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Joint Test Concept Pilot Year II Update

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Sponsor: DOT&E

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Interim Report

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Acronyms and Abbreviations

Acquisition Innovation Research Center	AIRC
capability immersion layer	CIL
community of interest	COI
contractor testing	CT
Decision Support Evaluation Framework	DESF
Department of Defense	DoD
developmental testing	DT
Director Operational Test and Evaluation	DOT&E
end-to-end capability lifecycle	E2ECL
Implementation Plan	I-PLAN
Integrated Decision Support Key	IDSK
Joint capability demonstration layer	JCDL
Joint Test Concept	JTC
Joint Warfighting Concept	JWC
live, virtual, and constructive	LVC
Mission Engineering	ME
National Defense Strategy	NDS
operational testing	OT
peer/near-peer	P/N-P
personnel, equipment/technology, training, resources, and authorities	PETRA
system performance layer	SPL
Systems Engineering Research Center	SERC
test and evaluation	T&E
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The Joint Test Concept community of interest (COI) workshop participants were critical to ensuring the JTC outcomes meet the needs of the diverse T&E-enterprise and stakeholder population. The reports and workshop design and execution relied on input from a smaller COI working group including VTNSI, MITRE, TROIKA, GTRI, JHU-APL, and Hepburn and Sons. The VT-ARC team would like to thank all these as well as government collaborators from DOT&E, USD(R&E), and OPTEVFOR for their support and dedication to the project.

Executive Summary

The rise of peer/near-peer (P/N-P) actors suggests the Joint force could be contested in all domains during the execution of distributed, potentially non-contiguous, combat operations. Ensuring the advantage and comprehensive Joint readiness will stretch traditional test and evaluation (T&E) capabilities further than ever before. T&E must be re-imagined, placing increased emphasis on the operational and mission context in which the system under test is expected to perform throughout the system lifecycle. Therefore, shifting the way in which we think about system performance and how T&E contributes to the overall assessment of measures and outcomes aligned with complex mission webs and Joint system of systems. As such, the evaluation of a system under test must go beyond discrete T&E blocks within the program lifecycle.

Director Operational Test and Evaluation (DOT&E) outlined several lines of effort to tackle the issue of a Joint T&E environment in the Strategy Update 2022 and Implementation Plan (I-Plan). Through the Acquisition Innovation Research Center (AIRC), DOT&E contracted the Virginia Tech Applied Research Corporation (VT-ARC), in partnership with Virginia Tech National Security Institute (VTNSI), to develop a Joint Test Concept (JTC) in support of the I-Plan. This multi-year effort, initiated in FY23, developed a JTC community of interest (COI) to serve as the guiding coalition and foundation of innovation and new concept development and produced the JTC pilot which applies an end-to-end capability lifecycle (E2ECL) approach, anchored in mission engineering, reinforced by decision support tools, and supported by a live virtual constructive environment to assess material and non-material solutions' performance, interoperability, and impact to service and Joint mission execution.

The JTC pilot is driving a paradigm shift in how the Department of Defense (DoD) approaches T&E. By transitioning to a continuously iterative campaign of learning across the full capability lifecycle, it will touch the entire T&E enterprise and associated functions, data, and information artifacts for which each stakeholder is responsible. With this shift in how we approach and execute T&E, it is critical to ensure that stakeholders are speaking a common language and using a common framework for architecture and solution development and JTC implementation. This report provides an overview of the JTC foundation and structural elements as well as the overarching reference architecture and seeks to cultivate and organize a cohesive stakeholder understanding for JTC implementation.

Background

The initial development of the Joint Warfighting Concept (JWC), in alignment with the 2018 National Defense Strategy (NDS), envisioned a future where the Joint force will be contested by P/N-P actors in all domains during the execution of distributed, potentially non-contiguous, operations. The resultant future Joint force will stretch core T&E capabilities further than ever before, requiring T&E to consider more domains and be compliant to more factors relative to previous eras.

In a memo dated 18 July 2022, the Secretary of Defense directed immediate action related to "connecting JWC-related wargaming, experimentation, exercises, education, and research directly to the NDS approaches of integrated deterrence, campaigning, and building enduring advantages." Similarly, the 2022 NDS identifies several areas that impact T&E execution. These include:

- Development of new operational concepts,
- Enhancing capabilities, and
- Facilitation of elasticity and readiness in the defense ecosystem (Department employees, industrial base, and private sector/academic enterprises), particularly in relation to the acquisition process and the ability to address challenges related to obsolescence, interoperability, and cost effectiveness.

On 30 January 2023, the Secretary of Defense directed the Assistant Secretary for Defense for Acquisition as the Acquisition Integration and Interoperability (AI2) lead tasked with creating an enduring acquisition infrastructure for delivering integrated joint, system-of-system capabilities. AI2 will include the development and restructuring of policies, forums, and processes to:

1. Enable the delivery of integrated defense capabilities, leveraging Department and service-specific system acquisition;
2. Drive adoption of threat-based mission thread analysis to inform acquisition, resourcing, and requirements decisions; and
3. Support acquisition portfolio reviews to drive resourcing and enterprise decisions.

AI2 is intended to address the interoperability disconnects that result from the lack of Joint capability acquisition management and is therefore highly relevant for Joint T&E and the JTC.

In support of strategic guidance, DOT&E developed the DOT&E Strategy Update 2022 and I-Plan which identified five pillars that support the desired end state. DOT&E contracted the AIRC through the Systems Engineering Research Center (SERC), a Department of Defense sponsored University Affiliated Research Center, to develop a Joint Test Concept (JTC) that integrates the best T&E practices in support of the I-Plan desired end state and aligns with the JWC and other key strategic guidance. As shown in

Figure 1, although the pillar one “test the way we fight” lead is responsible for JTC development, the JTC impact reaches across all five pillars.

Year I efforts of the multi-year JTC project worked to reimagine T&E, placing increased emphasis on the service and Joint operational and mission context in which the system under test is expected to perform. This in turn shifted the way we must think about system performance and how T&E contributes to the overall assessment of measures and outcomes aligned with complex mission webs[1] and Joint system of systems.

Throughout the first year, the AIRC VT-ARC study team cultivated a JTC COI across the diverse Joint T&E stakeholder groups that expanded from nine to 26 member organizations. The COI members worked collaboratively to conceptualize the future of Joint T&E both within the current structural constraints and restraints and a more idealized future where key roadblocks to efficient T&E could be mitigated or removed. This continued in year II where the COI expanded to nearly 60 organizations. The COI informed the JTC Pilot and overarching reference architecture over the course of four large and several smaller planning workshops.

The VT-ARC study team recognized that the JTC represents an innovation that could radically change the way T&E is envisioned and executed. As such, this report contains discussion on innovation and leading change to support JTC implementation following pilot validation.

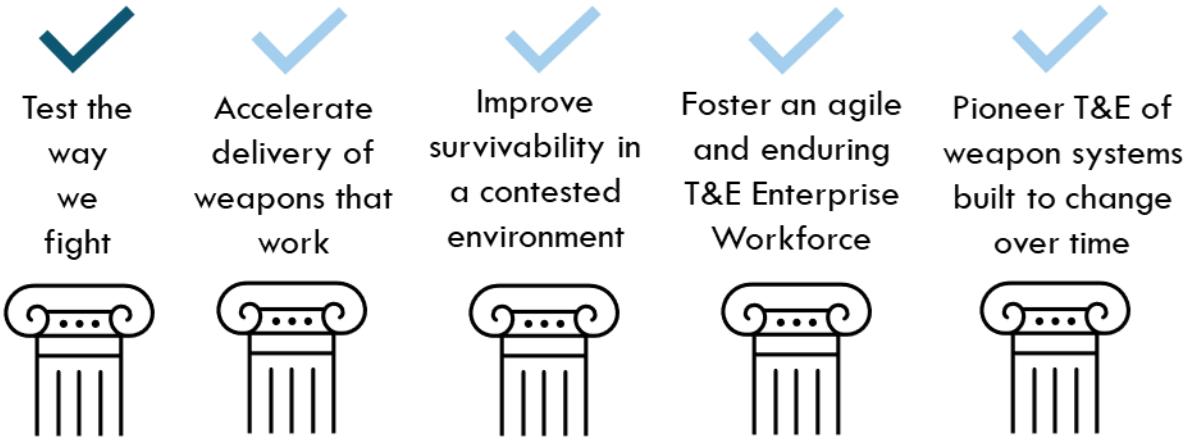

Figure 1: JTC I-plan Impact

[1] A mission web is a layered set of mission engineering threads with a shared mission architecture, that provides multiple pathways to achieve mission success as defined by the success criteria. A Kill web is a specific type of mission web featuring the Find, Fix, Track, Target, Engage, and Assess (F2T2EA) architecture.

Leading Change

Dr. Bruce Morris, WARCOM Strategic Capabilities Office Liaison, identified five factors that inform force capability and capacity, and therefore enhance mission effectiveness. Together these factors (personnel, equipment/technology, training, resources, and authorities) form the PETRA framework. Friendly and adversary changes in or innovation related to any one or multiple PETRA factors are likely to either improve or decrease mission effectiveness. It is important then to fully understand innovation.

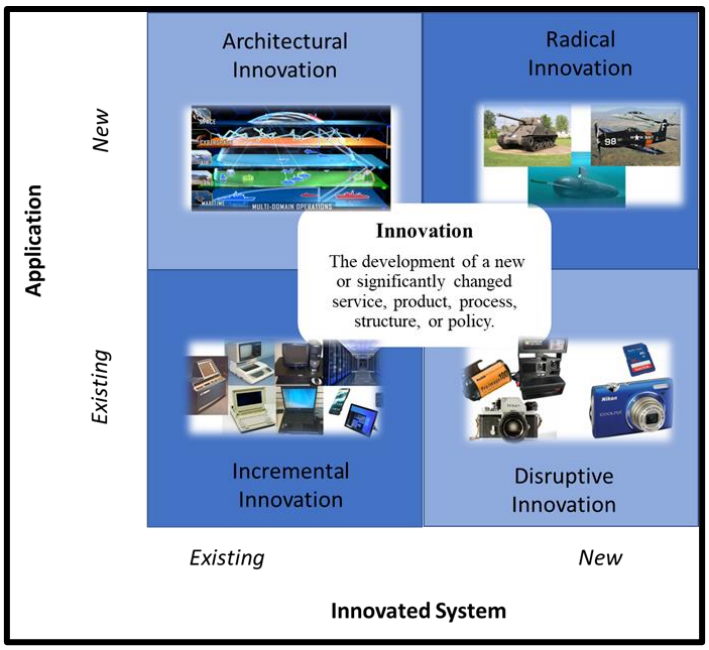

Figure 2: Innovation Matrix

Innovation is defined as "development of a new or significantly changed service, product, process, structure, or policy. Adoption occurs when change agents have identified, developed or acquired, integrated, and leveraged the value of an innovation. Change agents include innovators, facilitators, leaders, and users."[i] Innovation adoption is complete when innovation change agents identify, develop or acquire, integrate, and leverage the value of a new or significantly changed service, product, process, structure, or policy.

Legacy sectors are structured to resist or block innovations that radically change or disrupt their model. Without a forcing function, such as an impending high intensity P/N-P conflict, the services within the Department function as legacy sectors, innovating in ways that align with their perceived role in our nation's defense and with a vested interest in protecting their paradigm.[ii] As a result, the defense acquisition system successfully integrates incremental[2] and architectural[3] innovations but often struggles with radical[4] and disruptive[5] innovation integration. Effectively bringing change via innovative concepts, such as the JTC, to a legacy sector presents a complex challenge.

Additionally, while the JTC itself represents an innovation that could impact authorities, policies, and resourcing; in the near-term there are unlikely to be significant changes to these PETRA factors. Therefore, the greatest impact to mission effectiveness will be via

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[2] Incremental innovations create minor improvements to existing programs or products as occurs during standard weapon life cycle replacement.

[3] Architectural innovations combine existing innovation categories' components in a novel way, such as with the Joint Warfighting Concept.

[4] Radical innovations create a new service, product, process, structure, or policy that changes the way we defend our nation such as the invention of the tank, airplane, and submarine.

[5] Disruptive innovations create a new service, product, process, structure, or policy that creates an outsized impact on an existing system such as artificial intelligence.

training and equipment/technology innovations. These two factors are fully intertwined as the adoption of any new equipment/technology will require training and may involve updates to tactics, techniques, and procedures informing training more broadly.

With the JTC, T&E will play a major role in ensuring PETRA innovations can be adopted and integrated at the speed of relevancy. As a result, JTC study development and implementation require the application of techniques known to foster innovative thinking across the entire spectrum of change agents as well as integrating considerations for adoption latency, resistance, and leading change. It is the inclusion of these leading change principles that will provide the potential for effective JTC implementation, facilitate future innovation adoption, and enhance mission effectiveness.

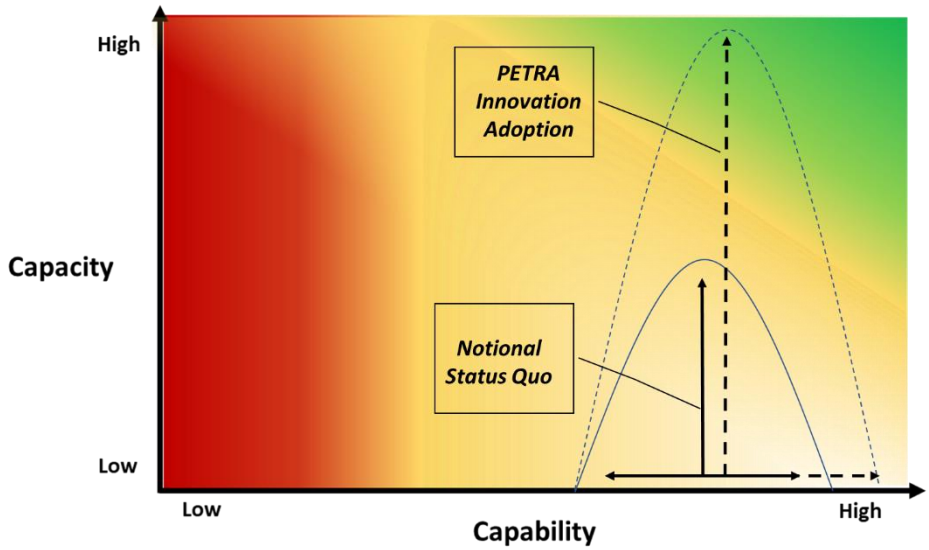

Figure 3: PETRA Impact

Leading change, particularly in relation to a concept that impacts a wide range of stakeholders, requires the application of a structured strategic framework. John Kotter's "Leading Change" model has been in use for four decades, most recently republished in 2012. Shown in Figure 4, the eight-stage framework identifies the key milestones or goals that must be achieved to successfully bring meaningful change to an organization.

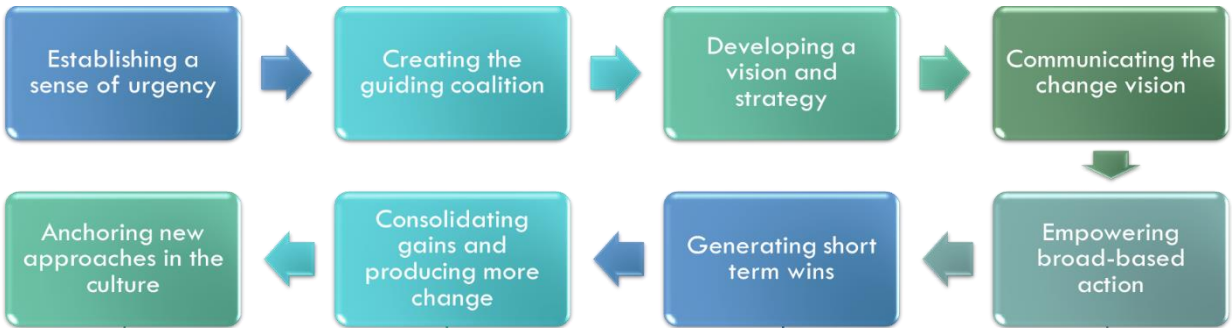

Figure 4: Kotter's Leading Change Framework

When leading change, there is risk that, without careful consideration of second and third order effects, change could create new and unexpected challenges.[6] Some change-related negative outcomes cannot be mitigated and therefore the risk associated with removing barriers to change must be carefully assessed. As such, to effectively lead change you must understand why things are as they are and consider ways in which change could create new issues. The JTC pilot recognizes the importance of mitigating negative outcomes and therefore will focus on generating short term wins within the existing construct before recommending significant change to structural barriers to full JTC implementation.

[6] Historic examples of change that resulted in negative outcomes include the rise of the mafia and associated violence during prohibition, the culling of the wolves in and around Yellow Stone national park which removed the elk's apex predator allowing the population to grow to a size that created significant impact to the environment, and an early 1970's era clean air initiative that banned New York apartment buildings from using incinerators to dispose of trash which resulted in a skyrocketing rat population. While the recent reintroduction of wolves has helped mitigate the environmental damage, the mafia-related violence and influence significantly exceeded prohibition's repeal, and the rat population has continued to grow exponentially despite ongoing efforts to reverse the trend.

The JTC pilot applies an end-to-end capability lifecycle approach, anchored in mission engineering, reinforced by decision support tools, and supported by an LVC environment to assess material and non-material solutions' performance, interoperability, and impact to service and Joint mission execution.

Recognizing that decision informing T&E data predates the program of record, the COI determined that the JTC must apply an end-to-end capability lifecycle (E2ECL) approach. The capability lifecycle initiates with the identification of a mission or capability need. The system lifecycle initiates with the down-select of a solution approach, followed by a commitment to design, develop, and deliver that solution (or solutions) following a defined acquisition pathway. The capability lifecycle continues beyond system deployment, with a need for ongoing T&E and performance monitoring in the field to support long-term sustainment, operational resilience, and Joint capability assessments. This approach enables capability portfolio management which in turn ensures appropriate operational redundancies in support of complex, operational mission webs, and enables ongoing integration of emergent requirements following fielding and throughout sustainment, across the capability portfolio.

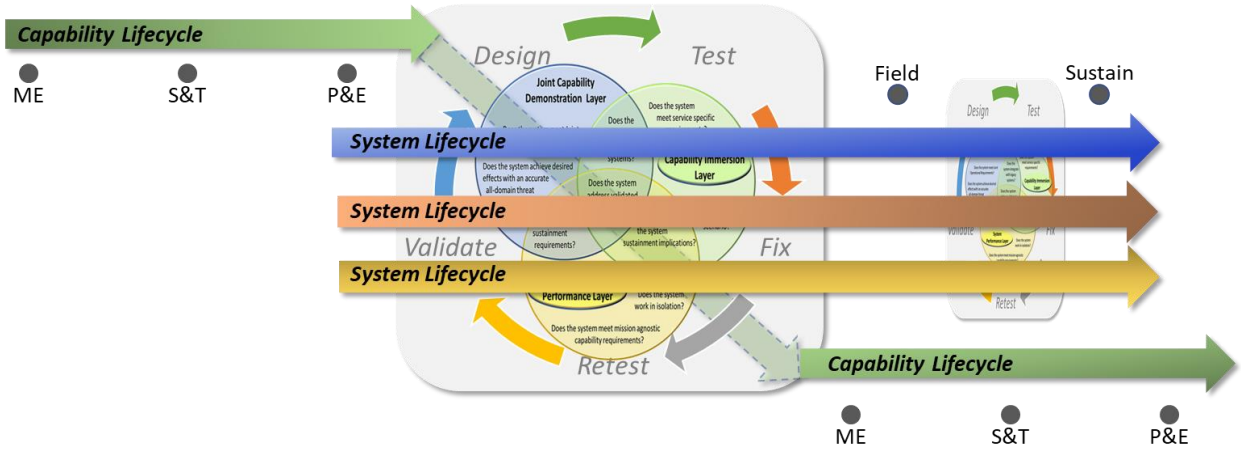

Figure 5: End-to-end Capability Lifecycle

In addition to the E2ECL approach, the JTC pilot envisions a two-part framework comprised of foundation and structural elements. The foundation consists of the three non-hierarchical layers, the system performance layer (SPL), capability immersion layer (CIL), and Joint capability demonstration layer (JCDL). The most flexible of all the layers, the SPL assesses the system under test's impact on known capability gaps within an operationally agnostic mission engineering thread. This layer ensures the system meets the success criteria for performance in isolation and in the predefined system of systems. The CIL assesses the system under test's performance against pre-determined success criteria within a set of validated mission threads executed in realistic operational environments. The JCDL assesses the portfolio of systems of systems in an operationally

representative (theater specific), multi-domain, Joint (combined), and potentially noncontiguous environment, to include a realistic adversary or threat and validated Joint mission webs. This provides the opportunity to assess the required performance parameters for fielding and to identify performance gaps in specific scenarios that must be addressed post-fielding, early in sustainment. Together the three layers provide four focus areas: system functional focus, system of systems & capability focus, service mission focus, and Joint all-domain mission focus. This approach enables consideration for Joint performance throughout the capability life cycle ensuring a service-specific system will meet both service performance requirements and address Joint interoperability needs.

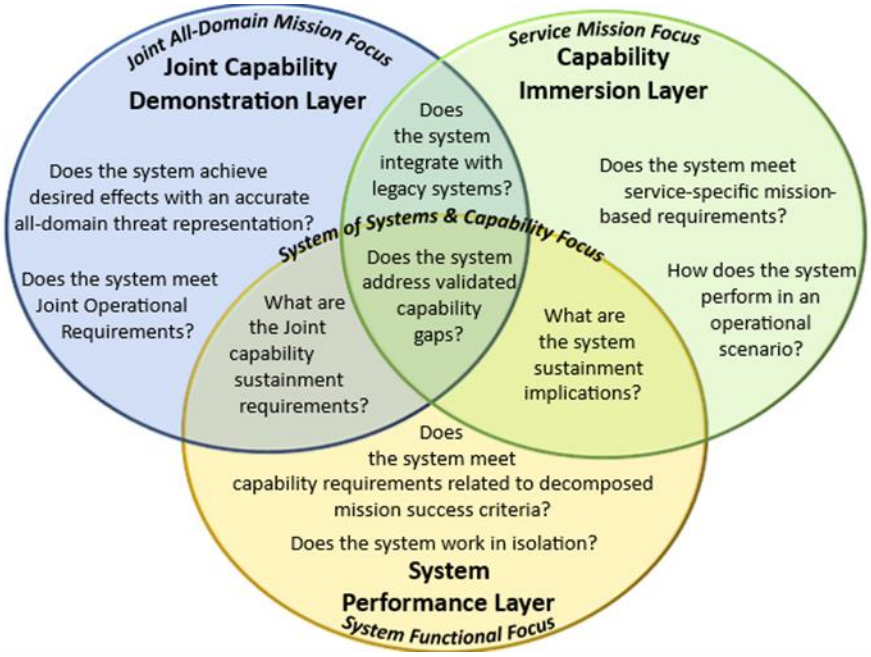

Figure 6: Non-hierarchical Foundational Layers

While the existing T&E structure is executed in a linear and unidirectional pathway wherein an assessment failure can be catastrophic to the program, the JTC recognizes a system may enter the formal JTC T&E assessment process at any phase of development, particularly if the developer has historic assessment data that may be integrated into the JTC T&E formal assessment. As such, the iterative JTC workflow is neither linear nor unidirectional.

The JTC foundation is based upon the assumption that the current acquisition process and associated practices for assessing systems will continue with the existing construct of contractor testing (CT), developmental testing (DT), and operational testing (OT); although to achieve the full benefits of the JTC vision, changes across the T&E enterprise to create a more iterative and flexible approach is necessary. Additionally, while the COI generated multiple recommendations for policy changes that would enable implementation, the JTC assumes that the current authorities and policies were unlikely to shift radically in the short-term but could well adjust in time. Therefore, the JTC is founded on the principle that it must provide quick wins within and in some cases despite the current system while envisioning a pathway for change.

To accomplish this flexibility the JTC does not use the current vernacular (e.g., DT, OT, CT) and instead looks to the three overlapping foundation layers that ensure the system meets performance requirements in isolation, within the pre-defined system of systems utilizing a mission engineering thread construct, and in a live, virtual, and constructive

(LVC) Joint multi-domain environment with realistic adversary representations and accurate mission webs.

While the JTC foundation is comprised of the three non-hierarchical layers which require flexible and iterative, the JTC structure has seven critical elements: 1) organization, 2) training and education, 3) authorities and policy, 4) resourcing, 5) end-to-end capability lifecycle continuity flow, 6) data strategy, and 7) the T&E environment. Described as fully separate categories, the reality is that there are many areas where the boundaries between structural elements are blurred and others where there is significant overlap. When combined with the foundational layers as pictured in Figure 7, they inform the development of a capability specific JTC T&E strategy.

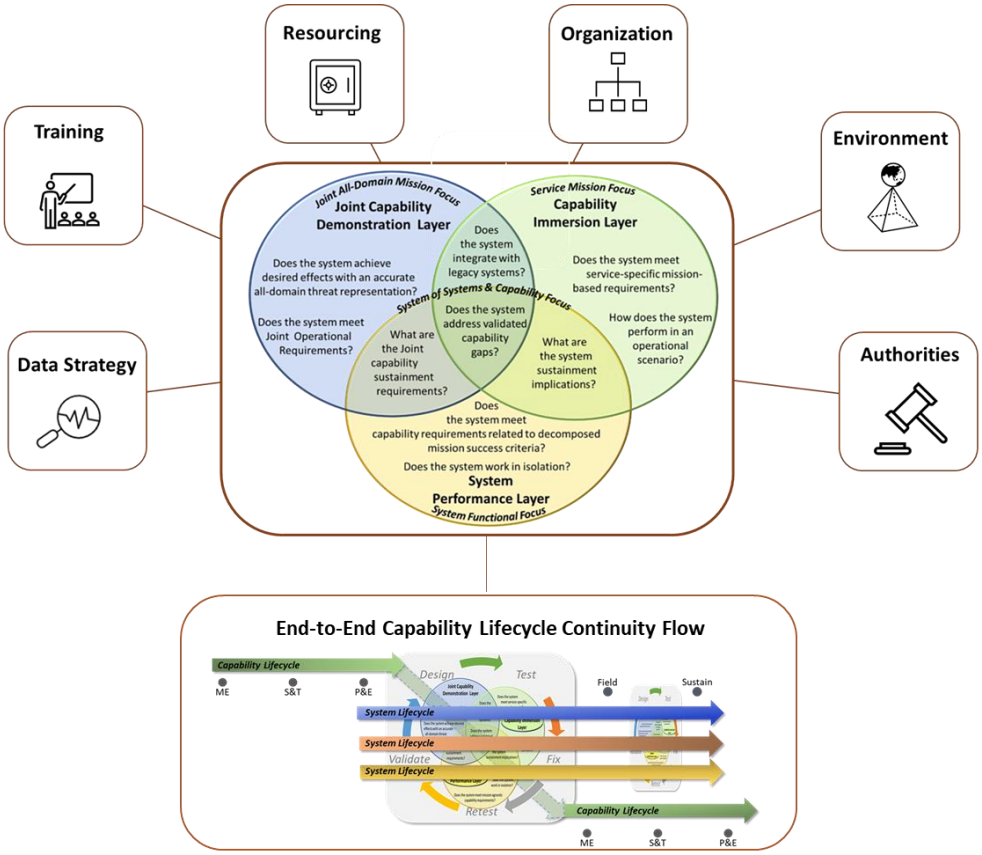

Figure 7: JTC Structural Elements and Layers

Mission Engineering

Understanding that T&E alignment with complex mission webs and Joint system of systems requires the development of a series of integrated end-to-end tasks linked by interoperable interfaces of specific systems, technologies, and/or people which are required to successfully achieve a desired outcome within a given tactical situation, the COI identified mission engineering as a critical JTC component. The JTC foundation aligns with the existing DoD reliance on systems engineering and nests within the systems engineering hierarchy. This same hierarchy integrates Mission Engineering (ME), Digital Engineering, and other systems engineering-related disciplines including project and program management.

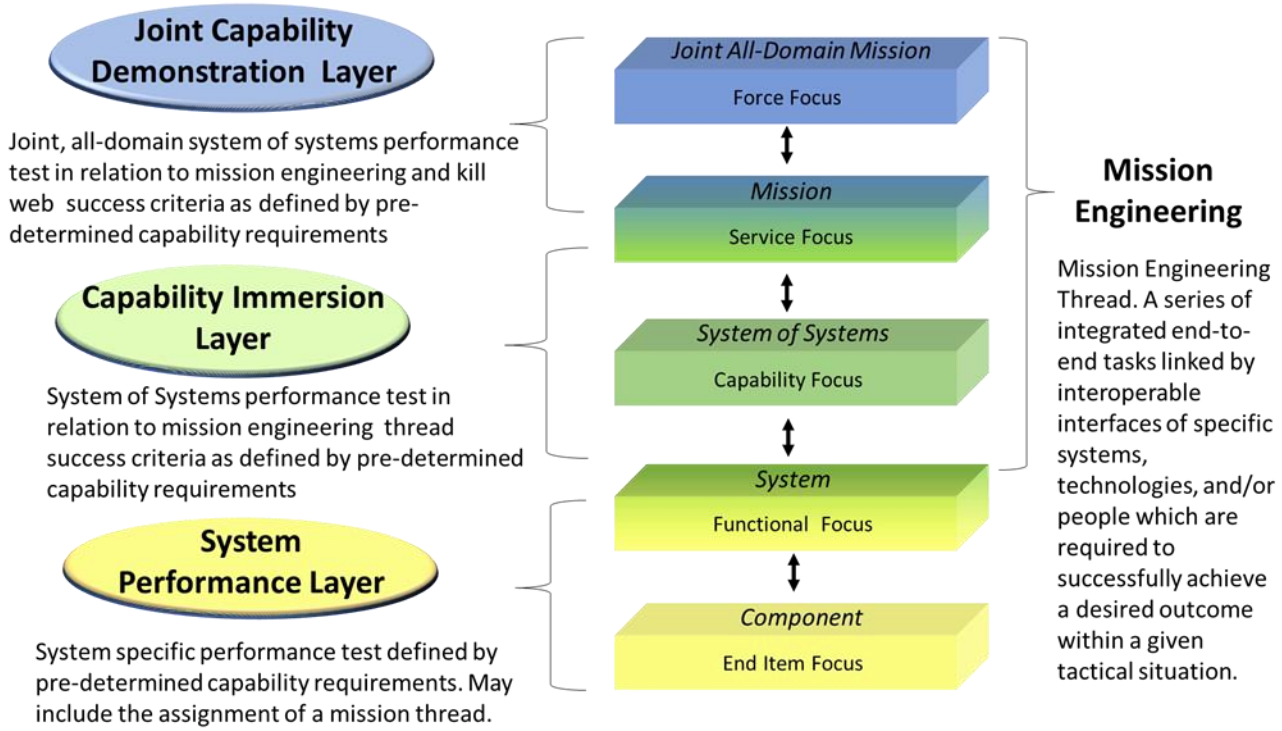

Figure 8: JTC Layers in relation to Systems and Mission Engineering Hierarchy

Mission Engineering is defined as "an interdisciplinary process encompassing the entire technical effort to analyze, design, and integrate current and emerging operational needs and capabilities to achieve desired mission outcomes."[iii] ME results in a systematic, quantifiable, and timely analysis of operational planning concepts and emerging threats to evolve end-to-end, system-of-systems architectures and capability attributes to define requirements. It establishes data driven technical architecture baselines and builds upon a systems engineering framework requiring authoritative data and a common structure.

The JTC Pilot recognizes that mission engineering must occur both at the beginning and iteratively throughout the capability life cycle. The iterative inputs allow for the flexibility necessary to update requirements, including Joint considerations, as new innovations and adversary capabilities change the operational landscape. To ensure efficient emergent requirement integration, contracting officers must be trained in the agile-like approach to ensure contracts are written in a way that allows for reasonable changes or timed to integrate larger deviations.

Furthermore, the COI agreed that ME is the optimal background and synthesizer for the future JTC simulation and, given time and development, could facilitate the sustainment of a new Joint methodology for acquisition decision-making in support of tomorrow's operational environment. The convergence of JTC testing layers that focus on overlapping nuances of system performance, service capability immersion, and Joint All-Domain capability integration pair neatly with the architecture and traceability provided by the ME process.

While ME provides a connective pathway to a traceable architecture, there is no existing capability or guiding activity to ensure a repeatable and iterative ME process will occur at the Joint level. To effectively incorporate ME into the Joint acquisition process, several assumptions must be made. First, ME will advance the JTC. Second, ME is here to stay; although Congress incorporated the practice in 2017 language (Section 855), the DoD must still grow a constituency of users. Third, the purpose and potential of a Joint endeavor is defeated when each individual service attempts to create its own mission engineering thread to accomplish a given mission entirely by itself. And fourth, a Joint community needs to pull the services out of isolated acquisition boxes to successfully fight against a large volume enemy.

Next, ME must bring together technologists and operators. It is a process and expertise, not a person or a checklist. There is a relationship between culture, strategy, and the way we fight. Current acquisition methods are not translating to the operational side of the house. ME is interdisciplinary by nature, and its mission threads must generate linkages through cross functional humans that connect the acquisition process and experimentation between operator and engineer. Some few organizations have already introduced ME working groups and practitioners' forums, as well as ME executive steering councils between Department flags and SES. We must transform our culture to embrace and implement it.

JTC Pilot Functions

The JTC Pilot envisions T&E across a campaign of learning through the iterative execution of six primary functions, beginning early in the capability lifecycle with the formulation of the T&E and Data strategies that guide the rest of the functions. These strategies capture the overarching plans, process steps, implementation requirements (i.e., data, information, resource, timing, and process requirements), and related resourcing needs for a specific JTC campaign of learning. These strategies create the pathway for the successful execution of the remaining JTC functions displayed in Figure 9.

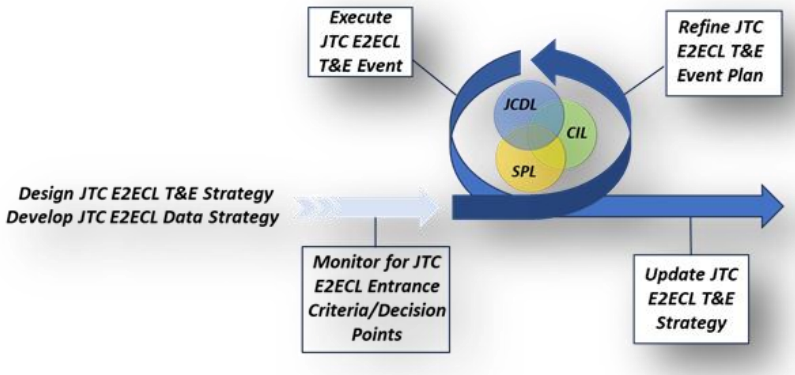

Figure 9: JTC Functions

The team structured the JTC Functions as an iterative loop, emphasizing that a JTC T&E campaign of learning requires iterative execution and feedback loops between functions to ensure all JTC Layers (SPL, CIL, and JCDL) and JTC structural elements (i.e., Organization, Resourcing, Authorities, Training, End-to-End Lifecycle Continuity Flow, Data Strategy, T&E Environment, and T&E Strategy) are adequately incorporated in T&E activities across the capability lifecycle.

The “Design JTC E2ECL T&E Strategy” function is the first major step, following initial ME, and will be revisited and executed as a JTC test program iterates across the lifecycle. The JTC E2ECL T&E Strategy captures and tracks key T&E questions, related decision points, and associated data/information requirements that will be used to drive, coordinate, and integrate T&E activities and assessments at all three JTC Layers and across JTC Structural Elements. These questions should align with, plug into, and ultimately integrate the key program of record (once created) and captured in decision support tools, as appropriate.

The COI identified risk management as a blind spot not specifically addressed in the JTC pilot. The potential testing issues, such as budget shortfalls, resource unavailability, and changing scenarios, pose many risks that must be identified and mitigated appropriately. In addition to these traditional risks, artificial intelligence poses new risks and will need to be considered. Similarly, uncertainty quantification is necessary to gain insights into the testing credibility. This is particularly important when computational models are used to evaluate a system.

While not called out as separate functions, risk management and uncertainty quantification should be incorporated into any JTC T&E Strategy. A solidified risk management plan will be vital to T&E early in the capability lifecycle and to inform the program manager’s risk management plan if the system undertest matures to a program of record.

The “Develop a JTC E2ECL T&E Data Strategy” function occurs either concurrently with or directly following the development of the JTC E2ECL T&E Strategy. This function details the strategy, requirements, and action plan for managing data, information, and knowledge surrounding JTC activities to ensure data is visible, accessible, understandable, linked, trustworthy, interoperable, and secure (VAULTIS) compliant throughout the entire campaign of learning.

Functions 3-6 occur iteratively throughout the capability lifecycle, with some sequential relationships between functions. Function 3 “*Monitor for JTC E2ECL Entrance Criteria/Decision Points*” actions the JTC T&E strategy formulated process for monitoring decision points and events. The “Update JTC E2ECL T&E Event Test Plan” function is prompted once the entry criteria/decision point for a distinct JTC joint-level test event OR if the JTC T&E program reaches a planned/known test event within the timetable specified in the JTC T&E Strategy. Therefore, Function 3 can have a sequential relationship with Function 4. The “Execute JTC E2ECL T&E Event” function occurs when a distinct JTC joint-level test is planned. The JTC T&E program will organize and conduct the planned test event and then use the JTC T&E and Data strategies to conduct a comprehensive assessment based on outcomes against the key T&E questions, decision points, and related evaluation criteria.

The “*Refine JTC E2ECL T&E Strategy*” function occurs iteratively throughout the entire campaign of learning. This function seeks to integrate new information to inform refinements to any of the strategies, plans, processes, and related planning artifacts created throughout the execution of Function 1-5. This serves as an important feedback loop to ensure the JTC E2ECL T&E process is adaptable and flexible.

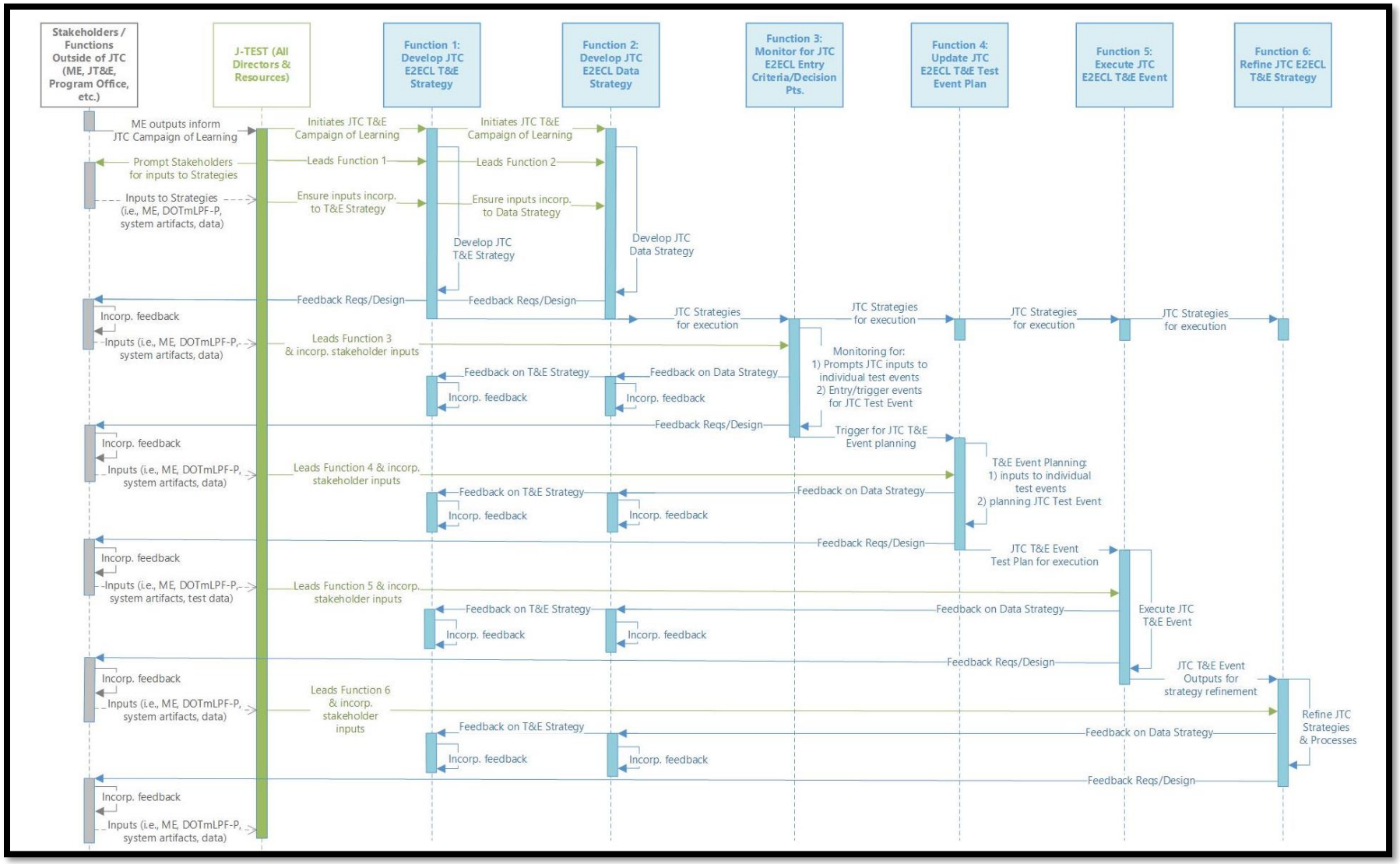

Figure 10: JTC Functions Sequence Diagram

JTC Campaign of Learning

The iterative nature of mission engineering and JTC execution throughout the capability life cycle shifts away from the binary pass/fail T&E construct, allowing for progression towards fielding despite some system attributes not meeting performance requirements. This requires both T&E and data strategies that support a T&E campaign of learning approach by finding efficiencies and reducing resource commitments such as service and Joint operational and training exercises, digital models, and LVC environments, and well written contracts. Additionally, the JTC recognizes the existing and developing decision support tools designed to facilitate data informed decisions, specifically the Integrated Decision Support Key (IDSK) and the Decision Support Evaluation Framework (DSEF).[7] MITRE's DSEF supports decisions related to developing capabilities beginning early in the Science and Technology (S&T) phase of the capability lifecycle. While the IDSK,[8] a multi -organization effort, is tailored to support a specific program of record and a defined acquisition pathway, the DSEF can provide broader capability portfolio management decisions by providing data across multiple systems in different stages of the capability lifecycle. As such the JTC assumes that although discrete decision support tools, the DSEF and IDSK will be able to share data and serve as the supporting architecture for the JTC data strategy.

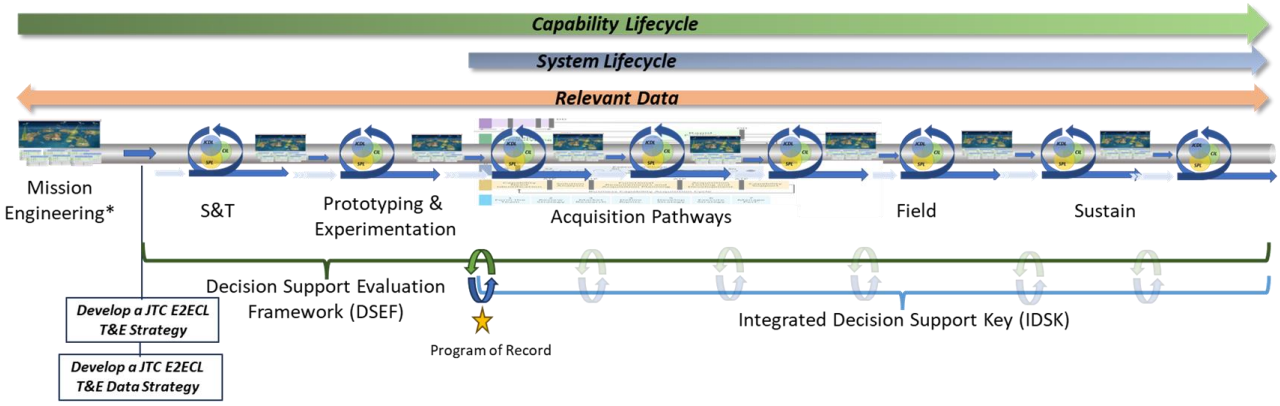

Figure 11: JTC Pilot Campaign of Learning

The resultant JTC pilot applies an end-to-end capability lifecycle approach, anchored in mission engineering, reinforced by decision support tools, and supported by an LVC environment to assess material and non-material solutions' performance, interoperability, and impact to service and Joint mission execution.

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[7] MITRE presented the DSEF as an expansion of the IDSK's critical thought process throughout the full capability delivery continuum (i.e., to the left and right of acquisition program of records). The critical thought process defines and relates decisions and decision-maker information needs in the form of questions, to operational and technical capabilities, and to data sources (e.g., test, M&S, exercise, experiments, etc.) for the capability evaluation and decision support.

[8] GTRI, JHU/APL, MITRE, VT-ARC, and VTNSI

JTC Pilot Reference Architecture Overview[9]

*A **reference architecture** is an authoritative source of information about a specific subject area that creates a common baseline of understanding amongst stakeholders and thus guides and constrains the instantiations of multiple architectures and solutions.*

The JTC pilot is driving a paradigm shift in how the DoD approaches T&E from discrete T&E blocks within a program lifecycle to a continuously iterative campaign of learning approach. The JTC foundation layers span both the capability and system lifecycles, and therefore touch all the T&E enterprise, stakeholders, and associated functions, data, and information artifacts for which each stakeholder is responsible. With this shift in how we approach and execute T&E, it is critical to ensure that stakeholders are speaking a common language and using a common framework for architecture and solution development and JTC implementation.

An overarching reference architecture framework provides strategic elements and guidance for detailed reference, data, and solution architectures to follow. From a design and engineering perspective, this guides separate design teams to make "compatible design decisions and identify interdependency of key design decisions."[iv] From a capability and enterprise-wide perspective, the high-level reference architecture enables robust, scalable, interoperable, and repeatable JTC implementations.

JTC reference architecture should not complicate the T&E processes, artifacts, or stakeholder roles and responsibilities. Instead, it cultivates and organizes a cohesive stakeholder understanding for JTC implementation. It seeks to build upon and leverage existing Joint, mission, and capability-based policies, authorities, and lifecycle artifacts to achieve efficiencies. This ensures adequate Joint perspective and equities are incorporated iteratively and effectively. The COI must continue to identify ways in which the JTC pilot could create such complications.

The following overview is not intended to serve as a complete representation of the of the 10 JTC reference architecture components. The full description can be found in the JTC Reference Architecture Workshop Report

1. **JTC Vision –** The JTC pilot envisions a T&E enterprise that applies an end-to-end capability lifecycle approach, anchored in mission engineering, reinforced by decision support tools, and supported by an LVC environment to assess material and non-material solutions' performance, interoperability, and impact to service and Joint mission execution through a fully integrated and coordinated T&E campaign of learning.

[9] For a more detailed description of the JTC Reference Architecture please see the JTC Reference Architecture Workshop Report.

2. **Strategic Purpose** – The overarching JTC reference architecture provides a strategic framework to guide JTC process, architecture, and strategy formulation. In doing so, this JTC reference architecture – and future detailed architectures and implementations– seeks to ensure data is visible, accessible, understandable, linked, trustworthy, interoperable, and secure (VAULTIS)[v] across existing and emergent Joint mission (kill/mission) webs for all systems under test throughout the entire capability lifecycle.
3. **Scope** – This overarching JTC reference architecture takes a high-level perspective of JTC process, architecture, policy, standards, and strategy. JTC implementation will require a concerted and coordinated effort across all stakeholders to define and align T&E strategies, functions, processes, mission and system modeling, and data and information artifacts to build upon this reference architecture in the development of interoperable and integrated implementations and solution architectures. There will likely be lower-level implementations and solution architectures unique to each stakeholder community, but the linkages and interdependencies among these are critical to and aligned with ensuring interoperability toward the JTC common vision.
4. **Stakeholders, Intended Use & Audience** – Joint capability gap analysis, integration, and development community including:
    - Mission engineering community
    - Intelligence & Threat representation community
    - R&E, S&T community
    - Acquisition community
    - Contracting community
    - Requirements community
    - Capability portfolio management community
    - Service stakeholder community
    - Program management community
    - Engineering community
    - T&E community
    - Logistics and sustainment community
    - Operational user community
    - Joint-Test & Evaluation Strategy Team (J-TEST) office[10]

[10] The JTC Pilot FY22 workshops determined the need for a Joint-Test & Evaluation Strategy Team (J-TEST) office with the requisite authorities and funding to ensure Joint T&E is executed to inform both system fielding and modernization decisions in addition to system integration into plans. The COI

5. **JTC Functions –** The six iterative JTC Functions critical to JTC T&E Campaign of Learning execution.
6. **Guiding Principles** – The guiding principles capture the high-level rules, culture, and values important to and impacting JTC implementation. Guiding principles are essential to developing a baseline of understanding across stakeholders of the expectations and needs relating to JTC implementation. These principles are used to drive the selection of technical positions and patterns. This section will be expanded upon in more detail as the JTC Pilot moves forward in implementation and the development of subsequent, nested reference architectures and implementations.
7. **Technical Positions** – Technical positions are essential to develop a baseline understanding of what guides, constrains, and restrains JTC campaign of learning activities. As emphasized by the JTC COI, there are many guiding documents across stakeholders, each with specific purpose and contexts for use. It will be important to understand the linkages between the various guiding documents and their impact as a control or input on JTC functions. This will enable the reconciliation of points of divergence and streamline processes for successful and efficient JTC implementation.
8. **Patterns & Templates** – Emphasized in the Guiding Principles, a successful JTC T&E campaign of learning will require coordination, synchronization, interoperability, and integration across a wide network of stakeholders. Each stakeholder has roles and responsibilities, and formal and informal methods, tools, and templates for architecture, data, information, and knowledge representation and capture (e.g., System Modeling Language (SysML)).
9. **Vocabulary** – Provides critical JTC terms, acronyms, and definitions. See Appendix D for the current list.
10. **Integration Definition (IDEF0) Functional Process Modeling Diagrams** – Depicts the functional relationships and process associated with executing each of the iterative JTC Functions using industry standard IDEF0 diagrams. The COI determined that robust modeling-based software with an underlying database and traceability capabilities should be used in the future.

envisioned seven separate but overlapping J-TEST lines of effort, each featuring a director: environment, security, strategy, integration, communication, and information. These J-TEST directors are covered more extensively in the JTC Pilot August 2023 report. A personnel director was added following the 7 February workshop.

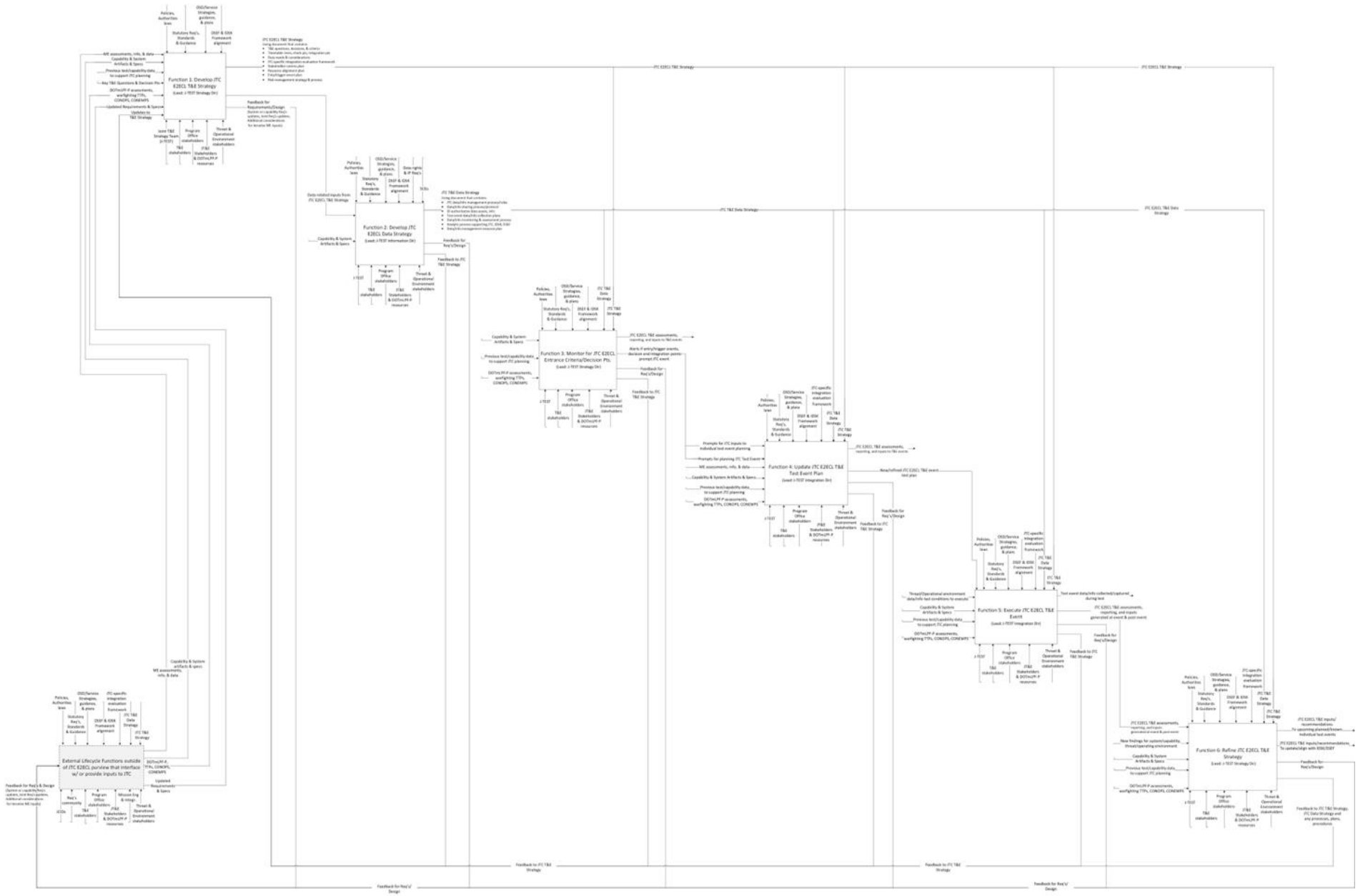

Figure 12: . Full Integration Definition (IDEF) Functional Process Modeling Diagram

Conclusions and Recommendations

The rise of P/N-P actors suggests the Joint force could be contested in all domains during the execution of distributed, potentially non-contiguous, combat operations. Ensuring the advantage and comprehensive Joint readiness will stretch traditional T&E capabilities further than ever before. T&E must be re-imagined, placing increased emphasis on the operational and mission context in which the system under test is expected to perform throughout the capability lifecycle. Therefore, shifting the way in which we think about system performance and how T&E contributes to the overall assessment of measures and outcomes aligned with complex mission webs and Joint system of systems. As such, the evaluation of a system under test must go beyond discrete T&E blocks within the program lifecycle. It must be carried out across both capability and system lifecycles, within context of expected contributions service and Joint effectiveness.

The JTC pilot is driving a paradigm shift in how the DoD approaches T&E shifting to a continuously iterative campaign of learning approach across the entire capability lifecycle and therefore touches the entire T&E enterprise and associated functions, data, and information artifacts for which each stakeholder is responsible. With this shift in how we approach and execute T&E, it is critical to ensure that stakeholders are speaking a common language and using a common framework for architecture and solution development and JTC implementation.

The JTC multi-year effort is ongoing. The upcoming JTC simulation workshop (12 June 2024 and the JTC Implementation workshop (July/August 2024) will continue to identify and address shortfalls in the JTC Pilot. Additionally, close coordination with the JT&E office will expand the COI to ensure the circle of competence is representative of all necessary competencies.

Appendix A: Community of Interest

DOT&E and VT-ARC determined the best initial step in the JTC development process was to create a JTC community of interest (COI) to serve as the foundation of innovation and new concept development. The establishment and growth of a diverse JTC COI ensures the JTC addresses challenges and provides value across stakeholders, including industry partners. Starting with nine organizations the COI expanded to 26 by the end of Year I. The diverse participants represented a comprehensive circle of competence that ensured a wide scope of expertise informed the JTC pilot development.[11]

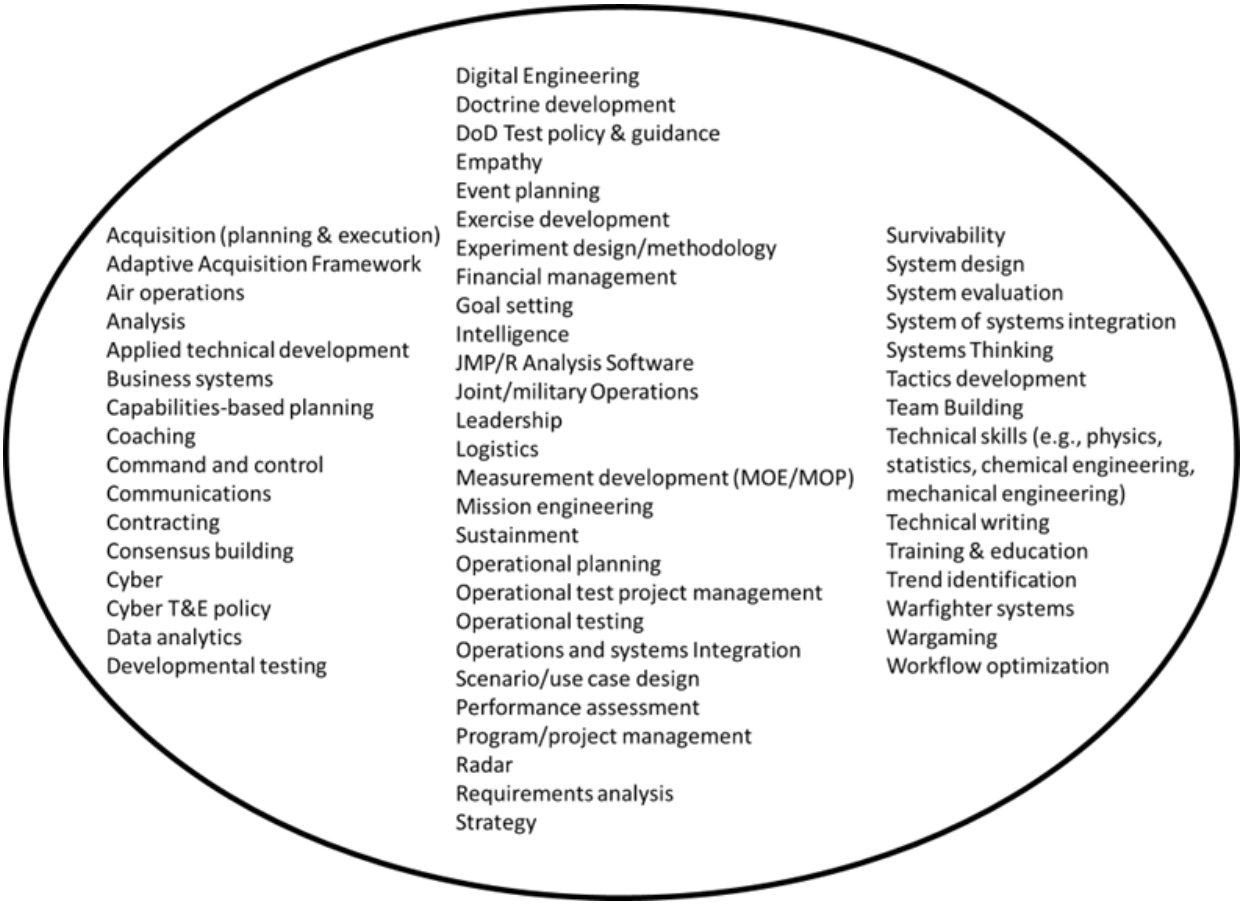

Figure 13: Year I Circle of Competence

The COI expanded during year II, adding about 20 member organizations and sub-organizations, targeting to cover gaps and create redundancies particularly related to the Adaptive Acquisition Framework, contracting, digital engineering, Joint operations, and mission engineering. A total of 60 participants from the COI registered to participate in

[11] The circle of competencies surrounding the COI reflects that of the JTC Year I effort. COI competencies have expanded through the JTC Year II effort in areas including live-virtual constructive (LVC) test conduct and integration, mission engineering, data storage and management, security, capabilities-based T&E, mission-based T&E, policy and guidance, joint operations, and system design.

the first workshop for year II, an increase of nearly 30 attendees over Year I. The COI member organizations COI include:

- AF SDPE/ DAF CMSO
- AFRL
- AIRC
- ASN RDA
- ATEC
- CDST
- Chief, Joint Assessment Division
- DAF Test & Evaluation, Programs and Policy (DAF/TEP)
- Deloitte
- DEVCOM
- DIA
- DIA/ST
- DOT&E
- DOT&E SIPET / ATEC-YPG
- GTRI
- HAF A5/7
- Hepburn and Sons, LLC
- HII Mission Technologies (Supporting NSWC PHD)
- IDA
- IDA / OED
- JHU-APL
- Joint Staff J2
- Joint Staff J7
- Joint Staff J6
- JT&E
- L3Harris
- LinQuest Corp
- MITRE
- NAVAIR
- Operations Analysis Directorate, Combat Development & Integration USMC
- OPTEVFOR
- OUSD I&S
- OUSD(R&E), Mission Capabilities, Mission Integration
- Rand
- Raytheon
- SAF/CDM Acq Intel-Joint Integration Cell
- Stevens
- Strategia Worldwide
- TRMC
- Troika-USMC
- U.S. Army Redstone Test Center
- USAF
- USASOC
- USD(R&E), DTE&A
- VTNSI
- VT-ARC

The COI welcomes new members. To be added to the COI please contact Natalie Wells at: Natalie.Wells@vt-arc.org

Appendix B: Multi-year Study Design

Following an extensive review of strategic guidance and documents related to the JWC, AIRC researchers from the VT-ARC, in partnership with VTNSI, designed a three-phase plan to develop the pilot JTC. Phase one includes the literature review, study framework design, and Workshop I design and execution. Phase two includes Workshop I report development and delivery, and Workshop II design and execution. Phase three includes Workshop II report development, delivery, Workshop III design and execution, and the drafting and delivery of a pilot JTC framework. The series of workshops employed a design-based approach leveraging an Agile-type methodology. Critical to the study framework design is the formation and expansion of a COI who contributed to the JTC structure development. While the purpose of each workshop did not change over the course of the project, the workshop tasks were informed by preceding workshops and refined during the workshop design windows.

The Year II study design maintains the three-phase approach to achieve three distinct but interrelated goals:

- ***Create*** a JTC reference architecture that ensures data quality, accessibility, utility, and analytic value across existing and emergent Joint mission (kill/mission) webs for all systems under test throughout the entire capability lifecycle.
- ***Assess*** the reference architecture performance through an end-to-end capability lifecycle T&E architecture simulation.
- ***Develop*** a JTC Implementation Roadmap that includes quick win opportunities.

Relying on the expanding COI to provide input towards each goal, the study team will execute a series of three workshops, each one primarily focused on one goal. Additionally, the Pillar I Lead, and the Joint T&E (JT&E) office are coordinating to ensure appropriate data is available to validate the final JTC.

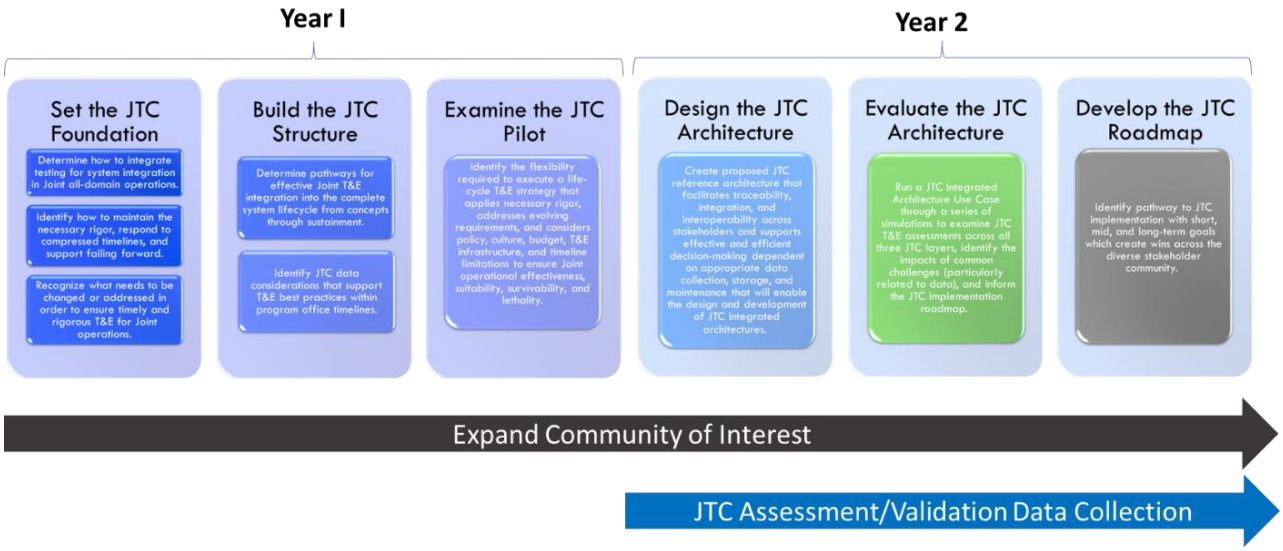

Figure 14: JTC Multi-year Study Design

Appendix C Year I Workshop Outcomes

The first workshop, *Set the JTC Foundation,* occurred in March of 2023. The VT-ARC study team executed the workshop using a human-centered design facilitation method that integrated design thinking, open thinking, and liberating structures principles to harness the group's analytic potential. The outcome of the first workshop included recommendations for an expanded COI, an initial JTC foundation, a set of recommendations for JTC best practices and associated necessities, a list of challenges to JTC execution, and a preliminary JTC value proposition.

Executed in May 2023, Workshop II: *Build the Structure* integrated considerations for leading change and innovation adoption and resistance; and relied on the outcomes from Workshop I. An expanded COI, and broadened circle of competency, worked to answer the question "How do we prepare for the future fight without losing our ability to execute the fight tonight?" through effective, iterative, efficient, and resilient T&E. The workshop outcome was an initial framework for the execution and implementation of the JTC.

Workshop III: *Examine the JTC Pilot,* conducted 13 July 2023, resembled a tabletop exercise with multiple breakout groups representing separate JTC T&E ecosystems all working on Service-specific JTC T&E strategy design for systems that support the *Joint Concept for Command and Control*, and/or Joint All-Domain Command and Control. Two breakout cells explored the application of the Workshop II framework against a notional, but realistic JTC strategy. During Turn I, a nominally joint mission thread required the teams to plan a T&E strategy for a limited and relatively simple operating environment. To ensure the JTC reflected the desired endstate of "test the way we fight", in Turn II the complex Joint, multi-domain operational scenario and realistic kill web forced the breakout cells to review and update their assessment approach, expanding the perspective from a single system to a capability lifecycle. A third breakout cell addressed the strategic challenges to JTC implementation including command and control and resourcing. The outcomes from all three workshops informed the Year I JTC Pilot found in the body of this report while each specific workshop outcomes can be found in the appendices.

For more details on the workshop outcomes please see the individual workshop reports.

Appendix D: Year II Workshop Outcomes

The year II first workshop executed 7 February 2024 intent was to create a proposed JTC reference architecture that facilitates traceability, integration, and interoperability across stakeholders and supports effective and efficient decision-making dependent on appropriate data collection, storage, and maintenance that will enable the design and development of JTC integrated architectures. derived the high-level JTC reference architecture that will inform the development of more detailed reference architectures. The resultant overarching JTC reference architecture framework will facilitate the use of a common language, understanding, and process implementation across stakeholders and provide strategic elements and guidance for detailed reference, data, and solution architectures to follow. An overview of the reference architecture is included in the body of this report.

Year II, workshop II is tentatively scheduled for June/July 2024. The purpose of this workshop is to run a JTC Integrated Architecture Use Case through a series of simulations to examine JTC T&E assessments across all three JTC layers, identify the impacts of common challenges (particularly related to data), and inform the JTC implementation roadmap.

The final workshop for Year II is tentatively scheduled for July/August 2024 and will Identify pathway to JTC implementation with short, mid, and long-term goals which create wins across the diverse stakeholder community.

Appendix E: JTC Vocabulary

The vocabulary list will evolve and expand as the JTC Pilot team, COI, and greater T&E Enterprise. Additionally, there will be a need for the development of JTC-related taxonomies, ontologies, schemas, and related mechanisms and structures[vi] to enable common language, understanding, and data/information management surrounding JTC Functions.

Term	COI-Derived Definition[12]
Authoritative data	(JTC Pilot-Derived Definition) ***Authoritative data*** is data* related to the capabilities (which includes system of systems (SoS), mission, system) to include context (test conducted under right conditions) via meta data and meets fidelity and quality standards with pedigree to enable a level of confidence in the derived information.
Authority	(JTC Pilot-Derived Definition) An ***authority*** is an entity's responsibility, power, and/or restrictions relating to the performance of some act, as defined by statutes and/or policy.
Capability	The COI recommended using industry standard definition, but noted this term will be context specific. (DODAF Industry Standard Definition) A ***capability*** is the ability to achieve a desired effect under specified standards and conditions through combinations of means and ways to perform a set of tasks.[vii] (Joint Capabilities Integration and Development System (JCIDS) Industry Standard Definition) A ***capability*** is the ability to complete a task or execute a course of action under specified conditions and level of performance.[viii] (JCIDS Industry Standard Definition) A ***capability solution*** is a materiel or non-materiel solution to satisfy one or more

[12] An asterisk (*) is used next to terms within definitions to denote a nested term that is also defined (or should be defined) within the JTC Reference Architecture and future architectures vocabularies.

	capability requirements and reduce or eliminate one or more capability gaps. [ix]
Capability lifecycle	(JTC Pilot-Derived Definition) The ***capability lifecycle*** initiates with the identification of capability gaps and ME mapping of systems to mission essential tasks in validated mission threads. This is followed by the exploration and maturation of alternate solutions approaches. The system lifecycle initiates with the down-select of a solution approach, followed by a commitment to design, develop, and deliver that solution following a defined acquisition pathway. The capability lifecycle continues beyond system deployment, with a need for ongoing T&E and performance monitoring in the field to support long-term sustainment and operational resilience.
Data	(JTC Pilot-Derived Definition) ***Data*** is (are) collected processible phenomenon(a) that contain(s) at least one feature.
Data set	(JTC Pilot-Derived Definition) A ***data set*** is a grouping of purposefully collected processible phenomena used to answer a question related to a known feature(s).
Data semantics	(JTC Pilot-Derived Definition) ***Data semantics*** is a branch of linguistics and logic[x] concerned with the study of meaning in data and information, focusing on metadata standards for how data and information is interpreted in a given context enabling human and machine readability.
Domain	(JP 3-0 Definition) In JTC context, the term ***domains*** refer to the areas of the cyberspace, air, land, maritime, and space.[xi]
End-to-end lifecycle (E2ECL) Campaign of Learning	Relying on the JTC foundation and structural elements and flexible workflows and allowing for progression towards fielding despite certain system attributes not meeting performance requirements. This requires both T&E and data strategies that explore efficiencies and reduce resource commitments.
Family of systems (FoS)	(JCIDS Industry Standard Definition) ***Family of systems (FoS)*** is a set of systems that provide similar interdependent capabilities through different approaches to achieve similar or complementary effects for example, the warfighter may need the capability to track moving targets. The FoS that provides this capability could include manned or unmanned aerial vehicles (UAVs) with the appropriate sensors, a space-based platform or special operations capability. Each can provide the ability to track moving targets, but with differing characteristics of persistence, accuracy, timeliness, etc. [xii]

Innovation	***Innovation*** is defined as "development of a new or significantly changed service, product, process, structure, or policy.
Innovation adoption	***Innovation adoption*** is a process that occurs when change agents have identified, developed or acquired, integrated, and leveraged the value of an innovation. Innovation adoption is complete when innovation change agents identify, develop or acquire, integrate, and leverage the value of a new or significantly changed service, product, process, structure, or policy.
Innovation change agents	***Innovation change agents*** are entities that identify, develop or acquire, integrate, and leverage the value of an innovation; change agents include innovators, facilitators, leaders, and users.
Integration	The COI recommended using industry standard definition, but noted this term will be context specific. (INCOSE Industry Standard Definition) In the context of systems/capability integration, ***integration*** is a process or a set of actions which ensures that the elements of a system [or SoS or capability] are compatible and function together such as to satisfy the requirements, meet cost and schedule and optimize the effectiveness of the system. It ensures the compatibility of all physical, functional, and program interfaces in a manner that optimizes the total system definition and design. It amalgamates all disciplines and specialty groups (i.e., reliability, maintainability, safety, survivability, human engineering, and others) into a total engineering effort to meet cost, schedule, supportability, and technical performance objectives.[xiii]
Interoperability	(JCIDS Industry Standard Definition) In the context of interoperable data and information artifacts that crosses service, functional, or program boundaries, ***Interoperability*** is the ability of systems, units, or forces to provide data, information, materiel, and services to, and accept the same from, other systems, units, or forces, and to use the data, information, materiel, and services exchanged to enable them to operate effectively together.[xiv] (JCIDS Industry Standard Definition) In the context of interoperability between systems and capabilities evaluated through JTC test events and assessments, ***interoperability*** is the ability to act together coherently, effectively, and efficiently to achieve tactical, operational, and strategic objectives.[xv]
Joint	(JCIDS Industry Standard Definition) ***Joint*** connotes activities, operations, organizations, etc., in which elements of two or more Military Departments participate.[xvi]

Joint Test Concept (JTC)	Envisions a T&E enterprise that applies an end-to-end capability lifecycle approach, anchored in mission engineering, and supported by an LVC environment to assess material and non-material solutions' performance, interoperability, and impact to service and Joint mission execution through a fully integrated and coordinated T&E campaign of learning.
Mission web/Kill Web	A ***mission web*** is an optimized and integrated set of mission threads* and mission engineering threads* for applicable scenario or vignette of interest.[xvii] A mission web may also be known as an effects web. A ***kill web*** is a specific type of mission web featuring the Find, Fix, Track, Target, Engage, and Assess (F2T2EA) architecture.
Measures	(MEG 2.0 Industry Standard Definition) A ***measure*** is the empirical, objective, numeric quantification of the amount, dimensions, capacity, or attributes of an object, event, or process that can be used for comparison against a standard or similar entity or process. [xviii] (DAU Industry Standard Definition, adapted with COI input) A ***measure of effectiveness*** is an indicator used to measure a current system state relating to specified tasks or conditions, with change indicated by comparing multiple observations over time.[xix] (DAU Industry Standard Definition, adapted with COI input) A ***measure of performance*** is an indicator used to measure a friendly action that is tied to measuring task accomplishment.[xx]
Mission	(MEG 2.0 Industry Standard Definition) A ***mission*** is the task, together with the purpose, that clearly indicates the action to be taken and the reasoning behind the mission. [xxi]
Mission Architecture	(MEG 2.0 Industry Standard Definition) A ***mission architecture*** is a view or representation that depicts the ways and means to execute a specific end-to-end mission, with relationships and dependencies amongst mission elements; mission essential tasks are defined in development of mission architecture. [xxii]
Mission engineering (ME)	(MEG 2.0 Industry Standard Definition) ***Mission engineering*** is an interdisciplinary process encompassing the entire technical effort to analyze, design, and integrate current and emerging operational needs and capabilities to achieve desired mission outcomes. [xxiii]
Mission engineering thread	(MEG 2.0 Industry Standard Definition) A ***mission engineering thread*** includes details of the capabilities, technologies, systems, and organizations required to execute

	the mission, assigning systems to tasks as well as integrating operational conditions. [xxiv]
Mission thread	(MEG 2.0 Industry Standard Definition) A ***mission thread*** gives the order in which the tasks must be completed in alignment with task performance criteria. [xxv]
Model	The COI recommended using industry standard definition, but noted there is nuance associated with this term across stakeholder communities. (MEG 2.0 Industry Standard Definition) A ***model*** is a physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process (DoDI 5000.61, DoDI 5000.70) per MSE. Per the Systems Engineering Body of Knowledge, Models are often categorized as Descriptive, Analytic, etc. (Systems Engineering Body of Knowledge). [xxvi] (INCOSE Industry Standard Definition) A ***model*** a representation of a system of interest from a particular viewpoint, capturing attributes for a specific purpose. A model is always an abstraction in that it focuses on properties of interest at the expense of properties not of interest and at a specified level of precision (detail).[xxvii]
Reference architecture	(DoD COI Industry Standard Definition) A ***reference architecture*** is an authoritative source of information about a specific subject area that creates a common baseline of understanding amongst stakeholders and thus guides and constrains the instantiations of multiple architectures and solutions.
System	The COI recommended using industry standard definition. (INCOSE Industry Standard Definition) A ***system*** is an arrangement of parts or elements that together exhibit behavior or meaning that the individual constituents do not, which can be either physical or conceptual, or a combination of both. (DoD Joint Publication Industry Standard Definition) A ***system*** is a functionally, physically, and/or behaviorally related group of regularly interacting or interdependent elements; that group of elements forming a unified whole.
System of systems (SoS)	(JCIDS Industry Standard Definition) A ***system of systems (SoS)*** is a set or arrangement that results when independent and useful systems are integrated into a larger system that delivers unique capabilities. SoS may deliver capabilities by combining multiple collaborative and independent-yet-interacting systems. The mix of systems may include existing, partially developed and yet-to-be designed independent systems.[xxviii]

Test data	(JTC Pilot-derived definition) ***Test data*** is trusted data* required to support a decision to include (but not all-inclusive) performance, modeling and simulation, and derivative products.
T&E Strategy	(JTC Pilot-derived definition) In the context of JTC implementation, a ***T&E Strategy*** is an overarching plan that provides the structure and objectives for a specific JTC T&E campaign of learning program, iterations, initial timetable with planned/known test events and entry criteria/trigger events for additional iterative JTC T&E events, necessary resources to accomplish each type of test, and specific action/implementation plans within required to achieve high cross-stakeholder interoperability supporting the various subsequent JTC functions.
VAULTIS	(DoD Definition) ***VAULTIS*** is a construct within the DoD Data Strategy (2020) that describes the 7 goals toward becoming a data-centric DoD: ***Visible*** – Consumers can locate the needed data. ***Accessible*** – Consumers can retrieve the data. ***Understandable*** – Consumers can recognize the content, context, and applicability. ***Linked*** – Consumers can exploit data elements through innate relationships. ***Trustworthy*** – Consumers can be confident in all aspects of data for decision-making. ***Interoperable*** – Consumers have a common representation/ comprehension of data. ***Secure*** – Consumer data is protected from unauthorized use/manipulation.[xxix]
Verification and validation	The COI recommended using industry standard definition. (DAU Industry Standard Definition) ***Verification*** is the process of determining that a model or simulation implementation and its associated data accurately represent the developer's conceptual description and specifications.[xxx] (DAU Industry Standard Definition) ***Validation*** is the process of determining the degree to which a model or simulation and its associated data accurately represent the real world from the perspective of the model's intended uses.[xxxi]

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