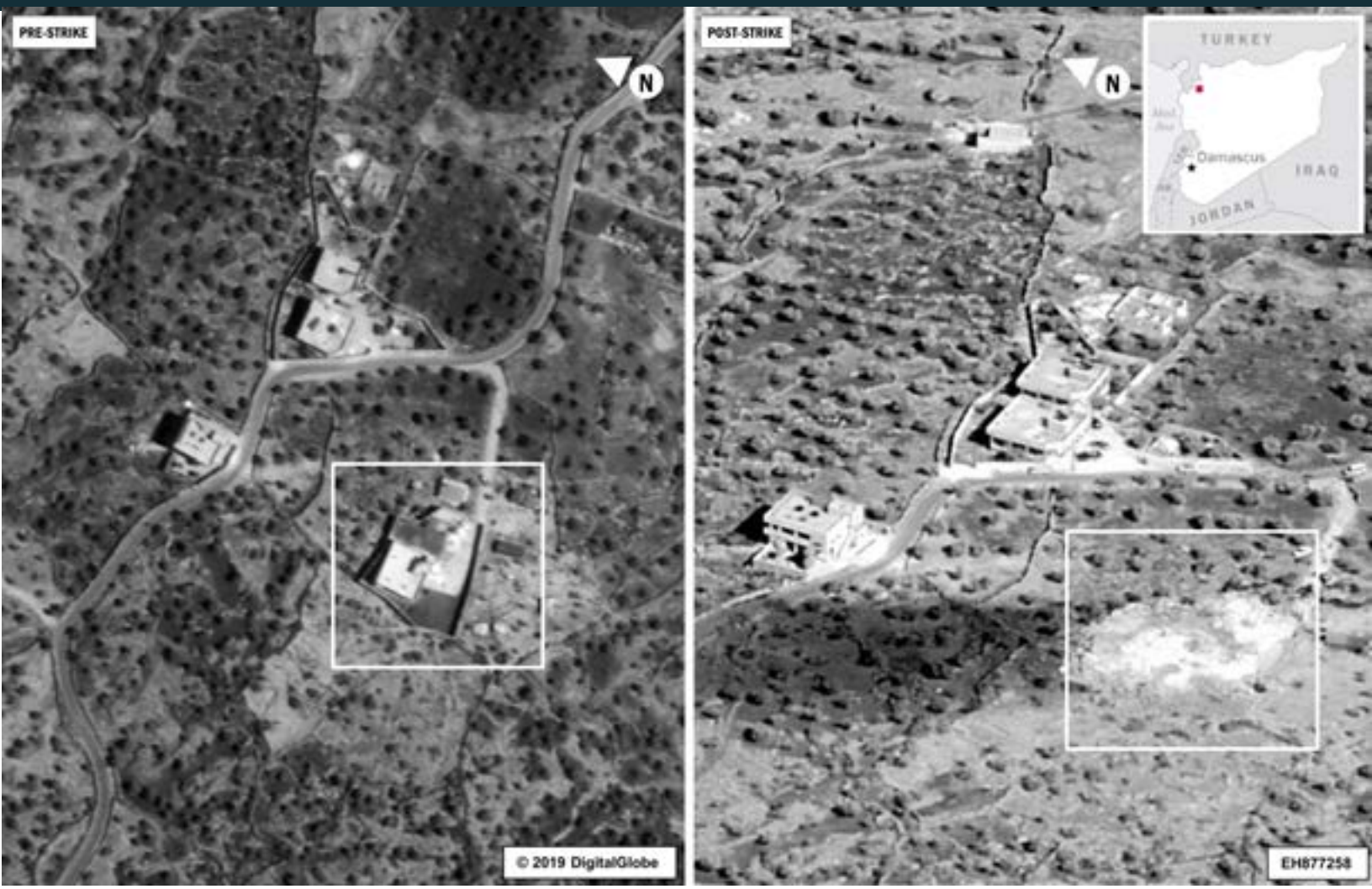
# Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) Program




**Combatant Command strike authorities rely on weaponeering tools developed by the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) program to estimate and optimize the type and number of U.S. weapons required to achieve the desired lethal effect against a range of strategic or tactical targets, while mitigating risk for collateral damage including civilian casualties.**

Current Joint Munition Effectiveness Manual (JMEM) products include:

- The Digital Imagery Exploitation Engine (DIEE), a tool that enables users to plan and execute strikes by seamlessly performing the following Advanced Target Development steps: 1) geographically locate and characterize the target, 2) weaponeer the target using JMEM Weaponeering Software (JWS) and perform target coordinate mensuration, 3) estimate collateral damage effects using the Digital Precision Strike Suite Collateral Damage Estimation (DCiDE) tool, and 4) produce output graphics to the appropriate databases.
- Weaponeering tools capable of estimating lethal effects for directed energy weapons (DEW), cyber, and electromagnetic spectrum (EMS) fires.
- The Joint Anti-Air Combat Effectiveness (J-ACE) tool used in combat mission planning, training, and in weapon schools to support the development of air combat tactics, techniques, and procedures. The J-ACE tool's main module is the Joint Anti-Air Model, which is discussed in the Joint Aircraft Survivability Program section of this report.

In FY22, the JTCG/ME continued to provide oversight of the Joint Live Fire (JLF) program to facilitate the development of adequate LFT&E tools, methods, and infrastructure required for credible development of both JMEM products and LFT&E programs. Examples of FY22 progress include the following: 1) development of new tools and methods to advance lethality evaluation of kinetic weapons, including hypersonic weapons, 2) advancement of a survivability and lethality assessment for maritime targets, 3) improved assessment of traumatic brain injuries (TBIs) due to kinetic threat engagements, 4) improved survivability assessments for U.S. weapon systems and forces against kinetic threat engagements, 5) development of new tools and methods to enhance the survivability and lethality evaluations against non-kinetic threats, and 6) advancement of the use of digital engineering tools to support full-spectrum survivability and lethality evaluations.

## JTCG/ME Delivers Credible Weaponeering Tools to Combatant Command Strike Authorities

JMEMs are used daily by warfighters in direct support of operations, mission planning, and training. The user base includes approximately 26,000 personnel, spanning all of the following entities:

- DOD Service members
- Joint Staff/Combatant Commands
- Acquisition community, T&E enterprise, Intelligence Community, and laboratories

In FY22, JTCG/ME conducted multiple Operational User Working Group meetings to facilitate open communication, gather additional operational requirements, and allow units to provide feedback on the products. As a result, JTCG/ME fielded updates to both DIEE and JWS to improve their accuracy and efficiency. Specifically:

- In collaboration with Office of the Under Secretary of Defense for Intelligence and Security and the Joint Staff Directorate for Intelligence, JTCG/ME is enhancing the Joint Targeting Intelligence process by developing and standardizing Advanced Target Development processes in support of the Joint Targeting Cycle. The process of linking desired effects to operational plan (OPLAN) outlined tactical tasks will increase the likelihood of meeting the commander's objective via enhanced integration and connectivity.
- JTCG/ME continued to field and develop DIEE and JWS with enhanced capabilities and incorporated new user interfaces to increase JWS tool usability. JTCG/ME provided a series of new weapon system characteristics, delivery accuracy, and target vulnerability data to the tool to more accurately estimate the final aimpoint, delivery conditions, and number of rounds on target to achieve the desired lethal effects. JTCG/ME included new weapon and weapon trajectory data to keep pace with technology development allowing the strike authorities to account for such enhanced capabilities in their calculations of target defeat. JTCG/ME also implemented an approved software development environment

for continuous JMEM evolution. In support of continued evolution of the DIEE/JWS Advanced Target Development capabilities, JTCG/ME conducted multiple technical reviews of the next generation, scene-based weaponeering product, to include enhanced product level testing, applicability of Development/Security/Operations (DevSecOps) for continuous and incremental increase in capability, and for increased user interface and experience. To maintain consistency with the latest National Geospatial-Intelligence Agency mensuration methods, JTCG/ME updated calculation tools for both Mensuration Services Program and Common Geopositioning Services.

- JTCG/ME enabled data-based updates to collateral effects radii tables, reducing their error margins. It advanced the collateral effects library mitigation tool to increase the efficiency of collateral effects analysis and enhance risk estimate distance calculations used by DCiDE to determine friendly force risk estimates. JTCG/ME also provided assistance with reach-back support for current operations. Multiple reach-back packages for weaponeering, Collateral Damage Estimation (CDE), and Munition Effectiveness Assessment were provided to operational units to assist Combatant Commanders in the decision making process. DCiDE output capability provides aimpoint and collateral effects radii graphics to aid in the decision-making for strike approval authority that are compliant with the Chairman of the Joint Chiefs of Staff Instruction. FY22 updates included collateral effects radii for weapons that implement Proximity and Point Detonation Fuzes.
- JTCG/ME has leveraged the JLF program to better understand collateral damage effects associated with TBI. In FY22, JLF initiated a project to develop a capability to assess possible TBI risk in different operational environments. JLF reviewed and assessed currently available TBI methodologies and models, conducted combat data analysis in coordination with the Joint Trauma Analysis and Prevention of Injury in Combat program, and awarded a contract to the University of Virginia for the development of TBI risk curves.
- JTCG/ME product training is imperative to the user community. To support this end, JTCG/ME facilitated 40 training classes/events for over 500 students at 27 locations. Training of integrated product capabilities (DIEE/JWS) continues to enable the operational community to successfully employ munitions while minimizing collateral damage.

## JTCG/ME Advances the Capability and Accuracy of Weaponeering Tools

JTCG/ME continues to advance the capabilities and accuracy of weaponeering tools to respond to Combatant Command needs in an increasingly complex and dynamic multi-domain operational environment. JTCG/ME upgraded existing capabilities to increase the effectiveness of kinetic strikes and developed new capabilities to enable deliberate and dynamic strikes using cyber, EMS, and DEW capabilities.

Kinetic threat lethal effects are complex phenomena that need to be adequately characterized to credibly predict their effect on the target of interest. Similarly, targets of interest are complex and the lethal effect predictions largely depend on our understanding of the target vulnerabilities.

### *Collateral Damage Estimates*

In FY22, JTCG/ME made progress in improving the DOD's ability to accurately characterize the lethal effects of U.S. weapons. Specifically, JTCG/ME leveraged the multi-year, Enhanced Weaponeering and CDE test program originally

*Figure 1. Buried Ordnance Test*

initiated by JLF to quantify the lethal effects of munition burial and building debris.

Figure 1 depicts a buried ordnance test, showing the potential collateral damage effects of munitions buried within the ground. Figure 2 shows a multi-sided collateral structure used to assess ground shock and secondary or collateral damage hazards on nearby structures.

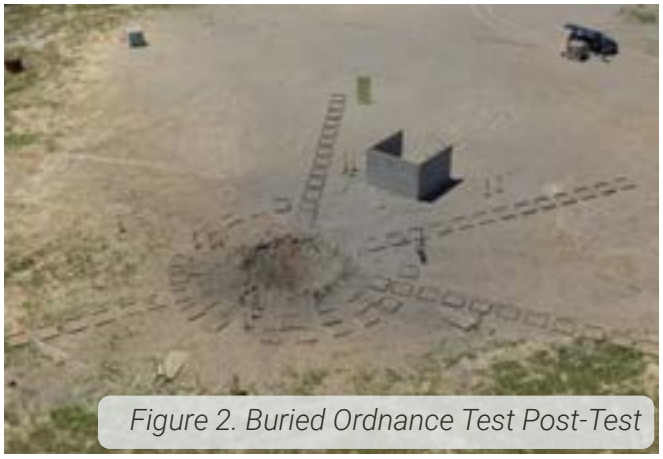


*Figure 2. Buried Ordnance Test Post-Test*

Figure 3 depicts a building debris test, showing the effects of munitions detonated inside structures.

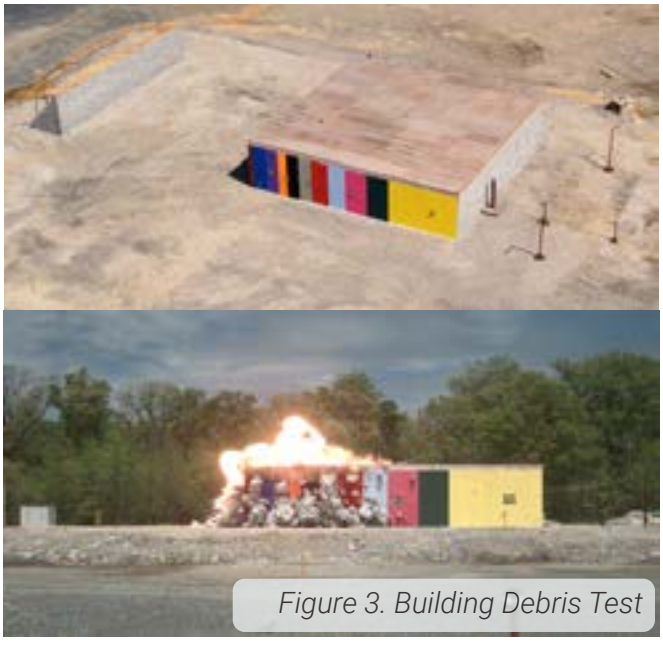


*Figure 3. Building Debris Test*

Data sets from the Enhanced Weaponeering and CDE test program have been used to improve, verify, and validate high fidelity modeling and simulation (M&S) tools used to predict building debris mass and velocity distributions from multiple structure types, along with crater ejecta, ground shock, and blast pressure for various soil and munition burial configurations. These predictions must be credible since they are the foundation of fast running engineering models used by DIEE and DCiDE to estimate weapon lethality and collateral damage. In FY22, under the Enhanced Weaponeering and CDE test program, JTCG/ME conducted several tests to further the understanding of munition burial and building debris effects on noncombatant personnel and nearby structures. A significant effort is underway to update the weaponeering tools using these newly generated data.

### *Lethal Effect Estimates*

JTCG/ME continues to leverage the Advanced Warhead Characterization project initiated by the JLF program to improve the fidelity of weapons data. In FY22, the program conducted a test series to further validate advances in science and technology that could be used for advanced warhead characterizations. Examples include emerging diagnostics tools (e.g., computed tomography imaging, digital image correlation, x-ray imaging, photon Doppler velocimetry, pressure measurements, and optical fragment tracking) to support efficient data collection and high-fidelity model validation for multiple munitions. Figure 4 shows advanced diagnostic test configuration to support improved fragmentation data with legacy z-data overlay.

The Advanced Warhead Characterization project has gained significant interest throughout the Department of Energy and DOD communities as it advances experimentation, M&S, data fusion, and policy guidance applicable to both Departments. JLF leveraged these successes and adopted the same approach for behind armor debris characterization that results from target/penetrator interaction with ground vehicle armor solutions. This FY22 project is developing credible high-fidelity finite element models of the Behind Armor Debris phenomena and validating it using optical tracking methods to capture fragment characteristics of the debris for use in fast-running vulnerability and lethality engineering models.

In addition, JTCG/ME leveraged the small-scale blast test program initiated by the JLF program to

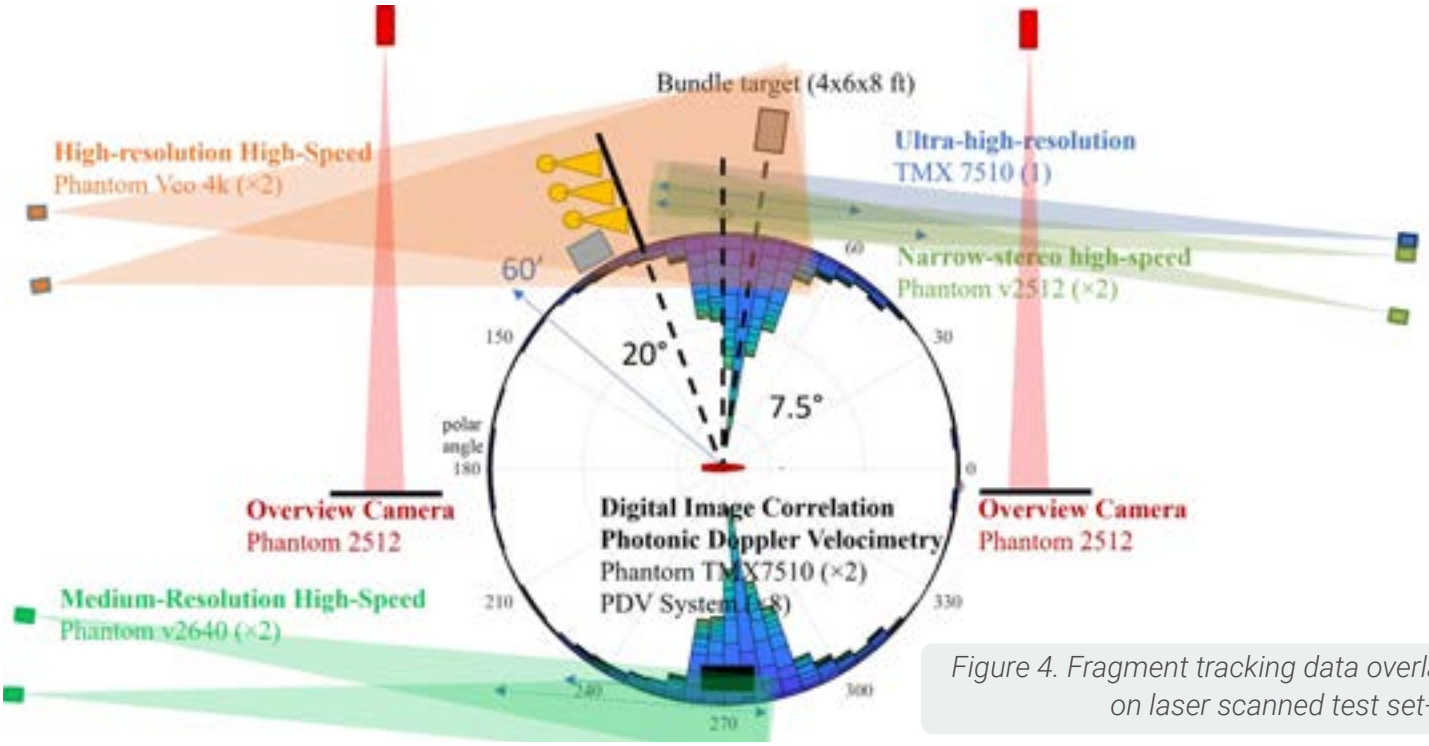



*Figure 4. Fragment tracking data overlaid on laser scanned test set-up*

provide a tailorable scale target model that will be used to efficiently collect larger volume and higher fidelity lethality data. In FY22, the Air Force Research Laboratory completed the design and fabrication of the test fixture modifications that included a new second-story wing (shown in Figure 5) to include highly non-orthogonal geometry, stairwell, and an elevator shaft, allowing vertical blast propagation across building levels. Blast data generated from tests using this fixture will be used to further update, verify, and validate the blast effects M&S.

In FY22, the JLF program continued to execute the Multiphase Blast Explosive (MBX) weapon system test program designed to increase the capability of weaponeering tools to estimate MBX lethal effects used in low-collateral-damage munitions. This effort is currently pursuing parallel efforts related to weaponeering of MBX against structural targets as a collaborative partnership with the Air Force Research Laboratory, the University of Florida, and Lawrence Livermore National Laboratory, through updated versions of JWS and high-fidelity Arbitrary Lagrangian–Eulerian three-dimensional analysis (ALE3D) modeling of reduced collateral weapons.

### *Lethal Effect Estimates – Hypersonic Weapons*

In FY22, JTCG/ME initiated a new effort focused on addressing lethality evaluation and weaponeering tool shortfalls to include collateral damage effects for hypersonic weapons. The initiative includes

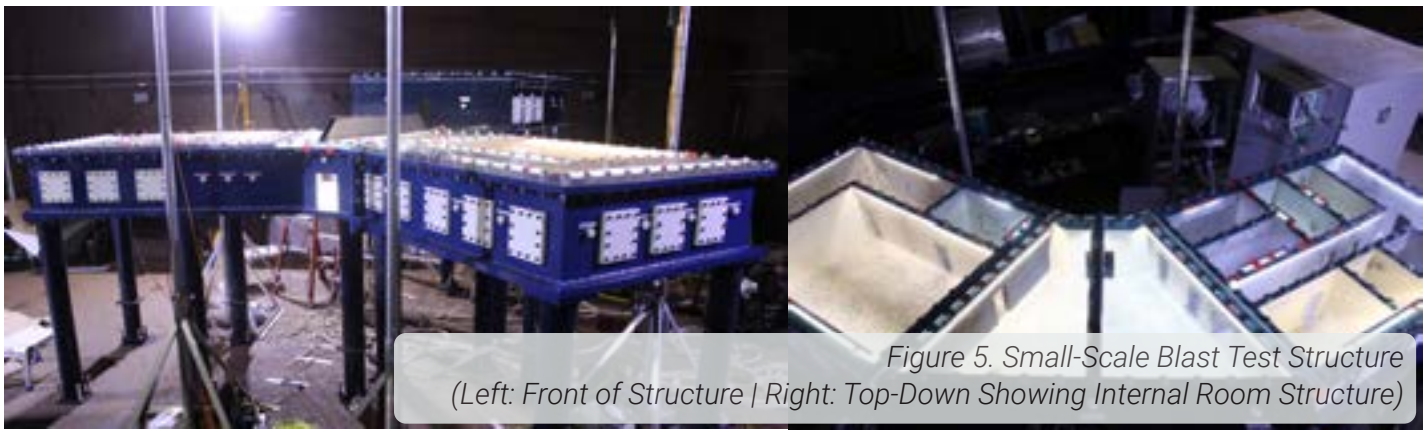


*Figure 5. Small-Scale Blast Test Structure (Left: Front of Structure | Right: Top-Down Showing Internal Room Structure)*

advancement of high-fidelity M&S comprised of an experimentation program to generate the required validation data. Near-term efforts will account for weapon characterization, including terminal effects, delivery accuracy, and associated data and methodology verification and validation. Calibrated model development is also being executed for capturing the required range of blast phenomena for weapon integration. Parallel efforts will develop fast-running engineering models. This hypersonic initiative will address longer-term hypersonic T&E improvements for broad-ocean-area tests, enabling weapon accreditation with greater granularity at reduced costs and with simplified logistics. Lastly, JLF continues to make progress in luminescent technology development and testing, which will enable optical characterization of fragment dispersion in flight tests in order to adequately evaluate emerging hypersonic weapons.

### *Lethal Effect Estimates – Maritime Targets*

In FY22, JTCG/ME initiated an effort to enhance the ability of DOD weaponeering tools to support the warfighter with credible and timely lethal effects estimates against adversary maritime (surface and subsurface) targets. Current weaponeering capabilities and data sets are either insufficient or non-existent for conventional surface, subsurface, and unconventional small-boat threats, which are capable of conducting attacks against the United States or allies. JTCG/ME leveraged the Maritime Survivability and Lethality Test program initiated by JLF to pursue a cohesive, enterprise-wide strategy that seeks to improve efficiency, collaboration, knowledge sharing, and analytical techniques across maritime organizations. To build on this effort, JTCG/ME has worked on developing weaponeering guides for several maritime targets not currently in JTCG/ME inventory. A prototype of a credible maritime weaponeering analysis tool for surface and subsurface targets was also developed under this effort and will be integrated and fielded in DIEE by December 2023. JTCG/ME will execute a collaborative test program that procures data to close knowledge gaps, improve current analytical tools and methods, and develop advanced M&S tools (e.g., the Advanced Survivability Assessment Program) required to support the delivery and fielding of weaponeering tools against such targets. Other M&S tools that will be advanced as part of this initiative include: Submarine Vulnerable Effects Model, Navy Enhanced Sierra Mechanics, and Dynamic System Mechanics Advanced Simulation. This effort will not only increase weapons systems' lethality against foreign maritime platforms but also will support the delivery of more survivable ships and submarines to the U.S. Navy and the DOD.

### *M&S Verification and Validation*

To further improve confidence in the JTCG/ME M&S efforts, the JLF program held Verification, Validation, and Accreditation (VV&A) and Uncertainty Quantification coordination meetings with the Army, Air Force, Navy, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratories representatives. VV&A experts presented current techniques, efforts, challenge areas, data gaps, and future development areas to foster potential areas for cross-organizational collaboration, which could improve practices and ensure confidence in JTCG/ME and T&E tools.

### *Battle Damage Assessment (BDA)*

One of the most comprehensive efforts used to verify, validate, and advance the effectiveness of weaponeering tools is tied to a multi-year effort to improve the BDA. The primary benefit of the BDA program is to enable credible post-strike analysis to ensure commander's intent has been achieved. To meet this intent, JTCG/ME continued to collect all BDA data to not only analyze strikes and inform reach-back support, but also to support weaponeering tool verification and validation, training, and expenditure analysis. In FY22, the BDA team developed automated data collection tools and collected data products for tens of thousands of strikes. The data from these strikes will be stored in a Microsoft Azure cloud environment named the Joint Battle Damage Analysis Repository.

As part of the Microsoft Azure Cloud architecture development, the BDA team took the first steps in the development of a virtual environment to provide

efficient scalability and agility to enhance processing performance and storage. This environment will allow for the connectivity to DIEE to enable the storage of new strike information through an application programming interface. This will ensure accurate and timely archival of strike reporting in the cloud-based Joint Battle Damage Analysis Repository for future use and reference, and the ability for the user community to interact with the data though a data analytic and mapping user interface.

### *Data Management*

JLF continues to evaluate a framework capable of consolidating available and future LFT&E data in support of data mining and data analytics intended to more effectively inform requirements, performance evaluations, and development of T&E tools. The U.S. Army Combat Capabilities Development Command (DEVCOM) Analysis Center performed a requirements analysis through stakeholder surveys and interviews in the development of a requirements definition document. In FY22, the DEVCOM Analysis Center focused on tracking the development of the Cloud Hybrid Edge-to-Enterprise Evaluation and Test Analysis Suite (CHEETAS), a big data analytics and knowledge management framework developed by the Test Resource Management Center, with the intention to leverage its capabilities to standardize and share LFT&E data. The DEVCOM Analysis Center has continuously collaborated with the CHEETAS development team to both verify and integrate T&E requirements into the software suite's development.

To support data and methodology enhancements discussed above, the JTCG/ME Capabilities and Standardization Integrated Product Team provided repositories for archival, review, approval, and access of data, methodology, and documentation. These 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 tri-Service review and approval processes. This data repository also serves the T&E and Acquisition Community by providing JTCG/ME-approved target vulnerability packages. JARVIS is under consideration to expand support in other focus areas, including directed energy and cyber data.
- For methodology, the Joint Effects Library is a repository of approved models, modules, plug-ins, and methodologies for Capabilities and Standardization Integrated Product Team Technical Working Groups.
- For documentation, the Bugle is a wiki-style website built on Defense Technical Information Center's (DTIC's) DOD Techipedia platform. This approach allows the JTCG/ME to contribute content while maintaining knowledge management. Hosting on DTIC makes JTCG/ME's technical reports, data requests, and model documentation accessible to the DOD community.

These three repositories work in conjunction to provide tri-Service approved munition effectiveness data, methodology, and documentation within JTCG/ME and throughout the DOD.

## JTCG/ME Enables Multi-Domain Superiority with DEW, Cyber, and Electromagnetic Spectrum (EMS) Fire Weaponeering Tools

JTCG/ME has made significant progress in supporting the warfighter with weaponeering tools intended to integrate kinetic and non-kinetic fires for optimized mission and lethal effects while mitigating collateral effects to noncombatants, infrastructure, facilities, and equipment. While JTCG/ME has focused on the development and fielding of separate weaponeering tools that can account for DEW, cyber-attacks, and EMS fires, it has also initiated the plans to provide an architecture for a single JMEM capable of estimating the appropriate number and type of both kinetic and non-kinetic weapons required to achieve superiority in a multi-domain operational environment.

### *DEW*

In FY22, JTCG/ME has continued the development of validated Joint Laser Weaponeering Software (JLaWS) and High-Power Microwave (HPM) Weaponeering Software (HPMWS) tools designed

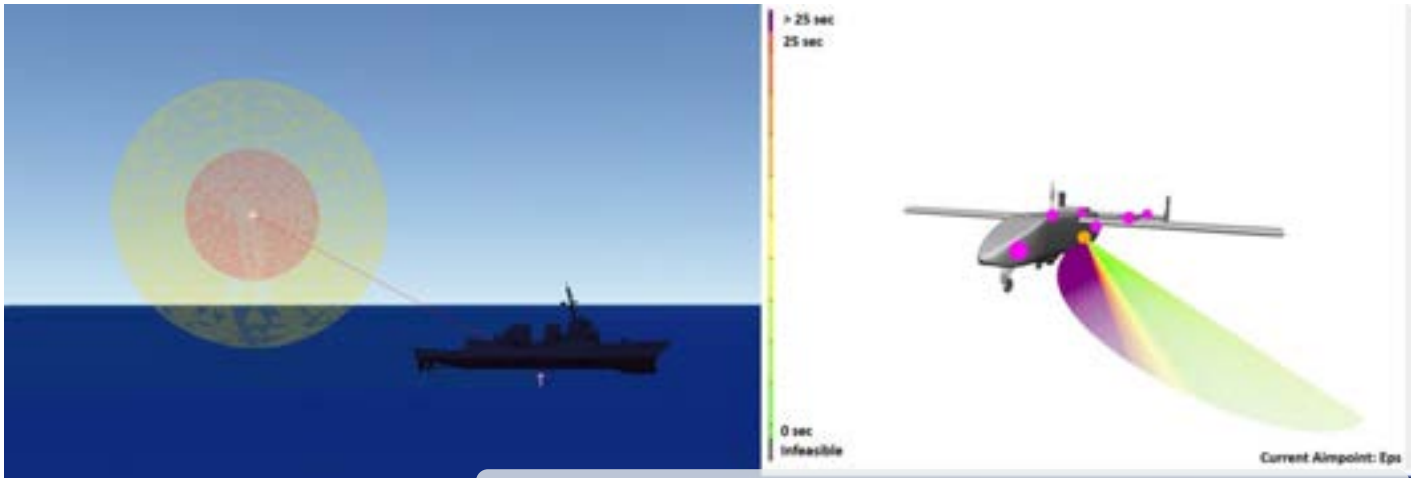



*Figure 6. JLaWS simulation with HELRAT laser radiation hazard zones*

to enable the Combatant Commands to estimate lethal effects on the target of interest using DEW (either high energy lasers (HEL) or HPM). Specifically, JTCG/ME conducted solid state laser weapon demonstrator testing against various targets and different component materials to collect critical data that were used to provide target vulnerability information. A previous release of JLaWS provides a tool that is accredited for use in functional domains, such as DOD exercises, training scenarios, and weapon system demonstrations. The newest release of JLaWS incorporates the HEL Risk Assessment Tool (HELRAT), a sophisticated software package that provides JLaWS with the ability to graphically portray the zones around a target that contain reflected laser radiation levels that could cause ocular hazards to friendly forces in the area. Figure 6 shows a JLaWS graphical rendering of a ship-based laser weapon system engagement with an unmanned aerial vehicle target – shown on the right – and the spherical zones around the target, as calculated by HELRAT, in which ocular hazards exist.

JLaWS was provided to HEL operators for feedback that will be used to further advance JLaWS utility, establish HEL reach-back support, and continue to advance the development of collateral risk tools for HEL. In the meantime, JTCG/ME supplied operators with JLaWS-developed target cards, which provide lethality estimates based on targeting aimpoints.

JTCG/ME is also developing a threat surrogation tool for use by the Laser Weapon System community, when information is limited or unavailable. The tool will map well matched donors to surrogates.

To advance the development, testing, and fielding of HPMWS (example system shown in Figure 7), JTCG/ME developed HPM lethal effects data standards and analytical tools required to characterize target vulnerability. JTCG/ME also identified and developed M&S tools required to estimate lethality and collateral damage effects due to an HPM engagement, to include a probabilistic risk assessment tools. While DEW tools are being developed in parallel with kinetic tools, users are still leveraging existing JMEM architecture until future integration of these capabilities.

### *Cyber*

In FY22, JTCG/ME continued the development and fielding of JMEM tools intended to estimate cyber effects with a focus on building a DOD user community. These efforts will accelerate the delivery

*Figure 7. Navy HPM System*

of a full-spectrum cyber effectiveness analysis capability for development, testing, and operational engagement. It will enable evaluation of defensive and offensive actions from the weaponeering and T&E perspectives. The Cyberspace Operations Lethality and Effectiveness (COLE) tool and deployment gateway is the foundational product, which enables commanders' operational decisions through advanced analytics used to adequately visualize, plan, evaluate, and assess the full spectrum of cyberspace activities. As shown in Figure 8, the COLE Mission Planning application provides the warfighter with a model that highlights nodes that have been compromised, designated by a hacker icon, and target nodes that are vulnerable (highlighted in red) and potentially accessible (highlighted in blue). Vulnerable nodes that are accessible from the warfighters' location and have a cyber-capability option in the database can hold those target nodes at risk. The state model includes information about the network and nodes such as connectivity, firewall rules, and operational status.

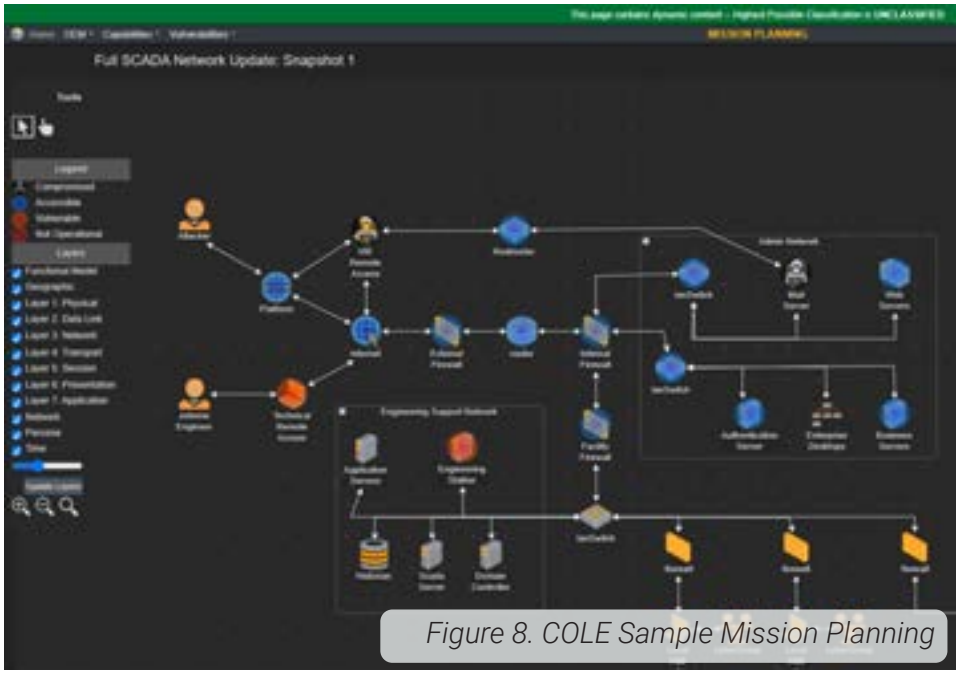


*Figure 8. COLE Sample Mission Planning*

In FY22, major contributions included completion and enhancements of data standards, demonstration of target vulnerability assessment, attack sequence modeling, effects-based modeling, functional tests, continued fielding across multiple security domains, and numerous engagements throughout the DOD in conducting capability briefings and demonstrations.

JTCG/ME teamed up with the Joint Aircraft Survivability Program to deliver an initial Machine Assisted Exploitability Simulation and Testing for Resilient Operations (MAESTRO) tool via the COLE deployment gateway. MAESTRO is intended to be used for assessment of U.S. platforms in a cyber-contested environment. It enables automated early discovery of system vulnerabilities that can be used to inform and refine cyber survivability T&E.

Additionally, the JLF program continued the Cyber Automated threat Discovery and Vulnerability Evaluation Reinforcement (CADAVER) tool development, which will also be deployed via COLE deployment gateway. CADAVER integrates enhanced vulnerability discovery fuzzing results into COLE/MAESTRO to increase fidelity of attack planning calculations, while adding parallel processing to improve the scale and speed of T&E. These efforts will also leverage artificial intelligence to allow identification of potential vulnerabilities to mitigate cyberattack access points through automated and semi-automated means.

These three programs are intended to deliver to the warfighters and the T&E enterprise the necessary tools to assess cyber effectiveness/vulnerability using tri-service approved data standards and streams. Leveraging technology and lessons learned of these three programs provide consistent, credible data and methodology for both offensive and defensive cyberspace operations.

### *EMS Fires*

In FY22, JTCG/ME continued the development of JMEM and weaponeering tools for EMS fires. The JMEM for EMS fires will estimate electronic

attack (EA) effects and the ability of the warfighter to effectively prosecute adversary targets in contested and congested EMS environments. JMEM for EMS fires will allow mission planners and targeteers to assess weapon and combat effectiveness in the presence of adversary EA (e.g., GPS denial and its effect on kinetic weapon guidance systems). It will also estimate the effects of friendly EA capabilities against adversary targets (e.g., jamming), which create a foundation of Joint standard EA effectiveness data and models used across the Joint Targeting Cycle. In FY22, JTCG/ME further refined the program plan, data standards, Capabilities Needs Statement, and the mission area analysis for EA effectiveness, which resulted in a plan to develop an initial set of JMEM capabilities via the Joint EA Prediction tool by 1QFY24.

## JTCG/ME Supplies Weaponeering Tools to Support Interoperability with U.S. Allies and Partners

In FY22, JTCG/ME supported the delivery of weaponeering tools, data sets, and training to 22 coalition partners in support of current operations under Foreign Military Sales agreements. This included the release of weapon effectiveness tables, collateral effects radii tables, and advanced target development capabilities to coalition partners to 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 via information exchange annexes with coalition partners. These exchanges facilitate collaboration with partners on methodologies and efforts of mutual interest in the area of weapons effectiveness and CDE for both kinetic and non-kinetic weapons. In FY22, a new International Exchange Agreement was finalized to continue weapons effectiveness analytical exchanges and to expand the scope of topics to better represent complex strategic and operational environments.