Joint Technical Coordinating Group for Munitions Effectiveness

The Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) program develops validated weaponeering tools derived from the policy-approved Joint Munition Effectiveness Manuals (JMEMs).

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, to include civilian casualties. Current Joint Munition Effectiveness Manual (JMEM) products include:

1. The Digital Imagery Exploitation Engine (DIEE) tool, used to geographically locate and characterize the target, weaponeer the target using JMEM Weaponeering Software, and then estimate collateral damage effects using the Digital Precision Strike Suite Collateral Damage Estimation (DCiDE) tool.
2. Weaponeering tools capable of estimating lethal effects for directed energy weapons (DEW), cyber, and electromagnetic spectrum (EMS) fires.
3. 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 (discussed in the Joint Aircraft Survivability section of this report).

In FY21, the JTCG/ME program assumed the management role 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 include: 1) development of new test data collection methods, 2) advancement of verification, validation, and accreditation of modeling and simulation (M&S) tools, 3) advancement of the use of machine learning to automate T&E, 4) development of a survivability and lethality data management strategy, 5) advancement of survivability/lethality analysis in a contested maritime environment.

Combatant Command Strike Authorities Require Credible Weaponeering Tools

JMEMs are used daily by the warfighters in direct support of operations, mission planning, and training. The user base includes approximately 26,000 spanning all Services across tactical, operational, and strategic objectives, as detailed in Figure 1.

Figure 1. User Community

- An example of the use of weaponeering tools can be seen in Figure 2, which demonstrates the lethal effects of U.S. strikes against targets of interest. To achieve such lethal effects, JMEM products were used to characterize the target and determine the type and number of weapons required to achieve such an effect.

Figure 2. U.S. Airstrike – Pre and Post Strike

Specifically, the DIEE is the tool that enables users to plan and execute this type of event by seamlessly performing the following Advanced Target Development steps: 1) geographically locate and characterize the target, 2)

weaponeer the target using JMEM Weaponeering Software and perform target coordinate mensuration, and 3) estimate collateral damage effects using the DCiDE tool. In FY21, JTCG/ME updated DIEE to further improve the accuracy and efficiency of all three steps:

- In collaboration with Office of the Under Secretary of Defense for Intelligence and Security and Joint Staff J2 Targets, JTCG/ME enhanced the Joint Targeting Intelligence process by developing, enhancing, and standardizing the intelligence database in support of the Joint Targeting Cycle.
- Incorporated new user interfaces to increase JMEM Weaponeering Software tool usability, which provides a series of weapon system characteristics, delivery accuracy, and target vulnerability data needed to estimate the final aimpoint, delivery conditions, and number of rounds on target to achieve the desired lethal effects. JTCG/ME included new weapon and trajectory data to keep pace with technology development by accounting for enhanced capabilities for target defeat, and implemented an approved software development environment for continuous JMEM evolution. To maintain consistency with the latest National Geospatial-Intelligence Agency mensuration methods, JTCG/ME updated both Mensuration Services Program and Common Geopositioning Services.
- Enabled data-based updates to the authenticated collateral effects radii tables, reducing their error margins, advanced the collateral effects library mitigation tool to increase the efficiency of collateral effects analysis, enhanced risk estimate distances calculations used by DCiDE to determine friendly force risk estimates, and provided assistance with reachback support for current operations. DCiDE complies with the Chairman of the Joint Chiefs of Staff Instruction (CJCSI) and provides lethal radii graphics to aid in the decision-making for strike approval authority.

JTCG/ME Advances the Capability and Accuracy of Weaponeering Tools

JTCG/ME continues to advance the capability and accuracy of weaponeering tools to respond to Combatant Command needs as they are challenged with the increased complexity and dynamics of the 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.

Increasing the Effectiveness of Kinetic Strikes

Figure 3. Buried Soil Test

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. In FY21, JTCG/ME made progress in improving the ability of the DOD to accurately characterize the lethal effects of U.S. weapons. Specifically, JTCG/ME leveraged the multi-year, Enhanced Weaponeering and Collateral Damage Effects (CDE) test program initiated by the JLF program to quantify the lethal effects of weapon burial and building debris. Figure 3 demonstrates the effects of a munitions buried within the ground, while Figure 4 demonstrates the lethal effects of munitions detonated inside structures. These and similar data sets are used to verify and validate high fidelity M&S tools being utilized to predict building debris mass and velocity distributions from structures along with crater ejecta, ground shock, and blast pressure for various soil configurations. These predictions must be credible since they are the foundation of fast running engineering models used by DIEE and DCiDE

Figure 4. Structure Test

to estimate weapon lethal effects and collateral damage, and to refine CDE tables. In FY21, under the Enhanced Weaponeering and CDE test program, JTCG/ME conducted several tests to further the understanding of bomb burial and building debris effects on noncombatant personnel.

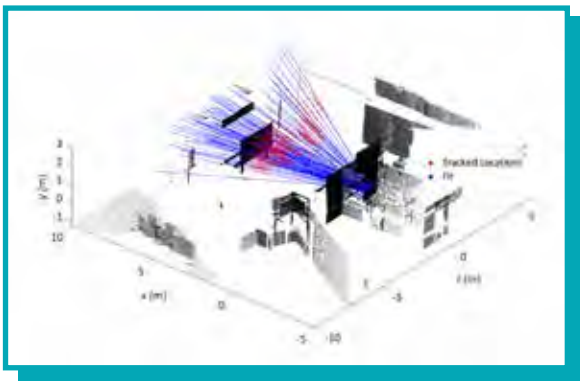

Figure 5. Fragment tracking data overlaid on laser scanned test set-up

JTCG/ME also leveraged the Advanced Warhead Characterization project and the Small-Scale Blast program initiated by the JLF program to improve the pedigree of weapons data. Specifically, in FY21, the program explored advances in science and technology and utilized emerging diagnostics tools (computed tomography imaging, digital image correlation, x-ray, photon doppler velocimetry, pressure measurements, and optical fragment tracking) to support efficient data collections and high-fidelity model validation for multiple munitions. Figure 5 shows optical tracking data overlaid on laser scan data for visualization of fragment distribution tests at Sandia National Labs.

In addition, JTCG/ME leveraged the small-scale blast test program initiated by the JLF program to provide a tailorable scale target model (shown in Figure 6) that will be used to efficiently collect larger volume and higher fidelity lethality data. In FY21, the Air Force Research Laboratory completed the design and fabrication of a scaled structure that will be used to update, verify, and validate the blast effects (BlastX) M&S.

Figure 6. Small Scale Blast Test Structure

In FY21, the JLF program initiated the Multiphase Blast Explosive (MBX) weapon system test program to update methodology for MBX lethal effect estimates used in low-collateral-damage munitions. In coordination with JTCG/ME, enhancements to enable optical characterization of fragment dispersion in flight tests are being developed to adequately evaluate emerging hypersonic weapons.

In FY21, JTCG/ME identified an opportunity to enhance the DOD weaponeering tools and their ability 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 U.S. and partner ships in the competition phase, or major combat operations. To provide an initial response, 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. With additional funds, the program could plan collaborative test programs that procure data to fill those gaps and improve current analytical tools and methods required to support the delivery and fielding of such weaponeering tools. This effort will not only increase weapons systems' lethality against foreign maritime platforms but also deliver the capability that will support the delivery of more survivable ships and submarines to the U.S. Navy.

The most comprehensive effort used to verify, validate, and advance the effectiveness of weaponeering tools is tied to a multi-year effort intended to improve the Battle Damage Assessment (BDA), initiated by JTCG/ME. The primary benefit of the BDA program is to enable credible post-strike analysis to ensure Commander's intent has been achieved in accordance with Chairman of the Joint Chiefs of Staff Manual. To meet this intent, JTCG/ME continued to collect all BDA data to not only analyze strikes and inform reachback support, but also to support weaponeering tool verification and validation, training, and expenditure analysis. Specifically, in FY21, the BDA team developed automated data collection tools and collected data products for thousands of strikes.

As part of the IL6 Microsoft Azure Cloud architecture development, the BDA team took their first steps in the development of virtual machines to provide efficient scalability and agility to enhance processing performance.

The BDA effort also offers a foundation for advancement of the T&E data management strategy that will support not only weaponeering tools, but also the acquisition community. In FY21, the JLF program funded an effort to evaluate a framework capable of consolidating available and future LFT&E data in support of a range of data mining and data analytics intended to more effectively inform requirements, performance evaluations, and development of evaluation/test tools. The DEVCOM Data Analysis Center performed a requirements analysis through stakeholder surveys and interviews in the development of a requirements definition document. A potential course of action is to utilize the Cloud Hybrid Edge-to-Enterprise Evaluation and Test Analysis Suite as a prototype data storage capability. Access to a comprehensive data storage capability is important to the success of artificial intelligence (AI)/machine learning efforts requiring large formatted data sets. An example of this has been demonstrated through another JLF initiated program: the machine learning to optimize armor/anti-armor performance. Effort is focused on leveraging AI and machine learning to optimize armor system designs and the evaluation of their effectiveness against a range of kinetic energy threats. Research laboratories and T&E centers continue to create robust scalable armor performance databases for use by future developed trained algorithms. These future algorithms will predict kinetic threat engagement solutions and optimize armor /anti-armor solutions at a fraction of the cost of full-scale live-fire tests.

Enabling Multi-Domain Superiority with Directed Energy Weapons, Cyber, and Electromagnetic Spectrum Strikes

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 both noncombatants, infrastructure, facility and equipment. While JTCG/ME has focused on the development and fielding of separate weaponeering tools that can account for DEW, cyberattacks, and EMS fires, it has also initiated the plans to provide an architecture for a single JMEM capable of estimating the appropriate number and types of both kinetic and non-kinetic weapon required to achieve superiority in a multi-domain operational environment.

Directed Energy Weapons

In FY21, JTCG/ME has continued the development of validated Joint Laser Weaponeering Software (JLaWS) and High-Power Microwave (HPM) Weaponeering Software (HPMWS) tools designed 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 to collect critical data that were used to verify and validate JLaWS. This tool was provided to users (shown in Figure 7) to obtain HEL operator feedback that will be used to further advance JLaWS utility, establish HEL reachback support, and continue to advance the development of collateral risk tools for HEL. As a result, JTCG/ME supplied operators with JLaWS-developed target cards.

Figure 7. Testing a Solid State Laser

To advance the development and fielding of HPMWS systems, (example system shown in Figure 8), JTCG/ME developed HPM lethal effects data standards and analytical

Figure 8. Navy HPM System

tools required to characterize target vulnerability, M&S tools required to estimate lethality and collateral damage effects, and probabilistic risk assessment tools. While DEW tools are being developed in parallel with kinetic tools, they are still leveraging existing JMEM architecture to enable future integration of these capabilities.

Cyber

In FY21, JTCG/ME continued the development and fielding of JMEM tools intended to estimate cyber effects. The Cyberspace Operations Lethality and Effectiveness (COLE) tool is the foundational product, which enables commander operations decisions through advanced analytics used to adequately visualize, plan, evaluate, and assess the full spectrum of cyberspace activities (Figure 9). In FY21, major contributions included fielding across multiple security domains, supplying probability of effects of cyberattacks while accounting for target configuration uncertainty and data gaps, enabling characterization and visualization of weapons and targets in a dynamic operational environment, and providing access to intelligence data support. These COLE efforts were used to deliver the Machine Assisted Exploitability Simulation and Testing for Resilient Operations (MAESTRO) tool used for assessment of fielded U.S. platforms in a cyber-contested environment. MAESTRO enables automated early discovery of system vulnerabilities that can be used to inform and refine cybersecurity T&E. Additionally, JLF initiated the Cyber Automated threat Discovery and Vulnerability Evaluation Reinforcement (CADAVER) tool, also underpinned by COLE methodology. It is intended to leverage AI/machine learning to allow identification of potential vulnerabilities to mitigate cyberattack access points through automated/semi-automated means. Combined, these programs ensure warfighters have 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.

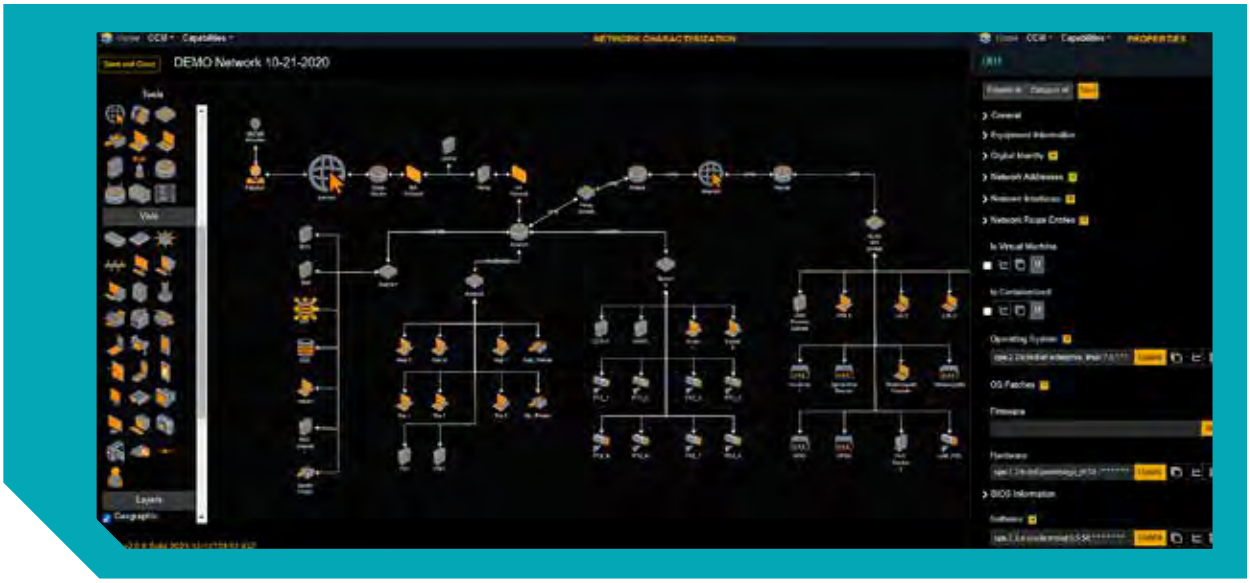

Figure 9. COLE Network Characterization – Notional Data

Electromagnetic Spectrum Fires

Combined with DEW and Cyber JMEM, EMS Fires JMEM enables targeteers and mission planners to adequately respond in a multi-domain operational environment. EMS JMEM will estimate electronic attack (EA) effects and the ability of the warfighter to effectively prosecute adversary targets in contested EMS environments. An illustration of EMS representing range of radiation frequencies used to transmit information wirelessly is shown in Figure 10. EMS JMEM will allow mission planners to assess weapon and combat effectiveness in the presence of adversary

Figure 10. Depiction of EMS deployment

EA (i.e., 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). In FY21, the EMS JMEM development efforts resulted in an initial weaponeering guide, development of data standards, mission area analysis for EA effectiveness, and the review of the Mission Planning GPS Analysis Services model.

Weaponeering Tools Support Interoperability with U.S. Allies and Partners

In FY21, JTCG/ME supported the delivery of weaponeering tools, data sets, and training to 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 on methodologies and efforts of mutual interest in the area of weapons effectiveness and collateral damage estimation. A final effort supported standardization of weapon characteristics and interoperability by providing coalition partners with the updated JTCG/ME weapon test information to augment international test operation procedures.