LIVE FIRE OVERVIEW

Live Fire Test and Evaluation (LFT&E) was enacted into law by Congress in FY86 and requires realistic survivability and lethality testing on platforms and weapons to assure that major systems perform as expected and that combat forces are protected. The Federal Acquisition Streamlining Act transitioned responsibility for the Live Fire Test program to DOT&E in Fiscal Year 1995. LFT&E mandated in Title 10, Section 2366 has many similarities with Operational Test and Evaluation that is mandated in Section 2399 of the same Title. While operational testing assesses the suitability and effectiveness of our major defense programs, live fire testing is required to independently assess the survivability of the nation's major air, land and sea platforms and the lethality of its major weapons systems. Both programs also require realistic testing in realistic operational environments.

In FY01 the number of Live Fire Test oversight programs grew to an all-time high of just over 100. These programs are nearly evenly divided between weapons platform survivability and weapons lethality. Six programs completed live fire testing and reporting during this fiscal year:

- The MH-47E and MK-60K Special Operations Aviation (SOA), November 2000.
- The V-22 Osprey, November 2000.
- The XM1001 40MM Canister Cartridge, November 2000.
- The B-2 Bomber, January 2001.
- The DDG-51 Flight 1A, January 2001.
- The M2A3 Bradley Fighting System (BFVS), April 2001.

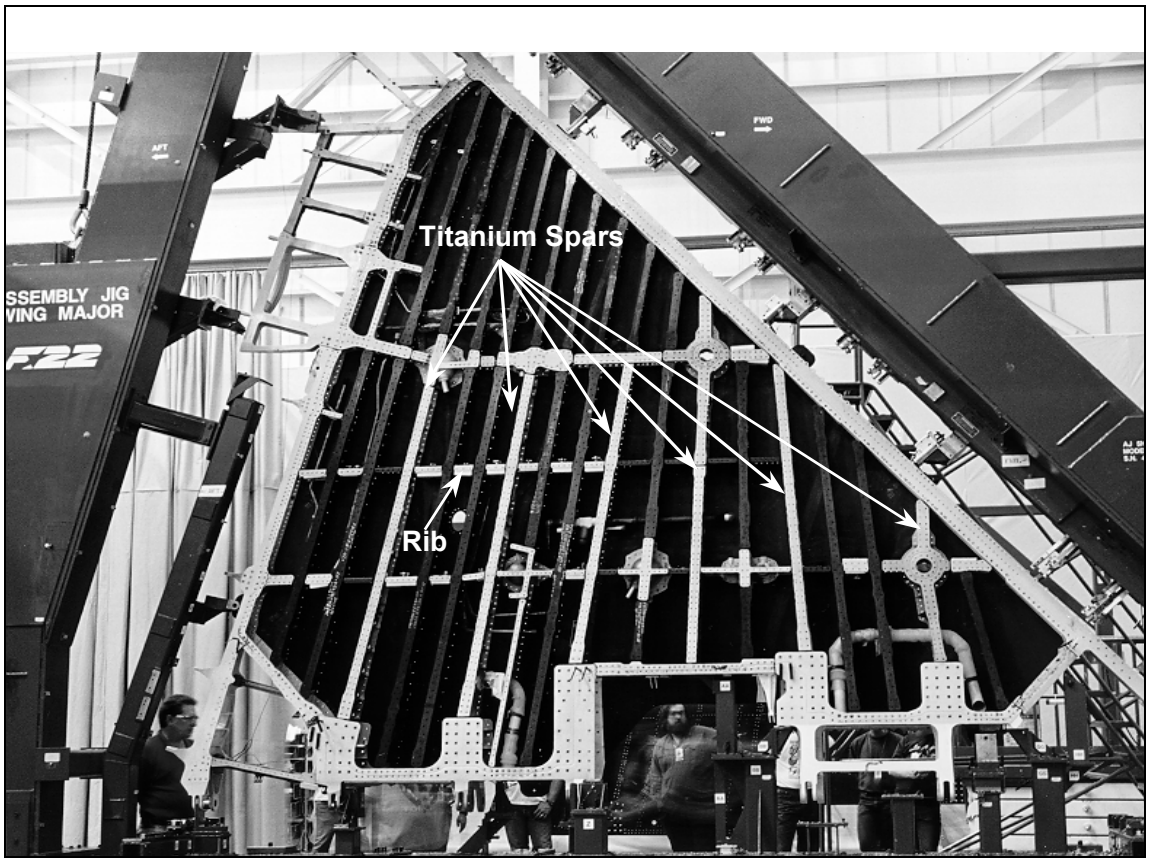
EXAMPLES OF LIVE FIRE CONTRIBUTIONS

Live Fire Testing has produced major improvements in systems by making system designs more survivable and lethal and by improving tactics, doctrine, and battle damage repair procedures. The contribution of Live Fire Testing is illustrated by the following two examples.

F-22 WING FUEL TANK HYDRODYNAMIC RAM LFT&E

An F-22 RAPTOR aircraft component-level test was conducted in the fall of 1992 against a production-representative piece of the aircraft's wing, roughly 3 by 4 feet in size. The pre-test prediction indicated that the wing would fully survive the impact and resultant damage inflicted by the threat projectile. This prediction was generated over a period of several months using one of the most complex computer codes available for this purpose.

The target wing sections (intended to be filled with fuel in the operational aircraft) were filled with water to assure that the damage mechanism to be assessed, hydrodynamic ram due to impact, could be clearly observed and evaluated. Upon impact, the wing failed totally and would have resulted in the loss of the aircraft, had that design been operational. Critics of the program would consider this test a failure. It would have only been a failure if the design remained unchanged; however, successful design changes were subsequently made and tested.



REDESIGNED F-22 WING WITH TITANIUM SPARS AND ADDITIONAL RIB

The final live fire shot to assess hydrodynamic ram was conducted on August 22, 2001 against the newly designed wing, shown above. By replacing every third composite longeron with titanium one, the new design added the necessary strength to enable the aircraft to survive such a threat impact and reduced the vulnerability of the aircraft by roughly 50 percent. Furthermore, the aircraft survived the impact under tactical airflow and loads, and with its fuel tanks completely filled with jet fuel.

USS COLE: DDG 51 – ARLEIGH BURKE CLASS DESTROYER

After the attack on the USS COLE, LFT&E personnel initiated an assessment of the causes of the casualties, their treatment, and other issues relating to the attack. The purpose was to collect information to identify procedures, designs and material changes, and other issues that could possibly help minimize casualties from any future attacks on these and other ships.

The Navy conducted at least four studies aimed at understanding the mechanism of the attack weapon, understanding the technical aspects of the structure of the ship and its ability to survive such a weapon, the operational nature of seamanship that affected the ship and her vulnerability to attack, and medical implications of the attack. DOT&E actively participated in the technical aspects of ship survivability design and the medical issues.

DOT&E concluded that certain additional design improvements to the ship class could improve crew survivability in the future. For example, the internal communication system would be less

vulnerable if a wireless system were employed to replace the current hard wire system. The failure mode logic and increased capacity of the pumps used for removing water from flooded spaces should be considered. Flooring material tends to shatter into glass-like shards that cause injury. Emergency water and rations should be available to provide nourishment to the crew in the case of power outage.

Autopsy and injury data indicated that the major cause of multiple blunt forces was flying metallic and non-metallic fragments. Although there was little fire associated with the damage to USS COLE, it was apparent that the weaknesses of the fire-fighting systems must be addressed to assure continuity of fire-fighting capability.

SPECIAL PROJECTS/INITIATIVES

MODELING AND SIMULATION INITIATIVES

LFT&E uses modeling and simulation in several ways, ranging from the immediate application of models to acquisition programs, to mid-term and long-term model development initiatives. These include:

- **LFT&E PRE-TEST MODEL PREDICTIONS:** Requiring pre-test predictions for each Live Fire and Joint Live Fire Program has added discipline to the T&E process. Comparing model predictions to test outcomes continues to provide valuable data to validate and improve our survivability/vulnerability/lethality models.
- **DEPARTMENT OF ENERGY (DOE) M&S:** Long-term model improvements are the objective of on-going LFT&E initiatives with the DOE National Laboratories to use and evaluate physics-based computer models. Since the LFT&E program is "test data rich" and Labs are "model rich," this effort has been mutually beneficial. DOE's high performance computing capability models have the potential to improve the understanding of system-level behavior by more accurately modeling fundamental component and material behavior. Advanced computer codes of the Accelerated Strategic Computing Initiative are being used to help make pre-shot predictions for a variety of Live Fire Test and Joint Live Fire test opportunities.
- **MODELING AND SIMULATION PILOT PROJECT:** In an effort to embark on more Simulation Based Acquisition, in FY00, DOT&E initiated an M&S pilot project with each of the three Services. In FY01, each Service selected a candidate acquisition program for the pilot project. The Army selected their Common Missile Program. The Navy selected their Extended Range Guided Munitions (ERGM) and the Air Force selected their T-38 Avionics Upgrade Program. The purpose of this project is to develop a methodology that more efficiently and effectively guides the use of M&S to support acquisition.

LIVE FIRE TESTING AND TRAINING PROGRAM

The FY01 Defense Appropriation included congressional funding to investigate alternative uses of simulation and training technology to support LFT&E. This initiative is the Live Fire Testing and Training (LFT&T) program.

The LFT&T Program directly supports the exchange of technology initiatives and opportunities among the live fire and training communities to better serve the warfighter. It also fosters the establishment of partnerships between the DoD and the civilian sector. The underlying LFT&T Program objectives are to enhance cost-effective testing and training and improve warfighting readiness. The program has funded twenty-five projects through FY01, totaling approximately $25M since its inception. Several projects have already transitioned to operational sponsors and are providing direct benefits to the warfighter.

The LFT&T Senior Advisory Group (SAG) manages the LFT&T program. The SAG is chaired by DDOT&E/LFT and members are the commanders of the four Services' training and simulation agencies. The SAG reviews government, industry and academia project proposals, selects the most promising projects, reviews project progress and products, and assures that program goals and objectives are achieved.

Live Fire Testing is unique in that, apart from actual combat, it is the only source of realistic combat vulnerability and lethality data, battle damage repair procedures, and estimates of user casualties. This program takes that realistic data and combines it with training technologies and opportunities in a synergistic way.

The LFT&T Program funded a total of fifteen projects in FY01. A summary of the FY01 projects follows:

- **WEAPONS AIMPOINT ANALYSIS AND TRAINING TOOL:** Small arms weapons systems and their associated fire control systems are becoming increasingly more complex. Advanced fire control systems, currently under development, will allow gunners to deliver airburst munitions against targets that were previously considered in defilade and difficult to attack. As a result, there is a need to develop better methods of measuring gunner/weapon performance during testing and training activities, against various targets.

  The testing and training communities currently rely on limited and expensive indirect methods to measure gunner and weapon performance. The tool developed in this project will provide new capabilities to validate ballistic models for complex fire control systems, gather real-time gunner/weapon aimpoint position data for stationary and moving targets, separate gunner errors from weapon system errors, and provide enhanced weapon aimpoint and tracking feedback.

- **MAN PORTABLE AIR DEFENSE SYSTEMS (MANPADS) TEST AND TRAINING RESULTS:** MANPADS shoulder-fired missiles are significant threats to national and allied aviation communities. MANPADS conferences and workshops have highlighted the need for more comprehensive data on the capabilities and effects of shoulder-fired missiles to meet analysis, testing and training requirements.

  This project provides an essential conduit for the transfer of MANPADS live fire test data and information to DoD and other Government agencies not

directly involved in Live Fire Test programs (*e.g.*, Justice Dept., Airport Security Committee, and the National Security Council). The data collected during this project will be used to train warfighters, train test engineers, analysts, anti-terrorism specialists and battle damage repair specialists involved in aircraft survivability and anti-terrorism activities.

- **SYNERGISTIC EFFECTS OF ALMOST-LOSS-OF-CONSCIOUSNESS (A-LOC):** The effects of gravity-induced loss of consciousness (G-LOC) and loss of situation awareness (SA) have been widely studied as a contributing factor in aircraft mishaps and pilot fatalities. Most recently, significant attention has turned to the physiological phenomenon termed Almost-Loss-of-Consciousness or A-LOC. During A-LOC episodes, aviators may not lose total consciousness, but may experience significant sensory, motor, and cognitive impairment from acceleration that could lead to loss of both aircrew and aircraft. A better understanding of A-LOC is required to improve the Services' aviator physiological/acceleration training programs.

The objectives of this project are to enhance the Air Force and the Navy centrifuge training programs, to improve A-LOC prevention, and reduce the incidence or severity of A-LOC episodes to include prevention of aircraft mishaps that result from A-LOC. The results of this project will offer insight into mitigating risks and loss of life through improved training for Air Force and Navy high-performance aircraft aircrews.

MOVING WEAPONS PLATFORM SIMULATOR (MWEPS): The testing of stabilized, mounted weapons is complicated, costly and often provides only subjective results. Platform and logistics costs, range availability, data collection time, and ammunition costs are all factors that drive testing costs and effectiveness. Both initial and weapon systems proficiency training are similarly affected by these factors. An integrated simulator with actual hardware, computer-generated visual scenes, and objective performance scoring and feedback capabilities is essential to overcome limitations of live fire exercises. The tool/simulator developed from this project will allow weapons concepts to be evaluated earlier in the design process; reduce the live fire range time requirements; and serve as an individual weapons operator training system.

- **VIRTUAL TARGET GUNNERY SYSTEM:** Testing and training activities require targets that are realistic in appearance and behavior. The project will significantly enhance live fire target technology by presenting intelligent, simulated targets to trainees learning to use the Mark 38 25-mm machine gun. These simulated targets will be presented in a real world setting, with the targets integrated in real time into the gunner's real-world view.

The use of simulated targets will:

- Provide realistic target signatures (visual, thermal, infrared, acoustic).
- Accommodate non-line-of-sight, beyond-line-of-sight engagements.
- Accurately replicate buildings, bunkers and other infrastructures.
- Realistically represent threat, friendly, non-combatant and neutral behaviors.
- Realistically simulate target vulnerability across a wide range of effects (electronic, lethal, non-lethal, etc.)

- **AUGMENTED REALITY (AR) FOR SHIP SURVIVABILITY:** This project examines the feasibility of using AR-based survivability technologies in shipboard testing and training environments. Specifically, investigations into various display and tracking technologies were evaluated and developed to demonstrate the capability to overlay realistic artificial fire, smoke, and extinguishing images onto images of the real world environment, including facilities, equipment, and other personnel.

A successful AR demonstration was conducted in June 2001 at the Navy Firefighter Training Facility in Mayport, FL. AR-based technology promises to provide improvements to existing shipboard fire fighting testing and training methods and capabilities through:

- Improved realism (e.g., images of real electrical fires versus propane simulation).
- Reduced operational costs (e.g., propane and corrosion maintenance).
- Dramatic safety improvements (e.g., elimination of potential explosion/explosive reflash), elimination of combustion byproduct--Carbon Monoxide/Formaldehyde, etc.)
- Elimination of environmental concerns (e.g., no atmospheric emissions).

- **AUGMENTED REALITY (AR) FOR PLATFORM DAMAGE CONTROL:** Shipboard damage control testing and training faces the same technology limitations as described in the preceding project. Advances in AR-based technologies are needed to improve shipboard damage control testing, training realism and effectiveness, and allow more comprehensive testing of total ship response to damage.

This project builds on the results of the AR for Ship Survivability project and advance current and future AR-based technologies to meet shipboard damage control testing and training needs. Specifically, the project will continue the investigation and evaluation of various display and tracking technologies and will culminate with the development and demonstration of a ruggedized prototype AR-based damage control visualization system for testing and training purposes.

- **EXPLOITING LIVE FIRE TEST DATA:** Situation awareness is crucial to attack aircrews who must make time critical decisions that directly impact first-pass attack success, survivability, fratricide avoidance, and minimize collateral damage. Advances in real-time-in-the-cockpit (RTIC) technologies are needed to improve aircrew SA and overall probability of mission success.

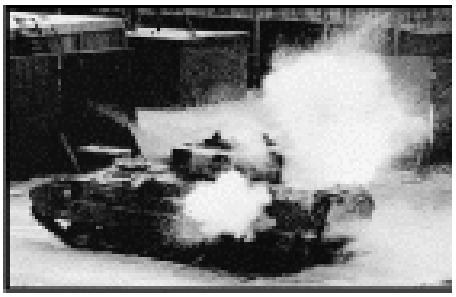
  This project investigates the feasibility of integrating advanced technologies to provide RTIC information to the aircrews to improve overall situational awareness and probability of first-pass attack success. Information to be integrated includes look-up values from the Joint Munitions Effectiveness Manuals (JMEMs), data from live fire and joint live fire tests, and information from intelligence and sensor sources. The effort includes the study of various algorithms and display technologies and will culminate with a proof-of-concept demonstration to show its operational, testing and training utility. The proof-of-concept will be designed for a specific host aircraft but will be applicable to aircraft from all military services.

- **SHIPBOARD INCIDENT MANAGEMENT:** Medical and non-medical personnel must be trained and exercised in first response procedures for incidents involving ship and systems damage and personnel injuries. This training is currently difficult to accomplish and, in some cases, is unrealistic. A better method and capability is needed to train and measure shipboard first response skills.

  This project develops a prototype shipboard training system that has the capability to train first responders in the management of major casualty incidents, and support the development of ship vulnerability, survivability and recoverability metrics. The prototype system will be developed from existing or commercial-off-the-shelf software. The initial focus for the prototype system is the LPD-17.

- **VULNERABILITY / LETHALITY (V/L) METRICS:** Traditional V/L metrics often adversely affect simulation fidelity by directly assessing the impact on component damage without considering the impact on total system capabilities. This leads to unrealistic outcomes and results in poor analytical, testing and training models, and simulations. Mathematically sound V/L methodology is needed to improve V/L metrics to overcome these current modeling and simulation shortfalls.

  This project provides a sound methodology and set of V/L metrics that will more accurately represent combat outcomes in both analytical and training simulations. Incorporation of the improved V/L metrics will provide for:

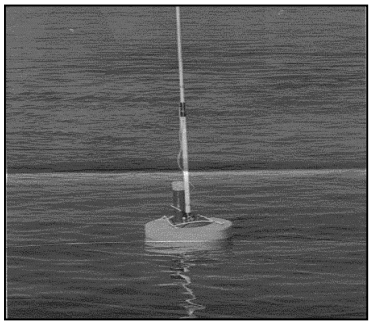
  - Higher fidelity of V/L modeling and simulation results.
  - More representative and realistic visual and damage effects.

- Improved analysis and understanding of the synergistic effects of munitions impacts.
- Better decisions regarding weapon systems optimization, training methods, tactics, force structure requirement and mission effectiveness predictions.

- **MISSILE WARNING SENSOR STIMULATOR (MWSS):** Electro-optical Missile Warning Sensors (MWS) and associated countermeasures are under development to counter the increasing light vehicle and man-portable anti-aircraft missile threat.

This project enhances the capability and utility of the MWSS prototype system developed by the Air Force Operational Test and Evaluation Center (AFOTEC). The improved production MWSS system was transitioned to the 46th Test Wing at Eglin AFB in September 2001. Its capabilities and utility were clearly demonstrated in recent testing where significant operational MWS deficiencies were identified.

- **VIRTUAL TARGET AND RANGE (VITAR) SYSTEM:** Carrier Battle Groups and Amphibious Ready Groups/Marine Expeditionary Units typically conduct combined training operations in the weeks before a forward deployment. These combined operations include live fire exercises. Suitable supplemental training alternatives to current live fire exercises are needed due to current range issues (e.g., Vieques, environmental hazards) and range limitations (e.g., inadequate footprint for advanced munitions).



This project provides a prototype system for conducting cost-effective live fire exercises and supplementary training to Navy units. The proposed VITAR system will have the capability to:

  - Determine the position of an impact and transmit the data back over the horizon to a systems controller.
  - Display the impacts on real maps over any simulated terrain or target.
  - Operate as a stand-alone system, or interfaced with shipboard systems to provide real time feedback to the crew.
  - Safely test long-range systems such as the Advanced Gun System (AGS), the Extended Range Guided Munitions (EGRM) and Barrage round.

  The VITAR system may not replace fixed ranges. However it will allow individual ships to conduct a wide selection of live fire training exercises almost anywhere at anytime. Additionally, VITAR will allow ships being sent to combat areas to perform live fire tests of their guns en route to ensure their accuracy and operational effectiveness.

  VITAR completed successful demonstrations in July and August 2001. It has received strong endorsement from Navy senior leaders and a follow-on project has been proposed for FY02 to make the current prototype system fully operational.

- **DISMOUNTED INFANTRYMAN TESTBED (DISALT):** Current simulation testbeds are focused at the individual/weapon level. These stand-alone systems do not provide the

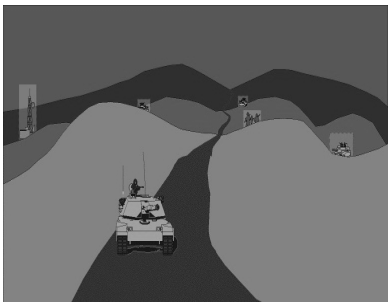
capability to examine the complex interrelationships and synergism of a fighting team employing multiple weapons.

This project provides a validated multi-user testbed that allows the live fire testing and training communities to analyze, and subsequently optimize, the lethality and survivability of a fighting team.

The DISALT system allows, for the first time, high fidelity testing of both weapon and human performance for both the individual and the fighting team in a validated simulation environment. Performance issues, such as weapon tracking, weapon handling, weapon effectiveness, weapon recoil, team and individual tactics, as well as communication and decision making skills, will all be directly measurable allowing for a total analysis of the lethality and survivability of the fighting team.

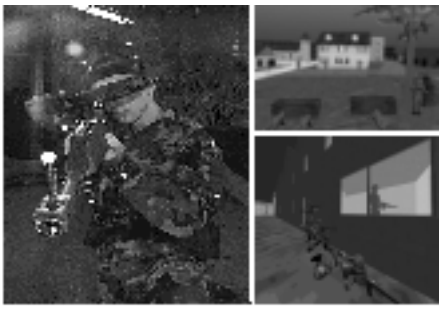
- **INFRARED TARGETS:** Forward Looking Infrared (FLIR) testing and training requires live fire targets that closely mimic the appearance of real infrared (IR) targets. The current approach to providing IR targets is costly and a more cost-effective means for providing IR targets is needed.

  This project develops IR projection capabilities that will provide realistic live fire targets, with scoring capability, for FLIR testing and training. This will be accomplished by adapting commercial-off-the-shelf technologies.



  Computer-generated forces software will be adapted to provide control of the target imagery. The projection machinery will be hidden and protected behind berms to avoid damage by live fire. This project will provide improved IR target realism and meet FLIR testing and training needs of the both the Navy and Marine Corps. Additionally, it will provide cost saving over the current methods used to provide IR targets.

- **LIVE FIRE ADVANCED CONCEPTS:** Small unit, live team exercises are complex and inherently dangerous. This project explores how existing technologies and efforts can be leveraged to create a test bed that can be used as a fully immersive simulation environment for small unit leader, collective, and dismounted infantry testing and training. The simulation will create an environment that:



  - Allows soldiers to maneuver throughout the battlefield, utilizing a head-mounted display to view the terrain and both friendly and opposing forces.
  - Is weapon system independent (although initially focused on the Objective Individual Combat Weapon and M16).
  - Can easily accommodate the addition of new individual or crew served weapons of the future.

- Facilitates the integration of other simulators and simulations into the scenario such as the Squad Synthetic Environment (located in the Land Warrior Test Bed at Ft. Benning, GA) or the Combat Trauma Patient Simulator (CTPS).

The immersive environment developed under this project will provide enhanced testing and training realism through the incorporation of 3-D audio and olfactory effects. The sight, sound and smell effects provided by the system will provide the soldier with a complete suite of sensory inputs to stimulate the human decision making process.

JOINT LIVE FIRE PROGRAM (JLF)

The JLF program was chartered by OSD in March 1984, to conduct Live Fire Testing of fielded U.S. and foreign air and ground weapons platforms and munitions. The aircraft systems tested under the JLF program (known as the JLF Air Systems Program) are managed by the Joint Technical Coordinating Group for Aircraft Survivability (JTCG/AS). Likewise, the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) manages the JLF Ground Systems Program.

In the fiscal year 2001 Air Systems Program, JLF testing addressed the vulnerability of the CH-47 Chinook, C-130 Hercules, F-16 Fighting Falcon and the lethality of the U.S. 20mm projectile PGU-28/B against selected foreign targets. In addition, FY01 efforts included continued development of Man-Portable Air Defense Systems (MANPADS) test technology to increase the amount of information gained from each shot.

Sea systems have not yet undergone JLF testing, but testing is planned with the Hellfire Missile against patrol boat targets, as described below.

- **MANPADS TESTING:** JLF's efforts in previous years included a limited number of firings of MANPADS missiles against targets, such as the F-14 and F-16, to obtain an understanding of the damage mechanisms produced by these threats as they interact with the targets.

  Efforts to develop the rail launch techniques for foreign MANPADS testing continued during FY01. This launch method has the advantage of greater control over the impact conditions and greater safety in testing unreliable foreign MANPADS. During FY01, a rail launch test of an SA-16 was successfully conducted against an array of plates designed to represent an aircraft wing. Test objectives were to demonstrate the launch technique, and determine the penetration capabilities, fuzing distance, blast pressures, and fragment sizes/patterns for this foreign missile. The report is in review and will be published in FY02. A test with an SA-16 against an actual C-130 wing is planned for FY02.

- **CH-47D TESTING:** The CH-47D Chinook JLF program includes a series of ballistic tests and analyses to determine the vulnerability of the rotor blades and the rotor drive train system. The results of these tests will complement the ongoing LFT&E program for the CH-47F Improved Cargo Helicopter program, since the rotor blades and drive train are common to both variants. During FY01, static blades were shot with various projectile sizes and the damaged blades were subjected to fatigue testing. The results will be used to plan a limited number of ballistic tests against rotating blades to validate the results from the static tests.

- **C-130E/H TESTING:** The C-130E/H Hercules JLF program conducted ballistic tests and analyses to determine the vulnerability of the wing to hydrodynamic ram damage from

projectile impacts into the wing fuel tanks. The ballistic tests also provided an opportunity for Air Force C-130 Battle Damage Repair technicians and engineers to gain practical experience on a C-130 with realistic ballistic damage. The ballistic tests were conducted in FY00 and the report was prepared in FY01.

JLF is conducting an analysis to determine the types of damage that will result in a C-130 mission abort and the vulnerable area of the aircraft for those types of damage. In the C-130J and C-130AMP, a number of function performed by the crew in older models have been automated and the crew size has been reduced. For ballistic damage that does not cause a loss of the aircraft, the question arises as to how well the newer models can tolerate with such damage and still complete their missions compared to the older C-130E/H models.

- **PGU-28/B LETHALITY TESTS:** The U.S. 20mm PGU-28/B SAPHEI (semi-armor piercing high explosive incendiary) projectile was developed in the mid 1980s (replacing the U.S. M-56A3 HEI projectile) for use in the air-to-ground role due to its armor penetrating capability. Since it provided significant performance improvements in terms of drag, effective range, time of flight, and graze angle tolerance, the round was selected for use against air-to-air targets in gunnery scenarios. The PGU-28/B is the only projectile currently used by the Air Force and Navy for fixed wing air-to-air combat. This projectile is fired from the M61A1 gun system that is utilized by the F-14, F-15, F-16, and F/A-18 aircraft. Current plans call for use of the PGU-28/B with the M61A2 gun system on the F-22 aircraft. With approximately 8,000,000 PGU-28/B rounds in the inventory, these tests will have a broad impact.

  While the PGU-28/B represents an improvement in aerodynamic performance, its lethality (damage capability given a hit) against actual aircraft targets has not been demonstrated. Detailed plans were prepared to test the lethality of the PGU-28/B against a Soviet MIG-29 aircraft and a MIL-24 Hind Helicopter. The tests will be conducted in FY02.

- **HELLFIRE MISSILE/PATROL BOAT TESTS:** Planning began in FY01 for a test program of Hellfire missile shots against two Navy MK III Patrol Boats that are no longer in service. The objective of the tests is to assess the lethality of the Hellfire missile against patrol craft. FY02 planned efforts include the development of a detailed test plan, cost estimate, and preparation of pre-shot aim/hit point and damage predictions, including the detailed target modeling needed to do pre-shot predictions. Testing, which may not occur until FY03 because of limited FY02 funding, is to be conducted either off Wallops Island or in the Navy's Virginia Capes Operating Area.

JTCG/AS

The Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) ensures joint, coordinated development of survivability technology, methodology and design tools necessary to provide the Warfighter with survivable, combat effective aerospace systems. In FY01 the JTCG/AS Vulnerability Reduction subgroup funded over ten projects, with the goal of the development and application of technologies onto legacy and future aircraft to reduce their vulnerability and to increase the survivability of the crew. Two are described below.

- The Advanced Survivable Rotorcraft project, initiated in FY00 and completed in FY01, had as its objective a reduction in the vulnerability of rotorcraft to the MANPADS threat. The

project involved vulnerability analysis, structural hardening concepts, decoy concepts, possible sacrificial structural components, and baseline and improved survivability demonstration testing. This project has generated vulnerability reduction techniques for future rotorcraft systems.

- The Survivable Engine Control Algorithm (SECAD) project, initiated in FY99, has now matured to the point that a follow-on effort was initiated in FY01 to couple the SECAD technology to current engine health monitoring and prognostic (EHMP) technologies. The SECAD project conducted research and implemented engine software enhancements that are able to detect, identify and mitigate engine damage, possibly allowing pilots to reach their home base or at least friendly territory before ejection. This technology has been developed and implemented on an F/A-18E/F F414 test engine and may also be used to enhance the Joint Strike Fighter engine development program.

The JTCG/AS Susceptibility Reduction projects address the electro-optical and infrared threat missile systems, radio frequency homing missiles, and the use of flares to draw the threat away from the aircraft. Two of these projects are described below.

- A project to evaluate Aerogels as a retrofitted material for thermal and infrared emission suppression in and around aircraft engines was initiated. This technology shows tremendous potential to reduce the susceptibility of our air fleet to thermal seeking missiles.
- The Active Core Exhaust (ACE) project was funded jointly with the Air Force Research Laboratory, DARPA and private industry. This innovative project has as its focus the removal of the Core Thrust Reverser of the C-17 aircraft and replacing it with a redesigned nozzle incorporating a fully integrated pulsed injection system and plug nozzle. During the summer of 2000, ACE was tested on a C-17 engine test stand. A flight test will be conducted during this calendar year.

The JTCG/AS, in cooperation with the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) and the Army Research Laboratory, developed a new physics-based simulation to assess the vulnerability of a wide range of targets as well as the lethality of many types of munitions. The Advanced Joint Effectiveness Model (AJEM) has the capability to calculate damage effects on a target system and determine the impact of that damage on the ability of the system to function. A milestone was achieved in FY01 with the release of AJEM version 1.0 to the user community. Work has begun on the next version.

JTCG/ME

The JTCG/ME was chartered by the Joint Logistics Commanders (JLC) over 30 years ago to serve as DoD's focal point for authenticated non-nuclear munitions effectiveness information (Joint Munitions Effectiveness Manuals or JMEMs) on all U.S. major non-nuclear weapons. The JTCG/ME's mission includes validating, standardizing, and disseminating M&S methodologies for evaluating the lethality of our systems. The JTCG/ME, under the auspices of the JLCs, authenticates and publishes data for use in training, systems acquisition, weaponeering, procurement, and combat modeling. JMEMs are used by the Armed Forces of the United States, NATO and other allies to plan operational missions, support training and tactics development, and support force-level analyses. The JTCG/ME also develops and standardizes methodologies for evaluation of munitions effectiveness and maintains databases for target vulnerability, munitions lethality and weapon system accuracy.

In FY01, the JTCG/ME executed the following:

- Conversion/updates of the following JMEMs to CD-ROM format: JMEM Air-to-Surface Weaponeering System (JAWS) v2.2; Joint Anti-air Combat Effectiveness – Air Defense (J-ACE: AD) v2.0; Joint Anti-air Combat Effectiveness - Air Superiority (J-ACE: AS) v2.0; Joint Anti-air Combat Effectiveness - Ship Anti-air Warfare (J-ACE: Ship AAW) v1.0; JMEM/Surface-to-Surface Weaponeering Effectiveness System (JWES) v2.0 and Target Vulnerability Manual v2.2 on JAWS.
- Distributed products via the classified Internet with the JTCG/ME Products and Information Access System (JPIAS) v2.0.
- Expansion of existing databases to incorporate weapons effectiveness and target vulnerability data (e.g., Air-to-Surface Basic Manual – Revision, Surface-to-Surface Direct/Indirect Fire, Air Target Geometry, Joint Component Vulnerability Archive (JCVA) and delivery accuracy).
- Technical coordination efforts to address Target Vulnerability data generation (e.g., industrial targets, Non-Nuclear Consumables Annual Analysis (NCAA) targets, small boats, building structures, SATCOMs and TBMs) and methodology improvements (e.g., counter proliferation, titanium fragment penetration/equation standardization, Operational Requirements-based Casualty Assessment (ORCA) extension, and target model generation).
- Development of standardized models and methodology for Air-to-Surface, Surface-to-Surface and Anti-air effectiveness calculations (i.e., Collateral Damage Module (CDM), Hardened Targets Module (HTM), Building Analysis Module (BAM), Bridge Analysis System (BAS), Joint Anti-Air Model (JAAM), JAWS Target Acquisition, Joint Smart Weapons Module (JSWM), GPS accuracy and Multiple Weapon Types (MWT)).
- Configuration Management/VV&A on specific JTCG/ME models (i.e., JSEM, AJEM, MEVA-GF, MUVES-S2, BEAMS/ABEL, GENESIS-BAT, PENCURV-3D, ORCA, Joint MAE, and ASAP).
- Released Advanced Joint Effectiveness Model (AJEM) v1.x (Generalized Body-to-Body and Internal Blast), and Joint Component Vulnerability Archive v1.x together with the JTCG/AS.
- Continued CINC data call and prioritization in support of FY02 program build and Operation Infinite Justice in coordination with J8.
- Facilitated development and publication of National Disclosure Policy and classification review of the JAWS CD-ROM to address requirements for coalition operations.

VULNERABILITY ASSESSMENT TO RADIO FREQUENCY THREATS

One of the roles of the LFT&E program is to assure that realistic testing is conducted using both current and future threats. This means both ballistic and non-ballistic directed energy threats. There is a growing concern that as the U.S. becomes dependent upon computer-driven command and control and, as military digitization becomes the norm, the possibility exists for a terrorist or rogue nation to seek to take advantage of this apparent dependency. LFT has supported the development of prototype high-power microwave (HPM) weapons and tests of these devices at DoD open-air ranges since FY97. As a result of these efforts, we now have some relevant equipment and experience with live fire testing of HPM weapons against military systems and commercial infrastructure.

The U.S. Congress provided an initial increment of $4.0 million in FY99 to "expand threat vulnerability testing and evaluation to include the threat of radio frequency (RF) weapons." These funds supported the development of a RF device, using components and technology from the open market, as well as the conduct of various tests. A testing program was initiated to assess the potential vulnerability of electronic systems representative of the U.S. military and commercial infrastructure to HPM/ultra wideband illumination under “operationally relevant” conditions.

Two different RF devices were tested against targets, which included both a military weapon system (AH-1W Cobra) and commercial off-the-shelf (COTS) technology. The COTS equipment was subdivided into two distinct sets: (1) industrial control and monitoring technology (telephone switching technology, an x-ray baggage screening device, portable power generators, and uninterruptible power supplies); and (2) medical equipment

Additionally, live fire, open-air test was conducted using the F-16B, Block 15 as the test target. Two different RF devices were employed, each varying in waveform characteristics, rise time, pulse repetition frequency, burst length, and power level, in the testing. Complete data from the test are still being analyzed.

Results from the vulnerability assessment program so far have shown that, within the confines of the conditions tested and the given parameters evaluated, some systems are more vulnerable to HPM and RF electromagnetic energy than others. The overall conclusion is that hardened systems are hard and soft systems are soft. Military weapon systems are more hardened and, as a result, less vulnerable than COTS technology,

This series of tests showed it is unlikely that terrorists, without the support of a sophisticated engineering capability, would be able to develop a RF device using components and technology from the open market. A sophisticated engineering capability is essential to design, acquire, and integrate available technology to produce an effective operational RF threat weapon system. U.S. contractors developed the RF systems that were developed and used to support these tests with an engineering capability. The systems did not produce an unexpected effect against the targets used in these tests. Military systems are hardened and routinely tested for electromagnetic environmental effects (E3) prior to fielding.