Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) Program

In FY25, the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) program leveraged modern software development methods to enhance the capability, user experience, and integration of weaponeering tools with greater efficiency and effectiveness. JTCG/ME weaponeering tools and data supported over 500 kinetic strike packages comprised of multiple unique weapon-target pairings. Some of the most visible FY25 strikes included approximately 3,600 unique weapons employments between Operation Poseidon Archer, which took place between January 2024 – May 2025; Operation Rough Rider, which took place between March – May 2025; and Operation Midnight Hammer in June 2025.

PROGRAM OVERVIEW

Chartered in 1968, the JTCG/ME program was established as the Department's focal point for munitions effectiveness information. Its mission began with the development of Joint Munition Effectiveness Manuals (JMEMs) – the sole source of non-nuclear weapons effectiveness data and methodologies for the DoW. These manuals serve as the "how-to" guides for employing kinetic and non-kinetic offensive capabilities, directly enhancing combat readiness, operational effectiveness, efficiency, and survivability.

JMEMs provide critical data in three key areas:

- Weapon characteristics – to quantify damage-producing mechanisms and munition reliability.
- Target vulnerability – to assess how susceptible a target is to specific weapon damage mechanisms.
- Delivery accuracy – to measure a weapon system's ability to place munitions on a target.

Today, JMEMs have transitioned to kinetic and non-kinetic tools used in operational weaponeering, and collateral damage estimation (CDE) in direct support of multi-domain operations, mission planning, and training to support combat operations at the speed, scale, and precision required to prevail in a major theater war.

These tools are used by joint and Service planners in force-on-force effect estimations, mission area analysis, requirements studies, and weapon procurement planning and by the Service acquisition community in performance assessments, analyses of alternatives, and survivability enhancement studies. Key tools and capabilities include:

- Digital Imagery Exploitation Engine (DIEE) – National Geospatial-Intelligence Agency (NGA)-validated mensuration tool that generates precise 3D coordinates for coordinate-seeking weapons. DIEE streamlines Advanced Target Development (ATD) through:
  - Geographically locating and characterizing the target.
  - Weaponeering the target using JMEM Weaponeering System (JWS) – A weaponeering tool that predicts lethal effects and provides warfighters with probability of kill data.
  - Performing target coordinate mensuration.
  - Determining CDE and Risk Estimate Distances – Critical for ensuring the safety of civilian and friendly forces during “danger-close” weapons employments, using the Digital Precision Strike Suite Collateral Damage Estimation (DCiDE) tool.
  - Producing and outputting graphics to the appropriate databases.
- Joint Anti-Air Model (JAAM) – A tool designed to enable air combat tactics, techniques, and procedures (TTP) development for operations at test and training ranges. JAAM is used daily across the DoW for planning and debriefing air combat operations.
- Non-kinetic weaponeering, battle damage assessment (BDA), and targeting workflow tools – These tools estimate lethal effects for advanced systems, including directed energy weapons (DEW), cyber, electromagnetic spectrum (EMS) fires, and maritime targets. They also support BDA and streamline targeting workflows to enhance operational efficiency. Specific tools include:
  - Joint Laser Weaponeering Software (JLaWS)
  - Joint High Power Microwave (HPM) Applied Weaponeering Knowledge Software (JHAWKS)
  - Cyber Operations Lethality and Effectiveness (COLE)
  - Joint Electronic Attack Prediction (JEAP)
  - Maritime and High Energy Laser (HEL) Target Damage Cards
  - Maritime Combat Effectiveness (MaCE)
  - Integrated Naval Simulation for Threat Effects
  - Joint Battle Damage Assessment Repository (JBAR)
  - Joint Target Intelligence Modernization (JTIM) Workflow Application for Recording Production and Targeting History (WARPATH)

The JTCG/ME program also oversees the Joint Live Fire (JLF) program, which plays a critical role in the survivability and lethality analytic community. JLF delivers infrastructure, models, simulations, and data to support the testing and experimentation of kinetic and non-kinetic systems in operationally relevant contexts. This ensures a consistent foundation for LFT&E and the development of warfighter tools and techniques.

MISSION

The JTCG/ME program develops, advances, and sustains weaponeering tools. These tools, frequently referred to as JMEM products, are used by the joint force and combatant commands (CCMDs) to estimate and optimize the type and number of U.S. offensive kinetic and non-kinetic capabilities required to achieve the desired lethal effect. These products support

assessment against a range of kinetic and non-kinetic strategic or tactical targets, while mitigating risk for collateral damage including civilian casualties.

JTCG/ME oversees the JLF program to develop and enhance full-spectrum survivability and lethality digital tools (including kinetic and non-kinetic effects); improve survivability and lethality T&E methods and processes; and enable live data collection to support rigorous verification, validation, and accreditation of survivability and lethality digital tools.

FY25 KEY ACTIVITIES

» DELIVERING CREDIBLE WEAPONEERING TOOLS TO CCMD STRIKE AUTHORITIES

JMEMs are used daily by warfighters worldwide in direct support of operations, mission planning, and training. The user base includes approximately 18,000+ accounts, spanning the following entities:

- DoW Service members
- Joint Staff/CCMDs
- Multiple coalition partners
- Acquisition community
- T&E enterprise
- Intelligence Community
- National Laboratories

In FY25, JTCG/ME fielded updates to improve product accuracy and efficiency in support of operational warfighters. Specifically:

- JTCG/ME has continued to improve the efficiency and effectiveness of the JTIM program by developing, standardizing, and integrating the ATD federated workflow management tool, WARPATH, and further the connection with battle damage assessment tool, JBAR. As part of this process, operational users will be able to link desired effects to tactical tasks outlined in operational plans, which will increase the probability of meeting the commander's objective via enhanced integration and connectivity across the targeting enterprise to enable targeting at scale.
- JTCG/ME has continued to apply modern software development methods to enable continuous and incremental improvement in capability, user interface, and experience of tools, including JWS, JAAM, COLE, and JEAP.
- JTCG/ME generated seven reach-back packages for weaponeering, CDE, and munition effectiveness assessment in support of FY25 operations.
- JTCG/ME facilitated 24 training classes/events for over 450+ students. Training of integrated product capabilities (DIEE/JWS) continues to enable the operational community to successfully employ munitions while minimizing collateral damage.

» JLF PROGRAM DATA SUPPORT

JLF serves as a cornerstone of the T&E community, providing essential infrastructure, models, simulations, and data to support the testing and experimentation of kinetic and non-kinetic systems in operationally relevant contexts. By delivering a consistent foundation for LFT&E and warfighter tools and techniques, JLF ensures informed decision-making and continuous improvement. In FY25, JLF partnered with naval surface warfare centers, U.S. Army Combat Capabilities Development Command, Sandia National Laboratories, Naval Air Warfare Center, Air Force Research Laboratory, Larence Livermore National Laboratories, Walter Reed Army Institute for Research, Air Force Lifecycle Management Center, Air Force Institute of Technology, and many industry partners to address leading-edge and unique weapon systems development challenges while ensuring that data and characteristics are rigorously analyzed to assess lethality and effectiveness.

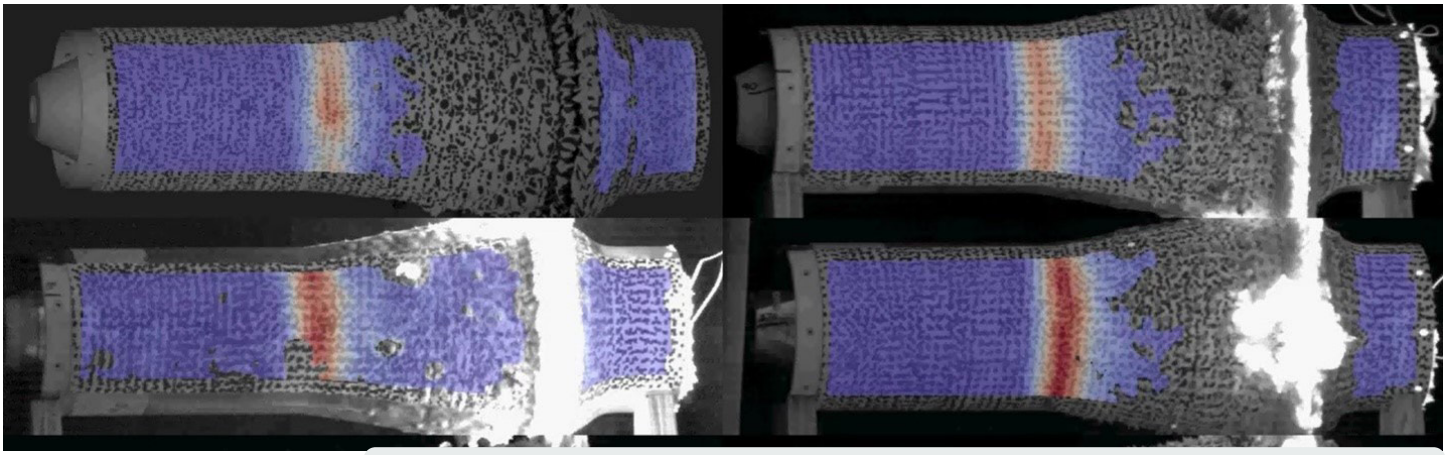

Figure 1. Advanced Warhead Characterization - Digital Warhead Compared to Test

Acquisition Support

JLF provided DOT&E with organic test, data, and modeling and simulation (M&S) capabilities to support T&E requirements – including joint testing that will benefit the entire DoW – emerging/unique testing capabilities and advancing M&S in preparation for Title 10 statutory required evaluations.

In FY25, JLF conducted testing and data collection to update methodologies and create new assessment tools. JLF successfully finalized comprehensive documentation outlining the digital engineering process for munition warhead characterization (as shown in Figure 1). This process is designed to support and enhance the JTCG/ME in its efforts to standardize and improve warhead performance evaluation across the DoW.

Expanding on previous Advanced Warhead Characterization (AWC) test successes, JLF executed over 60 behind armor debris experiments with optical fragment tracking for kinetic energy penetrators. They enhanced optical fragment tracking techniques and updated methodology that can reduce live fire costs by up to 30 percent.

As part of Active Protection System (APS) M&S capability enhancements, JLF expanded shaped charge jet vulnerability and lethality analysis to include multiple fragment impacts. JLF funded the development of methodologies to model damage to rocket-propelled grenades and anti-tank guided missiles from APS countermeasures, and updates to the Advanced Joint Effects Model (AJEM) damaged jet methodology for advanced scenarios. These efforts further improved the effectiveness and fidelity of APS evaluations.

Additionally, JLF improved the modeling of dismembered (misaligned) warheads by collecting test data for existing gaps (as shown in Figure 2) and then used the date to improve the End Game Model's methodology.

Vulnerability analyses depend on accurately defined damage criteria for critical components to predict the probability of kill at the component, system, and target levels. To support this, JLF conducted a series of tests to evaluate fragment penetration into wiring and wire bundles (shown in Figure 3), aiding in the development and validation of component damage criteria.

In FY25, JLF advanced its Traumatic Brain Injury (TBI) initiatives. JLF partnered with Walter Reed Army Institute of Research (WRAIR) to develop a preliminary dose-

Figure 2. Dismembered Warhead Projectiles

Figure 3. Wire Bundle Target Examples Before and After Test

response curve to establish thresholds for low-level, repeated blast exposure from weapons firing (shown in Figure 4). This curve is set to be integrated into the health hazard assessments used by DOT&E to evaluate weapon safety.

Figure 4. TBI Weapons Training Data Collection by WRAIR

Operational Suppport

JLF provided JTCG/ME with an organic test, data, and M&S capability to support warfighter requirements. This includes joint testing that will improve M&S capabilities foundational to operational tools, quick reaction testing to meet critical operational requirements, and advancing M&S in preparation for integration of fielded weapon systems into JTCG/ME operational tools.

In FY25, the JLF executed aluminized high-explosive blast experiments to validate and improve late-time blast effects M&S methodologies developed under the JLF Phase I - Aluminized High Explosive Modeling and Simulation Program. Figure 5 shows an example of the blast experimentation. This comprehensive program enables more accurate fast-running models and lethality assessments, allowing the weaponeering community to precisely evaluate the impact of enhanced-effect aluminized explosives on lethality.

To support injury risk assessments as part of JTCG/ME's CDE efforts, JLF continued collaboration with the University of Virginia (UVA) to develop an initial TBI risk model for large, acute blast event exposures to inform Danger Close calls (i.e., risk to friendly troops) for close air support and fires support missions. JLF delivered an initial software capability, with verification and validation planned for FY26.

Within the scope of non-kinetic capabilities, JLF tested and generated target vulnerability packages to assess the lethality and effectiveness of HEL and HPM weapons, accounting for threat vulnerabilities through high-fidelity and empirically based analyses. Figure 6 shows an HPM test fixture.

JLF investigated the kinetic effects that can penetrate shielding and make target components more vulnerable to HPM weapons. This involved conducting simulations and testing of attenuation through shields with relevant fragment holes and patterns to evaluate frequency susceptibility against relevant components.

JLF partnered with the Air Force Institute of Technology to include the Weather Integration Prototype (WIP) system in DoW field tests, tested WIP updates, and generated atmospheric and performance data sets for the Directed Energy community to provide improved real-time path characterizations for laser weapon systems and battlespace management applications. This work resulted in a Realtime Weather Sensor Package (shown in Figure 7) recommendation for ranges to accurately capture HEL effectiveness.

Full-Spectrum Survivability

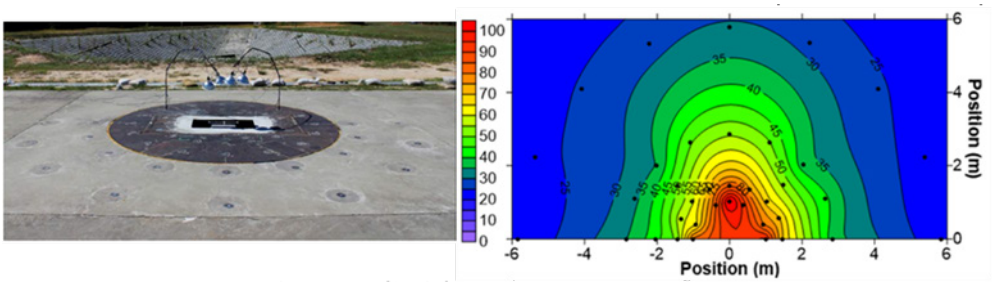

Figure 5. Blast Pad facility (left) and example of pressure impulse data (right)

In FY25, the JLF provided DOT&E with a surge capability to develop and implement tools, processes, and methods to enable credible full-spectrum survivability and lethality evaluations across the acquisition lifecycle, including operations and sustainment. This one-year surge effort focused on three operationally relevant scenarios: (1) weaponeering in multi-domain operations to support the commander's intent, (2) full-spectrum survivability to inform acquisition decisions, and (3) full-spectrum lethality to inform acquisition decisions. Deliverables from the JLF full-spectrum analysis surge will transition to DOT&E and JTCG/ME to improve system evaluation and warfighter capabilities across multiple, collaborative domains.

Figure 6. HPM Testing Capability

JLF advanced full-spectrum analysis capabilities by transitioning the Full Spectrum Survivability Tool to the lethality domain, delivering an updated graphical user interface (GUI) for scenario definition, and evaluating transition partners. Additionally, JLF completed initial research and modifications to integrate radio frequency connections between devices into COLE through the Cyber Link Effects Analysis for Radio Systems (CLEARS) project, enabling comprehensive analysis of wireless systems within the full spectrum framework depicted in Figure 8.

JLF expanded LLNL's Eucalyptus, a failure analysis logic tool. Eucalyptus generates system fault trees based on component and location variability. The fault tree is generated using engineering principles and outputs a visual representation of the layout (as shown in Figure 9), to support multi-domain effects and integrated the capability to model uncertainty of component location. Enhancements included the following: performance improvements, faster computations, improved test suite, and ability to generate a single executable file.

As part of the FY25 focus on enabling credible full-spectrum survivability and lethality evaluations across the acquisition lifecycle, JLF developed and delivered a proof-of-concept analysis demonstrating dynamic integration

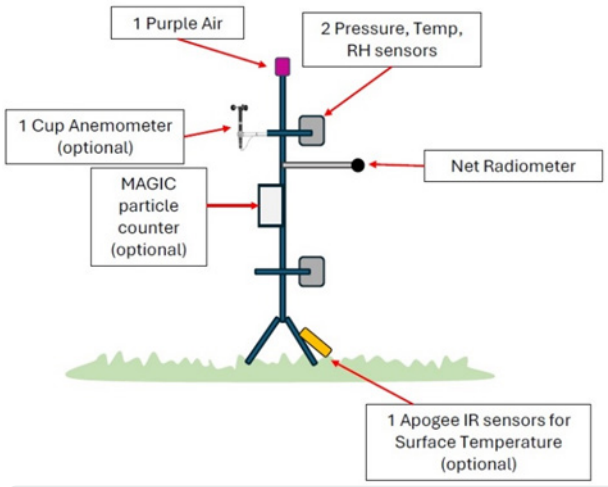

Figure 7. Realtime Weather Sensor Package

Figure 8. CLEARS Concept

In FY25, JLF transitioned and expanded data repositories to enhance the archival, review, and accessibility of lethality and vulnerability data, methodologies, and documentation. Key updates include the following:

- HEL Repository – JLF was the transition partner for the OUSW(R&E)-developed repository for HEL component-level testing, supporting test planning and M&S development.

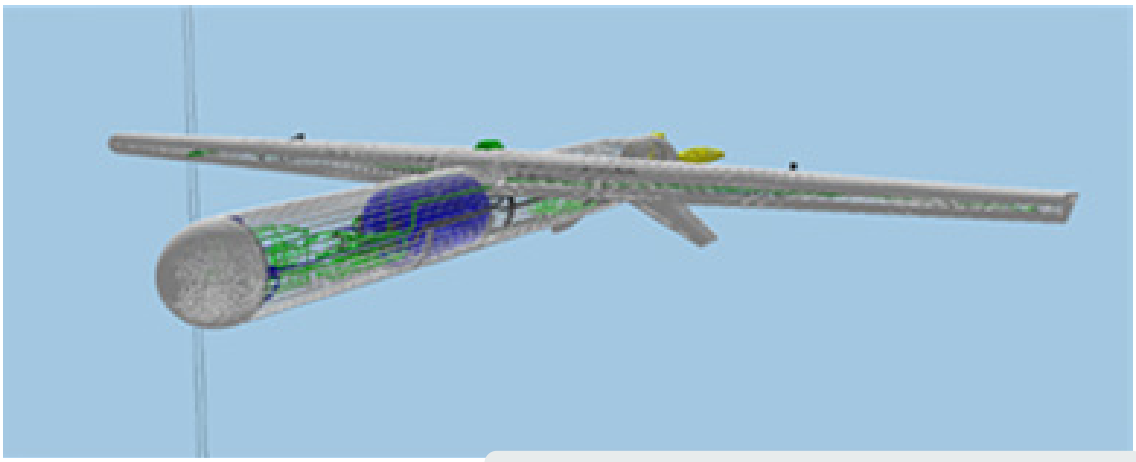

Figure 9. Eucalyptus Component Representation

- JBAR – JLF integrated test data into JBAR and added a user interface, enabling warfighters to search and access videos and data from test events (shown in Figure 10).
- Service-Specific Repository (SSR) – JLF developed and deployed a target vulnerability data repository shared across the DoW acquisition community. The SSR connects directly to the JTCG/ME target development and approval

between force-on-force level modeling with engineering level ballistic modeling. This effort included adjustments to human behaviors to reflect the reduced functionality of a vehicle. This final demonstration of full-spectrum survivability directly supports the JLF's operational priorities, including multi-domain weaponeering, survivability-informed acquisition decisions, and lethality assessments.

Knowledge/Data Management

Data is the foundation of acquisition and operational decision-making, with digital transformations playing a critical role in accelerating development, analysis, and production processes. JLF prioritizes validated data as the cornerstone of every project, ensuring accuracy and reliability to support informed decisions.

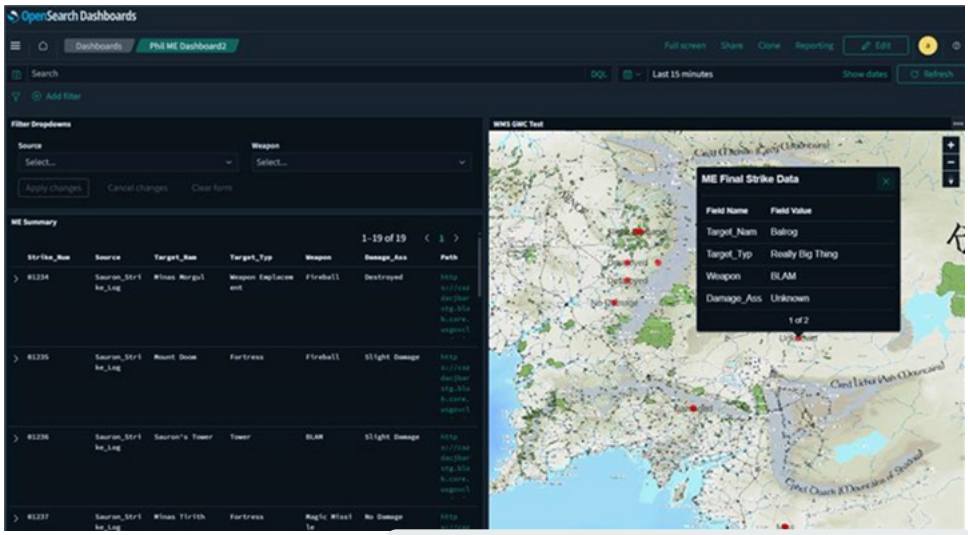

Figure 10. JBAR Screenshot User Interface

process and is accessible on both NIPRNet and SIPRNet.

These advancements ensure that critical data are readily available to improve lethality and survivability evaluations and to inform decision-making.

JLF remains an essential contributor to the T&E and warfighting communities, delivering innovative capabilities, tools, and data to advance all-domain survivability and lethality evaluations of DoW systems. Through rigorous testing, M&S, and analysis in operationally relevant environments, JLF continues to enhance JTCG/ME effectiveness estimates for both kinetic and non-kinetic systems. These efforts ensure that the DoW is equipped with the insights and tools necessary to maintain a decisive edge in modern warfare.

» ADVANCING THE CAPABILITY, EFFICIENCY, AND ACCURACY OF TARGET DEVELOPMENT TOOLS

ATD

DIEE is a vital software program for the targeting enterprise at the global level. It provides digital solutions to the essential Joint Targeting Cycle functions for the U.S. and coalition partners.

DIEE's intel and targeting capabilities transform workflow inefficiencies into automated and integrated solutions within one ecosystem. DIEE's critical targeting functions apply across the targeting spectrum and address basic, intermediate, and ATD. Key functions include the following:

- Target Coordinate Mensuration – Ensuring precise geolocation of targets.
- Weaponeering Methodologies – Utilizing the JWS for optimal weapon selection.
- CDE – Leveraging the DCiDE tool to assess effects and minimize risks.
- Targeting Graphics Production – Creating high-quality visual aids for operational planning.
- Combat Assessment – Evaluating mission effectiveness and refining restrike strategies.

FY25 accomplishments include extending DIEE's interoperability with the rest of the targeting enterprise to enable federation of target development. This includes interoperability with key systems such as the Machine-assisted Analytical Rapid-repository System and WARPATH.

Additionally, the fielding of Tactical DIEE versions 3.0.1 and 3.1 introduced several enhancements, including:

- Modernized integrated database updates for improved data management.
- 3D point mensuration capability for precise geospatial analysis shown in Figure 11.
- DCiDE updates aligned with Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3160.01E standards for CDE.
- Graphic generation updates compliant with CJCSI 3370.01D for targeting visuals.
- Initial release of maritime target damage cards to support maritime operations.
- The first iteration of the integrated JWS capability.

The development of Enterprise DIEE, a Public Key Infrastructure (PKI)-enabled and cloud-based solution, is underway with capability drops planned for FY26. Specific capabilities being developed include

Figure 11. Examples of native 3D imagery analysis and Target Coordinate Mensuration capability no longer requiring additional hardware

interfaces with other Services to conduct basic and intermediate target development as well as support for combat assessment.

As part of the OUSW(I&S) and J-2 JTIM initiative, JTCG/ME initiated the development of a federated workflow management tool, WARPATH. This tool aids in streamlining the targeting, production, and tracking process while reducing duplicative efforts and costs. WARPATH will be a stand-alone web application that is interoperable with DIEE and all other JTIM-associated programs.

Weaponeering

The JWS combines a series of weapon system characteristics, delivery accuracy, and target vulnerability data needed to estimate the final aimpoint, delivery conditions, and number of weapons on target necessary to achieve combatant commanders desired lethal effects. In FY25, JWS version 2.4.2 was published for foreign disclosure review and accreditation. JWS v2.4.2 provides cyber security updates and enhanced connectivity capabilities with the DIEE application. Development of a follow-on release, JWS v2.5, was also completed. This version of JWS provides a refined data set that allows deployment to additional coalition partners and tightens interactions between the U.S. and foreign partners within joint environments.

The next-generation JWS 1.x plug-in product line will continue the development of weaponeering capabilities, including:

- Support for structural targets (e.g., building cross-section, as shown in Figure 12).
- Enhanced modeling for interior and exterior personnel targets.
- Materiel target analysis.
- Modernized weaponeering support tools.
- Seamless integration with DIEE 3.x.

While initial capabilities are reviewed and tested, future capabilities, to include bridge, bunker, and runway targets are being integrated and prepared for operational weaponeer community review.

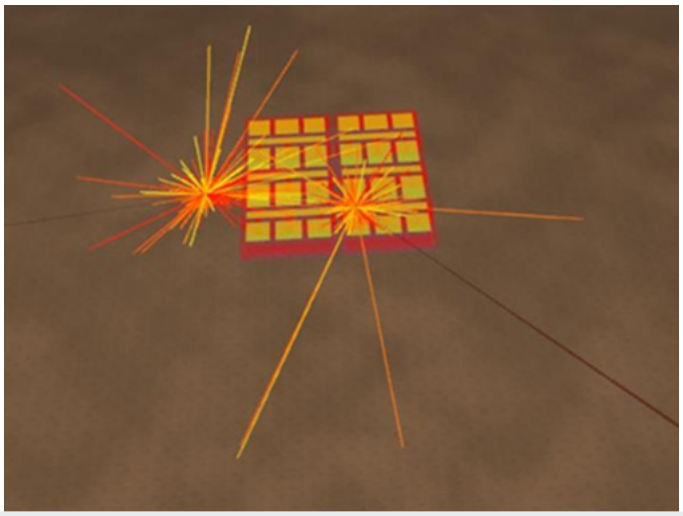

Figure 12. JWS Plug-in 1.x Fragment flyout interaction with cross-section of structural target

CDE

In FY25, JTCG/ME made significant progress toward improving the ability of the DoW and coalition partners to accurately characterize the CDE associated with lethal effects of weapons employments. Specifically, JTCG/ME continued the execution of the multiyear Enhanced Weaponeering and CDE test program to quantify the collateral effects resulting from munitions detonating in the ground or beneath structures. Data sets from the Enhanced Weaponeering and CDE test program were used to develop, improve, and validate methodologies to predict building debris characterization (e.g., fragment distribution, mass, velocity), cratering, soil ejecta, ground shock, and blast pressure for mitigated munitions. These methodologies are used by operational tools, including DCiDE and JWS, to estimate weapon collateral damage and lethality.

In FY25, JTCG/ME conducted multiple tests, shown in Figure 13, to further the understanding of deeply buried munitions and building debris effects, shown in Figure 14, on personnel and nearby structures. These data supported the evaluation of camouflet - formation resulting from below-ground detonations that do not open to the soil surface, as well as the effects of a munition buried beneath a two-story structure. The data enabled the characterization of blast and fragmentation mitigation and the collateral risk from secondary debris. This program has fostered

Figure 13. Buried ordnance test conducted in partnership with the U.S. Army Engineer Research and Development Center at Fort Johnson, Louisiana

Figure 14. Two-story over-burial building debris test conducted in partnership with the U.S. Army Aberdeen Test Center, Maryland

collaboration opportunities among multiple organizations, enabling the collection and sharing of valuable data for other M&S and methodology development efforts.

BDA

JTCG/ME continued the multiyear effort to verify, validate, and advance the effectiveness of JMEM weaponeering tools by capturing perishable strike information for future analysis. The goal of the BDA program is to collect all strike information to not only analyze strikes and inform reach-back support, but also to support weaponeering tool verification and validation, training, and expenditure analysis.

In FY25, JTCG/ME worked with U.S. Central Command (USCENTCOM) to update the JBAR GUI to ensure it meets their operational strike reporting needs. Application programming interface (API) connections were made to the Defense Intelligence Agency's Modernized Intelligence Database and the Air Force's air mission repository MARAUDER to collect mission reports, graphics, weaponeering data, and full-motion video for USCENTCOM and U.S. Africa Command (USAFRICOM). The data were subsequently entered into the JBAR database, making them accessible through queryable web maps.

As part of the JTIM program, JBARs development team is working to make connections to data scraping tools and WARPATH to maintain interoperability and integrate into the National Geospatial-Intelligence Agency Common Operations Release Environment (NGA CORE) cloud environment. Connections to scraping tools will allow for the collection of strike-related information from operational chat logs. WARPATH will receive a strike identification number from JBAR for tracking through the combat assessment process.

Lethal Effect Estimates – Maritime Targets

In FY25, JTCG/ME continued to enhance the ability of weaponeering tools to support the warfighter with credible and timely lethal effects estimates against adversary maritime (surface and subsurface) targets. Within this effort, JTCG/ME continued to develop and publish updates to the "Maritime Weaponeering Handbook," covering several maritime targets not currently in JTCG/ME inventory. Version 1.3 of the Target Damage Cards software, developed by JTCG/ME will be integrated into DIEE to update the interim maritime weaponeering analysis tool for

Figure 15. Maritime Target Damage Card visualization tool

surface targets shown in Figure 15, with follow-on versions including subsurface targets.

Development of the MaCE operational weaponeering tool progressed in FY25, adding to the capabilities of Target Damage Cards (shown in Figure 15). Ultimately, MaCE will be integrated into DIEE. MaCE will be able to calculate results on the fly and visualize precalculated data within DIEE.

JTCG/ME continues to execute a collaborative test program that procures data to close knowledge gaps, improve current analytical tools and methods, and develop advanced digital tools required to support the delivery and fielding of weaponeering tools against maritime targets. This includes the Integrated Naval Simulation for Threat Effects, which is an engineering-level model replacing multiple existing tools and offering best-of-breed methodologies from those tools for both surface and subsurface targets. Work continues to advance capabilities across the federation of tools, including:

- Submarine Vulnerable Effects Model
- Navy Enhanced Sierra Mechanics
- Dynamic System Mechanics Advanced Simulation

The test program includes methodology development to predict fire initiation within targets and damage due to missile-body debris. JTCG/ME also provided reach-back support for urgent operational user requests and has delivered 29 operational user reach-back packages to date. These efforts increase weapons systems' lethality against foreign maritime threat platforms and will support more effective and efficient survivability evaluation of U.S. ships and submarines for LFT&E programs.

Aircraft and Weapon Tactics

In FY25, JTCG/ME finished the JAAM version 6.0 application, with a planned release early in FY26. The JAAM application is the authoritative, two-sided (e.g., blue and threat), multi-domain combat simulation utilized to underpin common air warfare training and operational tactics. JAAM development leverages an authoritative suite of supplier simulations and data, fused within a common framework. JAAM significantly enhances the lethality of U.S. fighter pilot training by providing accurate assessments rather than assumptions, guesswork, or unverifiable maneuvers. JAAM is critical to warfighters having the weapons and tactics required to win in combat.

Warfighters utilize JAAM version 5.4 daily across 370 sites to enable TTP development and refinement, as well as reinforcement training for air-to-air and surface-to-air threat engagements.

Users across the joint force use JAAM for a breadth of operational requirements:

- Test and training ranges use JAAM to support tactics development, mission rehearsal, debriefing, and reinforcement training for pilots.
- Combat Air Forces and the Navy and Marine Corps air fleets use JAAM to support operational doctrine and technical manual development.
- The Intelligence Community uses JAAM to support tactics analysis.
- The joint fighter integration community utilizes JAAM for cockpit-used data kneeboard devices detailing the timelines approved for efficient and effective tactics.

JAAM leverages both stand-alone and external APIs:

- The stand-alone JAAM version 6.0 application and GUI display show aircraft and weapon flight paths and key tactical events, such as aircraft target detection, weapon launch, weapon seeker activation, weapon performance, aircraft performance, and target intercepted-killed (Figure 16). These graphical displays enable users to critically assess aircraft maneuvers and weapon shots, with high-fidelity, authoritative information.
- The JAAM external API provides the same authoritative results accessible to the warfighter when using JAAM stand-alone. The JAAM API allows interoperability within debriefing tools such as Personal Computer Debriefing System, Live Missions Operations Capability, and Tactical Combat Training System. This interoperability allows JAAM to support event playback using post-event aircraft cartridge data (i.e., time-space-position information data and GPS data).

JTCG/ME developed the new JAAM version 6.x product line to address warfighters' needs for unique large-scale data simulation and ease-of-use workflow. The JAAM 6.x product line uses the Air Combat Effects Library (ACEL) which contains the government-owned framework, Hybrid Integration and Visualization Engine. JAAM leverages collaborative

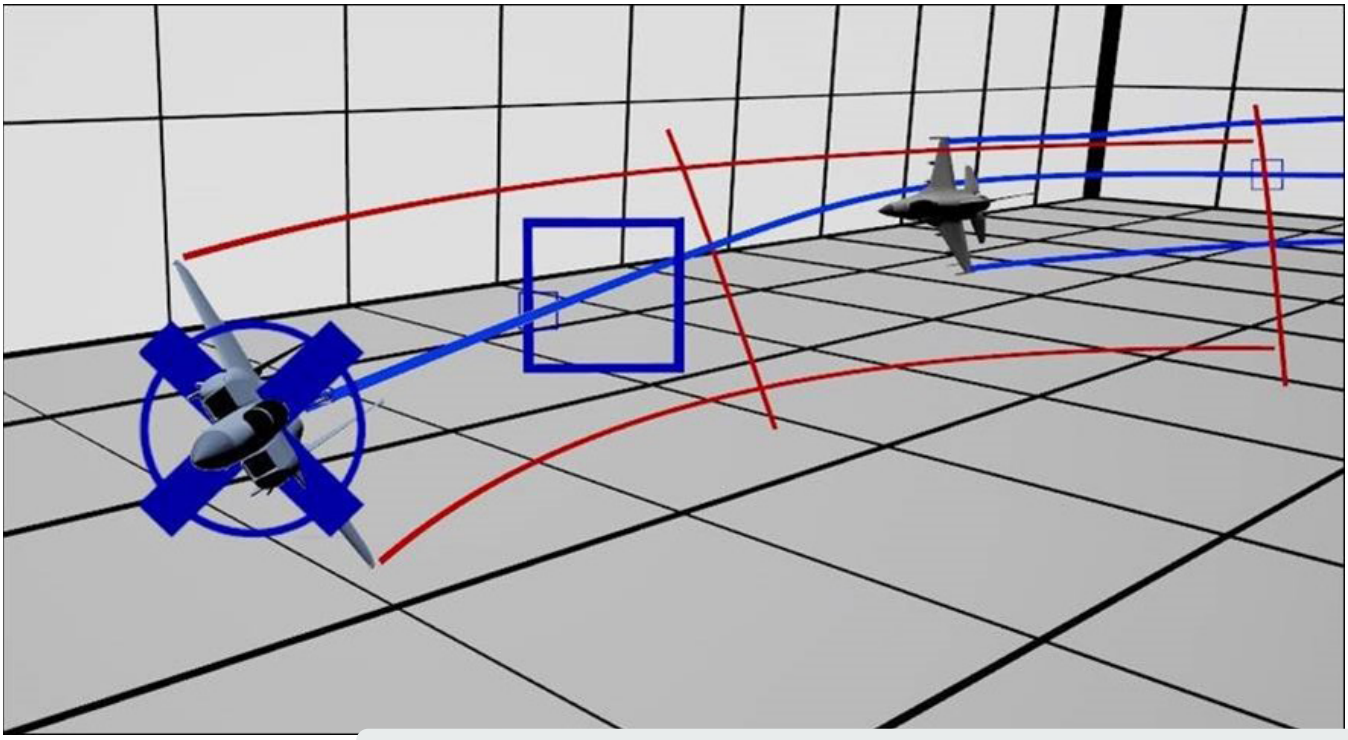

Figure 16. JAAM version 6.0 Interactive GUI showing key simulation events (weapon launch, seeker activation, and intercept/kill)

efforts with the Joint Aircraft Survivability Program (JASP) and intelligence centers to provide users with ACEL's authoritative, high-fidelity simulations and data needed. JAAM's design enhances aircraft survivability and weapons lethality in a multi-domain, contested combat environment.

JAAM version 6.0 enhances productivity and workflow to support large-scale data analytics needed to develop and refine tactics against emerging threats. JAAM's warfighter-friendly parametric GUI, simplifies workflow and increases output options for the warfighter assessing multiple aircraft and weapons with hundreds of thousands of parametric engagement conditions. Data content is user selectable and is available in standard eXtensible Markup Language (XML) and spreadsheet formats, suitable for external data processing. GUI-enabled batch processing increases productivity by removing operator-overhead and instead utilizing the framework to efficiently handle the processor allocation and sequencing within individual engagements. This key capability directly supports efficient tactics development. The new in-line GUI editing eliminates disconnected workflow. The GUI redesign enables growth for additional capabilities such as terrain masking and displays. JAAM version 6.0 will introduce rotary-wing platforms as part of the low-altitude combat scenarios, providing critical value-added insights to warfighters.

Data Management

In FY25, JTCG/ME supported implementation of the DoW Data Strategy. Beyond the previously mentioned JLF knowledge/data management initiative, JTCG/ME expanded the repositories for access of lethality and vulnerability data (e.g. archival, review, and approval) methodology, and documentation. The following four repositories serve multiple user communities with corresponding features and capabilities:

- For data, the Joint Analysis Repository and Visual Interface System (JARVIS) is a web-accessible repository with the authoritative data to support JTCG/ME's portfolio of warfighter applications. A critical requirement is to facilitate the data development and joint-Service review and approval processes. This repository also serves the T&E and acquisition communities by providing JTCG/ME-approved target vulnerability packages. In FY25, JTCG/ME deployed several updated versions of JARVIS that provided significant enhancements, including data management capabilities for weapon characteristics and pre-generated weaponeering results.
- For methodology standards and practices, the Joint Effects Library (JEL) is the official repository for all implemented methodology and supporting functions that are approved by JTCG/ME and used in weapon effects applications. Not only does it serve as an archive for all JTCG/ME-approved modules, but it also enables the incorporation of standard acceptance workflow and supporting material. The intent is to improve quality, increase reusability and reliability, and reduce time to integrate modules into weaponeering applications. In FY25, JTCG/ME incorporated several additional modules into the JEL to support kinetic penetration effects, cratering, material targets, and blast effects.
- For documentation, the Bugle is a wiki-style website built on Defense Technical Information Center's DoDTechipedia platform. Hosting on DoDTechipedia makes JTCG/ME's technical reports, data requests, and model documentation accessible to the DoW community. In FY25, additional content was added to share information and collaborate on JTCG/ME products, models, and methodologies. In addition, JTCG/ME improved the site navigation and the overall user experience.
- For the acquisition community, the JLF Secure Targeting Exchange Platform (STEP) is a web-accessible and secure repository for the joint target vulnerability development community. This application provides transparency of target vulnerability development efforts throughout the DoW for cost sharing opportunities. Analysts can use the repository to store, manage, and share target vulnerability data throughout the acquisition community. In FY25, the STEP was enhanced with token-based authentication, improved access controls, and easier loading of large data sets. The product has users in the Army, Navy, and Air Force analytic agencies.

These four repositories work in conjunction to provide joint-Service-approved munition effectiveness data, methodology, and documentation within JTCG/ME, JLF, and throughout the DoW.

» ENABLING MULTI-DOMAIN SUPERIORITY WITH DEW, CYBER, INFLUENCE OPERATIONS, AND EMS FIRE WEAPONEERING TOOLS

DEW

In FY25, JTCG/ME continued to develop and validate DEW weaponeering tools – JLaWS and JHAWKS – to enable the CCMDs to estimate lethal effects using HEL and HPMs.

JLaWS

JLaWS uses target vulnerability data, weather effects, and optical risk characteristics to provide effectiveness results for solid state laser weapon systems. JLaWS accounts for the effect of weather on laser propagation by automatically downloading location-specific weather files from established services. It allows the user to calculate optical risk in the event of HEL reflections from targets using the High Energy Laser Risk Assessment Tool (HELRAT). HELRAT graphically portrays the risk distances around a target that contains reflected laser radiation levels that could cause ocular hazards to friendly forces. Figure 17 shows a JLaWS graphical rendering of a ship-based laser weapon system engagement with an unmanned aerial vehicle target and the spherical zones around the target, as calculated by HELRAT, in which ocular hazards exist.

In FY25, JTCG/ME fielded JLaWS version 2.x and continued development of JLaWS version 3.1.2. The JLaWS version 3.x products will include new weapons, target vulnerability characterization, and enhancements from test and analytical events. Focus areas include validating and verifying both the underpinning methodology and data that support JLaWS, and increased data reviews/approvals for improved capability.

JTCG/ME supplied eight operational threat packages to Commander, U.S. Seventh Fleet (C7F) for a HEL

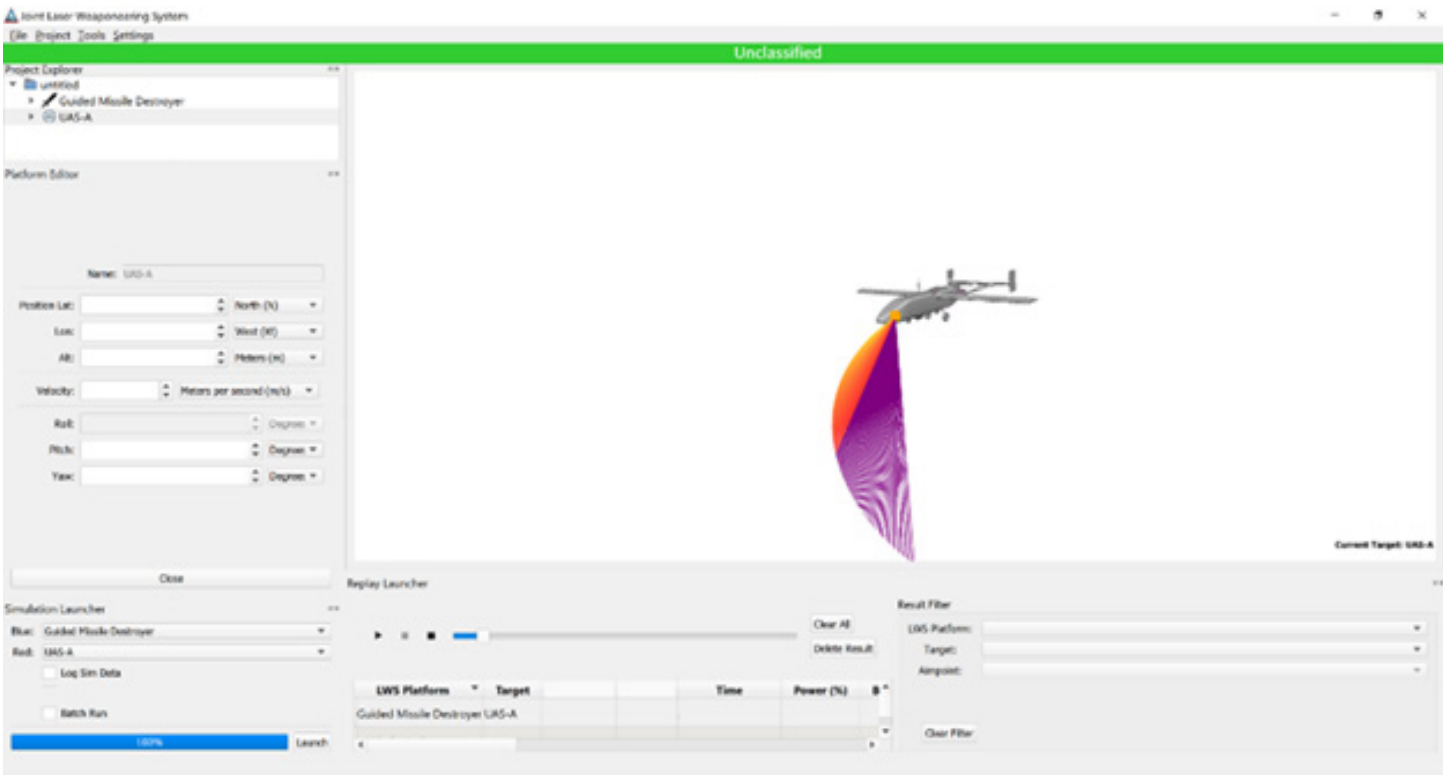

Figure 17. JLaWS Vulnerability Explorer and examples of shot lines

system of interest. In addition, supported operational target card packages, and engaged in multiple warfighter events, allowing critical operator feedback to support weaponeering and CDE for HEL weapon systems.

JTCG/ME's further development and validation of the surrogation tool, Characteristic-based Laser Objective Surrogate Evaluation (CLOSE), allows for subject matter experts to generate efficient, reliable, and tractable HEL surrogate vulnerability packages from an existing assessment database, allowing quick turnaround HEL analyses and studies.

JHAWKS

JTCG/ME continued development of its HPM tools and released JHAWKS version 1.0 Beta for user feedback, with the next release scheduled in FY26. JHAWKS version 1.0 Beta, shown in Figure 18 displays a single drone and a stationary HPM source. This use case allows users to output the overall power directed on target and establishes a foundational minimum viable product that can be expanded to model more mission-relevant scenarios, such as swarm engagements. Additionally, the JHAWKS team developed HPM vulnerability modules (VMs) and refined the HPM VM interface control document, for review and concurrence with the HPM community. These efforts serve as critical inputs for JHAWKS development.

In FY25, JTCG/ME supported the release of the Effectiveness ToolBox (ETB) 9.0, with significant enhancements in graphics and capabilities that support HPM engagement evaluations as shown in Figure 19. ETB is an advanced engineering-level M&S tool designed to address capability gaps and enable accurate modeling of dynamic HPM engagements, critical for providing reliable JHAWKS inputs and ensuring validated and accurate data are used in operational planning. The ETB 9.0 release marks a significant advancement in HPM modeling capabilities and supports next-generation non-kinetic weaponeering tool development.

COLE

In FY25, JTCG/ME continued developing and fielding cyber JMEM capabilities. COLE is the foundational product, enabling commanders and decision makers at all echelons to generate accredited, quantitative, and predictive effects of cyber operations in joint force operations. COLE provides the user with a cyber operations modeling and analysis capability for offensive cyber operations, T&E of operational systems, and risk assessments of cyber resilient systems. JTCG/ME partnered with JASP and JLF on

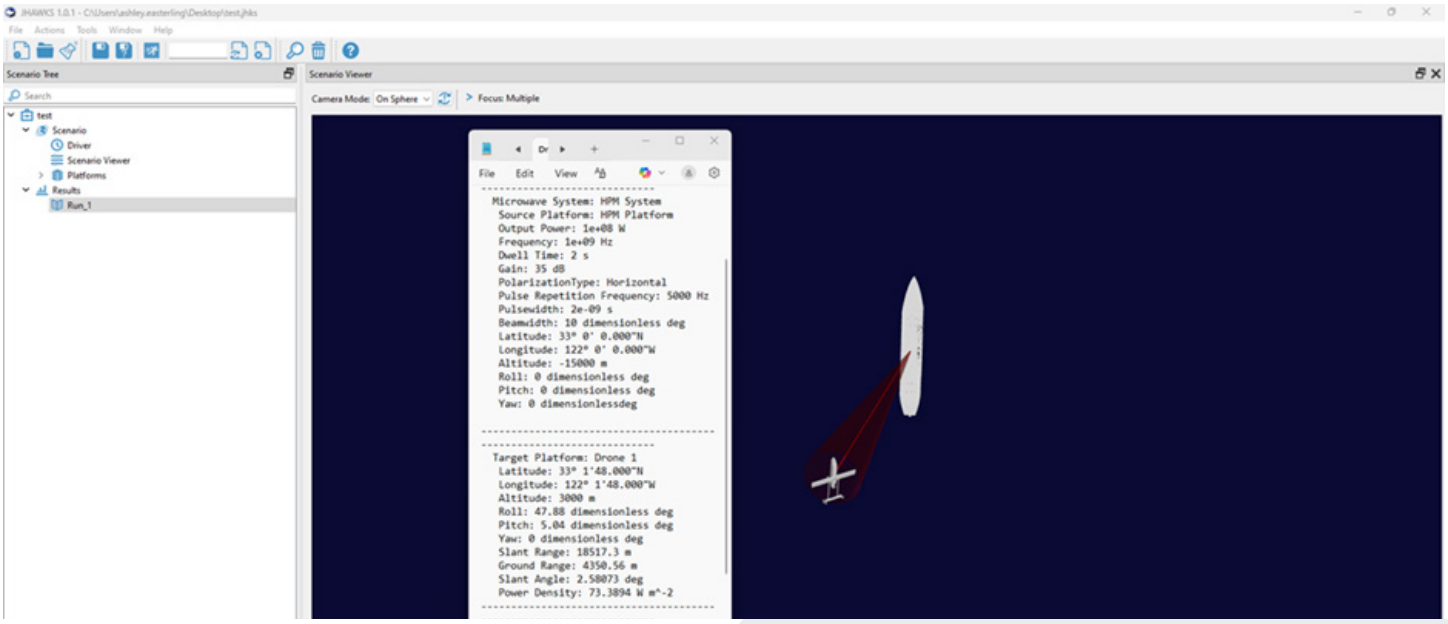

Figure 18. JHAWKS Initialization and Platform Editor

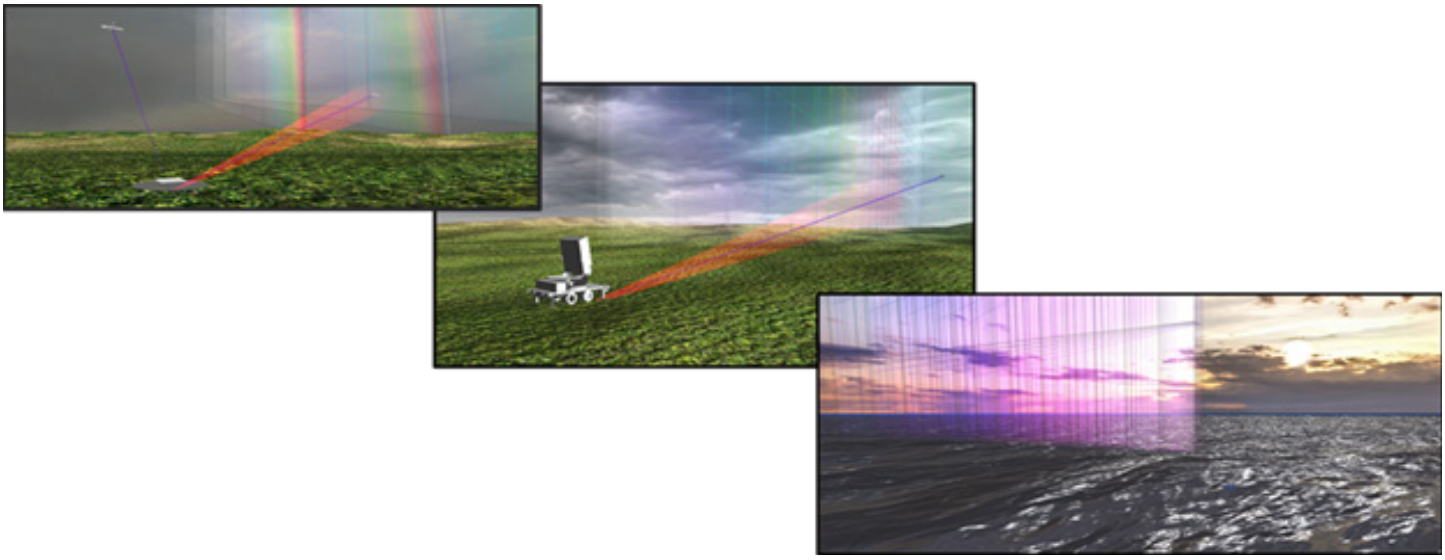

Figure 19. ETB HPM Propagation for Land and Maritime Environments

T&E efforts within COLE, to include Machine Assisted Exploitability Simulation and Testing for Resilient Operations (MAESTRO) and Cyber Automated Threat Discovery and Vulnerability Evaluation Reinforcement (CADAVER) programs.

In FY25, JTCG/ME deployed COLE version 4.1, enabling planning elements to model cyber networks, characterize properties, determine potential network vulnerabilities to cyber capabilities, develop TTP for cyber operations, and develop cyber capability requirements.

Major FY25 COLE achievements included a significant framework update, improvements for increasing automated data ingestion capabilities, including a Software Bill of Materials importer. Enhancements to the attack-path optimizer, which automatically generates possible courses of action, increase the thoroughness of options and speeds analytical efforts via automatic generation and tracking of options. COLE developers also integrated MITRE's D3FEND™ and the National Institute of Standards and Technology's Common Vulnerability Scoring System version 4.0. There were also built-in tool improvements to enable direct and immediate feedback to the COLE requirements and development teams.

JTCG/ME concluded its work with the JASP on the MAESTRO effort to further develop COLE's ability to assess cyber vulnerabilities of U.S. platforms. COLE for T&E provides a framework of models and tools to aid in examining aircraft cybersecurity. This year's analysis included completion of two aircraft assessments.

JLF concluded its work to develop enhanced vulnerability discovery abilities to assist in rapidly and automatically characterizing, discovering, and reporting cyber vulnerabilities within complex software configurations through the CADAVER program. CADAVER is intended to leverage artificial intelligence and machine learning to allow identification of potential vulnerabilities and to mitigate cyber-attack access points. In FY25, a hardware model was constructed to simulate environmental effects on radio frequency communications. Combined, COLE and CADAVER ensure warfighters have the necessary tools to assess cyber effectiveness and vulnerability using tri-Service-approved data standards and streams.

In FY25, JTCG/ME continued to partner with the DoW Test Resource Management Center, initiating two projects which will carry through FY26. The first, to model and examine the potential for adversary attacks against test facilities, has already generated new models within COLE for removable media and

data movement between networks. The second brings modifications to COLE's results page, enabling selected format outputs based on executive-level preferences.

JEAP

In FY25, JTCG/ME continued to develop an EMS fire – electronic attack JMEM, known as JEAP, with the capability to:

- Assess the impact of EMS effects on blue precision-guided weapons and salvos.
- Assess the effects of blue electronic attack capabilities against adversary emitter targets.

Ultimately, these JEAP tools will enable the warfighter to effectively prosecute adversary targets in contested, congested, and constrained EMS operations (as shown in Figure 20).

FY25 efforts included completion of a multi-year radar cross section data re-baseline for use in ACEL-based products for the joint community, as well as model-based systems engineering and data ontology models to support improved relational architecture and data streams for JEAP and Joint electronic warfare planning tools. JEAP also hosted and supported multiple user/supplier engagements within the joint electronic warfare community to underpin product requirements.

Additionally, the JEAP team provided interfaces to GPS operational awareness capabilities, as well as a Joint coordinated effort for enhanced analytical tools for assessing impacts to GPS guidance on weapon delivery and effectiveness based on operational use cases. An initial capability leveraging the GPS Interference and Navigation Tool (GIANT), and one blue high-fidelity weapon trajectory model, with other weapons initiated. JTCG/ME provided short-term support via reach-back to units and will continue to do so, until a more long-term product is fielded. JTCG/ME also supported an API effort to directly ingest high-fidelity models from DoW munition owners into GIANT. This API capability streamlines the ability to add high-fidelity 6-degrees-of-freedom models,

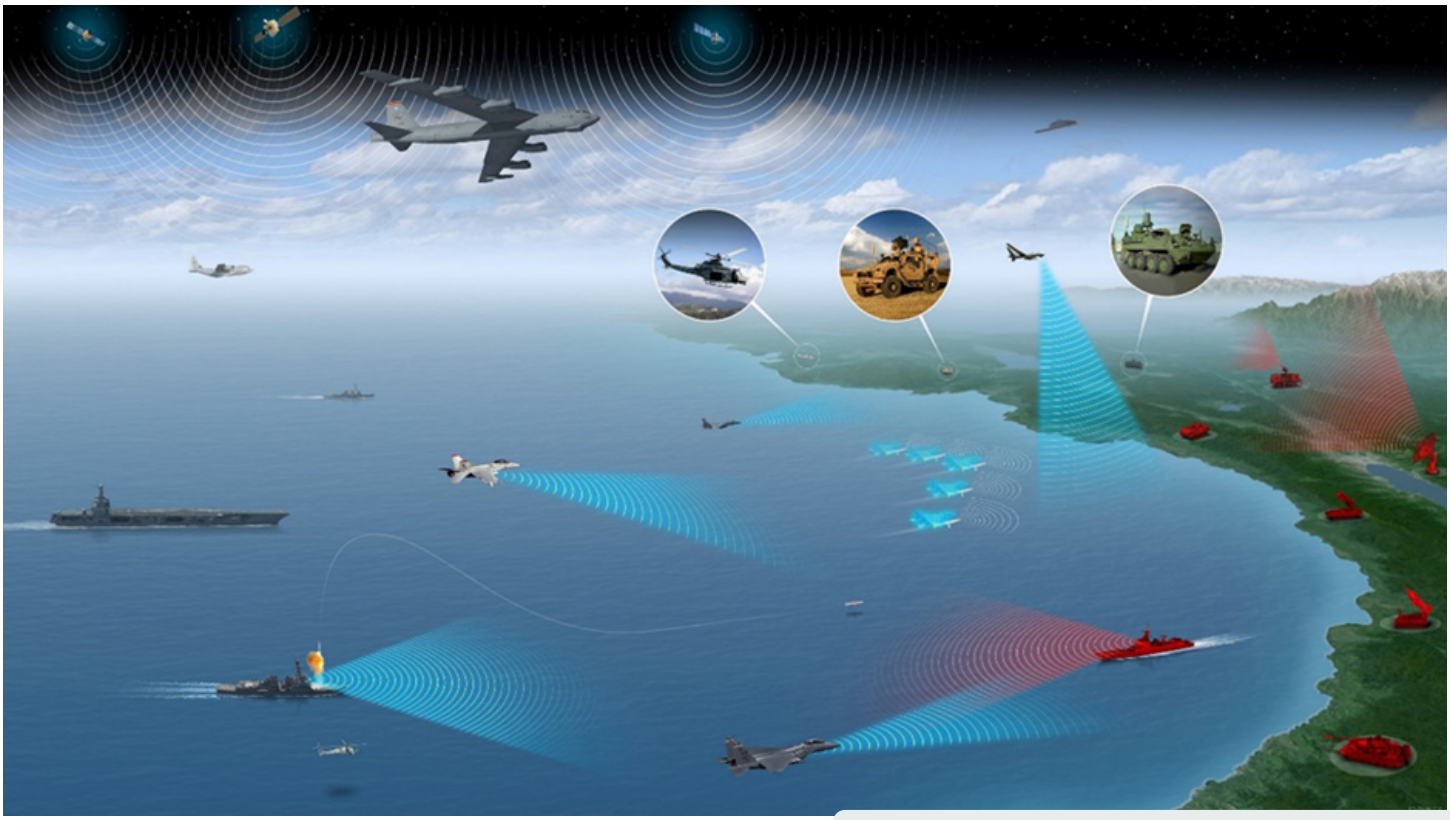

Figure 20. Sample Notional EMS Environment

while protecting proprietary, sensitive information, and thereby expediting and increasing the number of high-priority munitions models within GIANT.

Finally, JEAP developers started executing an integration path into an advanced framework that will dynamically depict high-fidelity electronic attack interactions against threat emitters leveraging ACEL framework. This includes naval surface assets via Navy models, air assets, and Army systems via the Builder software simulation environment. ACEL interfaces were initiated for GIANT, as well as interfaces to enhance visualization capabilities for two high-priority joint air systems.

» SUPPLYING WEAPONEERING TOOLS TO SUPPORT INTEROPERABILITY WITH U.S. ALLIES AND PARTNERS

In FY25, JTCG/ME provided weaponeering tools and data sets in support of training to 14 partner countries under Foreign Military Sales (FMS) or Foreign Military Financing agreements. This included the foreign release of the JWS product or JWS-derived data to approved partners, weapon effectiveness tables, collateral effects radii tables, and ATD capabilities that will help minimize collateral damage and reduce civilian casualties. These efforts directly supported the Presidential Conventional Arms Control Policy to build partner capacity and prevent civilian casualties. A second effort supported information exchange forums with coalition partners. These exchanges facilitate collaboration with partners on methodologies and efforts of mutual interest in weapons effectiveness and CDE for both kinetic and non-kinetic weapons. In FY25, JTCG/ME continued to prepare multiple information exchange annexes, to provide weapons effectiveness analytical exchanges and to expand the scope of topics to better represent complex strategic and operational environments.

In FY26, JTCG/ME will continue to provide ATD tools, methodology, and data through legally binding security cooperation activities, including FMS, in accordance with multiple laws and policies, which will enable international partners to employ U.S.-purchased and releasable munitions. JTCG/ME will continue to support and deliver JWS version releases and stand-alone Probability of Kill Look Up Tables to key coalition partners in support of current operations under FMS cases. FMS efforts are expected to increase, given new JMEM product lines. In addition, JTCG/ME will continue to support coalition interoperability via information exchange agreements forums.