Predictive Analytics & Predictive Maintenance with AI

Solving the Navy's problems with the help of AI

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Executive Summary

Artificial intelligence has been around for many decades, and as such, is not a new concept to the government, military, and defense industries. In fact, many of the first early advances in AI came out of military applications and defense funding[1], with funding originating from Defense and Intelligence communities to support initiatives around machine translation, computer vision, robotics, and many of the concepts around machine learning that we still use to this day. However, many of these early AI efforts were limited in scope, and wide-spread adoption of AI stagnated across the public and private sectors. With the recent resurgence of interest and funding in AI, military branches such as the Navy are now taking a closer look at how AI and machine learning approaches can help with a wide variety of problems such as predictive maintenance, personnel and logistics management, and data integration and visibility challenges.

Private sector enterprises, civilian agencies, and the defense and intelligence community are seeing widespread benefit in applying more intelligent forms of analytics to common business problems. Now that AI is starting to become incorporated in predictive tools, the benefits may start to go even deeper. Predictive analytics, one of the core seven patterns of AI identified by AI market research and analysis firm Cognilytica, is defined as using machine learning and other cognitive approaches to understand how past or existing behaviors can help predict future outcomes or help humans make decisions about future outcomes based on these patterns. The objective of this pattern is helping humans make better decisions. Predictive analytics and other AI initiatives to-date have been hindered by poor data quality and challenges in data access and integration – but new technologies have arisen that help address these issues.

Predictive analytics can be applied in many critical areas that are of necessity for military branches such as the Navy. In fact, predictive maintenance is a matter of life or death in many instances, especially when dealing with complicated equipment such as nuclear submarines, aircraft, or land vehicles where malfunctions and unplanned equipment downtime can cost lives and/or significant expense. At sea and in combat situations are the last places you'd want to have a failure of a critical system component.

Besides systems maintenance, the use of effective predictive analytics can help more efficiently deliver goods, staff appropriately, and proactively re-route, re-direct, and re-arrange various cargo and equipment as needed. The use of AI-based predictive analytics helps predict asset shortages, anticipate machine failure, predict and optimize maintenance, optimize logistics and personnel, and simplify access to disparate data in the organization. In this manner, AI is playing an augmentative role, not replacing humans but helping humans do their job better and eliminating routine, shifting the labor force to higher-value work.

The U.S. Navy can potentially use AI-based predictive analytics to eliminate unplanned downtime for critical shipboard systems, manage materiel and personnel, and simplify the connection of data across the organization. In this whitepaper, we outline current pain points for the Navy, how

organizations with problems similar to the Navy have addressed these problems, and how the Navy can use AI to help with their mission and defense of the nation.

Outlining the problem

For an organization as large as the Navy, it takes a lot of planning to keep everything running smoothly. As a complex defense organization with a worldwide footprint, the Navy faces unique challenges that private sector enterprises and most civilian agencies don't have to deal with on an ongoing basis. The Navy must be constantly ready to defend our nation from attack, anticipate potential problem areas to keep readiness at a high level, continually maintain large fleets of equipment and systems including aircraft, ships, and submarines, and manage a logistically complex organization that requires delivery of personnel, materiel, information, and assets around the world in extraordinarily challenging situations. In this context, technology plays a vital role in making sure that lives and assets are not lost and the entire organization is equipped to perform at its most optimum level.

The Current State of Predictive Maintenance in the Navy

Predictive maintenance is at the heart of all complex operations requiring constant monitoring of various equipment and hardware[2], and the Navy is certainly no exception. Organizations use predictive maintenance in a wide range of industries in which equipment and systems are required to operate with high degrees of reliability, predictability, and with greater cost efficiency of their maintenance operations. As stated in a ReliablePlant article on the subject, “also known as condition-based maintenance (CBM), predictive maintenance has been utilized in the industrial world since the 1990s.” Predictive maintenance requires using information collected from a variety of locations, analyzing that data, using the analysis to identify and predict failures, and then taking proactive measures to prevent downtime of the equipment and machines[3]

Currently the Navy has many manual processes and steps in their predictive maintenance practices to ensure everything is working at peak performance. As mentioned by former Navy officer Bryan Van Itallie in his article “A Navy Perspective on Predictive Maintenance” these steps include weekly and monthly preventive maintenance inspections and check-off sheets for routine items such as oil filter changes or motor-generator brush repair[4]. These maintenance activities are done on a predictable, repetitive schedule, whether or not repair work really needs to be done. Strict adherence to inspections has ensured safe and successful equipment and missions for decades with a focus on keeping everything operating safely and efficiently. Additionally, ongoing data collection and analysis are done on various systems allowing for continuous evaluation of equipment and systems to make sure everything is operating and running as it should and is maintained properly.

> *“[Condition-based Maintenance] is one of the things we’re doing to … operate the ships we have today more efficiently and more effectively.*
>
> *- Rear Adm. Lorin Selby, chief engineer and deputy commander, NAVSEA*[15]

However, these processes are still mostly manual for collecting and analyzing data. This is not unique to the Navy, as maintenance has been one of the last areas for investment and

improvement for many industries and organizations. The Navy as a whole still relies on regular, scheduled maintenance or run-to-failure approaches rather than taking a more cognitive approach to this problem. In contrast, large private sector, commercial organizations also operating in highly available situations are increasingly moving to more predictive, analytical-based forms of maintenance. These new approaches move critical issues to the fore while not wasting maintenance time and money on items that don't require servicing or repair.

Technology has already reached a point where remote condition monitoring and analysis can be done at scale affordably, accurately, timely, and with reliability. Rather than having a large group of military personnel manually recording and monitoring systems, computer systems can now perform data collection and analysis tasks automatically with the help of sensors, machine learning, and analytics. More-advanced sensors are now available that enable detection of changes that indicate early symptoms of a future problem[5]. These sensors can also report findings in real time to allow for immediate proactive responses.

As adversaries begin to probe new ways of breaking through the country's defenses, a greater understanding of predictive maintenance is required to keep things in continuous operation. The Navy needs to ensure that military assets and personnel are prepared for battle at all times. They require the ability to see where they are falling short in combat readiness across the organization in order to solve the problem. The use of more intelligent approaches to predictive maintenance is clearly a requirement in the modern era to eliminate the many processes that are manual, time-consuming, error-prone, and expensive. The vast amount of data coming in from sensors, databases, and other inputs, and the need to maintain increasingly more complex systems with limited staff, is requiring the capabilities of more intelligent systems to provide required predictive capabilities[6].

Challenges in Logistics and Personnel Management

As a complex defense organization with a worldwide footprint and hundreds of thousands of employees, the Navy has logistically complex challenges for delivery of personnel, materiel, information, and assets around the world in extraordinarily challenging situations. Between the management of suppliers, sub-suppliers, and the movement of goods, materials, and people, operations get incredibly complicated. While organizations like Amazon have pioneered many areas of supply chain and logistics to extreme efficiencies, unlike private industry counterparts, many best-in-practice supply chain and logistics methods don't work for the Navy. For example, while retail organizations and other private sector companies can adopt just-in-time approaches to having just enough quantity of a certain inventory available on hand, the military cannot run its supply chain with this ultimate level of efficiency[7]. In an environment where not having enough or running out is not an option due to potentially placing lives in danger, having an overabundance of inventory is more acceptable.

Likewise, the military procurement process has much different criteria than traditional business procurement processes. Non-government businesses have the ability to shop around and compare prices and technology features. However, the military needs to have reliability of supply during war and peace-time operations, so price and features are not necessarily the primary

decision factors as much as availability and reliability. Using AI and cognitive approaches can help make logistics and personnel management more reliable, more effective, and focus procurement on the equipment and people that will provide the greatest value to meet current requirements.

Challenges in Data Management and Integration

A large and complex operation such as the Navy has an inordinate number of IT systems, databases, data stores, applications, integration middleware, desktop, laptop, mobile, ship-based, land-based, and even space-based technologies that all need to be connected together to meet current and future operational needs. It's a significant challenge to tie together all these disparate, heterogeneous data sources in a way that can provide continuous agility at real-time speeds.

The military has more data than ever before. Between documents, images, emails, online data, and videos, they are drowning in data. Up to 80%-90% of the content generated is in the form of unstructured data[8] which is any data that's not organized in a way that computers can easily process the information. Structured information is usually classified and organized in relational databases and data stores with defined schemas. Unstructured data may be in digital format, but there's no predictability to the structure or schema of that data; it's usually text-based, and the content is highly variable – making it difficult to organize and search, and to relate to other information without significant manual effort. Examples of unstructured data include emails, documents, images, videos, social media posts, and a wide range of documents in paper and converted forms such as invoices, purchase orders, communications, contracts, applications, IDs, meeting notes, and contracts. The rate of unstructured data grows at an astounding 55%-65% per year[9].

Rigid, relational databases are increasingly showing their inability to respond to the growing quantity of unstructured data in the organization and the constantly changing needs to query, analyze, and access that data. The Navy is using traditional systems and processes: relational databases, Excel sheets and a lot of paper. They rely on proprietary data stores such as Oracle and other SQL databases that are unable to communicate with each other and they don't know how to solve the problem of getting information out and making it usable to address today's challenges.

Relational, SQL-based databases also lack the flexibility to readily adapt to new data and new system requirements, because of their reliance on fixed schemas and the corresponding need for upfront schema development. Every time the Navy wants to incorporate a new data element or new type of data, they have to go through an Extract-Transform-Load (ETL) process repeatedly and develop new data models. For any new data-related requirements, whether they are in the middle or at the end of a project, they must start all over from the beginning. Large private sector organizations such as Amazon, Google, LinkedIn and Facebook[10] have realized the benefit of moving to more flexible, schema-agnostic data infrastructures such as NoSQL/non-relational databases that avoid the ETL challenges that occur when things change. Using this modern

technology infrastructure approach, organizations can acquire data incrementally, work with that data as needed, and start getting results immediately.

- ★ **Up to 90%+ of data in the organization is unstructured, growing at up to 65% per year**
- ★ **The complexity of processing unstructured data prevents organizations from gaining value from this significant data asset**[11].

Use Case: AI-Enabled Predictive Maintenance

Organizations that rely heavily on equipment know that unexpected downtime can be costly. Private sector enterprises, governmental, and defense establishments are increasingly using or looking to use predictive analytics systems augmented with AI to help detect and prevent failures. The Navy is also beginning to apply best practices learned from other industries in regard to predictive maintenance. Power plants need continuous monitoring to make sure they are functioning properly and safely and to make sure they are producing energy to the many customers that rely on them[12]. In the energy industry, predictive analytics is being used to help run early warning systems that can identify anomalies and notify managers of issues weeks to months earlier than traditional warning systems[13]. This can lead to improved maintenance planning and more efficient prioritization of maintenance activities. Similarly, the Navy has many systems that require proper function and safety to ensure safe conditions for the crew on board. One wrong move could be the difference between life and death.

AI-enabled predictive maintenance systems can self-monitor and report equipment issues in real time[14]. By continuously evaluating how equipment is working they know when and how to maintain it optimally. Machine learning is core to AI systems in that they can learn patterns from existing data and predict future trends that match learned patterns. The data that feeds those predictive maintenance systems comes from a wide range of sources. They come from data sources that are updated via logs and entry systems as well as through an increasing array of sensors attached to critical equipment. The Navy already deploys a wide range of sensors to keep an eye on critical components such as turbines, generators, and air conditioning plants[15].

Together, these systems are able to gather real-time data, spot anomalies or potential problems as soon as they arise and notify the correct personnel immediately at the time of issue rather than hours or days after the fact so they can respond to them right away. The systems can also formulate predictions of upcoming issues, reducing costly unplanned downtime. Additionally, the use of AI-based predictive maintenance can help predict when a component or piece of equipment might fail, reducing unexpected equipment failure and unplanned downtime, while also lowering maintenance costs.

The Navy is already thinking of taking steps to adopt more intelligent forms of predictive maintenance. The objective is to help the Navy address critical maintenance and supply related issues such as finding parts that are keeping ships in ports longer than they should be. These predictive analytics tools also help address what is going on with the human element of the supply chain, such as scheduling and managing maintenance personnel that can fix the problem.

Additionally, the Defense Innovation Unit (DIU) is formulating plans to bring predictive maintenance to the Navy, as predictive maintenance is one of DIU's transformative projects[17]. The goal is keeping naval, aircraft and land vehicles online and avoiding costly last-minute downtime and repairs. AI has already been successfully deployed in both the U.S. Army and Air Force fleets, with the Navy the next logical step to adopt this technology. The AI-based system would have an overview of the entire operation, allowing it to quickly spot any anomalies or abnormalities and notifying Navy officers in real time. In this way, DIU's vision of AI-enabled predictive maintenance for the Navy is a form of early warning system to avoid expensive repairs or failures in battle.

Navy personnel want to make sure that all equipment is safe and ready to go when it's needed. Predictive maintenance should make it easier for them to answer which jets have to come off mission because they need critical maintenance. They can also use this predictive maintenance system to identify potential outages before they happen, the conditions in which the asset is used, and to analyze maintenance logs to discover which parts are in need of critical repair.

Other branches of the military have already invested in AI-based predictive maintenance. According to National Defense magazine, "The Army is taking advantage of artificial intelligence to better predict when vehicles will break down or need parts replaced. The service recently awarded … a $1 million contract facilitated by the Defense Innovation Unit to integrate the company's predictive maintenance software into Bradley Fighting Vehicles. The Army plans to use it to anticipate component failures and reduce the amount of unplanned maintenance."[18]

The ultimate goal is to use AI-enabled predictive maintenance to reduce in a meaningful way the time that a maintenance job takes. For the condition-based maintenance program, it is being able to predict outages based on disparate data feeds.

> ***"The fact that folks are clamoring for [predictive maintenance] within the DoD, I think is a good sign this is going to be very fruitful.***
>
> ***- Travis Burton, project manager at the Defense Innovation Unit***[18].

Use Case: AI-Enabled Personnel and Logistics Management

The effective movement of goods, ammunition, armaments, and troops is an essential component of successful military operations. At any given point, leadership needs to know who is on duty, who is on leave, where specifically trained personnel are, where equipment is located, how much material and supplies are currently on hand, and a plethora of additional information to inform efficient operations and continuous readiness. The data that supports these needs are continuously changing as well, and is often complicated by inaccurate data and data access challenges. AI can potentially add a critical element to military supply and logistics of people and materials, providing many efficiencies to otherwise manual processes including lowering supply chain costs, improving reliability and efficiency, giving greater visibility, and reducing human operational effort[19]. Applied to logistics, AI is helping enterprises that rely on the movement of people and products to streamline their operations and automate tricky last-mile problems[20]. The Navy can potentially see dramatic improvements by adopting some of these best practices.

The biggest area where AI is making its presence felt in various industries and organizations is in automating many of the previously manual and time-consuming processes that, while necessary, are a big drag on organizational efficiency and reliability. For organizations such as the Navy that have large supply chains with millions of orders or purchases to process, and many back-office operations handling procurement and fulfillment, processes can be significant. Increasingly, many public and private sector organizations are putting AI into supply chain and logistics processes, using AI to automatically process paperwork such as purchase orders and invoices, and support process automation tools that can handle moving information across disparate systems[21]. The Navy could see similar benefits doing the same. These AI-based systems can also perform regular audits of data, catching improper or mistaken information before they cause detrimental impact. In addition, AI plays a role in inventory management by using image recognition to perform inventory analysis and constant inventory audits.

Part of what's driving all this activity is the sheer amount of data generated throughout supply chain operations. AI and machine learning excel in handling large volumes of data, spotting patterns and anomalies, and otherwise providing intelligence and context from the mountain of available data. AI systems can quickly spot when logistics movements are trending the wrong way, reroute shipments when exceptions happen, and handle personnel-related issues in an automated manner, reducing the need for manual human involvement. These systems also help improve forecasting and planning, especially around time and availability of people and materials, which can generate significant benefits in the form of reliability and availability. Organizations such as the Navy could potentially apply AI to address unexpected issues relating to weather or regional disruptions. In other industries such as retail, machine learning algorithms are being applied to find optimal shipping routes, use intermediate storage locations to store goods en route to customers, and even make predictions of potential service disruptions[22].

AI is also being used to improve the productivity of workers that are involved in logistics. Machine learning systems can observe and learn proper and optimal behavior patterns of workers and monitor how they execute tasks, providing coaching and support to do things the best way. These AI systems can learn over time about how specific supply chain issues were previously

resolved, giving human workers the tools needed to respond to future events with greater speed, accuracy, and knowledge. Being able to quickly learn and spot patterns of productivity can be vital to make sure things continue to run smoothly.

The Navy can also apply AI to improve logistics and decision-making for future missions. Just like how private companies are using AI to deliver goods and optimize a set of distribution and delivery mechanisms, the Navy can tailor these best practices to their own needs. For example, machine learning and other intelligent technologies are applied to help speed up deliveries by optimizing routes, reducing overall shipping costs and time in transit. Companies are able to automate logistical work processes or quickly find alternate routes for vehicles derailed by unforeseen circumstances such as road construction or bad weather[23].

For a given mission, Naval officers need to know what engineering support personnel have to be on duty at a location where a job/mission will occur. They need to know who is available and what they are capable of doing, as well as critical performance and security clearance related information. Officers and Navy leadership need a 360-degree view of personnel to make more informed decisions. The ultimate goal is to easily bring together supply chain and support personnel information to more effectively get key equipment, materiel, and personnel where it's needed, when it's needed, and how it's needed.

At the end of the day, the Navy needs a high performance, high capacity system for logistics that can assimilate multiple data repositories that are in different formats. They desire:

- ★ A 360-degree view of material and personnel assets during planning and execution.
- ★ Better resource availability, higher efficiency, improved safety, and maintenance control.
- ★ Streamlining logistics processes to provide significant cost avoidance benefits and money.
- ★ A more cost-effective system that allows them to shift budget to other mission goals.

Introducing MarkLogic's Solution

For mission-critical data, trust is an absolute must. To protect from the constant threat of attack, the military needs to make fast, reliable decisions. This requires integration of complex data delivered safely, securely, and at mission speed. Organizations looking to make sure they can get the most accurate data at the speed and quality they need should look to a solution like MarkLogic. MarkLogic is not new to the defense and intelligence space as they currently support several enterprise defense and intelligence programs to help with their data needs.

In today's ever-changing environment data comes in from multiple sources, in multiple forms, and at varying speeds. For an organization as large as the Navy, it takes a lot of planning to keep everything running smoothly. To bridge data silos, data management means being able to deal with heterogeneous, multi-shaped, multi-formatted data. Because MarkLogic is a true multi-model database, with the flexible document model at its core, it easily loads that multi-shaped data without upfront modeling. For organizations looking to use AI at any point in the future, making sure their data is accurate and accessible is paramount. After all, data is at the core of AI. Without good, clean, accurate data, doing AI is just not possible.

Current relational databases just can't keep up with the rapid, constant change of data. MarkLogic's modern database platform was designed to keep pace with the velocity and variety of today's data, allowing organizations to integrate data 4x faster – seeing results in weeks, not years.

MarkLogic Quick Overview

MarkLogic is a database designed for NoSQL speed and scale, without sacrificing the enterprise features required to run mission-critical, operational applications. Using a multi-model approach, MarkLogic provides unprecedented flexibility to integrate and store all of your most critical data, and then view that data as documents, as a graph, or as relational (rows and columns) data. You can avoid expensive and brittle ETL and better manage entities and relationships.

Data integration is one of the most complex challenges, and the MarkLogic Data Hub Platform simplifies this. MarkLogic removes friction at every step in the process so that organizations can achieve a 360 degree view faster than ever. With MarkLogic, it only takes days or weeks – not months or years – to integrate data and build secure data services that enable it to keep pace with the speed of business.

The MarkLogic Data Hub Platform

The MarkLogic Data Hub is a comprehensive data platform that excels at multi-model data integration. It enables you to load data as-is, curate that data to form a unified, actionable 360° view – and provide easy ways to access that 360° view. It's able to handle documents, graphs, and relational data at scale and with government-grade, certified security.

• **Unified platform** – Don't waste time stitching together components. MarkLogic combines a true multi-model database, search engine, data ingestion tools, mastering capability, and more – all accessible through a simple user interface. It's less expensive and easier to manage

• **Smart curation** – Leverage MarkLogic's Smart Mastering, data harmonization, and automated provenance tracking to curate data quickly and easily for use in downstream systems

• **Advanced security** – MarkLogic is the most secure NoSQL database, having the most granular security controls and highest level of certifications. And, with redaction and anonymization capabilities, data sharing is both simple and safe

• **Flexible deployment** – Build your app once and run it wherever you want, whether in the cloud, on-premises, or a hybrid environment. MarkLogic is cloud-neutral and there is no cloud lock-in

- ★ Why MarkLogic?
  - **Increased Agility**: 4-12x faster results with less risk when things change
  - **Lower Costs**: Millions saved with lower IT, development, and operational business costs
  - **Secure:** Sharing petabytes of data around the world every day

MarkLogic Data Hub Service

MarkLogic Data Hub Service is a fully automated cloud service that allows you to focus on your business and leave database infrastructure and operations to the experts at MarkLogic. This

means agile teams can immediately start integrating data and building apps while also reducing infrastructure and personnel resource needs.

- **Automation**: with automated scalability, you define limits and thresholds and MarkLogic scales up and down to meet demand — quickly, transparently, and automatically. The service also has automated backups and upgrades.
- **Reliability**: with security, governance, and transactional consistency, it is designed for mission-critical systems and is managed by the same engineering team that built the underlying, enterprise-grade MarkLogic database.
- **Predictable cost**: start small and auto-scale based on demand. Even better, spikes in demand don't cause spikes in cost. MarkLogic's unique architecture and elastic cloud credit pricing keeps costs consistent and predictable.

Find out how MarkLogic can help you on your AI journey

If you're ready to get started on your data journey, let MarkLogic be your solution. Go to https://www.marklogic.com/ to learn more and have them help guide you through the on-boarding process.

Sources, Citations, and References

[1] Cognilytica, "Will There Be Another AI Winter?" (2018)
[2] Enterprise IoT Insights, "Three Predictive Maintenance Use Cases" (Jan. 31, 2018)
[3] Reliable Plant, "Predictive Maintenance Explained" (2018)
[4] Plant Services, "A Navy perspective on predictive maintenance" (Jun 18, 2019)
[5] Wikipedia Entry, Predictive maintenance
[6] InformationAge, "Preparing for AI with Predictive Maintenance" (2017)
[7] Supply Chain Drive, "If Your Supply Chain Works, Thank a Veteran" (2018)
[8] Wikipedia Entry, Unstructured Data
[9] Cognilytica "No, Data is NOT the New Oil" (Oct. 23, 2018)
[10] DeZyre NoSQL vs SQL- 4 Reasons Why NoSQL is better for Big Data applications (Mar 2015)
[11] Cognilytica, "How Content Intelligence Will Transform the Enterprise" (Oct. 2019)
[12] Defense Systems, "Navy ships on track to get predictive maintenance" (Sept. 2019)
[13] TechTarget, "Better together: Predictive analytics and AI boost each other" (Apr. 2019)
[14] TechTarget Using AI in manufacturing processes surges quality and design (Jan 2019)
[15] USNI News, "Navy Refining How Data Analytics Could Predict Ship Maintenance Needs" (Jun. 2019)
[17] Defense Systems, "Navy ships on track to get predictive maintenance" (Sept. 2019)
[18] National Defense Magazine, "Army Investing in Predictive Maintenance for Bradleys" (Sep. 2018)
[19] Cognilytica, "INFOGRAPHIC: AI in the Supply Chain" (Jan. 2019)
[20] Cognilytica INFOGRAPHIC: AI in the Back Office (Oct 2018)
[21] RTInsights Defense Department to Extend Predictive Maintenance to Navy (Oct 2019)
[22] TechTarget Using AI in manufacturing processes surges quality and design (Jan 2019)
[23] Hackernoon 8 ways in which AI helps the logistics industry (Aug 2019)

Image Sources

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