Live Fire Test and Evaluation (LFT&E)

DOT&E executed oversight of survivability and lethality test and evaluation for 121 acquisition programs in FY14. Of those 121 programs, 21 operated under the waiver provision of U.S. Code, Title 10, Section 2366, by executing an approved alternative Live Fire Test and Evaluation (LFT&E) strategy in lieu of full-up system-level testing. DOT&E submitted eight reports on LFT&E results prior to programs entering into full-rate production.

DOT&E published reports on the following programs during the past year (reports marked with an asterisk were sent to Congress):

LFT&E Reports
- HELLFIRE Romeo Final Lethality Assessment
- HELLFIRE R-9E Initial Lethality Assessment
- Modernized Expanded Capacity Vehicle-Survivability (MECV-S) Survivability Assessment Report*

DOT&E Reports (with combined OT&E/LFT&E results)
- Joint High Speed Vessel (JHSV) Initial Operational Test and Evaluation (IOT&E) and LFT&E Report*
- M982E1 Excalibur Increment 1b IOT&E and LFT&E Report*
- P-8 Poseidon Multi-Mission Maritime Aircraft (MMA) IOT&E Report*
- Littoral Combat Ship (LCS) Early Fielding Report*

Special Reports
- DOT&E Response to Chief of Naval Operations Report to Congress on the Current Concept of Operations and Expected Survivability Attributes of the Littoral Combat Ship*

In addition to satisfying acquisition oversight requirements, the LFT&E program:
- Funds and executes technical oversight on investment programs that provide joint munitions effectiveness data (Joint Technical Coordinating Group for Munitions Effectiveness)
- Funds projects to develop advanced technologies and analytical methods to increase aircraft survivability (Joint Aircraft Survivability Program)
- Conducts vulnerability and lethality testing of fielded platforms and weapons systems and improves survivability analysis tools (Joint Live Fire Program)
- Supports quick reaction efforts addressing urgent operational commander's needs.

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

Joint Logistics Commanders chartered the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) more than 40 years ago to serve as the DOD's focal point for munitions effectiveness information. This has taken the form of widely used Joint Munitions Effectiveness Manuals (JMEMs), which address all major, non-nuclear U.S. weapons. JTCG/ME authenticates weapons effectiveness data for use in operational weaponeering, strike mission planning, training, systems acquisition, weapon procurement, and combat modeling and simulation. The Armed Forces of the U.S., NATO, and other allies use JMEMs to plan operational missions, support training and tactics development, and support force-level analyses. JTCG/ME also develops and standardizes methods for evaluation of munitions effectiveness and maintains databases for target vulnerability, munitions lethality, and weapon system accuracy. The JMEM requirements and development processes continue to be driven by operational lessons learned and the needs of Combatant Commands, Services, Military Targeting Committees, and Operational Users Working Groups for specific weapon-target pairings and methodologies.

The primary JMEM application is weaponeering, which is the detailed technical planning of a combat strike. Strike planning occurs at multiple levels in the operational chain of command before actual combat. JTCG/ME produces, distributes, and regularly updates JMEMs, which provide computerized effectiveness tools and data for rapid evaluation of alternative weapons and their delivery against specific targets. In many cases, effectiveness and collateral damage estimates generated by these tools are part of the decision criteria for strikes approved at the highest levels of the U.S. Government.

JOINT MUNITIONS EFFECTIVENESS MANUAL (JMEM) TARGETING AND WEAPONEERING SOFTWARE

U.S. Africa Command (USAFRICOM) and U.S. Central Command (USCENTCOM) used JTCG/ME Joint Munitions Effectiveness Manual Weaponeering System (JWS) v2.1 software and Collateral Effects Radii tables for operational weaponeering and collateral damage estimation in direct support of operations in the USAFRICOM and USCENTCOM Areas of Responsibilities. The JTCG/ME developed various analytical and operational methodologies and target models to provide continued support to operational commanders, weaponeers, and planners. Additionally, JTCG/ME released the air-to-air and surface-to-air planning model, the Joint Anti-air Combat Effectiveness System (J-ACE) v5.2.1, in April 2014 to provide aircraft survivability data.

The fielded JWS v2.1 software incorporates integral building analysis and hardened target modules to create a merged tool that generates weapon effectiveness and damage assessments against infrastructure targets to include buildings, bunkers, and tunnels. JWS v2.1 contains new/updated targets and munitions, new explosive equivalent weights based on blast testing, as well as an improved 3-D viewer. JWS v2.2 development is ongoing to support coalition partners for fielding in FY15.

J-ACE v5.2.1 simulates air-to-air and surface-to-air engagements and includes Blue, Red, and Gray air-to-air missile and Red and Gray surface-to-air missile fly-out models. J-ACE v5.2.1 provides an updated Joint Anti-Air Model (JAAM), a missile fly-out model including hundreds of weapon target pairings and JAAM-Enhanced surface-to-air missile countermeasures simulation. J-ACE v5.2.1 also provides new Endgame Manager (EM) software and data sets, which add missile lethality and target vulnerability. EM allows explicit evaluation of weapon miss distance, fuze performance, weapon lethality, and target vulnerability. EM provides a Probability of Kill given an intercept. In addition, J-ACE v5.3 is being developed to provide extended and updated data sets for missile and aircraft target aero-performance, anti-air missile lethality, and air target vulnerability.

OPERATIONAL SUPPORT TO MISSION PLANNING

The JTCG/ME provided updates for Collateral Effects Radii values for newly-fielded/updated weapons (e.g., Small Diameter Bomb (SDB) II, Griffin, HELLFIRE, GBU-49, BLU-133, etc.), in support of the Combatant Commands. In addition, the JTCG/ME released the Digital Precision Strike Suite Collateral Damage Estimation (DCiDE) v1.1.1 tool, which has the capability to calculate collateral damage estimates along a route. This new capability has been used in support of multiple kinetic strikes by the task force in Afghanistan. Additionally, JTCG/ME trained nearly 300 users at 12 different commands to support Collateral Damage Estimation decisions.

JWS v2.1 has ongoing initiatives to include a new imagery interface to implement aimpoint development that leverages the Tasked Target Text Data (T3D) format implemented by currently fielded mission planning systems. JWS software and the T3D imagery interface will be modified to support integration of electronic light table viewers. Also, Modernized Integrated Database and Joint Targeting Toolbox interfaces will be developed with additional capabilities to support connectivity. These developments will enable the integration of weaponeering, precision point mensuration, and collateral damage estimation, decreasing the speed at which strike planning can be conducted.

To more effectively support operational mission planning, particularly at U.S. Strategic Command, the J-ACE v5.2.1 release also provides a direct interface to force-level simulations. The fidelity is adequate for studying tactics, training evaluation, relative missile performance, and scenario planning. Additionally, U.S. Strategic Command integrated JAAM into the Individual Combat Aircrew Display System and the Personal Computer Debriefing System for direct use for tactics, planning, and training at operational test squadrons for fighters and bombers.

INFORMATION OPERATIONS TOOLS AND CAPABILITIES

To address an emerging Cyber Operations JMEM, JTCG/ME re-deployed the following Joint Capability Analysis and Assessment System (JCAAS) tools: Computer Network Attack Risk and Effectiveness Analyzer, Network Risk Assessment Tool, Communications Radar Electronic Attack Planning Effectiveness Reference, Effectiveness of Psychological Influence Calculator, and Joint Broadcast Analysis Tool. JCAAS will provide a shared interface for operational users in selecting the capabilities to best meet given objectives based on effectiveness derived from target vulnerability and capability characteristics. The JCAAS scope includes weapon characterization; coordinating test and target data development; testing and evaluation of cyber data standards; and developing a new database schema for electronic warfare mission planning.

JOINT AIRCRAFT SURVIVABILITY PROGRAM (JASP)

The Joint Aircraft Survivability Program (JASP) office funds development of techniques and technology to improve the survivability of U.S. military aircraft. Working with Joint Staff, Service organizations, other government agencies, and industry, JASP develops new capabilities and works to assure they are pursued jointly by the Services.

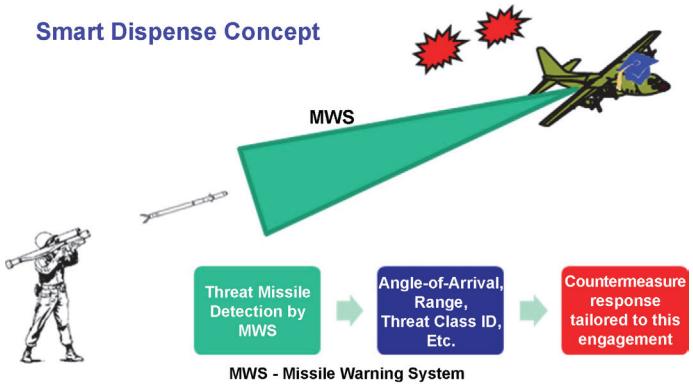
DOT&E sponsors and funds JASP. The Naval Air Systems Command, the Army Aviation and Missile Command, and the Air Force Life Cycle Management Center charter the program. DOT&E establishes objectives and priorities for the JASP and exercises oversight of the program.

JASP is supporting the Joint Multi-Role (JMR) Technology Capabilities Demonstration (TCD) program as a member of the Platform Integrated Product Team. The JMR TCD is expected to demonstrate transformational vertical lift capabilities to prepare the DOD for developing the next-generation, vertical lift fleet. JASP was a driving force in establishing the assumptions and requirements for the vulnerability analysis used in evaluating the initial three government model prototypes.

JASP funded 66 multi-year survivability projects and delivered 48 final reports in FY14. The following summaries highlight selected JASP efforts in four focus areas: susceptibility reduction, vulnerability reduction, survivability assessment, and combat damage assessment.

SUSCEPTIBILITY REDUCTION

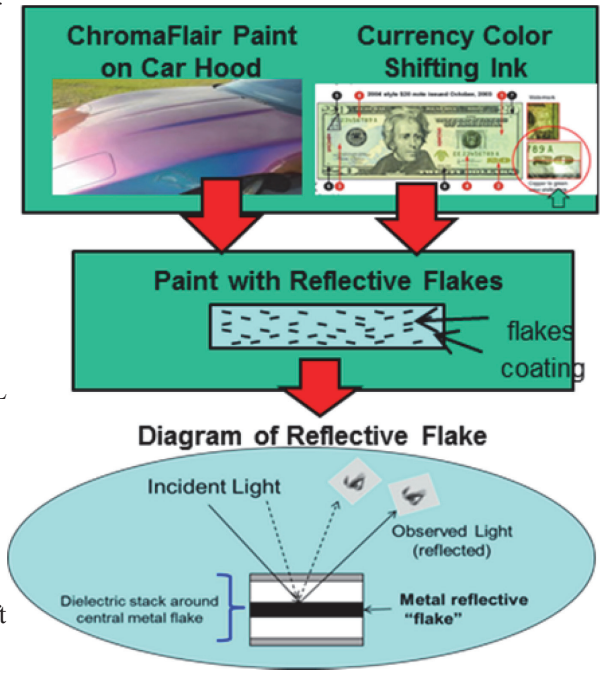
Multiple Objective Differential Evolution Smart-dispense Techniques (MODEST). The Naval Research Laboratory (NRL) in conjunction with the Naval Surface Warfare Center - Crane Division (NSWC-Crane) and the Air Force Research Laboratory are developing techniques to improve dispensing infrared countermeasures (IRCM).



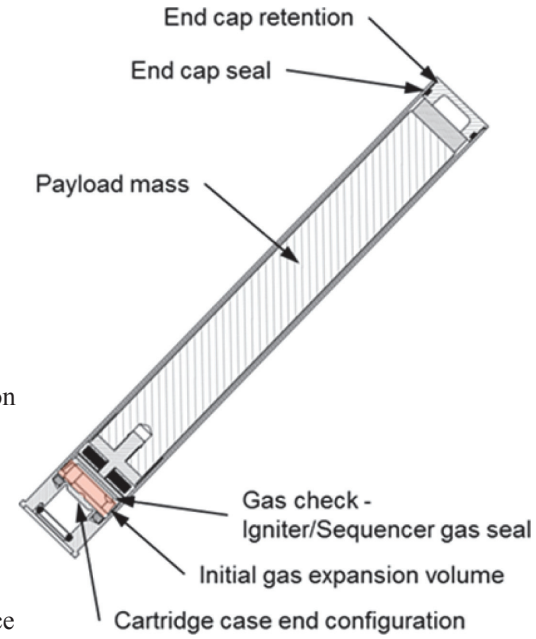
They have leveraged recent advances in multiple objective differential evolution to develop a methodology/tool to obtain near-optimal, smart-dispense techniques for infrared decoys. They also formulated an optimal, non-linear effectiveness measure for jam codes based on measurements from actual test scenarios. The improved dispense algorithms will reduce flare usage and improve other countermeasure synergistic effects. The initial plan is for the Navy to implement new dispense techniques on Navy/Marine Corps aircraft. Other services plan to assess techniques and implement as needed.

High Resolution Infrared Clutter Measurement and Analysis. The Army Communications-Electronics Research, Development and Engineering Center/Intelligence and Information Warfare Directorate is studying techniques for developing a cross-Service definition of clutter and creating a database of high-resolution narrow field of view (FOV) clutter for all Services. The study will improve the government's ability to adequately define and test the effectiveness of missile warning systems to pointer/tracker handoff. The project intends to establish clutter-level definitions and a narrow FOV/high-resolution clutter database to support development of tri-Service directed IRCM systems. The Army Program Manager Aircraft Survivability Equipment is providing data and funding to develop a test tool and clutter scene injection capability. The project is also leveraging additional data collected from the Advanced Threat Infrared Countermeasures (ATIRCM) program. The project will result in more reliable and effective directed IRCM systems by allowing the government to ensure pointer trackers perform per specification. The Army will use the capability to improve fielded algorithms for ATIRCM and/or the Common Infrared Countermeasures systems.

Ultraviolet Reflective Coating. The NRL is leveraging commercial technology for visibly-reflective coatings that contain reflective dielectric multi-layer flakes. This technology will help them design and fabricate a coating using reflective polymer flakes to approach 100 percent ultraviolet reflectivity without compromise in the visible and infrared wavelength performance. NRL will test and evaluate coating performance and durability as applied to representative aircraft surfaces. Initial methods to disperse polymer flakes into coating have been identified. NRL has completed modeling of best-candidate, commercially-available polymers to determine preliminary designs for multi-layer polymer stacks. NRL will contract with a commercial vendor to fabricate multi-layer polymer stacks using co-extrusion techniques based on NRL designs. The improved coating will make aircraft less susceptible to anti-aircraft systems. The NRL and Army Aviation Applied Technology Directorate plan to test coatings in conjunction with other IRCM trials.



Airborne Expendable Countermeasure (CM) Velocity Study. The NSWC-Crane started this project in FY14 to determine the critical characteristics in airborne expendable CM design that effect ejection velocity in order to optimize performance. Demonstrating a more consistent, optimized velocity will improve decoy effectiveness and aircraft survivability. A consistent ejection velocity will give accurate placement of the CM, greatly assisting threat defeat. Additionally, once



a desired ejection velocity is obtained and parameters that affect it are identified, a common impulse cartridge for all Services will be more easily achievable, thereby reducing support costs. In the next phase, NSWC-Crane will conduct a flight test to determine how tailored flares improve effectiveness. Methods to adjust ejection velocity will be used to enhance effectiveness of current expendables.

VULNERABILITY REDUCTION

JASP vulnerability reduction projects address the survivability of the crew and passengers, as well as the aircraft itself. A portion of these projects have focused on improving armor and developing lighter-weight opaque and transparent ballistic protection systems. In FY14, projects were initiated that focus on fuel containment technologies and their related fire protection systems, along with numerous structures and materials projects, including self-healing composites. JASP has begun to explore occupant seat technology, in order to make them more crash-worthy, and helicopter transmission technology, to make them and their lubrication systems more tolerant to ballistic damage.

Improved Advanced Survivable Canopy Transparent Armor. The Army Research Laboratory (ARL)-Weapons and Materials Research Directorate teamed with Naval Air Warfare Center – Weapons Division (NAWC-WD) to work this project, which completed in FY14. Transparent armor is typically made of several layers of materials separated by polymer interlayers. The outer layer is usually a type of glass, such as soda-lime silica or borosilicate, and the inner plies are usually a polymer, such as a polycarbonate or polyurethane with a thicker interlayer. The use of these different materials induces inherent stresses due to the thermal expansion mismatches across the material's depth. Additionally, the principal requirements of unhindered visibility for situational awareness and defeat of a designated threat with a multi-hit capability have to be considered.

Multi-hit Transparent Armor

The goal of this project was to reduce total system weight, while improving performance at temperature extremes found in current combat areas. Variables considered for improvement included surface treatments, ply layup alterations, and edge framing. This was a successful proof of concept effort achieving systems in the five pounds per square foot range over a greater temperature range, compared to current advanced prototype systems weighing more than seven pounds per square foot.

Unmanned Aerial Vehicle (UAV) Self-Sealing Polymer. As unmanned aerial vehicles (UAVs) become more prevalent and greater contributors in the battlespace, their survivability becomes more crucial. NAWC-WD investigated ways to improve the survivability of the MQ-8B Fire Scout using lightweight polymer coatings for fuel leak mitigation. UAVs do not typically employ any type of fire detection and suppression systems, nor system hardening to protect against projectiles or other threats. Applying a coating that self-seals (closes over a fragment or projectile penetration) and prevents fuel leakage onto a hot surface and subsequent possible ignition is a valuable contributor to vulnerability reduction. The project focused on applying a coating to a thin aluminum fuel cell tray that sits above the engine bay and holds the aft fuel cell. Test scenarios observed different impact angles, coating thickness, and configuration (entry or exit side of fuel tray). Test results showed that coating the bottom of the fuel tray (entry configuration) with a nominal coating of a polyurea is effective in preventing hot surface fuel ignition at a very minimal weight (under six pounds) and material cost ($150). The Fire Scout Program Office is currently evaluating the retrofit of aircraft during depot-level maintenance.

Adaptive Seat Energy Absorber for Enhanced Crash Safety. The ARL-Vehicle Technology Directorate is investigating seat energy dispersion technologies for aircraft cockpits to enhance crash safety. The focus of the project is to evaluate and demonstrate two novel energy absorber (EA) technologies: Rotary Magnetorheological EA with Magnetic Bias (MREA) and Magnetostrictive Friction EA (MFEA). In the MREA system, a fluid that changes physical properties in the presence of a magnetic field is used, allowing changes in the applied current to alter the viscosity of the fluid for optimum performance. In the MFEA system, magnetostrictive materials change dimensions when magnetized and can be used to adjust the normal force between two surfaces to modulate frictional energy absorption. In each case, the system is tuned to the actual occupant weight and crash scenario to optimize occupant survival. The project team has made substantial progress with the MREA system—fabrication of a seat-level test asset is near completion. The MFEA component device is being redesigned. Due to the limited stroking capability of magnetostrictive technology, force amplification is needed to meet the design load requirements for the crash application.

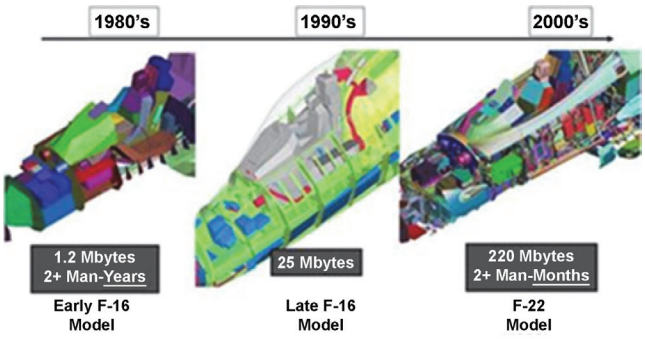
SURVIVABILITY ASSESSMENT

JASP continues to develop and maintain survivability assessment tools that are widely used by acquisition programs for analyses of alternatives, design studies, and specification development and compliance. JASP also supports the test community to assess survivability in pilot training exercises and countermeasure effectiveness.

Improved Fire Modeling. Based on testing and analysis, fire has been identified as the largest contributor to aircraft

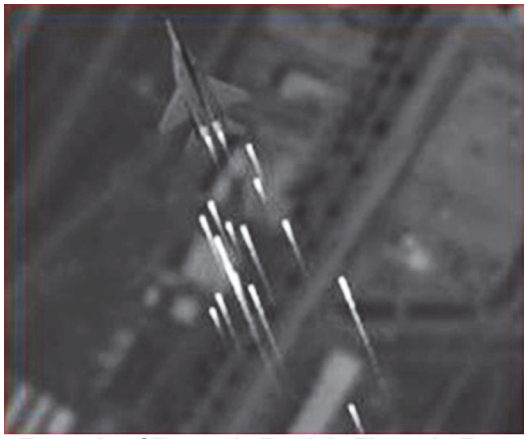
vulnerability. For many years, JASP has supported development of the Fire Prediction Model (FPM) to provide a tool for analysts and testers to understand and mitigate this vulnerability. JASP currently has three projects addressing fire modeling deficiencies. The Air Force 96th Test Group (96TG) is developing a hydrodynamic ram engineering model that will provide accurate fuel spurt characteristics to determine the likelihood of fire ignition. The ARL/Survivability Lethality Analysis Directorate (ARL/SLAD), with participation from the 96TG and NAWC-WD, is conducting a review of all of the documents and test data referenced in the FPM Analyst and User Manuals to identify discrepancies between the documents and the FPM code. In the third project, Next Generation Fire Modeling Plan, the 96TG, in partnership with NAWC-WD and the Air Force Life Cycle Maintenance Center, is generating a long-term plan to guide the development of a credible and validated dry bay fire assessment capability for armor-piercing incendiary and fragment threats. These projects all affect the development of the next generation FPM that will be used for live fire test planning and survivability assessments of future combat vehicles, providing a better understanding of the vulnerability of these systems to combat initiated fires.

Improved Target Geometries. Target descriptions (geometries) for aircraft vulnerability analyses have grown so detailed, with attendant enormous computer run times, that they restrict the ability for development programs to conduct analyses in time to affect design decisions. Interrogation, via ray tracing methods, of target geometric models is a cornerstone of vulnerability assessments. JASP has funded two projects to improve ray tracing and target geometry optimization. Ray Tracing Speed Enhancements is investigating several ways to speed up the ray tracing process. The Air Force Life Cycle Maintenance Center is leading this project with participation from ARL/SLAD. Benchmark testing accomplished to date has demonstrated a 30 percent decrease in run times. The enhanced ray tracing algorithms will be integrated into the Computation of Vulnerable Area Tool (COVART) for use on future vulnerability assessments. The Target Geometry Optimization Utility project is investigating ways to optimize the target geometry. The goal is to reduce files sizes by 33 percent while changing presented area estimates by less than 1 percent. NAWC-WD is leading this project with participation from ARL/SLAD. The results of this project will be distributed with COVART as part of the Defense Systems Information Analysis Center Vulnerability Toolkit for use on future vulnerability assessments.



Example of Target Geometry Growth

Imaging Infrared (IIR) Threats. JASP has three related projects to address countermeasures for the challenging Imaging Infrared (IIR) threat. In the Physics-Based IRCM Modules project, NSWC-Crane investigated the specific data and level of detail required to model flares in an IIR environment. This project developed formats for physics-based models for both pyrotechnic and pyrophoric IRCMs that are integrated in the Fast Line-of-Sight Imagery for Targets and Exhaust Signatures (FLITES) software. FLITES is an industry standard scene generation software package. This new format is referred to as the Dynamic Particle Flare representation. In the Flare Aerodynamic Modeling Environment and Tri-Service Flare Database Modernization project, NSWC-Crane is updating the Flare Aerodynamic Modeling Environment model to add 3-D aircraft flow fields and modernize the Tri-Service Flare Database so it can accommodate flare models in the Dynamic Particle Flare format. In the Imaging Flare Models for Missile Simulations project, the NRL, with NSWC-Crane participation, will produce 12 validated flare models in the Dynamic Particle Flare format that are compatible with the FLITES scene generation software. This project will also develop the Flare Imagery Analysis Tool to generate radiometrically- and spatially-correct imagery of flares used in FLITES. These projects will provide tools, available through the Defense Systems Information Analysis Center, to evaluate the effectiveness of advanced flares against IIR threats.



Example of Dynamic Particle Flares in Fast Line-of-Sight Imagery for Targets and Exhaust Signatures (FLITES)

COMBAT DAMAGE ASSESSMENT

JASP continued to support the Joint Combat Assessment Team (JCAT) in FY14. JCAT is a team of Air Force, Army, and Navy personnel deployed in support of combat operations. JCAT continued its operation in Afghanistan with full-time deployments in Regional Commands – South, Southwest, and East. Iraq and other areas of the world were supported remotely or by rapid deployment from Afghanistan or the Continental U.S.

JCAT inspects damaged and destroyed aircraft, acquires maintenance records, and conducts interviews with aircrew and intelligence personnel to develop an accurate and comprehensive assessment of each aircraft combat damage event. They provide

consultation to weapons, tactics, and logistics personnel and comprehensive briefings to commanders in charge of daily air operations. These efforts inform battlefield commanders, allowing them to adjust operational tactics, techniques, and procedures based on accurate threat assessments. As of August 31, 2014, the JCAT had initiated 131 and completed 69 aircraft combat damage assessments in FY14.

The JCAT strengthened aircraft combat damage incident reporting in the Services and the DOD. The Combat Damage Incident Reporting System is the repository for all U.S. aircraft combat damage reports. JCAT worked with OSD and USCENTCOM to continue collecting combat incident reports from USCENTCOM's databases to more quickly identify, assess, document, and distribute aircraft combat damage incident data to the Services and DOD. JASP and the Office of the Deputy Assistant Secretary of Defense for Systems Engineering submitted a revision to DOD Instruction 5000.02, released in November 2013, which included combat data reporting requirements for major weapon systems. Language providing additional guidance for the aircraft combat damage reporting process is included in the draft revision of the Defense Acquisition Guide.

The JCAT trains 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 tactics, techniques, and procedures; and the combat damage collection and reporting mentioned above. The attendees include aircrews, maintenance personnel, intelligence sections, Service leadership, industry, and coalition partners.

JOINT LIVE FIRE (JLF)

The purpose of the Joint Live Fire (JLF) program is to test fielded systems, identify vulnerable areas, and understand damage mechanisms to provide the information needed for design changes, modifying tactics, techniques, and procedures, or improving analytical tools. The need for these tests results from systems being exposed to new threats; being used in new, unanticipated ways; or being operated in new combat environments, thereby requiring an updated assessment of their performance.

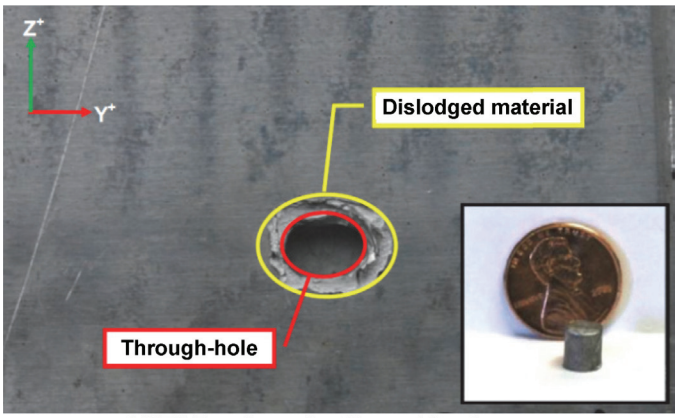
JLF supplements LFT&E of systems by testing systems against new threats the requirements community did not anticipate during original development or against old threats employed in new ways. The rocket-propelled grenade (RPG) is an example of a threat employed differently than initially intended. Originally developed as an anti-tank or anti-personnel weapon, hostile forces in combat often use the RPG as an anti-aircraft weapon.

AIRCRAFT SYSTEMS PROGRAM

JLF-Air completed six test series in FY14. Seven of this year's projects will continue into FY15. Below are selected examples of this year's projects.

Advanced Hit Efficiency and Destruction (AHEAD) Sub-projectile Characterization Testing. This project determined the penetration characteristics for a modern threat, anti-aircraft artillery projectile—the air burst Advanced Hit Efficiency and Destruction (AHEAD) projectile. The penetration characteristics of its tungsten sub projectiles were measured for three thicknesses and three obliquities of aluminum panels representative of aircraft structures and flight critical components. Data will help the development of a penetration model to effectively model air burst munitions sub-projectiles, providing an analysis capability presently unavailable in commonly used aircraft vulnerability codes, such as COVART and the Advanced Joint Effectiveness Model (AJEM).

ARL/SLAD conducted 248 tests in FY14 and calculated the V50 (the velocity at which 50 percent of the projectiles penetrate the target material) ballistic limits, and associated 80 percent confidence intervals for each material thickness-obliquity pairing. Additional data collected included impact orientation, residual mass, and flash characterization.



AHEAD sub-projectile and its damage

Man-portable Air Defense System (MANPADS) Residual Fuel. This project collected blast pressures produced by stationary and moving Man-portable Air Defense System (MANPADS) missiles when a portion of the missile's rocket motor fuel remains at the time of warhead detonation. Results will be coupled with blast pressures measured during previous JLF-Air tests and used to further improve MANPADS threat models used in aircraft vulnerability assessment codes, such as COVART and AJEM, as well as damage prediction and assessment tools such as LS-DYNA and the Combat Assessment Tool.

The NAWC-WD, Weapons Survivability Laboratory, located at China Lake, California, conducted testing. They collected 42 pressure measurements at radial distances of 12, 20, 30, 40, and 72 inches from the MANPADS warhead centroid for 2 stationary detonation events and a single detonation event with a surrogate MANPADS missile traveling at 1,600 feet per second.

Crew Compartment Fire Survivability. This project collected data to determine the effects of fuel fires on temperatures, oxygen depletion, carbon monoxide, and other toxic gases. The aircraft survivability community can use these data to support assessments of physiological hazards within military aircraft crew compartments as a function of time and distance from the fire source under realistic ventilation conditions. Collected data will establish baseline assumptions for future crew casualty models and analysis efforts.

Crew Compartment Fire Testing

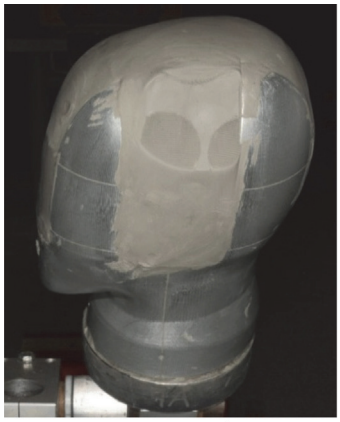
ARL/SLAD, located at Aberdeen, Maryland, conducted testing. They completed 48 tests using Design of Experiments (DOE) techniques along with several excursion tests in FY14. The DOE test matrix was based on factors of fluid pressure, piping diameter, ventilation configuration, mean airflow, and fire location. Excursion tests used baseline (Halon 1301, CO2) hand-held fire extinguishers and potential replacement fire extinguishers with selected repeats using hydraulic fluid instead of aircraft fuel.

GROUND SYSTEMS PROGRAMS

Sustained Fire-Start from Near-Field Detonations of Blast/Frag Weapons. The JLF-Ground program funded the Air Force Research Laboratory and ARL to conduct a study of sustained fire start research as it relates to weapons effects against ground vehicle targets. Initiation of sustained fires is one of several lethal mechanisms, which can impart significant levels of damage to a materiel target. Experiments are being conducted on fuel tanks at varying ranges from a threat, using optical pyrometry to characterize the fireball. Physical understanding and empirical data will be transitioned to fire start prediction models improving developer and evaluator predictions of effectiveness, especially catastrophic kill of ground targets.

Adobe Wall Combatant Commander Validation Test. The Army conducted a series of tests to evaluate the protection provided by an adobe wall from fragments from MK82 and HELLFIRE Romeo warheads. These tests will provide benchmark data for warhead fragments from two weapons that undergo extensive operational use against high-interest targets in theater. The results of this testing will provide understanding of the methodology not previously available, along with updated lethality data of warheads that will improve effectiveness and collateral damage analyses for Combatant Commanders.

Assessment of Peepsite Generation 2 (PG2) Headform for Ballistic Testing of Helmets. This project assessed the capability of the PG2 headform to measure back face deformation (BFD) for helmet testing compared to the National Institute of Justice (NIJ) headform. The current, single-sized NIJ headform has limitations due to its current design, which utilizes two clay channels and four aluminum pillars that interfere with BFD. Phase I of testing encompassed 48 subtests (each subtest had 3 shots per helmet) comparing BFD repeatability. Phase II assessed test-induced variation and explored additional capabilities of the PG2 headform. Phase II was completed with 48 subtests (each subtest had one shot per helmet).



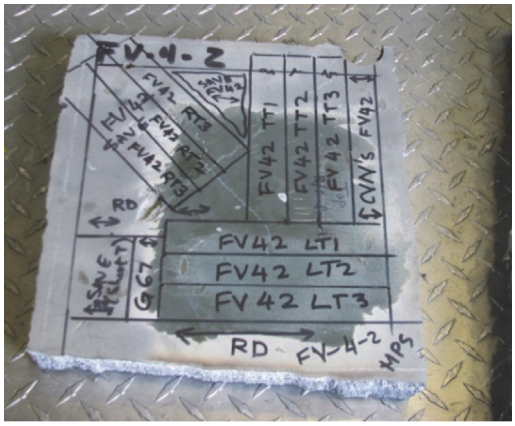
National Institute of Justice (NIJ) Back Face Deformation (BFD) Headform

Peepsite Generation 2 (PG2) Back Face Deformation (BFD) Headform

Enhanced Modeling of Behind-Armor Debris from Kinetic Energy Penetrators. ARL conducted tests of medium-caliber kinetic energy penetrators to support the modeling of the behind-armor debris (BAD) from the penetrators. Physical characteristics (mass, velocity, spatial distribution, shape factor) of the residual penetrating fragments were collected with flash x-ray, plywood/Celotex bundles, and witness panels. ARL will use these data to enhance the current BAD algorithm in the Army's primary vulnerability/lethality model by producing a more accurate physical representation of medium-caliber residual fragments.

Testing and Evaluation of Current U.S. Army Body Armor against Emerging Threats. This project quantifies and compares the penetrative capability of selected emerging or persistent non-standard threats against particular U.S. Army body armor protection levels. Data collected of resistance to penetration and ballistic protection limits will determine a logistic regression prediction of the V05, the V50, and the V95 (velocities at which 5 percent, 50 percent, and 95 percent of projectiles penetrate the armor, respectively) ballistic limits. Data from the ballistic protection limit (V50) will include BAD characterization against a ballistic gelatin backing. The selected threats for ballistic testing are undergoing cross-sectional profile characterization, including optical microscopy, digital photography, evaluation of material composition (elemental and alloy analysis), cross-section dimensional characterization, and hardness testing. ARL/SLAD and the Aberdeen Test Center are currently performing the resistance to penetration and ballistic limit testing for this project.

Environmental Aging Effects on the Protection Levels of Armor. The USMC Combat Development Command (MCCDC) conducted a series of ballistic and material tests on aluminum specimens removed from original manufactured Amphibious Assault Vehicle hulls to understand potential effects of age that can affect a variety of material properties. With an anticipated platform upgrade utilizing existing hulls, knowledge of present protection levels is imperative. Plates were removed from several locations that had been exposed to varying heat levels over their lifetime. MCCDC executed V50 tests for several penetrators at various obliquities to determine if the plates still met the original minimum requirements for armor protection. MCCDC also performed material tests (tensile, hardness, metallographic, inter-granular corrosion susceptibility, and Charpy impact) to assess current material properties and extent of change due to aging that occurred. Testing showed that while the materials incurred significant aging, the plates still meet the original minimum protection requirements of the armor.



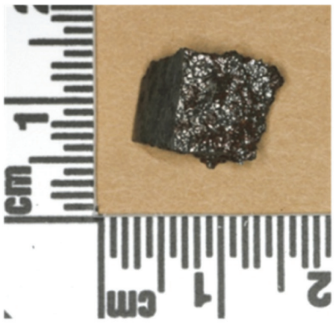
Test Specimen Cut from Amphibious Assault Vehicle (AAV) Hull

Collaborative Validation of Mandible Blunt Impact Methodology. To better evaluate the efficacy of mandible protection systems, this project obtained operationally-realistic blunt impact loadings that vehicle occupants may experience. Data collected from instrumented headforms included, but were not limited to: mandible and nasal force, head acceleration, and neck-bending moments. ARL used these values to determine whether existing simplified test apparatuses, such as a drop tower or pendulum, could be used to evaluate blunt impact loadings.

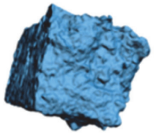

Helmet with Mandible Protection under Test

Characterizing the Penetration of an Explosively-Formed Penetrator Mine. The Army conducted testing to determine the lethality of an explosively-formed penetrator mine and its lethality against underbody armor. The data obtained from these tests provide the ability to better assess the vulnerabilities of armored combat vehicles to the penetration of this mine. Penetration tests documented the penetrator formation, flight characteristics, and penetration performance into semi-infinite and spaced rolled homogenous steel targets. Additionally, BAD tests determined the amount of fragmentation resulting from both the residual threat and the spall production.

Irregular Fragment Penetration Characterization and Model Validation. The objective of this project is to identify and validate the most appropriate Fast Air Target Encounter Penetration model representation of irregular fragments. To accomplish this, ARL collected and laser scanned approximately 125 irregular fragments from an OF540 152 mm artillery shell to develop multiple shape characterizations.



Irregular Fragment


Scanned Fragment

ARL will fire the 125 fragments against steel plates at a sufficient distance to allow random tumbling to occur. Fragment orientation, striking and residual mass, and velocity will be collected. Pre-shot penetration characterizations of the multiple shape models will then be compared to the test data and a determination made on the most appropriate shape factor model. This project will improve future LFT&E through improved pre-test prediction capabilities and/or reduced number of tests required due to increased confidence in modeling.

SEA SYSTEMS PROGRAM

The JLF Sea Systems Program made significant progress in FY14 towards improving the capability to assess the survivability of submarines and surface ships. These projects benefit ship and submarine acquisition programs, as well as the fleet of fielded U.S. Navy vessels.

Large Volume Shipboard Space Fire Protection. Large volume spaces such as aircraft hangars on aircraft carriers and vehicle stowage areas on amphibious ships are frequently used to stow large quantities of ordinary combustible (Class A) material. These spaces are usually protected with overhead Aqueous Film Forming Foam (AFFF) sprinkling systems, which testing has shown have limited effectiveness against shielded, large Class A, vehicle, and weapon-induced fires. As part of this project, a fire hazard analysis determined that supplementing legacy AFFF sprinkling systems with bulkhead-mounted AFFF monitors or water/foam cannons could potentially improve the system's capability against these fires. During FY14, NRL designed and installed a water/foam cannon system and monitor control system in the hangar bay test area of the ex-USS *Shadwell* Full-Scale Fire Research and Test Ship. The system was commissioned and preliminary fire testing completed in October 2014. In FY15, NRL will conduct full-scale testing against large and obstructed Class A and pool and running-liquid fuel fires to demonstrate the capability of the system against these difficult fires. Testing will include low visibility conditions.

Deep-Depth Underwater Explosion Testing of Asymmetric Cylinders. Future submarine pressure hull design will likely include structural features that will influence the primary mode of collapse when subjected to a deep-depth underwater explosion. This project will provide a new and experimentally-based understanding of asymmetric pressure hull failure modes and an assessment of the effects of unique geometries on lethal depth. This new understanding will improve future submarine vulnerability assessments. Additionally, the data set provided by this program will be used to validate computational models, leading to increased confidence in lethal depth predictions for asymmetric pressure hulls. During FY14, the NSWC – Carderock Division designed test cylinders and identified shot geometries. They will fabricate the test cylinders in FY15 and test them during FY16.

LFT&E SPECIAL INTEREST PROGRAMS

PERSONNEL PROTECTION EQUIPMENT

DOT&E continues to exercise oversight over personal protective equipment. The U.S. Special Operations Command (USSOCOM) and Services continue to implement rigorous, statistically-principled testing protocols approved by DOT&E for hard body armor inserts and military combat helmets. In partnership with USSOCOM and the Services, DOT&E has begun developing a protocol for soft armor vest testing that will standardize testing of soft armor vests and require them to meet rigorous statistical measures of performance. This represents the final commodity area (in addition to hard armor plates and combat helmets) for which DOT&E intends to develop a statistically-based protocol for future testing.

The National Research Council (NRC) completed its independent review of helmet testing protocols. The NRC's final report contained several recommendations that closely align with ongoing efforts to improve helmet performance and testing within the Department. DOT&E has also modified the relevant protocols to reflect recommendations from the NRC and other external reviews. This revised protocol reduces government risk and achieves simplification, both of which the NRC recommended.

As noted by the NRC in their final report on helmet testing, a clear scientific link to the modes of human injury from ballistic impact, blast, and blunt trauma do not exist. This is a serious limitation for the test and evaluation of all personal protective equipment. DOT&E is monitoring a JLF-funded effort to establish injury risk criteria for one type of injury due to behind-helmet blunt trauma; the initial results of this study should be available next year. DOT&E is also monitoring a multi-year Army program to investigate behind-helmet blunt trauma, determine injury mechanisms and risks, and develop an injury criterion that can be used for helmet testing. DOT&E is overseeing and participating in the Army's effort to improve helmet test mount headforms by developing multiple-sized headforms to replace the single-sized headform currently used to test all helmet sizes. This year, the Army completed initial testing of a multiple-sized headform and is determining how to implement it in future testing. DOT&E will work with USSOCOM and the Services to update personal protective equipment test standards and procedures to incorporate the results of these efforts.

WARRIOR INJURY ASSESSMENT MANIKIN (WIAMAN)

DOT&E continued its oversight of the Warrior Injury Assessment Manikin (WIAMan) project, an Army-led research and development effort to design a biofidelic prototype anthropomorphic test device (ATD) specifically for underbody blast testing. In FY14, the project faced challenges as a result of a disruption in the supply of post-mortem human subjects (PMHS) available for medical research. This disruption was the consequence of a combined state and federal investigation into the practices of a PMHS supplier who provided specimens to both DOD and non-DOD research facilities all over the country, and resulted in the temporary suspension of PMHS testing in the project. The WIAMan Project Management Office, along with the ARL Health and Safety Office with guidance from the Army Medical Research and Material Command, implemented an improved protocol for vetting specimen suppliers to minimize the probability of similar disruptions in the future. In FY14, DOT&E contributed financially to this process, which will ultimately establish a DOD-trusted PMHS supply network for future PMHS testing conducted within the Department.

The restructuring of the WIAMan medical research program DOT&E reported in FY13 resulted in significant progress on this front in FY14. In addition to developing initial biofidelity response corridors to guide the design of the ATD, the project completed concepts for the ATD and its instrumentation/data system. Another key accomplishment in FY14 was the creation of an injury research plan responsive to LFT&E needs as expressed in the 2010 DOT&E issue paper on this subject; the original medical research approach had not previously been refined in a manner suitable for the development of an LFT&E-specific research plan. This plan also incorporates data derived from the WIAMan project's efforts to examine imagery from combat injuries to better define the specific types of injuries that should be assessed, and ultimately prevented, when using the new ATD in underbody blast LFT&E. An example of the success of the current approach is the emergence of new injury probability curves for the foot and ankle using velocity data derived from the LFT&E environment, in conjunction with examination of x-rays of lower limb injuries that occurred during underbody IED events in combat. The combat data trends revealed that foot and ankle fractures are prevalent injuries in theater. In addition, the radiographic images gave the medical researchers insights into what kinds of fractures are representative of combat injuries when conducting their experiments, using inputs representative of the loading imparted through the vehicle and into the occupant during a live fire test. The timely and ongoing provision of de-identified medical imagery and data to the project are critical to complementing the refined injury research plan to ensure the injuries produced by the medical researchers are representative of injuries occurring in combat operations. Such knowledge will continue to facilitate the success of the WIAMan project as it significantly improves the Department's underbody blast LFT&E capabilities and builds better, more protective vehicle platforms for our Soldiers, Sailors, Airmen, and Marines.

SMALL BOAT SHOOTERS' WORKING GROUP

Small boats represent a growing threat class to ships operating in littoral waters. They have been identified as a required class of targets for a wide variety of tactical missile, rocket, and gun weapon programs on DOT&E oversight, including 25 mm, 30 mm, and 57 mm ammunition; HELLFIRE, Joint Air-to-Ground Missile (JAGM), Evolved SeaSparrow Missile, Rolling Airframe Missile, SDB II. They are also threats of concern for ships, including the LCS and the DDG 1000.

On September 11, 2014, DOT&E sponsored the third meeting of the Small Boat Shooters' Working Group at the Naval Surface Warfare Center in Dahlgren, Virginia, which 55 warfighters, evaluators, and weapons designers from all Services attended. The objective of the meeting was to: 1) examine the general nature of the small boat threat in littoral waters; 2) summarize the threat classes and available targets and models available for ammunition, rocket, and tactical missile weapon systems; and 3) attempt to "harmonize" 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.

An important success story reported at the Small Boat Shooters' Working Group is the sudden, widespread use of a standard Fast Attack Craft (FAC) boat target, the decommissioned Coast Guard 41-foot patrol boat (CG-41). Two years ago, DOT&E learned the Coast Guard was phasing out this boat class, and determined that it would likely provide a good interim structural and mechanical live fire surrogate for FAC threats. DOT&E rapidly informed the Services, and worked with them to alter live fire plans to accommodate the test articles. The Services responded and reported at the meeting that they obtained 26 of the 54 available ex-CG-41 boats for tests of HELLFIRE, JAGM, the SDB II, F-35 Joint Strike Fighter ammunition, and LCS. Most of these boats were obtained free of charge from the Coast Guard.

U.S. Coast Guard CG-41

Briefings this year centered on the nature of the small boat threat; the availability of targets and lethality models representing those threats; and the data collection, test techniques, and instrumentation that have been applied to small boats. Attendees also discussed upcoming test plans for the HELLFIRE R-9E missile, JAGM, Griffin missile, SDB II, and F-35 Joint Strike Fighter ammunition against a variety of FAC and Fast Inshore Attack Craft threats. Of special interest were test results from

HELLFIRE Romeo missiles fired against the ex-Coast Guard CG-41 FAC surrogate, and HELLFIRE Longbow missiles vertically fired from a ship against ex-Coast Guard, 25-foot "Guardian" boats.

Two of the central observations from the group are the need for a broader variety of surrogate small boat targets and better live fire data collection from operational test events. Participants stressed the need for evaluating the likelihood of mobility kills in conjunction with live fire evaluations against small boats, since this is the most clearly observable kill mode in fleet exercises. Evaluators also encouraged the increased use of small, easy-to-place "in-situ" camera and overpressure measurement packages on the boats in order to better observe and record the types of damage to target boats during weapons tests.