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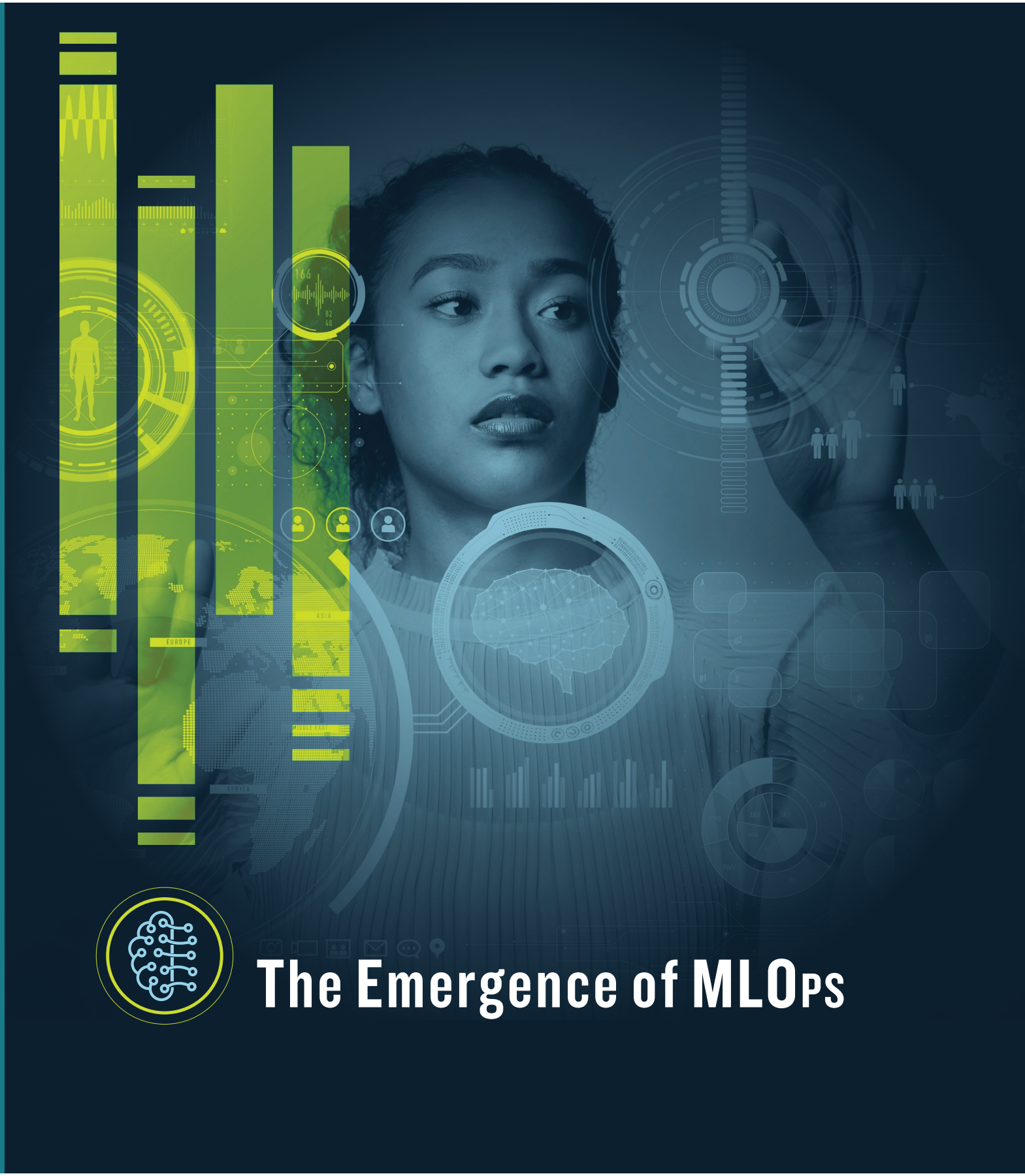

The Emergence of MLOps

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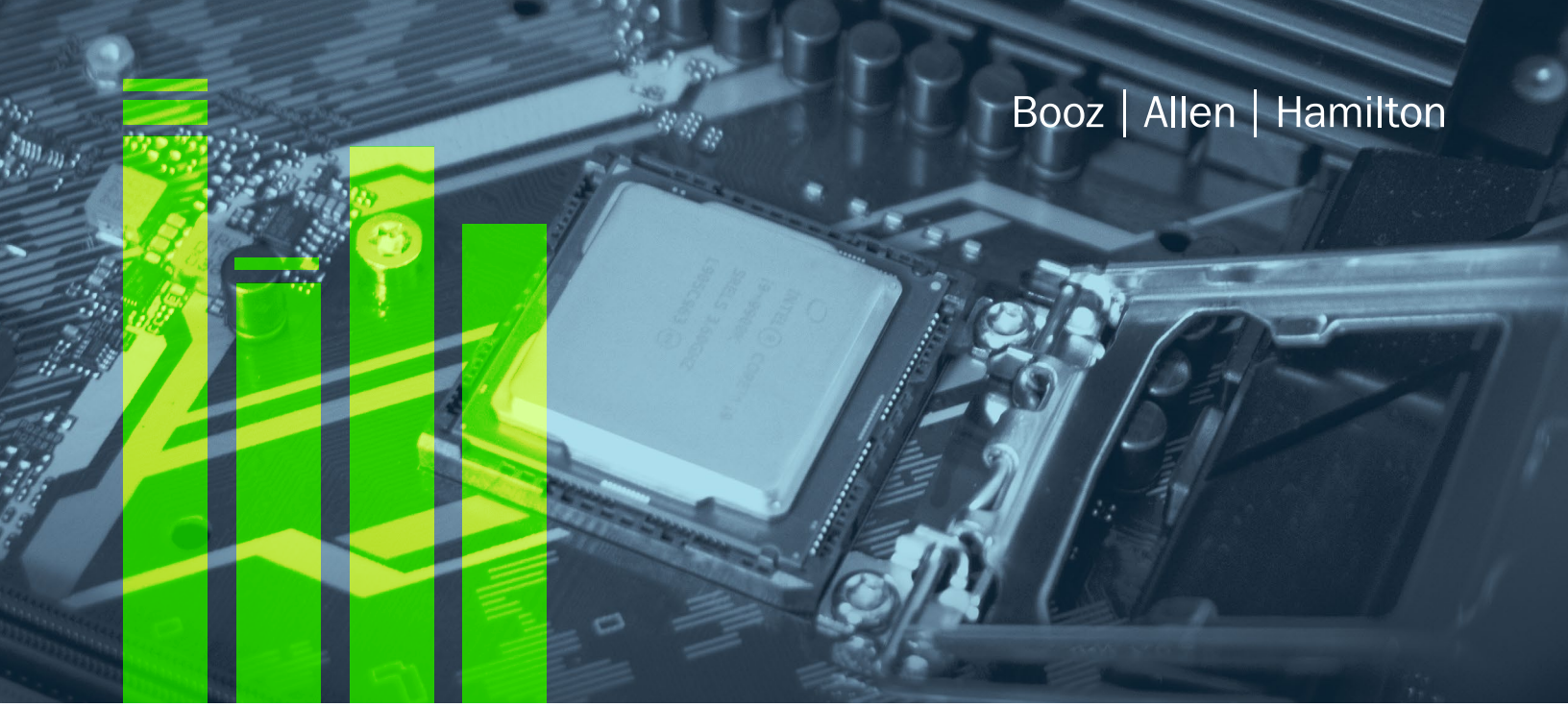


Machine Learning Operations (MLOps) is a set of emerging technologies that will enable AI to reach its full potential, solving large scale problems in real time.

The machine learning (ML) revolution is changing the way that organizations approach problem solving and product development. The capabilities of the technology have evolved exponentially over the past ten years, thanks in large part to sophistication and pervasiveness of pattern recognition algorithms, known as neural networks, and advances in graphics processing units (GPUs). This progression has transformed computers from tools to trusted partners in solving problems and developing products.

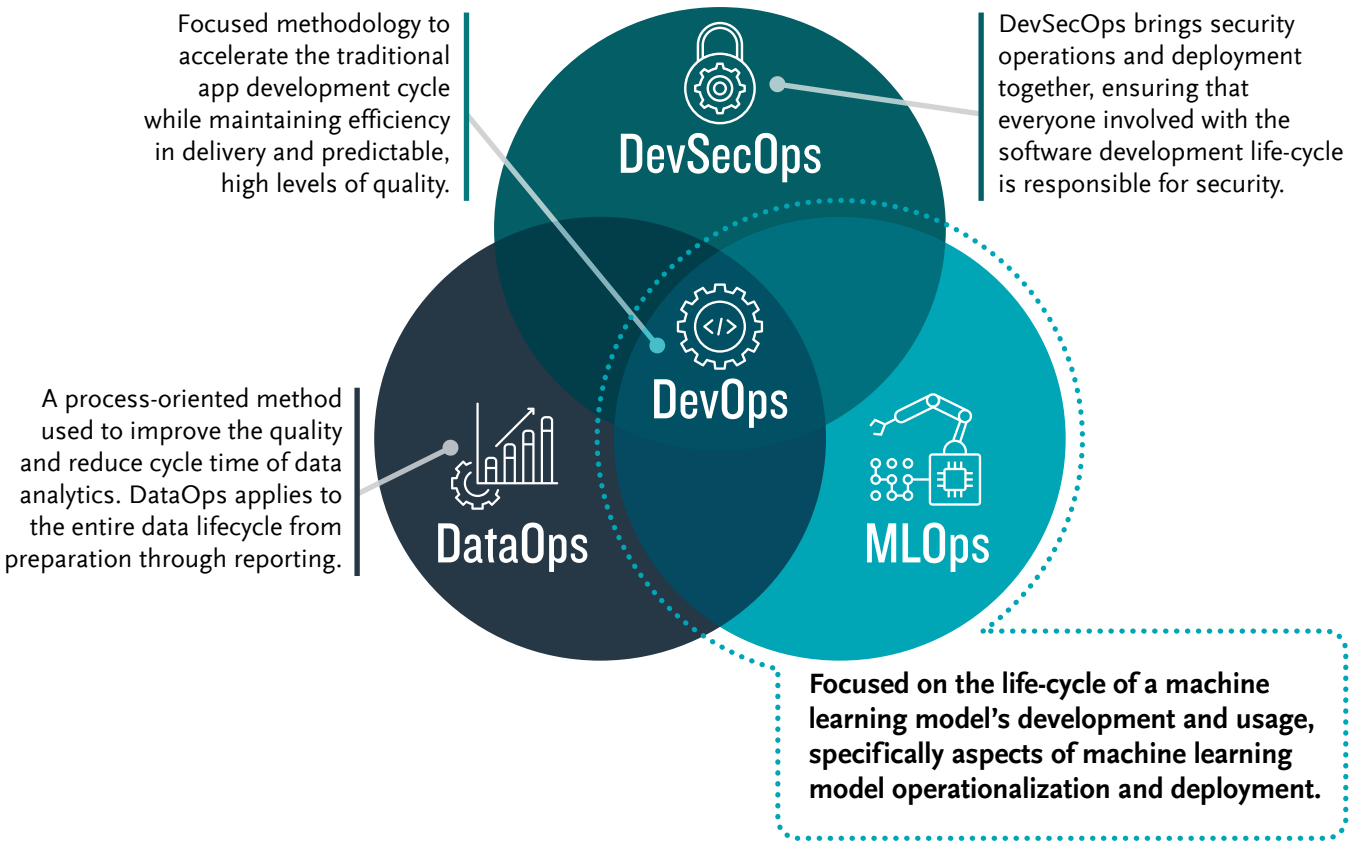
However, much of the power of machine learning is still isolated to small groups of specialized data scientists using these tools to solve very specific problems within their respective organizations. This analyst-led use of ML, generally referred to as Analytical ML, is useful for better informing human-driven decision making, but a lack of standardization limits its usefulness in delivering consistent results across an organization. To address this challenge, organizations are turning to **MLOps**—a standard set of practices for **M**achine **L**earning **Op**eration**s** at scale—to more fully actualize the power of AI and deliver trusted, machine-led decisions in real time.

WHAT IS MLOPS?

Put simply, MLOps is a set of complementary technologies that work together to make AI algorithms effective and useful in real world environments. The way these technologies work together emulates DevOps, which successfully merged the fields of software development and operations. MLOps aims to combine the model development and model operations technologies that are essential to high-performing AI solutions.

MLOps is not the first field to mimic the success of the DevOps movement, and progress in other fields has helped set the stage for MLOps' emergence: for instance, the integration of data technologies into operations pipelines (DataOps) in organizations has improved the usefulness and relevance of data for ML modeling efforts. ***Figure 1*** details how MLOps relates to other fields in the DevOps movement, and the role that each field plays in an organization's digital operations:

Figure 1–MLOps focuses on intricacies of the ML lifecycle often neglected in the DevOps framework



The shift from pure ML workflows has emerged largely from lessons learned by organizations that have created models in lab environments but subsequently struggled to implement them in real-world scenarios. In the new processes defined in the MLOps framework, established data scientists and deep learning engineers develop model architecture and associated workflows with available data in mind, and then train the model in a real-world environment. Without MLOps, ML engineers hand off an algorithm to an operations team responsible for implementing the algorithm in run time environments. If the operations team does not understand the model they are deploying, algorithms are more likely to deliver subpar performance, and all teams must troubleshoot to find a solution that meets performance requirements. By combining these workflows and creating records of engineering decisions or changes, MLOps solutions empower teams to be more efficient and allow algorithms to run more predictably with better results.

A CLOSER LOOK: THE COMPONENTS OF MLOPS

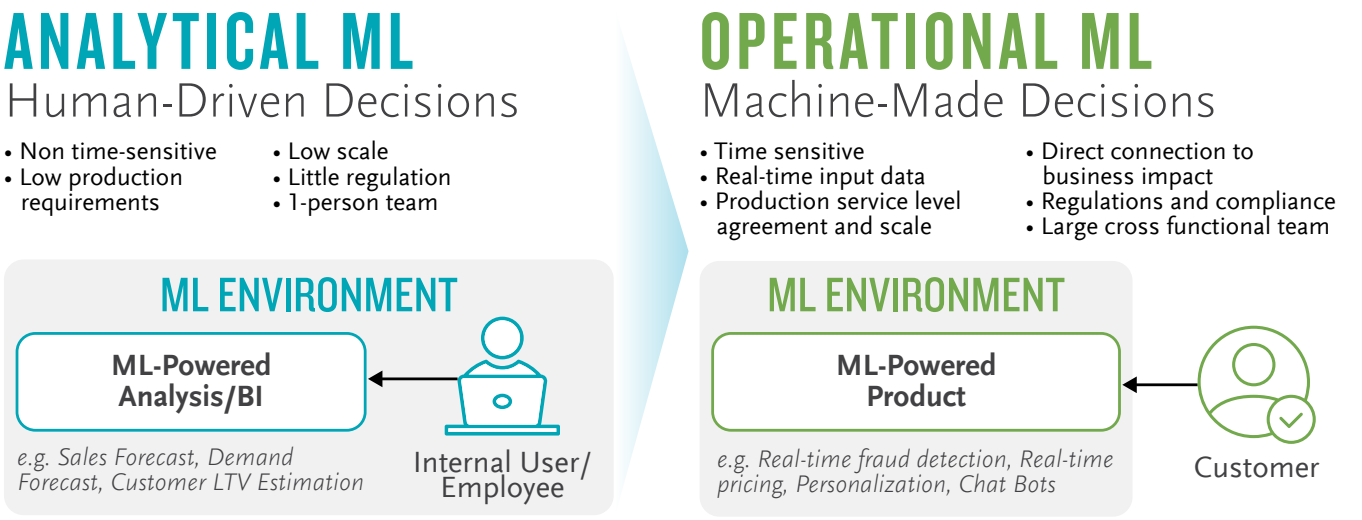
Any technology ecosystem consists of, or can be broken down into, a set of core components. Over time, capabilities and offerings sprout up around these core components as they mature. To fully understand a technology, it is often easier to analyze the individual components. We identify the following six (6) core components for MLOps:

Core Components	What It Is	Why It Matters – and what leaders should look for
Continuous Lifecycle Management	Continuous synchronization of data and ML models with connecting elements of the environment	This is the glue connecting the MLOps technologies. These technology components tie together the data, model architectures, testing, and publishing of models.
Model Versioning and Iteration	Continuous integration and tracking of models into the production environment	Model versioning is similar to code versioning. Rather than treating models as entities that are constructed and left untouched, versioning enables and tracks the way models change over time.
Model Monitoring	Active evaluation of both model accuracy and runtime speed	Because model performance depends on many factors outside the control of operators, monitoring is essential to ensure proper performance and outputs.
Model Governance	Determining and tracking model metadata, including training data, creator data, and training experiments	Having an end-to-end system that enables tracking by model is beneficial in identifying errors or unexpected functioning. Maintaining this data is also helpful model explainability.
Model Discovery	Providing models to consumers, with visibility into available models and how they can be used effectively	Model discovery enables an end user to find and use models (internal or third-party) to meet mission needs. This could be thought of as an app store for machine learning models.
Model Security	Ensuring models are not being impacted by nefarious operators and are robust enough to perform consistently	Security can be highly specific to where an organization's data and models are located. For this reason, security should be built into every part of the ML pipeline management, model monitoring, and model governance if a model is going to be a core business component.

IMPACT HIGHLIGHT

As ML models become more mainstream, market focus has shifted from Analytical ML to Operational ML (i.e., machine learning operationalized through MLOps). Analytical ML solutions are designed to answer a single specific question in curated environments (e.g. Is there a dog in this picture?). Operational ML solutions are designed to be robust solutions with broad requirements (e.g., What kinds of animals are there in this video feed of my backyard?). Operational ML solutions are often designed and subsequently updated to allow the algorithm to maintain top performance.

Figure 2–We are observing a continued shift from Analytical ML to Operational ML (MLOps) in the ML market



COMMON GOALS OF OPERATIONAL ML

Auditability: A given model will have multiple versions, a specific set of training data, and finely tuned hyperparameters. Each must be carefully tracked for versioning and testing purposes

Different Environments: Different environments for data preparation, training, and model deployment reduce speed and scalability of model deployment

Model Transparency: Individual models are difficult to understand and/or explain to others

Scalability: Models created from scratch for individual problems reduce deployment speed because of the inability to reuse and recycle code

Model Drift: Models may lessen in accuracy over time as the statistical properties the model tries to predict change in the real world

Most MLOps solutions often share common goals born from the problems encountered in Analytical ML solutions. These include the need for auditability, performance across a variety of environments, transparancy into the functioning of a model, technology that enables the AI solution to scale, automation for model updates, and solving the common issue of model drift.

FIVE TAKEAWAYS FOR FOUR AUDIENCES

Booz Allen's emerging technology tech scouting team aims to distill crucial information about fast-moving technologies to help build technology acumen for our partners and the general public, which is likely to view technology outcomes from different vantage points. Takeaways by persona are summarized below:

	PUBLIC SECTOR LEADERS	BUSINESS LEADER	TECHNOLOGIST	INVESTOR
Educational Recommendations	Learn about the breadth of AI use cases and prevailing emerging trends and risks associated with AI	Learn more about how AI drives business value and when it makes sense to integrate AI solutions	MLOps will expose AI technologies to broader technical skillsets. Learn about ways that your skills relate to AI and are integrated via MLOps	Learn about what types of problems are Analytical AI problems and which are Operational AI problems and encourage MLOps integration
Technology Relevance	Many government environments are very specialized. MLOps will make it easier to deploy AI to these specialized environments	MLOps is laying the foundation for businesses to build ML-based products. Expect a shift from ML supporting products to ML *being* the product	MLOps transforms ML from a specialized field to a cross functional capability. Stay abreast of other technology skills that are becoming relevant due to MLOps	Analytical AI solutions is currently a leading investment area, but MLOps supports higher value solutions with a broader customer base
Upcoming Disruptions	As MLOps grows more prevalent it will be easier to augment human capability in government, expanding their impact and efficiency	MLOps will usher in the age of AI. Before it's too late, work with your teams to find ways they can augment their jobs and workflows to stay ahead of competitors	If you don't currently work as a data scientist or ML engineer, find ways to plug in technical skills to new MLOps tech to stay ahead of the curve	MLOps will continue to disrupt the market and demand will increase as this holistic approach produces better, more accurate deployment results
Suggested Next Steps	AI is a National Security risk in large part because AI talent is not in the government. Find ways to integrate AI with fewer technical staff using MLOps	ML will allow smaller teams to make faster and larger impacts (e.g., using AI to choose marketing hashtags and slogans). Integrate teams with AI tools early	AI will augment technical development skillsets. Find ways to use AI to work faster and focus on human problems like novel code or backend architectures	MLOps solutions will support huge industry swaths compared to analytical ML solutions. Investments in MLOps should see large returns
Short Term Recommendations	Look for a trusted partner with relevant sector experience that can implement leading ML solutions	Collaborate with companies tracking the future of MLOps to find new use cases and solutions for your business	MLOps is actualizing the impact that AI can have on a large scale. Seek out employers working on meaningful problems in this emerging space to apply your skills in world shaping ways	Collaborate with firms working in spaces where AI adoption has lagged, as these groups will have a need for new and emerging MLOps solutions as well as many lucrative use cases

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To learn more, visit BoozAllen.com/mena. (NYSE: BAH).

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