Artificial Intelligence (AI) in the Automatic Test Environment

AI enabled solutions for the Marine

by the Automated Test Systems Team, Portfolio Manager Logistics Combat Element Systems, Marine Corps Systems Command

>The Automated Test Systems Team, under Program Manager Supply and Maintenance Systems, Portfolio Manager Logistics Combat Element Systems, at Marine Corps Systems Command, provides automatic test systems that support the Marine Corps ground maintenance strategies in order to enhance organic maintenance capabilities and facilitate maintenance operations as far forward as possible.

As automatic testing becomes more complex with increased technology and the need for rapid and accurate weapons system screening and diagnostics, the Marine Corps is exploring innovative ways to modernize maintenance testing and diagnostic capabilities across weapons systems and their associated subsystems. Increasing throughput, reducing maintenance cycle times, and enhancing fleet asset reliability by changing the paradigm on weapons system testing are key enablers to successfully support operational readiness of a technology-enhanced FMF.

How We Are Currently Operating

Weapons system maintenance in the Marine Corps is grouped into three basic categories: organizational, intermediate, and depot. Organizational maintenance consists of the on-platform tasks necessary for day-to-day operation, including inspection, servicing, and remove-and-replace operations for failed components (this includes Line Replaceable Units [LRUs] or weapon-replaceable assemblies). Intermediate maintenance consists of off-platform repair capabilities possessed by operating units, logistics units, and in-theater sustainment organizations. These capabilities can be quite extensive and include remove-and-replace operations for subcomponents of LRUs (so-called shop replaceable units or assemblies), local manufacture, and other repair capabilities. Depot maintenance consists of repairs beyond the capabilities of the operating units, including rebuild, overhaul, and extensive modification of equipment platforms, systems, and subsystems.

Automatic Test Systems (ATS) are developed to test and fault isolate at all three maintenance levels. ATS complexity varies depending upon which level the weapons systems are tested and maintained. At the organizational level, the maintainer is able to test and perform a remove-and-replace operation on the LRU, put the weapons system back in service, and send the LRU to the intermediate level for further fault isolation and repair. The primary automatic test system used at the organizational level is the Marine Corps Electronic Maintenance Support System, which provides the maintainer access to networked tools, Electronic Technical Manuals, Interactive Electronic Technical Manuals, and diagnostic applications that enable at-platform testing of weapons systems to MAGTFs in both deployed and garrison environments. The Electronic Maintenance Support System capability addresses important gaps in the execution of Marine Corps maintenance missions and tasks. It provides diagnostic capabilities and access to technical information and the Global Combat Support System-Marine Corps (GCSS-MC) when connected to the Marine Corps Enterprise Network (MCEN). After the weapons system is placed back in service, the suspect LRU is sent to the intermediate or depot facility for further fault isolation and repair. The primary automatic test system used at this level is the General Purpose Automatic Test System coupled with various Application Program Sets to test and diagnose a wide variety of weapons systems at the LRU and Circuit Card Assembly level. The General Purpose Automatic Test System provides deployable maintenance support capabilities as far forward as possible.

Test program development on these legacy systems often involves adding new capability and performance (which is frequently gated by technology). The design scope is requirement driven and tailored to screening for defects and fault isolation to the LRU. It is limited based

on methods and technology, which generate large amounts of parametric data that is used primarily for pass/fail determinations and then discarded. These test systems are often isolated from the MCEN because of Cyber Security restrictions that present obstacles to data access and system performance. These impediments have been accurately identified in the *38th Commandant's Planning Guidance* (*CPG*):

> We do not currently collect the data we need systematically, we lack the processes and technology to make sense of the data we do collect, and we do not leverage the data we have to identify the decision space in manning, training, and equipping the force.[1]

AI and Machine Learning (ML) technologies offer many opportunities that can be applied to legacy ATS systems and will change the paradigm on how weapons systems are tested and maintained in the FMF.

Where We Need to Be

The desired state for weapon system maintenance is best described in the concept of the "Super Maintainer." This concept of providing maintainers (11XX, 13XX, 21XX, 28XX, 35XX, and 59XX MOS communities at a minimum) with analytical tools and expert systems will permit the capability of diagnosing every known weapons system failure mode in realtime by identifying root cause, corrective action, available spares inventory, and replacement cycle times in one operation and reduce the cognitive burden on the Marine. This desired state can be realized using automatic test equipment enhanced with AI and ML capabilities connected to Marine Corps weapons systems data sets and GCSS-MC to provide fast and accurate repair solutions. The ideal future state is to utilize one common connected platform that is capable of testing and collecting parametric data at the organizational (system) and intermediate (LRU) level with access to historical weapons system and LRU test data, failure scenarios, LRU Factory Acceptance Test and reliability data, and field and depot maintenance records from GCSS-MC. A weapons system has a finite number of failure modes which can be predetermined and predicted based on historical trends on test parameters. These trends can be forecast in the time domain to determine the future failure date of a specific parameter, identify the usable life of any given weapons system LRU, and allow the maintainer to "predict" the maintenance intervals based on actual LRU performance having synergy with the Capability Based Maintenance initiative. This concept is attainable with the current AI technologies and is envisioned in the *38th CPG* as follows:

> We will make strategic investments in data science, machine learning, and artificial intelligence. Initial investments will be focused on challenges we are confronting in talent management, predictive maintenance, logistics, intelligence, and training.[2]

Current AI technologies provide "leap ahead" solutions to these challenges in ATS development; they are essential for removing the inefficiencies in legacy systems and will enable us to have streamlined maintenance systems that are necessary to support expeditionary advanced based operations, littoral operations in a contested environment, and distributed operations.

Current AI and ML technologies can offer "leap ahead" solutions to the challenges of legacy automatic test systems. *(Photo by LCpl Caleb McDonald.)*

How We Get There

Centering on ground, communication, and optical test assets by integrating AI into Marine Corps Systems Command test programs, the Marine Corps has the opportunity to change the paradigm on how weapons systems are tested and maintained in the FMF. Utilizing the extensive amount of parametric data available to the maintainer when performing automatic tests at all levels of maintenance is one example of how the Marine Corps will enhance the maintenance process (with the objective of reducing touch labor, improving fleet asset readiness, and increasing weapons system reliability and availability). This paradigm shift will be accomplished by employing ML with Rule Based AI Modalities in the data rich ATS environment, allowing the Marine Corps to investigate the true performance capability and life cycle of their weapons systems. Additionally, a multitude of benefits will be enabled, including but not limited to:

- Shorter test program release cycles permitting rapid deployment of program features to the Marine.

- Reduction of the annual operations and maintenance burden on the FMF and the identification of capability gaps that will yield an advantage of superiority for the warfighter.
- Defect forecasting and predictive/preventative maintenance creating a thorough understanding of weapons system asset reliability, usable life, and maintenance cycles.
- Decreased test and maintenance cycles resulting in reduced touch labor and faster weapons system deployment.
- Increased system-level fault isolation capability and effective root-cause/corrective action supporting the development of fault tolerance in system design. This can be realized by leveraging Industry and Academia partnerships through the Joint Artificial Intelligence Center to improve AI-enabled weapons system design.

To achieve this, we will need to standardize repair records and improve the way we collect quality weapons system test data at all maintenance levels. Creating an accessible database of weapons system test runs using cloud technology, traceable by component LRU serial number and connected to the MCEN, will be necessary in a realtime ML environment. With this database linked to GCSS-MC installed base repair history and weapons system service records, the maintainer would have advanced capabilities in determining root-cause and corrective action of any particular failure. One of the challenges that will need to be addressed and overcome to accomplish this will be the cyber safe connection of the ATS systems to the MCEN network at all three maintenance levels (organizational, intermediate, and depot). The ML algorithms can then be employed to the historical data sets and used for realtime analysis of a weapons system or LRU being tested (linking current failure modes to historical failures and the historical identified root-cause and corrective action).

Ultimately, this will provide the maintainer with a rich source of historical repair solutions while freeing up and elevating our Marines' intellectual output to complete tasks for which humans are best suited. This ML system will "learn" and develop as the failure/root-cause/corrective action database grows and new failure/repair-solution pairs are identified and added (and will remain effective as long as the weapons system remains in service). Additional improvements necessary to move forward involve enhancements in our command and control node, data infrastructure, data capture, data collection, design requirements, and resource commitment at the highest levels.

One level of effort currently underway by Naval Surface Warfare Center, Crane Division Mobility Systems Engineering Branch for Marine Corps Systems Command is a four phase plan spanning four fiscal years allowing Program Manager Supply and Maintenance Systems (PM SMS) ATS to integrate new AI/ML capability and functionality into current legacy systems. Phase I of this effort involves gathering the required resources and knowledge to successfully begin implementing AI/ML features into the PM SMS ATS projects. Phase II will implement software solutions to automate the tasks measured in Phase I. These efforts will involve both adding new features to existing government off-the-shelf software and utilizing commercial off-the-shelf software, if applicable. In Phase III, information collected from the previous phases will be analyzed and aggregated to produce useful reporting tools for insight and identification of data trends. Additionally, software used to analyze user trends will be used to track metrics on other applications, such as platform specific software. Finally, PM SMS ATS will begin coordinating with platform program offices to identify AI/ML needs. These actions will be used to further refine and expand the current AI/ML capabilities of PM SMS ATS and prepare for complex AI implementations. The purpose of the fourth phase will be to combine all the tools, data, and technical expertise gained from the previous phases to begin actively supporting platform specific AI/ML needs. Using the cases analyzed and proposed in the previous phase, the Naval Surface Warfare Center, Crane Division, will implement new platform specific solutions to handle platform requirements. At this point, platform needs will be evaluated and prioritized based on key information, such as deployment rate and overall impact to the maintainers. A baseline of relevant and accurate data, a thorough understanding of user needs, and a significant amount of market research must come first if the eventual solution to a problem is to be cost-effective and, most importantly, maximally helpful to its intended users.

Successful execution of these opportunities will provide significant tangible/(quantifiable) and intangible/(unquantifiable) benefits and will be in keeping with the *38th CPG* as follows:

> All of our investments in data science, machine learning, and artificial intelligence are designed to unleash the incredible talent of the individual Marine.[3]

The Marine Corps Logistics Combat Element Systems Strategic Plan challenges us to *"Accelerate Innovation and deliver operationally relevant solutions."*[4] The Marine Corps LCES SMS ATS team seeks to accomplish this Mission by integrating AI into our test programs as the "way we work forward." To enhance human capability, the Logistics Combat Element Systems SMS ATS team hopes to replace legacy capabilities with AI-enabled solutions that benefit Marine Corps troops across the globe.

Notes

1. Gen David H. Berger, *38th Commandants Planning Guidance*, (Washington, DC: July 2019).

2. Ibid.

3. Ibid.

4. Col John T. Gutierrez, *Strategic Plan 2020–2023,* (Quantico, VA: Logistics Combat Element Systems, January 2020).