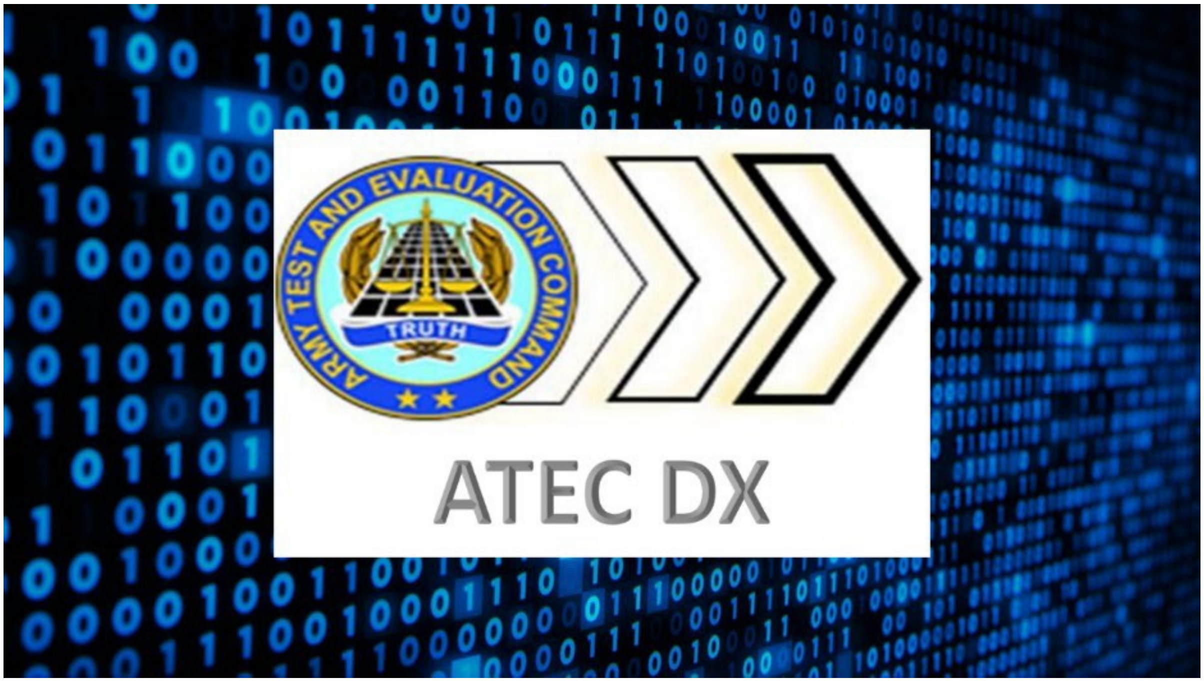

U.S. ARMY TEST AND EVALUATION COMMAND DIGITAL TRANSFORMATION (DX) STRATEGY

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COL Alex MacCalman

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1. Introduction

The purpose of this document is to outline the U.S. Army Test and Evaluation Command (ATEC) Digital Transformation (DX) Strategy in support of the ATEC Campaign Plan for 2020-2035, titled ATEC Next. The ATEC DX Strategy aligns with the 2019 DoD Digital Modernization strategy, the DoD Digital Engineering Strategy, the Army Data Plan, the Army Cloud Plan, and the Army Futures Command (AFC) Data Experimentation Strategy. This document will serve as the authoritative source of ATEC's plan to modernize infrastructures, advanced digital capabilities, innovative digital processes, and digital workforce talent development while inspiring a data-centric, digital culture.

2. The Environment.

Tomorrow's multi-domain competition will be won by those who are best able to extract timely, actionable information from the sea of data and provide it to decision makers who are empowered to act. Smart autonomous systems, mixed reality, Artificial Intelligence (AI) and Machine Learning (ML) algorithms, increased computational capabilities, and other emergent technologies will change the way we think and operate as well as develop, test, and evaluate systems—especially as the digital universe grows exponentially with increased access to data. In order to deliver these emerging technologies to the warfighter at the speed of relevance, ATEC must develop new infrastructure, capabilities, processes, and workforce talent capable of evaluating these complex system of systems. AI and autonomous systems requires extensive amounts of data, computational resources, and iterative development that must be tested as early as possible within the acquisition life-cycle. In order to test early, the DoD needs a unified cloud-based digital infrastructure environment to execute continuous, adaptive testing with feedback loops, common data standards, and networks. Within these new digital environments, we need new test capabilities and systems engineering processes to acquire evidence based assurance that is conditioned on the data and context used to develop these systems. Empowering our workforce with these digital environments is not enough to achieve our digital transformation. We must develop our workforce talent to learn the data skills needed to increase our capacity to accomplish our mission.

"...The Army cannot maximize its modernization strategy without the cloud, which is the backbone for artificial intelligence."

- Ryan D. McCarthy
United States Secretary of the Army

3. A New Digital Culture

AFC seeks to create a culture that unifies talent, capabilities, and infrastructure across the Army Modernization Enterprise (AME) to strategically and effectively develop and deliver the future force. AFC developed an integrated and iterative framework for discovery, invention, and innovation. This framework facilitates a continuous iteration of material and non-material elements, comprised of early, data-driven modeling, experimentation, science & technology demonstrations, testing, and analysis. The deliberate focus on concept, material, and requirement iteration is intended to reduce risk by developing operationally valid, defensible requirements into DOTMLPF-P solutions that achieve a desired warfighting effect. Central to this new iterative framework is an experimental governance process empowered by a digital environment that allows senior leaders to exercise mission command across the AME; these processes and digital environments are articulated within the AFC Experimentation Data Strategy. In order for ATEC to support the AFC Experimentation Data Strategy, we must adopt a data-centric, digital first mindset. Some of the leading hurdles to digital transformation are culture, archaic IT systems, lack of skills, and lack of clear leadership vision. Culture change is a long-term effort to transform growth oriented mindsets, inspire innovation, embrace systems thinking, adopt agile, lean processes, foster collaboration, and acquire new skills. In order to inspire a new data-centric culture, ATEC will employ the following guiding principles to inspire a culture change:

- **Deploy change agents to become "digital ambassadors".** Find champions within the ATEC Enterprise that have a passion to become a self-learned data scientist that can import, clean, tidy, transform, visualize, and model data to communicate relevant operational insights. Identify use case opportunities that demonstrate increase work efficiencies and accelerated insights. Offer training opportunities to inspire others to learn data skills. Reward and recognize individuals that achieve long term skill development and demonstrate their utility to enhance the T&E mission.
- **Use digital collaboration tools.** Encouraging the workforce to use collaboration tools will increase transparency and access to people, improve document versioning, strengthen partnerships, and facilitate better collaboration of digital products. These tools include Microsoft Teams, Atlassian Confluence, Gitlab, and JIRA tools and others.
- **Embrace a systems thinking mindset.** According to the Cabrera Research Lab, systems thinking involves four simple rules that define how we think. They include making distinctions, developing part whole system structures, defining relations, and taking perspectives. These rules develop information that can be structured in new ways to create new knowledge in the form of mental models. An organizational culture thrives when individual team members share the same mental models that support the mission and vision. We use mental models to understand reality and continually update them as we learn more information. An organization that learns to do its mission every day and shares the same mental models will achieve its vision. In the next section, we restate ATEC's mission and vision and elaborate on these statements with mental models that align with the ATEC DX Strategy.

4. Mission

ATEC's mission – our purpose – remains constant: *Provide direct support to the Army Futures Command and relevant, timely information to senior Army leaders to make future force decisions enabling Multi-Domain Operations through requisite independent developmental testing, operational tests, and evaluations*.

In order to accomplish our mission, ATEC must *rapidly synthesize perspectives and deliver relevant operational insights to decision makers*; the elements of this mental model are elaborated here:

- **Rapidly**: In order to deliver capability at the speed of relevance, we must innovate new ways to increase efficiencies and leverage technology to rapidly assemble insights. These new innovative ways include cloud computing technologies, high performance computing resources, analytical tools, and computer languages.
- **Synthesize Perspectives**: ATEC interfaces with many stakeholders. Soldiers, capability developers, material developers, AFC/CFTs, Analytical Organizations, Labs and ATEC all have unique perspectives. To synthesize these perspectives, we must strengthen partnerships while using a unified digital infrastructure environment with common data formats and networks.
- **Deliver Relevant Operational Insights to Decision Makers**: Operational insights will not only

involve material release decisions but also inform concepts and requirements developed by the AFC. While ATEC seeks to shift operational precepts left, our evaluations of the modernization concepts and requirements will have a high impact on our future system development. We must visualize and communicate these insights in a way that resonates with senior leaders with new methods and tools.

5. Vision

ATEC's vision – our future end state – is: *ATEC will be structured with agile processes, advanced capabilities and infrastructure; foster an innovative and resilient workforce; and establish and maintain partnerships needed to enable the Army's modernization effort.*

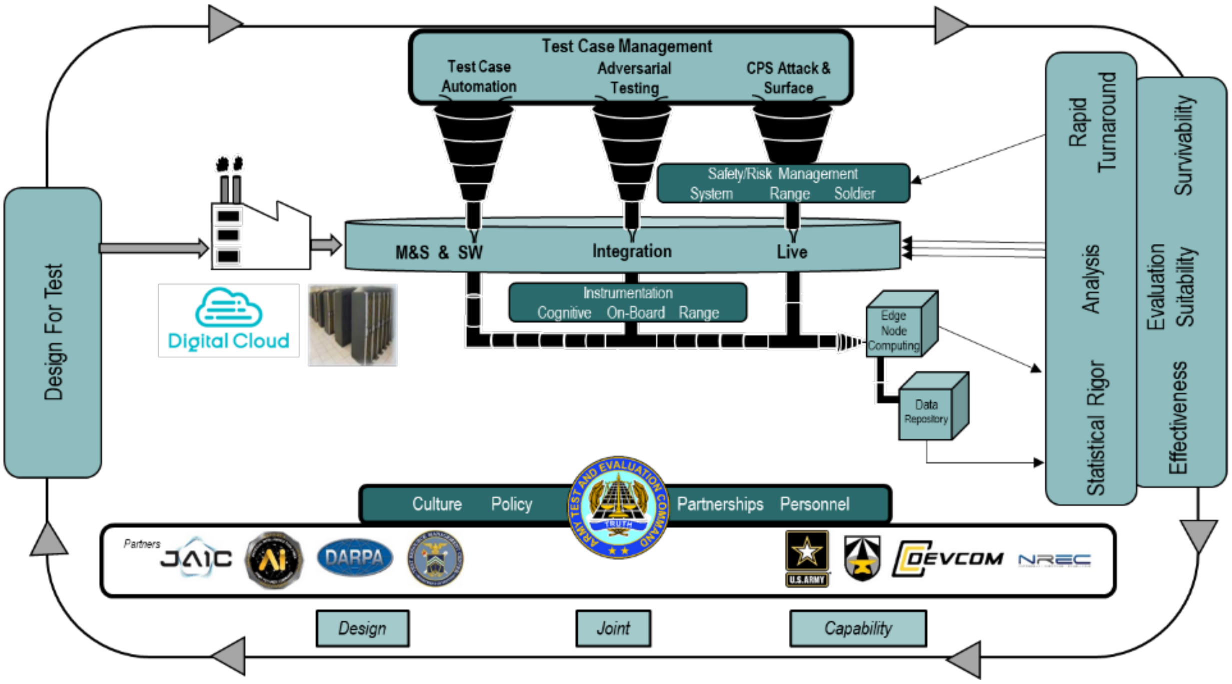
Our vision is a future where our processes are enhanced with new methodologies, infrastructures, and skills that will accelerate decisions. We envision a future where *all decisions are accelerated with democratized, quality data*; the elements of this mental model are elaborated here:

- **Accelerate Decisions.** Acceleration within a T&E context involves two aspects. First, we want to embrace the six core operational testing principles; they include (1) early Operational Testing (OT) involvement, (2) tailor testing to the situation to increase flexibility, (3) continuous and cumulative feedback for timely feedback, (4) streamline processes and products to remove bureaucratic constraints, (5) integrated and combined collection/test among contractors, developers, Developmental Testing and OT, and (6) adaptive testing. The second aspect is to leverage analytical data pipelines that involve data engineering, DCRA, model building, analysis, visualization, and delivery of insights. The critical enablers of these pipelines are the teaming of the right talent among test engineers, data engineers, data scientists, software engineers, data analysts, and evaluators.
- **Democratized Data**. Democratized data means that data is accessible to all. This requires an enterprise architecture that integrates data and applications with services. Additionally, AFC has cloud initiatives that will democratize data for all experimental activities. ATEC's teaming within these AFC initiatives will inform a better Enterprise Architecture.
- **Quality Data**. Quality data encompasses the entire data management framework that involves data governance, architectures, modeling and design, security, integration and interoperability, document and content management, reference and master data, data warehousing and business intelligence, metadata, and the data quality elements. The ATEC Data Analysis Division will establish our Data Strategy that aligns with the Army Data Plan.

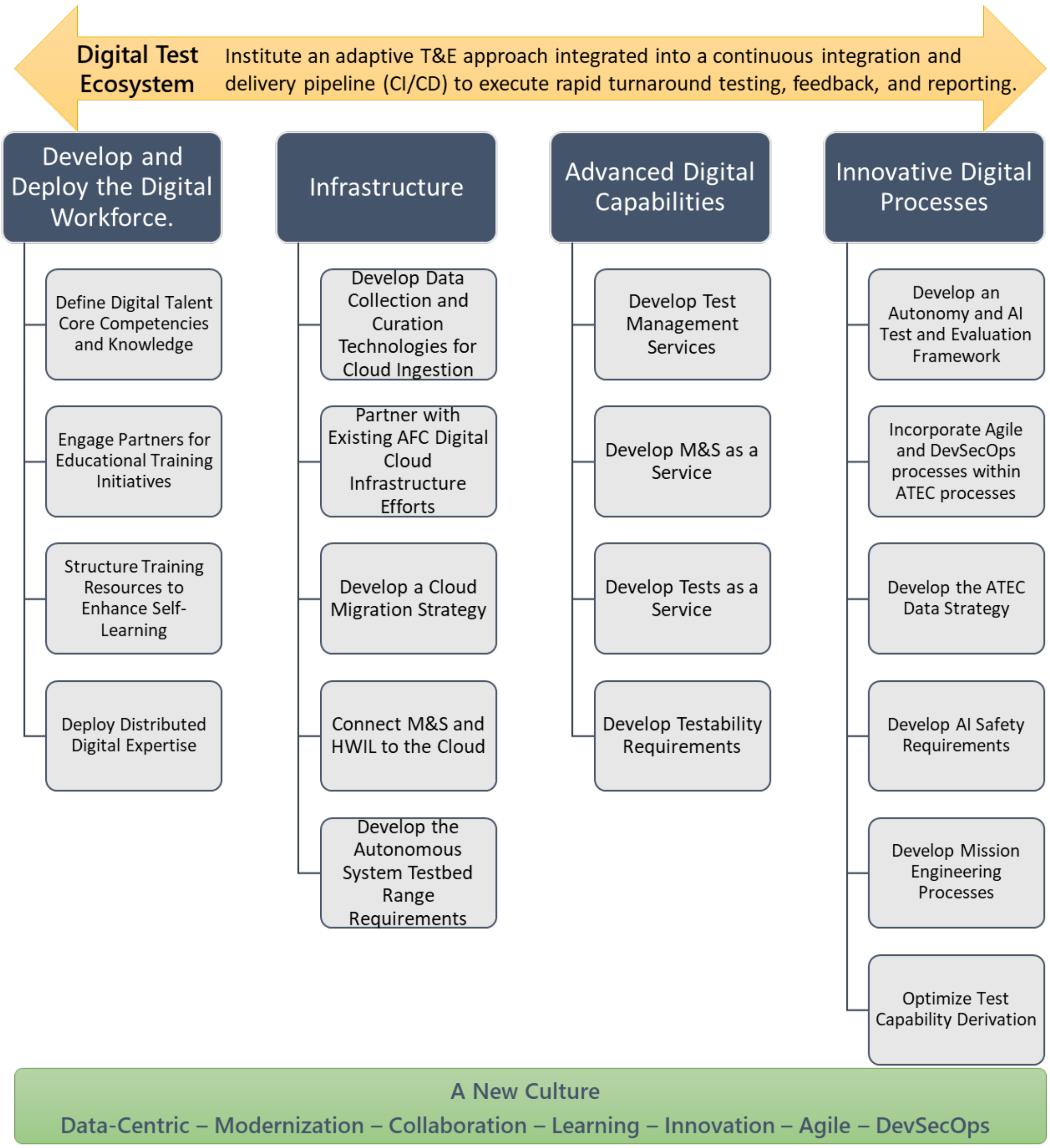
These mental models of the ATEC mission and vision allow us to focus the ATEC DX implementation strategy towards achieving the ATEC Vision. The next section discusses the strategic approach.

6. Strategic Approach

Historically, T&E focused on specific platforms composed of several subsystems that each required its own specific test. The test cycles for each platform or subsystem generated its own test execution results that are usually stored in the form of a spreadsheet or a flat file. These results frequently became the endpoint for that test cycle and are discarded after they are manually analyzed and a test report is created. These end-point results do not allow for a continuous T&E approach that leverages learning throughout the entire system life-cycle. The T&E mission is rapidly progressing from a platform focus to a focus on system of systems with embedded AI. Embedded AI involves a stack of technologies above the system of systems platform and networking layers that interact in complex ways. These additional layers include massive data management, machine learning, world view modeling, decision support, planning and acting, autonomy and human-AI interaction. See Appendix A for a detailed description of these layers. In order to develop and test these complex system of systems with embedded AI, we need new infrastructure, advance digital capabilities, innovative digital processes, and new data-centric talent with a unifying environment that facilitates a Digital Test Ecosystem. A Digital Test Ecosystem will enable an adaptive T&E approach integrated into a continuous integration and delivery pipeline (CI/CD) to execute rapid turnaround testing, feedback, and reporting. The figure below shows the concept of the Digital Test Ecosystem.



The development of a unifying environment in the form of a Digital Test Ecosystem will involve a strategic effort aligned with the following four goals: (1) develop and deploy a new digital workforce, (2) develop new infrastructure, (3) advance digital capabilities, and (4) innovative digital processes all while inspiring a new culture. The below figure shows the ATEC DX strategic approach that will achieve these goals with clearly defined objectives.


Digital Test Ecosystem
Institute an adaptive T&E approach integrated into a continuous integration and delivery pipeline (CI/CD) to execute rapid turnaround testing, feedback, and reporting.
Develop and Deploy the Digital Workforce.
Define Digital Talent Core Competencies and Knowledge
Engage Partners for Educational Training Initiatives
Structure Training Resources to Enhance Self-Learning
Deploy Distributed Digital Expertise
Infrastructure
Develop Data Collection and Curation Technologies for Cloud Ingestion
Partner with Existing AFC Digital Cloud Infrastructure Efforts
Develop a Cloud Migration Strategy
Connect M&S and HWIL to the Cloud
Develop the Autonomous System Testbed Range Requirements
Advanced Digital Capabilities
Develop Test Management Services
Develop M&S as a Service
Develop Tests as a Service
Develop Testability Requirements
Innovative Digital Processes
Develop an Autonomy and AI Test and Evaluation Framework
Incorporate Agile and DevSecOps processes within ATEC processes
Develop the ATEC Data Strategy
Develop AI Safety Requirements
Develop Mission Engineering Processes
Optimize Test Capability Derivation
A New Culture
Data-Centric – Modernization – Collaboration – Learning – Innovation – Agile – DevSecOps

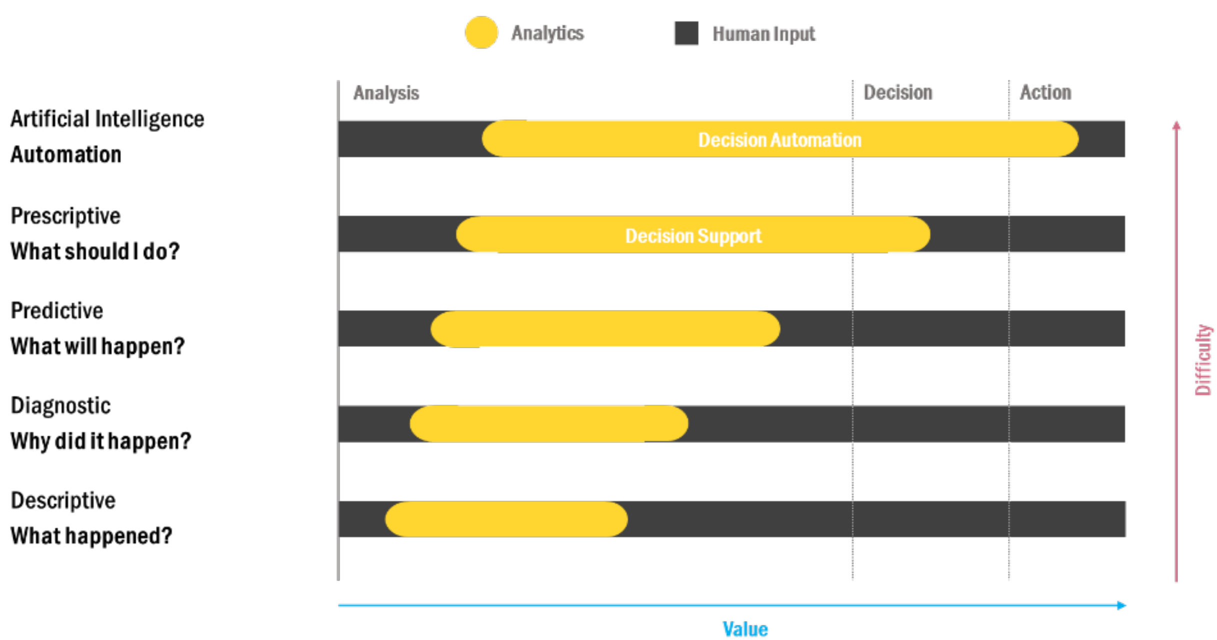
The following sub-sections defines the goals and each of the strategic objectives.

6.1. Develop and Deploy the Digital Workforce.

Goal: Provide comprehensive training for AI, Data Science, Cloud technologies, DevSecOps, and architecting to cultivate test expertise and sourcing critical skills and talent through recruitment and partners while emphasizing a culture of learning.

As complex systems continue to be instrumented with more and more sensors, the amount of data collected for each test has surpassed the level of an evaluator's cognitive processing ability. As a result, large amounts of instrumentation data collected during testing currently goes unused. Additionally, evaluator's time is consumed with reading hundred or even thousands of Test Incident Reports (TIRs), watching hours of video, and manually correlating observational logs, instrumentation data, and other forms of data. To address these challenges, ATEC must use AI to perform the T&E mission.

AI is a capability that sits on top of a collection of a fully mature data science ecosystem that involves various levels of analytics and human input. The figure below shows each of the data science project types and indicates the amount of human input and analytics involved in each of them.

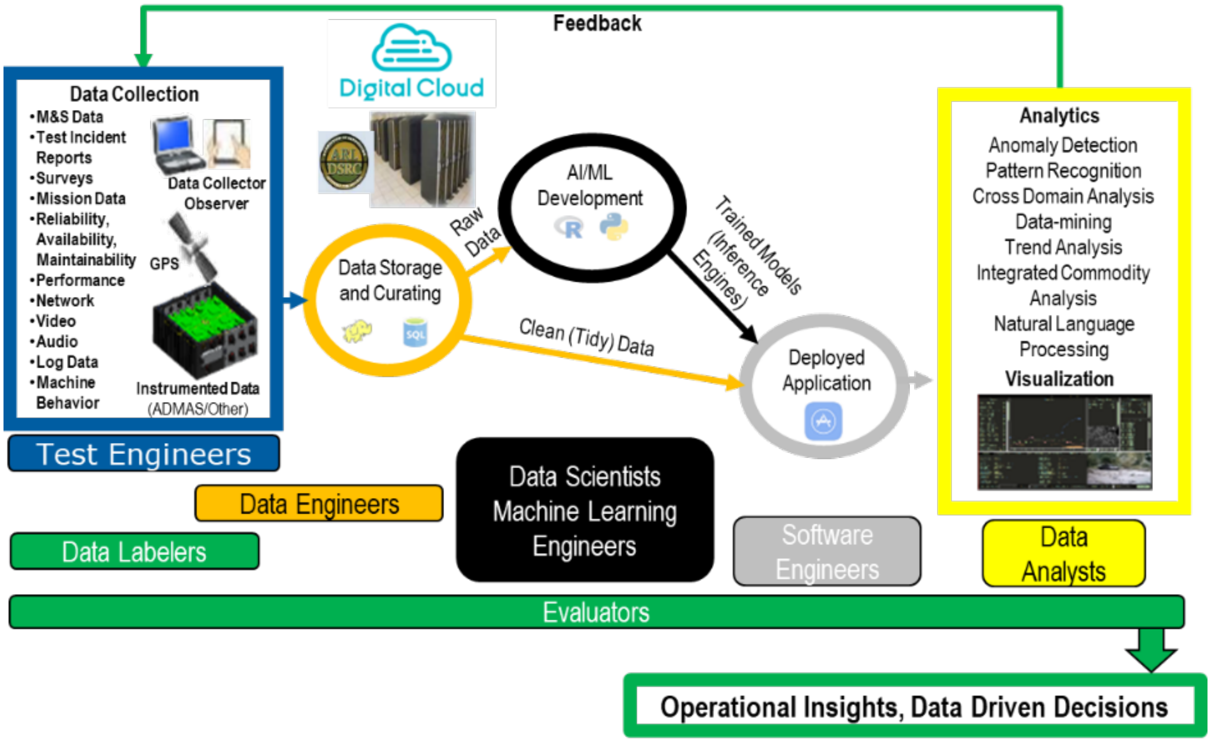


The data science project types depicted in the above figure are described here as they relate to the T&E mission. Starting from the bottom, each layer type builds on the previous layer with increased reliance on the machine for analytics and less on human input.

- **Descriptive: What happened?** Data aggregation from various structured and unstructured sources allows us to uncover a wealth of information that could not otherwise be possible. Transforming and relating data in new ways allows the evaluator to identify trends, anomalies, recurring issues, or unexpected correlations. Datasets include instrumentation or log files, video and audio data, M&S data, manually collected data, and many more. When datasets are clean and tidy, the evaluator will be able to visualize multi-dimensional data to uncover key insights that will described what happened during a test.

- **Diagnosis: Why did it happen?** Statistical methods allow us to infer insights from a collection of sample data. We develop regression models to help understand complex behavior by identifying the system parameters that drive performance or result in test incidents. Not only can we identify the key system parameters that influence the result, we can also describe the nature of their effect on the outcome of interest. Diagnostic methods allows us to associate various system parameters with test incident reports for causality analysis across multiple commodity areas. Understanding the behavior of a system under test allows us to uncover why something happened.
- **Predictive: What will happen?** Prediction involves using mathematical models developed with labeled data to predict an outcome. These types of models could predict test incident severities, preliminary hazards, or performance based metrics. A collection of predictive models allows evaluators to illuminate tradespaces by identifying interesting regions of the outcome space. These interesting regions may uncover unsafe conditions or areas where the system performs poorly or effectively.
- **Prescriptive: What should I do?** Prescriptive analytics will support test case management across M&S and live testing. The predictive models from the previous layer will prescribe the most beneficial allocation of test runs in a test program, ensuring every run provides value in the testprogram. This will result in more confidence in testing in a shorter time frame, saving resources, time, and personnel.
- **Artificial Intelligence: Automation.** AI involves the use of machines to reduce or remove the cognitive burden of decision making for a human operator. Leveraging the machine to perform tasks automatically will reduce the amount of time needed to watch videos, listen to audio data, and manually exploring hundreds of test incident reports and terabytes of instrumentation data. Automating these types of tasks will expedite the evaluations leading to accelerated insights while reducing the amount of testing and the time for each test needed.

Our goal is to expedite the evaluation workflow processes by leveraging all forms of test data, AI, and data science methods. The ATEC DX Strategy describes the type of infrastructure, advanced digital capabilities, and innovative digital processes needed to develop and test AI. Empowering the workforce with these elements alone will not bring about our vision. We must develop our workforce with data-centric talent that can employ these elements effectively. These new forms of talent require new teaming approaches with specific roles. The below figure depicts the future evaluation workflow with the collection of roles involved in this workflow.



Each role depicted in the above figure is defined here:

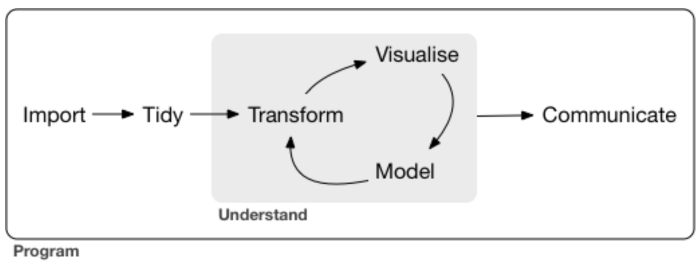
- **Test Engineer**: Subject matter experts in specific commodities with knowledge of all forms of instrumentation data relevant to the system or system of systems
- **Data Labeler**: A person with specific domain knowledge tasked with labeling a data element with a result or specifying which forms of instrumentation data are the measures of effectiveness or performance. These labels are a key enabler for predictive machine learning models.
- **Data Engineer**: Responsible for preparing big data infrastructure ecosystems to be analyzed by data scientists. Experts in database management, distributed processing, and cloud architecting.
- **Data Scientist**: Responsible for turning volumes of data into valuable and actionable insights. Performs a process that translates needs into questions, cleans and explores data, creates models and visualizations to answer questions.
- **Machine Learning Engineer**: Responsible for developing machine learning systems that automate predictions with continual feedback from new data that improve performance.
- **Software Engineer**: Responsible for developing cloud-native applications within the DevSecOps process by continuously integrating and deploying software services and applications into production for users to consume and interface with.
- **Data Analyst**: ORSAs that translate results from models and visualizations to arrive at the technical insights for evaluators to consume.
- **Evaluator**: Responsible for reviewing and developing the COIC, MOEs, and MOPs and arriving at the operationally relevant insights. Additionally, the evaluator interfaces with several external stakeholders and manages the T&E process.

Developing the skills needed to perform these roles will not only require a deliberate training strategy but a leadership emphasis on fostering a culture of learning. Inspiring the workforce to self-learn and reward their demonstrated achievement in this learning journey will ensure we transform into the digital age.

Develop Digital Workforce objectives.

6.1.1. Define Digital Talent Core Competencies and Knowledge

To effectively train our workforce, ATEC must develop a competency model as a foundation to trace the skills we need to the ways we will acquire them or find people that already have them as a part of our talent management initiatives. To help define our ATEC workforce competency models the following are categories of digital talent that will assist our development of our talent management initiatives.



AI and Data Science Talent. The ATEC workforce needs to develop data science competencies to effectively work on data projects, especially once we are empowered by the COEUS platform in the future. COEUS will allow the DoD workforce to access data across various cross-domain networks, provision computational resources, collaborate with teams, and provide the tools and environments we need to perform data science. An effective visual to describe the types of competencies ATEC needs is shown in the following figure developed by Hadley Wickham and Garrett Grolemund. Our workforce must learn to *import* data from a variety of sources stored in files, databases, data lakes, and websites, *tidy* the data into variables and observations, and *transform* data into new forms suitable for analysis. *Visualizing* data allows us to explore our data, generate questions, and uncover insights. *Modeling* complements our visualization with mathematics that allows us to diagnose tests events, predict outcomes, and prescribe actions. Once we develop new insights, we must learn to effectively *communicate* to decision makers in a way that is operationally relevant. A new form of analysis reporting are web applications with interactive displays used to communicate insights that are hosted in cloud environments. Shiny is an effective framework for creating web applications using the R programming language. Computer *programming* is an essential competency needed to perform the workflow shown in the above figure, automate analysis procedures, and build interactive visualizations. The two most relevant programming skills for data science are the R language for statistical computing and graphics and Python. The following references will assist the ATEC workforce to embark on the data science journey.

- R FOR DATA SCIENCE
- MASTERING SHINY
- PYTHON FOR EVERYONE

Cloud Architecting Talent. Cloud computing will bring unprecedented speed, agility, and resilience in the application development, management, and test process that will ensure the Army delivers capability at the speed of relevance. ATEC's ability to leverage the cloud for the T&E mission will rely heavily on the talent we develop in cloud computing. There are a host of skills related to architecting, connecting, and using applications hosted in the cloud. These skill involve understanding cloud deployment models (public, private, and hybrid), cloud service models (on-premises, infrastructure as a service, platform as a service, and software as a service), virtualization (storage, compute, networking), and cloud management (deployment of services, pricing, governance, monitoring).

Software Engineering and DevSecOps Talent. The Task Force on Design and Acquisition of Software for Defense Systems recommended that the acquisition workforce develop modern software development expertise. Although ATEC does not have a need to develop modern software, we do need to understand how to employ test services within DoD software factories in the future. Therefore, ATEC needs to develop competencies in the use of DoD software factories as defined in the DoD Enterprise DevSecOps Reference Design.

System Architecting Talent. The effectively perform mission engineering, there are three skill areas necessary to develop system architecting talent. First is to develop a deep understanding of the various views of the DoD Architectural Framework. Second is to understand the syntax and semantics of the System Modeling Language (SySML) and the Unified Profile for DoDAF and MODAF (UPDM) language. The third skill relates to using the MagicDraw tool to perform the architectural analysis that will support ATEC system evaluation planning.

6.1.2. Engage Partners for Educational Training Initiatives.

DoD agencies have recognized the importance of skillset transformation for digital technologies. To date, there have been opportunities identified in areas such as artificial intelligence being investigated by the Office of the Secretary of Defense (OSD) AI Educational Task Force. Some examples of opportunities include: the CCDC Armament Center is in process of developing AI college curriculums and courses; Joint Artificial Intelligence Center provides an AI boot camp program in Crystal City, VA; the Army Management Staff College is curating "Visionary of iWar" training program; the Air Force Platform One team provides onboarding programs for digital platforms; and the Air Force Institute of Technology has embedded new training modules in DAU for T&E of autonomous systems. These present opportunities for building partnerships and enabling unconventional training approaches for test personnel, with the added benefit of cross-domain expertise and perspectives to foster innovative thinking. We need to increase awareness of opportunities and foster interaction to open doors to these programs where feasible.

6.1.3. Structure Training Resources to Enhance Self-Learning.

In the digital age, we have access to a multitude of learning content at our fingertips. Self-learning refers to the ability of T&E professionals to seek and engage learning as a part of their individual development plans. Supported by an understanding of the core competencies required in DX initiatives, we can curate training roadmaps in various talent areas to include academic offerings, online instruction, certification programs, and massive open online courses (MOOC). As an example, computational literacy for autonomy and AI would require basic literacy in programming and programming languages. This could be addressed through a graduate course within an AI or computer science curriculum (academia), classroom learning (AMSC), or an online Python programming course (open online course). The key is to provide insight and resources to T&E professionals for ease of discovery and vetted courses where value to the test mission has been analyzed.

6.1.4. Deploy Distributed Digital Expertise

With a strong technical base, we need to consider team structure and dynamics. With the use of tools such as the Common Virtual Remote (CVR) environment, we recognize new opportunities to deploy forward-thinking digital test teams to support experimentation and design of digital solutions. This will require a closer look at our organizational structures to reimagine our digital project teams based on domain expertise and cross-functional support. For example, modeling and simulation environments replicating multi-domain operations may span mission areas across the ATEC enterprise, requiring domain expertise in multiple functional areas to be brought together as part of a distributed team. Understanding a model for composition of digital test teams will enable us to institute diverse and targeted team composition, iterative goal setting, and continuous learning approaches. This can be further strengthened by shifting the locus of power to the teams for democratized decisions and considerations for reward structures that evaluate team contributions as opposed to individual.

6.2. Infrastructure.

Goal: Develop a unifying digital infrastructure using common data formats, networks, and the cloud to facilitate integrated test approaches for rapid deployment, scaling, testing, and optimization of software as an enduring capability.

To effectively develop and test system of systems with embedded AI we need an environment with the right data collection infrastructure, cloud-based digital infrastructure, and physical infrastructure. The following table lists the types of infrastructure investments related to the Continuous T&E pipeline.

Data	Digital Infrastructure	Physical Infrastructure
Collection Devises	Cloud Computing	Software Integration Labs
Storage Solutions	Networking (integrated data exchange)	Hardware in the loop facilities
Curation Pipelines	High Performance Computing	System Integration Facilities
	Virtual Integration Testing/ M&S	SoS Integration Facilities
	Virtual Operations Center	Live Training Ranges
	Visualization Tools	Live Test Ranges
	Cyber-Autonomy Test / National Cyber Range	

Infrastructure Objectives.

6.2.1. Develop Data Collection and Curation Technologies for Cloud Ingestion.

ATEC needs a secure, certified, and repeatable edge data collection process that can capture test data from system of systems with embedded AI during live, virtual, and constructive test events. Additionally, test centers need the ability to upload the collected data efficiently to a secure, monitored, cyber-protected enterprise cloud for processing and curation. The protection and curation of the collected data must be managed as an enterprise assets reusable by the Army's software development and data science community. The types of data collected and monitored will include the following:

- Unmanned Autonomous Platforms – data log files, mapping and navigation files, etc.
- Audio Files – tactical communications, body camera and ambient noise microphones, etc.
- Video – high resolution surveillance, target recognition, and weapon aiming cameras.
- Machine Behavior Data – status updates, system states, subsystem commands; mission change

orders, etc.

- Geospatial Test Data Tracking – geo-referenced activity information from system under test (SUT) elements (time, space, position).
- Test Incident Reports.
- Surveys – collected from tablet devices.

Solutions to this objective are in the form of containerized microservices that reside on the edge collection devices. Examples of edge collection hardware are Amazon Snowball Edges and Azure Data Boxes. Examples of containerized microservices include data ingest services, digital interface control document viewers, data quick look (real-time monitoring of data ingest), data transformation services, entity attribute editors, user-defined quick look analysis, custom user tools, and security management services.

6.2.2. Partner with Existing Army and AFC Digital Cloud Infrastructure Efforts.

The DoD digital environment has very specific cross-domain network interfacing needs, security, authority to operate, authentication standards, and many other requirements. Therefore, the DoD needs digital platforms that can operate within the DoD environment and allow for easy access to data, computational resources, software development, and test environments. There are a number of Army efforts to build unified digital infrastructure environments for ATEC to utilize. These efforts are listed here.

AFC Modernization Application Data Environment (MADE): A Microsoft Azure cloud hosting environment for a variety of AFC applications, it will facilitate access to a centralized, authoritative set of experimentation data to properly execute enterprise management, governance, and oversight of Army experimentation activities. Current plans call for MADE to fold into the cArmy cloud environment when it expands to Azure.

- **cArmy**: A set of Army-wide enterprise cloud hosting environments on both Amazon Web Services and Microsoft Azure, offering information level (IL) 2, 4, 5, and 6 (SIPRNET) platform as a service capability to all Army customers. Managed by the HQDA CIO/G-6 Enterprise Cloud Management Office, cArmy environments are expected to be fully operational by the end of calendar year 2020. If and when the DOD-wide JEDI cloud platform becomes available, cArmy may fold into that environment.
- **COEUS**: A cloud-native collaborative digital platform accessed through a web browser that enables the entire lifecycle of a data project from initial data collection to delivered capability.
- **Army Capabilities Analysis, Development, and Integration Environment (ArCADIE)**: The operational enterprise architecture platform used to host all authoritative governance modeling artifacts. A mature capability based on MagicDraw and managed by AFC Futures Concepts Center, Architecture and Integration Division, ArCADIE will increasingly be used to develop “mission threads” (use cases) for AFC experiments and ATEC T&E projects.
- **Army Experimentation Results Data Repository (AERDR)**: A MADE cloud-based, central data repository for all Level 2 -3 data results from experimentation activities.
- **FORGE**: The FORGE Experimentation Module, hosted on MADE, will be the authoritative data source for all Army experimentation planning activities, the AFC experimentation COP, and the centralized repository for all experimentation analytic artifacts including analyses, summaries, and reports.
- **Code Repository And Transformation Environment (CReATE)**: the Army Enterprise DevSecOps software factory pipeline intended to increase teaming and sharing of development, security, and

operations process, tools, and techniques.

- **Orion Forge**: a DevSecOps environment led by the Network CFT focused on the Intelligence and Warfighting Missions.
- **DoD High Performance Computing Modernization Program (HPCMP)**: High Performance Computing resources provide DoD processing for AI development, computational physical modeling, Battle Lab simulation runs, and other acquisition engineering efforts. The HPCMP also manages the Defense Research and Engineering Network (DREN).
- **Battle Lab Collaborative Environment (BLCSE)**: a closed SECRET wide area network to support AFC Modeling & Simulation community and Future Concepts experimentation and development.

The Army seeks to develop a unifying cloud-based architecture that federates the above platforms and infrastructure. ATEC's involvement in each of them will ensure the testing community stays relevant within the Army Modernization Enterprise.

6.2.3. Develop a Cloud Migration Strategy

Current ATEC enterprise business systems, to include content management systems and organizational data repositories containing the all-important T&E results data, are not cloud-ready and will require major overhaul or replacement. The Secretary of The Army (SA) directed a focused effort to implement a data plan to support migration to the cloud in August 2019. As a result of this directive, the Army will implement Cloud Migration and the Army Data Plan across Mission Areas and Data Repositories through governance and management via cloud technology, as appropriate, to gain efficiencies, improve decision making, and leverage emerging technologies to support ongoing operations and modernization.

6.2.4. Connect M&S and HWIL to the Cloud

AFC, ATEC, and the Joint Modernization Command (JMC) are organizing an effort to connect all Army RDT&E and DAC Labs and Facilities, ATEC test centers, COE Battle Labs, new and legacy intelligence and combat platforms and soldier-borne equipment Hardware-In-The-Loop (HWIL) Labs into a single integrated cloud-based operationally-representative test and demonstration architecture. This effort is called the Integrated Army Modernization Experimentation Plan (IAMEP). IAMEP is intended to be an integrated process and persistent cloud-enabled capability to rapidly assess combat platform capabilities against evolving threats and demonstrate distributed platform-to-platform interoperability at scale with imbedded data collection, subjective soldier feedback and archiving to continuously validate models and simulations, field warfighting capability and demonstrate MDO readiness by 2028. The IAMEP along with the cloud-based infrastructure will facilitate a campaign of learning with a unified T&E pipeline that begins with M&S and progresses to distributed ground test, integrated ground tests, COCOM Live Fire Exercises, and Project Convergence demonstrations. The IAMEP's intent is to establish an annual cadence that leverages data and insights acquired through M&S, distributed, integrated ground testing, COCOM live fire exercises leading up to a system of systems demonstration. The following are the IAMEP objectives:

- **Objective 1** – Develop integrated process to rapidly develop and manage an Integrated Army Modernization Test Plan (FY21-28) that synchronizes the 31+3, MDTF and ASL priority programs into a deliberate annual cadence of demonstrations and testing.
- **Objective 2** – Develop persistent cloud-enable distributed M&S and HWIL architecture(s) to

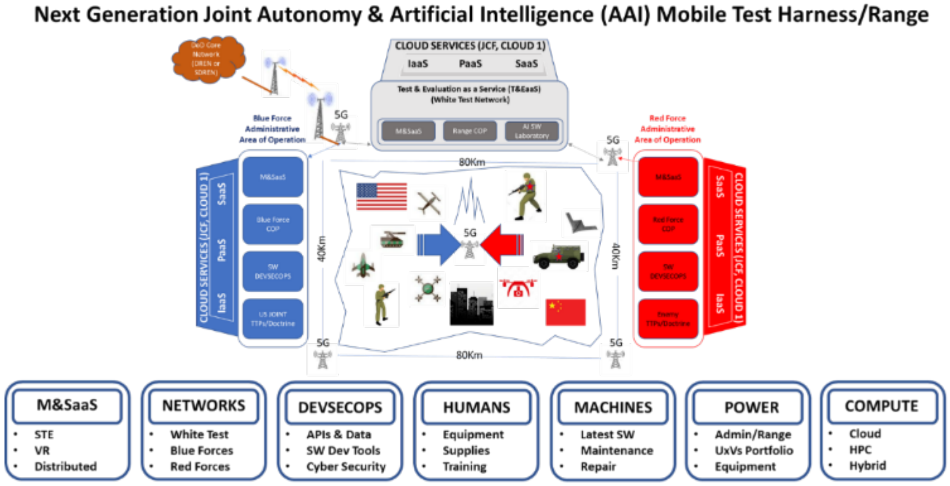
demonstrate and test platform-to-platform interoperability at scale against evolving threats.

- **Objective 3** – Develop integrated Data Management Plans with embedded data collection capability that seamlessly collects test data, archives and anchors M&S and informs Wargaming, Army Modernization Guidance and DOTMLPF.
- **Objective 4** – Establish repeatable, sustainable and trainable test planning and execution teams needed to conduct distributed M&S and HWIL test events.
- **Objective 5** – Develop a test strategy to leverage and drive IAMTP to meet program test objectives.
- **Objective 6** – Establish IAMEP and Data Management Configuration Control governance Process.

6.2.5. Develop the Autonomous System Testbed Range Requirements

In order to effectively exploit the benefits of the DevSecOps process, the Army needs Live Virtual Constructive (LVC) testbeds that are specifically designed to test human and machine warfighting tactics while ensuring the safe and ethical use of AI and Autonomous systems. The LVC testbed employs a closed network at a range that facilitates a LVC experience with autonomous systems, operators, software developers and AI engineers. The testbed is intended to deliver real time observations, analytical findings, and recommendations which system developers can use to make development changes in the field using "test-fix-test" DevSecOps process. The figure below shows the concept of the testbed that multiple networks, humans, machines, digital infrastructure, and M&S capabilities that can facilitate LVC experiments.

Next Generation Joint Autonomy & Artificial Intelligence (AAI) Mobile Test Harness/Range



6.3. Advanced Digital Capabilities.

Goal: Develop enhanced T&E digital capabilities to include: adversarial testing, test automation, advanced M&S, model-based test generation, advanced instrumentation, and predictive analytics.

A new form of digital capability: Cloud-Native. Digital transformation is driving the adoption of new modern applications and deployment approaches including cloud-native. A cloud-native approach is a methodology of building and running modern applications that fully exploits the power of cloud computing. We use the term application to mean a piece of software deployed onto a system that provides a capability to the warfighter. Every application has a collection of software services that supports its functionality. Legacy software systems build applications using a monolithic approach where software services are tightly coupled together making it very difficult to deploy or change. Cloud-native modern applications are often composed of microservices packaged in containers that can operate independent of each other. The independent nature of these small microservices allows for the rapid deployment to the warfighter, continuous monitoring during operation, rapid upgrades, and rapid repair of failed services with minimal downtimes. Additionally, microservice architectures can take full advantage of the cloud that offers on-demand, highly scalable computing power. Cloud-native modern applications can be automatically scaled up or down massively as needed while optimizing the use of computing resources. They are also easily portable across different network domains that conform to the cloud-native approach. These cloud-native, containerized applications will bring additional commercial capabilities into the Army space.

The advanced capabilities relevant to our digital transformation will be in the form of containerized microservices used within a digital environment to perform the ATEC test mission. We use the term environment to mean a digital "place" enabled by computers, networks, and digitals tools we access through the web. These environments will be hosted on the data collection, cloud-based digital, and physical infrastructure described in the Infrastructure section. The test services will be new COTS and GOTS cloud-native test capabilities ATEC will need to effectively test and evaluate modern applications that will deliver autonomous and AI capability. Examples of test services include test management services, Modeling & Simulations services, cognitive instrumentation, adversarial testing, run-time monitoring, formal methods and many more. Standardizing these test services will ensure we identify the safety and performance issues prior to the software being deployed onto hardware early in the life-cycle. There are some forms of test services that will embed with the modern applications that are integrated with hardware. These test services are intended to monitor the safety and performance while in production and will be critical enablers during developmental and operational testing. The more we can automate these test service capabilities within the digital environments while performing the DevSecOps process the faster we will deliver capability at the speed of relevance. There are three categories of test services that comprise the objectives under the advanced capabilities goal, they are test management, M&S as a Service, and Test as a Service.

Advanced Digital Capabilities Objectives:

6.3.1. Develop Test Management Services.

- **Intelligent Test Selection**. Automated test case planning via optimization algorithms (OA) and clustering to rapidly generate salient test scenarios.
- **Human Systems Integration**. Calibrate dimensions of trust with traceable evidence to support an acceptable safety, security, performance, and risk envelope for human-machine teaming.
- **Cyber Physical System Surface Attacks**. Risk mitigation of vulnerabilities and exploitation of the algorithmic behaviors which will prevent its operational deployment, to include verification of the five pillars of cybersecurity (confidentiality, integrity, availability, non-repudiation, and authentication).

6.3.2. Develop M&S as a Service.

The Army lacks an integrated capability to model the aspects of the Joint All Domain Command and Control concept (JADC2). Instead, simulations execute some aspects, and other models independently execute other aspects, potentially missing the dynamic interplay between domains. Existing approaches to modeling and simulation are increasingly challenged to meet the evolving complexities of our world. Models and simulations are difficult to build. Once they are built, they are difficult to find and share. This leads to an inability to respond to ever changing demands for simulation. Current simulations have limited re-use and inefficient investment where different communities pay for similar M&S resources more than once. To address these challenges, the Army can leverage the Modeling & Simulation as a Service (M&SaaS) microservices architectures to piece together complex simulations involving all domains.

The M&SaaS concept employs the cloud-native approach to containerize M&S functionality as a modularized plug-and-play capability. The key difference between M&SaaS and existing M&S approaches, such as federation development, is thinking of M&S as an ecosystem in which models and simulations are not developed in silos for a small number of users. They are developed in an ecosystem that sustains those resources, provides tools to support their integration and use, and delivers those resources on demand to many users. This requires innovation by the M&SaaS implementation provider, but technology alone will not reach the vision. It requires governance and stewardship by the owning government or commercial customer.

However, M&SaaS implementations are in their infancy, and there are several challenges that must be overcome for their successful implementation. These include operational challenges such as governance policies and business models, technical challenges such as cyber-security and model composition, and legal challenges such as intellectual property rights. The Army needs to build its own M&SaaS implementation to assess the expected advantages and devise solutions to M&SaaS challenges.

6.3.3. Develop Tests as a Service.

There are several challenges related to testing and evaluating systems with embedded AI. These challenges include how we analyze post-fielded learning, emergent behavior, exploitable vulnerabilities, safety concerns and hazards, trust, and verifying and validating the data used to train an AI capability. The following are a set of services that are relevant to the testing of autonomous and AI systems and are examples of future containerized services ATEC will employ with the cloud environments.

- **Cognitive Instrumentation Service**. Enable measurement of internal system states to inform diagnostic tools distinguishing coding errors from inadequate algorithms or deficient training data to assess the quality of decision-making capability.
- **Adversarial Testing Service**. Focus testing of the state space by identifying test cases to systematically discover scenarios and sequences of input conditions that can trigger emergent behavior or identify vulnerabilities in the learning system.
- **Run-Time Monitoring Service**. Run-time architectures can constrain the system to a set of allowable, predictable, and recoverable behaviors.
- **Formal Methods Service**. Specifies certain properties that the software should have, produce the software, and verify that it does have those properties without needing to confirm that empirically by testing for them.
- **AI Dataset indexing and Auto-labeling Services**. Automated data labeling services on AI T&E datasets in order to reduce the time, improve model performance and accuracy, and reduce total cost of labeling through automation, and expose data sets and models as a service through an indexing service. Service should programmatically build, maintain, and allow for forklifting of existing data sets into a managed environment; automatically apply labels and annotations, allowing for human intervention and quality control. Transform and slice datasets functions to expand the available T&E datasets needed to increase performance.

- **Synthetic Data Service**. Synthetic Data services to expand T&E datasets, and improve model confidence scores and performance. Provide an alternative to bypass or augment manual data labeling through synthetic generation of the raw images. Provide realistic synthetic 3D models to generate synthetic data that when combined with real data will improve performance.
- **Metrics Service**. Automated AI performance metrics that can explain and share the test and validation of AI models with the acquisition community. Provide a mechanism for both manual and automated testing for model quality metrics in accuracy, precision, and recall. Allows for the splitting of data into Validation & Test sets before models are trained.
  Model Security Service: Provide a framework for testing model sensitivity to attacks or adversarial manipulation.
- **Edge Case Services: Provide** a workflow engine and method for AI model sensitivity that automatically identifies edge cases, providing machine forensics to improve model performance.

6.3.4. Develop Testability Requirements

In order to focus test driven development, the test community needs to identify precise, structured standards to automate requirement evaluation for testability and traceability. This relies on our ability to support consolidation of existing standards and development of an integrated system of interfaces to bring key architectures together through application design and interface control documents (ICDs). For example, algorithmic software must be developed in such a way that it can easily be executed either on a platform or in a partially or wholly simulated environment. This requires close collaboration and coordination with system developers so that test harnesses are built-in and accessible through our instrumentation payloads and analytic engines. Successful implementation is a critical factor in structuring a continuous test model where test packages can be rapidly configured and deployed based on immediate need. The T&E community will need to inform contractual mechanisms through program management offices to ensure verbiage is included to build in the necessary interfaces and test APIs.

There is a host of testability requirements needed to enable the testing of these complex software. This includes modularity in the software design, interfaces for instrumentation of internal states, and data exchange layers to identify and configure data streams. The following reference provides an example of testability requirements for autonomy engines: TESTABILITY REQUIREMENTS.

6.4. Innovative Digital Processes.

Goal: Incorporate DevSecOps processes, develop data plan and the safety, cyber, and analytical techniques for AI and autonomy, and update doctrine to include regulations, policies, and guidelines to reflect the new mission space.

Innovative Processes Objectives. The ATEC Next, LOE 3, intends to employ innovative and adaptive T&E processes to accomplish the ATEC mission and achieve our vision. The processes described here support the following four outcomes. First, ATEC seeks to improve T&E agility by increasing our ability to plan, prepare for, and conduct T&E projects and support for AFC experiments faster, cheaper, and produce results of greater accuracy than legacy processes. Second, we seek to improve ATEC persuasiveness and influence with reports that accord greater respect by key Army acquisition decision makers who understand our processes and produce results of unparalleled accuracy. Third, ATEC wants Material developers to rely on ATEC more for developmental testing earlier because our value proposition is greater. Our value proposition includes the value of the data, information, knowledge, and wisdom we produce for the money we charge. The fourth outcome is to ensure ATEC is prepared with the right methodologies necessary to T&E system of systems with embedded AI and autonomous capabilities.

6.4.1. Develop an Autonomy and AI Evaluation Framework

To effectively test and evaluate system of systems with embedded Autonomy and AI (AAI), ATEC needs to develop new evaluation frameworks for the system evaluation plans. ATEC will explore a series of different efforts across the AFC Enterprise to develop a unifying mental model framework with new AAI metrics that will assess and evaluate future systems. The following are some of the key considerations ATEC must consider when evaluating AAI systems.

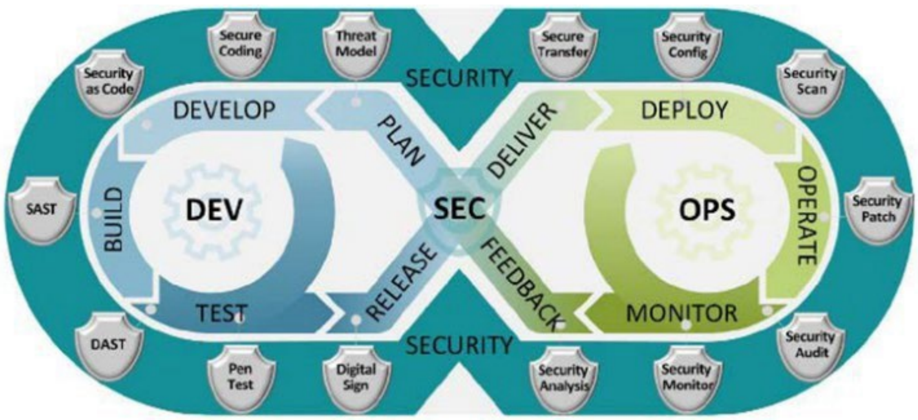
- Impact of AI enabled automation of processing and synthesizing large and diverse data sets in support of military analysts, planners, and decision makers.
- Impact of AAI enabled platforms, and human/machine teaming tactical concepts.
- Impact of AI enabled systems designed to reduce Soldier physical and cognitive workloads.
- Impact of AI enabled systems that increase efficiency of sustainment and operational planning.
- Impact of AI enabled systems that increase situational awareness and facilitate enhanced decision making.
- Impact of AAI enabled threat systems on military operations.

6.4.2. Incorporate Agile and DevSecOps processes within ATEC processes.

In February 2018, the DoD Defense Science Board (DSB) published a report from a Task Force on Design and Acquisition of Software for Defense Systems. The goal of the DSB was to determine whether iterative software development practices evolved in the commercial world are applicable to the development and sustainment of software for the DoD. The Task Force recommended that the iterative approach of DevSecOps process for software development and sustainment is applicable to the DoD and that it should be adopted as quickly as possible.

DevSecOps fosters the collaboration between software developers, security testers, and IT operations while building a culture and practice where building, testing, and releasing software happens rapidly, frequently, and more consistently. The DevSecOps process allows for a continuous delivery model with software pipelines that facilitate the develop-build-test-release-delivery-deploy-operate-monitor-feedback cycles while ensuring the authority to operate. The HQDA CIO/G6 Enterprise Cloud Management Office plans to empower the Army with an environment that will allow industry, academia, and government software developers to deliver applications using the cloud-native approach and DevSecOps process. This environment is called the Code Repository and Transformation Environment (CReATE).

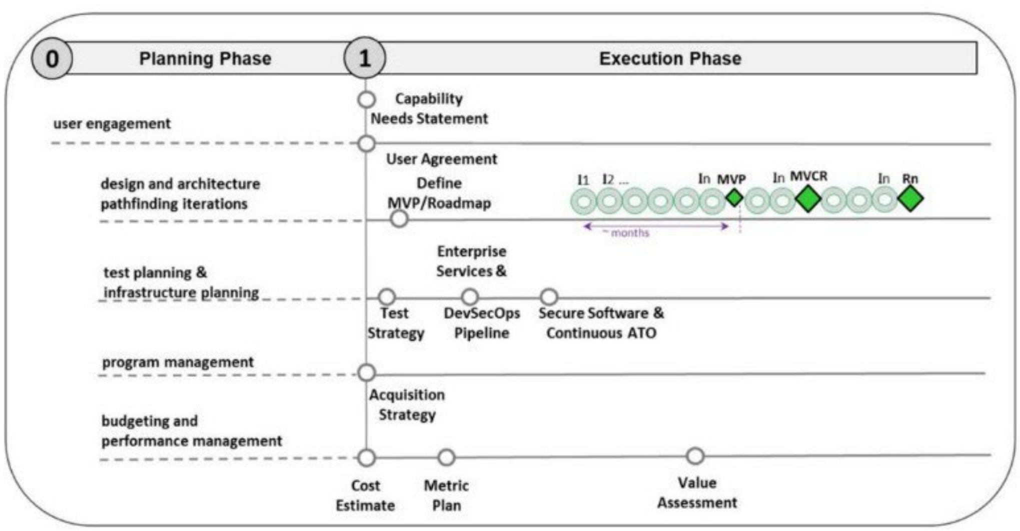
The DevSecOps process embeds automated quality assurance tests into the development lifecycle as early as possible to reduce the cost of rework and increase the speed of the feedback loop into development as it is happening. With the ability to provision compute and storage in the cloud on demand, our ability to design, test and field solutions are no longer inhibited by long hardware lead times and lengthy test processes performed late in the life-cycle. These modern approaches are a central enabler of any digital transformation strategy. The figure below shows a visual depiction of the DevSecOps process that facilitates the develop-build-test-release-delivery-deploy-operate-monitor-feedback cycles.



The DoD has established an interim policy for a new software acquisition pathway that employs the DevSecOps process. The new pathway is intended to accomplish the following:

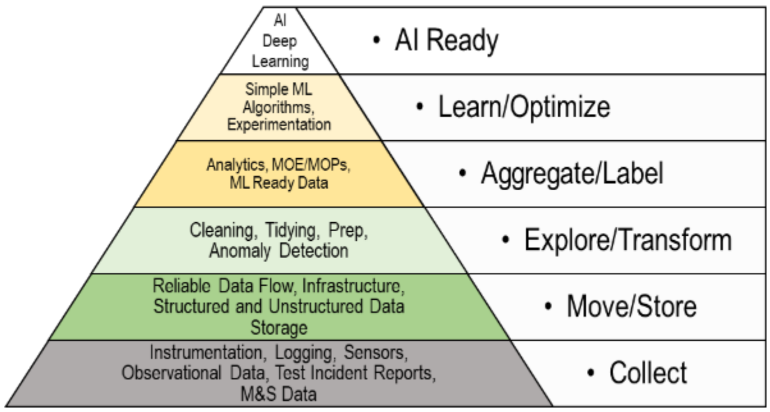
- Simplifies the acquisition model to enable continuous integration and delivery of software capability on timelines relevant to the Warfighter/end user.
- Establishes the Software Acquisition Pathway as the preferred path for acquisition and development of software-intensive systems.
- Establishes business decision artifacts to manage risk and enable successful software acquisition and development.

In response to this new change, ATEC must adopt a culture that shifts away from legacy software acquisition processes to the agile and DevSecOps approach. The agile methodology contracting practices will have a significant impact on the current ATEC T&E processes. ATEC needs to understand the DevSecOps process and how to best integrate into it in order to rapidly produce feedback during the development while maximizing productivity as early in the life-cycle as possible. Rather than focusing on requirements, the agile methodology focuses on the users. Instead of the traditional milestone decision gates, agile processes focus on user stories that incrementally delivers minimal viable products for early Soldier feedback. The following figure shows the software acquisition lifecycle view.



6.4.3. Develop the ATEC Data Plan.

To adopt a data-centric culture we must formalize data as an Enterprise Asset. A data asset is something that brings value to the decision maker that is managed and protected effectively. This value is only realized when the right data is transformed into actionable information. Increased access to the right data, transformed into actionable information will aggregate knowledge towards enhanced judgement. An effective data strategy nested with the Army Data Plan and the AFC Experimentation Data Strategy will ensure ATEC implements the governance and data management processes that will ensure our data becomes an Enterprise Asset. The figure below shows the hierarchy of needs to become an AI Ready organization where we can fully exploit our enterprise data assets.



The Directorate for Capabilities Integration (DCI) Data Analytics Division (DAD) is creating a Data Analytics Plan (DAP), which will collect and share information about ATEC's current data analytic activity and identify data analytic friction points and propose solutions. The DAP will be refreshed annually, to reflect current trends and challenges and will be organized under the following topics:

- Data Governance. Define how authority and control (planning, monitoring, and enforcement) should be exercised over data assets. Data Interoperability. Data interoperability addresses the ability of systems and services that create, exchange and consume data to have clear, shared expectations for the contents, context and meaning of that data.
- Data Engineering. Focus is on the production readiness of test data and on creating the data pipeline between test items and evaluators. Includes collection, reduction and transformation of data to ensure that it is clean, reliable, and ready for analysis.
- Data Analytic Tools. Catalog the data analytic tools in use across ATEC and provide opportunity for collaboration by tool users at dispersed locations. Identify promising tools and techniques (including Machine Learning) to speed data analysis and for automating understanding of very large data sets.
- Data Management. Examine challenges in management of source data and analytic products. Understand overall scope of current ATEC data storage volume and review possible need for update to the ATEC data-retention policy regarding the saving of data related to test and considerations for disposition of data. Data Quality. Focus is on planning, implementation, and control of activities that apply quality management techniques to data, in order to assure it is fit for consumption and meets the needs of data consumers.

6.4.4. Develop AI Safety Requirements

In order to better understand the safety implications of AI on the Solider, the Army established an AI

Safety Working Group as a multi-disciplinary team of system safety experts established under Office of the Director of Army Safety (ODASAF) to provide qualified advisory group to develop an AI safety framework. The working group purpose is to define issues associated with safety of AI systems, establish Army policy and standards to address AI safety, determine appropriate artifacts to assess the safety of AI systems, and develop a framework for AI safety testing. The working group established seven subgroups to investigate distinct areas of interest. The following are the subgroups and their intended outcomes in support of the AI safety requirements development.

- **Requirements**.
    - Develop precepts (design, programmatic, operational).
    - Develop guidance on safe integration into existing systems.
- **V&V (Test and Data Sets).**
    - Develop methods and best practices.
    - V&V of AI training data sets.
    - Develop framework and methods to test safety of AI systems.
    - Develop requirements for tagging safety-significant data and control of data.
    - Develop requirements for test deliverables.
    - Develop requirements for control of test data.
- **Risk Management**.
    - Develop methods to identify, analyze, assess, and control hazards.
    - Identify hazard analysis artifacts and minimum requirements.
    - Develop framework for use of AI as hazard mitigation.
    - Develop level-of-rigor (LOR) metrics.
    - Evaluate criticality index for appropriateness.
- **Human Systems Integration (HIS).**
    - Develop guidance on identification/mitigation of human use issues.
    - Develop guidance on AI explainability.
    - Develop guidance on trust (confidence) and organizational change management.
    - Identify TTP Changes.
- **Robust and Resilient AI.**
    - Develop guidance on identification/mitigation of security issues.
- **Workforce Training.**
    - Develop strategies to increase AI safety awareness.
    - Develop training for AI safety.
    - Develop guidance on identification/mitigation of cybersecurity issues.
- **Pilot Program**.
    - Identify and coordinate with acquisition programs for use as pilot for processes and products developed by Army AI Safety WG.
    - Explore using Project Convergence as pilot program.

Operational impacts of this effort include the following:

- Overall reduction of risk to Army personnel and equipment introduced by the use of AI technologies.
- Optimization of safety engineering and test activities leading to faster acquisition timelines.
- Increased Soldier/operator confidence in AI technologies leading to faster adoption of AI

technologies.
- Increased trust from public civilian partners resulting in increased support and collaboration from academia, government, and industry sectors.

6.4.5. Develop Mission Engineering Processes

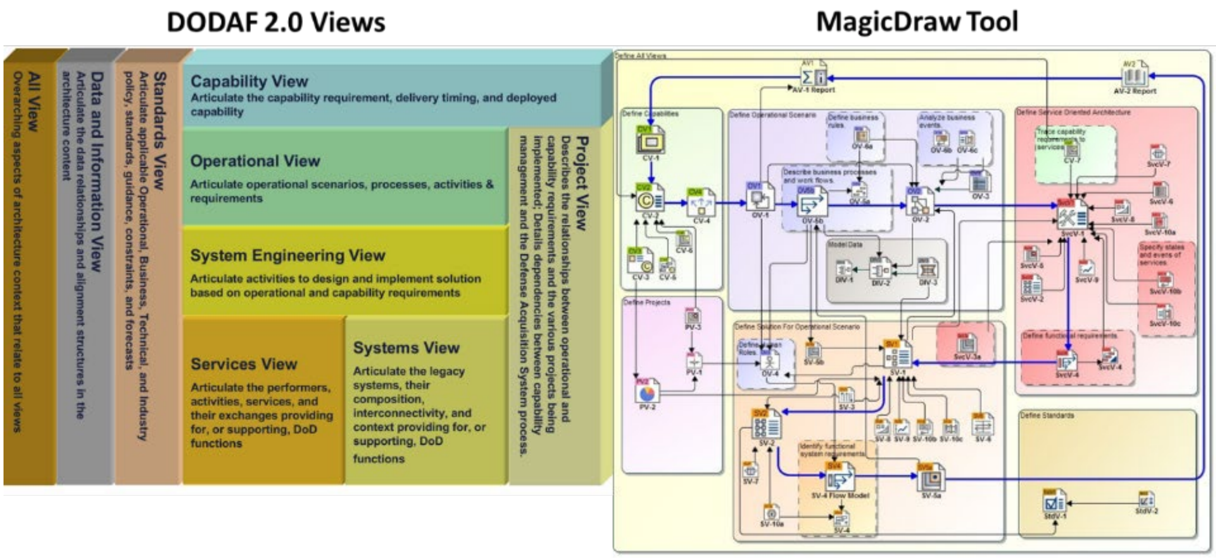
ATEC, along with most of society, is entrenched in a document-based paradigm where we version documents that are dispersed across several organizations without a unifying state-of-truth. When something changes, it is difficult, often impossible, to propagate the change. A Model Based Systems Engineering (MBSE) paradigm formalizes the application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases. The MBSE paradigm ensures that authoritative data, models, and architectures are accessible. AFC has embraced MBSE by adopting an Architecture Governance process to elaborate on the mission threads and use cases for all experimentation exercises.

The use of MBSE allows AFC to perform mission engineering. The goal of mission engineering is to compose model artifacts to enable and enhance mission assurance, protection, and resilience of critical assets. The following are the key benefits of mission engineering:

- Supports identification and prioritization of critical missions, functions, and capabilities.
    - Mission decomposition coupled with validation with assurance tests.
    - Allows mission essential capability filtering.
    - Informs prioritization of critical assets investments & potential gaps at every stage of the lifecycle.
- Informs and supports the risk management framework.
    - Supports mission assurance focused threat, vulnerability, and consequence analysis.
    - Supports capture of risks (hazards and faults).
    - Performs failure probability discovery – assurance tests coupled with risks.
    - Entire stakeholder-base participation using model and test artifacts.
- Supports optimization of risk mitigation solutions
    - Inform mitigation design and development decisions – every stage of the lifecycle.
    - Model artifacts coupled with assurance testing analyze multiple mitigation solutions.
    - Informs prioritization and investment in critical asset risk remediation and mitigation.
- Supports mission assurance assessment standardization.
    - Model artifacts coupled with verification by assurance testing sets baseline of metrics.
    - Shared assurance testing metrics informing decision-making at all DOD levels.
    - Integrates internal and external stakeholders though common assessment artifacts.

There are many types of model artifacts used within the MBSE approach. Generally, MBSE consists of a methodology, a modeling language, and a tool. AFC is using the DoD Architecture Framework (DoDAF) methodology to develop the model artifacts. A modeling language is a standard that provides a common language and notation for model elements, views, and viewpoints. AFC is using the Unified Profile for DoDAF and MODAF (UPDM) language to develop the modeling artifacts.

The figure below shows the various views of the DoD Architecture Framework (DoDAF) that are intended to facilitate integration and promote interoperability across capabilities and integrated architectures so that it can be easily understood by decision-makers. Tools are needed to manage the complex relations between views. The right side of the figure below is a visual developed using the UPDM language that shows the complex relationships between views. MagicDraw is the tool that facilitates the creation of integrated architectures with all types of relationships between elements in separate views or viewpoints.



The architectural artifacts developed by AFC will be governed by the Futures Concepts Center and hosted in the ArCADIE platform within the AFC MADE digital cloud. These architectures are intended to be the authoritative data source of all mission threads and uses cases for AFC experiments and will be a critical enabler for ATEC. ATEC will develop architects that can embed within the AFC Architecture governance processes to allow AEC evaluators to consume architecture artifacts that will inform system evaluation planning.

6.4.6. Optimize Test Capability Derivation

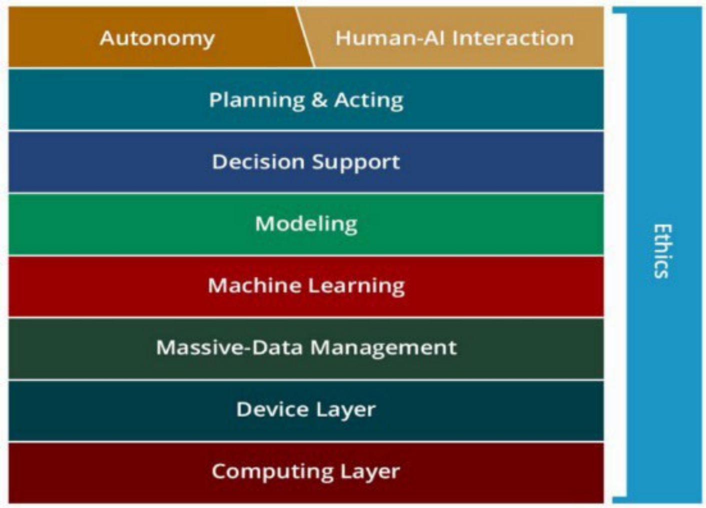
To strengthen our agility and responsiveness to modernizations initiatives, we need to target advancements to management and business intelligence (BI) tools to flexibly respond to emerging needs, rapidly deploy test products and services, and implement accelerated decision making through real time analytics. This requires a robust management layer for needs assessment, gap analysis, and solution generation with continuous monitoring to improve the T&E capability prioritization process. Implementation of advanced analytic models and tools will enable our teams to acutely sense and recognize opportunities and swiftly configure resources, information, relationships, and relevant partners. By transcending the status quo of spreadsheets and monolithic applications, teams will be adaptive and responsive by capturing knowledge during resultant shifts in the operational environment and reducing redundancies in disparate processes.

The key outcome is to improve effectiveness and efficiency of our ability to sense T&E capability needs based on modernization priorities and customer requirements and understand technology gaps resulting from infrastructure and capability shortfalls and opportunities. This models close engagement with the customer base to reduce risk in experimentation and make rapid adjustments to produces and services with end users.

- Investigate the use of machine learning applications to conduct automated analysis and clustering of requirements data to identify trends
- Identify business intelligence (BI) tools and data analysis models to facilitate requirements engineering and management processes

Appendix A: The AI Technology Stack

The below figure shows the AI technology stack define by Moore et. al[i]



Computing Layer: All artificial intelligence is built on the computer systems that came before it. This includes the systems, networks, programming languages, operating systems and interactions between devices that make computing possible.

Device Layer: The device layer is all of the sensors and components needed for machines to perceive the world around them. Traffic lights, for example, can observe traffic levels and negotiate with each other to improve traffic flow. Facial recognition systems can detect and match a contact from 600 meters away.

Massive Data Management Layer: There's so much data in the world, and it continues to grow at an explosive rate [21]. At this layer, experts work to ensure that good information is accessible, and they develop ways to use that data to locate valuable information in giant datasets.

Machine Learning Layer: Machine learning focuses on creating programs that learn from experience. It advances computing through exposure to new scenarios, testing and adaptation, while using pattern- and trend- detection to help the computer make better decisions in similar, subsequent situations. A relevant example of work in machine learning is using speech recognition technologies to identify the age, sex and location of the hoax callers that plague the U.S. Coast Guard.

Modeling Layer: AI systems at the top of the stack rely on computer modeling to understand information. Models use computers to construct and manipulate abstract representations of situations and natural phenomenon in the world. For example, new research has allowed scientist to analyze photos of people to track their facial features and recognize their emotional states.

Decision Support Layer: This layer includes technologies that help humans make decisions. Where should 500 Lyft drivers be deployed, based on information we know about events and demand? How should emergency services be distributed after a disaster? Exciting examples of research in this area include work to identify instances of human trafficking, help locate victims, and collect and synthesize enough information that trends and patterns can be discovered and used to combat the problem.

Planning and Acting Layer: Systems in this part of the stack rely on optimization, safety, the knowledge network and strategic reasoning to make the best possible decision available and learn from the information researchers give them. Though slightly less sophisticated than systems employing the blocks at the very top of the stack, planning and acting technologies still rely on advanced systems and algorithms to positively impact the world. One great example of technology that falls into this category is the national kidney exchange — a sophisticated algorithm that matches potential kidney donors with people who need transplants.

Human-AI Interaction Layer: When we create artificial intelligence in this part of the stack, we're augmenting what humans can do. These technologies make our lives easier or allow us to make faster and better decisions. One good example of work in this area is robotic arms attached to motorized wheelchairs that people with spinal cord injuries can direct with their gaze. Another exciting example is research that allows a computer system to interview a patient remotely to determine if they're depressed and need human intervention.

Autonomy Layer: AI technologies at this level focus on creating systems that make their own decisions without human intervention. These systems solve problems when humans cannot. For example, robots can search through rubble for disaster survivors, and sensors in self-driving cars can respond more quickly to impending accidents than human drivers.

Ethics: Ethics permeates the entire AI Stack. The decisions people make as they build AI systems involve serious ethical questions that we can't ignore. A vital component of AI is giving tomorrow's scientists the tools they need to perform ethical reasoning and the skills to create AI for good.

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[i] Andrew W. Moore, Martial Hebert, and Shane Shaneman "The AI stack: a blueprint for developing and deploying artificial intelligence", Proc. SPIE 10635, Ground/Air Multisensor Interoperability, Integration, and Networking for Persistent ISR IX, 106350C (4 May 2018); https://doi.org/10.1117/12.2309483