Live Fire Test and Evaluation (LFT&E)

Summary

- In FY17, DOT&E conducted LFT&E oversight for 124 acquisition programs, managed 3 LFT&E investment programs (Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME), Joint Aircraft Survivability Program (JASP), and Joint Live Fire (JLF)), and participated in 2 special interest programs (Warrior Injury Assessment Manikin (WIAMan) and Small Boat Shooters' Working Group).
- In support of a range of acquisition decisions and activities, DOT&E published three LFT&E reports and one combined OT&E and LFT&E report. The reports include recommendations to the Services to further improve the survivability of the subject systems for a range of operationally relevant scenarios in existing and expected combat environments.
- In support of the respective investment portfolio charters:
  - JASP funded 42 multi-year projects addressing aircraft survivability enhancement technologies and aircraft survivability evaluation tools needed to increase the ability of our aircraft to counter near-peer and second-tier threats, to reduce combat-induced aircrew injuries, and reduce combat-induced aircraft fires.
  - JLF funded 21 projects and delivered 16 reports. Focus areas for JLF included projects that either: 1) characterized new survivability issues; 2) characterized new lethality issues; 3) improved accuracy and fidelity of weapon data; 4) improved test methods; or 5) improved modeling and simulation (M&S) methods.
  - JTCG/ME enhanced the capabilities of its two major products – the Joint Munitions Effectiveness Manual (JMEM) Weaponeering System (JWS) and Joint Anti-air Combat Effectiveness (J-ACE) – to meet new Combatant Command (CCMD) requirements while supporting real-time operations with collateral damage mitigation analysis packages for high value target precision strikes.
- Special projects continued to make progress in addressing a test instrumentation shortfall for assessing injuries to vehicle occupants during combat-induced, underbody blast (UBB). WIAMan has produced four fully integrated first generation WIAMan prototypes that exhibit improved human-like response, and the program is on track to verify, validate, and accredit the prototypes in anticipation of full-up system-level testing in FY20.

LFT&E ACQUISITION PROGRAMS

- The primary objective of LFT&E is to evaluate the survivability and lethality of acquisition programs and to identify system design deficiencies to be corrected before those systems get deployed or enter full-rate production. Of the 124 acquisition programs under LFT&E oversight, 19 operated under the waiver provision of section 2366, title 10, U.S. Code, by executing an approved alternative LFT&E strategy in lieu of full-up system-level testing. DOT&E published three LFT&E reports and one combined OT&E and LFT&E report in FY17.
- The four reports provided system survivability evaluations for use by the Service and Program Office:
  - The Mine-Resistant Ambush Protected Cougar Category I A1 Block 1 Upgrades and Category II A1 Seat Survivability Upgrade Report evaluated the protection against UBB afforded to occupants of the Marine Corps Cougar Category I A1 Block 1 Upgrades and Category II A1 Seat Survivability Upgrade MRAP vehicles. DOT&E made two recommendations to further improve the survivability of these Cougar variants and their crew.
  - The update to DOT&E's January 2014 Modernized Expanded Capacity Vehicle – Survivability (MECV-S) Survivability Assessment Report updated the 2014 evaluation with comparative data from Joint Light Tactical Vehicle (JLTV) testing. The report update indicated that although the MECV-S and JLTV have similar survivability against underbody threats, the current JLTV design exceeds the mission capability of the MECV-S.
  - The M1070A1 Heavy Equipment Transporter (HET) Urban Survivability Kit (HUSK) Report evaluated the protection against small arms, IEDs, artillery rounds, and blast mines afforded to the occupants of the HUSK. DOT&E made four recommendations to further reduce the crew vulnerabilities to underbody threats and vehicle egress.
  - The CH-53K Heavy Lift Replacement Program Operational Assessment and Live Fire Test and Evaluation Report evaluated the survivability against small arms, automatic weapons fire, and legacy man-portable defense system threats prior to the Milestone C decision. The report indicated that when compared to the legacy CH-53E aircraft, the CH-53K is significantly more survivable. DOT&E made three recommendations to further improve the survivability of the CH-53K system.

LFT&E INVESTMENT PROGRAMS

JOINT AIRCRAFT SURVIVABILITY PROGRAM (JASP)

The mission of JASP is to increase military aircraft combat survivability in current and emerging threat environments. This is accomplished directly and indirectly. The mission is directly supported through funding and oversight of Research, Development, Test, and Evaluation to develop aircraft survivability technologies and assessment methods. The mission is indirectly supported through cross-Service coordination, educating the community about aircraft survivability, maintaining and improving core survivability tools, and taking a lead role in combat data collection. In FY17, JASP funded 42 multi-year projects and delivered 22 final reports. In FY17, JASP focused on projects intended to 1) defeat near-peer and second-tier adversary threats by developing measures to avoid detection and counter engagement of advanced radio frequency (RF) and infrared (IR)-guided threats; 2) improve aircraft force protection; and 3) improve aircraft survivability to combat-induced fires.

Defeat Near-Peer and Second-Tier Adversary Threats

To defeat near-peer and second-tier adversary threats, JASP focused on developing: 1) measures to counter adversary RF-guided threats and anti-access/area-denial capabilities, coupled with quantifiable improvements in Enhanced Surface-to-Air Missile Simulation (ESAMS) and hardware-in-the-loop (HWIL) capabilities; and 2) measures to counter emerging IR homing threats with advanced counter-countermeasures, coupled with quantifiable improvements in the Modeling System for Advanced Investigation of Countermeasures (MOSAIC) and HWIL capabilities.

- In the RF domain, JASP has funded projects to develop and implement algorithms to detect Digital RF Memory (DRFM)-based jamming, mitigate DRFM jamming, and employ DRFM jamming to counter advanced RF threat weapons systems.
  - In FY17, the Naval Research Laboratory (NRL) completed a multi-year project to develop algorithms that enable a friendly system to detect hostile DRFM emissions and then provide an electromagnetic screen for friendly radar systems to operate freely behind. NRL completed testing with the ALQ-214 system and published the results.
  - In FY17, the Air Force Special Operations Command completed a 3-year project to develop 12-bit DRFM techniques against three RF threat systems with non-traditional signals of interest. The Special Operations Command has transitioned the first technique into the ALQ-211(V)2 (utilized by a variety of fixed-wing and rotorcraft) and is working to add the second and third techniques to ALQ-211(V)6 & 9 in FY18.
- ESAMS is a primary tool used by Government and industry to assess the engagement of U.S. aircraft by radar-directed surface-to-air missile systems. JASP, in coordination with the Air Force Life Cycle Management Center, developed several upgrades to ESAMS to maintain its relevancy to current and future threat environments. These upgrades include:
  - Models of chaff as an RF countermeasure to improve the model accuracy and credibility.
  - Improved capability of two threat engagement radar models by adding their electronic counter-countermeasure features. The first system was released in ESAMS 5.4 in FY17; the second system will follow in ESAMS 5.5 in FY18.
  - Improved ESAMS signal architecture to represent and analyze dynamic and reactive signal interactions between multiple players and signals. JASP intends to release this capability in ESAMS v5.5 in FY18.
- Two new JASP projects will take advantage of the recent ESAMS enhancements:
  - First is a study that will determine requirements for future RF expendable decoys. The team will apply modeling, simulation, and analysis to assess the sensitivities and optimal ranges of various Key Performance Parameters for RF expendable decoys. Metrics will include missile break-lock, miss distance, and the size, weight, power, and cost of the candidate decoy technologies. Additionally, the team will study the impacts of maneuver and decoy deployment timings and the increased effectiveness of salvos of decoys.
  - A second effort will develop a new electronic attack (EA) capability against an advanced RF threat radar using a combination of: developing theoretical threat surrogate M&S software; executing HWIL lab testing of the actual threat surrogate to collaborate the M&S model; developing generic advanced coherent EA techniques and testing against the HWIL threat surrogate in the lab; and finally conducting EA jammer flight tests against the threat surrogate in the field to determine EA effectiveness. The successful EA techniques will then be transitioned to existing operational EA jammer systems (such as the ALQ-214 and Next Generation Jammer), subject to their current hardware/software/firmware limitations, and/or be used to generate specifications for upgrading current or developing future EA jammer systems.
- A continuing need across the DOD is valid countermeasure models. The ability to model countermeasures is a critical component in the threat engagement simulations used to develop and optimize tactics, techniques, and procedures (TTPs) in response to near-peer and second-tier adversary threat improvements.
  - JASP funded the development of a physics-based model of chaff dispensed in airflow around fixed- and rotary-wing aircraft. This will improve modeling of chaff effectiveness as a countermeasure; current models do not optimize chaff dispersion based on the influences of aircraft flow field vortices. Additionally, chaff models estimate cloud growth based on empirical test data rather than physics-based modeling of individual particles on the Radar Cross Section (RCS) or Doppler effects. The Naval Air Systems

Command (NAVAIR) and the Office of Naval Intelligence completed development of a model for prediction of the chaff cloud RCS based on the physics-based chaff dispense model and developed datasets for use in ESAMS.

- Helicopter loss rates during Operation Iraqi Freedom, Operation Enduring Freedom, and subsequent counterinsurgency operations were significantly reduced by employment of Missile Warning Systems and effective countermeasures. JASP funded the following efforts to develop technologies and techniques to counter newer classes of IR-guided seekers:
  - NRL development of missile warning algorithms using two-color IR imagery for early identification of threat missiles to enhance countermeasure effectiveness. The main goals are to develop missile identification algorithms capable of exploiting two-color IR imagery, determine the ability to perform missile identification in urban clutter, and characterize jamming performance for Distributed Aperture Infrared Countermeasure (DAIRCM). In FY17, the NRL completed missile identification algorithm development, established performance metrics, and updated its jamming concept of operation in preparation for testing in FY18.
  - The Naval Surface Warfare Center Carderock Division (NSWCCD) and the Air Force Research Lab (AFRL) are conducting a study to determine the advantage of using guided infrared countermeasure (IRCM) expendables to counter advanced IR-guided missiles. In FY17, the team developed three basic concepts for guided IRCM expendables. Each of these concepts seeks to improve IRCM effectiveness against a particular threat or class of threats in the near-peer category. Implementation of the concepts in the Flare Aerodynamic Modeling Environment five degree-of-freedom (5-DOF) equations-of-motion (EOM) implementation in Simulink was completed. A MATLAB/Simulink application was also developed to allow the analyst to pick decoy waypoints in aircraft-continuous coordinates. Integration of the models into the MOSAIC simulation is in progress.
  - In FY16, NSWCCD and the Army Armament Research, Development and Engineering Center (ARDEC) completed development of the JASP-funded Common Setback Measurement Tools, a standardized test set to measure expendable countermeasure launch setback forces. In FY17, NSWCCD and ARDEC received requests from the Services and Industry to use the equipment for future testing and the data to support flight clearance requirements. NSWCCD also agreed to take responsibility for managing, maintaining, and distributing expendable countermeasure setback data for the tri-Service community.

Improve Aircraft Force Protection

To improve the ability of U.S. aircraft to avoid threat detection and to mitigate damage when hit, JASP funded multiple projects focused on the following objectives: improve situational awareness; counter unguided threats; harden aircraft systems; and improve the accuracy and confidence of vulnerability assessments.

- **Improve Situational Awareness.** JASP funded the NRL to develop a sensor package that incorporates both mid-wave infrared and acoustic waveforms for detecting hostile fires and determining the location of the shooter. In FY17 (the final year of a 3-year program), the project completed DAIRCM live fire validation testing. Data analysis and reporting will be completed in 1QFY18 to support DAIRCM Joint Urgent Operational Need fielding on Navy H-60, H-1, and H-6 helicopters in FY18.
- **Counter Unguided Threats.** Aircraft and crew losses to rocket-propelled grenades (RPGs) and other unguided threats are a concern for rotary-wing aircraft. JASP funded NAVAIR and the ARDEC to develop and test anti-RPG warhead concepts. In FY16, ARDEC and NAVAIR developed and tested Dust and Aluminum Frag warhead concepts. In FY17, NAVAIR and ARL researched, designed, and fabricated Consumable Fragmentation warheads for testing in FY18.
- **Harden Aircraft Systems.** During the past year, JASP vulnerability reduction efforts focused on three major areas to improve aircraft force protection: RPG defeat, innovative opaque and transparent armors, and aircraft hardening against high-energy lasers (HEL). In FY17, JASP:
  - Began development of a test capability to replicate Helicopter Active RPG Protection (HARP) RPG countermeasure kill vehicle engagements. HARP is a Future Naval Capabilities program designed to intercept incoming RPGs to reduce rotary-wing vulnerabilities against the RPG threat. The JASP project will provide live fire test data for threat model development, platform and personnel vulnerability analyses including the resultant RPG debris, and support evaluation of kill vehicle effectiveness for milestone decisions.
  - Undertook a major study to develop a scalable nomograph on the amount of aircraft hardening against HEL system threats that will provide a tactically significant survivability improvement. The solution set is mapped to mission profile, altitude, velocity and time on station and is based on intelligence data defining near-, mid-, and far-term HEL irradiances as a function of altitude. The nomograph will define the conditions for testing potential HEL hardening solutions in FY18 and FY19.
  - Completed development and optimization of a composite metal foam armor in conjunction with the University of North Carolina. Target threats were 7.62 and .50 caliber armor piecing rounds, with some preliminary testing against larger blast and fragmentation threats. Although probably too heavy and bulky for aircraft applications, the energy absorption of the system proved promising and should be further evaluated for possible ground vehicle application against larger explosives and IEDs.
  - During live fire testing of a recent armor development program, a significant performance shortfall was uncovered when ultra-high molecular weight polyethylene laminate was impacted at 25 degree obliquity. This anomaly could have serious threat protection implications. JASP initiated a test program to determine the physical mechanism(s)

causing this phenomenon. Testing was completed in FY17; data reduction and analysis are in progress with a report release scheduled for March 2018.

- **Improve the Accuracy and Confidence of Vulnerability Assessments.** In FY17, JASP continued efforts to improve the accuracy and confidence of the prediction of projectile and warhead fragment penetration used to assess aircraft vulnerability.
  - JASP continued to refine the Computation of Vulnerable Area Tool (COVART) Integrated Analysis Environment (IAE) that will improve analysis quality and productivity. The COVART instantiation of the Modular UNIXTM-based Vulnerability Estimation Suite (MUVES) Tool Kit IAE provides a consistent environment for tri-Service vulnerability and lethality analysis in COVART, MUVES, and the Advanced Joint Effectiveness Model (AJEM). The JASP team completed the Beta 3 release for COVART Version 6.9 in FY17.
  - JASP continued to improve the DOD vulnerability/lethality analysis capability by modifying COVART to use the six degrees of freedom (6-DOF) projectile penetration capability JASP added to the ProjPen model in FY16. Coding to implement 6-DOF processing was completed in FY17. After software testing and documentation in FY18, the capability will be released in COVART Version 7.0.

Improve Aircraft Survivability to Combat-Induced Fire

Threat-induced fire is the largest potential contributor to fixed-wing aircraft vulnerability and the greatest source of uncertainty in aircraft vulnerability analysis. In FY17, JASP focused on developing solutions to maximize residual flight capability in the event of threat-induced onboard fires and a robust and reliable fire prediction capability.

- JASP completed a thorough compilation and review of self-sealing fuel bladder performance results from qualification, acceptance, live fire testing, and combat incidents. Analysis of the data and the resulting recommendations were presented to the tri-Service Fuel Bladder Roundtable for consideration of changes and improvements in the fuel bladder qualification testing standard MIL-DTL-27422. The results should also influence requirements and key performance indicators in future acquisition programs.
- JASP completed testing in an operationally relevant environment of the Smart Multiport Fire Suppression System designed to reduce aircraft vulnerability and mitigate occupant casualties from threat-induced fuel fires. A continued development from the first self-contained single ejection port nozzle for confined spaces, this effort completed system integration and optimization of a multi-port nozzle and sensor system for use in large open areas like a helicopter cabin. The system was installed in a CH-53E carcass and tested against RPGs and armor piercing incendiary projectiles.
- JASP continued data collection and module development for the Next Generation Fire Prediction Model (NEXTGEN FPM). JASP began development of a physics-based Hydrodynamic Ram Spurt model to predict the ballistically induced fuel spray/vapor cloud produced by the penetration of a ballistic threat into an aircraft fuel cell. When combined with models of fragment flash and projectile incendiary, the NEXTGEN FPM is expected to predict ballistically initiated aircraft fires with 80 percent accuracy and 80 percent confidence, a significant improvement over current models.

Combat Damage Assessment

JASP continued aircraft combat damage incident reporting in the Services and the DOD through the Joint Combat Assessment Team (JCAT). The JCAT is a team of Army, Navy, and Air Force personnel that deploy to investigate aircraft combat damage in support of combat operations. The team continued to support assessments remotely from the continental United States and is ready to deploy rapidly outside of the United States if necessary.

- The JCAT continued working with the U.S. Army Aeromedical Research Laboratory (USAARL) to study and document aviation combat injuries in Operation Iraqi Freedom and Operation Enduring Freedom. Analysis of UH-60 Black Hawk helicopter incidents was completed in FY17, release of the results and reports is pending USAARL leadership approval. JASP will begin review of AH-64 Apache helicopter incidents in FY18. The results will be documented in USAARL reports and the Combat Damage Incident Reporting System.
- The JCAT and JASP Program Office worked in coordination with the Office of the Deputy Assistant Secretary of Defense for Systems Engineering, Office of the Under Secretary of Defense for Personnel and Readiness, and the Joint Staff's Force Structure, Resource, and Assessment Directorate, J8, on an Aircraft Combat Damage Reporting (ACDR) Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Policy (DOTMLPF-P) Change Request (DCR) proposal that would institutionalize ACDR through changes in joint doctrine, training, information technology infrastructure, and policy. The DCR was approved by the Joint Requirements Oversight Council on November 29, 2016. The JCAT and JASP began working with the Services to implement the approved DCR recommendations.
- The JCAT trained the U.S. aviation community on potential aircraft threats and combat damage. This training includes but is not limited to: capabilities briefs, intelligence updates, recent "shoot-down" briefs to discuss enemy TTPs, and the combat damage collection and reporting mentioned above. The attendees include aircrews, maintenance personnel, intelligence sections, Service leaders, symposia attendees, and coalition partners.

JOINT LIVE FIRE PROGRAM (JLF)

In FY17, JLF funded 21 projects and delivered 16 reports. Focus areas for JLF included projects that either 1) characterized new survivability issues; 2) characterized new lethality issues; 3) improved accuracy and fidelity of weapon data; 4) improved test methods; or 5) improved M&S methods.

Characterization of New Survivability Issues

- **Rocket-Propelled Grenade (RPG) Subcomponent Aircraft Material Penetration Demonstration.** JLF is investigating the penetration characteristics of basic RPG subcomponents impacting aircraft structural material represented by an array of 2024-T3 aluminum target plates (Figure 1). Active Protection Systems (APS) are being developed to provide fixed- and rotary-wing aircraft with the means to intercept and defeat incoming line-of-site threats, including RPGs. When an RPG is intercepted by an APS, the threat RPG may be broken apart (with or without warhead detonation) forming irregular kinetic debris. Questions exist as to the extent of damage caused by such debris when striking an aircraft. In addition to aircraft design details, factors that influence the damage outcome include the type of threat, its orientation, position, and velocity in relation to the aircraft when intercepted, and physical aspects of the debris such as shape, material type, mass, and velocity.
  - The penetration capabilities of the sustainer motors and booster assemblies showed the need to account for vulnerability effects of RPG debris produced during an APS intercept.
  - Ongoing data analysis is occurring to determine what additional information/testing is needed for APS modeling to assess the required safe distance for the APS intercept requirement.

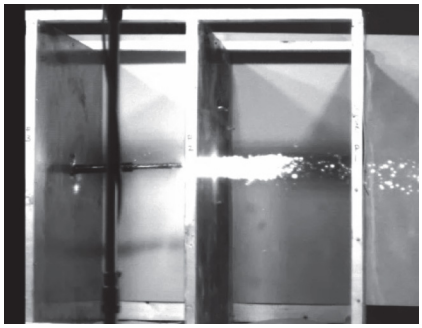

Figure 1. RPG Debris Penetration of Aircraft Structural Material

- **Large Engine Fan Vulnerability to Man-Portable Air Defense Systems (MANPADS).** JLF is investigating large engine fan vulnerability when directly impacted by a MANPADS missile. A fully functional and running JT9D turbofan aircraft engine combined with the inboard section of a B767 left wing and engine pylon were the test articles for this test (Figure 2).
  - This was the first time an operating turbofan engine, running at full power, has been impacted in the front low pressure compressor section, also known as the bypass fan section, by a representative MANPADS threat.
  - Analysis continues to assess MANPADS damage, estimate crew casualty issues, and estimate damage effects on ability to maintain controlled flight.

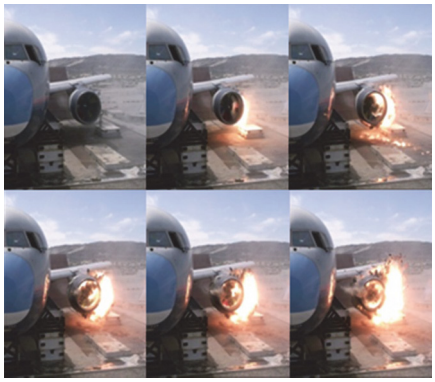

Figure 2. Still Video Images of MANPAD Impact upon an Operating JT9D Turbofan Aircraft Engine and the Ensuing Damage to the Aircraft

Characterization of New Lethality Issues

- **Fragment Penetration Testing of Concrete Masonry Unit (CMU).** JLF obtained fragment penetration data for CMU walls for implementation within the Fast Air Target Encounter PENetration (FATEPEN) model. The FY17 effort completed 45 of 80 planned tests; the remaining 35 tests will be conducted in FY18.
  - Warfighters require the ability to use FATEPEN to accurately predict damage to buildings constructed from CMU blocks. A CMU material model, however, does not currently exist in FATEPEN.
  - Gun-launched annealed 4340 rectangular steel rods impacted CMU block targets built to represent typical exterior walls of hardened and unhardened structures (Figure 3).
  - Impact locations were selected to characterize a wide range of impact conditions affecting penetration mechanics such as solid versus hollow cores, interior webs, mortar joints, obliquity, fragment mass, and impact velocity.
  - JTCG/ME will utilize the results to develop an accredited CMU material model for FATEPEN.

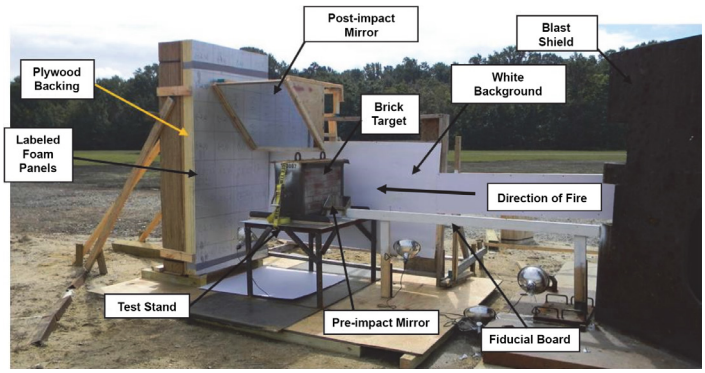

Figure 3. Test Setup for CMU Fragment Penetration Test

Improved Accuracy and Fidelity of Weapons Data Accuracy

- **Bomb Burial Lethality.** JLF is developing testing methods and formal test procedures for quantifying the effects of burial on warhead performance and collateral damage. A demonstration test of a buried HELLFIRE R9E warhead test will be conducted in 1QFY18.
  - Full or partial burial of warheads is a relatively new tactic being employed in military operations in urban terrain to reduce collateral damage from blast and fragment impact.
  - The lethality and collateral effects of weapon burial have not been sufficiently quantified.
  - This program will support a multi-year JTCG/ME test program (begins in FY18) to characterize the effects of burial depth, soil type, and impact orientation for four selected weapons: Small Diameter Bomb (SDB) 1, MK 82, MK 83, and MK 84.
  - JTCG/ME will utilize the results to improve collateral damage risk estimates from crater ejecta, fragmentation, and ground shock.
- **MK 84 Vertical Arena Test Number 2.** JLF obtained new vertical arena test data on the MK 84 general purpose bomb (Figure 4) due to concerns about the quality of existing MK 84 characterization data. JTCG/ME intends to incorporate the results of this test into JTCG/ME M&S and JMEM products. This testing complements similar testing done in FY15 and FY16 to produce a robust data set.
  - Initial examination of the fragment speeds from the test indicated a variance from the current characterization data. This variance has a strong potential to influence weapon usage for lethality, collateral damage estimates, and risk assessment.
  - In addition to the direct application of the characterization by the warfighter, JTCG/ME will compare the data with the output of shock physics predictive tools to improve the warhead detonation model in order to produce high fidelity results, potentially reduce the number of tests required for characterization of other warheads, and provide a better understanding of the fragment cloud.
  - Sandia National Laboratories utilized the test to explore optical fragment tracking techniques. These tracking techniques have the potential to provide additional data that will improve physics-based modeling.

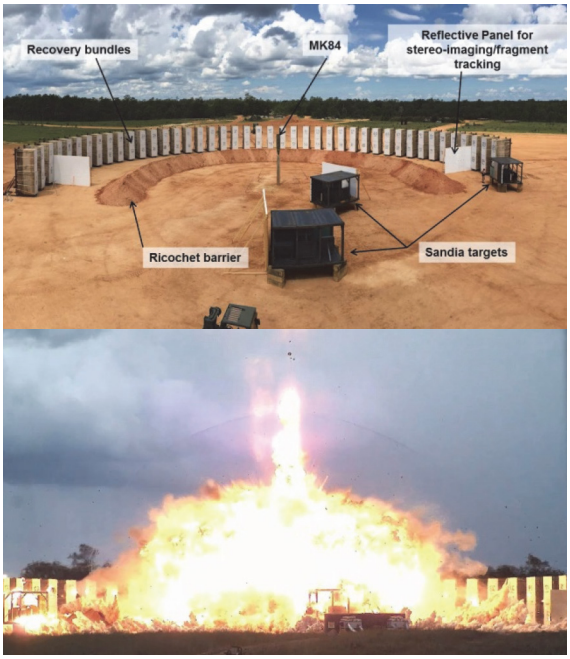

Figure 4. MK 84 Vertical Arena Test: Arena Setup (top); Still Image from High Speed Video after Detonation (bottom)

- **Building Debris Characterization.** JLF conducted a test to characterize the secondary debris produced by the detonation of a HELLFIRE R9E warhead inside a concrete masonry unit structure target (Figure 5). This testing complements similar testing done in FY16 using a PGU-44/B 105 mm High Explosive Projectile.
  - Warfighters require the ability to accurately predict risk to non-combatants from secondary debris. The current collateral damage methodology does not include damage from building debris although it has been operationally observed to be a hazard.
  - Building debris will be characterized in a manner similar to that of warhead fragments.
  - The results will be used to improve risk estimates of personnel injury resulting from both weapon fragments and building debris.

Figure 5. Still Image from Concrete Masonry Unit Building Debris Characterization Test

- **Updating the 1981 Armor Handbook (Initial Volume).** JLF began updating the "Ballistic Technology of Lightweight Armor" published by Francis Mascianica in 1981. This approximately 1,000-page compendium of ballistic data, referred to as the Mascianica Armor Handbook, provides a baseline performance for a wide variety of metal, composite, and ceramic systems against a wide spectrum of threat projectiles. The data in this handbook are useful for developing estimates of armor designs, analyzing the expected performance of armor systems, developing steel equivalencies for use in the MUVES vulnerability/lethality model, and determining the effectiveness of various models and simulations.

- In the intervening 36 years, many new materials (such as Dyneema, SpectraShield, and 7085 aluminum alloy) and threat munitions (both U.S. and foreign) have emerged that were not in the original handbook.
- Since updating the entire handbook cannot be accomplished in 1 year at a reasonable cost, this task updated the highest priority volume (of 11) of value to the vulnerability/lethality community: fragments and fragment simulating projectiles. Data mining is the only practical method to accomplish this update for a relatively modest cost within a reasonable timeframe.
- The data are provided in a format similar to the original Mascianica, such as mean penetration velocity (V_{50}) plotted as a function of armor material thickness (Figure 6). This figure also illustrates the efficiency of the data mining approach since magnesium alloy AZ31B was not included in the 1981 handbook.

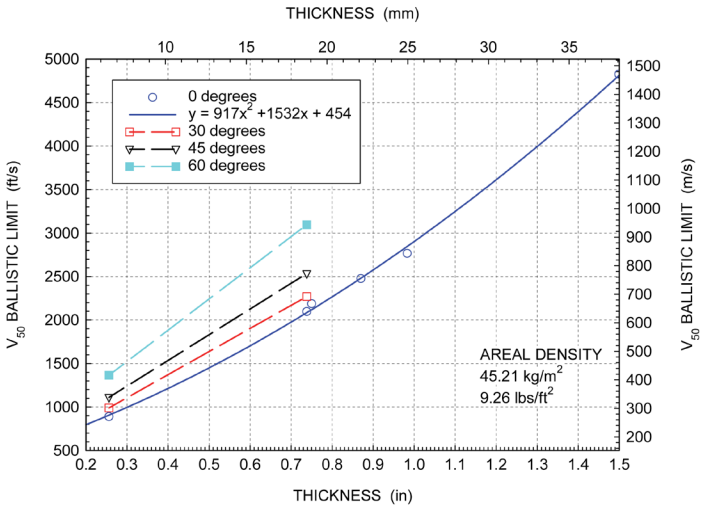

Figure 6. Protection Provided by Magnesium AZ31B-H24, MIL-DTL-32333, Class 1 (Plate Areal Density 45.21 kg/m2) against the .30-cal (44 grain) Fragment Simulating Projectile

Improvements of Live Fire Test Methods

- **Modified RG-31 Testing in Engineered Soil.** JLF conducted six identical UBB tests on a vehicle-like target and collected 410 channels of data to be analyzed and used to understand the sources of variability in UBB testing.
  - UBB testing is used during LFT&E to evaluate vehicle crew survivability in the event of a mine or IED attack. Variability exists in UBB testing, but the extent of that variability is unknown. The data collected from UBB testing drives the evaluation of vehicle crew survivability and influences future vehicle designs. The data are also used to support verification and validation of M&S tools that supplement the live fire data set used for evaluation. The results of this project provide a baseline understanding of the degree of variability in UBB testing.
  - The variability contributed by the soil type used in UBB testing is of special interest to the live fire community due to a 2016 change in the test standard. The new test standard, Engineered Soil with Roadbed Compaction (ERB), was designed to be more controlled and reduce the potential for variability as compared to the old test standard. However, there is limited repeat test data from ERB that includes a crew survivability assessment. Current ongoing analysis of the results from this JLF program will inform the test community regarding the variability from test to test using ERB in terms of vehicle jump height as well as crew survivability assessment.
  - The test series included one Warrior Injury Assessment Manikin (WIAMan) anthropomorphic test device (ATD) alongside four standard Hybrid III ATDs. The WIAMan is currently under development by the Army Research Laboratory and is the first ATD developed specifically for use in UBB testing.
- **Underbody Blast (UBB) Live Fire Test Threat and Blast Box Interaction Analysis.** In the execution of UBB live fire test events, steel box enclosures buried within the ground are used for preparation of soil test beds and emplacement of blast event threats (Figure 7). The current use of 24 by 24 by 10 feet test boxes are approved for use with engineered soil based on previous experimental tests and blast modeling. While maintaining box size sameness was essential to building a robust dataset across multiple UBB charge sizes, the current 24 by 24 by 10 feet blast boxes present a logistical challenge for LFT&E program execution due to their limited number, increased emplacement times, and increased labor and materials costs (especially when testing relatively small UBB LFT&E charge sizes).

Figure 7. UBB Live Fire Test: Soil Being Placed in Test Box (top); Test Bed Complete (middle); Detonation (bottom)

- The majority of primary live fire test ranges utilize 15 by 15 by 6 feet boxes, which currently do not support the use of engineered roadbed soil. Therefore, the need exists to explore charge size limits, utilizing realistic LFT&E charge weights, in both "small" (15 by 15 by 6 feet) and "intermediate" (18 by 18 by 7 feet) boxes to determine how large of charge weight can be used in each blast box without undesirable wall effects.
- JLF funded the Aberdeen Test Center to generate data in terms of impulse, wave velocity through the soil, and overpressure to define the influence exerted on the blast response as a result of interaction with an intermediate size blast box. This would enable establishment of guidelines to define the minimal test box size applicable to relevant live fire test threat sizes.
- This program is being conducted in concert with an ongoing Army Research Laboratory effort currently executing a complementary series at smaller explosive weights in a 15 by 15 by 6 feet box.
- Upon completion of this effort, results will be coordinated and the Aberdeen Test Center will update IOP-SLV-005 "Procedures for Preparation of an Engineered Soil Test Bed in Support of Blast Testing of Vehicles and Test Structures" and publish TOP 02-2-630 "Engineered Soil Test Bed Emplacement Procedures for Live Fire Testing." This will reduce or remove test throughput constraints, increase test execution throughput three-fold, and reduce LFT&E program costs.

• **Instrumented Inert Threat Systems for Active Protective System (APS) Applications.** JLF funded the Army Redstone Test Center to develop a unitary RPG instrumented inert threat system for use in counter-munition effectiveness evaluation during live fire hard-kill APS testing.
  - The development and use of this system will provide a realistic threat that yields more accurate countermeasure impact location and time, while lowering risk to APS vehicle platforms and reducing the dependency on high-speed cameras that do not yield accurate kill or intercept measurements.
  - The instrumentation system design, undergoing field tests and integration development, is composed of transmitters installed inside an inert RPG warhead. Three transmitter circuits will identify three unique zones of the warhead – the front tip (green), the front ogive (blue), and the explosives area (red), as seen in Figure 8. A flexible mesh screen, shaped to the contour of the inner surface area of each zone, will act as a break screen to identify a break in the circuit caused by a counter-munition impact – identifying the impact zone.
  - With the dependable transmitters, high signal resolution, and post-test analysis capabilities, testers/evaluators will be able to more precisely evaluate an APS's claims at reducing threat lethality, more accurately analyze the reduction in platform vulnerability, and ultimately reduce risk to the APS platform.

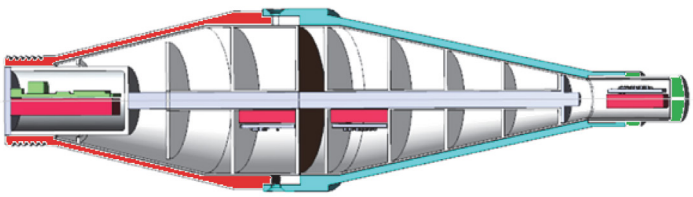

Figure 8. Unitary RPG Instrumented Inert Threat System

• **Assessing Local Accelerative Loading.** JLF funded the improvement of evaluation protocols for accelerometers utilized in live fire and ballistic shock testing. This project complements FY15 efforts that characterized the current state of accelerometer instrumentation and established a basic test protocol for evaluating gauges in the future. The FY17 project is extended to ultimately characterize the effectiveness of accelerometers used in live fire testing, develop and evaluate concept accelerometers, and write a user's guide to educate testers on the advantages and disadvantages of using specific accelerometers in a range of blast environments.
  - This work is being completed in two phases with over 500 individual test events. The first phase consists of characterizing the accelerometers in the laboratory using bench tests that stress the accelerometers at multiple frequency ranges. The second phase of testing consists of characterizing the accelerometers in repeatable explosive tests using a symmetrical blast rig (pictured in Figure 9) that can accommodate multiple accelerometers and that is designed to mimic the frequency response of a ground vehicle.
  - As a result of this effort, testers will have more insight and guidance to help them select the appropriate instrumentation to use in live fire testing based on the expected loads and desired type of data output, improving the DOD's ability to capture accurate and informative data from ground vehicle live fire blast testing.

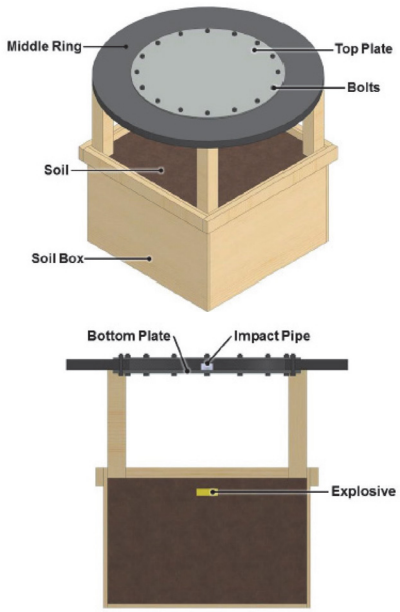

Figure 9. Explosively Driven Test Rig Isometric View (left) and Section View (right)

Improvements of Live Fire Modeling and Simulation (M&S)

- **Enhanced Modeling of Behind Armor Debris (BAD) Velocity Field for Explosively Formed Penetrators (EFPs).** JLF continued to support the improvement of the BAD algorithm by collecting unprecedented, high-speed images of EFP BAD using a pulsed laser illumination system (Figure 10). This testing complements similar testing with shaped-charge and kinetic energy warheads completed in FY15 and FY16, respectively. The BAD algorithm is in both the Army's (MUVES) and joint test and evaluation communities' (AJEM) vulnerability/lethality models. This series of test data builds confidence in modeling the damage produced from BAD fragments to internal vehicle components (including personnel) and will improve future vulnerability/lethality analyses that incorporate BAD.
  - Test data was collected from six shots, including three different EFP warhead sizes.
  - Three-dimensional analyses of these images produced fragment speeds as a function of the fragment's angle from the residual jet.

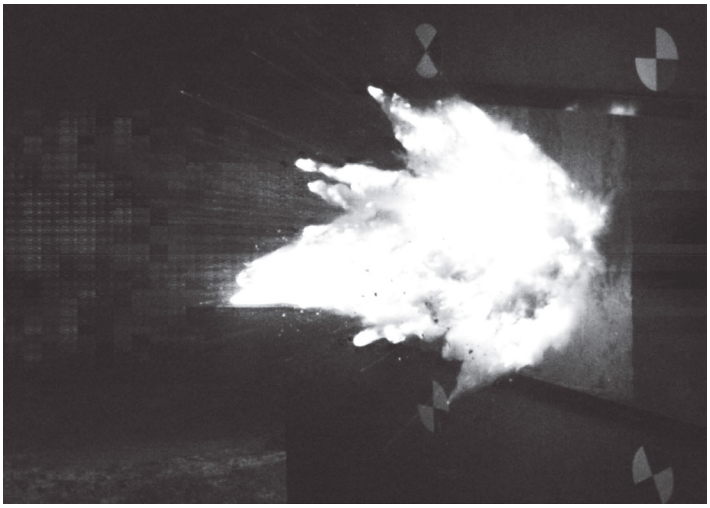

Figure 10. High-speed Image of BAD Fragments Resulting from an EFP

- **Statistical Quantification for LFT&E Planning of Small Arms Munitions.** JLF is investigating a new procedure to improve development of live fire test matrices for small-caliber terminal-ballistics testing by quantifying variation in the collected test data. This work will improve lethality evaluation against personnel as well as potentially reduce the time/cost of performing small-caliber LFT&E testing.
  - The current procedure for weapons effectiveness evaluation relies strongly on M&S to convert the fragments captured during terminal-effects test events into human injury estimation. In the current procedure, all M&S is run after the conclusion of all terminal-effects test events.
  - By interleaving the terminal-effects test events with M&S runs evaluating the terminal performance, it is possible to optimize the distribution of future test events across the predictor space of the system under test and may even be possible to cut the testing short if the variation in results is sufficiently small.
- **OG-7V Fragmentation Grenade Threat Model Development.** JLF is developing an OG-7V grenade threat model based on empirical data. Live fire testing against UH-60A partial fuselages is in execution and will allow for fragment/blast damage mapping comparison between M&S outputs of impacted components and observed test results.
  - JLF encountered a large number of dud OG-7V test articles. JLF then had five munitions X-rayed and visually inspected. No discernable defects were observed that suggested there would be problems preventing detonation. JLF is inspecting the possibility of dud fuzes.

JOINT TECHNICAL COORDINATING GROUP FOR MUNITIONS EFFECTIVENESS (JTCG/ME)

JTCG/ME continued to update and develop weapons effectiveness and target vulnerability data, standards, and methods to evaluate munitions effectiveness, including target vulnerability characterization, munitions lethality, weapon system accuracy, and specific weapon-target pairings driven primarily from current operational lessons learned, Joint Staff Data Calls, and CCMD needs. These capabilities are crucial for developing theater commander force employment options as well as the execution tasking orders to tactical units.

The principal products of the JTCG/ME are the JMEMs. JMEMs enable users to plan the mission by determining the effectiveness of weapon systems against a specified target for a range of weapon delivery modes. JMEMs include: detailed data on the physical characteristics and performance of weapons and weapon systems; descriptions of the mathematical methods that employ these data to generate effectiveness estimates; software that permits users to calculate effectiveness estimates; and pre-calculated weapon effectiveness estimates. This information enables a standardized comparison of weapon effectiveness across all Service communities. Current JMEM product lines products include JWS, J-ACE, Digital Precision Strike Suite (DPSS) Collateral Damage Estimation (DCiDE) tool, and the Digital Imagery Exploitation Engine (DIEE). New product lines include Joint Non-Kinetic Effectiveness (J-NKE) capabilities. There are also specialized solutions that are driven by the needs of CCMDs, coalition partner interoperability, and lessons learned from current operations. Such solutions include Probability of kill (Pk) Lookup Tools; Collateral Damage Estimation (CDE) tables; scenario specific CDE analysis packages; munitions weaponeering guides; rapid response target surrogation; and foreign military sales. Since JTCG/ME products are user focused and requirements driven, considerable effort goes into working with users to establish warfighter requirements for current and future JTCG/ME products, as well as continued training events and day-to-day support.

Air-to-Surface and Surface-to-Surface Weaponeering: Joint Munitions Effectiveness Manual Weaponeering System (JWS)

JWS is the DOD source for air-to-surface and surface-to-surface weaponeering, munitions, and target information used daily by the U.S. Central Command (USCENTCOM), U.S. Special Operations Command (USSOCOM), and U.S. Africa Command (USAFRICOM) in the deliberate planning process directly supporting Joint Publication 3-60, "Joint Targeting." JWS enables CCMDs to prosecute their target sets. JWS incorporates accredited methods, certified munition characteristics, delivery accuracy, target vulnerability data, and numerous user aids to support the operational use of JWS to predict weapons effectiveness for fielded weapons and delivery systems. In FY17, JTCG/ME:

- Continued to facilitate coalition interoperability and information exchange forums. It delivered multiple JWS version releases and standalone Pk Lookup tools to key coalition partners in support of current operations under foreign military sales agreements. This capability improves the effectiveness of U.S. fires and targeting personnel working in combined environments. JTCG/ME also held successful information exchange forums via information exchange agreements with the United Kingdom and Republic of Korea. These exchanges help leverage methods and efforts of mutual interest in the area of weapons effectiveness.
- Supported 19 rapid response surrogations and developed Pk Lookup data for 7 weapons against 13 targets and 119 surrogations based on urgent operational needs for target vulnerability data. These specialized products directly assisted CCMDs to meet the requirements of a dynamic environment as formal products are developed.
- Initiated and finished JWS v2.3 final phase development; fielding is scheduled for FY18. JWS v2.3 will include enhanced data sets and capabilities with a focus on connectivity to other targeting and mission planning capabilities for improved estimates and more seamless planning. More specifically, JWS v2.3 enhanced capabilities include:
  - Improvements to information assurance and cybersecurity.
  - Connectivity to the Modernized Integrated Database, Joint Targeting Toolbox (JTT), and DIEE. This will permit automatic and more optimum transfer of data and information between planning tools.
  - Fast Integrated Structural Tool (FIST) enhancements, such as connectivity to DIEE and JTT and updated target options (building type, material, and features). These updates will improve weapons effectiveness estimates and planning optimization for structural targets.
  - Improvements to the Ship Weaponeering Estimation Tool that optimize database use and improve the user interface. These updates will improve weapons effectiveness estimates and planning optimization for maritime targets.
  - Inclusion of a weapon delivery accuracy module along with updates for the Gunship Delivery Accuracy Program, Rotary Wing Delivery Accuracy Program, and Joint Delivery Accuracy Program. This will provide enhanced calculations for F-35 gun munitions and C-130 gunship effectiveness in JWS.
  - The Dilution of Precision Tool, which improves the predicted accuracy of GPS/Inertial Navigation System weapons from satellite time and space calculations.
  - The Target Location Error Tool, which enables a single JWS tool to provide Target Location Error from airborne- and ground-based sensors.
  - Updates on weapons delivery accuracy and characterization data for multiple systems. This included trajectory model updates based on available Guided Weapon Trajectory Software, Joint Direct Attack Munition, and Small Diameter Bomb (SDB).
  - Over 65 target vulnerability data sets across ground, aircraft, small boats, ships, and submarines, as well over

375 updated images and Quickfacts, which provide the Weaponeer quick-reference characteristics of systems for analysis.

- Continued development of JWS v2.4. JWS v2.4 will provide enhanced data and connectivity capabilities, while maximizing the final JWS v2.x product line and laying the groundwork for the next JWS series (JWS v3.x). Development highlights include a more streamlined database-driven product with enhanced, separated business logic and user interfaces. This will allow for accelerated weapons and target data updates; tailored product versions for releasability; and more effective, focused testing. Specific capabilities will include updated weapons and targets, as well as FIST v2.1 with inclusion and updates to WinBlast, Bridge Analysis System, Linear Target Module, and surface response and penetration functions in burst point editor. These capabilities will enable more options for the Weaponeer and improve the underlying phenomenology representation in JWS.
- Continued development on the next JWS series, JWS v3.x. With the architecture strategy established and a JWS v3.x Capability Needs Statement (CNS) developed in FY17, plans for FY18 include determining the methods to best meet the CNS-established requirements. To ensure long-term viability of the down-selected methods, the characteristics of developmental munitions will be surveyed and included in the decision matrices.
- Supported current use and future development requirements by hosting and supporting JWS training sessions, Operational Users Working Groups (OUWG), and user help desk support via the JMEM Product Information Access System and JWS newsletter. Specifically, JTCG/ME supported approximately 30 JWS sessions at 19 locations with over 400 students. The training sessions allow users to optimize use of JWS capabilities, while providing JTCG/ME with critical input on warfighter use for future development. OUWGs are critical venues for receiving direct user feedback and development of future requirements from the operational community in regards to needed software enhancements and capabilities to support air-to-surface and surface-to-surface weaponeering. JTCG/ME continued to chair OUWGs, with participation from USCENTCOM, USAFRICOM, U.S. Strategic Command (USSTRATCOM), U.S. Pacific Command, USSOCOM, the Services, the Defense Intelligence Agency, the Defense Threat Reduction Agency, the Fires Center of Excellence, Service School Houses, the Marine Aviation Weapons/Tactics Squadron, Operations Support Squadrons, Intelligence Squadrons, and numerous other operational units.

Collateral Damage Estimation, Reach Back, and Planning Connectivity: Digital Precision Strike Suite (DPSS) Collateral Damage Estimation (DCiDE) Tool and the Digital Imagery Exploitation Engine (DIEE)

With the changing complex strategic environment, urban and close-combat operations have become a focal point of military restructuring. Using lessons learned from traditional-based strategies, military commanders and leaders have sought innovative answers in decreasing collateral damage, saving innocent lives, and reducing military costs. Decreasing these measures meant progressing computing and communications equipment, enhancing lines of communication, increasing response times to High Value or Time Sensitive Targets, improving mission planning objectives, and increasing situational awareness on the battlefield. JTCG/ME continues to support these complex needs by developing and providing accredited collateral effect radii (CER), interoperable CDE capabilities, enhanced methodology, and reach back support for the warfighter. In FY17, JTCG/ME:

- Continued to enhance the Collateral Effects Library (CEL) tool in support of advanced CDE mitigation techniques.
- Updated the accredited CER Reference Tables for selected air-to-surface and surface-to-surface weapons, which are the basic data that support the CDE methodology. The JTCG/ME CER tables and CDE methodology are used in every planned kinetic strike in all Areas of Responsibility (AORs) to meet commanders' intent and to minimize civilian casualties. JTCG/ME implements the CER and CDE methodology within the DCiDE tool, an accredited and automated tool that expedites and simplifies the CDE process. DCiDE enables JTCG/ME to continuously support the Chairman of the Joint Chiefs of Staff Instruction 3160.01B, "No-Strike and the Collateral Damage Estimation (CDE) Methodology." DCiDE is the only automated CDE tool authorized for use in the USCENTCOM and USAFRICOM AORs.
- Supported the fielding of DIEE v2.0 and development of DIEE v2.1, with expected fielding in late 2017. DIEE is an enterprise targeting solution that provides both seamless planning and linkage to various mission planning systems and tools in operational units. It interconnects precision point mensuration, weaponeering, and collateral damage estimation applications, allowing targeting or planning personnel to develop strike plans, while linked to mission planning systems for target execution.
  - DIEE v2.0 included full DCiDE functionality for automated CDE, quick weaponeering tables for automated weaponeering solution development, production of standard targeting package graphics, and connectivity to mission planning systems. DIEE v2.1 will include user requested enhancements, JWS interface, and updated Common Geopositioning Services for precision point mensuration capability. Future versions will include 3D viewer capability.
  - Supported DCiDE and DIEE training sessions for approximately 100 personnel.
- Leveraged CEL and other high fidelity techniques to deliver 25 collateral damage mitigation analysis packages to operational users for high value targets. JTCG/ME also provided collateral damage mitigation tables for use by the broader operational community. These efforts directly assisted CCMDs to meet commander's intent and minimize collateral damage.

- Planned, in conjunction with JLF, a focused program (beginning in FY18) to enhance and validate collateral damage. The enhancement will support improvements in weaponeering methodology to minimize risk to mission and forces while not increasing risk of collateral damage by providing foundational data for the development of higher fidelity predictive tools. Specific efforts will generate buried ordnance characterization data based upon usage statistics from CCMD expenditure reports, and AOR specific building debris data to enhance and validate current weaponeering/collateral damage estimation methods required by Strike Approval Authorities to make their strike decision calls. FY18 efforts build off three FY17 JLF testing events and multiple collaboration forums.
- Provided direct forward presence support to Combatant Commanders, which enabled target materiel development, weaponeering, and CDE solution development.

Air-to-Air and Surface-to-Air Combat Tactics, Techniques, and Procedures Development: Joint-Anti-air Combat Effectiveness (J-ACE)

J-ACE provides authoritative air-to-air and surface-to-air weapons effectiveness information, and serves as the primary tool used by the Air Force and Navy to underpin air combat tactics, techniques, and procedures (TTPs) development. J-ACE (Figure 11) is the umbrella program that includes both the Joint Anti-air Model (JAAM) and Endgame Manager, which provides a full kill chain end-to-end capability. Other users include National Test and Training Ranges for air-to-air and surface-to-air shot validation and various members of the analytical community for air combat studies and planning. USSTRATCOM leverages J-ACE capabilities to support route planning for the execution of strike packages. JAAM supports operational squadrons' mission debrief tools such as the Personal Computer Debriefing System. In FY17, JTCG/ME:

- Finished J-ACE v5.3, which extended and updated data sets for missile and aircraft target aero performance, anti-air missile lethality, and air target vulnerability. These data include over 40 air-to-air missile models (blue and threat), over 50 surface-to-air missile models (threat), and approximately 40 aircraft models (blue and threat). New capabilities include:
  - Initial Hybrid Integration and Visualization Engine computer architecture interface, which will allow for increased future leveraging and modularity for enhancements.
  - The BLUEMAX6 (6-DOF aero performance) model for increased aircraft aero performance modeling, with Hands-on Throttle and Stick allowing for actual flight control of the aircraft.
  - Increased ability to estimate countermeasure effectiveness by leveraging Enhanced Surface-to-Air Missile Simulation (ESAMS) to assist planning in ever-increasing area denied environments.
  - Factoring in the effect of weapon system reliability when calculating the probability of a successful engagement.
- Developed a standalone weaponeering guide for an electronic attack/warfare capability that will be integrated into future J-ACE versions.
- Continued J-ACE v5.4 development, with expected completion in 2018. J-ACE v5.4 fielding will include an enhanced BROWSE module for descriptive material to support new weapons in the JAAM and Endgame Manager. J-ACE v5.4 will enhance Personal Computer Debriefing System capability, and further evaluate enhancement of aircraft maneuverability modeling with Hybrid Integration and Visualization Engine (HIVE)/BLUEMAX6 data and models. In addition, JAAM will include initial capability to evaluate two-sided Suppression of Enemy Air Defense (SEAD) and Destruction of Enemy Air Defense (DEAD); improved target detection capability leveraging National Air and Space Intelligence Center Radio Frequency (RF) models and data; and increased ESAMS capability.
- Worked and performed requirements analysis for longer development needs for future J-ACE versions, to include rotary-wing aircraft capability, increased SEAD/DEAD capability, and increased electronic warfare and countermeasure capabilities. Specifically, JTCG/ME worked several aspects needed for rotary-wing capability to include review of potential aero performance models, as well as data and methodology needs to address the broader threat and operational effect spectrums as compared to fighters and bombers already on the product (slower, lower altitude with more terrain effects). Additionally, JTCG/ME reviewed opportunities to address increased SEAD/DEAD capability by leveraging existing air-to-surface weapon trajectory models and interaction with JWS effectiveness estimates. JTCG/ME continued to investigate how to best leverage electronic warfare and countermeasures engineering level investments in an operational modeling environment.
- Led and hosted External Interface Working Group (EIWG) forums. These forums are pivotal for J-ACE developers to understand requirements and align development with other external debrief and analytical capabilities that use J-ACE as the underlying analytical engine to underpin results. The

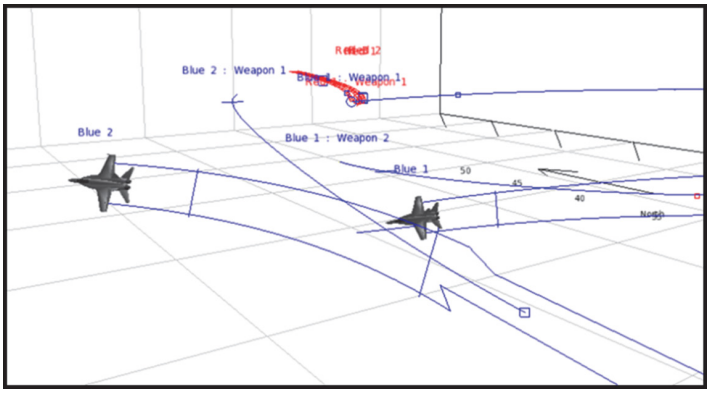

Figure 11. The primary J-ACE interface is through the Joint Anti-Air Model (JAAM). JAAM is a fast running simulation of air-to-air missiles and surface-to-air missiles as well as aircraft aerodynamic performance.

EIWG meeting allowed J-ACE external application developers to receive an update on the upcoming J-ACE v5.3 release and continued development of J-ACE v5.4. The forums included user agreement process updates, application programming interface changes, final v5.3 product review, v5.4 development review, and use case presentations. Participants included the Air Force Weapons School, TOPGUN, Intelligence Community, USSTRATCOM, Air Force Life Cycle Management Center, Naval Air Warfare Center, as well as contract developers of J-ACE, Personal Computer Debriefing System, Individual Combat Aircrew Display System, Joint Debriefing Subsystem, Common Mission Debrief Program, and Extended Air Defense Simulation.

Cyber and Directed Energy Effectiveness: Joint Non-Kinetic Effectiveness (J-NKE) - Cyber and Directed Energy JMEMs

Joint Non-Kinetic Effectiveness is intended to be the single source for operational warfighters, analysts, targeteers, and planners to analyze offensive cyber capabilities and directed energy effects. In FY17, JTCG/ME, in conjunction with other stakeholders:

- Continued planning and development of cyber effects estimations with a focus on standardization of data required to address weapon characterization, target vulnerability, operational environment, and uncertainty metrics to support the development of a Cyber Operation Lethality and Effectiveness tool. Efforts continue with linkages to the U.S. Cyber Command and other key stakeholders to ensure Combatant Command and Service warfighter requirements are articulated and understood. DOT&E will receive additional funding to address some of these shortfalls in FY18.
- Coordinated with a FY18/19 Joint Test Project to leverage, enhance, and develop directed energy effects estimation and standardization tools. The FY18/19 Joint Test Project, Joint Laser Systems Effectiveness (JLaSE), was approved as a conduit for warfighters to solve joint laser operational issues and provide a non-materiel solution to the warfighter. Efforts will take advantage of work completed by the High Energy Laser Joint Technology Office and various planned Use Cases throughout the 2-year cycle. Focus will be on various Service near-term capabilities that take advantage of the directed energy laser (DEL) weapons low cost per shot, deep magazine, precision engagement, and scalable effects. Collateral Damage concerns will also be addressed. Results of the tasking will provide Joint Fire Support Planners and Targeteers the Tactics, Techniques, and Procedures for Weaponeering and Collateral Damage Estimation, to adequately plan for and execute Directed Energy Laser Weapons in the joint battlespace.

LFT&E SPECIAL INTEREST PROGRAMS

WARRIOR INJURY ASSESSMENT MANIKIN (WIAMan)

- The WIAMan Engineering Office (WEO) is currently leading the WIAMan project (Figure 12) on behalf of the Army Research, Development, and Engineering Command (RDECOM), with the Army Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI) supporting acquisition-related preparation activities. RDECOM and PEO STRI have a memorandum of agreement defining the leadership, responsibilities, and funding relationships between these two organizations.
  - The WIAMan project plans to enter the acquisition cycle as a post-Milestone A program of record via a Materiel Development Decision in 1QFY18. The WEO will transition leadership of the WIAMan project to PEO STRI at Milestone B, but will continue to support PEO STRI in certain non-severable activities related to the WEO's expertise in biomechanics, ATD development, and LFT&E.
  - The WEO continued to demonstrate that the current ATD used in LFT&E, the Hybrid III, lacks biofidelity in the UBB test environment, meaning it does not exhibit a human-like response when exposed to UBB loading conditions. ATD biofidelity is assessed via compliance with biofidelity response corridors (BRCs) for the human body regions and response parameters of interest.
  - In FY17, the project delivered the remainder of the 15 whole-body BRCs, completing planned BRC testing. These BRCs focused on human response to different combinations of parameters that vary in LFT&E, such as loading rate inputs, occupant posture, and use of Personal Protective Equipment.
  - The project continued injury biomechanics research to support development of both human injury probability curves (HIPCs) and injury assessment response curves (IARCs). IARCs provide the probability of human injury as a function of the various measurements recorded by the ATD during test events. The WEO delivered the first two preliminary HIPCs and IARCs to evaluators in 4QFY17, in support of armored multi-purpose vehicle (AMPV) system-level LFT&E testing scheduled for FY18.
- The WEO continued its 3-year pilot study to investigate the effects of the UBB environment on female soldiers. The objective of this study is to determine if UBB loading conditions affect females differently than males and, if so, for what reasons. The WEO intends to use the results of this pilot study to inform a decision about the need to develop unique injury assessment capability for female soldiers. A total of five whole-body female biomechanics tests were executed in FY17, with an additional test planned for FY18. The component testing phase (approximately 80 tests) of this study will occur in FY18. The WEO plans to complete this study in FY18.
- Diversified Technical Systems delivered on schedule four fully integrated first generation WIAMan ATD prototypes in June 2017. The WEO has started to use these prototypes during IARC testing, and is completing the verification, validation, and accreditation plan for these prototypes. When

the opportunity presented itself, the WEO successfully incorporated a WIAMan Technology Demonstrator ATD in a series of UBB experiments to gain insight on the WIAMan's biofidelic response, design, and durability.

- The WEO continued its refinement of an optimized ATD finite element model (FEM), with a view to evaluating how well the FEM will work when integrated as a sub-system of the Army's current UBB modeling methodology. The WEO is also refining the FEM to reflect the final configuration of the delivered prototypes.
- The WEO continues to accomplish its technical goals regarding establishing human body response to the UBB load regime, to include expanding its investigation into potential gender-based differences. The Army has refined its previous plan and schedule to more rapidly develop and deliver an initial WIAMan capability. The acquisition program is funded through FY19 and will procure additional prototypes that will be used for AMPV full-up system-level testing in FY20. The Army is working to fund WIAMan beyond FY19.

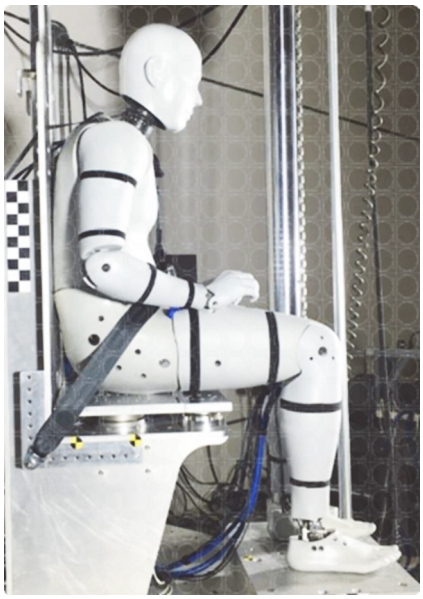

Figure 12. Generation 1 WIAMan ATD

SMALL BOAT SHOOTERS' WORKING GROUP

Small boats are a significant asymmetric threat to ships operating in littoral waters. Several weapon systems that can provide defense against these threats are being developed, tested, and evaluated by the Army, Navy, Air Force, and Marine Corps. The Small Boat Shooters' Working Group facilitates the coordination and collaboration of the various efforts underway to counter and defeat this threat.

- In FY17, DOT&E sponsored the sixth annual Small Boat Shooters' Working Group meeting. At this meeting, the current small-boat threats were reviewed, and updates were provided on defensive system programs, including test results. Information on related programs, such as targets, instrumentation, test ranges, and lethality models, was also provided. Specific topics included results from HELLFIRE longbow missiles vertically fired from a ship against High-Speed Mobile Surface Targets (as part of the Littoral Combat Ship program), results from Air Force tests of various weapons against high speed boat targets at test ranges near Eglin AFB, and plans for upcoming Joint Air-to-Ground Missile tests against the High Speed Maneuverable Surface Target and Coast Guard 41 Fast Attack Craft surrogate targets.