Point-of-Need Joint Integrated Air and Missile Defense LVC Training Solutions

Colby McAlexander, Matt Martin
CAE USA
Arlington, TX
colby.mcalexander@caemilusa.com, matthew.martin@caemilusa.com

ABSTRACT

Sophisticated peer adversaries with greater force numbers, the tyranny of distance, and the complexity of all-domain environments threaten combined/joint operational effectiveness—especially in a standing-start scenario. Countering drives new agile kill-web concepts incorporating autonomous systems and high-speed sensor–to–shooter data flows. Today's operational complexity juxtaposed with required command and control (C2) speed-of-the-fight decision-making creates unprecedented capability gaps to support strategy-to-task planning, while balancing risk, survivability, and lethality. Additionally, United States Indo-Pacific Command (INDOPACOM) requires the ability for forward deployed forces to train in their Joint Operating Area, without revealing their hand, to preserve combat credibility and/or achieve desired deterrent effects. Equally important is enabling on-demand training with requisite 'reps and sets,' unhindered by exercise schedules and range limitations. To whittle down these gaps Pacific Multi-Domain Training and Experimentation Capability (PMTEC) has demonstrated an innovative Live, Virtual, and Constructive (LVC) solution demonstrated at forward-deployed locations. There are five facets to this paper.

First, it presents a solution integrating an Artificial Intelligence enabled engine, constructive off-the-shelf-capabilities, and virtual and live aircraft. Second, it discusses the integration with other LVC capabilities, experimentation, and test efforts across multiple iterations and events on operational networks. Third, it presents key LVC groundbreaking achievements which enabled the accomplishments of key objectives (e.g., the first Joint Integrated Air and Missile Defense of Guam mission rehearsal). Fourth, this paper addresses initial lessons learned and recommendations on developing and employing LVC in the INDOPACOM Area of Responsibility. Finally, it touches on a next steps Five-Dimensional (5D) Chess concept of taking 'a posteriori' observations and applying them to new iterations as synthetic 'a priori' knowledge to improve plans (i.e., how new constraint identification or a key sequel or branch plan can effectively be moved back in the timeline or to adjacent parallel planning activities being run by the engine).

ABOUT THE AUTHORS

Colby McAlexander is the Manager of the Solution Engineering Team in the Technology and Product Development Department at CAE USA. Retired Naval Aviator, Information Warfare Officer (25-years). Experience in joint, combined, multi-national, and all-domain operations and planning; lead IW expert in the highest multi-classification, pedigreed multi-threat war games at U.S. Naval War College. B.S. in Computer Science, Texas A&M University, College Station, TX; MOAS, Air University, Montgomery, AL.

Matt Martin is the Director of C2ISR and RPA Strategy at CAE. He is a technology leader and strategic thinker of Command & Control and Intelligence, Surveillance, and Reconnaissance (C2ISR) capability with deep experience across the entire spectrum of military operations. Experienced NATO warfighter and joint planner, a joint-qualified action officer, and published writer on defense issues. Business growth innovator with a track record of creating markets by solving DoD and NATO defense hard problems.

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INTRODUCTION

Sophisticated peer adversaries with greater force numbers, the tyranny of distance, and the complexity of all-domain environments threaten combined/joint operational effectiveness—especially in a standing-start scenario. Countering drives new agile kill-web concepts incorporating autonomous systems and high-speed sensor–to–shooter data flows. Today's operational complexity juxtaposed with required command and control (C2) speed-of-the-fight decision-making creates unprecedented gaps in capabilities to support strategy-to-task planning, while balancing risk, survivability, and lethality. In a Proceedings article, ADM Scott Swift (2018) offered

> We succeed when and where we are most adept at not only out gunning, but also out thinking and out maneuvering our adversaries. … commanders and future commanders must study and practice C2 at every opportunity in war games and in real-world operations, while never ceasing to learn how to implement it at every level of command. This will be key to our success in a future conflict with a peer or near-peer competitor. It also will be core to any failure we may face in that conflict.

A capability gap often overlooked when focused on the science or supporting technology of C2 is a solution which provides commanders and their staffs the ability to practice the art of C2 at a time and point-of-need of their choosing; As evidenced by current events in Ukraine and Israel, there is an increasingly clear demand for *Point-of-Need Joint Integrated Air and Missile Defense LVC Training Solutions*. This paper focuses on an exemplar from a recent Guam Defense System (GDS) exercises. The GDS is a defense-in-depth, multi-layered Enhanced Integrated Air and Missile Defense (IAMD) system of systems integrating capabilities across the Missile Defense Agency (MDA) and the U.S. Army, Navy, Air Force, and Space Force. In an article about the GDS Joint Program Office, Gonzales (2005) wrote:

> Guam [is] a vital United States [(U.S.)] territory in the Pacific, [it] is poised to become a cornerstone of American defense strategy. Spearheading this transformation is the [GDS] Joint Program Office (GDS JPO), a unique organization tasked with rapidly developing and deploying a comprehensive, 360-degree air and missile defense system. This isn't just about protecting an island; it's about creating a blueprint for integrated defense that can be replicated across the nation.

Problem

The joint GDS has lacked onsite, on-demand training and assessment tools to allow tactical rehearsal and evaluation of all-domain IAMS mission effectiveness outside of combatant command or service exercise; Nor does the GDS fully integrate with C2, Intelligence, Surveillance and Reconnaissance (C2ISR) Live, Virtual, and Constructive (LVC) tools and data sets. Moreover, these tools do not provide non-experts, including senior leaders/decision-makers, easy to use solutions with the means to discern meaningful information that can aid in decision making and planning. Furthermore, "instructors" or exercise control members are further burdened by the lack of interoperable LVC modeling and simulation (M&S) emulators, which can operate across common distributed network node architectures, link with the baseline of geographically dispersed networks and share data across the Joint and Coalition Synthetic Theater

Environment. (Note, in the paper, distributed network node examples include: Joint Synthetic Environment (JSE), Joint Training and Experimentation Network (JTEN), Distributed Mission Operations Network (DMON), Navy Continuous Training Environment (NCTE), etc).

Purpose

United States (U.S.) Indo-Pacific Command (INDOPACOM) requires the ability for forward deployed forces to have the ability to train in their Joint Operating Area (JOA), without compromising operational security, to preserve combat credibility and achieve desired deterrent effects, and with the means to do so when live platforms are not available for participation. Equally important is enabling on-demand training with requisite 'reps and sets,' unhindered by exercise schedules and/or range limitations to examine readiness, command and control (C2)—including supporting/supported organizational structures, relationships, and communications—as well as exploring rapid problem solving at operational, tactical, and technical levels in execution of joint warfighting concepts.

Objectives

An overarching objective for a point-of-need training and assessment solution is to facilitate cross service, agency, and allies or mission partner unit level joint training in the whitespace between INDOPACOM or Service training events (e.g., exercises, wargames, pipeline-training) and operations through novel, game-changing, disruptive joint training solutions in the JOA; Ultimately, provide tactical and operational level units the ability to inform future warfighting Platforms/Concepts by through combined/joint LVC (C/JLVC) solutions composed of M&S tools, virtual environments, operational hardware/software in the loop, and live platforms. Enduring C/JLVC solutions should consider the following objectives and requirements:

- Transition legacy LVC environments and capabilities to sustainable future C/JLVC solutions.
- Emulate modern threats, at various levels of fidelity, which are interoperable across systems of systems.
- Employ hardware-/software-in-the-loop and/or emulate modern communications to foster a greater understanding of C2 organizational structures.
- Examine the interoperable strengths and weaknesses of operating in a Combined and Joint Mission Partner Environment (MPE) against peer-/near-peer threats.
- Demonstrate distributed capabilities at high security/classification levels through secure, high data transport—for high bandwidth, and zero to low latency—employing high fidelity, emerging networks.
- Utilize a common architecture and standards for constructive (e.g., M&S) and virtual (e.g., aircraft desktop trainers) across the services (e.g., JTEN, JSE) which can span multiple geographically dispersed locations connecting a variety of training systems.
- Employ Development, Security, and Operations (DevSecOps) —to ensure cybersecurity is baked in from the start—and ensure Zero Trust Architecture is engineered as an enabler for both end-to-end cybersecurity and plug-n-play providing a scalable deployment mechanism for authoritative M&S data (e.g., threat and weapons models, terrain databases, space effects).

AN APPROACH TO C/JLVC INNOVATION

> "A missile defense system is only as effective as its ability to command and control all integrated elements."
>
> — **Lieutenant General Heath A. Collins, USAF, Director, Missile Defense Agency**

In an article, *Winning the War—Virtually,* Molenda (2023) discussed the significant importance LCV capabilities bring to wargames, Fleet Battle Problems (FBP), and exercises. As well, he noted to fully exploit advantages LVC can bring to bear "… the Navy must accelerate its focus and investment in LVC training capabilities at the task force level and above. Though the Navy is focusing attention on injecting LVC to augment training at the tactical and unit levels, there has been little attention to incorporating [enhanced] LVC tools such as large-scale data mining, artificial intelligence, and machine learning in operational-level-of-war education and training, where it is needed most. This is especially problematic as warfare technologies rapidly advance and outgrow the training ranges built for Cold War–era training requirements" (Molenda 2023). As such, Pacific Multi-Domain Training and Experimentation Capability (PMTEC) Program Office is spurring development of such novel enhanced C/JLVC solutions via demonstration events at forward-deployed locations, inserting these technologies during Operational Readiness Exercises (ORE) (e.g., Valiant Shield 2024, Sling Stone 2024).

A solution PMTEC and industry partners seek to bring forward is an integrated Artificial Intelligence (AI) enabled engine, constructive off-the-shelf-capabilities, and virtual and live aircraft. This effort focused on the integration of this concept with other constructive capabilities, experimentation, and test efforts across multiple iterations of multiple events on operational networks. Results included key C/JLVC "firsts," which enabled the accomplishments of key objectives (e.g., the first Joint Enhanced IAMD of Guam mission rehearsal. The effort produced insightful lessons learned and recommendations on developing and employing C/JLVC in the INDOPACOM Area of Responsibility (AOR). The prospect for future next steps are analogous to a Five-Dimensional (5D) Chess/Checkers concept of taking 'a posteriori' observations and applying these observations to new iterations as synthetic 'a priori' knowledge to improve plans (i.e., how new constraint identification or potential key sequel or branch plan(s) can effectively be moved back in the timeline or to adjacent parallel planning activities being run by the engine).

Air Force Brig. Gen. Richard Goodman, USINDOPACOM J7, stated "The success of Sling Stone and PMTEC's operations, activities, and investments are forging a path towards incorporating future capabilities that enable data capture and analysis, deep learning, data science solutions, and artificial intelligence/machine learning tools to advance the collaborative relationship between services and combatant command at the forward edge."

—USINDOPACOM, ***Sling Stone enhances warfighter capabilities, defense of Guam.***

Organizational Foundation

PMTEC is an organization within the INDOPACOM J7 Training and Exercises Directorate; Its charter is to deploy forward joint training capabilities in the INDOPACOM Area of Responsibility (AOR), particularly those areas West of the International Dateline referred to as the Second Island Chain (SIC), and possibly the First Island Chain (FIC). PMTEC's technology insertions enable joint, combined, and coalition warfighters to realistically rehearse operations in highly contested, all-domain environments. Per the J7 Director, this is crucial for preparing against peer adversary capabilities and supporting integrated deterrence. When existing stand-alone LVC training systems capabilities were integrated under PMTEC's visionary oversight, they formed the basis for a future Advanced Training Environment (ATE) to create a more realistic presentation for mission rehearsal. These integration efforts were furthered during Valiant Shield 24 and Sling Stone 24 Capabilities Exercise (CAPEX), held on or about Guam; PMTEC partnered with industry and Department of Defense (DoD) stakeholders to derive true needs and deliver C/JLVC capabilities across the Pacific theater to allow joint and coalition warfighters to conduct high-end training without revealing tactics, techniques, and procedures to our adversaries.

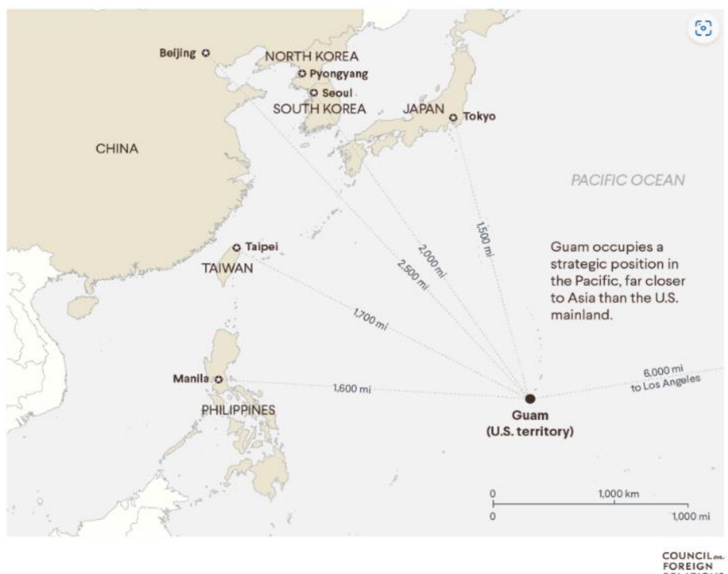

Figure 1 Guam's Strategic Location

Much as Guam has historically been a strategic critical capability at the 'tip of the spear,' it is even more today due to its location in the Pacific (Figure 1) allowing the U.S. to sustain as a logistics hub and military infrastructure for rapid responses forward power projection to deter potential adversaries (Fong, 2024). "Amid China's expanding military capabilities, one of the greatest current threats to [Guam] is Beijing's DF-26 intermediate-range ballistic missiles (IRBM), said J. Michael Dahm of the Mitchell Institute for Aerospace Studies. Nicknamed the "Guam killer," China's versatile missile can carry both conventional and nuclear warheads and has a maximum range of over 2,000 nautical miles, putting Guam within its reach" (Harpley, 2024).

USINDOPACOM Joint Defense of Guam Event – Sling Stone '24 CAPEX

Sling Stone 24 CAPEX, held 04 to 10 December, was a USINDOPACOM tactical capabilities exercises CAPEX to rehearse Defense of Homeland (DoH)/Defense of Guam (DoG) concepts of operation—specifically IAMD—and associated coordination between Combatant Command, Services, and Agencies (CC/S/A), JTF-Micronesia, and the local Guam government. To note, this exercise was held concurrently and as a precursor to MDA's Flight Experimentation Mission 02 (FEM-02) (Figure 2), a live fire test of the Aegis Guam System missile intercept capabilities. "FEM-02 is the first demonstration from Guam as part of the long-term initiative for the defense of Guam and will inform the larger effort to develop, install and operate GDS, comprised of a combination of DoD service components working together to provide an Enhanced [IAMD] system. Together the DoD service components would develop and deploy a persistent layered integrated air and missile defense capability" (Jones-Bonbrest, 2024).

"The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD

Figure 2. Missile Defense Agencies Flight Experimentation Mission 02 (FEM-02) Interceptor Launch

The Sling Stone 24 CAPEX was a tactical multi-domain training in a C/JLVC environment to rehearse and develop tactics, techniques, and procedures (TTPs), and coordination between Guam Local Authorities, Joint Task Force-Micronesia, and IAMD CC/S/A units. In a 11 December 2024 online news article, USINDOPACOM stated "Sling Stone was the catalyst for INDOPACOM's [PMTEC] to accelerate multi-domain joint training and link theater-wide [IAMD] capabilities to the GDS." USINDOPACOM stated a goal of Sling Stone '24 CAPEX tactical training event was "… to hone skills, increase interoperability, and improve communication and understanding between forces while also coordinating with civil authorities to train for a whole-of-government approach to crisis response."

SLING STONE 2024 CAPEX SOLUTION(S) OVERVIEW

The overarching system of systems C/JLVC solution was a outcome of weeks long collaboration between MDA, PMTEC and it's industry partners, GDS JPO, U.S. Department of Air Force (DAF) Program Executive Office (PEO) Command, Control, and Communications Battle Management (C3BM), PEO Missiles and Space, U.S. Army Tactical Systems Integration Lab (TSIL) and Space and Missile Defense Command (SMDC), Naval Surface Warfare Center (NSWC) Dahlgren Division. The C/JLVC solution is based on MDA—the Technical Authority for IAMD—prototype of the Joint Tactical Integrated Fire Control (JTIFC); Its "architecture focusing on multi-domain, cross-Service kill chains, enabling true 'right sensor, right shooter' capability to counter emerging threats. JTIFC enhances integrated fire control capabilities across the Services and agencies by essentially 'connecting' existing sensors, command and control systems, and weapons at the tactical level" (Lieutenant General Collins, 2025). For a level set understanding of live, virtual, and constructive for this paper's terms of reference, the following description and examples are offered:

- **Live**: Blue Force Training Audience using operational hardware/software – (e.g., live flight aircraft, Army Integrated Battle Command System (IBCS) for Terminal High Altitude Area Defense (THAAD) and Patriot Batteries, Air Force Tactical Operations Center – Light (TOC-L)).
- **Virtual**: Blue Force Training Audience using dedicated platform simulators (e.g., Virtual Aegis Ashore Weapon System (VAWS), Navy Cooperative Engagement Capability (CEC), fast-jet fighter desktop trainers, ISR feeds).
- **Constructive**: Red force entities and Blue Force entities – as required to account for where there were no live Blue Forces (e.g., C-RAM Distributed System of Systems Simulation (CDS3), various commercial-off-the-shelf CGFs).

PMTEC's Combined/Joint LVC Insertion for the Defense of Guam

PMTEC brought forward an integrated solution consisting of the following suite of tools:

1. Multi-domain constructive generated forces tool, with both an instructor operator station and exercise control/white cell stations to generate both blue and red forces.
2. AI-enabled engine to aid exercise control/white cell in movement & maneuver, intelligence, and fires of constructive forces which emulate complex blue and red force entity behavior in specific roles within scenarios, as well as enable natural language interaction between live players and constructive entities.
3. Virtual ISR dynamic data feeds controlled in real-time and fed directly to C2 and intelligence terminals.
4. Virtual fighter trainers to stimulate realistic defensive counter air IAMD training for the Regional Air Defense Commander (RADC), Sector Air Defense Commander (SADC), and Tactical Operations Center (TOC).
5. Planning, execution, and analysis reconstruction tool to facilitate kill chain debriefs and assessments.

This suite of tools provided commanders, their staffs, operators, and C2ISR professionals a dedicated, highly affordable means to train, conduct mission rehearsal, or assess their tactical plans on any mission set from initial preparation of the operational environment (IPOE) to real-time interdiction support of high value targeting and strike, and all-domain near-peer threat assessment. To note, the virtual ISR data streams generated simulated real-time mission data such as full motion video (FMV) of both electro-optical (EO) and physics-based infrared (IR) (near and far spectrum IR), synthetic aperture radar (SAR) with moving target indication, and signals intelligence data collected by ISR platforms (e.g., MQ-9 and RQ-4).

GDS System of Systems C/JLVC Integration for Sling Stone '24 CAPEX

Sling Stone 24 CAPEX brought together an integration of various live systems, constructive capabilities, experimentation data, and test efforts across multiple iterations of multiple events on operational networks. Specifically, PMTEC's solution integrated with JTIFC—which includes MDA's Joint Track Management Capability (JTMC) Bridge—Army IBCS, Navy CEC and VAWS, and Air Force TOC-L Programs of Record. To note, JTMC Bridge "is designed to connect Army, Navy, Marine Corps, and Air Force weapons, sensors, and fire control networks into a Joint Integrated Fire Control Network. … The Guam Defense System builds on the JTIFC core architecture and future capabilities, ensuring joint weapons and sensors are integrated for layered area defense." (Lieutenant General Heath, 2025). Each of these systems can operate as standalone solutions or connect to other systems and share either High Level Architecture (HLA), Distributed Interactive Simulation (DIS), Joint Range Extension Applications Protocol (JREAP), Link-16 data, to name a few.

> Sling Stone 2024 was "… the first Department of Defense [(DoD)] exercise to integrate postured joint warfighters, service technical teams, industry partners, and Battle Management Command, Control, Communication authorities all engaged in a collective and collaborative effort to develop, exercise, and operate GDS capabilities."
> — **USINDOPACOM, *Sling Stone enhances warfighter capabilities, defense of Guam.***

DISCUSSION

While it is not the intent of this paper to address, in depth, all groundbreaking achievements and lessons learned from Sling Stone '24 CAPEX, it is important to highlight several.

Key GDS C/JLVC Groundbreaking Achievements during Sling Stone '24 CAPEX

Most notably, Sling Stone 24 CAPEX "…was the first [DoD] exercise to integrate postured joint warfighters [from all military services, JTF-Micronesia, and MDA], service technical teams, industry partners, and Battle Management Command, Control, Communication authorities all engaged in a collective and collaborative effort to develop, exercise, and operate GDS capabilities" (U.S. Indo-Pacific Command, 2024). Additional key firsts include:

- First event purposely designed, developed, and executed to inform combined and joint stakeholder of Defense of Guam IAMD requirements, with further positive moving ball forward implications for the current administrations "Golden Dome."

- First Enhanced IAMD rehearsal in Guam combining C/JLVC solutions in Guam and the Continental U.S. with real-world hardware/software in the loop systems.
- First event to integrate PMTEC's C/JLVC solution, Aegis Ashore / VAWS, IBCS, TSIL CDS3, and TOC-L.
- Sling Stone '24 CAPEX prepared operators for the first combined/joint ballistic missile end-to-end tracking and intercept (i.e., FEM-02) from Guam.
- First dynamic 360° dynamic air threat (hypersonic, ballistic, and cruise missiles, red airborne ISR, etc) represented by the combined C/JLVC solutions.

Lessons Learned

The JTMC bridge was critical to enabling integration and interoperability between disparate hardware/software-in-the-loop operational systems and M&S tools communicating across different protocols (e.g., Link-16, JREAP, DIS, HLA, etc). JTMC worked well for capabilities which had previously been tested and frequently operated with the JTMC bridge, or few new capabilities which could communicate via two or more protocols.

However, it was noticed there was 'DIS Indigestion' between two virtual trainers (i.e., one causing occasional freezing and/or stuttering of one system or the other even though they both communicated only over DIS) both of which had not operated in the GDS environment previously. This highlights a few points. First, a lesson 're-learned.' There needs to be both due-time scheduled and executed for and a concerted effort to participate in integration, testing, and training prior to an event's execution. This said, resources available (i.e., people, time, and money) are ever increasingly a constraint to dedicating more than a few days for pre-event setup. Second, the criticality and benefit a standing mission engineering environment would bring for system of systems such as GDS to be able to test new or updated C/JLVC capabilities while not being 'encumbered by a training audience.' Specifically, on one side of the coin, not being encumbered or tied to waiting for the next ORE to allow testing in a fully integrated environment consisting of multiple tools by multiple government and industry partners. On the other side of the coin, when an ORE occurs, ensuring the training audience meets objectives is prime and when system issues present themselves. Troubleshooting during an ORE often leads to band-aid fixes of symptoms not allowing for a detailed debug of causal factors; Post event, the circumstances causing the crash cannot be replicated easily or not at all until the next time all parties come together for a new event.

In this light, the U.S. Army's WRAITH device way key. The primary purpose of the WRAITH device is a resilient communication edge device for connecting on-premise and forward deployed tactical edge systems to home-garrison networks and systems. Additionally, WRAITH can act as a message gateway / message broker for systems with disparate messaging protocols. A side benefit of the WRAITH during Sling Stone '24 CAPEX is it facilitates event logging and troubleshooting— in real-time— integration and interoperability issues. This feature expeditiously facilitated the isolation of any system or messages being passed which were causing greater issues across the C/JLVC systems of systems. Furthermore, the Wraith device provided a cyber secure data sharing enabling capability.

There were considerable timing mismatches between some of the systems. One system's time walked off very significantly compared to others. This made the troubleshooting considerably harder; Specifically, balancing issue identification and resolution juxtaposed with ensuring the exercise events stayed the course of execution. Thereby, it was noted having a central timing device to synchronize all disparate systems is a highly recommended must have.

Finally, during the final planning conference and the integration and test weeks, the scenario 'vulnerability (Vul) windows' (a.k.a.vignettes) were not available to both fully burden the disparate system-of-systems solution during tests and have the Vuls preloaded prior to the first day of execution. This in part was due to information sharing challenges created by not having a common location to coordinate exercise planning. It is recommended utilizing the Joint Training Tool (JTT), starting with the concept development conference through post-execution assessments and lessons learned captures. JTT is "…a web application that acts as a one-stop shop for the machine-readable planning & design of a training event [through execution and assessments of a training event]. … The continued modernization of JTT will both enable the use of current technologies and facilitate an evolutionary transition from application-centric applications and simulations to a data-centric, web-based, and single digital environment" (Chambers, 2023). Bottomline, JTT facilitates open-collaboration for scenario Vul builds including, but not limited to, 'Road to Crisis,' master scenario event lists, "…query data across the JTT exercise repository, showing the linkage to a C/JLVC-supported event…," and access to Joint Training Data Service (JTDS) Order of Battle Service (OBS), force structures, and Terrain Generation Services, to name a few. (Chambers, 2023). JTT also facilitates pulling scenarios and MSEL from previous exercises, which can greatly streamline the time required to plan and execute an on-demand, ad-hoc training of opportunity; As well, this feature allows a commander and their staff to ‘replay’ to get in the ‘reps and sets’ or explore outcomes of alternative decisions.

Recommendations on Developing and Employing C/JLVC in the INDOPACOM Area of Responsibility

During a Virtual Flag, “Battle Management’s use of LVC training improved air combat training systems enabling all-domain air dominance in combat against peer- and near-peer adversaries. LVC training also expanded combat operations training by enabling rapid execution of multiple scenarios over a limited time frame; the rapidly adaptable environment encourages learning and builds experience without the time or cost of an exclusively live exercise” (Henley, 2022). While it is widely accepted C/JLVC training solutions (e.g., pilot and flight officer training) provide significant enhancement to readiness, TTP and CONOPS development, and testing theories, not all C/JLVC solutions provide the right benefit all. Hoke, Townsend, Giambarberee, and Schatz (2017) provide good recommendations for consideration on simple methods to assess utility and effectiveness of a C/JLVC capabilities at time of employment. Several aspects of these efforts will be key in not only developing effective C/JLVC solutions, but ensuring those solutions are synchronized to the development of weapons systems to ensure sound investment and operational and tactical success. Requirements for C/JLVC capability must be a function of both training audience experience and objective measurements of the improvement of tactical outcomes. To glean this knowledge, training event debriefing, surveys, and studies of tactical outcome must be conducted to gain this insight.

As such, future GDS and other C/JLVC development events should include the following:

- Capturing C2 data from both the simulation and live components of training and test events to provide a basis for objective analysis.
- Development of Measures of Performance/Measures of Effectiveness (MOP/MOE) assessments against which to analyst the performance of Air and Missile Defense operators both at the beginning and end of exercise cycles to determine if their performance was improved via the introduction of LVC capabilities.
- The use of training audience surveys, through structured interviews and written questionnaires, to capture the qualitative elements of the use of LVC for training
- A regular cycle of exercises over the next several years, similar to Sling Stone, to produce sufficient body of data to produce meaningful conclusions.
- The use of the results of these studies to inform not just the benefit of LVC, but to asset the value of new C2 automation tools as they are introduced into emerging IAMD control systems.

WAY AHEAD RECOMMENDATIONS

Current Approaches

The cost and complexity of operations, C2, ISR, and the required speed-of-the-fight decision-making creates unprecedented gaps in C2 capabilities to support operations/planning cycles, while balancing risk, autonomy, survivability, and lethality. Current Modeling, Simulation and Analysis (MS&A) tools are not fully sufficient to interactively and iteratively synthesis, analyze, and condition operations/plan refinement, nor synchronize various parallel joint force efforts to ensure a timely and integrated achievement of operational end states. Scenarios can take much time to develop and then ingested into MS&A suites by non-experts. Also, the scenarios are often not easily ‘rheostated’ on-the fly in level of difficulty and/or complexity.

Today’s integrated solutions use disparate and inaccessible friend and threat model databases, which hinders a networked training audience or joint planners—operating systems representative of planned blue force operations against these threats—to use the same or equivalent models, from a single and authoritative source. Additionally, A common approach to creating entity behaviors in simulations is model entire platforms as single entities. CGFs lack any natural language communication capability which makes intuitive interaction with them difficult. Furthermore, today’s solutions do not offer a constructive MS&A capability which conduct dynamic tradeoffs between speed and fidelity for different interactions and are accessible by non-MS&A experts. Nor do current approaches facilitate operations planning by combining AI-driven planning with interactive gaming to significantly reduce planning and operations cycles (e.g., Air Tasking Order, Fires, etc).

An Innovative Future Approach Recommendation

CC/S/A's training and planning can better benefit by a C/JLVC mission engineering environment which is automated, adaptable, C/JADC2-compliant, and readily provides foundational, cross-cutting and shared MS&A tools, fostering the integration of disparate MS&A capabilities CC/S/A's have presently invested to enable rapid human-guided planning and assessment to explore the possibility space. Key features should include:

- Enable rapid creation of complex courses of action (COAs) and targeting/effects for thousands of targets and threats in two to four hours with a high-level of confidence.
- Support an automated, adaptable, zero-trust, cloud-deployable architecture coupled with a DevSecOps package of tools, leveraging both novel and proven commercial and government capabilities.
- Present an intuitive front-end gaming interface to achieve automated, human-guided planning and assessment.
- Enable effective, debrief and/or trade-space analysis of structured/unstructured data in a dynamic system and reduced human workflows through a novel, scalable, extensible AI-/machine learning (ML) enabled emulator with actionable, easily understood output.
- Provide an accessible all-domain experimentation sandbox and connected mission engineering environment technologies (i.e., digital twins, virtualizations, emulators) to serve as a testing/proving ground to fully understand and characterize the design trade-space, explore military utility, and inform new concepts, evaluation, and development of plans.

Human-guided AI would generate myriad potential COAs and the gaming environment will allow operators to explore, cull, and evaluate combat plans, gaining insight into the future battlespace. Developing plans in coordination with AI at the rapid pace and scale of current operations (COPS) and future operations plans (FOPs) demand requires a common infrastructure with the following capabilities:

- Formalization of the representation and data needed to feed AI models and analytics.
- Flexible, persistent data interfaces enabling 'standing-start' modeling and analytical capabilities timely information about the operating environment with consumer applications with M&S and analytical output.
- Interactive user interfaces for users to provide guidance, real-time feedback, and quickly communicate details of complex operating environments in real time.
- Computationally scalable representations to manage state and update of large numbers of entities in an interactive, real-time/faster-than-real-time environment.

This paper's recommendation is an interactive plan (or scenario build) refinement solution (Figure 3) which is experiential based on autonomous AI/ML powered mission planning with contingency options and resource allocation employing human-machine 'Advanced Teaming' concepts. A four-step approach could result in new paradigms in mission planning with evolving doctrine to achieve overmatch against our adversaries.

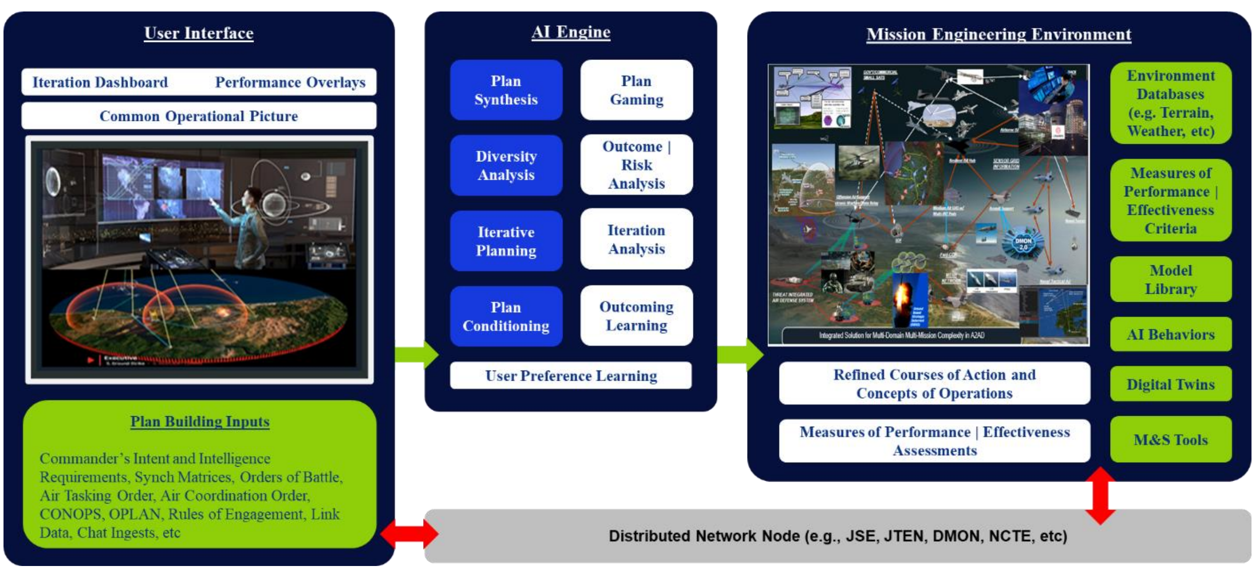

Figure 3. Interactive Plan (or Scenario Build) Refinement Solution

1. Analyze battlefield scenarios by ingesting a multitude of Intelligence data assets using AI powered data analysis, to aid in AI decision development.
2. Calculate the asset availability (via service maintenance status reporting system) and capabilities utilizing existing flight performance, weapon system, and threat models against the mission requirement(s).
3. Modify previously developed AI/ML powered agents to derive plausible Mission Options with Situation Change Indicators (SCI) to provide commanders and planners at the speed-of-the-fight. The system will iterate steps 1-3 as the training scenario or real-world operations situation changes which drives the predictive outcome while automatically assessing risk.
4. Develop best to worse case outcomes based on the mission options developed and intel from the proven, near real-time, data analytics engine game-like User Experience (UX).

This Interactive Plan Refinement Solution solutions process starts with Plan, or Event Scenario, Synthesis.

Plan, or Event Scenario, Synthesis

Commander's intent and end state would be decomposed into desired effects which must be achieved to successfully accomplish the mission, as input by the user. The generation of the initial plausible plan is automated through the operational plan (OPLAN) or concept of operations (CONOPS) ingestion to allow the main components of a mission plan to be created and used as the first level of automated planning with the low fidelity details regarding mission execution to identify obvious gaps in resource availability [feasibility]. A resourcing agent (use of resources identified by the user) will be based on platform performance models, configuration details (e.g., sensors, armament, communications), and weaponeering. Other constraints may be expressed within, such as minimal loss of assets, limited collateral damage, or all friendly forces recovered by "x" date and time to prepare for follow on operations. Feasibility can be determined prior to the operational concepts transitioning to the plan diversity analysis process.

Plan Diversity Analysis

Plan diversity will be evaluated by identifying differentiation factors between plans based on priorities of actions, sequence of objective accomplishment, duration, and risk assessment. The future outcomes will be analyzed for similarities relating to the end state, economy of force, resultant mission risk, and estimated probability of success. Each COA statistical quantification for predicted success or failure would be compared to the required score determined by the measures of effectiveness [constraint]. We define a metric of separation so redundant occurrences of plan features are not consuming computational resources. Based on the systems assessment of attributes that directly relate to a high probability of success, combining them into an AI/ML recommended COA for approval is feasible. The highest rated COAs transition to the iterative planning function.

Iterative Planning

Based on mission constraints, any iteration of a plan that encounters a given constraint – or identifies a previously unidentified constraint – should terminate the planning iteration and capture the causal factor. This information will be looped back to the initial algorithmic step for follow-on planning iterations, which would achieve a self-learning function. This new constraint would be observed a posteriori and then applied to new plans as synthetic a priori to improve the iterations quality. Improved plans, like the new constraint identification or a key sequel or branch, can effectively be moved back in the timeline or to adjacent parallel planning activities being run by the service (5D Chess, or Checkers, concept) (Figure 4). In reduced time scenarios, the plan iterations can be selected as a sampling of the aggregate statistical ranges to ensure the full spectrum of operational considerations are included in the conditioning phase. Based on variation estimates interpolated from intelligence analysts and targeting personnel and data, plans will iterate using that information to generate more granularity and increase fidelity prior to delivery to a more comprehensive longer-run monte-carlo simulation.

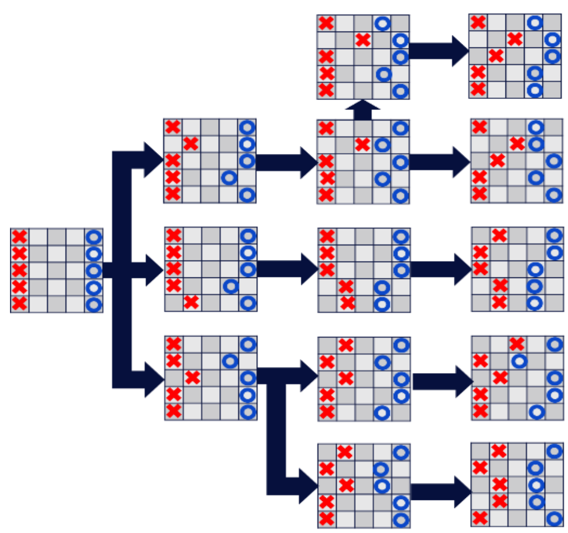

Figure 4. 5D Chess/Checkers Concept

Plan Conditioning
Feasibility evaluation would occur continuously beginning in the Plan Synthesis step and continuing until the COAs are developed for upload to the modeling and simulation environment. Additional granularity will be pursued by the inclusion of statistical data for probability of kill data. Combined with the estimate of the enemy force composition, this information will be critical in defining the measurable indicators to evaluate success.

Plan Gaming, Outcome Analysis, and Outcome Learning
The above functions should be supported by Plan Gaming and Outcome Analysis. The ability to interactively simulate execution of attack plans, assess variance of out-comes based on uncertainty, and generate empirical analysis of plausible futures. Planners should be able to explore and understand how a plan will unfold against a simulated adversary employing a variety of strategies and/or responses. The proposed solution should also support modification of plan elements, operating conditions, and capabilities for both friendly and adversary forces to determine how those changes will impact plan effectiveness and risk.

The gaming platform will provide deep insight and experience with combat plans, allowing planners to analyze expected performance and update plans based on simulated outcomes and associated risk calculations. This is a key innovation that seeks to leverage commercial gaming technology to build intuitive, responsive interfaces that are designed to maximize human understanding of complex operating environments. Interface capabilities include faster-than-real-time plan execution, visual representation of spatial and temporal events of interest that have impact on plan outcomes, and methods for depicting where plan outcomes diverge or converge based on events. This solution must address the following challenges:

- **Gaming Interface**: a human-centered, interactive set of visual interfaces for building, rehearsing, and assessing combat plans, driving and leveraging automation underlying this solutions system of systems. These interfaces will aid planners in contemplating the plausibility of force allocation and task prioritization options, the performance of the resulting plans, and the implications of hypothetical operating conditions.
- **Plan/Analytics Data Store**: a data storage solution with indexing across related plans, variations, assessment, and outcomes. Data representations and storage will need to account for the continuous refinement of plan options and the need for analytical techniques to access multiple plan options simultaneously.
- **AI Behavior Models**: automated players for friendly and adversary forces, enabling simulated plan execution and response to events. This will drive analysis of outcomes by executing plans over a range of conditions and uncertainty to support statistical analysis and visualization.
- **Planning Execution Engine**: a game environment for plan execution enabling analysis of expected plan outcomes under uncertainty and against varying adversary strategies. Adversary and friendly forces should be able to execute autonomously, driven by AI players of varying strategy and skill. The environment allows planners to explore potential futures, further refining the pace and timing of effects, constrain operating parameters, and identify opportunities and vulnerabilities that could emerge during conflict.
- **Plan Analytics Engine**: automated analytics to aggregate data on the various outcomes and present the planners with an overall assessment of the resulting outcome space. A visual depiction of these results will aid planners in focusing their efforts on the most likely and worst-case outcomes as part of the overall risk assessment and military decision-making processes.
- **Auto Exploration**: automated exploration of adjustments to friendly and adversary resources, capabilities, and constraints to determine what impacts those changes will have on expected outcomes.

CONCLUSION

Highly accessible, user-friendly C/JLVC capabilities better inform acquisition, training, and warfighting decision-making in order to bring game-changing decisive mission capabilities and concepts to bear. AI-enabled, constructive toolsets increase the warfighters' ability to rapidly explore current and future capabilities faster than the speed-of-the-fight. The recommended approach this paper offers is use-case-agnostic, with potential applications to combined and joint training events, exercises, wargaming, current and future operations, and future planning. Today's decision advantage demands novel decision support technologies to analyze performance – in real and faster-than-real time, objectively, and automatically – of warfighters, platforms, systems, and weapons in dynamic, high-stakes, peer and near-peer contested operations in all-domains.

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