Live Fire Test and Evaluation (LFT&E)

INTRODUCTION

- In FY16, DOT&E executed LFT&E oversight for 132 acquisition programs, 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 3 special interest programs (Warrior Injury Assessment Manikin (WIAMan), Home Made Explosives (HME), and Small Boat Shooters' Working Group).
- In support of a range of acquisition decisions and activities, DOT&E published two LFT&E reports and two combined OT&E and LFT&E reports. The reports include recommendations to the Services to further improve the survivability or lethality of the subject systems for a range of operationally relevant scenarios in existing and expected combat environments.

LFT&E Investment Programs Summary

- The Joint Technical Coordinating Group for Munitions Effectiveness:
  - 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 Commands' requirements. These efforts equipped the Combatant Commands with added operational targeting, weaponeering data and solutions, and collateral damage estimation capability in direct support of new operations, mission planning, and training. This includes the Digital Precision Strike Suite (DPSS) Collateral Damage Estimation (DCiDE) tool and Digital Imagery Exploitation Engine (DIEE), as well as standalone resources such as the Probability of kill (Pk) Lookup Tools, Collateral Damage Estimation (CDE) tables, and munitions weaponeering guides. These solutions rapidly provide Service members with authoritative weapons effectiveness data when needed, as well as seamless end-to-end strike package development during planning (i.e., weaponeering, collateral damage estimation, and precision point mensuration).
  - Supported the air warfare community – in particular the Naval Strike and Air Warfare Center and the Air Force Weapons School – with its J-ACE tool to develop tactics, techniques, and procedures manuals for air superiority applications and to perform post-shot analysis following exercise and training missions (e.g., Red Flag FY16 exercises at Nellis Test and Training Range, Nellis AFB, Nevada).
  - Worked with DOD, Joint, and Service planners to support force-on-force modeling, mission area analysis, requirements studies, and weapon procurement planning such as the Army's Total Army Analysis, the Air Force's Nonnuclear Consumables Annual Analysis, the Navy's Naval Munitions Requirements Process assessment, and annual Army Capabilities Integration Center simulation exercises.
  - Supported the acquisition community in performance assessments, analysis of alternatives (AoA), and survivability enhancement studies such as the Army's Echelon Above Brigade M113 Family of Vehicles Replacement AoA. This AoA leveraged standard JTCG/ME analytical tools, such as the Joint Mean Area of Effectiveness Model.
  - Developed a preliminary non-kinetic JMEM capability, to include a prototype Cyber JMEM. This provided the analytical foundation for standard processes and data to enable effectiveness estimates for cyber, electronic attack, and directed energy capabilities.
  - Continued work on JWS versions releasable to the United Kingdom, Canada, Australia, Republic of Korea, and other coalition partners for planning, operational weaponeering and collateral damage estimates, support of training and tactics development, and support of force-level analyses.
- JASP funded 47 multi-year projects addressing aircraft survivability enhancement technologies and aircraft survivability evaluation tools. In FY16, JASP made progress in improving:
  - The ability of aircraft to counter near-peer and second-tier threat by 1) developing and testing countermeasure techniques, which included improving both the fidelity of countermeasure simulations and the collection of flight test data on a new chaff design; 2) updating survivability tools such as the Enhanced Surface-to-Air Missile Simulation (ESAMS) with the latest threat types and countermeasures; and 3) investigating new countermeasure concepts for emerging threats.
  - Aircraft force protection by 1) developing improved hostile fire detection; 2) investigating anti rocket-propelled grenade warhead concepts to improve rotorcraft survivability; 3) investigating aircraft hardening against high energy lasers; and 4) improving the accuracy and confidence of vulnerability assessment tools.
  - Aircraft survivability to fires, the primary threat-induced aircraft vulnerability.
- JLF supplemented LFT&E of fielded systems, addressed operational commander's needs, and characterized new survivability and lethality effects of fielded systems either: 1) in response to the exposure of U.S. systems to new threats; 2) as a result of systems being used in new, unanticipated

ways; or 3) as a result of systems being operated in new environments. Specifically, JLF:
- Assessed the effect of fielded system design changes on survivability (e.g., CV-22 add-on armor)
- Assessed weapon lethality of a new ammunition mix for A-10 aircraft as well as behind armor debris of an anti-tank penetrator mine
- Improved the accuracy and fidelity of weapon data used as part of mission planning in order to estimate weapon effectiveness and effects with higher confidence (e.g., improved collateral damage estimates)
- Advanced live fire test methodology to improve collection of fragment velocity and spatial distribution data during arena testing
- Supported the development and improvement of modeling and simulation tools that contribute to survivability and lethality evaluations (e.g., new data to support improvements in predicting weapons effects against aircraft, vehicles, and military structures)

LFT&E Special Interest Programs Summary

- The WIAMan project, an Army-led effort, made significant progress in biomechanics testing and anthropomorphic test device development to design a biofidelic prototype for assessing injuries to vehicle occupants during underbody blast. However, the Army has not programmed the funding for this project in FY18 or beyond, which could adversely affect the delivery of this capability.
- HME-C investigated and tested the repeatability of HME surrogate effects relative to those of TNT and the effects of soil condition and IED emplacement on HME threat performance. DOT&E used the test data to develop LFT&E policy for employing buried underbody blast surrogates that mitigates soil-induced test data variability. This included a new, engineered soil standard for use with underbody blast testing.
- The Small Boat Shooters' Working Group continues to synchronize live fire and other operational test approaches against this growing threat class, which operates in littoral waters.
- DOT&E briefed Congressional staff on helicopter seating system improvements per the House Report to accompany the National Defense Authorization Act for FY16. DOT&E determined that seating system improvements would improve force protection in some crash conditions, but addressing controlled flight into terrain and collision threat avoidance with near-term technology solutions would provide a higher payoff by mitigating leading cause of fatality in helicopter mishap and combat-induced crashes.

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 platforms or munitions get deployed or enter full-rate production. In FY16, DOT&E executed LFT&E oversight for 132 acquisition programs. Of those, 17 operated under the waiver provision of U.S. Code, Title 10, Section 2366, by executing an approved alternative LFT&E strategy in lieu of full-up system-level testing. DOT&E published two LFT&E reports and two combined OT&E and LFT&E reports in FY16 (see Table 1).

LFT&E Reports	Combined OT&E and LFT&E Reports
Multiple Launch Rocket System (MLRS) M270A1 Launcher Improved Armored Cab (IAC)*	Mine Resistant Ambush Protected (MRAP) Family of Vehicles MaxxPro Long Wheel Base (LWB) Ambulance with Independent Suspension System (ISS) and MaxxPro Survivability Upgrade
Soldier Protection System (SPS) Torso and Extremities Protection (TEP)*	M829A4 120 mm Armor-Piercing, Fin Stabilized, Discarding Sabot – Tracer (APFSDS T)*

* Reports sent to Congress.

- Three reports supported Full-Rate Production decisions:
  - "Multiple Launch Rocket System (MLRS) M270A1 Launcher Improved Armored Cab (IAC)" reported on the protection that the IAC provides to the MLRS crew. The report included three recommendations to improve MLRS crew survivability.
  - "Soldier Protection System (SPS) Torso and Extremities Protection (TEP)," regarding a single soft armor system to replace the Army's Improved Outer Tactical Vest, reported on the protection the TEP provides soldiers against small-arms and fragmenting threats.
  - "M829A4 120 mm Armor-Piercing, Fin Stabilized, Discarding Sabot – Tracer (APFSDS-T)" reported on the lethality of the M829A4 120 mm APFSDS-T. This report included four recommendations to improve operational effectiveness and lethality, and one recommendation to improve test and evaluation practices in future similar lethality test programs. DOT&E continues to observe the follow-on tests and will report on the accuracy problems with the M829A4 service rounds that were observed during the User Beta Test for Version 4.6 of the Abrams software.
- One report provided a system survivability evaluation for use by the Service and Program Office:
  - "Mine Resistant Ambush Protected (MRAP) Family of Vehicles MaxxPro Long Wheel Base (LWB) Ambulance

with Independent Suspension System (ISS) and MaxxPro Survivability Upgrade" reported on the protection against underbody blasts afforded to occupants of the MaxxPro LWB Ambulance MRAP vehicle (also known as the M1266A1). LFT&E made five recommendations to further reduce the underbody vulnerability of the M1266A1 and its crew.
- DOT&E published one classified Special Report, "Market Survey of Active Protection Systems," in response to Senate Committee Report 114-49 (2015).
- DOT&E provided the classified "Assessment of the Performance and Effectiveness Characteristics of the 5.56 mm M855A1 and Mk318 Mod 1 Rounds" to the Under Secretary of Defense for Acquisition, Technology and Logistics in response to Senate Committee Report 114-49 (2015).

LFT&E INVESTMENT PROGRAMS

JOINT TECHNICAL COORDINATING GROUP FOR MUNITIONS EFFECTIVENESS

The Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) continued to update and develop weapons effectiveness and target vulnerability data, standards, and methodologies that are crucial for developing theater commanders' force employment options as well as the resulting execution tasking orders to tactical units. The principal products of the JTCG/ME are the Joint Munitions Effectiveness Manuals (JMEMs). JMEMs enable users to plan the mission adequately 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 methodologies 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. JMEM products include existing software product lines, such as the JMEM Weaponeering System (JWS) and the Joint Anti-air Combat Effectiveness. Future product lines will include the Joint Non-Kinetic Effectiveness capability. Specialized solutions are driven by the needs of Combatant Commands and lessons learned from current operations. Such solutions include Probability of kill (Pk) Lookup Tools; Collateral Damage Estimation (CDE) tables; munitions weaponeering guides; and enablers for more efficient targeteering (e.g., the Digital Precision Strike Suite (DPSS) Collateral Damage Estimation (DCiDE) tool and the Digital Imagery Exploitation Engine (DIEE)).

Joint Munitions Effectiveness Manual Weaponeering System

- 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 Combatant Commands to prosecute their target sets. JWS incorporates accredited methodologies, 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.
- JTCG/ME deployed JWS v2.2 in FY16. JWS v2.2 included a total of 220 methodology, functionality, weapons/warheads/fuzes, and target updates. JWS v2.2 included initial connectivity with the DCiDE tool (Figure 1), as well as updates to the Fast Integrated Structural Tool (FIST) (containing building types and a quasi-static blast capability). The connectivity with DCiDE improves both speed and throughput of data.
- JTCG/ME continued to facilitate coalition interoperability. It is currently completing several JWS version releases 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 continued development on JWS v2.3 in FY16; fielding is scheduled in 1QFY17. 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:
  - Connectivity to the Modernized Integrated Database, Joint Targeting Toolbox, and DIEE (currently in finalization for separate fielding). This will permit automatic transfer of data and information between these planning tools.
  - Multiple updates to FIST to incorporate connectivity with DIEE and the Joint Targeting Toolbox, along with updated target options (such as building type, material, and features). These updates will improve weapons effectiveness estimates.
  - Improvements to the Ship Weaponeering Estimation Tool that optimize database use and improve the user interface.
  - 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 (e.g. M982 Excalibur satellite-guided artillery shell, M395 Precision Guided Mortar Munition, AGM-65E2/L Maverick air-to-ground tactical missile, M1061 60 millimeter mortar, M120 Towed/M121 120 millimeter mortar, BLU-110 general purpose bomb, AGM-114 Hellfire variant, M31 Guided Multiple Launch Rocket System, M1156 Precision Guidance Kit, and numerous small arms).
- Fifty target vulnerability data sets across ground, aircraft, small boats, ships, and submarines, as well as 352 updated image Quickfacts, which provide the Weaponeer quick-reference characteristics of systems for analysis.

• JTCG/ME will continue development of JWS v2.4 during FY17 to provide enhanced data capabilities and connectivity.

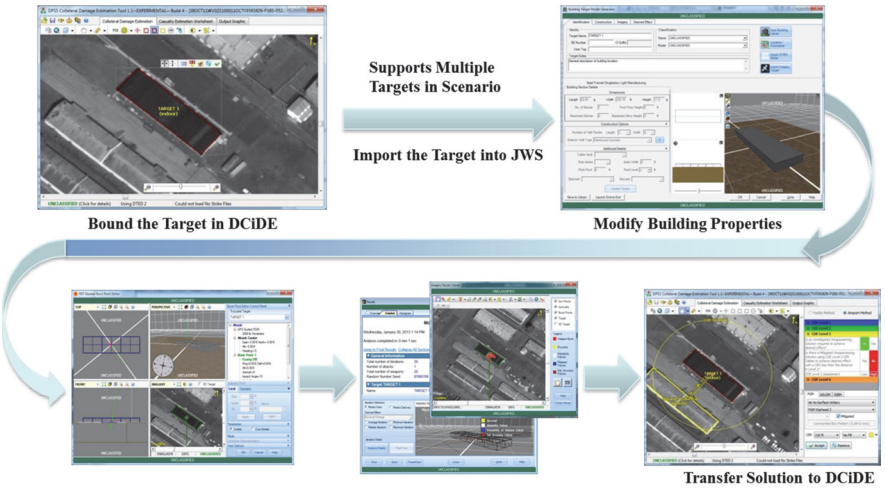

Figure 1. Connectivity between Weaponeering and Collateral Damage Assessment Enables Combatant Commanders to More Rapidly Prosecute Targets

In FY16, JTCG/ME released DCiDE v2.0 to support the Chairman of the Joint Chiefs of Staff Instruction 3160.01B, "No-Strike and the Collateral Damage Estimation (CDE) Methodology." This release provides the latest approved Collateral Effect Radii (CER) and CDE data as of FY16.

- The DCiDE tool is an accredited and automated CDE tool that expedites and simplifies the CDE process. As such, it is critical to the Warfighters' ability to meet urgent operational needs. DCiDE is the only automated CDE tool authorized for use in the USCENTCOM and USAFRICOM Areas of Responsibility Operation (AORs). The JTCG/ME CDE tables are used in every planned kinetic strike in all AORs to meet Commanders' intent and to minimize civilian casualties. DOT&E continues to receive positive feedback on the use of the CER values, collected as part of the Joint Live Fire efforts, as a critical enabler in support of munitions employment against HVTs.
- JTCG/ME 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. Changes included additions for airburst munitions, nomenclature changes, and additional updates for newly fielded/updated systems (e.g., HELLFIRE family). JTCG/ME also developed and accredited the Collateral Effects Library tool in support of advanced CDE mitigation techniques.

• JTCG/ME is working with the Navy's DPSS program based at the Naval Air Weapons Center – Weapons Division in China Lake, California, to provide the Digital Imagery Exploitation Engine (DIEE). DIEE is an enterprise targeting solution that provides both seamless planning with the various planning tools and a direct linkage to mission planning systems in operational units.

- DIEE is a self-contained Government off-the-shelf (GOTS) computer system with internal software. It can derive mensurated coordinates from the Digital Point Positioning Database and will combine applications so that targeting or planning personnel can develop strike plans where the weaponeering, collateral damage estimation, and precision point mensuration conducted during planning is both seamless and linked to mission planning systems for target execution. JTCG/ME began fielding DIEE at the beginning of FY17, and both USCENTCOM and USARFICOM have already committed to using DIEE as their primary targeting planning tool.

Joint-Anti-air Combat Effectiveness

• Joint-Anti-air Combat Effectiveness (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, technics, and procedures development. J-ACE 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. The U.S. Strategic Command (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 and several others.

• JTCG/ME is releasing J-ACE v5.3, which will extend and update 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:

  - The Hybrid Integration and Visualization Engine computer architecture interface
  - The BLUEMAX6 (six degrees of freedom aero performance) model for increased aircraft aero performance modeling, with Hands-on Throttle and Stick allowing for actual flight control of the aircraft
  - Increased countermeasure capabilities leveraging ESAMS
  - Factoring in the effect of weapon system reliability when calculating the probability of a successful engagement
  - The ability to estimate countermeasure effectiveness
- J-ACE v5.4 is in development to field and add Browse descriptive material to support new weapons in the JAAM and Endgame Manager. The fielding of J-ACE v5.4 in 2017 will facilitate greater connectivity for outbrief capability by units, target detection estimation, counter air defense prediction capability, and enhanced architecture allowing future version growth and compatibility.

Joint Non-Kinetic Effectiveness – Cyber/Electronic Attack and Directed Energy JMEMs

- JTCG/ME is continuing the development of non-kinetic weaponeering tools and methodologies. Joint Non Kinetic Effectiveness is intended to be the single source for operational Warfighters, analysts, targeteers, and planners to analyze offensive cyber capabilities, electronic attack weapons, and directed energy effectiveness.
- In conjunction with DOT&E and the Air Force's 363rd Intelligence, Surveillance, and Reconnaissance Group, the JTCG/ME continued development of a JMEM process for cyberspace operations, electronic attack, and directed energy. FY16 efforts centered on developing the foundational elements for JMEM production, including weapons characteristics, target vulnerability, and effects estimation tools (e.g., U.S. Cyber Command's Cyber Capabilities Registry, Electronic Warfare/Cyber Critical Elements/Weaponeering Guides, and Directed Energy Effectiveness Lookup Tables). These efforts culminated in an initial Cyber JMEM prototype for user review and set the foundation for a full joint non-kinetic suite that includes other non-kinetic effects.

Operational Users Working Group

- The Operational Users Working Group is a critical venue 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, surface-to-surface, anti-air, and non-kinetic engagements. Examples of user requirements include the ability to release weaponeering information to coalition partners; connectivity between tools and mission planning systems; current weapon and fuze information; updated training materials; quick weaponeering guides; graphical user interface enhancements; and improved blast/fragment methodologies in support of small precision munitions.
- JTCG/ME continued to chair Operational Users Working Groups with representatives from USCENTCOM, USAFRICOM, 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 operational units.

Joint Aircraft Survivability Program

The mission of the Joint Aircraft Survivability Program (JASP) is to increase military aircraft combat survivability – and, by extension, effectiveness – in current and emerging threat environments. JASP supports the mission through funding and oversight of Research, Development, Test, and Evaluation to develop aircraft survivability technologies and assessment methodologies. JASP also supports the mission 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 FY16, JASP funded 47 multi-year projects and delivered 27 final reports. In FY16, JASP focused on projects intended to either 1) defeat near-peer and second-tier adversary threats by developing measures to avoid detection and counter engagement of advanced radio frequency and infrared guided threats; 2) improve aircraft force protection; or 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 radio frequency-guided threats and anti-access/area-denial capabilities, coupled with quantifiable improvements in ESAMS and Hardware-in-the-Loop capabilities; and 2) measures to counter emerging infrared homing threats with advanced counter-countermeasures, coupled with quantifiable improvements in The Modeling System for Advanced Investigation of Countermeasures (MOSAIC) and Hardware-in-the-Loop capabilities.

- ESAMS is the 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:
  - The capability to model the flow fields around chaff release to more accurately represent chaff bundle dispersion patterns. This capability will be released in ESAMS v5.3 in March 2017.
  - Integration of an advanced naval surface-to-air missile threat, which was developed in cooperation with the Office of Naval Intelligence. This capability will be released in ESAMS v5.3 in March 2017.
  - Improvement of two threat engagement radar models by adding their electronic counter-countermeasure capabilities. These upgrades will be released in ESAMS v5.4 in FY18.
- MOSAIC is the primary digital tool used to develop and assess effective U.S. aircraft infrared countermeasures (IRCM).

- JASP concluded a multi-year effort with Large Aircraft IRCM (LAIRCM) and Common IRCM (CIRCM) program support elements of the Air Force Research Laboratory and the Naval Surface Warfare Center, Crane Division to verify and validate MOSAIC for LAIRCM IOT&E. This effort verified and validated nine threat missile models in MOSAIC for directed energy IRCM supporting LAIRCM, CIRCM, and other future system development, test, and evaluation.

- A continuing need across the DOD is ready access to valid countermeasure characterization model data. 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 Army's Armament Research, Development and Engineering Center in conjunction with Naval Air Systems Command (NAVAIR) to conduct flight tests to collect Radar Cross Section data on a new chaff design. The data will be used to determine the optimum response range of metamaterial for countering radio frequency threats. Initial analysis indicates that the chaff can be utilized from the S through W bands.
  - 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 the effectiveness of chaff 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 or Doppler effects. NAVAIR conducted flight testing to collect chaff dispense characteristics in various fixed and rotary-wing aircraft flow fields. NAVAIR, the Army Aeroflightdynamics Directorate, and the Office of Naval Intelligence are working together to develop the Computational Fluid Dynamics model to include flow field effects.
- 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 infrared-guided seekers:
  - Naval Research Laboratory development of missile warning algorithms using two-color infrared 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 infrared imagery, determine the ability to perform missile identification in urban clutter, and characterize jamming performance for Distributed Aperture IRCM (DAIRCM).
  - Testing threat system Infrared Counter-countermeasures' performance against current countermeasure technologies using a two-color tracker to understand how color ratio is used to discriminate between flares and the target; the results will be used to develop more effective countermeasures.
  - Development of a new capability to field test missile seekers against model aircraft with countermeasures including paints and directed energy to optimize electro-optical/infrared countermeasures. The countermeasure effectiveness of various aircraft paints and paint schemes is determined by testing with a surrogate threat infrared seeker. The scale model test facility at the Naval Research Laboratory's Blossom Point Research Facility is a bridge in test capability between laboratory tests and field tests with full scale aircraft. Validation of seeker results provides a surrogate advanced threat seeker for use in countermeasure development and evaluation.
  - Investigation of the feasibility of using Ultra-Short Pulse lasers for aircraft IRCM. The results of the study will support an Office of Naval Research initiative to further test and develop Ultra-Short Pulse IRCM.
  - Completed design and testing of a standardized test set to measure expendable countermeasure launch setback forces. Developed a standard operating procedure to generate expendable countermeasure setback force data and created a database for tri-Service use. Standardizing the testing of expendable launchers (i.e., flare buckets) across the tri-Service community will minimize test duplication and reduce development costs.

Improve Aircraft Force Protection

To improve the ability of U.S. aircraft to avoid threat detection and to mitigate damage when hit, JASP funded several 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 Naval Research Laboratory to develop a sensor package that incorporates both mid-wave infrared (MWIR) and acoustic waveforms for detecting hostile fires and determining the location of the shooter. In FY16 (the second year of a three year program), the project enhanced the baseline approach to further reduce false alarms and improve shock wave propagation predictions. Shock-wave generation propagation simulation models and detection algorithm updates were provided to the DAIRCM program. The algorithm update achieved a 2.5X detection improvement in forward flight/maneuver and a greater than 10 percent improvement in hover over previous algorithms. Analysis of hostile fire detection system noise and performance on HH-60 corrected detection issues in forward flight maneuver.
- 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 Army Armament Research, Development and Engineering Center (ARDEC) to develop an anti-RPG warhead. ARDEC

and NAVAIR developed four anti-RPG warhead concepts that could launch from a helicopter expendable countermeasure launcher. Testing of prototypes will begin testing in FY17, and the results will aid the Navy's Helicopter Active RPG Protection program.

- Harden Aircraft Systems. In FY16, 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). During FY16, JASP:
  - Determined, by compiling existing test data, that there is insufficient data on the response of the PG-7 piezo fuze to high-velocity impacts of common aircraft materials at oblique angles to model potential defeat mechanisms. Since RPG-7 testing has primarily focused on heavy track and ground vehicles there is little data to define constraints in designing solutions to mitigate RPG effects on aircraft.
  - Integrated low-power laser mitigation technology into the highly successful Multi Impact Transparent Armor System. For this initial JASP HEL hardening effort, the focus was to mitigate dazzling from a common, commercially available Nd:YAG (neodymium-doped yttrium aluminum garnet) laser at a wavelength of 1,064 nm. The technology blocked the targeted wavelength while maintaining a 97.2 percent transmission rate in the visible spectrum compared to the pre-notched baseline system with minimal transmission effect in the night vision goggle performance band. However, the system multi-hit capability was compromised due to the ceramic strike face de-bonding on the first hit. Additional development and testing is required before fielding.
  - Initiated a project to determine composite material loss of strength (under mechanical load) as a function of time when exposed to short-duration, high-intensity, thermal loads typical of HEL impingement. From this data, time-dependent probabilities of component damage (Pcd/h) curves can be developed for use in system-level vulnerability assessments.
- Improve the Accuracy and Confidence of Vulnerability Assessments. In FY16, JASP funded efforts to improve the accuracy and confidence of the prediction of projectile and warhead fragment penetration used to assess aircraft vulnerability.
  - JASP developed, implemented, and verified standard formats for the 11 threat projectiles and the 12 single fragments that are most often used in system-level aircraft vulnerability assessments and fire prediction studies. These files will provide consistency across studies performed by different organizations and will be incorporated into the unified threat characterization database that was released in the Air Force Vulnerability Toolkit v6.8 in December 2016.
  - JASP continued to improve projectile penetration predictions by converting the ProjPen projectile penetration model to a six degrees of freedom model with the goal of predicting residual yaw within five degrees and reducing the error in the prediction of system-level vulnerable area.

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 FY16, JASP focused on developing solutions to maximize residual flight capability in the event of threat-induced onboard fires.

- JASP compiled and began evaluating data from across the Services to determine if self-sealing fuel bladders are performing as expected and whether military-standard qualification test methods adequately address threshold survivability requirements. JASP presented the results at the Tri-Service Fuel Bladder Roundtable and will document them in a final report.
- Developed and optimized, with a statistical design of experiments, next-generation self-sealing fuel bladder materials and construction layups. The next-generation bladders are lighter, more responsive to alternative aviation fuels and blends, and better at preventing fuel loss. Testing will continue during FY17.
- JASP continued work to optimize fire-resistant resin formulations for use as barrier ply on polymer matrix composites used in military aircraft. Integration of this type of resin could increase protection against internal fires and HELs. Coupon testing against heat flux conditions representative of small dry bay fires and HEL radiation is underway.

Combat Damage Assessment

- JASP enforced aircraft combat damage incident reporting in the Services and the DOD by continuing to support 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. JCAT ended its operation in Afghanistan in October 2014 with the return of deployed assessors to the United States. The team has 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 started 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. 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 completed the Joint Staff review and comment process and was submitted for Joint Requirements Oversight Council approval.

- 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.

The Joint Live Fire Program

In FY16, Joint Live Fire (JLF) funded 27 projects and delivered 21 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 methods.

Characterization of New Survivability Issues

- Military Combat Eye Protection (MCEP) systems (spectacles, goggles) help protect soldier's eyes from debris and fragments associated with explosive munitions and IEDs. MCEP systems typically use lenses made from polycarbonate. JLF is assessing whether another material, Trogamid CX, is also a suitable lens material. Limited prior ballistic testing indicates Trogamid CX has superior ballistic impact resistance at room temperature.
  - JLF conducted testing to assess the ballistic performance of polycarbonate and Trogamid at various temperatures and to compare and contrast the ballistic performance of both materials.
  - The test data were used to develop curves that illustrate ballistic performance versus temperature for polycarbonate and Trogamid lenses, enabling a comparative assessment of the ballistic performance.
  - The data are currently being evaluated. The U.S. Army Natick Soldier Research, Development, and Engineering Center will use the results to assess the suitability of using Trogamid to manufacture protective eyewear in the future.
- Crew survivability in the event of a propellant fire onboard a M109A7 155 mm self-propelled howitzer is a concern. Unlike a fuel fire, a propellant fire is self-oxidizing and cannot be extinguished by the integral automatic fire extinguisher system; it has the potential to be more lethal to crewmen than a fuel fire.
  - JLF conducted a fire test focusing on the adequacy of various design solutions to improve crew survivability from a propellant fire prior to M109A7 full-rate production.
  - The data obtained during this test have been analyzed and will provide a basis for recommendations to improve M109A7 crew survivability. The recommendations will be included in the Live Fire Test and Evaluation Report provided as input to the March 2017 M109A7 full-rate production decision review.
- The U.S. military operates the C-12 aircraft in a number of roles including intelligence, surveillance, and reconnaissance; medical evacuation; and passenger and light cargo transport for the Army, Navy, Air Force, and Marine Corps in both hostile and non-hostile environments. However, the survivability of the C-12 aircraft in hostile environments has not been fully characterized. In FY16, JLF assessed the survivability of the C-12 due to direct ballistic engagements to the aircraft fuel system.
  - The results of this project will provide the information necessary to make informed operational and acquisition decisions based on an understanding of the likelihood and resulting damage levels from small arms threat engagements.
  - Since the fuel system is one of the largest contributors to aircraft ballistic vulnerability, this project examined ullage reaction to a variety of ballistic engagements. Data analysis is ongoing.
- JLF investigated the effectiveness of an improved ballistic armor system to protect CV-22 Osprey crewmembers from ballistic threats. The project used threats not previously tested as part of LFT&E to investigate the armor system performance when challenged along different shotlines. The results of this project will help guide future development efforts for the Osprey's next generation ballistic protection systems.
- Emerging High Energy Lasers (HELs) represent an emerging threat to aircraft and unmanned aerial vehicles (UAVs). The fuel systems of many UAVs have a large presented area which makes them vulnerable to HEL engagements. JLF obtained baseline damage-effects data for both fuel-backed dry bay and adjacent subsystems subjected to HEL thermal flux, and assessed both suppression of laser-induced dry bay fires and laser hardening methods. JLF will use the data to support modeling and simulation of HEL engagements and the improvement of hardening methods to reduce vulnerabilities from HEL engagements.

Characterization of New Lethality Issues

- JLF funded the Army Research Laboratory to characterize the behind armor debris (BAD) of an anti-tank penetrator mine. BAD consists of fragmentation from both the target vehicle's armor and the residual penetrator that spreads out as it is ejected into the vehicle's interior.
  - The additional BAD data for this threat will provide empirical data to support the design of protection systems against this threat.
  - The Army Research Laboratory will also use the test results to construct BAD models for use in vulnerability/lethality analyses. The Army Research Laboratory uses these BAD vulnerability/lethality analyses to support acquisition programs and the planning and evaluation of vehicle vulnerability testing.
- JLF funded the Air Force's 780th Test Squadron (780 TS) to conduct a modeling and simulation analysis to evaluate the lethality of a mix of 30 mm target practice ammunition and high-explosive incendiary (HEI) ammunition to determine the most effective alternative for the A-10's current combat mix.
  - The original A-10 combat load included a mix of both armor-piercing incendiary ammunition with depleted uranium penetrators and HEI ammunition. Environmental

health concerns with depleted uranium and aging-related reliability concerns have resulted in commanders using only HEI ammunition instead. This use of 100 percent HEI ammunition has demonstrated reduced lethality and effectiveness in engagements with combatants shielded by light armor vehicles, soft-skinned vehicles, or structures such as adobe brick walls.
  - This project has the potential to introduce an Urban Combat effective Mix (UCM) using target practice and HEI ammunition that provides an increased lethality over a 100 percent HEI combat load. Lessons learned from this application of target practice ammunition could later be applied to 20 mm and 25 mm weapon platforms for all users throughout the DOD. The results of this effort will also provide the Joint Munition Effectiveness Manual with 30 mm target practice round lethality data.
  - Live ammunition testing will occur in FY17 following the results of this modeling and simulation analysis.

Weapons Data Accuracy

- JLF was resourced to obtain new arena test data on the MK 84 general purpose bomb (Figure 2) due to concerns about the quality of existing MK 84 characterization data. JTCG/ME will incorporate the results of this test into JTCG/ME products. This testing complements similar testing done in FY15.
  - 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 2. Still photograph from MK 84 vertical arena test

- Mk 82 and Hellfire vs Adobe Walls. JLF funded the Naval Surface Warfare Center, Dahlgren Division to evaluate the effects of the blast and fragmentation from a MK 82 MOD 1 General Purpose bomb and HELLFIRE R9E warhead on adobe block structures.
  - JLF will collect critical data to determine a threshold radius for wall destruction.
  - The results will be used to improve collateral damage estimates and safe engagement distances for targets in close proximity to adobe buildings with civilian occupants. There currently exists no test data to support these estimates.
- Building Debris Characterization. JLF funded the Naval Surface Warfare Center, Dahlgren Division to conduct a test to characterize the secondary debris produced by detonation of a 105 mm PGU-44/B high-explosive projectile within a concrete masonry unit structure target (Figure 3).
  - JLF will collect critical information to characterize building debris 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. No test data exists to support these estimates.

Figure 3. Concrete masonry unit for characterizing building debris

Improvements of Live Fire Test Methods

- Penetration Profiles of Ballistic Backing Material. JLF is investigating a test procedure to improve the characterization testing of materials currently being evaluated for use as backing material during ballistic testing of Personal Protective Equipment. The current clay backing material is subject to variations that can influence test results.
  - The current characterization tests for backing materials do not replicate the dynamic deformation rates those materials experience during ballistic testing.
  - The results of this effort will permit selection of backing materials based on testing at deformation rates closer to those experienced during ballistic testing. The technique will permit comparisons between emerging prototype backing materials as well as with historical data on the current clay backing material.
  - Testing was recently completed, and the results will be used to screen potential new backing materials and compare their behavior with the current clay backing material.
- Optimization of Arena Test Data Collection Methodology. JLF is investigating the use of a new methodology, based on

techniques developed by NASA, to improve collection of fragment velocity and spatial distribution data during arena testing.

- The technique utilizes piezoelectric film panels for detection, which immediately reports fragment impact locations to a data recorder and requires no additional work for locating the fragments.
- JLF will use the data collected during this program to assess the feasibility incorporating piezoelectric film sensors as a standard method of collecting fragmentation impact location and velocity data during arena testing. The initial results from this project should be available in early FY17.

Improvements of Live Fire Modeling and Simulation

- Enhanced Modeling of BAD Velocity Field for KE Penetrators. JLF supported the improvement of the behind armor debris (BAD) algorithm by collecting unprecedented, high-speed images of kinetic energy warhead BAD using the pulsed laser illumination system (Figure 4).
  - Three-dimensional analyses of these images produced fragment speeds as a function of the fragment's angle from the residual jet.
  - The test data indicate the scatter of kinetic energy BAD fragments may not be a simple function of cone angle, however the Gaussian velocity field used in the BAD algorithm is an improvement over the previous function. Based on the results of this project, the Gaussian velocity filed will be used to represent kinetic energy BAD fragment velocities.

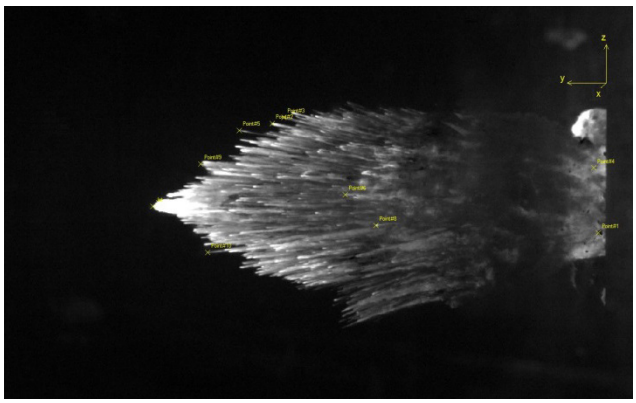

Figure 4. High-speed image of BAD fragments

- Joint Light Tactical Vehicle (JLTV) Underbody Blast Vulnerability Assessment. JLF is investigating the use of high-fidelity computational physics models to simulate vehicle underbody blasts at multiple vehicle locations with several threat sizes. This approach will improve the ground survivability community's understanding of vehicle structural response and occupant injury risk for various threat size and blast location scenarios.
  - JLF will perform system-level underbody blast simulations on the JLTV in at least 12 blast locations using up to 3 sizes of threat and assess the results against the DOT&E survivability criteria used for the JLTV program (see Figure 5). The high fidelity mesh model to support these simulations is in development.
  - This modeling approach would represent a new assessment capability: a multi-threat and multi-location methodology for mapping vehicle structural response and occupant injury risk of combat systems. Performing simulations at multiple threat locations should show the changes in vulnerability across different regions of the underbody, while simulating different charge sizes will help identify the estimates of most vulnerable underbody areas to increasing threat size.

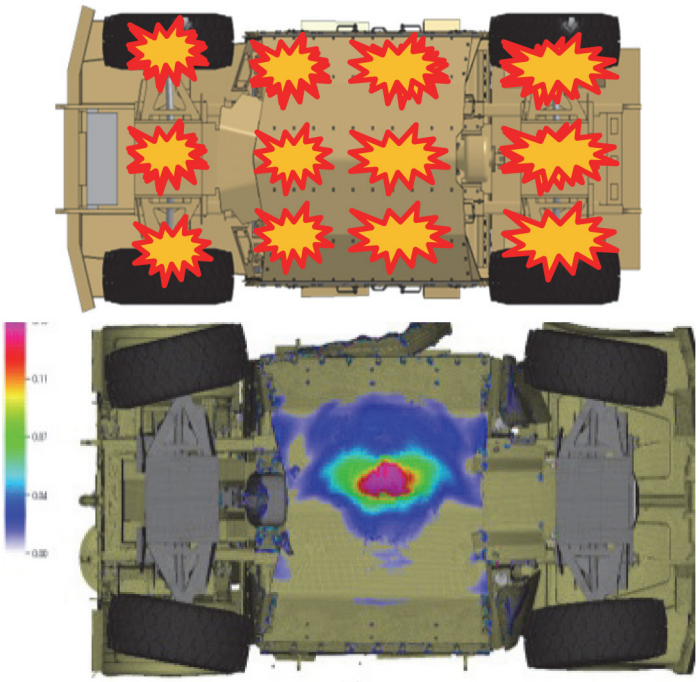

Figure 5. Shotline selection for simulations (top) and structural response of vehicle underbody (bottom)

- JLF supported the development of a shaped charge jets effects model.
  - Initiation of stowed 25 mm ammunition is one of several lethal mechanisms that can impart catastrophic levels of damage to a ground vehicle. Testing on stowed 25 mm training rounds with shaped-charge jets of varying size and velocity collected quasi-static pressure versus time data that will be used to develop a new ammunition compartment vulnerability model.
- JLF continued a joint effort with Germany to develop and validate the Dynamic Systems Mechanical Advanced Simulation (DYSMAS) hydrocode used to model bottom and near-bottom underwater explosions effects.
  - In FY14, several tests were conducted in the Briar Point test pond at the Aberdeen Test Center, Maryland, using a floating shock platform to collect data on platform response from charges located at mid-depth, near-bottom, and on the bottom.
  - The analysis of those test results was completed in FY15, providing additional validation for the use of DYSMAS in vulnerability assessments for the modeling of underwater

explosion loading and ship responses in littoral or harbor environments, where bottomed or tethered mines are likely to be encountered. DYSMAS predictions are improved with the use of sea-bottom data for the location of interest.

- JLF continued to investigate sea-based weapons effects phenomena to improve the fidelity of modeling and simulation used to assess both platform survivability and weapon effects.
  - In FY16, work continued to improve the understanding of combined shock and submergence effects from underwater explosions on unique submarine structural configurations when at deep depths. Scaled test models were fabricated in preparation for FY17 testing. The data from these tests will be correlated with modeling and simulation results to determine which models are best for assessing underwater explosion shock loads in combination with submergence pressure loadings on submarines.
  - In FY16, JLF developed a plan to conduct a collaborative research and test effort with the Canadian Navy to improve the ability to model the effects of near-field underwater explosions and the resulting bubble and bubble jetting loading on structural damage. The data gathered will validate modeling and simulation tools used to evaluate the survivability of Navy platforms against torpedo and mine threats and to improve weapon lethality estimates.

LFT&E SPECIAL INTEREST PROGRAMS

Warrior Injury Assessment Manikin

- The Warrior Injury Assessment Manikin (WIAMan) Engineering Office (WEO) is currently leading the WIAMan project (Figure 6) 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 signed a memorandum of agreement defining the leadership, responsibilities, and funding relationships between these two organizations.
  - The WIAMan project will enter the acquisition cycle as a post-Milestone A program of record via a Materiel Development Decision in FY17. 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, anthropomorphic test device (ATD) development, and Live Fire Test and Evaluation (LFT&E).
  - The Army developed and validated a Test Capability Requirements Document (TCRD) for the WIAMan project. The Army Test and Evaluation Command, RDECOM, and DOT&E all signed the TCRD. The TCRD identifies the key performance parameters, key system attributes, and requirements for the WIAMan ATD system. In addition to the development of a validated TCRD, the WIAMan project held an Industry Day in June 2016 in order to gauge the level of interest and available competition in the ATD industrial base.
  - The WEO continued to demonstrate that the current ATD used in LFT&E, the Hybrid III, lacks biofidelity in the underbody blast (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 FY16, the project delivered the remaining 13 component-level BRCs. These BRCs are focused on the human response in the head/neck, lumbar spine, pelvis, and lower leg/foot and ankle body regions.
  - The project delivered 6 of 12 whole-body BRCs. These BRCs focused on human response to different combinations of parameters that vary in LFT&E, such as loading rate inputs, occupant posture, and Personal Protective Equipment. The remaining whole-body BRCs will be developed in FY17.
  - The project generated initial data on the tolerance of bones to severe loading conditions and developed a notional human injury probability curve (HIPC) for foot and ankle fractures. The WEO also conducted a prioritization exercise that benefitted from updated analyses of injuries experienced by soldiers in combat; this exercise resulted in an executable biomechanics test plan that will result in no less than 36 unique HIPCs, spanning the head, neck, lumbar spine, pelvis, leg, and foot/ankle body regions.
- In FY16, the WEO initiated a 3-year, $3 Million 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 results of this pilot study will be used to inform a decision about the need to develop unique injury assessment capability for female Soldiers. A total of 5 whole body female biomechanics tests were executed in FY16, with an additional 13-17 planned for FY17.
- The WEO continued to implement emerging biomechanics data into the development of a WIAMan ATD through new task order awards to Diversified Technical Systems (DTS). In FY16 DTS delivered a Technology Demonstrator ATD that demonstrated improved biofidelity and usability in the UBB test environment when compared to the Hybrid III ATD. Test results to date indicate that the WIAMan Project is on track to achieve a Technology Readiness Level 6 prior to program transition at Milestone B. DTS also delivered the first data acquisition system (DAS) units for benchtop testing in September 2016, and will deliver four fully integrated first generation WIAMan ATD prototypes for verification and validation testing in June 2017.

- The WEO continued its refinement of an optimized ATD finite element model. This model supported analyses to accelerate the redesign of the ATD to achieve strength-of-design, biofidelity, and usability goals. A full three-dimensional description of the ATD has been created and validated in accordance with the current Technology Demonstrator design and performance.
- 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 Assistant Secretary of Defense for Health Affairs has committed to fully funding the medical research required to meet the WEO's scientific goals. However, the planning and execution of the formal acquisition program envisioned by the Army is behind schedule, while incurring significant overhead costs. Despite the Army's and the Department's large investment in this project, the Army's concerns about the cost of procuring and incorporating this much-needed technological advancement into UBB LFT&E have resulted in no acquisition funding programmed for the project after FY18.

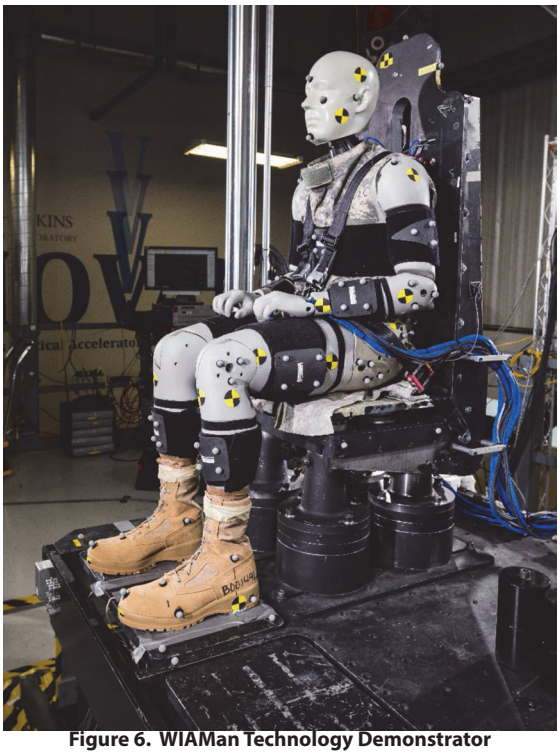

Figure 6. WIAMan Technology Demonstrator

Homemade Explosives

DOT&E continued to participate in the Army-led, multi-Service effort known as the Homemade Explosives Characterization (HME-C) working group. The HME-C effort originated to address concerns regarding the Department's ability to test operationally significant scenarios involving underbody blast threats, and to ensure adequate LFT&E of military vehicles now and in the future. In FY16:

- The HME-C working group completed the planned scope of test and evaluated the data resulting from all of the program's test phases.
- DOT&E used the information and data to develop LFT&E policy for employing buried underbody blast surrogates. This included a new soil standard for use with underbody blast testing.
- The Army Test and Evaluation Command developed operating procedures to implement this policy.

Small Boat Shooters' Working Group

Small boats represent a growing threat class to ships operating in littoral waters and are targeted by a wide variety of weapons systems.

- In FY16, DOT&E sponsored the fifth annual Small Boat Shooters' Working Group, which examined the general nature of the small boat threat in littoral waters; summarized the threat classes and available targets and models available for ammunition, rocket, and tactical missile weapon systems; and attempted to synchronize various LFT&E and other operational test approaches among the various programs/Services by sharing the breadth of test and evaluation options available to evaluators.
- The working group assessed the nature of the small boat threat; the availability of targets and lethality models representing those threats; the data collection, test techniques, and instrumentation that have been applied to small boats; and the performance of shipboard and aircraft weapons against small boat threats. The group also reviewed results from DDG-1000 gun tests, a test concept for HELLFIRE longbow missiles vertically fired from a ship against High-Speed Mobile Surface Targets (as part of the Littoral Combat Ship (LCS) program), and results from tests of special 30 mm gun ammunition under development specifically to counter the small boat threat.

Helicopter Seating Systems

The House Report accompanying the National Defense Authorization Act for FY16 required a briefing describing any plans for improvements to current helicopter seating systems. DOT&E briefed Congressional staff that, while improved helicopter seating would improve force protection, it is just one aspect of the overall helicopter force protection/survivability improvement effort. Addressing leading causes of fatalities in mishaps and combat-induced crashes with near-term technology solutions such as controlled flight into terrain collision and threat avoidance would provide a higher payoff.

- The leading causes of mishaps and combat-induced casualties cannot be mitigated via improved helicopter seating systems.
  - The leading cause of mishaps is controlled flight into terrain due to loss of situational awareness. These events are typically not survivable but could be mitigated through implementation of crash avoidance technologies. Crash avoidance technology has been demonstrated on the UH-1N at technology readiness level 9 (use in operational conditions). If crash avoidance requirements are set, solutions could be fielded on existing systems.
  - The leading causes of helicopter combat-induced casualties are aircraft vulnerabilities leading to catastrophic crashes that are not survivable. These crashes could be mitigated through improved situational awareness, adaptive flight

control, and countermeasure technologies. Additional RDT&E investments in these areas are warranted.

- In many survivable crashes, helicopter seating systems provide adequate protection for the pilot/crew but not for troops and passengers. The troop seating system standard has been waived to enable mission performance. Therefore, existing troop seating systems do not meet the military standards, resulting in preventable casualties.
- Current helicopter seating system ergonomics may be detrimental to mission effectiveness and result in long term disability, but the extent and exact causes have not been determined. Additional analysis is warranted to determine the root cause of casualties, especially to troops and passengers, and the root cause of long-term disabilities.
- DOT&E recommended identifying and addressing the root causes of crew casualties in mishaps and combat-induced crashes and funding the systems that have the greatest return on investment for avoiding or reducing fatalities and injuries.