Overview of the U.S. Army's Small Arms Live Fire Test and Evaluation Process

ATEC

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Introduction

This briefing does <u>NOT</u> present or reveal results or details related to any specific Live Fire Programs. This briefing is an overview from the LF Evaluator's perspective of the <u>U.S. Army's</u> Live Fire Test and Evaluation process only.

What is Live Fire Test & Evaluation (LFT&E)?

- Congressionally Mandated by Title 10, United States Code, Sec. 2366.

- VULNERABILITY: Firing of threat munitions against combat configured U.S. systems to test their vulnerability. Vulnerability is considered a subset of survivability. (DoD 5000.2-R) Not commonly applicable to Small Arms.

- LETHALITY: Firing of U.S. munitions/missiles against combat configured threat systems to test the lethality of munitions/missiles. Lethality is a subset of survivability. (DoD 5000.2-R)

- LFT&E must be considered in all phases of the acquisition cycle: Milestone A though C.

Survivability

- Live Fire is a subset of Survivability
- The AEC LFT&E Division: Responsible for ballistic vulnerability and lethality.
- The AEC Survivability Division: Responsible for:
  - Soldier Survivability
  - Electromagnetic Environmental Effects (E3)
  - Electronic Warfare
  - Nuclear, Biological, and Chemical (NBC) Effects
  - Nuclear Weapons Effects (NWE)
  - Information Operations
  - Effects of Obscurants and Atmospherics

An overall System Evaluation Report (SER) may include all or some of the above areas, including lethality.

Primary Live Fire Guidance

- United States Code, Title 10, Section 2366
  - Defines qualifications for Live Fire candidates.
  - It is mandatory that OSD, DOT&E submit an independent evaluation report to Congress prior to full-scale production.
- DoD 5000.2-R REQUIRES:
  - Mission Critical systems shall be survivable to the threat levels anticipated in their operating environment.
  - Survivability from all threats found in the various levels of conflict shall be considered and fully assessed.
- AR 5-11, 70-1, 73-1
- DA Pam 73-6

Live Fire Objectives

- Conduct a timely and thorough **assessment of the vulnerability/lethality** of a system as it progresses through its development and subsequent production phases.
- **Provide the decision makers with information** on potential user casualties, vulnerabilities, and lethality.
- LFT&E based upon **combat realistic conditions.**
- **Design deficiencies** identified to allow correction before LRIP.
- Battle damage assessment and repair (**BDAR**) - (for vulnerability).

Small Arms Munitions

- Munitions =/< 40mm diameter
- Weapons:
  - Rifles, Carbines
  - Machine Guns, light, medium, heavy
  - PDW (Personal Defense Weapons)
  - Grenade Launcher, Grenade Machine Gun
  - Cannon Caliber Weapons, vehicle or aircraft fired
  - Hand Grenades
- Munitions:
  - Ball; HE; AP; APDS; APFSDS; HEAB; HEPD; API; HEI; SAPHEI; HESC; etc.

Annual Small Arms Live Fire Review Meeting at Picatinny Arsenal

Qualified for Live Fire?

Live Fire Oversight List

1,000,000 Rounds

Major system that provides protection for user (vulnerability)

Product Improvement Program (PIP)

Funding : FY80 (FY01):
RDT&E: $75M ($143M)
Total Procurement: $300M ($531M)

OSD Designates LF Candidates

Small Arms on 2001 LF Oversight List

OICW
OCSW
XM1001 40mm Cartridge
XM96 LFHG

Test Item Must Be Production Representative!

Live Fire Team

AEC

DUSA (OR)

OSD, DOT&E, LFT&E

SME

CONTRACTOR

ATC

ARL

TSM

AMSAA

PMO

DTC

Live Fire IPT

Evaluator's Mission

- Independent Evaluator for Army
- Chair of the Live Fire IPT
- Develop Live Fire Strategy
- Develop Live Fire Event Design Plan
- Witness Testing
- Write Live Fire System Evaluation Report

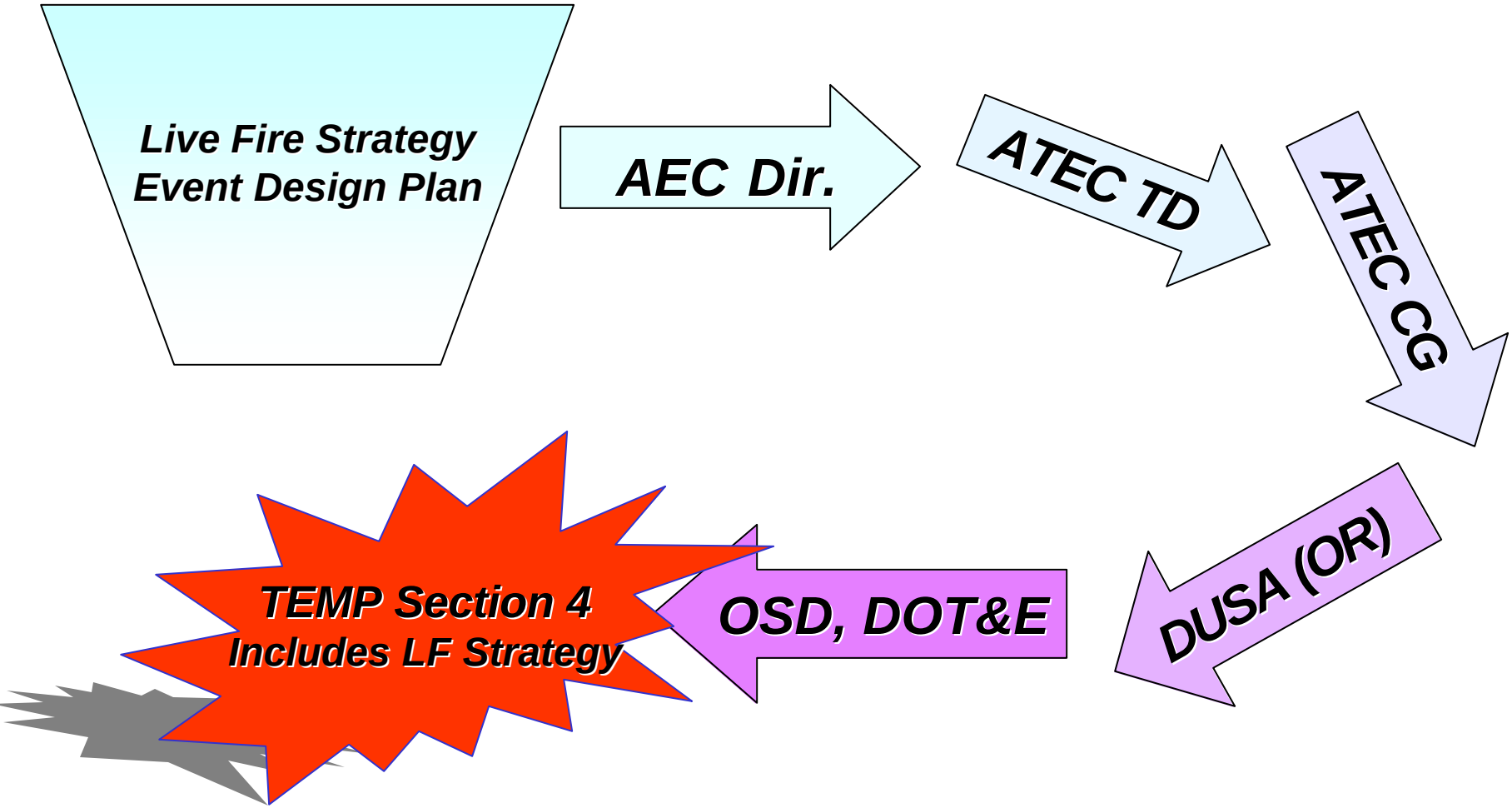
Evaluator's Documents

- **System Evaluation Plan (SEP)**
  - Defines overall evaluation criteria and plan
- **LF Strategy**
  - Section 4 of TEMP
  - Defines LF Shots, test scope, cost, resources
  - Required for Milestone A and B TEMP Updates
  - Approved by DUSA (OR) and OSD, DOT&E
- **Event Design Plan (EDP)**
  - Defines shotlines
  - Feeds DTP
- **System Evaluation Report (SER)**
  - Compares Test and Modeling results to requirements and criteria
  - Approved by DUSA (OR); forwarded to OSD, DOT&E
  - Feeds OSD, DOT&E Evaluation Report for Congress

Tester's Documents

- **Detailed Test Plan (DTP)**
  - Approved by DUSA (OR) and OSD, DOT&E
- **Detailed Test Report (DTR)**
  - Approved by DTC
  - Feeds SER
  - Forwarded to DUSA (OR) and OSD, DOT&E

Live Fire Strategy & EDP Approval Process



LFT&E Program Build Approach

Blue = Intel Document
Green = User Document
Purple = ATEC Document
Yellow = PMO Document
Tan = Tester Document

Spec Requirements

ORD Requirements

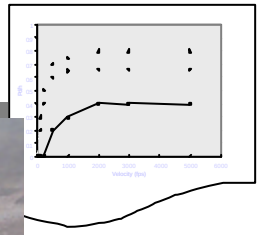
MNS

COIC

STAR

Identify Critical Issues

Develop Threat Matrix



Review Previous Tests & Analysis

Identify Data Voids (Threats/Components not tested)

Determine required tests and methods of evaluation to fill remaining data voids

LFT&E Strategy

TEMP

Event Design Plan

Detailed Test Plan(s)

Conduct Test(s) & Evaluation(s)

Detailed Test Report(s)

System Evaluation Report

Data Sources

- Live Fire Tests
- All data may be used for Live Fire Evaluation
  - DT and OT
  - Must validate data from Non-Live Fire Tests
  - Witness Non-Live Fire Tests
- Government Tests
- Contractor Tests

All Testing is Live Fire Testing

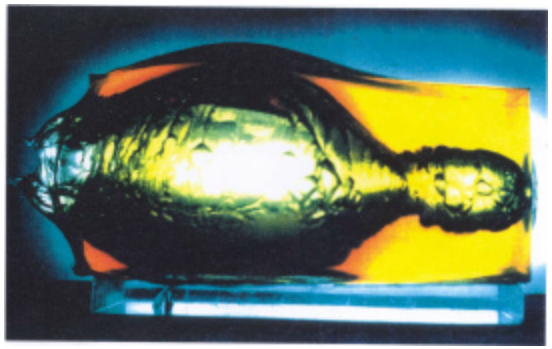
Develop LF Evaluation Criteria, Design Live Fire Tests IAW Criteria,
and Evaluate Test Results IAW Criteria.

Targets in Small Arms LFT

- Personnel Simulants - Plywood Mannequins
  - Orthogonal panels are sufficiently 3-D
  - Records shotline location, direction, and hole geometry
  - Provides input to ComputerMan Model
- Materiel Targets
  - Unarmored Vehicles
  - Light Armor Vehicles
  - Helicopters
  - Fixed Wing Aircraft
  - Self Propelled Anti-Aircraft Guns and Air Defense Systems
  - Surrogates

Personnel Simulants

- 20% Gelatin Block
  - Penetrations correlate with soft tissue data.
  - P(I/H) calculated from total or incremental kinetic energy transfer.
  - P(I/H) specific for the tactical stress situation and time after wounding to onset of incapacitation.
  - Not used in LFT but provides essential data to evaluate P(I) for projectiles.



Personnel Simulants
(cont)

- Plywood Mannequins.
  - Positioned according to combat realistic scenarios:
  - Range of engagement
  - With uniform and helmet, w/wo Personnel Armor System, Ground Troops (PASGT) body armor, with weapons
  - Standing, kneeling, or prone postures.
  - Open or partial defilade (berm, foliage, window opening, bunker, vehicles)
  - Single (point) or area (multiple) targets in assault or defensive positions.

Personnel Simulants

Realistic Engagement Scenarios

Measures of Effectiveness (MOE)

- Personnel Targets
  - Lethality or P(I/H) vs range or at a specified range.
  - P(H) vs range or at a specified range.
  - P(I) vs range or at a specified range.
  - Maximum range of engagement.
  - Rate of fire and ammunition expended.
  - Fraction of enemy force incapacitated.
  - In combat models, various force effectiveness indicators, e.g., incapacitation rate, loss exchange ratio (LER) between Red and Blue forces.
  - Suppression

- Materiel Targets
  - Similar to above with vehicle kills K substituted for incapacitation I, to obtain P(K/H) and P(K).

Target Environments
Combat Realistic Conditions

- Personnel Targets
  - Open
  - Partial concealment
  - Complete defilade. Can be attacked by air burst munitions
  - Military Operations in Urban Terrain (MOUT) - behind a wall, window, or rubble.

- Materiel Targets
  - Vehicles or surrogates - tested statically
  - Moving target can be subsequently modeled.

Evaluation Procedure

- Address critical issues in COIC and LFT&E Strategy.
- Address ORD key performance parameters (KPP).
- Include realistic combat scenarios.
- Compare performance to that of legacy systems.
- Obtain side-by-side LFT data, if necessary.
- Identify design deficiencies to ensure correction before system proceeds beyond LRIP.
- Identify modeling deficiencies to improve analytical capabilities.

Models Support Evaluation

- **Pre-shot Predictions**
- **Post-shot Analysis**
- **Enhance Evaluation : Various ranges, targets, postures, Criteria**

Models for Terminal Ballistics/ Vulnerability-Lethality/Effectiveness

- **Single Projectile P(H) and P(I) Model - uses circles and rectangles, normal distributions with delivery errors.**
- **Salvo (Multiple Projectile) P(H) and P(I) Models - adds a within-burst distribution.**
- **Penetration Models - FATEPEN and THOR Equation, for body armor, ground vehicles, aircraft.**
- **Probability Distribution of Engagement Range - a target encounter density function (Gamma density).**
- **JMEM (Joint Munitions Effectiveness Manual) Arena Fragmentation Model - zoned data of mass, velocity, and number of fragments.**
- **CASTFOREM (Combined Arms and Support Task Force Evaluation Model) - a force-on-force combat model - Calculates LER (loss exchange ratio) for Red and Blue forces.**

Models for Terminal Ballistics/ Vulnerability-Lethality/Effectiveness (cont.)

- P(I/H) <u>Lethality Models for Wound Ballistics</u>
  - <u>Fragment and Flechette Model</u> (Kokinakis/Sperrazza). Based on MV3/2 and requires no experimental data. An older predictive method which is becoming outdated.
  - <u>Energy Transfer Model</u> (Dziemian). Based on energy transfer ∆E from 1 to 15 cm in a gelatin block. Uses empirical rules for estimating ∆E for spheres, cubes, and stable flechettes. Dynamical data in gelatin are required to evaluate bullets and tumbling flechettes.
  - <u>Expected Kinetic Energy (EKE) Transfer Model</u> (Sturdivan). Computes 45 discrete energy deposits multiplied by the probability of the projectile location in the discrete body tissue depths. Requires dynamical gelatin block data and is applicable to bullets and fragments, but is complex.

Models for Terminal Ballistics/ Vulnerability-Lethality/Effectiveness (cont.)

- P(I/H) Lethality Models for Wound Ballistics (cont.)
  - ComputerMan. Anatomical model of 80,000 cells for discrete shotline analysis. Simulates multiple wounding of fragmenting munition. Separates wound assessments and resulting biomechanical degradation from performance degradation.
  - ORCA (Operational Requirements-based Casualty Assessment). Extends the tactical roles to multi-service occupation codes. Maps injury to elemental capability vector, the occupational functions required and a performance assessment matrix to determine the probability of an operational casualty versus time.

Models for Terminal Ballistics/ Vulnerability-Lethality/Effectiveness (cont.)

- P(I) Models. Can also compute P(H) information.
  - FBAR Model. Calculated the expected value F of the fractional part of a single target or area target incapacitated. Uses a Monte Carlo simulation of a direct-fire weapon firing sweeps of bursts of bullets or fragmentation munitions. Multiple targets in a given rectangular region may be in specific positions or randomly distributed. Uses 2 or 3 normal distributions and provides mixed soldier postures and posture sequencing.
  - CASRED (Casualty Reduction) Model. Estimates effectiveness of bursting munitions and reduced effectiveness due to body armor. Uses submodels of weapon accuracy, fragmentation, environmental degradation, target parameters, penetration, lethality, and incapacitation. Outputs are polar grid plots of P(I) given a burst.

Models for Terminal Ballistics/ Vulnerability-Lethality/Effectiveness (cont.)

- **P(I) Models. (cont.)**
  - **<u>ICEM (Integrated Casualty Estimation Methodology).</u> Builds upon the modular start-to-end approach of CASRED with increased functionality, flexibility, and resolution. Incorporates the ORCA model and the ComputerMan model to extend the operational criteria beyond the current limb functions. Out-year objectives will add direct-fire bullets and effects of blast, flame, and blunt trauma.**

Models for Terminal Ballistics/ Vulnerability-Lethality/Effectiveness (cont.)

- P(K/H) and P(K) Models for Materiel Targets.
  - PVTM (Passive Vehicle Target Model). Monte Carlo simulation of direct-fire munitions vs ground vehicle targets for single-shot and burst-fire modes. The vehicle targets are passive, i.e., do not return fire, but may be stationary or moving. Computes cell by cell lethality to form polar grids and overall P(K) and P(H).
  - GEM (Gun Effectiveness Model). A simplified endgame simulation of an air defense gun without directed fire control. The target is a single aircraft in arbitrary orientation and displayed as a rectangle. Uses a table look-up to compute fly-out trajectory and weapon accuracy with salvo fire. Computes the vulnerable area of the projected target. Performs a random draw of P(K) values.
  - Target Descriptions. Provides geometrical details of the complete exterior and interior components for vulnerability analysis.

Models for Terminal Ballistics/ Vulnerability-Lethality/Effectiveness (cont.)

•P(K/H) and P(K) Models for Material Targets (cont.)

- MUVES (Modular Unix-Based Vulnerability Estimation Suite). Ground vehicle, component-level models using directly observed shotline test data. Computes M, F, and K kill values as a function of range, attack angle, and target exposure.
- AJEM (Advanced Joint Effectiveness Model). A lethality, vulnerability, and endgame simulation capable of analyzing threats attacking a single rotary-wing or fixed-wing aircraft. Capability extended to run in the MUVES environment for ground vehicles. Combines target model viewing, threat model, encounter kinematics, generation of burst points, propagation of damage mechanisms, and target interaction/loss of function. Also evaluates battle damage repair (BDR).
- HEIVAM (High Explosive Incendiary Vulnerability Assessment Model). A vulnerability model for analyzing aircraft attacked by HEI or SAPHEI munitions.

Models for Terminal Ballistics/ Vulnerability-Lethality/Effectiveness (cont.)

- P(K/H) and P(K) Models for Material Targets (cont.)
  - COVART (Computation of Vulnerable Area and Repair Time). An aircraft vulnerability model including blast effects.
  - MGEM (Modern Gun Effectiveness Model). A Monte Carlo simulation that evaluates air defense guns used at short range and low altitude. Uses submodules of the aircraft flight path, gun system sensor and tracker, predictor and gun servo, projectile ballistics and lethality and target vulnerability.

Summary of LFT&E Guidelines

- **Adhere to LF timelines** for tests and documents
- Plan LFT with **sufficient numbers of rounds and targets** in realistic combat scenarios.
- Monitor improvements in **modeling and simulation** to ensure their use in pre-shot predictions and test evaluations.
- Be responsive to **Critical Operational Issues and Criteria (COIC).**
- Keep informed of all **exploratory, DT, and OT pertinent to LF**.
- Ensure that the test design **provides sufficient data** to answer the critical issues.
- Combine **LFT with DT and OT** when feasible.

Well defined requirements simplify the evaluation.