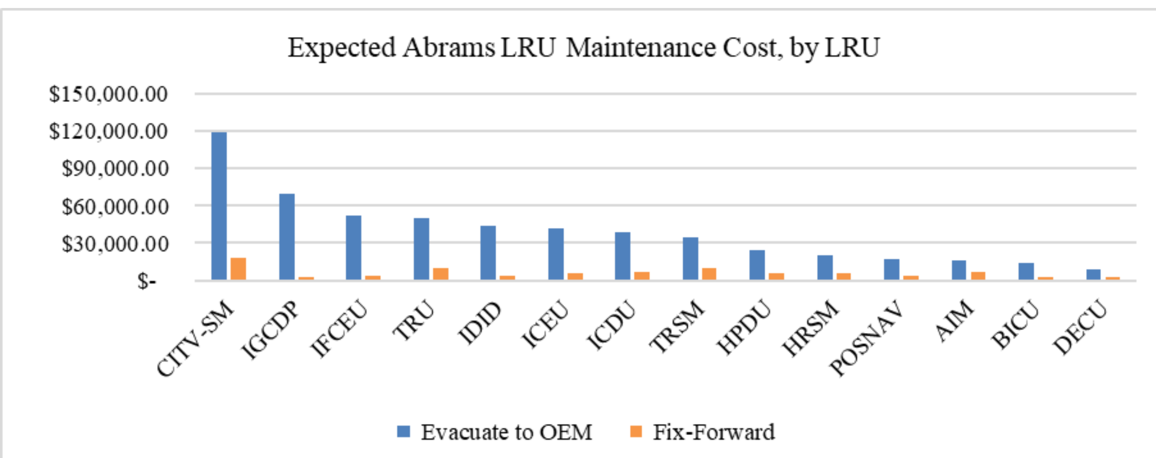

Figure 3. Expected Cost of Abrams LRU Maintenance, by LRU

Once the Abrams decision tree was developed, average NEOF and LRU failure rates as well as average SRU replacement costs were used to create a generic model that could apply to other platforms. This generic decision tree produced an average of 77.5% savings by fixing-forward. Figure 4 shows the results applied to several platforms, using actual LRU costs and assuming a uniform distribution of breakdowns across all platform LRUs. The Husky Mine Detection System (HMDS) had the highest cost per work order, while Stryker had the lowest. This variation is primarily explained by the cost of a platform's LRU's. The HMDS has expensive LRUs, while Stryker LRU's are less expensive.

4.2 Projected Cost Savings of NGATS

The savings from Figure 4 were annualized in Figure 5 for all platforms in the Army's inventory that had available LRU cost data and that are proposed to be supported by the NGATS. Even though all these platforms will not be assigned to units with a BSB, they should at a minimum be able to receive area support from a nearby unit and avoid defaulting to OEM maintenance. These annualized costs were based on the frequency of work orders per day per platform observed in the 3ABCT, 4ID data. As data for the frequency of individual LRU breakdowns becomes available for additional platforms, these results can be updated. The results show a collective savings of nearly $198 million annually, or $2 billion over a 10-year period.

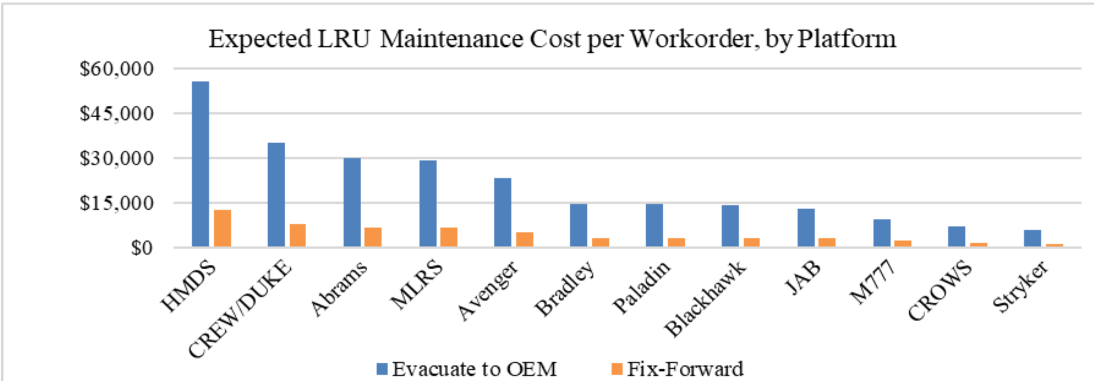

Figure 4. Expected Average Cost Incurred per LRU Workorder, by Platform

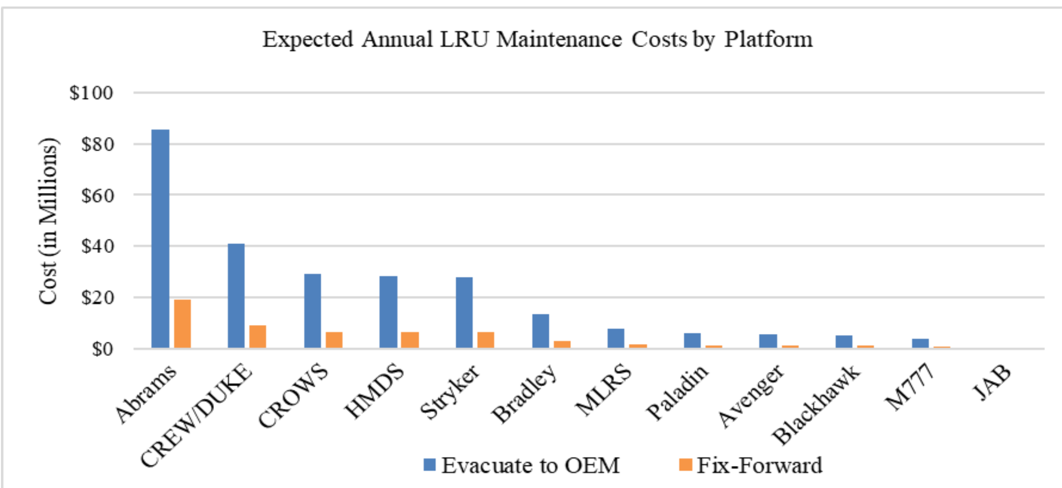

Figure 5. Expected Annual LRU Maintenance Costs by Platform

4.3 Model Sensitivity

One-way sensitivity analysis was conducted on some of the parameters of the generic decision tree, which was used to determine the average cost per LRU workorder shown in Figure 4. The model was measured for sensitivity to the LRU failure and NEOF rates and the probability that a tested LRU will need to be replaced, as seen in Figure 6. For this sensitivity analysis, each variable was increased and decreased by 25% to capture the effect of the variable on the model's cost avoidance output.

The results indicate that the model is not overly sensitive to reasonable variations in the parameters. Not surprisingly, of these parameters the model was most sensitive to the probability that a tested LRU would need to be replaced. However, even if this rate is increased by 25% of its current estimated value, the cost savings only decreased from 77% to 73%. This analysis shows that even the most sensitive variables have only limited effects on the overall cost savings of the decision tree, and that the model is robust to some of the modeling assumptions which were required.

In addition to conducting a sensitivity analysis on the percent cost savings, an analysis was also conducted on the annual electronic maintenance costs - an extrapolation of the model's output as seen in Figure 5 on the previous page. The

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most sensitive variable for annual maintenance costs is workorder frequency, which is directly proportional to the output. In other words, a 25% increase in the number of annual workorders, would increase the projected maintenance costs by 25%. This sensitivity indicates that further data should be collected as soon as possible to understand LRU workorder frequency for other platforms, in order to refine the annualized results presented here.

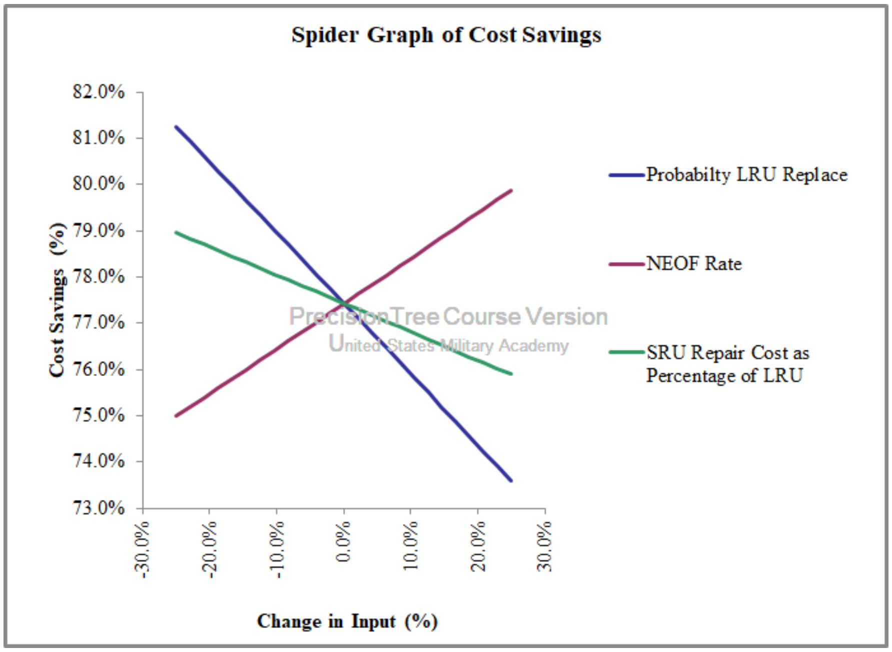

Figure 6. Spider Sensitivity Graph of Model Variables upon Cost Savings

5. Conclusions and Future Work

By modeling the implementation of NGATS in a fix-forward environment, this study provides quantitative support for the accelerated distribution of the NGATS. Estimated cost savings were platform-specific, primarily dependent on the cost of the platform's LRUs and the number of platforms in Army inventory. The projected annual maintenance savings of $198 million provided here will only increase as LRU-level cost data becomes available for more platforms. The NGATS has the potential to support more systems not included here including radios, night vision devices, and additional aircraft such as the Apache Helicopter. The eventual NGATS support of these platforms will significantly increase the Army's electronic maintenance cost avoidance beyond the savings projected in this study.

The developed model and established data format allow for new platforms to be incorporated into the analysis in a matter of days, once LRU-level information is obtained. Establishing true Army-level savings will require more detailed information on additional recurring and non-recurring costs associated with developing and fielding the NGATS and TPS for additional platforms.

This study only focused on the cost savings of fix-forward electronic maintenance. Future work should examine how fix-forward operations not only reduces cost, but also increases equipment operational availability by reducing turnaround time for LRU maintenance.

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