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The development of a verification and validation (V&V) plan for a proposed tactical engagement simulation system for the AH-64D attack helicopter

Robert Andrew Pupalaikis

To the Graduate Council:

I am submitting herewith a thesis written by Robert Andrew Pupalaikis entitled "The development of a verification and validation (V&V) plan for a proposed tactical engagement simulation system for the AH-64D attack helicopter." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

William D. Lewis, Major Professor

We have read this thesis and recommend its acceptance:

Ralph D. Kimberlin, Fred W. Stellar

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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The Development of a Verification and Validation (V&V) Plan for a Proposed Tactical Engagement Simulation System for the AH-64D Attack Helicopter

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Robert A. Pupalaikis
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DEDICATION

To Nanètte and Eden

for all of your love, patience, and support.

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I thank Dr. William Lewis, Dr. Ralph Kimberlin, and Professor Fred Stellar who served as my thesis committee and foremost as mentors. With their consultation, criticism, and advice, I was able to achieve success that would have been otherwise impossible.

ABSTRACT

Advances in weapon systems technology creates the potential for increased warfighting capability. These advances simultaneously create the need for effective simulation systems of these contemporary technologies. The credibility and capability of these weapons systems Models and Simulation (M&S) are evaluated by a Verification and Validation (V&V) process, typically performed during the system development and subsequent Developmental Testing (DT). The tactical effectiveness and suitability of the integrated system are then evaluated through Operational Testing (OT). Historically, the tasks associated with DT and OT are performed by separate organizations in isolation.

This thesis proposes a methodology for the Verification and Validation of the weapons systems models implicit in the AH-64D Longbow Apache Tactical Engagement Simulation (TES) System. In addition, this thesis develops a V&V plan to evaluate the simulation provided by the integrated Longbow TES system. The design of this plan provides for the simultaneous collection of OT data to support system suitability evaluation. This will reduce future OT requirements, thus decreasing the time required for the acquisition cycle. This proposition of performing the TES V&V as a combination of DT (V&V) and OT supports the rapid prototyping philosophy which is useful in proving the concepts of new technology and complex systems.

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LIST OF ACRONYMS AND SYMBOLS

A_0	Operational Availability
AAR	After Action Review
ADA	Air Defense Artillery
AGM	Air-to-Ground-Missile
AH	Attack Helicopter
AIP	Aircraft Instrumentation Package
AKI	Aircraft Kill Indicator
AMCOM	Aviation and Missile Command
AMSAA	Army Materiel Systems Analysis Agency
AOI	Additional Operational Issue
ARS	Aerial Rocket System
ASDP	Army Software Development Process
ATEC	Army Test and Evaluation Command
ATESC	*Advanced Tactical Engagement Simulations Concepts*
AWS	Area Weapon System
BIT	Built In Test
CATS	Combined Arms Training Strategy
CCF	Central Collection Facility
CECOM	Communications and Electronics Command
CIU	Communications Interface Unit
CLS	Contractor Logistic Support
CMTC	Combat Maneuver Training Center
COI	Critical Operational Issue
COIC	Critical Operational Issues and Criteria
CPG	Copilot/Gunner
CTC	Combat Training Center
DBMS	DataBase Management System
DCI	Data Communications interface
DMSO	Defense Modeling and Simulation Office
DP	Display Processor

DT	Developmental Testing
EGI	Embedded GPS/INS
FCR	Fire Control Radar
FFAR	Folding Fin Aerial Rocket
FLASHWESS	FLASH Weapons Effect Signature Simulation
FOF	Force-on-Force
FY	Fiscal Year
GFE	Government Furnished Equipment
GFV	Government Furnished Vehicle
GPS	Global Positioning System
HFE	Human Factors Engineering
hr	hour
HTI	Homestation Training Instrumentation
HVAC	Heating Ventilation and Air Conditioning
ICU	Indicator Control Unit
IDM	Improved Data Modem
IHADSS	Integrated Helmet and Display Sight Subsystem
ILV	Improved Low Visibility
IOT	Initial Operational Test
IPS	Instrumentation Power Supply
JRTC	Joint Readiness Training Center
KBaud	KiloBaud
Km	Kilometer
LBHMMS	Longbow Hellfire Modular Missile System
LMP	Load Maintenance Panel
LRFD	Laser Rangefinder Designator
LRU	Line Replacement Unit

M&S	Models and Simulation
MAF	Mission Affecting Failure
MANPRINT	MANPoweR INTegration
MHz	megahertz
MK	Mark, as in Mark 66 rocket
mm	millimeter
MOS	Military Occupational Specialty
MP	MultiPurpose
MR	milliradian
mR	Maintenance Ratio
MSRR	Modeling and Simulation Resource Repository
MTBMAF	Mean Time Between Mission Affecting Failure
MTTR	Mean Time to Repair
MUX	Multiplex
NET	New Equipment Training
NTC	National Training Center
OC	Observer Controller
OPFOR	OPposing FORce
OPORD	OPeration ORDer
ORD	Operational Requirements Document
OT	Operational Testing
PD	Point Detonating
PEO	Program Executive Office
P_h	Probability-of-hit
P_k	Probability-of-kill
PM	Program Manager
PNVS	Pilot Night Vision Sensor
QR	Quality Research
RD	Requirements Document
RF	Radar/Radio Frequency

RFI	Radio Frequency Interferometer
RTCA	Real Time Casualty Assessment
RWR	Radar Warning Receiver
SAL	Semi Active Laser
SAWE	Simulated Area Weapons Effects
SME	Subject Matter Expert
SMODIM	SMart On-board Data Interface Module
SP	System Processor
STAARS	STandard After Action Review System
TADS	Target Acquisition Designation Sight
TALDT	Total Administrative and Logistics Delay Time
TCMA	Total Corrective Maintenance Actions
TCMT	Total Corrective Maintenance Time
TDPU	Training Data Playback Unit
TECU	TADS Electronic Control Unit
TES	Tactical Engagement Simulation
TEU	Tads Electronic Unit
TIR	Test Incident Report
TLIA	Training Laser Interface Adapter
TMAF	Total Mission Affecting Failures
TMDE	Training, Maintenance, and Diagnostic Equipment
TMMH	Total Maintenance Man Hours
TMT	Total Mission Time
TOT	Total Operating Time
TPMT	Total Preventative Maintenance Time
TRADOC	TRAining and DOCtrine Command
TSD	Tactical Situation Display
TST	Total Standby Time
TTM	TES System Training Missile
TTR	Time To Repair
USAAVNC	U. S. Army AViatioN Center
UTP	Unit Training Program

UTSI	University of Tennessee Space Institute
V&V	Verification and Validation
VRS	Video Recording System
VV&A	Verification, Validation, and Accreditation
WES	Weapons Effect Simulator
WSPS	Wire Strike Protection System
Δ	Delta
Δ_{AZT}	Training Zone Azimuth Delta
Δ_{RT}	Training Zone Range Delta

PART ONE

Part One explains the evolution of the need for a Tactical Engagement Simulation (TES) System for the AH-64D Longbow Apache Attack Helicopter, as well as its functions, elementary hardware, and software.

CHAPTER 1

INTRODUCTION

OVERVIEW

Advances in weapon systems technology creates the potential for increased warfighting capability. These advances simultaneously create the need for effective simulation systems of these contemporary technologies. Meeting the simulation requirements ensures that military training and warfighting strategies are in alignment, thus promoting the U. S. Army's "train-as-you-fight" objective. The evaluation of Tactical Engagement Simulation (TES) systems in a realistic operational environment is a formidable task. As part of Developmental Testing (DT), a weapon system simulation device and its implicit weapon system models must be evaluated in terms of the design intentions; further testing is then required to determine their performance in an operational environment. The credibility and capability of these models are typically assessed by a Verification and Validation (V&V) process. The V&V is normally performed during the system development and subsequent Developmental Testing. The tactical effectiveness and suitability of the integrated system is then evaluated through Operational Testing (OT). Developmental Tests and Operational

Tests encompass different tasks; historically, the tasks associated with DT and OT are performed in isolation. Considering the present day fiscal constraints placed on defense acquisition, it makes sense to accomplish the requirements of the V&V in conjunction with OT if the situation allows.

PURPOSE

This thesis proposes a methodology for the Verification and Validation of the weapons systems models implicit in the AH-64D Longbow Apache Tactical Engagement Simulation (TES) System. In addition, this thesis develops a V&V plan to evaluate the simulation provided by the proposed integrated Longbow TES system. The design of this plan provides for the simultaneous collection of OT data used to support the evaluation of system suitability to reduce the future OT requirements, thus decreasing the time required for the acquisition cycle and conserving resources. The resulting test plan, presented in Appendix B., consists of a description of the required tests, the conditions under which the system is to be tested, a statement of the test criteria, and a data management scheme. V&V activities can span a broad spectrum of issues. Consequently, the Verification and Validation techniques are specific to the Longbow TES System and may be altered for similar simulation applications. This approach can be expanded in detail and applied to future V&V efforts if required.

ORGANIZATION

This thesis is divided into three parts. Part One describes the development, functions, and the purpose of the Longbow Tactical Engagement Simulation System.

Part Two provides the description of the requirements for Verification and Validation, and proposed methodologies for V&V of the Longbow TES.

Part Three presents the development of a fundamental test plan by which a team can qualitatively and quantitatively evaluate the Longbow TES models and the integrated system in an operational environment. The methodology is founded upon the Army's approach to conducting materiel systems evaluations and is aimed at inspiring thought on how to accurately assess the Longbow TES models when faced with a prescribed test schedule and environment.

CHAPTER 2

OVERVIEW OF ARMY TACTICAL ENGAGEMENT SIMULATION

TRAINING PHILOSOPHY

The U. S. Army trains by using realistic, live maneuver exercises as a primary means of meeting combat readiness standards. These exercises involve combined arms training at the Army's Combat Training Centers (CTCs) and at the individual units' home stations. Soldiers train using real and surrogate weapons systems operating in authentic combat conditions. Competing demands for shrinking resources during the post Cold War era have dictated the need to meet readiness objectives at a lower cost. As a result, the Army of the late 1990s was faced with reducing its reliance on traditional resource-intensive operations and implementing new training methodologies. The resulting methodology combined field training exercises with virtual and constructive battle simulations to effectively train to standards at a lower resource cost. However, synthetic environments lack the realism generated by maneuvering forces under representative battlefield conditions. The virtual and constructive simulations can at best augment live maneuver training while never fully replacing it as the foundation of Army training. Live exercises, executed in field conditions using tactical equipment, are enhanced by simulation and simulators. One example is Tactical Engagement Simulation (TES) which replicates weapons actions and effects under combat conditions. The Army's TES training methodology is characterized by "...the free interplay of two forces using a Real Time Casualty Assessment (RTCA) system that reinforces training tasks through immediate feedback response to correct individual and collective task accomplishment" (TRADOC, 1998b, 1-3).

CURRENT AVIATION TES SYSTEMS

The current baseline of Tactical Engagement Simulation used for air to ground Force-on-Force (FOF) exercises at the CTCs provides for instrumented terrain and the use of the Multiple Integrated Laser Engagement System/Air to Ground Engagement System II (MILES/AGES II) and the Simulated Area Weapons Effects (SAWE) system. The MILES/AGES II simulates in real time, tactical engagements of select rotary wing aircraft and direct-fire ground weapon systems by the use of Line-of-Sight (LOS) laser transmitters and receivers to pair shooters and targeted vehicles. Casualty and damage assessment for the aircraft and ground vehicles are based on their vulnerabilities to various direct fire weapons; the MILES detectors recognize the type of weapon represented by the laser signal fired and apply the appropriate probability of kill (P_k) for an engagement. Audio and visual cues to the operators of the equipment involved in the engagement identify results as near-miss, hit, or kill. The MILES devices can interoperate with other simulators and external instrumentation systems to collect training performance data. These data serve as a primary source of information for After Action Reviews (AARs) for maneuver CTC exercises. MILES/AGES II is currently fielded both to units and to the maneuver CTCs for limited types of aircraft. The SAWE uses Radio Frequency (RF) and Global Positioning System (GPS) technology to simulate the effects of direct and indirect fire weapons and is currently fielded at the maneuver CTCs.

THE NEED FOR LONGBOW TES

The Longbow was scheduled to participate in the Army's Advanced Warfighting Experiment (AWE) "Task Force XXI" in 1997; however, an acceptable amount of training fidelity could not be realized since the aircraft's non Line-of-Sight missile capability would have to be excluded from the battle. Existing Real Time Casualty Assessment TES systems at all of the Army's three major maneuver Combat Training Centers and home stations are currently unable to support the full capabilities of the Longbow's weapons systems. Both the MILES and SAWE do not have growth provisions for emerging non-Line-of-Sight technology. The MILES II, is scheduled to be replaced within the next ten years by an upgraded version called MILES 2000. This new version will also be limited to use with LOS weapons systems. Reduced program funding for SAWE prohibits the integration of additional vehicle kits, weapons, or munitions. The growth of new weapons systems technology and capabilities are increasing faster than the advances in the training arena. Consequently, the present generation of Tactical Engagement Simulation systems are diminishing as effective training tools.

FUTURE TES

"Force XXI", a term used to define the modern, streamlined Army of the 21st century, is characterized by the use of predominantly digital information systems technology throughout the battlefield. Modernization initiatives projected for Force XXI have currently identified 275 systems or munitions which have potential use in live-fire exercises. The goal of generating realistic simulated engagement training for the Longbow weapons systems at the training centers and home stations poses an additional challenge since each CTC location differs in terms of instrumentation, weapon system simulation capability, data message formats, terrain, size, battlegroup makeup, and mission. As a solution to the weapon system/training environment disparity, the Army proposed an operational concept for the integration and standardization of Tactical Engagement Simulation throughout the Army. This concept is outlined in the *TES Master Plan* (MP). The Master Plan earmarks the Longbow Apache TES System to be fielded at the Joint Readiness Training Center

(JRTC), the Combat Maneuver Training Center (CMTC), the National Training Center (NTC), and at select unit home stations. The TES Master Plan defines numerous research efforts which assess and project the impacts of future technologies and Army force modernization initiatives on live training support. Two proposed research initiatives, The *Advanced Tactical Engagement Simulations Concepts* (ATESC) and *Future TES*, will define the feedback needed to train Force XXI and will identify the detailed requirements for future TES development and use. These initiatives however are programmed for Fiscal Year (FY)99-00 and FY01-02 research respectively. Therefore, in the interim, materiel, training, and combat developers must work closely on the development efforts for a new generation of TES to ensure the development is aligned with the Combined Arms Training Strategy (CATS) and compatible with the Army's anticipated training infrastructures. The training and combat developers must define the requirements of new training systems based upon the general guidelines set forth in the TES Master Plan. In order to direct a successful materiel development, the workgroups formed between the developers should be intimately involved with the process from its inception throughout the entire acquisition lifecycle.

LONGBOW TES DEVELOPMENT

Inter-Coastal Electronics (ICE), Incorporated of Mesa, Arizona was awarded contracts through the Army's Communications and Electronics Command (CECOM) and the Aviation and Missile Command (AMCOM) to conduct a proof of concept for a unit Homestation Training Instrumentation (HTI) system. The Homestation Training Instrumentation initiative aims to design a number of standard, fixed sight, state-of-the-art training centers capable of supporting new weapons capabilities while providing for a growth potential. The HTI will be an integrated system of computer software and hardware, workstations, databases, voice and video recorders, production and presentation equipment, interface devices, and communication systems. The system is to be capable of automated data collection and analysis to control tactical exercises and provide training performance feedback. The initial demonstration of this system was called Collective Helicopter Operations in a Combat Environment (CHOICE). The functions, interfaces, and equipment for a proposed Tactical Engagement Simulation system for the Longbow Apache were conceived and developed under the CHOICE system Phase I demonstration during the first quarter of FY98. ICE along with the Boeing Helicopter, are continuing the development of the Longbow TES System as an extension of the CHOICE capabilities.

VERIFICATION AND VALIDATION EFFORTS

As the proponent for the Longbow TES system, The U. S. Army Aviation Center (USAAVNC), U. S. Army Training and Doctrine Command (TRADOC) is examining the impact of new materiel systems development on combat aviation training. As a result, the Program Executive Office (PEO), Longbow Apache, directed an independent Verification and Validation (V&V) for the proposed TES system. The Program Manager (PM) requested assistance from Quality Research (QR), Incorporated and the University of Tennessee Space Institute (UTSI) flight systems research group to examine the proposed TES system at its current stage of development. That support was provided under contract number F40600-94-D-0001. The V&V effort for the integrated Longbow TES System was to be initiated during the August 1998 timeframe at Fort Hood, Texas, with it installed on Lot 1 aircraft; Serial No: 96-5001 through 96-5027, 97-5025, and 97-5027. The V&V plan was conceived, but due to scheduling the fully installed TES system was not available for operation. The V&V effort is projected to continue during FY-00 on Lot 4 aircraft.

CHAPTER 3

SYSTEMS DESCRIPTIONS

AH-64D LONGBOW APACHE ATTACK HELICOPTER

The AH-64D Longbow Apache helicopter is a twin engine, tandem seat aerial weapons platform (DA, 1988, 2-1). Wings attached to the center fuselage accommodate a total of four external stores/weapons pylons with hydraulic and electrical quick-disconnects. The Longbow is designed for multiple combat missions to include attack, reconnaissance, and security. The current AH-64D weapons subsystems include the M139 Area Weapon System (AWS) which includes the M230E1 30mm gun, Longbow Hellfire Modular Missile System (LBHMMS) with Radio Frequency (RF) and Semi-Active Laser (SAL) guided missiles, and the M140 Aerial Rocket System (ARS). A list of standard weapons configurations and associated mission profiles is presented as Table 3-1. A more detailed description of the aircraft weapons systems are included in Appendix A.

The Longbow is an improved variation of the AH-64A Apache. The significant technological improvement is the incorporation of a mast-mounted, millimeter wave Fire Control Radar (FCR). The FCR is an air/ground targeting system used in conjunction with the Hellfire Missile system to allow the aircrew to employ the

Table 3-1

AH-64 Mission Configurations

(Adapted from: Attack Helicopter Operations, p. A-5)

Load	Pylons				Role
	Left Outboard	**Left Inboard**	**Right Inboard**	**Right Outboard**	
A	4 Hellfire	19 Rockets	19 Rockets	4 Hellfire	Recon/Attack
B	4 Hellfire	fuel tank (230) gal.	19 Rockets	4 Hellfire	Recon/Attack
C	4 Hellfire	4 Hellfire	4 Hellfire	4 Hellfire	Attack
D	4 Hellfire	4 Hellfire	fuel tank (230) gal.	4 Hellfire	Attack
E	19 Rockets	19 Rockets	19 Rockets	19 Rockets	Recon/Attack, Security
F	19 Rockets	fuel tank (230) gal.	19 Rockets	19 Rockets	Recon/Attack
G	4 Hellfire	19 Rockets	fuel tank (230) gal.	4 Hellfire	Recon
Note: All loads include 1200 rounds of 30mm ammunition					

AGM-114K RF Hellfire Missile against non-Line-of-Sight targets. It is capable of operation during day or night and in adverse weather conditions. Other improvements include additional power, expanded avionics bays, upgraded systems processors, integrated avionics, refined crew stations, and an Improved Data Modem (IDM) that allows secure target and situation data transfer. The U. S. Army accepted the first production model AH-64D at the Boeing Company (formerly McDonnell Douglas) facility in Mesa, Arizona, on March 21, 1997. The Longbow Apache is depicted in Figure 3-1.

Figure 3-1

AH-64D Longbow Apache

(Source: Boeing, 1998)

TACTICAL ENGAGEMENT SIMULATION (TES) SYSTEM DESCRIPTION

General

The Longbow TES System is designed to perform Tactical Engagement Simulation using Global Positioning System geometric pairing technology and be interoperable with the current Multiple Integrated Laser Engagement System/Air-to-Ground Engagement Simulation (MILES/AGES II). The TES system is designed to faithfully replicate the capabilities of all on-board weapons systems, sensors, and designators for Force-on-Force training. The TES System is designed to provide for the following weapon engagement simulations: GPS geometric pairing of the Radio Frequency Hellfire missile, Semi-Active Laser Hellfire missile, Aerial Rocket System, and 30mm cannon. It is to also include laser simulation of the SAL Hellfire missile and 30mm cannon using eye-safe weapon system laser emitters. The TES system is projected to interface with the instrumentation systems planned for the National Training Center, Joint Readiness Training Center, Combat Maneuver Training Center, and select unit home station locations. Additionally, the TES System is designed to reduce Longbow Apache Contractor Logistic Support in the training environment (MDHC, 1997, 1).

TES System Instrumentation Package

The TES System Instrumentation Package consists of the following sub-elements: ten (10) sets of the Longbow Apache TES System Aircraft Instrumentation Package (AIP) equipment, one (1) Central Collection Facility (CCF) van, thirty-five (35) Target Instrumentation Kits to be used as a credible Opposing Force (OPFOR), four (4) Repeater Units, and two (2) Training Data Playback Units (TDPU). The capabilities from Phase I CHOICE will be expanded to include Real Time Casualty Assessment. Portions of the integrated TES System Instrumentation Package will be designed, built, tested, and fielded initially, while other portions are planned as optional efforts that will be exercised later.

Aircraft Instrumentation Package (AIP)

The Longbow TES Aircraft Instrumentation Package employs the Army's "embedded training" concept. This concept requires that a major portion of the essential training functions are built into the aircraft subsystems. The remainder of equipment and software are installed or attached to the aircraft when needed, and removed when not needed. The TES AIP consists of two separate subsystems, designated as the "A-Kit" and "B-Kit".

A-Kit Description The A-kit is limited to modifications that are made to on-board, organic aircraft software in order to conduct initialization and operation of TES, and Built In Test (BIT) functions. The A-Kit consists of software modifications to the following aircraft Line Replacement Units (LRUs) that support TES implementation:

- Weapons Processor (WP)
- System Processor (SP)
- Display Processor (DP)
- Communications Interface Unit (CIU)
- Radio Frequency Interferometer (RFI)
- Radar Warning Receiver (RWR)

- TADS Electronic Unit (TEU)

B Kit Description The B kit is comprised of the following appended hardware components plus embedded software:

- Smart On-Board Data Interface Module (SMODIM)
- Training Laser Interface Adapter (TLIA)
- Data Communications Interface (DCI)
- Indicator Control Unit (ICU)
- TES System Training Missile (TTM)
- Laser Rangefinder/Designator (LRFD)
- Area Weapon System Simulator (30mm Gun Laser)

The integrated TES System architecture is depicted in Figure 3-2; A Kit components are designated by an "A" and B Kit components are designated by a "B". A detailed description and photographs of the proposed Longbow TES System components are located in Appendix A.

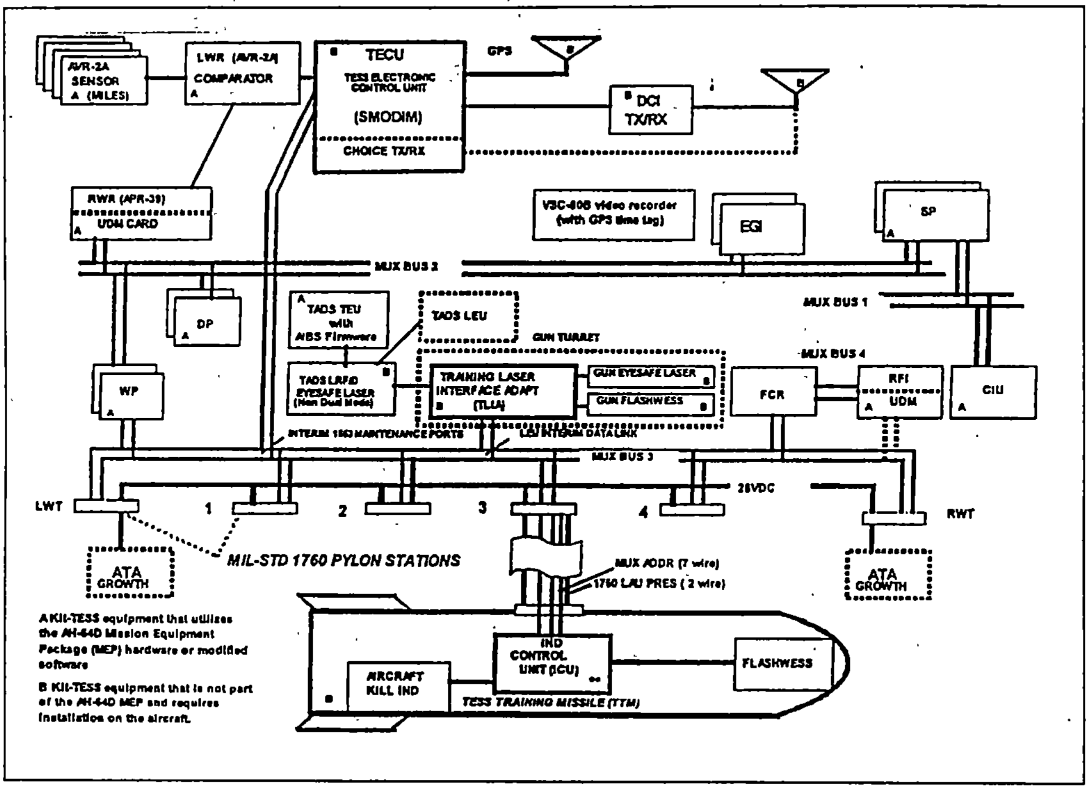


Figure 3-2

Longbow TES System Architecture

(Source: Production Longbow Test Plan, Phase II of TES System, p. 3)

CHAPTER 4

TACTICAL ENGAGEMENT SIMULATION (TES) AND MODEL

OPERATIONAL CONCEPT

Geometric Pairing

The Longbow's capability to employ the AGM-114K RF Hellfire Missile against non Line-of-Sight targets renders the MILES/AGES II incapable of performing RTCA commensurate with the aircraft's capabilities. Consequently, the Longbow TES System will employ a concept known as GPS geometric pairing to match all LOS and non-LOS weapons engagements. Using this concept, the aircraft and targeted vehicles are paired by their known positions as determined by GPS, for the purpose of performing RTCA. The AH-64D is equipped with a dual Embedded GPS/INS (EGI) that provides the aircraft position and velocity information. Raw data from the EGI in the helicopter are downlinked to a ground reference station, as depicted in Figure 4-1. The reference station computes the GPS pseudorange corrections, the rate of change of the corrections, and then applies the corrections to the aircraft's measurements to compute the actual time/space/position information. This method offers the option to send all GPS geometric pairing RTCA data to the CTC host computer where the data can be combined with other range data. During a non-LOS RF

Hellfire missile engagement, the Longbow's aimpoint location is determined by the FCR target position relative to the aircraft position provided by the EGI. During a LOS engagement, the aimpoint (range, azimuth, and look-down angle) is determined by triangulation referenced to the aircraft heading, attitude, and GPS position. The aimpoint information is extracted from the aircraft bus by the SMODIM and transmitted by the Data Communications Interface (DCI) to the range data management facility's host computer. The data facility then places the specific weapons footprint over the aimpoint and calculates the time (UTC time stamped) of the engagement event. The data

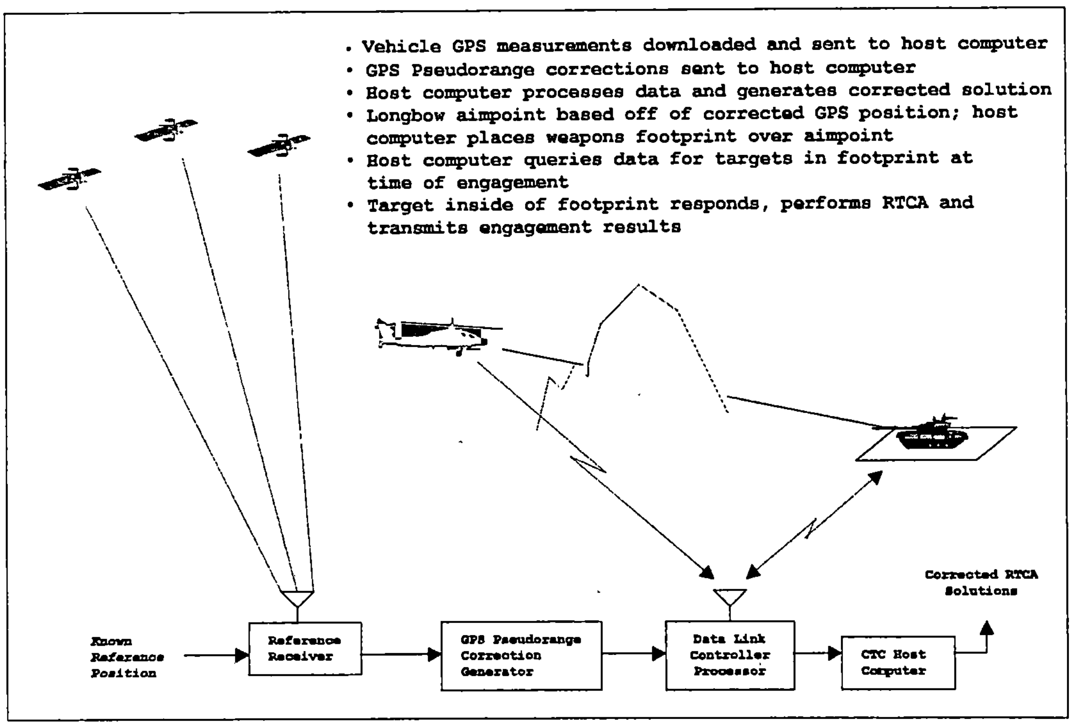


Figure 4-1

GPS Geometric Pairing (Non-Line-of-Sight Engagement)

facility searches back in time history and queries the data to determine which target was in the footprint when the weapons trigger was pulled. If a target was determined to be in the footprint at that time, the targeted vehicle will perform the RTCA computations and send the results of the engagement to the data management facility via a repeater for scoring. Software upgrades will be necessary for the communication networks at the CTCs to accept the Longbow TES data message structures. While operating at a unit's homestation, the TES System is designed to allow player aircraft to act as repeaters and establish its own communication network by use of the CHOICE System telemetry radio and the TES System Central Collection Facility. The Longbow TES System is projected to operate in the commercial (902-926) MHz band at a data rate of (115.2 KBaud).

WEAPONS SIMULATION

General

The TES System is to allow all weapons to be emulated when the system is placed in the "ready mode". The emulation will drive the display symbology to replicate actual weapons displays.

Gun Simulation

The gun rounds inventory is loaded through the weapons page by the flight crew. The Weapons Processor (WP) and the SMODIM decrement the rounds fired based upon the burst limit and trigger pull duration. Upon trigger pull, the WP commands the Training Laser Interface Adapter (TLIA) to fire the gun Flash Weapons Effect Signature Simulation (FLASHWESS)/LASER mounted on the 30mm gun. The TLIA provides a *"GUN LASER PRESENT"* message to the WP when the laser is installed on the gun. When the gun is enabled, the WP positions the gun to the Line-of-Sight (LOS) of the crewmember that has selected the gun. The WP applies fuselage body bending corrections, gun boresight corrections, and parallax corrections when determining the LOS. The display in the Display Processor (DP) will be identical to that of an actual gun engagement. The System Processor will generate gun sound effects based upon WP firing data.

Rocket Simulation

The rocket type, quantity, and zone are automatically determined by the SMODIM. During the initialization process, the SMODIM reads the inventory previously loaded into the rocket Load Maintenance Panel (LMP) by the groundcrew. A trigger pull results in the rocket inventory being decremented based upon the zone, type fuze selected, and trigger pull duration. When the rocket system is enabled, the Weapons Processor positions the rocket steering cursor to the LOS of the crewmember who actioned the weapon; the aimpoint is computed based upon the selected LOS. The FLASHWESS will simulate rocket fire effects and the System Processor (SP) will simulate rocket sound effects. Additionally, the pylons will articulate as they would with the actual weapon system.

Hellfire Simulation

The missile type and quantity information is loaded during the inventory initialization; each missile type is emulated. Display information is sent to the DP to replicate tactical displays. Upon trigger pull, the Weapons Processor sends the missile launch status, tracking, and missile time of flight to the DP and subsequently decrements the missile count.

TES MODEL

A preliminary model for a rocket engagement is presented as described in a developmental information paper prepared by McDonnell Douglas Helicopter Systems. The model has been translated from computer code and is presented in a form which allows the reader to understand its composition and the relevance of specific event data required for a simulated weapons engagement of this type. One example illustrates the simulation sufficiently to provoke thought on how to formulate a test for model fidelity.

Geometrically Paired RTCA Rocket Engagement

Cockpit Displays The rockets inventory, quantity, fuze and warhead type, and system status are provided to the aircrew by the TES System through the rocket system controls display (Figure 4-2).

Preconditions for the event The firing restrictions and limitations imposed by the aircraft are described as a prelude to an example rocket engagement. The aircraft will restrict the crew from firing when the:

- Aerial Rocket System (ARS) detects a failure
- Salvo limit is reached
- Rocket inventory ≤ 0

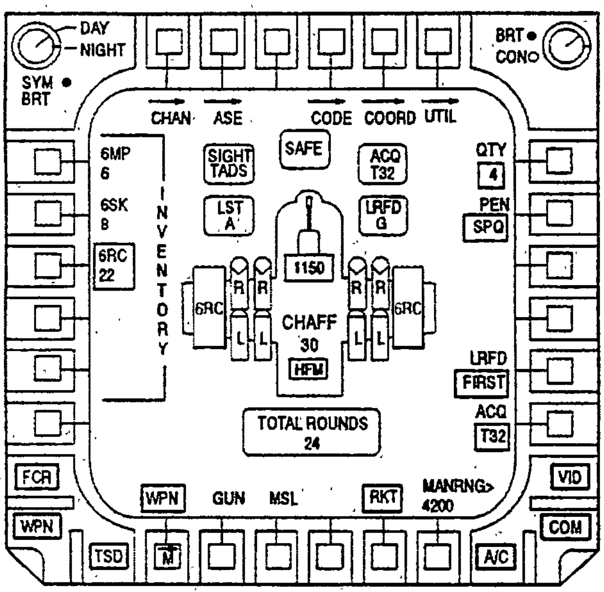


Figure 4-2

Aerial Rocket System Controls

(Source: Operator's Manual for AH-64D Helicopter, P. 4-81)

The target zone or "target footprint" is determined by the rocket type which has been inventoried. For the MK66 rocket with a Point Detonating (PD) warhead, the target zone range delta (Δ_{RT}) = 125m, and the target zone azimuth delta (Δ_{AZT}) = 23mR. This means the TES System constructs a virtual box that is 125 meters deep and 23 milliradians wide that defines the impact zone of the rockets. For the MK66 rocket with the Multi-Purpose submunitions (MP) warhead, the (Δ_{RT}) = 200m, and (Δ_{AZT}) = 34mR. Table 4-1 depicts the probability-of-hit (P_h) as a function of the target characteristics ("hard-skin" vs. "soft-skin"), and warhead type. For actual aerial rocket shots, angular errors produce a larger and larger footprint with increased range, thus the widening of the target zone with increased range is a good modeling assumption. Referencing table 4-1, the P_h is independent of the range when the constraints have been met with no limitations. It is however, contingent upon the number of rocket pairs fired during an engagement sequence. For each additional pair of rockets launched during an engagement, the probability-of-hit is defined by the following binomial expansion in disguise:

$$P_{h\ n\ pairs} = 1 - (1 - P_{h\ 1\ pair})^{n\ pairs}$$

This expression implies that regardless of how many pairs are fired, the P_h reflects the probability of at least one pair hitting the target. The expression says nothing about the

Table 4-1

Rocket Event Probability of Hit (P_h) for Pair Fired

(Adapted from: TES System Geometric Real Time Casualty Assessment (RTCA), p. 23)

	Rocket Type, 6PD			Rocket Type, 6MP	
Target Zone Azimuth Delta (Δ_{RT}), mR	23mR			34mR	
Target Zone Range Delta (Δ_{AZT}), mR	125m			200m	
Range, m	**(P_h) soft**	**(P_h) hard**	**Target Δ (m)**	**(P_h) soft**	**(P_h) hard**
500 - 1500	0.035	0.035	540	0.15	0
1500 - 2000	0.035	0.035	630	0.15	0
2500 - 3500	0.035	0.035	520	0.15	0
3500 - 4500	0.035	0.035	330	0.15	0
4500 - 5500	0.035	0.035	240	0.15	0
5500 - 6500	0.035	0.035	160	0.15	0
6500 - 7500	0.035	0.035	105	0.15	0
>7500	0.035	0.035	70	0.15	0

probability of hitting with 2,3 ... or *n* pairs, or even killing the target. Understanding this fundamental P_h characteristic will be important for constructing the test to verify the model.

The model also imposes a degradation in P_h when the commanded pylons position is at the limit. When the crew receives an "AT LIMITS" message, the target range is re-calculated by subtracting a Range Delta from the crew's selected range. The Range Delta is defined as:

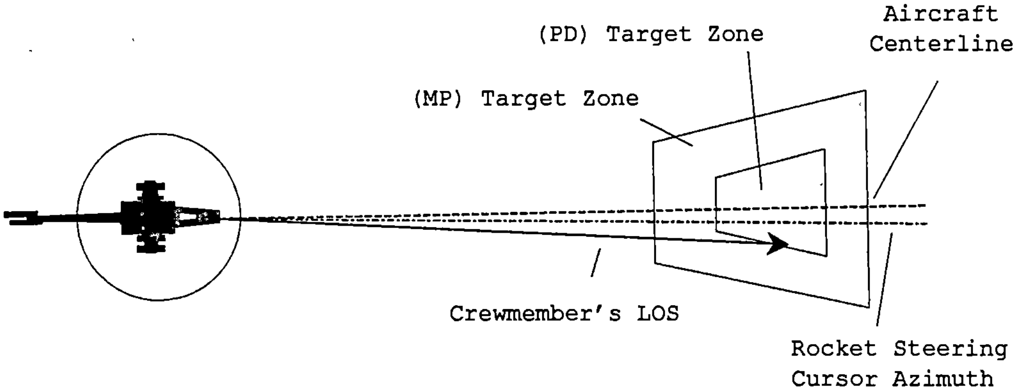
Range Delta = (Pylon Elevation - 4°) x Target Δ

where: Target Δ = (value from Table 4-1)

The Engagement Sequence When the rockets are selected and the weapons trigger is pulled and the aircraft detects no firing restrictions, then the weapon event is initiated. When the firing terminates and the rocket type has been detected as 6PD or 6MP, then the range delta is applied if necessary. The TADS Electronic Control Unit converts the MUX data to a weapon event message and transmits the message to all players. The players determine the Longbow Apache rocket weapon event from the data. If a player was in the target zone (referenced to the aircraft GPS position) at the weapon event time, then the player continues to process the message. The player or players in the target zone perform(s) the RTCA based upon the P_h data (Table 4-1) from the received message. The target position is a function of the following independent variables: aircraft position, aircraft heading, rocket steering cursor azimuth offset, and firing crewmember's LOS. When the actual time equals the time of impact of the previously stored weapon event message or if the time of impact has passed, the RTCA results are implemented and the target notifies its status. Figure 4-3 depicts the geometrically-paired rocket engagement.

Model Assumptions

For the purpose of simplification, the rocket event model employs certain assumptions:



Rocket Geometric Event
• Longbow Player ID • Event Time (event end time) • Weapon Type (Rocket-6PD or 6MP) • Aircraft Position • Target Position • Target Zone 6PD for point detonating warhead 6MP for submunition warhead • Time of Impact • Rockets Fired • P_h: F(range, warhead, rockets fired)

Figure 4-3

Geometrically Paired Rocket Event

(Adapted from: Real Time Casualty Assessment (RTCA) for the Longbow TES System, 1998)

- all Longbow aircraft perform identically if the event conditions are met.
- all environmental and human factors influences affecting the engagement remain constant.

The P_h for each munitions type in the model is purely an average that has been determined over time. The constants implicit in this average are weather and atmospheric conditions, ballistics, crew experience, and proficiency. A moderately experienced attack helicopter aircrew realizes that the dispersion pattern is also a function of aircraft accelerations (natural and pilot induced) and the effects of rotor downwash inconsistencies which can be influenced by the crew. Additionally, asymmetrical dispersion may be pronounced due to crosswinds. The model essentially rewards a substandard or inexperienced crew with a higher P_h while employing improper weapons techniques. Conversely, it applies an artificially low P_h to a crew that adjusts for aircraft inconsistencies. The important point is that this model like all others that attempt to simulate some aspect of reality, has limitations. It is recommended that the materiel, combat, and training developers work in coordination with the Army Material Systems Analysis Agency (AMSAA) to focus the development efforts on weapons systems models that take into account the aircraft accelerations and aerial ballistic effects. These would be superior to the preliminary rocket model which simply applies a generic P_h given the launch constraints have been met. When the Longbow TES System weapons models to be used for RTCA are made available, the developers should look closely at the limitations and collectively determine the amount of training fidelity that can be sacrificed for training benefit. The development team must also weigh the training fidelity against the cost per unit improvement of model design and determine to what degree the added fidelity would justify the extra cost.

PART TWO

Part Two provides the description of the requirements for Verification and Validation, and proposed methodologies for V&V of the Longbow TES.

CHAPTER 5

VERIFICATION, VALIDATION & ACCREDITATION

GENERAL

Verification, Validation, and Accreditation (VV&A) refers to the total process used to ensure that the application of Models and Simulations (M&S) results are appropriate for a specified purpose. The term VV&A does not refer to a single entity, but rather consists of three separate processes that address Verification, Validation, and Accreditation of M&S separately. Verification and Validation (V&V) functions are performed throughout the M&S development process. Accreditation is a subsequent decision to use M&S and the results for a particular application. The intent of this Verification and Validation is to measure the credibility and capability of the Tactical Engagement Simulation performed by the proposed Tactical Engagement Simulation System for the Longbow Apache. A subsequent accreditation will formally approve, conditionally approve, or disapprove the integrated system as an adequate weapons system simulator to be used in a representative operational environment.

TERMINOLOGY

The precise definitions of the terminology used in the intent statement of this VV&A are essential to understanding the activities involved, the scope of these activities, and the techniques used to establish the value of the TES System as a training tool. The definitions are consistent with those currently used throughout the Department of Defense (DoD) and industry.

Models and Simulation (M&S)

Model According to Army Regulation 5-11, a model is a "physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process" (DA, 1997b, 16). In the case of the Longbow TES, the model is the conceptualization of the aircraft weapons systems capabilities converted into mathematical equations and solution approaches (algorithms).

Simulation A simulation is the software implementation of the equations within the context of a scenario. Simulation is a method for implementing a model over time (ibid, 17). The software used to represent the actions and effects of the aircraft weapons systems is the simulation in the case of Longbow TES. The U. S. Army recognizes three categories of simulations: virtual, constructive, and live. Virtual simulation involves networking a series of simulators to support collective training on a simulated battlefield. Constructive simulation uses networked computers to conduct wargames that focus on command and control decision making. Live simulations are combined arms field training exercises, conducted by soldiers employing real and training weapons systems in representative battlefield conditions.

The Tactical Engagement Simulation System, composed of a combination of hardware and software, is a tool designed for the purpose of carrying out the effects of live simulation. It is in essence, a simulator, intended to provide an artificial, but realistic environment in which a pilot can interact with certain aspects of reality. The simulator aims to reproduce those aspects of reality essential to training Army pilots in the proper employment of weapons systems and contemporary attack helicopter tactics in a representative operational environment.

Verification Fundamentals

Verification focuses on the capability of the Models and Simulations. According to DA PAM 5-11, verification is the process of determining that a model accurately represents the developer's conceptual description and specifications, and meets the user's needs stated in the requirements document (DA, 1993, 26).

Validation Fundamentals

Validation focuses on the credibility of the Models and Simulations. According to DA PAM 5-11, validation is "the process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model" (ibid, 26). It is important that emphasis is placed on assessing the Tactical Engagement Simulation in terms of how it will be used. This emphasis determines the degree of detail that must be represented for the simulation to provide meaningful results, and the degree of relationship with real-world phenomena that will be sufficient in order to use the TES with confidence.

Validation aims to ensure that the simulation conforms to a specified level of fidelity when the TES system outputs are compared to real-world weapons engagements. Thus, there are two stipulations for good validation: an understanding of the intended use of the model, and a clear definition of the real-world. Knowledge of the intended use outlines the requirements for what needs to be modeled and how well those functions need to match the real-world.

Accreditation Fundamentals

Once a simulation has been verified and validated in accordance with requirements defined by the intended application, a determination of accreditation for the specified use is made.

According to DA PAM 5-11, "accreditation is the official certification that a model or simulation is acceptable to be used for a specific purpose" (ibid, 25). Accreditation should not be considered an assumed conclusion. It is a decision that a specific simulation can be used for a specific application, based on evidence of suitability for the application. Neither is it intended to be a binary choice; credit or not accredit. The accreditation process makes provisions for conditional accreditation pending evidence of increased suitability for the application. To ensure that confidence in the TES is justified, the V&V should ensure that the modeling assumptions are well documented, the results produced by the M&S are reasonable, and the correlation between the M&S behavior and real-world behavior is understood.

V&V TASK SELECTION

The *Longbow TES System Requirements Document* defines the functional requirements, which specify what the TES must be able to do: "...*faithfully* replicate the weapons systems of the Longbow Apache" (TRADOC, 1997, 1). The fidelity requirements, are broadly defined by the term faithfully. How closely these functions of the TES correspond to the real-world will determine the adequacy of the system for use as a training tool. The accepted techniques used for V&V are generally grouped into four categories: informal, static, dynamic, and formal. Informal techniques to a large degree depend on human reasoning and subjectivity without the use of rigorous mathematical concepts. Static techniques examine the accuracy of a static model design and its source code. Dynamic techniques assess the behavior of model outputs based upon specific inputs. Formal techniques rely heavily upon the use of formal mathematical proofs (DMSO, 1996, 4-1). Table 5-1 depicts the four general V&V categories and some commonly used techniques associated with each. The TES weapons models (algorithms) and the integrated TES System will be evaluated through the use of dynamic V&V techniques; specifically functional testing or *black-box testing*, and field testing. Functional testing assesses the accuracy of input-output transformation (DMSO, 1996, 4-18). The concept of functional testing is depicted in Figure 5-1; the behavior of the models outputs (specifically the prescribed P_h associated with each

Table 5-1

V&V Categories and Techniques

(Adapted from: VV&A Recommended Practices Guide, p. 4-2)

Informal	Static	Dynamic	Formal
Audit	Data Flow Analysis	Functional Testing	Induction
Inspection	Fault/Failure Analysis	Field Testing	Inference
Review	Cause-effect analysis	Product Testing	Logical Deduction
Walkthrough	Structural Analysis	Performance Testing	Inductive Assertion

algorithm) and the degree to which the integrated TES System replicates the real-world, will be assessed based on specific inputs (realistic operating conditions). Field testing is a generic term used to describe any tests which are conducted by placing M&S in operational scenarios. Field testing is a major element of V&V activities conducted during the development of new weapons systems and military combat systems in general, and is regularly conducted as part of the test and evaluation process for DoD system acquisition. Other methods in the category of dynamic V&V techniques that are suitable for the validation of the Longbow TES are product testing, performance testing, and field testing. Product testing is normally conducted by the M&S developer after a piecewise validation has been performed on all

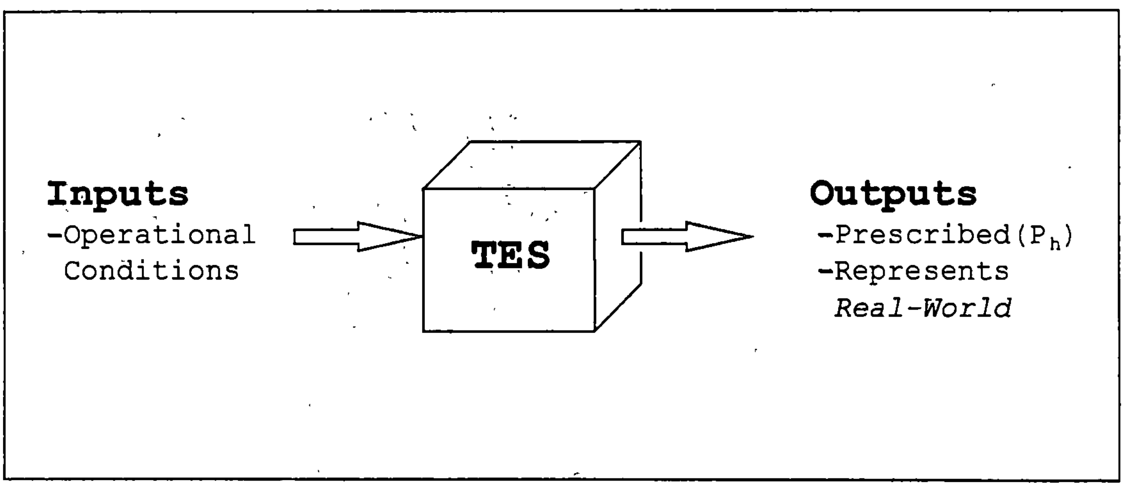


Figure 5-1

Dynamic V&V of Longbow TES

of the sub-components, and before the acceptance testing is performed by the M&S sponsor or proponent (Schach, 1996). Performance testing is used to substantiate system performance characteristics (Blanchard, 1990). Product testing and performance testing activities were scheduled to be completed by the prime contractor and the materiel developer prior to this V&V effort, but due to system availability, were not conducted.

VERIFICATION METHODOLOGY

The proposed models verification methodology is a rudimentary form of functional testing. The weapons systems models will be run under test data; their accurate execution will be substantiated through attaining the representative P_h for each engagement type, given the appropriate operational inputs and firing constraints. Models are typically evaluated by comparing their outputs to the actual system outputs after both the model and the system are run under identical test data. Multivariate statistical techniques are then used to correlate the outputs (DMSO, 1996, 4-27). This proposed methodology relies on the use of weapons algorithms created from correct and accurate ballistics data. This precludes the need to simultaneously evaluate the P_h of the actual weapons systems, and the use of rigorous statistical analyses. The methodology employs the use of a "success template" and tracking sheet for each engagement type. The success template defines success as achieving the expected number of hits for the particular engagement type under the prescribed conditions. The preliminary RTCA rocket engagement from Chapter 4 is referenced for the purpose of presenting an example template and tracking sheet. The appropriate conditions were extracted from Table 4-1; (Rocket Event P_h for Pair Fired) to derive the rocket event template depicted as Table 5-2. As an example, during an engagement sequence, the model is executed and the hit information is recorded to an output file used for the RTCA process. The output file is examined to reveal the actual hit/miss information. The inputs (firing constraints data and the independent variables) are extracted from the symbology, messages, icons, and video from the Longbow's on-board Video Recording System. These input data and the output are copied to the rocket event tracking sheet (Appendix D, Figure D-1) maintained in the performance database. The DataBase Management System (DBMS) is explained in detail in Appendix B. The output data provided by the RTCA process will be verified over time to ensure that the outputs correlate with their associated inputs. If the hit data does not meet the required minimum percentage, a causality investigation will be initiated. A causality investigation will also be prompted if the system awards hits when the firing constraints are not met. The most realistic simulation occurs during battles supported by RTCA; testing during these events however, is resource intensive due to complex instrumentation requirements (DA, 1997c, 6.29).

Table 5-2

Rocket Event Success Template

Independent Variables			Required Output (P_h)
Target Type	**Warhead Type**	**Pair(s) Fired**	
Hard/Soft-Skin	(PD)	1	0.0350
		2	0.0688
		3	0.1014
		4	0.1328
Soft-Skin	(MP)	1	0.1500
		2	0.2775
		3	0.3859
		4	0.4780

The advantage of this methodology is that the instrumentation requirements are minimized. There is no need for additional instrumentation beyond that required for RTCA. Considering the complexity of the software and hardware interfaces of the integrated TES System, this input-output correlation is an effective means to assist in detecting possible model representation errors as a result of message-passing between the various sub-modules of the integrated system. The construction of the success templates and their associated tracking sheets were initiated but have not been completed due to the lack of availability of approved weapons algorithms for the proposed system. Additionally, the data transmission protocol for the RTCA process (to provide hit/miss information) is not available. It is recommended that following the implementation of the weapons algorithms and the development of the RTCA capability, the Program Manager in coordination with Army research analysts further refine and implement the success template/tracking methodology for the V&V of the integrated Longbow TES System.

VALIDATION METHODOLOGY

The proposed validation methodology assesses the degree to which the TES System accurately represents real-world weapons employment, actions, and effects from the perspective of the system operators. The methodology however, is not intended to validate that the demonstrated (P_h) of the TES models match the expectations of the aircrews. This correlation is implicit in the selection of weapons algorithms based upon correct and accurate ballistics data, and ideally is a precondition for the V&V of the integrated system. The methodology requires that system operators complete questionnaires to rate the capability of the TES system to perform the required simulation. The user rating questionnaire is presented as Appendix C, Data Collection Form 1. A comparative rating scale is used to compare specific phenomena in relation to the Longbow Apache. Example survey statements are "The displayed weapons symbology with the TES System installed *were identical* to the symbology presented during normal operations" and "The weapons initialization procedures with the TES system installed *were identical* to the procedures during normal operations". The ratings are based on a scale from 1 to 5, where 1 = strongly disagree and 5 = strongly agree. Any response less than 4 is considered a negative response. The comparative rating scale was selected over the use of binary choices; yes or no answers. This allows each question to encompass a broad scope and precludes a protracted survey where its length outweighs its usefulness for gathering information (Fink, 1998, 29). For example, the statement regarding the symbology incorporates the gun, rockets, missiles and all other ancillary symbology, messages, and icons provided during a tactical engagement. If a pilot responds to this statement with any value less than 5, his substantiating comment(s) may reveal an anomaly that would not have been disclosed by the use of "yes or no" answers; the survey may not have made provisions which cover that specific anomaly. The questionnaire responses will be entered into the performance database. Additionally, data will be aggregated from the Longbow's on-board Video Recording System (VRS) to augment questionable system-rating data when necessary. The results of each question will be tabulated; the mean value will be calculated among the survey population and provided as output. The results of each supporting question will then be arithmetically averaged to arrive at a quantitative measure. Implicit in this measurement approach is that the numeric results of each question are identically weighted. The design of each question allows it to cover a broad area without any overlap into another domain. For example, the statement referring to the display of symbology will not overlap with that pertaining to the weapons initialization procedures unless it can be determined that incorrectly displayed symbology caused the crew to make an adjustment to the initialization procedures. The benefit of such a performance measurement strategy where the criterion is determined by the arithmetic mean is that it allows the survey questions to be modified anytime without making major adjustments to the relative weights. The survey composition may be arbitrated between the Program Manager and the materiel developer prior to implementation; adjustments can be made quickly and easily. The shortcoming to such a method is demonstrated as follows. The TES system proponent may deem that the real value of the TES lies in its ability to promote positive habit transfer in weapons employment. Consider a case where the TES System presents two anomalies, one which forces the crew to alter the way that they must select the weapon during an engagement sequence, and another which manifests itself as the inability of the system to show the rounds decrement after successive engagements. The proponent may view the alteration in the weapon selection procedures by the crew to be more crucial to training and thus be required to have a greater effect on the quantitative output. The important point is, regardless of which method is chosen, the database outputs for each statement clearly depict the operators' unadjusted relative rating of the TES System. Database output for the pilot's questionnaire using sample data is included as Appendix D, Figure D-2.

V&V IN THE TES LIFECYCLE

The unavailability of the weapons algorithms and the lack of RTCA capability are major limitations to the V&V of the integrated TES System. The decision to conduct V&V of the integrated system at the current stage of development was premature. Ideally, the V&V activities should have been initiated during the "application process" when the initial need for Longbow TES was identified. The V&V activities should continue throughout the acquisition lifecycle.

It is recommended that the Program Manager work closely with the materiel developer and actively conduct and manage V&V activities at all stages of Longbow TES development. These activities should include but not be limited to:

- ensuring correctness and accuracy of the selected weapons algorithms prior to their implementation.
- focusing V&V activities to support the development of RTCA using GPS geometric pairing technology.
- emplacing formal procedures for configuration management and documentation status.

In addition, subsequent V&V efforts should be documented in the Army's Modeling and Simulation Resource Repository (MSRR). This would ensure that the materiel, combat, and training developers have easy access to information regarding TES development, thus providing clear focus for future V&V efforts. The MSRR can potentially foster Longbow TES development through additional sources within the M&S community; the repository promotes leveraging of M&S technology throughout DoD by information sharing and communication.

PART THREE

Part Three presents the development of a fundamental Test Design Plan to quantitatively and qualitatively evaluate the TES weapons models and the integrated TES System in an operational environment.

CHAPTER 6

DEVELOPMENT OF THE V&V

GENERAL

An Initial Operational Test (IOT) was selected as the format of the Verification and Validation for the Longbow TES System to determine its operational effectiveness and suitability. The Army defines IOT as "a field test, conducted under realistic operational conditions, of a production or production-representative system for use by typical users in combat or otherwise deployed" (DA, 1995, 5-3). An IOT is conducted any time prior to the Milestone III development phase of materiel systems, typically to support a full-rate production decision. Modeling this V&V plan as an IOT is not intended to circumvent the requirements set forth in AR 73-1 and other applicable Army Regulations, nor is it proposed in lieu of specific tests required by the Army prior to a production decision. The selection of an IOT format was two-fold. The IOT is an Army recognized method which implies a dynamic V&V technique through the use of field testing; in the case of TES, the IOT lends itself to model verification. Furthermore, the IOT format allows for additional, important non-V&V data to be collected simultaneously. These additional data, normally collected during Operational Tests will assess the suitability of the TES System. Where possible, these data will be accepted as valid OT data to reduce the future OT requirements, thus decreasing the time required for the acquisition cycle and conserving resources. This philosophy is consistent with the Army's Accelerated Software Development Process (ASDP) to expedite the development, testing, and fielding of materiel systems with extensive embedded software. In the past, traditional weapon system OT required the entire system to successfully complete OT before being fielded. The ASDP allows for incremental blocks of testing and subsequent fielding of portions of software intensive systems once successful OT of a representative sample has been performed (DA, 1997c, 2.8). Performing the TES V&V as a combination of DT (V&V) and OT supports the rapid prototyping philosophy of the ASDP. Considering the complexity of the integrated TES System, rapid prototyping is useful in proving the concept of RTCA through the use of GPS geometric pairing. Additionally, due to the lack of explicit guidance by the TES Master Plan, and because the lack of detailed requirements for future TES development, the IOT format facilitates examining the interoperability with the future CTC and homestation training infrastructures.

Development of the V&V for the Longbow TES System was accomplished by following the basic steps traditionally used in the DoD materiel systems evaluation process. The important points of each step relative to the Longbow TES System are emphasized. The basic steps include the following:

Step 1: Understand System/Mission/Operating Environment

Step 2: Develop Operational Issues

Step 3: Determine Criteria

Step 4: Formulate Measures

Step 5: Determine Data Elements

Step 6: Develop Evaluation Plan, to Include:

- Define Test Events
- Define Test Conditions
- Determine Sample Sizes and Operating Times
- Develop a Data Management Scheme

Step 7: Review V&V Plan (Steps 2-6) by Subject Matter Experts and the Program Manager

UNDERSTANDING SYSTEM/MISSION/OPERATING ENVIRONMENT

The preparation for the V&V was initiated by a literature review to obtain a background history of TES, the proposed employment and maintenance concepts, and training implications. Information regarding the Longbow Apache and the baseline of RTCA systems currently available for aviation Force-on-Force training was reviewed. Additionally, an on-sight inspection of the progress of Longbow TES was conducted at the Boeing Plant facility and the ICE facility in Mesa, Arizona, and at Fort Hood, Texas.

ESTABLISHING ISSUES

Operational issues include any aspect of the proposed TES system capabilities that must be tested to determine the system effectiveness or suitability. The issues collectively determine if the system meets a capability and to what degree. The operational issues were derived from the required capabilities listed in the *Longbow TES System Requirements Document*. As an example, "Does the TES System faithfully simulate the actions and effects of the aircraft weapons systems?" is one of the operational issues. The required capabilities have been formalized as issues and sub-issues and then arranged in a "dendritic" structure. The dendritic technique, a procedure commonly used by the Army for presenting operational issues, requires that the system functions are first listed and then divided into primary issues. The primary issues are subdivided into lower issues known as test criteria. The process, depicted in Figure 6-1, is continued until all issues terminate at data elements. Data are items which can be collected without any judgment on the part of the data collector and are not predicated on any previous tests. This subdivision process provides a linkage between the data elements necessary to satisfy the operational issues, and an easy reference to the issues at later stages in test preparation and during the evaluation process. Figures 6-2 and 6-3 are initial dendritic diagrams depicting the required capabilities established by the *Longbow TES System Requirements Document*.

Critical Issues

Critical issues identified for OT are typically those issues which are of primary importance to the Program Manager (PM) or the decision making authority for determining if the system is to continue at the milestone III phase of acquisition. In the case of this V&V effort, the critical issues verify and validate the TES models and the fidelity of the simulation

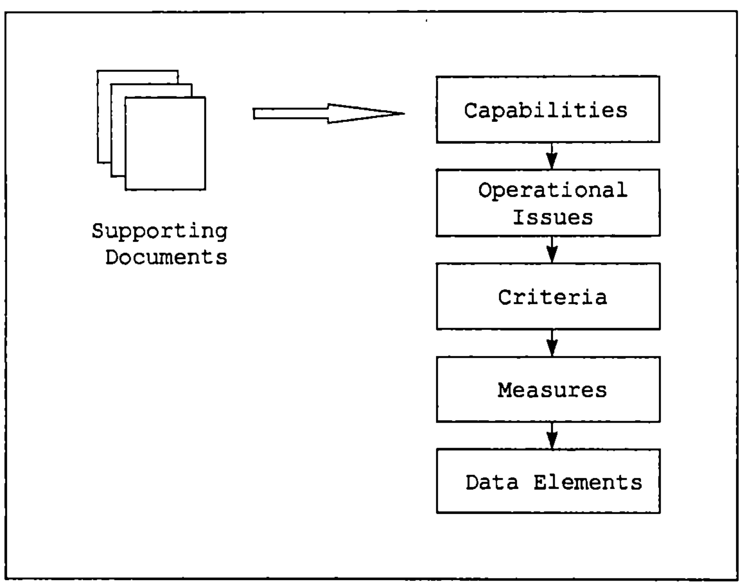


Figure 6-1

Dendritic Technique

Performance Capabilities

- The TES System will provide a means of simulated kills for Real Time Casualty Assessment (RTCA) during Force-on-Force collective training exercises.
- The TES System will operate in the same geographical area, climatological, and weather conditions as the MILES/AGES.
- The TES System will interface and be compatable with the AH-64D Longbow Apache weapons systems suite.
- The TES System will employ the same procedures with the same accuracy as the actual weapons systems.
- The TES System will be capable of flash and smoke effects representative of actual weapons employment.
- The TES System will capitalize on on MILES/AGES and SAWE technology to replicate the Longbow Hellfire missile fire-and-forget capability.
- The TES System will be integrated with other aircraft systems to minimize the necessity to rely on MILES/AGES technology.

Figure 6-2

TES System Required Capabilities (Performance)

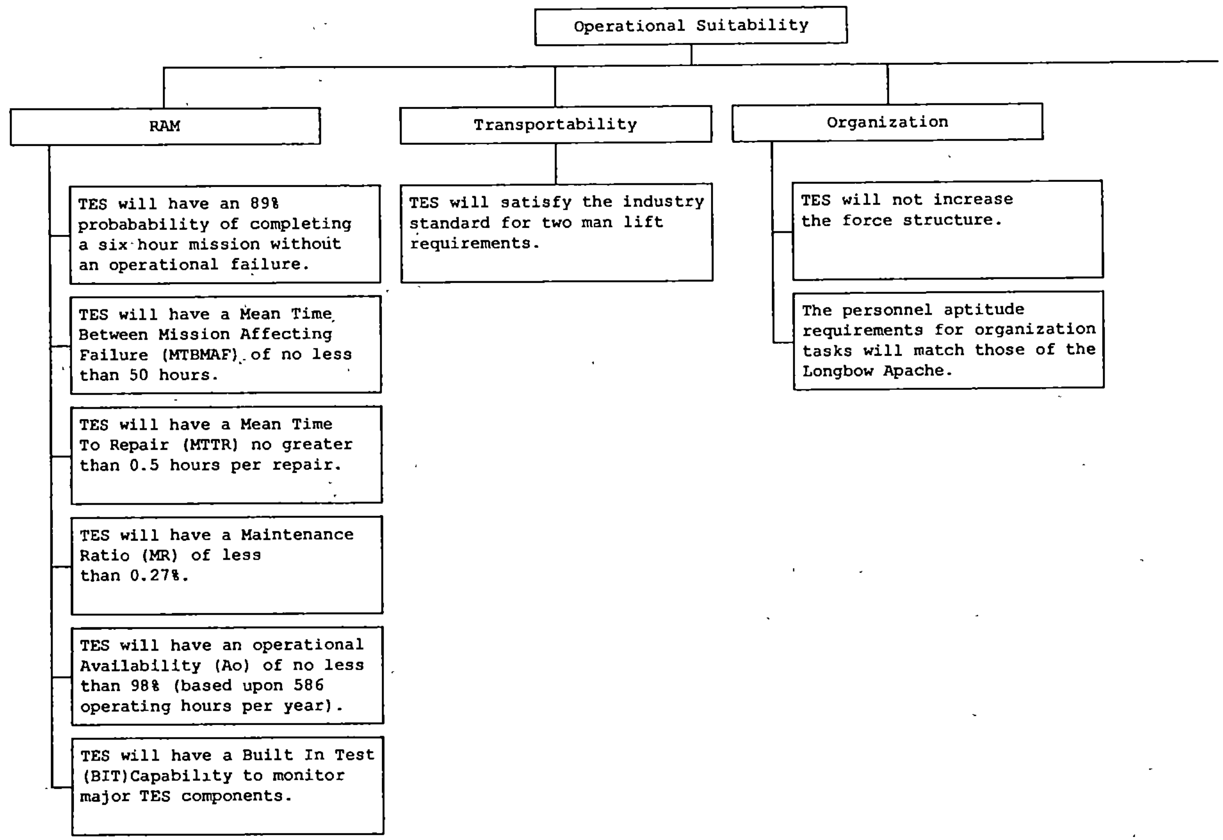


Figure 6-3

TES System Required Capabilities (Suitability)

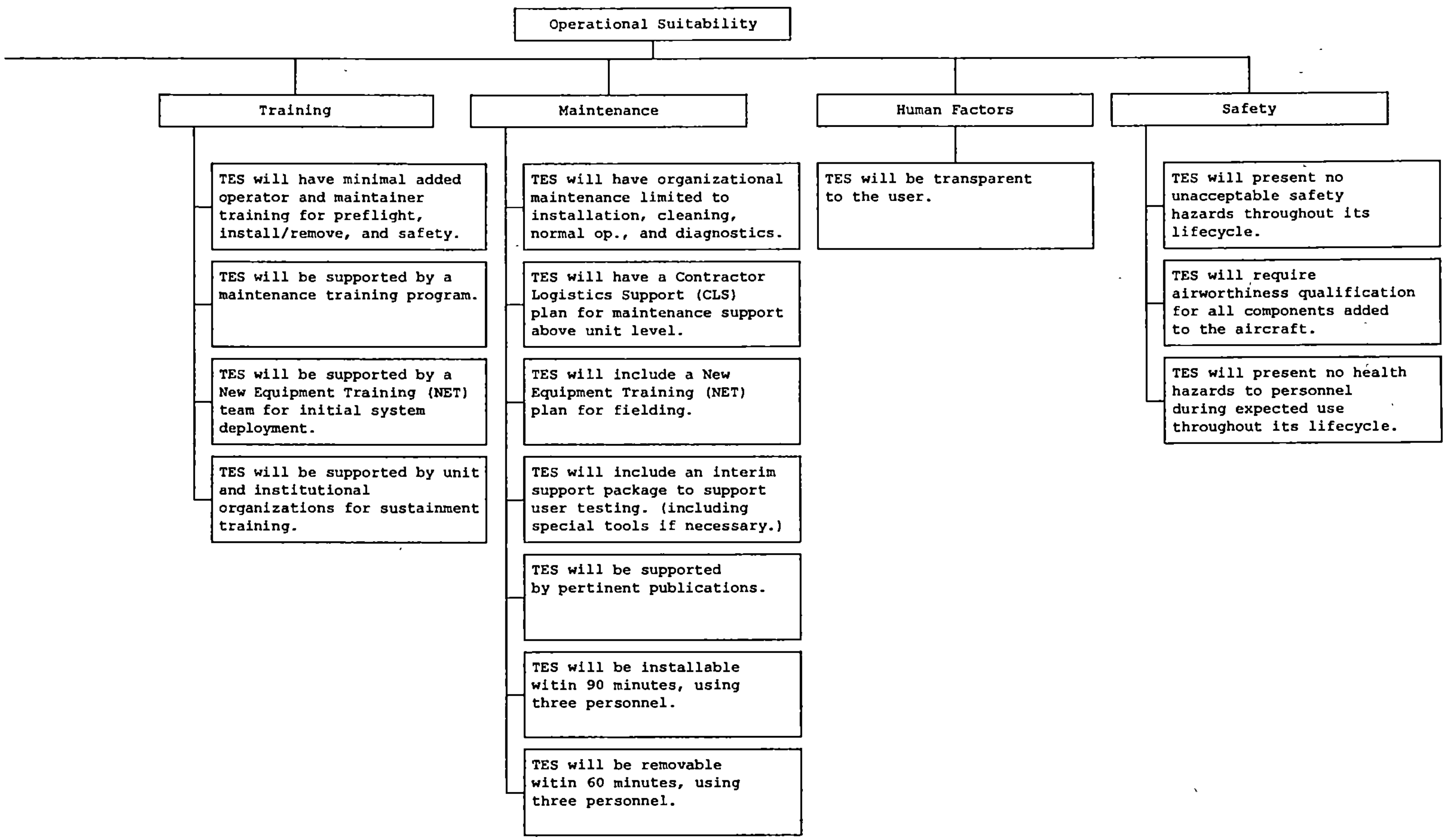


Figure 6-3 (Continued)

provided by the integrated TES System. The critical issues focus on system performance and mission effectiveness. These issues, if satisfied, signify the TES models are ready for the accreditation process. All other issues are considered Additional Operational Issues (AOIs).

Additional Issues

The Additional Operational Issues assess the suitability of the TES System and complement the critical elements. Information regarding system suitability is not critical for the Verification and Validation of the weapons systems simulation; the AOIs allow the system proponent to steer the development toward the requirements of future TES. For instance, Annex F to *OPORD 1-95* expresses that all future TES will be required to interoperate with a standardized After Action Review System (STAARS) by the year 2005. The *STAARS Operational Requirements Document* (ORD) provides advance planning information regarding the necessary criteria of the proposed systems, and the *STAARS Handbook* provides guidance concerning AAR products. This handbook defines the standard items that the materiel developers will be required to incorporate within future TES. Therefore, although the functions of the TES System Central Collection Facility are not crucial for the V&V, knowledge of the interoperability between the CCF and the TES System Aircraft Instrumentation Package is important for the control of future development. The data collected regarding suitability (AOIs) will be flags used to alert the Program Manager where future interoperability issues may arise and allow for resolution early enough in the system development.

DETERMINING TEST CRITERIA

Test criteria are expressions of the level of performance required of the Longbow TES System when operated by typical aviation personnel, to demonstrate effectiveness or suitability for given functions. For example, "the similarity between the actions and effects of the TES System and the actual aircraft weapons systems" is one criterion used to satisfy the operational issue regarding TES simulation. The criteria have been refined by the judgment and experience of Subject Matter Experts in an attempt to fully address and satisfy the issues (COIs and AOIs). Figure 6-4 depicts the Critical Operational Issues and their associated criteria (collectively referred to as COIC). This structure was developed by refining the performance capabilities dendritic (Figure 6-2). The COIC are not pass/fail criteria. Instead they are intended to provide the decision making authority with a level of credibility and capability of the TES models and the integrated system. The evidence will be used later in support of the accreditation process. The COIC are few in number relative to the AOIs which is consistent with the Army's current philosophy regarding COIC. In the past, there was no specific consideration given to the designation of critical criteria. All were, therefore, determined to be critical. This produced COIC sets with numerous issues and criteria often reflecting performance expectations. Consequently, operationally adequate systems had little chance of satisfying all of these expectations (DA, 1996). The COIC may appear "soft" at this point. They have been determined by SMEs to be realistic with respect to the maturity of the Longbow TES System. The COIC will evolve into more "firm" standards later in the development of the system. A refined dendritic depicted as Figure 6-5 presents the Additional Operational Issues and their associated criteria (referred to as Complimentary Measures).

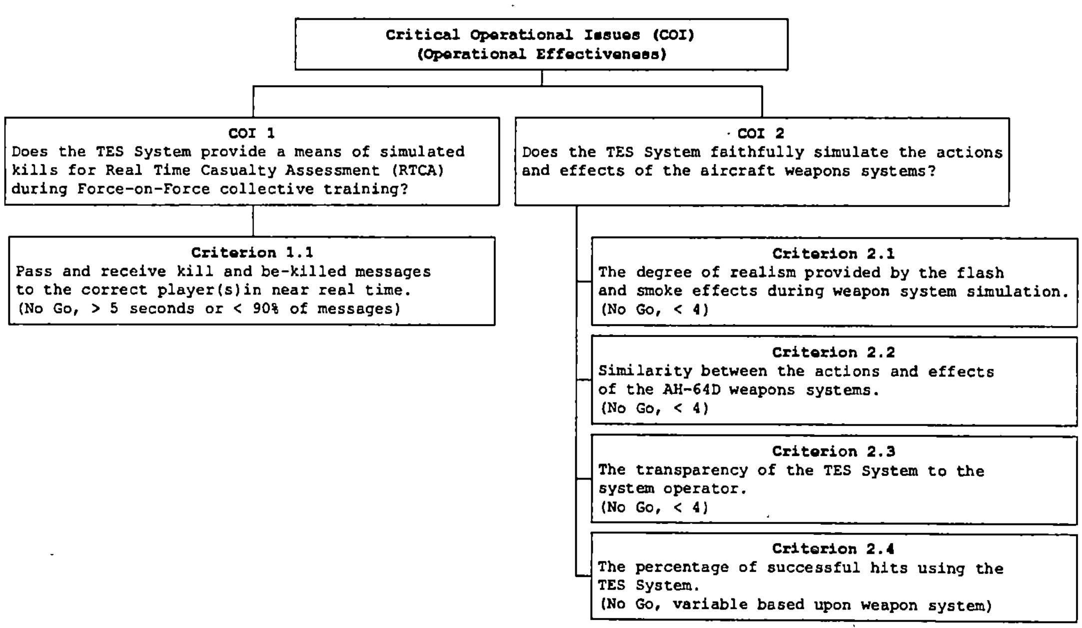


Figure 6-4

Critical Operational Issues and Criteria

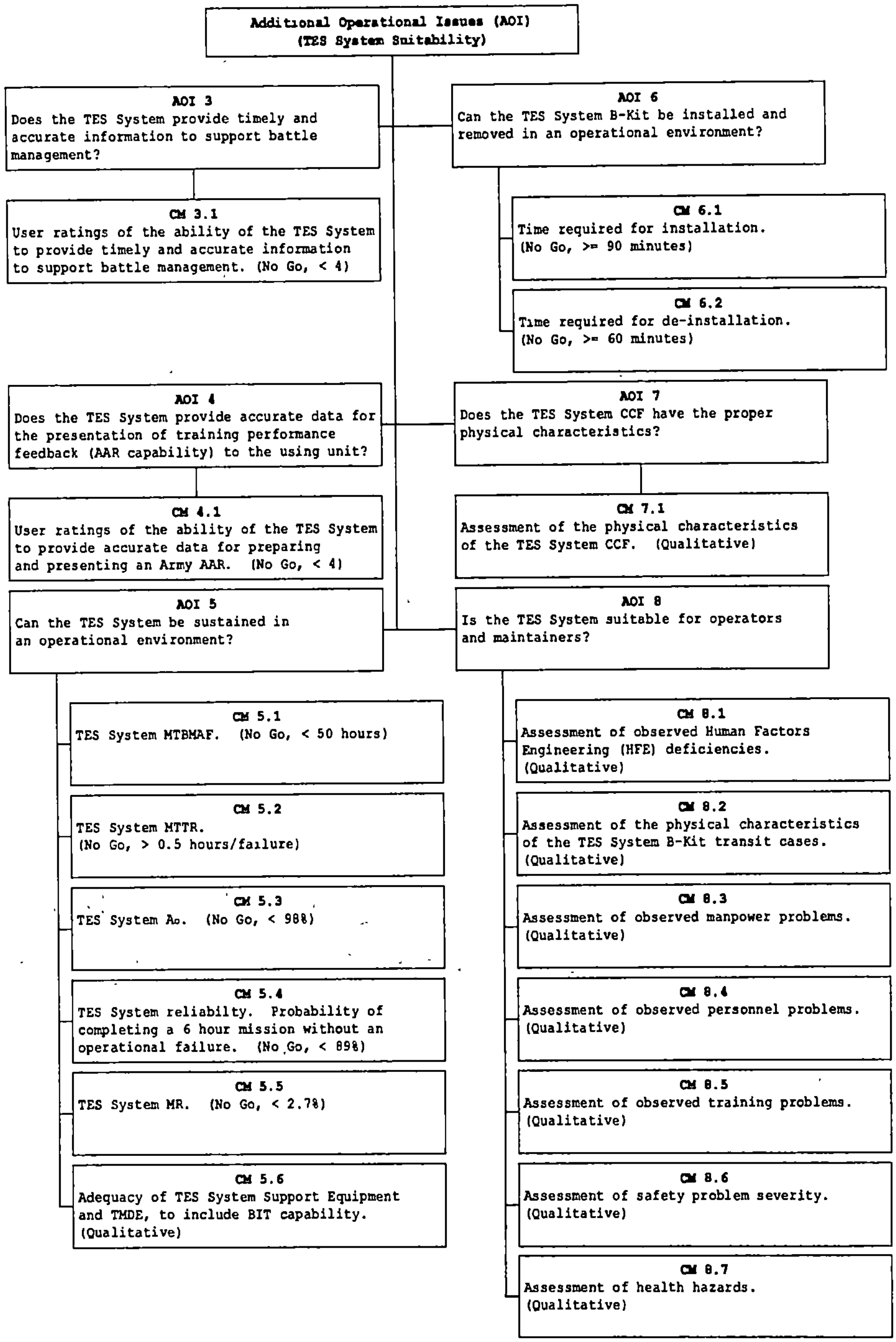


Figure 6-5

Additional Operational Issues and Complimentary Measures

FORMATION OF MEASURES AND DATA ELEMENTS

A measure is a numeric element or relation used to quantify or describe the level of performance or effectiveness specified by a criterion. Typically during Operational Tests, measures rely heavily on qualitative analysis. Observations by experienced aircrews are used to formulate broad based opinions regarding TES System performance. For example, a rating scale is applied to questionnaire responses that rank the similarity between the actions and effects of the TES System and the actual aircraft weapons systems. This rating scale applies a quantitative measure to qualitative data to satisfy the criterion, which in turn is used to satisfy the operational issue. All issues and measures have received a complete analysis to ensure all dendritic paths end with a meaningful data requirement. Table 6-1 depicts the measures, associated data requirements, and possible data sources.

DEVELOPMENT OF EVALUATION PLAN

General

The development of the Test Design Plan was accomplished using the Army's Operational Test Design Concept (OTDC). The OTDC requires an analysis of the data elements to determine the types of test events and tactical scenarios necessary to answer the operational issues.

Table 6-1

Measures, Data Requirements, and Data Sources

Measure of Performance/ Complimentary Measure	**Data Requirements**	**Data Sources**
Percentage of kill and be-killed messages sent to the correct player(s) in near real-time	• Shooter ID • Target ID • Shooter Location • Target Location • Time Message Sent • Time message Received • RTCA Results	• Instrumented Source
User's rating of the degree to which the TES System provides for the use of accurate weapons procedures.	• Pilot Opinion • Pilot Observation • Cockpit Displays, Tactical Situation Displays (TSDs) • Symbology • Icons • Messages	• VRS Tapes • SME Observation • Questionnaire
User's rating of the degree to which the TES System delivers realistic simulations of flash and smoke produced by the weapons systems.	• Pilot Opinion • Pilot Observation	• VRS Tapes • SME Observation • Questionnaire
Transparency of TES System instrumentation to operators.	• Pilot Opinion • Pilot Observation	• VRS Tapes • SME Observation • Questionnaire
Percentage of successful hits using the TES System. (P_h)	• Weapon System • Munitions Type • Range • Azimuth • Target Type • Crewmember LOS • Rounds Fired • Rounds Hit	• Instrumented Source • VRS Tapes
User's rating of the degree to which the TES System provides timely and accurate information to support battle management.	• Battlestaff Opinion • Tactical Icons • Messages • Engagement Event No. • Engagement Time • Receipt of RTCA Message	• Video/Audio in CCF • Instrumented Source (for messages) • Questionnaire • SME Observation
User's rating of the degree to which the TES System provides accurate information to support the preparation and presentation of After Action review (AAR).	• Battlestaff Opinion • Pilot Opinion • OC Opinion • Tactical Icons • Engagement Displays • Engagement Times	• Video/Audio during AAR • Questionnaire • SME Observation
Mean Time To Repair (MTTR).	• Repair Times • Maintenance Actions	• RAM Data Collection Procedures
Operational Availability (A_o).	• Operating/Standby Times • Maintenance Times	• RAM Data Collection Procedures

Table 6-1 (Continued)

Measure of Performance/ Complimentary Measure	Data Requirements	Data Sources
Mean Time Between Mission Affecting Failures (MTBMAF).	• Total System Operating Time • Mission Affecting Failures	• RAM Data Collection Procedures
Reliability.	• Operating Times • Mission Affecting Failures	• RAM Data Collection Procedures
Maintenance Ratio (MR).	• Maintenance Times • Operating Times	• RAM Data Collection Procedures
Adequacy of support equipment and Test Measurement and Diagnostic Equipment (TMDE).	• Reports of TMDE and Maintenance Problems due to TMDE	• Informal Review Checklist • SME Observation
Installation/De-installation	• Start Time • Stop Time	• SME Observation • Stopwatch • Video/Audio Recordings
Assessment of the physical characteristics of the Central Collection Facility (CCF).	• Physical Characteristics • Power Requirements • Weight/Stability • Heating, Ventilation, Air Conditioning • Secure Lighting • Seating Capacity	• Questionnaire • Informal Review Checklist • SME Observation
Assessment of Human Factors Engineering (HFE) deficiencies	• Observation and Reports of HFE Problems	• Informal Review Checklist • SME Observation
Assessment of physical characteristics of TES B-Kit transit cases.	• Physical Characteristics • Carrying Handles • Size • Weight	• Informal Review Checklist • Test Observation
Assessment of training problems	• Observation and Reports of Training Problems	• Informal Review Checklist • Test Observation
Assessment of manpower problems	• Observation and Reports of Manpower Problems	• Informal Review Checklist • Test Observation
Assessment of personnel problems	• Tasks that Require Different Personnel Characteristics than Authorized • Observation and Reports of Personnel Problems	• Informal Review Checklist • Test Observation
Assessment of health hazards.	• Reports of Health Hazards	• Test Observation
Safety problem severity.	• Reports of Safety Hazards	• Test Observation
Assessment of soldier survivability problems.	• Reports of Soldier Survivability Problems.	• Test Observation

The OTDC identifies the:

- scenarios and the types of events.
- list of factors and conditions likely to effect the outcomes of test events.
- sample sizes and system operating times required to control the risks associated with the anticipated analyses (DA, 1997b, 6.26).

The resulting Test Design Plan included as Appendix B, presents the operational issues in detail to include the scope of each issue, supporting criteria (or Complimentary Measures), basis for the criteria, and the measures. In addition, the plan provides a detailed description of the data management scheme. Data collection forms to support the test plan are included in Appendix C. This plan can be modified as necessary and is intended to be used for future Longbow TES System V&V efforts if required.

Test Events

General In an ideal world where resources and schedules are not concerns, the data requirements generally form the basis for postulating the test scenarios. The decisions where and when to conduct the V&V activities for the integrated Longbow TES System were determined independently of the development of the formal test plan. The proposed test events are examined to determine the data elements that can potentially be collected. These data are compared to the required data; the effects of any differences are compared to those necessary to reach meaningful conclusions. Any disparity between the required events and the proposed events which could have an effect on obtaining defensible test results is documented as a test limitation.

The functions, interfaces, and equipment for the proposed Longbow TES system were conceived under the Phase I demonstration of CHOICE at Fort Hood, Texas. The TES System, intended to be an extension of the capabilities of CHOICE, is being developed simultaneously. Like CHOICE, the development of the TES System is to be characterized by a rapid-prototyping paradigm. The CHOICE System is currently being used at Fort Hood by the 21st Cavalry Brigade, for the purpose of conducting AARs. Implicit in using the system, executable pieces of CHOICE are being demonstrated to the 21st Cav as the functions are made available. Consequently, the unit provides the necessary feedback to refine the system. The intent of the prime contractor and the materiel developer was to initiate the same type of iterative development process for the TES System, beginning when the Longbow was introduced into the Army inventory.

As each of the Army's newly formed Longbow equipped aviation battalions takes delivery of its aircraft, the battalion must progress through a Unit Training Program (UTP). The 21st

Cav conducts the program by training and evaluating Army AH-64D pilots in unit level mission essential tasks. Upon completion of the training, the 21st Cav confirms the unit as combat-ready. The Army's first Longbow unit, the 1/227th Aviation Battalion, was scheduled to go through the Unit Training Program at Fort Hood from August through October of 1998. This UTP rotation was to simultaneously provide the test events for the Longbow TES V&V activities. Table 6-2 depicts the events that currently constitute the AH-64D Unit Training Program.

Aerial Gunnery Exercise Prior to completing the Table VIII crew qualification aerial gunnery exercise, each aircrew receives practice, known as a Table VII. This practice table will simultaneously serve as a pilot test to familiarize the test control personnel and data collectors with the general conduct of the V&V procedures to ensure seamless execution of their responsibilities. During the exercise, each aircraft and target will be instrumented with the TES system and employed individually in a series of controlled engagement scenarios. This gunnery table adds realism through the employment of target acquisition and engagement opportunities, both moving and stationary, that an aircrew would likely encounter in an isolated (single-ship) combat situation. Data collected during this event will focus on the TES system performance issues. The gunnery

Table 6-2

AH-64D Unit Training Program Events List

(Source: 21st Cavalry Brigade, Fort Hood, TX., 1998)

MISSION EVENT	ECHELON SUPPORTED	THREAT	DURATION PER MISSION (hr)	ITERATIONS	TOTAL TIME (hr)
Aerial Gunnery (Crew Qual.)	Crew	Heavy Armor, Soft-skin (14)	≈ 1.0	24	24
Movement to Contact/Screen	Company	Company Size Element	≈ 2.0	3	6
Deliberate Attack	Company	Company Size Element	≈ 2.0	3	6
Hasty Attack	Company	Company Size Element	≈ 2.0	3	6
Screen/Flank	Battalion	Battalion Size Element	≈ 5.0	2	10
Movement to Contact	Battalion	Battalion Size Element	≈ 5.0	2	10
Guard	Battalion	Battalion Size Element	≈ 5.0	2	10

event provides for the use of surveyed firing pads, firing lanes, and controlled target arrays which will allow for instrumented collection of truth data regarding aircraft and threat target location to evaluate the GPS geometric pairing accuracy used for RTCA. Data collectors will gather data for mission performance, scenarios. Reliability, Availability, and Maintainability (RAM), manpower and personnel integration (MANPRINT), and installation and de-installation. Table 6-3 provides a detailed list of the target engagement scenarios used in the AH-64D Table VII/VIII gunnery during the UTP.

TABLE 6-3

AH-64D Longbow Apache Table VII/VIII (DRAFT) Target Engagement Group Summary

(Source: 21st Cavalry Brigade, Fort Hood, TX., 1998)

TEG #	Weapon	Sight	Range	Target	Rds Req	Mode	Stds	Type Eng	Eng No.
1 (ABF1)	30mm	TADS	1500-2000m	Sta. Lt. Armor	30	Running	Hit	Defensive	9
[00:00:00]	30mm	BS IHADSS	1000-1500m	Sta. Troops	40	Hover	Hit	Defensive	4
	SAL HF	TADS	>2000m	Mov Armor	1	Hover	Hit	Offensive	1
2 (ABF2)	2.75	IDM-TADS	1500-6000m	Sta. ADU	6	Hover	2 of 6	Offensive	11
[00:00:00]	SAL HF RAPID	TADS	>3000m	Sta. Armor	2	Hover	Hit x 2	Offensive	6
3 (ABF3)	SAL HF	TADS	<2000m	Sta. Armor	1	Hover	Hit	Defensive	2
[00:00:00]	SAL HF REMOTE	NAV SYS	>4000m	Sta. Armor	1	Hover	Hit	Offensive	3
4 (ABF4)	2.75	COOP	2000-4000m	Sta. Lt. Armor	8	Hover	3 of 8	Offensive	5
[00:00:00]	30mm IDM	TADS	500-3500m	Sta. ADU	30	Hover	Hit	Offensive	10
5 (ABF5)	RF HF-TADS HO	TADS	>800m	Mov Armor	1	Hover	Hit	Defensive	8
[00:00:00]	2.75	COOP	1500-6000m	Sta. ADU	6	Moving	2 of 6	Defensive	12
	SAL HF RIPL	TADS	>800m	Mov Armor	2	Moving	Hit x 2	Offensive	7

Notes:

1. Target Engagement Group (TEG) times are total times for all engagements contained in the group. Points are deducted for going over the maximum alloted time to complete all individual engagements listed.
2. Individual engagements still have minimum and maximum times and point scoring associated with each shot.
3. Crews must ensure they are moving tactically between positions. Individual firing points within ABF's are up to the crew and points will be deducted for improper selection as outlined in the ATM.
4. Crews must ensure that the proper video source is selected to ensure proper scoring as required.

Company and Battalion Maneuver Exercises The live maneuver exercises will be used to evaluate the Tactical Engagement Simulation in an operationally representative combined arms environment. With large numbers of instrumented aircraft and ground vehicles participating in the Force-on-Force exercises, there exists the possibility of data transmission latency that may not be encountered or evident during the Table VII gunnery event. The effects of data latency translate into a target management issue for the Longbow that could impact the timing and outcomes, and thus the realism of engagement simulation. The effects of data latency will be examined during the maneuver exercises. These exercises will serve as a secondary source of system performance and effectiveness data used to augment the gunnery event data. In addition to providing data for Tactical Engagement Simulation, these events afford qualitative and quantitative data on how well the TES System provides timely and accurate information to support battle management by examining the interoperability with the Central Collection Facility. The maneuver exercises will also support data collection for RAM, MANPRINT, and installation and de-installation operations.

Tactical Context of the Events During the gunnery Table VII and the maneuver exercises, the TES System will be employed against various tactical echelons of wheeled and tracked vehicles (single vehicle, team, platoon, company, and battalion). The target sets are operationally realistic and their activities will be consistent with the appropriate threat tactical doctrine. The level of conflict intensity will be low for the gunnery exercise, and will range from low to high-intensity for the maneuver exercises.

Test Factors and Conditions

Test factors, sometimes called variables, are those items which could possibly influence the system performance during the test. Factors are generally divided into three categories; friendly, enemy, and environmental. Friendly factors include: equipment, doctrine, mission, crew, training, logistic support, morale, and leadership. Some examples of enemy factors are: target types, countermeasures, and mobility. Environmental factors are items such as terrain, weather, and climate. These factors are further defined as either controllable or uncontrollable. Controlled factors are those that can be varied or held constant during the test to produce the desired conditions. Uncontrolled factors also may produce different conditions during the test, however there is little or no control over them. Examples of uncontrolled factors are pilot or maintainer motivation and weather. The controlled variables can be an asset to the V&V because they potentially add variations to a particular test and should produce additional data. Recognition of the uncontrolled factors is important since they lead to test limitations. An example of a test limitation is the presence of adverse weather during authorized range test period; reduced visibility during allocated test time may restrict flight crews to perform limited range weapons engagements.

Realizing that there is practically no limit to the number of variables associated with a test, a list was constructed which contains only the major factors which may significantly impact the test. The factors were then associated with the conditions under which they should be observed. The appropriate conditions are representative of those under which the TES system is to be employed as stated in the mission profile section of the Requirements Document. Emphasis was placed on selecting systematically variable conditions for only those factors necessary to test the system. The major event factors, conditions, and variable control methods are listed in table 6-4.

In developing a test design, it is desired to vary each factor that can possibly be varied, to collect as much supporting data as possible. The drawback to such a philosophy is that by introducing more combinations of variables into a test, the magnitude of the test effort quickly becomes unwieldy.

Referencing Table 6-4, there are nine major factors that can be systematically varied during a proposed test. Holding the range constant, there are 12,960 distinct combinations of the variable factors. One realistic combination could be defined by the following engagement: aircraft at night, part of a company level

Table 6-4

Event Factors, Controls, and Conditions

FACTOR	CONTROL	CONDITIONS
Echelon supported by the TES System	Systematically Varied	Single-Ship, Platoon, Company, Battalion
Interoperability	Held Constant	MILES/AGES, Central Collection Facility (CCF)
Mission	Systematically Varied	Gunnery, Attack, Reconnaissance, Security
Mission Duration	Systematically Varied	Gunnery Event: ≈1hr Company Mission: ≈2hr Battalion Mission: ≈5hr
System Operating Status	Uncontrolled	Fully Mission Capable, Part. Mission Capable, Not Mission Capable
Aircraft Activities	Systematically Varied	Hovering Moving
Weapon Systems	Systematically Varied	30mm gun 2.75″ rockets Hellfire Missile
Crewmember Line-of-Sight (LOS)	Systematically Varied	IDM-TADS/TADS IHADSS Cooperative
Target Types	Systematically Varied	Light Armor, Heavy Armor, Wheeled/Track Vehicles, Troops, ADA
Target Activities	Systematically Varied	Moving, Stationary
Target Range	Systematically Varied	500m to 8000m
Personnel	Held Constant	MOS 152XX Aviator MOS 68X Maintainer
Organization	Held Constant	Two 152XX Per TES System Aircraft Instrumentation Package
Training	Held Constant	Provided by System Contractor
Maintenance and Logistics Support	Held Constant	Operator and Unit Level-68X, Above Unit Level-System Contractor
Electromagnetic Interference Environment (EMI)	Uncontrolled	As Occurs
Weather Conditions	Uncontrolled	As Occurs
Light Conditions	Systematically Varied	Day, Night

attack mission, engaging a stationary, heavily armored vehicle at 2,000 meters with 3 pairs of (6MP) rockets. Some of the conditions can be grouped together thus reducing the complexity of the V&V effort. For instance, the function "Target Type" can be varied in six ways: heavy armor, light armor, wheeled vehicle, tracked vehicle, air defense, and troops. The preliminary TES rocket algorithm in Chapter 4 does not differentiate between vehicle types; it merely defines a target in one of two ways, heavy armor (hard-skin) or not heavy armor (soft-skin). Consequently, this function only needs to be varied in two ways. Since the TES System should not perform any different during the day than it does in darkness, the function "Light Conditions" no longer needs to be an independent variable. Additionally, the range can be defined by a limited number of discrete increments, i.e. 1000m range intervals. After consolidating these few conditions, the possible combinations have dropped significantly. However, care should be taken when reducing the number of conditions. For instance, it could be argued that "Mission Duration" does not need to be an independent factor, since the behavior of the TES models should be independent of system operating time. However, longer continuous operation time is associated with the battalion Force-on-Force missions which involve large numbers of instrumented aircraft and ground vehicles. The expected increase in the frequency and amount of dataflow between aircraft and ground targets examines the GPS geometric pairing capability of the TES System under extreme workload conditions. The increase in the system workload may create congestion which translates into the inability to correctly pair targets and arbitrate hits. Additionally, longer continuous operating times provide data to substantiate system reliability. Table 6-5 depicts the factors, controls, and conditions after combining appropriate conditions.

Engagement Opportunities and System Operating Time

The gunnery event provides for approximately 336 total engagement opportunities, however the total number of engagements can not be reasonably estimated for the maneuver exercises. In all cases of the live maneuver exercises, the initial battle conditions are determined (systematically varied) before the start of each event, however the individual engagement opportunities develop tactically and can not be guaranteed. As an example, the movement-to-contact mission often results in a meeting engagement where forces enter into conflict with each other by chance rather than by design. The gunnery event and the maneuver exercises provide for approximately 24 hours and 48 hours of event time respectively, which collectively afford approximately 468 hours of total system operating time. Table 6-6 depicts a proposed TES System usage schedule which maximizes the amount of event time for each of the ten (10) TES System AIPs designated for the V&V effort.

Table 6-5

Event Factors, Controls, and Combined Conditions

FACTOR	CONTROL	CONDITIONS
Echelon supported by the TES System	Systematically Varied	Single-Ship, Other Than Single-Ship
Interoperability	Held Constant	MILES/AGES, Central Collection Facility (CCF)
Mission	Systematically Varied	Gunnery, All Other Mission Types
Mission Duration	Systematically Varied	Gunnery Event: ≈1hr All Other Missions: >1hr
System Operating Status	Uncontrolled	Fully Mission Capable, Part. Mission Capable, Not Mission Capable
Aircraft Activities	Systematically Varied	Hovering Moving
Weapon Systems	Systematically Varied	30mm gun 2.75″ rockets Hellfire Missile
Crewmember Line-of-Sight (LOS)	Systematically Varied	IDM-TADS/TADS IHADSS Cooperative
Target Types	Systematically Varied	Light Armor, Heavy Armor
Target Activities	Systematically Varied	Moving, Stationary
Target Range	Systematically Varied	Discrete 1000m Increments from 1000m to 8000m
Personnel	Held Constant	MOS 152XX Aviator MOS 68X Maintainer
Organization	Held Constant	Two 152XX Per TES System Aircraft Instrumentation Package
Training	Held Constant	Provided by System Contractor
Maintenance and Logistics Support	Held Constant	Operator and Unit Level-68X, Above Unit Level-System Contractor
Electromagnetic Interference Environment (EMI)	Uncontrolled	As Occurs
Weather Conditions	Uncontrolled	As Occurs

Table 6-6

TES System Usage Schedule

TES System AIP No.	Operating Time ~ hours			
	Gunnery Event	Company Exercises	Battalion Exercises	Time per AIP
1	2	15	30	47
2	2	15	30	47
3	2	15	30	47
4	2	15	30	47
5	2	15	30	47
6	2	15	30	47
7	2	15	30	47
8	2	15	30	47
9	2	15	30	47
10	6	9	30	45
		Total Operating Time (TOT)		468

Test Limitations By inspection of Table 6-5; (Combined Conditions), the proposed test events can potentially generate the required data elements listed in Table 6-1; (Measures, Requirements, and Data Sources). These events however can not provide the number of engagement opportunities necessary to determine the fidelity of the weapons models. Furthermore, the corresponding total system operating time is marginally sufficient to establish the confidence of the additional OT data; specifically the reliability data. Table 6-7 depicts the number of engagement opportunities required to establish an 80 percent confidence level that the probabilities-of-hit provided as output by the TES System are reliable data. This table was constructed based on the data provided by the rocket event success template combined with the rocket engagement opportunities afforded by the

Table 6-7

Sample Size Required to Establish an 80% Confidence Level

ENGAGEMENT NUMBER	TARGET TYPE	WARHEAD TYPE	PAIR(S) FIRED	PROBABILITY OF HIT (P_h)	REQUIRED SAMPLE SIZE
5	Soft-skin	(PD)	1	0.0350	22
			2	0.0688	42
			3	0.1014	60
			4	0.1328	76
11	Soft-skin	(MP)	1	0.1500	84
			2	0.2775	132
			3	0.3859	155
12	Soft-skin	(MP)	1	0.1500	84
			2	0.2775	132
			3	0.3859	155

test events listed in Table 6-3;(Table VII/VIII Target Engagement Group Summary). The following formula was used to determine the sample size for each engagement type:

$$n = \frac{z^2 P_h (1 - P_h)}{e^2}$$

where:

n = the required sample size

z = value for an 80 percent confidence level, using a normal distribution

P_h = expected probability of hit (P_h) from template

e = margin of error (±5 percent)

The values for the confidence level and margin of error are reasonable values for OT and were arbitrarily chosen for the purpose of illustration (DA, 1997c). Estimates of sample sizes are useful for controlled experiments; Neville (1964) provides a detailed explanation for determining sample sizes for the design of experiments. Due to the large number of combinations of test conditions which may occur during Operational Testing, the conditions necessary for precise sample sizing are rarely satisfied. However, fundamental statistical assumptions and quasi-experimental design provide reasonable sample size approximations for planning of OT (DA, 1997c, 6.31). Assuming 24 flight crews participate in the Table VII/VIII gunnery event, engagement No. 5 would provide at most 24 engagement opportunities out of 76 required to establish an 80 percent confidence level. Additionally, assuming that 6MP warheads are used for engagements 11 and 12, these engagements would provide at most 48 opportunities out of 155 required. The proposed test events only guarantee 336 total engagement opportunities; the rocket events would collectively require 231 to substantiate only the rocket algorithm. Furthermore, if an aircrew shoots less than the pairs of rockets allocated for any of these engagements, the expected P_h is no longer the same so the data can not be incorporated into the analysis. Therefore, based on the preliminary rocket algorithm, the proposed test events can not be expected to generate enough data to adequately evaluate all of the weapons systems models. It is recommended that following the implementation of the weapons systems models to be used for RTCA, the Program Manager in coordination with Army research analysts determine the required weapons engagements to substantiate the input-output transformation of the TES algorithms using the success template methodology. The resulting determination should then be used to define the specific V&V events and scenarios. Furthermore, it is recommended that the V&V activities of the integrated TES System be performed at the unit homestations and CTCs in addition to Fort Hood to expedite the acquisition of the TES System. Boeing had scheduled 186 hours of product/performance testing preceding the V&V effort; it is recommended that they focus their data collection efforts on weapons engagements that reveal the statistical need for larger sample sizes, and also on engagements that are not likely to be performed during the maneuver exercises. This includes engagement scenarios at the maximum limits of the weapons systems i.e. 4,000m gun engagements and 8,000m Hellfire missile engagements. These data could be used to augment the Army's V&V data as necessary. In the worst case, if fiscal constraints preclude testing beyond one UTP rotation, the decision to extrapolate the data for the purpose of model accreditation would incur risk.

The total system operating time provided by the proposed test events to establish confidence in the OT data is marginal. The mean time between failure, defined as the Mean Time Between Mission Affecting Failure (MTBMAF) by the *TES Sytem Requirements*

Document, is one of the basic and more important measures included in formal tests and demonstrations of repairable systems (Blanchard, 1990, 105). Figure 6-6 was developed to facilitate determining the maximum allowable number of Mission Affecting Failures (MAF) during the prescribed test period. This chart, commonly used by DoD for reliability testing was constructed using the following assumptions:

1. 10% risk to the materiel developer that the TES System with a true reliability which meets the required value (MTBMAF > 50 hours) will be rejected as not meeting the requirement.

2. 10% risk to the system proponent that the TES System with a true reliability which does not meet the lower test limit (MTBMAF < 40 hours) will be accepted as meeting the requirement.

40 hours represents the lowest MTBMAF that is considered to be acceptable based on actual test results. Figure 6-6 reveals that if the TES System experiences at least one MAF during the prescribed test period depicted in Table 6-6; (TES System Usage Schedule), the corresponding amount of system operating time is not sufficient to accurately determine system reliability. The intersection of Total Operating Time and Total Mission Affecting Failures must fall below the "accept" line. Therefore, in the case that these V&V activities are used to simultaneously support

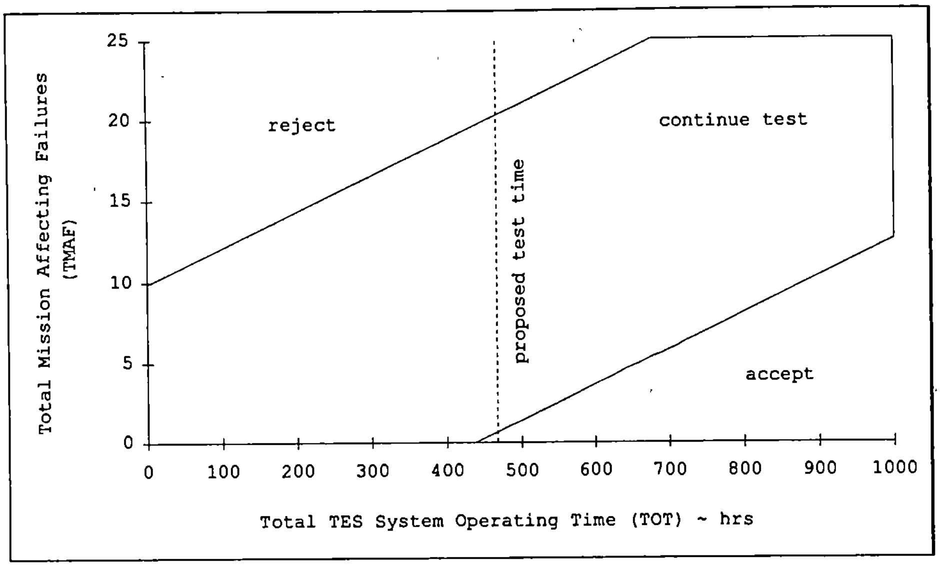


Figure 6-6

TES System Reliability Test Plan

OT, one Mission Affecting Failure implies that the decision making authority can not advocate a subsequent production decision in good faith without further testing. Blanchard (1990) provides a detailed explanation regarding the construction and use of the reliability test plan (382). Again, it is recommended that the V&V activities of the integrated TES System be performed at other training sites in addition to Fort Hood to increase the amount of TES system operating time.

Data Management

The data management process condenses and formats the V&V data for analysis, documentation, and storage. A preliminary "level-four" database structure has been developed for the V&V effort. The Army defines level-four data as tables, charts, bar graphs, relative frequencies of judgments or qualitative data, and data summaries showing totals, means, and elapsed times. A detailed description of the DataBase Management System (DBMS) is included in Appendix B. Database outputs using sample data are included as Appendix D.

REVIEW EVALUATION PLAN

Coordination and integration between the participants of the V&V effort, and the materiel, training, and combat developers is essential to the success of the V&V processes in the acquisition of the Longbow TES System. It is necessary for the evaluators and the combat and training developers to review the V&V plan; the output of these reviews are necessary to further refine the plan prior to the V&V of the integrated TES System. The development of the V&V plan is intended to be an iterative process. The tasks associated with the development of a sound V&V plan for a complex system such as the Longbow TES System, span a large spectrum. Consequently, the planning of future V&V efforts would be well served by an organization that has broad experience in applicable specialized areas such as software engineering, modeling and simulation, systems engineering, operations research, and test and evaluation. It is recommended that the Program Executive Office (PEO), Longbow Apache, identify the U. S. Army Test and Evaluation Command (ATEC) to work closely with the University of Tennessee Space Institute on the planning of future V&V efforts. It is recommended that ATEC review the proposed V&V methodologies and the Test Design Plan, and adapt them as necessary for future testing of the Longbow TES System.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The proponent for the Longbow TES, the U. S. Army Aviation Center (USAAVNC), U. S. Army Training and Doctrine Command (TRADOC) is examining the impact of Tactical Engagement Simulation development on combat aviation training. Consequently, the Program Executive Office (PEO), Longbow Apache, directed a Verification and Validation (V&V) to examine the proposed Longbow TES System at its current stage of development. A fundamental verification methodology was developed to evaluate the fidelity of the Longbow TES weapons algorithms in a realistic operational environment. This method employs a rudimentary form of functional testing; verifying the model outputs (the expected weapons systems P_h) based upon the inputs (operational conditions). The advantage of this methodology is that the instrumentation requirements are minimized; there is no need for additional instrumentation beyond that required for RTCA. The disadvantage of this methodology is the requirement for large sample sizes needed to adequately verify the model outputs (P_h data). A validation methodology was developed to determine the fidelity of the simulation provided by the integrated system.

This methodology validates system performance by applying quantitative measures to principally qualitative system outputs. A test plan was developed that incorporates these Verification and Validation techniques with the simultaneous collection of valuable Operational Test data. This promotes rapid-prototyping, thus reducing future OT requirements, and conserving resources by expediting the TES System acquisition process. The test plan incorporates a data management scheme and a level-four database structure designed specifically for evaluation of the Longbow TES System. The V&V efforts conducted by the University of Tennessee Space Institute (UTSI) flight systems research group resulted in the following conclusions:

1. The decision to conduct V&V of the integrated TES system at its current stage of development was premature; the installed system was not available for operation. The lack of finalized weapons systems algorithms and lack of RTCA capability (GPS geometric pairing) were major limitations to the Verification and Validation of the integrated system. Consequently, the proposed V&V methodologies and Test Design Plan were not implemented.

2. V&V activities should not to be conducted as a one time process during system development. Ideally, the V&V activities should have been initiated during the application

process when the initial need for Longbow TES was identified. A strong V&V plan which promotes efficient system development, incorporates Verification and Validation techniques beginning at the application process and continuing throughout the acquisition lifecycle.

3. The development of the Longbow TES System and V&V efforts are not being tracked or documented in a Resource Repository.

4. Based upon the data from a preliminary weapon system model, the events scheduled for these V&V activities would not have been adequate to verify the weapons systems models to a reasonable (80 percent) confidence level.

5. In the event that these V&V activities were to simultaneously support OT, the amount of total system operating time would have been marginally sufficient to support a production decision, based on reliability data. One (1) Mission Affecting Failure during the proposed test period would prevent the decision making authority from making a production decision in good faith without further testing.

RECOMMENDATIONS

1. It is recommended that the Program Manager work closely with the materiel developer and actively conduct and manage V&V

activities at all stages of Longbow TES development. These activities should include but not be limited to:

- ensuring correctness and accuracy of the selected weapons algorithms prior to their implementation.
- focusing the V&V activities to support the development of RTCA using GPS geometric pairing technology. V&V efforts of the integrated system should be continued only after the RTCA technology is developed.
- emplacing formal procedures for configuration management and documentation status.

2. Subsequent V&V efforts should be documented in the Army's Modeling and Simulation Resource Repository (MSRR). This would ensure easy access to information regarding TES development, thus providing clear focus for future V&V efforts. The MSRR can potentially foster TES development (RTCA capability) through additional sources within the M&S community.

3. The materiel, combat, and training developers should work in coordination with the Army Material Systems Analysis Agency (AMSAA) to focus the development efforts on weapons systems

models that take into account aircraft accelerations and aerial ballistic effects, to provide greater training value.

4. Army research analysts should use these proposed V&V methodologies as a starting point and further refine and implement them for V&V of the integrated Longbow TES System.

5. Army test and evaluation personnel should determine the required weapons engagements to substantiate the input-output transformation of the TES algorithms using the success template methodology. The resulting determination should subsequently be used to define the specific V&V events and scenarios.

6. Performing V&V activities of the integrated TES System at the unit homestations and CTCs in addition to Fort Hood would expedite the acquisition of the TES System. Furthermore, it is recommended that Army test and evaluation personnel work closely with Boeing to guide the focus of the prime contractor's data collection efforts during product/performance testing. This would potentially facilitate augmenting the Army's V&V data with contractor data if necessary.

7. The planning of future V&V efforts would be well served by an organization that has broad experience in applicable specialized areas such as software engineering, modeling and simulation, systems engineering, operations research, and test and evaluation. It is recommended that the Program Executive Office (PEO), Longbow Apache, identify the U. S. Army Test and Evaluation Command (ATEC) to work closely with the University of Tennessee Space Institute on the planning and implementation of future V&V efforts.

8. It is recommended that ATEC review the proposed V&V methodologies and the Test Design Plan, and adapt them as necessary for future testing of the Longbow TES System.

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APPENDICES

APPENDIX A

DETAILED SYSTEMS DESCRIPTIONS

WEAPONS DESCRIPTIONS

Fire Control Radar (FCR)

The Fire Control Radar (FCR) is an integrated millimeter wave radar system with a mast-mounted transmitter and receiver. The FCR detects, locates, and classifies ground and airborne targets and provides terrain profile mapping for operating in limited visibility conditions. The FCR, in combination with the RF Hellfire missile, provides a fire-and-forget capability. A mast-mounted Radio Frequency Interferometer (RFI) is incorporated to provide threat emitter warning, azimuth, and direction finding. RFI detected emitter signals may be correlated with FCR target data to derive the identity and location of a particular threat. The target information is sent to the Weapons Processor for the determination of target location coordinates and is used to direct the weapons against potential targets. FCR target information is displayed to the aircrew on the FCR page and the Tactical Situation Display (TSD) page. The FCR page targeting format may also be displayed on the Copilot Gunner's (CPG) displays. In addition, the information is processed for the generation of FCR target symbology for overlay onto the Target

Acquisition and Designation Sensor (TADS)/Pilot's Night Vision Sensor (PNVS) video.

AGM-114 Hellfire Missile System Description

AGM-114 Hellfire Missile (HELicopter-Launched FIRE-and-forget missile) is the primary weapon system of the Longbow Apache, used for the anti-armor role. The Longbow is capable of employing two variants of this missile, the AGM-114A/C/K Semi-Active Laser (SAL) guided missile, and a Radio Frequency (RF) guided version. The Hellfire missile can be launched by the pilot or the Copilot/Gunner. There are four available SAL missile modes and one RF mode. All of these missile modes may be designated autonomously or handed-off from another aircraft equipped with with a compatible digital information source.

AGM-114A/C/K Semi-Active Laser (SAL) guided missile Following a launch, this missile tracks reflected, coded pulse laser radiation from a target which has been illuminated by the aircraft that launched the missile or a separate laser designator. The missile must be able to see the reflected laser light from the time of launch until it reaches the target. It features an Improved Low-Visibility (ILV) detection autopilot and a low-smoke motor to reduce detection. The warhead is an 8 kilogram shaped-charge with a copper liner. The Hellfire missile travels at a speed of Mach 1.4 and has a maximum range of between 5-8Km.

AGM-114K Radar Frequency (RF) guided missile The AGM-114K Hellfire II features a digital autopilot and improved warhead; the copper liner of the shaped-charge warhead has been replaced by a molybdenum steel liner. Hellfire II includes a tandem warhead intended to defeat reactive armor with two charges, a minor initial explosion followed by the main shaped-charge warhead. The range of the Hellfire II is in excess of 8Km.

M140 Aerial Rocket System (ARS)

The Folding-Fin Aerial Rocket (FFAR) is an area-effect weapon for the Apache Longbow. This unguided rocket measures 70mm in diameter and is characterized by a set of three wings which fold around the body of a MK66 rocket motor. Upon exit from the launcher, the fins spring outward to aid in stability. Additionally, the rocket nozzles are scarfed at an angle to add a spin to the rocket during flight for added stability. The wingspan is 186mm when deployed. The maximum range is approximately 7.5Km. The rockets may be employed by either crewmember or cooperatively. There are a variety of warheads which can be attached to the MK66 rocket motor to be used for anti-materiel, anti-personnel, and suppression missions. The available warheads are characterized by either penetration or time delay detonation. The available warheads are:

- Point-Detonating (PD) or penetration fuze
- airburst-range with a settable fuze using Multi-Purpose Sub-Munitions (MP).

M230E1 Chain Gun

The M230E1 Chain gun is located beneath the forward fuselage, directly below the Copilot/Gunner's position. The gun is hydraulically steered and has an electrical firing mechanism. To reduce jamming, the ammunition feed uses an electrically-driven one-piece chain to feed the linkless shells into the gun. Ammunition travels down the starboard side of the feed chute while the spent shell casings are carried up the port side to be returned to the magazine. The rate of fire for the M230 is 600-650 rounds per minute. Each round takes approximately 2 seconds to travel 1000m and 12 seconds to travel 3000m.

TES SYSTEM DESCRIPTION

A-Kit

Weapons Processor (WP) The Weapons Processor is the MIL STD 1553 Databus controller. It schedules message traffic on the weapons bus between the remote terminals of the TES System. Software functions include weapons inventory, TES System initialization, weapons emulation, and eye-safe laser range processing.

System Processor (SP) The System Processor software controls the additional bus messages that the TES System generates between the WP and Display Processor (DP), and the DP and the Communications Interface Unit (CIU). When the TES System is installed, the "TES mode" message is sent from the WP to the SP, and additional data is sent from the SP to the DP to drive TES System displays. The SP simulates all arm functions when the TES system is installed.

Display Processor (DP) TES System displays are to be added to the DP. Additional displays include advisory messages from RTCA results and player status.

Communications Interface Unit (CIU) The CIU provides audible real-time feedback for RTCA. Audio alert enunciation exists in the CIU. Sound effects for the gun, rockets, and missiles are provided by the CIU.

Radio Frequency Interferometer (RFI) The RFI permits detection and identification of the simulated threat emitters used at the CTCs.

Radar Warning Receiver A data module for the APR-39 Radar Warning Receiver will be integrated which permits identification of the simulated threat emitters at the CTCs.

B-Kit Description

Figure A-1 depicts B-Kit components with transit case. From left to right; SMODIM mounting assembly, GPS antenna, SMODIM, and DCI.

SMODIM The SMODIM is the heart of the TES System Aircraft Instrumentation Package. Mounted in the aircraft survival kit

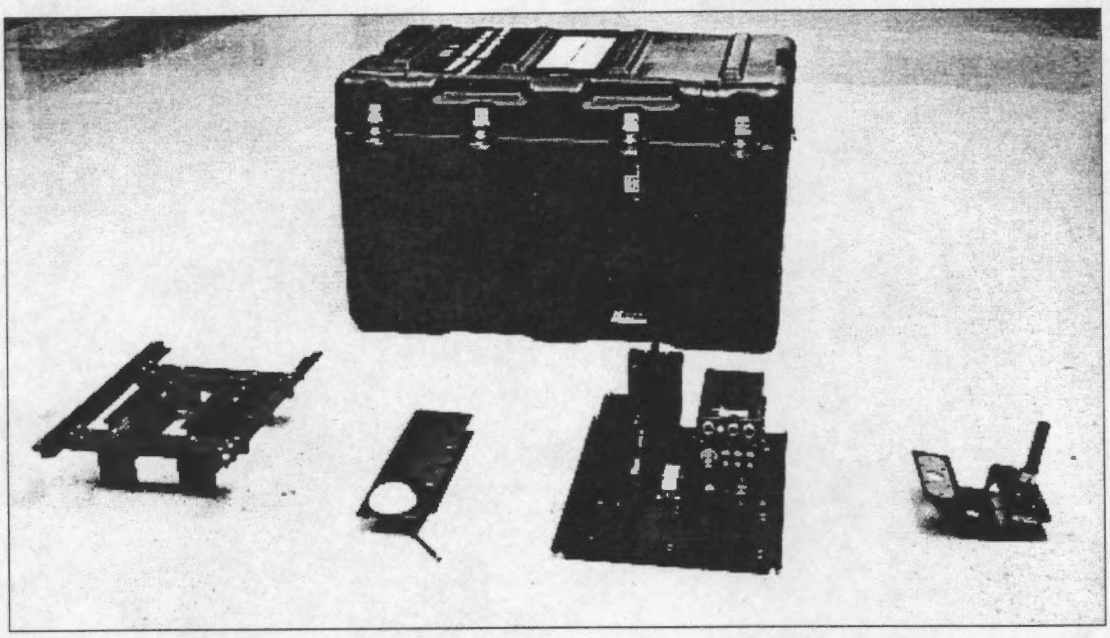

Figure A-1

TES System B-Kit Components with Transit Case

bay depicted in Figure A-2, the SMODIM includes an embedded Data Recorder and performs MILES decoder functions. The SMODIM communicates with the aircraft WP as a remote terminal. It obtains position information from the aircraft Embedded GPS/INS and provides this information to the range telemetry system or the CTC range system through the DCI during the conduct of live maneuver exercises. The SMODIM coordinates weapons inventory status with the WP and receives laser inputs from the AVR-2A laser Detector and performs threat probability of hit (P_h) and probability of kill (P_k) evaluation. The laser inputs are sorted and filtered for false messages, assessed, and verified. This permits determination of cumulative hit or miss information and resultant damage. The SMODIM performs the "footprint" calculations that support the Longbow Hellfire and rocket geometric pairing as well as the 30mm gun and SAL Hellfire targeting. The installed software will also provide MILES/AGES 30mm gun and SAL Hellfire geometric pairing if the training center infrastructure supports that means of engagement. The SMODIM also records defined event and mission data.

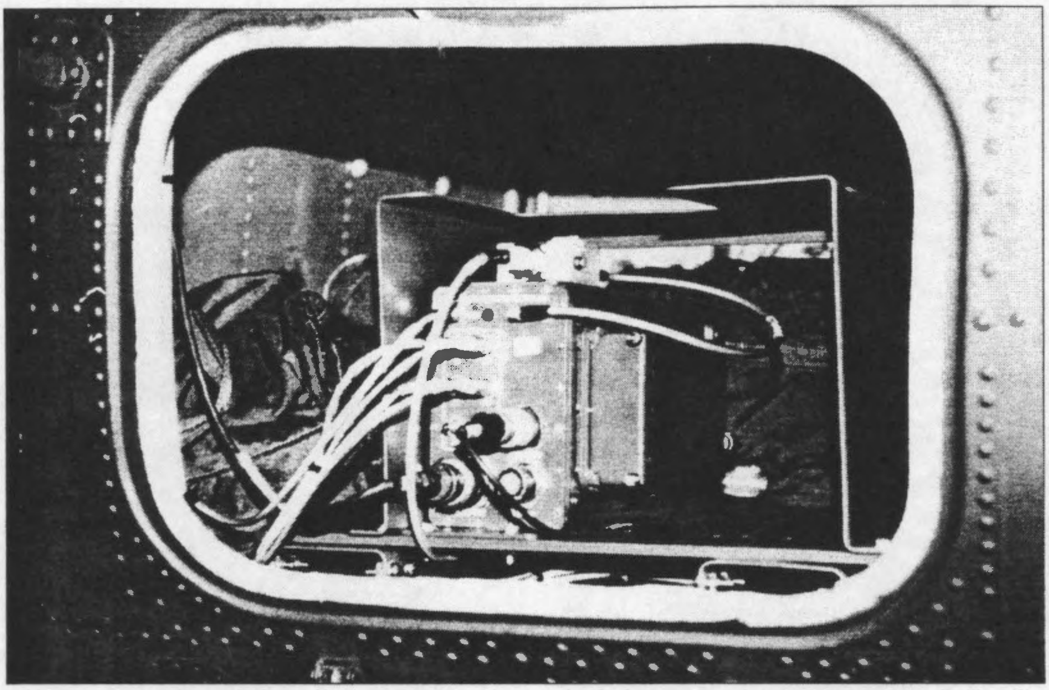

Figure A-2

Smart On-Board Data Interface Module (SMODIM)

Data Communications Interface (DCI) The DCI communicates aircraft position and event data from the SMODIM to the aircraft Embedded GPS/INS (EGI) and receives commands from the CTC communications network. The DCI antenna is depicted in Figure A-3 installed underneath and aft on the tailboom. Note the GPS antenna installed at the intersection of the aft fuselage and the tailboom. Also pictured is the AVR-2A laser receiver attached to the side of the tailboom.

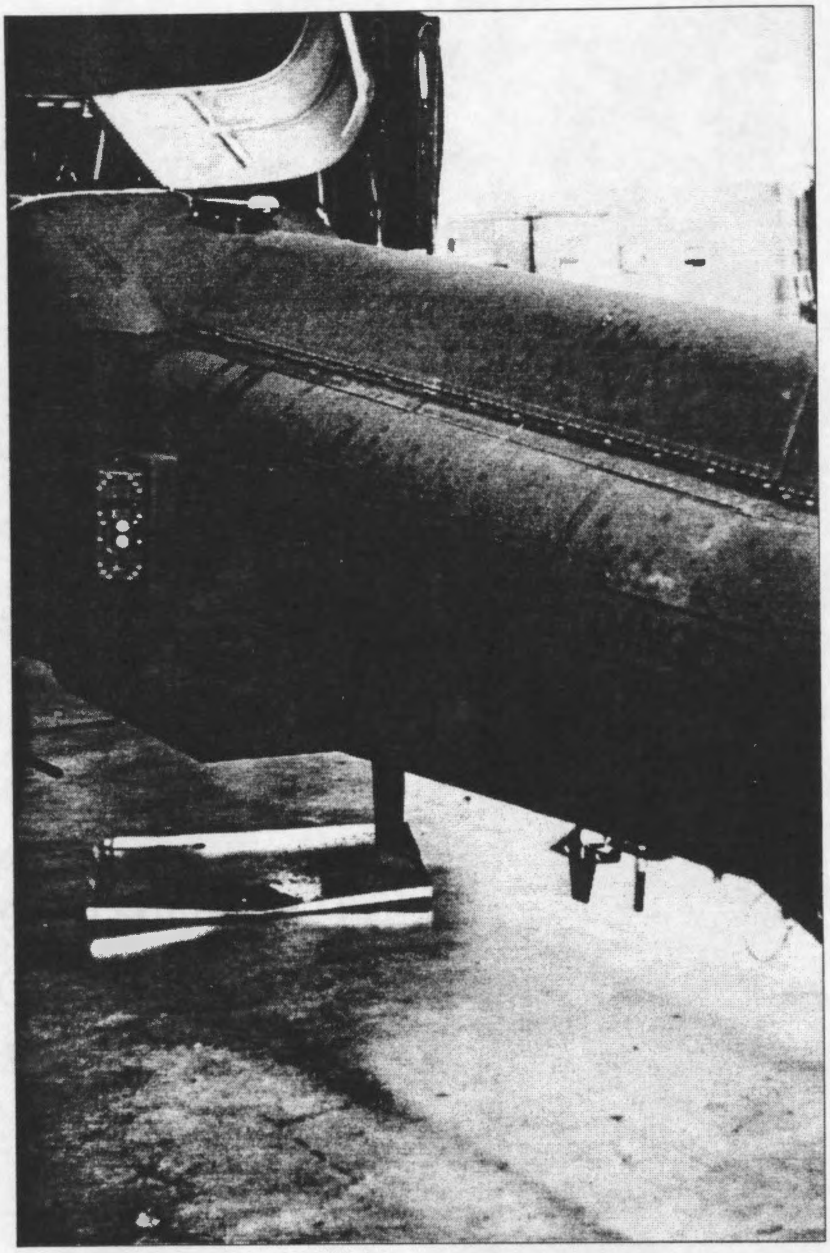

Figure A-3

Data Communications Interface (DCI) Antenna

Indicator Control Unit (ICU) The Indicator Control Unit (ICU) is located in the TES System Training Missile. The ICU controls power, BIT, and the commands to the Aircraft Kill Indicator (AKI) and FLASHWESS. It acts as a remote terminal on Multiplex Bus (MUX) No. 3. The ICU performs self-test and reports AKI/FLASHWESS BIT status to the Weapons Processor.

TES System Training Missile (TTM) The TTM is a Hellfire missile body containing the ICU, FLASHWESS, and associated cabling. The TTM interfaces with the aircraft via a wing pylon 1760 connector. The TES System Training Missile is depicted in Figure A-4. Note the FLASHWESS recessed in the seekerhead and the Aircraft Kill Indicator (blue light) on the missile body.

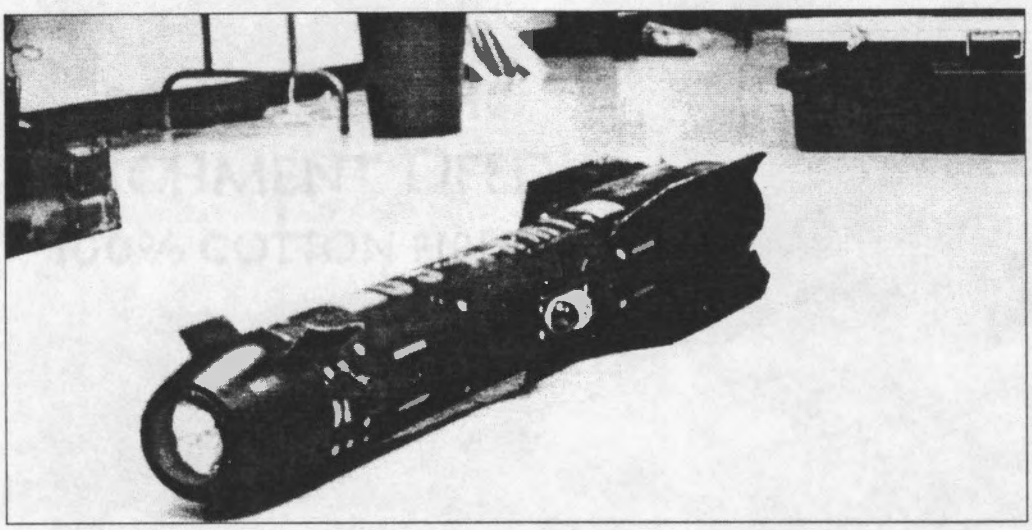

Figure A-4

TES System Training Missile (TTM)

Laser Rangefinder/Designator (LRFD) The LRFD is an electronic assembly used in place of the aircraft Laser Transceiver Unit and Laser Tracker Receiver located in the TADS turret. The LRFD interfaces electrically with the aircraft via the TLIA.

Training Laser Interface Adapter (TLIA) The TLIA provides a two-way interface between the aircraft MIL STD 1553 data bus, two training lasers, and a Flash Weapons Effects Signature Simulator (FLASHWESS).

30mm Gun Laser The gun laser installs on the gun carriage to preclude interference with the lower Wire Strike Protection System (WSPS) blade mounted on the gun carriage. It receives power and signals from the TLIA and transmits Line-of-Sight MILES/AGES event data to simulate the effects of the 30mm gun. Figure A-5 depicts the LRFD, TLIA, 30mm gun laser, and associated cabling.

Central Collection Facility (CCF) Van The CCF van includes two Pentium 300MHz computer systems, a 54-inch color display, a communications interface, a self-erecting antenna mast, and an independent power supply/generator. The CCF van is completely mobile and field supportable. It provides commanders the ability to monitor Longbow training engagements in near real-time and the ability to conduct After Action Reviews and briefings.

Figure A-5

30mm Gun Simulation Components

The engagement data are stored and can be replayed at the single unit or multiple player levels. The CCF also hosts the master TES System instrumentation package processor that provides for data storage, system analysis, and report output. The TES System CCF van (Figure A-6), initially fielded under the Phase I of CHOICE, will be upgraded incrementally to expand the multimedia capabilities required for future TES. Real time command net recording will be provided to augment AAR capability; this includes the added capability of recording both video and audio during debriefs.

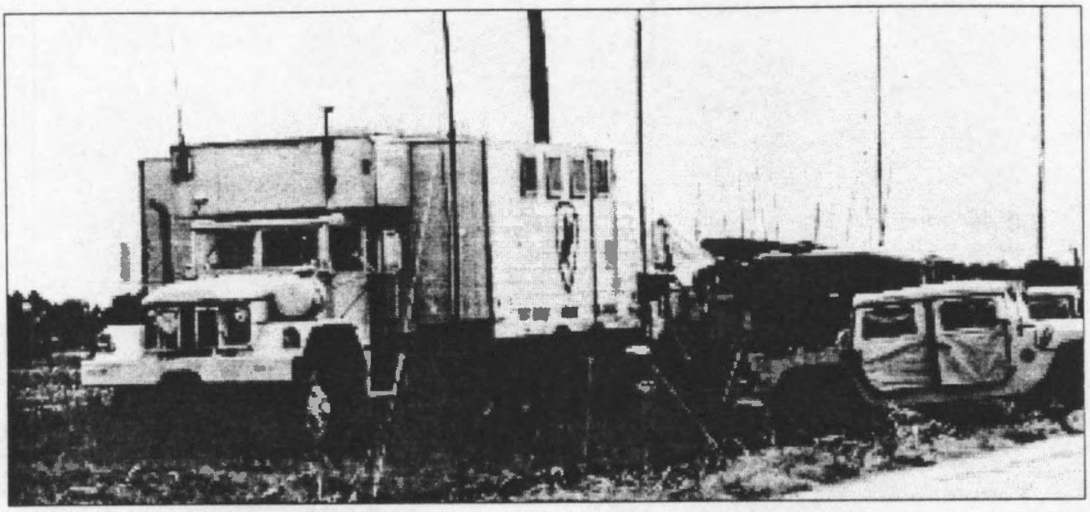

Figure A-6

Central Collection Facility (CCF)

A third computer will be added to act as a server to enhance the system's data capturing capability and to off-load the graphics manipulation to the workstation. The CCF workstation is depicted as Figure A-7.

Target Instrumentation Kits The 35 target instrumentation kits include eye-safe, laser based weapons simulators, a communications interface, and a ground unit data recorder. These components are capable of being mounted on Government Furnished Vehicles (GFV) using vehicle power supply. Utilizing a standard interface to Government Furnished Equipment Weapons Effect Simulation (GFE WES) kit hardware, the targets will

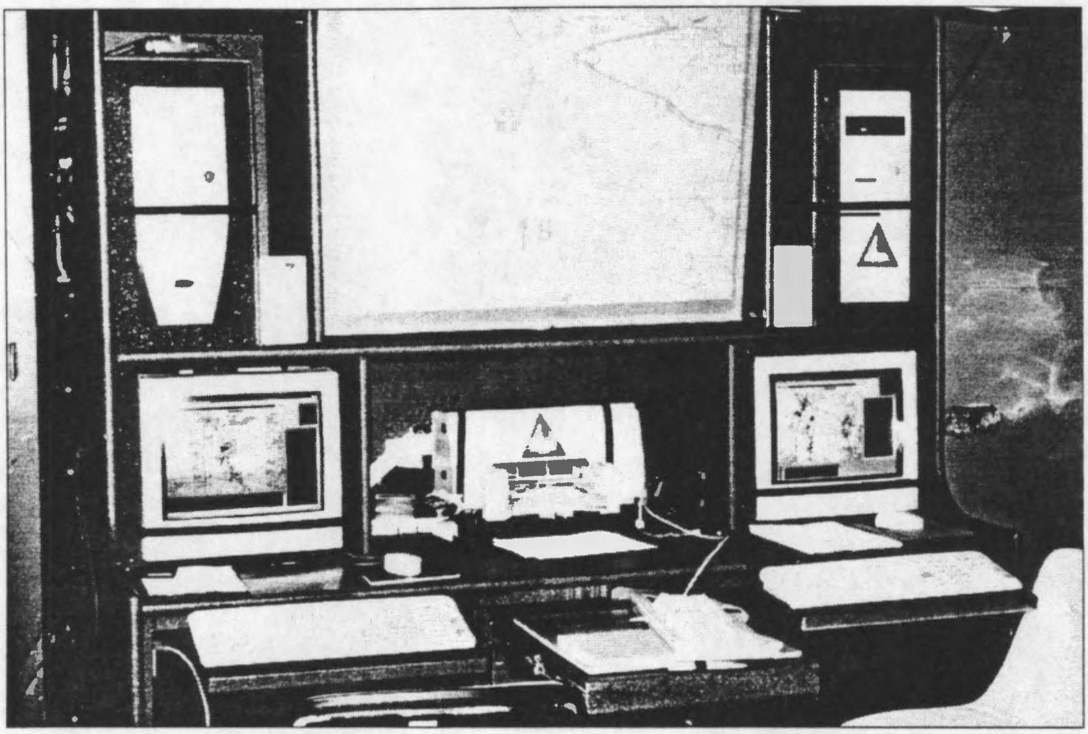

Figure A-7

Central Collection Facility (CCF) Workstation

have a laser based shoot-back capability against aircraft equipped with the TES System.

Ground Repeater Units Four ground repeater units are specialized instrumentation kits configured to provide expanded training area coverage to support the TES System data communications scheme. The ground repeater units are comprised of a mobile communications interface and a rechargeable power supply. The portable ground repeater units do not have a weapons simulator capability, but are operable with either vehicle or Instrumentation Power Supply (IPS).

Training Data Playback Units (TDPU) Two Training Data Playback Units provide field support, operation, data replay, and source data collection functions for the deployed TES System Instrumentation Package. The TDPU is capable of accepting data from the Longbow flight data recorder, allowing data files from multiple players or targets to be saved and/or merged, and viewed.

APPENDIX B

TEST DESIGN PLAN

OPERATIONAL ISSUES AND CRITERIA

Critical Operational Issue (COI) 1
Does the TES System provide a means of Real Time Casualty Assessment (RTCA) capability for Force-on-Force collective training exercises?

Scope This issue examines the capability of the Longbow TES System to provide a means of (RTCA) in near real-time using GPS geometric pairing. Single-ship gunnery tables will be conducted and company and battalion size maneuver exercises will be played in a representative combined arms environment with the TES System installed. The system will be operated and maintained by qualified soldiers and contractor support.

Criterion 1.1 The Longbow TES System will pass and receive 90% of kill and be-killed messages to the correct player(s), to include a status notification in near real-time (≤ 5 seconds) during Force-on-Force training exercises

Basis for Criteria Criterion 1.1 is derived from the *Longbow TES System Requirements Document*, Sections 1 and 2.

Measure of Performance (MOP) 1.1 The measure(s) used to evaluate this criterion will be determined pending development of the RTCA capability using GPS geometric pairing technology.

Critical Operational Issue (COI) 2
Does the TES faithfully simulate the actions and the effects of the aircraft weapons systems?

Scope This issue examines the capability of the Longbow TES System to simulate the actions and effects of the aircraft weapons systems. This capability includes weapons initialization and selection procedures, the portrayal of weapons symbology (to include messages) and weapon status information, and the capability of achieving the probability of hit (P_h) dictated by the appropriate weapons systems models. Furthermore, this issue evaluates the weapons range capabilities to include portrayal of reduced weapons capabilities commensurate with adverse weather conditions. Single-ship gunnery tables will be conducted, and company and battalion size maneuver exercises will be played in a representative combined arms environment with the TES installed. The Longbow TES will be operated and maintained by qualified soldiers and contractor support.

Criterion 2.1 Similarity between Longbow weapons procedures and TES System weapons procedures. Evaluation Criteria: No Go, < 4.

Basis of Criterion Criterion 2.1 is derived from the *Longbow TES System Requirements Document*, Sections 1 and 2.

Measure of Performance 2.1 System operator ratings of the degree to which the TES System provides for the use of accurate weapons employment procedures. These include weapons initialization procedures and sequence, weapons selection, weapon status information, appropriate symbology, and weapons range capabilities during engagements.

MOP Methodology System operators will complete questionnaires to rate the capability of the TES system to perform the tasks identified in the criterion. Data will be aggregated from questionnaires and aircraft VRS tapes. Upon completion of the test event, the test control personnel and Subject Matter Experts will review the data and enter questionnaire responses into the performance database. The test control personnel will assess the information received from the video recordings to collect and verify missing or questionable data. The test control personnel will render opinions by the application of military judgment to augment the system rating questionnaire data when necessary. Mean values will be calculated and provided as output.

Criterion 2.2 The degree of realism provided by the flash and smoke system during weapons system simulation. Evaluation Criteria: No Go, < 4.

Basis for Criteria Criterion 2.2 is derived from the *Longbow TES System Requirements Document*, Section 2.

Measure of Performance 2.2 System operator ratings of the degree to which the TES System Aircraft Instrumentation Package delivers realistic simulations of the flash and smoke produced by the actual weapons systems.

MOP Methodology Event player personnel will complete questionnaires to rate the system capability to perform the tasks listed in the criterion. The Measure of Performance methodology, data collection method, data aggregation and reduction methods, and database output will be similar to Criterion 2.1.

Criterion 2.3 Transparency of TES System instrumentation to operators. Evaluation Criteria: No Go, < 4.

Basis for Criterion Criterion 2.2 is derived from the *Longbow TES System Requirements Document*, Sections 1 and 2.

Measure of Performance 2.3 System operator ratings regarding the transparency of the TES System Aircraft Instrumentation Package to the aircrew.

MOP Methodology The TES System Aircraft Instrumentation Package must not enhance or detract from the normal perceptions of the aircrew regarding the sensors, weapons systems, or cockpit environment. Additionally, the TES System components must not degrade the operational characteristics of the prime system or host weapons systems or interfere with crew duties. System operators will complete questionnaires to rate the system capability to remain effectively transparent to the aircrew. The Measure of Performance methodology, data collection method, data aggregation and reduction methods, and database output will be similar to Criterion 2.1.

Criterion 2.4 Percentage of successful hits (P_h) using the TES System. Evaluation Criteria: No Go, variable based on weapons engagement type.

Basis for Criterion Criterion 2.2 was derived from the *Longbow TES System Requirements Document*, Sections 1 and 2, requiring the TES System to provide the same accuracy as the aircraft weapons systems.

Measure of Performance (MOP) 2.4 Percentage of successful hits using the TES System.

MOP Methodology The demonstrated percentage-of-hits shall be the same as the expected probability of hit (P_h) for the TES weapons models (rocket, gun, or missile simulation). The output (P_h) of the TES model will be verified using the success template/tracking methodology given specific inputs (operational conditions and firing constraints). Data will be aggregated from VRS tapes and RTCA instrumentation.

Additional Operational Issue (AOI) 3
Does the TES System provide timely and accurate information to support battle management?

Scope This issue assesses the ability of the TES System to provide timely and accurate information regarding the disposition of friendly and enemy forces in near real-time, to affect probable courses of action and schemes of maneuver. This issue investigates how well the interface between the TES System Aircraft Instrumentation Package and the CCF supports the tactical decision making efforts of the battlestaff. Company and battalion size maneuver exercises will be played in a representative combined arms environment with the TES System installed. The battle staff will monitor the exercises from the Central Collection Facility (CCF). The console operations in the CCF will be performed by contractor support.

Complimentary Measure (CM) 3.1 Battlestaff member ratings regarding the ability of the TES System to provide timely and accurate information to support battle management?

Basis for Measure This measure is determined by the *TES Master Plan*, Section 5-4, regarding the implications of future TES requirements, and the *HTI-ORD*, Section 1. (3), regarding Exercise Management.

CM Methodology Battle management will be answered via the use of rating questionnaires, administered to the battlestaff representing the various echelons supported by the TES System. The battlestaff shall monitor the exercise from the Central Collection Facility and answer questions about how well the TES System Aircraft Instrumentation Package/CCF interface supports their tactical decision making efforts. Data for this measure will be collected from video recordings of the CCF operator console screens and video and audio recordings of battlestaff actions and conversations inside the CCF. Upon completion of each test event, the test control personnel and Subject Matter Experts will review the data and enter questionnaire responses into the performance database. The test control personnel will assess the information received from the video recordings to collect and verify missing or questionable data and will render opinions by the application of military judgment to augment the rating questionnaire data when necessary. Mean values will be calculated and provided as output.

Additional Operational Issue (AOI) 4
Does the TES System provide accurate data for the preparation and presentation of training performance feedback (AAR Capability)?

Scope This issue assesses the ability of the TES System to to provide accurate, readily interpreted data to be used in the preparation and presentation of an After Action Review (AAR). Company and battalion size maneuver exercises will be played in a representative combined arms environment with the TES System installed. The battlestaff and Observer Controllers will use these data for conducting After Action Reviews.

Basis for Measure The basis for this measure is determined by *OPORD 1-95*, Annex F, 1. e., and the *HTI-ORD*, Section 1., regarding the projected requirements for Army Standardized After Action Review products.

Complimentary Measure (CM) 4.1 User ratings regarding the ability of the TES System to provide accurate, readily interpreted data to be used in the preparation and presentation of an Army After Action Review.

CM Methodology Performance feedback capabilities will be assessed via the use of rating questionnaires administered to the aircrews and the battlestaff representing the various echelons supported by the TES System. The battlestaff members and Observer Controllers involved in conducting the After Action Review shall answer questions about how well the TES System supports their ability to conduct a thorough and meaningful AAR. The pilots will answer questions regarding how well the TES system presents the necessary information for a thorough and meaningful AAR. The test control personnel will attend and review the AARs for completeness. The test control personnel will compare the recorded real-time battle exercise information to the data available for the purpose of preparing and presenting the After Action Review. The test control personnel will render opinions by the application of military judgment to augment the rating questionnaire data when necessary. The data will be aggregated from questionnaires and video/audio tapes. The data will be reduced and stored in the performance database. Mean values will be calculated separately for the pilots and for the Battlestaff/OCs and provided as output.

Additional Operational Issue (AOI) 5
Can the TES System be sustained in an operational environment?

Scope This issue assesses the sustainability of the TES System, RAM, and the adequacy of the logistics support plan. Data will be collected on the ten (10) TES System Aircraft Instrumentation Package sets designated for the V&V effort. The logistics support plan is for two levels of maintenance: unit and contractor support. Unit level maintenance will be soldier supported and limited to installation, cleaning, normal operation, and simple troubleshooting. The logistics support plan provides for the use of a Contractor Logistics Support (CLS) program for major maintenance and logistical support for the life of the system. Since the "A-kit" portion of the TES System AIP consists largely of software imbedded within organic aircraft components, maintenance data will be collected for both unit and contractor levels of maintenance. Data will be collected during single-ship gunnery tables and during company and battalion size maneuver exercises played in a representative combined arms environment.

Complimentary Measure (CM) 5.1 TES System Mean Time Between Mission Affecting Failure (MTBMAF). System evaluation criteria: No Go, < 50 hours.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 3, regarding RAM requirements.

CM Methodology Data will be collected and aggregated from RAM data collection sheets. Upon completion of each test event, the data will be reduced and stored in the RAM database. The MTBMAF for each TES System will be calculated and provided as output. In addition, the mean MTBMAF will be calculated and provided as output for the ten (10) TES System AIPs designated for the test. The MTBMAF will be computed using the following formula:

$$\mathbf{MTBMAF} = \frac{\mathbf{TOT}}{\mathbf{TMAF}}$$

where:
TOT = Total system Operating Time
TMAF = Total number of Mission Affecting Failures

Definitions of data elements:

TOT - Time during which the TES System is fully mission capable, and the system or any component is operating or being controlled by the operator. TOT may include time during which the TES System is partially mission capable but is fully capable of performing all essential mission functions. TOT does not include maintenance time. The TOT will be taken from the TES System RAM tracking sheets.

TMAF - The count of MAFs as defined in the Failure Definitions and scored by the test control personnel.

Complimentary Measure (CM) 5.2 TES System Mean Time To Repair (MTTR). System evaluation criteria: No Go, < 0.5 hours per failure.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 3, regarding RAM requirements.

CM Methodology The Mean Time To Repair (MTTR) is generally used to quantify a maintainability characteristic for repairable systems. The maximum Mean Time to Repair is defined as the time below which all corrective maintenance tasks must be completed. It is an on-system parameter and does not include off-system repair of replaced components. This measure is used to compute both unit and contractor level support on-system MTTR for the TES System. System component MTTRs will be evaluated for their relative impact on TES System maintainability and availability. Data will be collected, aggregated, and reduced similar to CM 5.1. The MTTR will be computed using the following formulas:

$$MTTR_{(Unit)} = \frac{TTR_{(Unit)}}{TCMA_{(Unit)}}$$

$$MTTR_{(Contract)} = \frac{TTR_{(Contract)}}{TCMA_{(Contract)}}$$

where:

TTR = Time To Repair
TCMA = Total Corrective Maintenance Actions
MTTR = Mean Time To Repair

Definitions of data elements:

MTTR - The mean time required to perform corrective maintenance actions.

TTR - Total unit or contractor on-system corrective maintenance clock time.

TCMA - Total number of corrective maintenance actions performed by unit or contractor support.

Complimentary Measure 5.3 Operational availability (A_o) of the TES System. System evaluation criteria: No Go, < 98 percent (based on an operating time of 586 flight hours per year).

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 3, regarding RAM requirements.

CM Methodology This measure examines the TES System demonstrated availability characteristics. Operational availability is generally defined as an objective determination of how well a system meets specified performance requirements. A TES System AIP may only be in one availability category at any time. Data will be collected, aggregated, and reduced similar to CM 5.1. A_O will be computed using the following formula:

$$A_o = \frac{TOT + TST}{TOT + TST + TCMT + TPMT + TALDT}$$

where:

TOT = Total Operating Time
TST = Total Standby Time
TCMT = Total Corrective Maintenance Time
TPMT = Total Preventive maintenance Time
TALDT = Total Administrative and Logistics Delay Time

Definitions of data elements:

TOT - As previously defined (CM 5.1).

TST - Time during which the TES System is capable of performing all essential functions but is not in TOT status. TST includes time when the system is capable of operation, but TST does not include maintenance time.

TCMT - Time during which the TES System is under active maintenance to correct a deficiency. TCMT does not include preventive maintenance time or administrative and logistics delay time.

TPMT - Time during which the TES System is capable of full operation but is receiving preventive maintenance or scheduled services as defined in the appropriate technical manual. TPMT does not include corrective maintenance time.

TALDT - Time during which the TES System is not capable of full operation and is not being actively maintained. TALDT includes time waiting for the maintainer and waiting for repair parts. The TALDT will be computed from the administrative and logistics delay times.

Complimentary Measure 5.4 Probability of the TES System successfully completing a six hour training mission without an operational failure (P_S). System evaluation criteria: No Go, < 89 percent.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 3, regarding RAM requirements.

CM Methodology This measure assesses the reliability stated in terms of a probability of completing a six hour mission. The expression for the reliability function for the TES System is derived from the fact that the system is composed primarily of electrical (*non-mechanical*) equipment. The cumulative failure distribution, or simply the probability of failure as a function of time for electronic equipment generally exhibits the character of a negative exponential during its useful life. The failure distribution F(t) is the probability that the system will fail by time t. It is defined by expression:

$$F(t) = \int_0^t f(t)\,dt$$

The reliability function R(t) is the probability that the system will survive beyond time t. It is defined by the following expression:

$$R(t) = 1 - F(t) \qquad \text{or}$$

$$R(t) = \int_t^\infty f(t)\,dt$$

Since the time to failure is described by a negative exponential function, then

$$R(t) = \int_t^\infty \frac{1}{M} e^{-t/M}\,dt$$

Where M is the mean life (mean time between failures) and t is the period of interest, So

$$R(t) = e^{-t/M}$$

Data will be collected, aggregated, and reduced similar to CM 5.1. The probability of completing a six hour mission, and the demonstrated reliability will be computed from the previously derived formula:

$$\mathbf{Ps} = \mathbf{e}^{-(6\,/\,MTBMAF)}$$

$$\mathbf{Re} = \mathbf{e}^{-(TOT\,/\,MTBMAF)}$$

where:

Re = Demonstrated reliability
e = Natural logarithm
MTBMAF = Mean Time Between Mission Affecting Failures
TOT = Total Operating Time

Complimentary Measure (CM) 5.5 TES System maintenance ratio (MR). System evaluation criteria: No Go, < 2.7 percent.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 3, regarding RAM requirements.

CM Methodology The Maintenance Ratio is a measure of the total maintenance manpower burden required to maintain the TES System in an operational environment. The system must display a MR that does not result in a significant maintenance burden on the unit. Data will be collected, aggregated, and reduced similar to CM 5.1. The MR will be computed and summarized for both unit and contractor maintenance according to the following formulas:

$$MR_{(Unit)} = \frac{TMMH_{(Unit)}}{TOT}$$

$$MR_{(Contract)} = \frac{TMMH_{(Contract)}}{TOT}$$

where:

TMMH = Total Maintenance Man Hours
TOT = Total Operating Time

Definitions of data elements:

TMMH - Total maintenance man-hours by unit and contractor, includes both corrective and preventive maintenance.

TOT - As previously defined (CM 5.1).

Complementary Measure 5.6 Adequacy of the TES System support equipment and the TMDE.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 3, regarding RAM requirements.

CM Methodology This issue assesses the interim support package and TMDE. The logistics support hardware and software needed to support the system will be examined. Hardware includes tools and test equipment. Software includes technical manuals, repair parts and special tools listings. The adequacy of the support equipment and TMDE will be assessed via the use of an informal review checklist. The review checklist consists of questions presented in a checklist format, designed to assess whether the appropriate characteristics have been considered and incorporated into the TES System support equipment and TMDE. The results will be entered and stored in the RAM database.

Additional Operational Issue (AOI) 6
Can the TES System Aircraft Instrumentation Package B-kit be installed and removed in an operational environment?

Scope This issue assesses the installability of the TES System. Data will be collected in an operational environment for the time required to install the system for operation, and to de-install the system for movement.

Complimentary Measure 6.1 Time required for installation. System evaluation criteria: No Go, > 90 minutes.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 2, regarding technical capabilities.

CM Methodology Installation will be measured by the amount of time required for a standard crew of three maintenance personnel to bring the TES System B-kit to preflight-ready status from travel configuration (in transit crates). Data collectors will record the time to perform the installation. Test personnel will take photographs and video tape recordings of crew actions during the installation to document the process. Additionally, data collectors will gather data by the use of an informal review checklist designed to assess whether the TES System design features have an impact on installation. The installation times and the review checklists will be entered into the MANPRINT database. The mean values for the installation time and observations from the review checklists will be provided as output. The installation time will be calculated using the following formula:

Installation Time = Start Time - Stop Time

Definitions of data elements:

Start Time = When the TES System B-kit is uncrated (removed from the transit cases).

Stop Time = When the TES System B-kit is fully installed without restrictions or limitations that preclude the system from being mission ready.

Complimentary Measure 6.2 Time required for removal. System evaluation criteria: No Go, > 60 minutes.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 2, regarding technical capabilities.

CM Methodology Same as for CM 6.1 using a crew of three maintenance personnel. The time required for removal.

Removal Time = Start Time - Stop Time

Definitions of data elements:

Start Time = When the crew commences to remove the TES System B-kit from the aircraft.

Stop Time = When the TES System AIP has been removed and brought to travel configuration (B-kit packed in the transit cases).

Additional Operational Issue (AOI) 7
Does the TES System Central Collection Facility Van have the required technical physical characteristics?

Scope This issue assesses of the physical characteristics of the TES System CCF, to include power, weight and stability, heating, ventilation, and air conditioning (HVAC), secure lighting, seating capacity, and the impacts of growth potential in these areas.

Complimentary Measure (CM) 7.1 The physical characteristics of the TES System Central Collection Facility.

Basis for Measure The basis for this measure is determined by the *TES Master Plan*, Section 5-4, regarding the implications of future TES requirements.

CM Methodology This measure examines the technical parameters of the TES System CCF via the use of an informal review checklist designed to assess whether the appropriate characteristics and Human Factors Engineering have been considered and incorporated into the design of the TES System CCF. Additionally, photographs will be used to augment the checklist data. Observations from the review checklists will be entered into the MANPRINT database and provided as output.

Additional Operational Issue (AOI) 8
Is the TES System suitable for operators and maintainers?

Scope This issue compares the design of the TES System with the capabilities of the target audience operators and maintainers. Application of HFE considers the efficiency of the hardware and software interfaces with the soldier, the task environment, the task characteristic, and how these factors affect the workload of the soldier.

Complimentary Measure 8.1 Assessment of observed Human Factors Engineering (HFE) deficiencies.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 4, regarding Human Factors Engineering requirements.

CM Methodology HFE questionnaires and interviews will be administered to the system operators and maintainers to obtain opinions regarding the human engineering design. Each TES System operator (pilot) and maintainer will complete the questionnaire at least once during the V&V. Additionally, information will be gathered by the use of an informal checklist designed to assess whether the appropriate HFE engineering has been considered and incorporated into the design of the TES System. Photographs will be used to document any foreseen problems with the human factors engineering. Observations and interviews will be entered into the MANPRINT database.

Complimentary Measure 8.2 Assessment of the physical characteristics of the TES System B-kit transit cases.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Section 2, regarding the technical capabilities.

CM Methodology This measure assesses the portability of the TES System B-kit in transit cases (travel configuration) which satisfy operational transportability two-man lift requirements. The V&V will provide observations, photographs, and operator comments on the TES System storage capabilities. Information will be gathered by the use of an informal review checklist designed to assess whether the appropriate HFE engineering has been considered and incorporated into the design of the TES System transit cases. Photographs will be used to document the data. Data will be entered into the MANPRINT database and provide as output.

Complimentary Measure 8.3 Assessment of observed manpower problems.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraphs 5 and 6, regarding maintenance and manpower.

CM Methodology This measure assesses the number of people needed to operate, maintain, and support the TES System. The assessment includes determining whether the doctrinal requirements of the TES System are appropriate with respect to total number of soldiers, MOS, skill level, and skill identifiers. Data will be collected by the use of an informal review checklist, and by comments, interviews, and observations as needed.

Complementary Measure 8.4 Assessment of observed personnel problems.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 6, regarding manpower.

CM Methodology This measure examines the experience of TES System operators and maintainers as they relate to observed personnel problems. Data will be gathered prior to the start of the test to establish baselines for operator and maintainer experience and proficiency levels. These data will be collected on a feeder report and stored in the MANPRINT database.

Complementary Measure 8.5 Assessment of observed training problems.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 6, regarding manpower requirements.

CM Methodology This measure examines the necessary training and time required to impart the knowledge, skills, and abilities to soldiers for operation and maintenance of the TES System. The test control personnel will review the New Equipment Training (NET) support package and observe training conducted by the system contractor. Test control personnel will examine initial training provided to operators and maintainers, following contractor conducted training and completion of the V&V. Additionally, the test control personnel will gather information using an informal review checklist and by conducting interviews with the operators, maintainers, and instructors regarding the adequacy of training, training devices, training materials, and the user acceptability of training manuals. Training adequacy is assessed in terms of operator and maintainer proficiency in performing the tasks required to effectively employ the TES System. Any training devices, training publications and literature, and methods of instruction included in the Program Of Instruction (POI) will be addressed. Data will be entered into the MANPRINT database and provided as output.

Complementary Measure 8.6 Assessment of safety problem severity.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 8, regarding safety requirements.

CM Methodology This measure examines any system characteristics detailed during the test that could cause injury to the operator or maintainer of the TES System. The test control personnel will observe all V&V events and will record data as needed on a Test Incident Report (TIR) form. Additionally, photographs will be used to document any data if necessary. Any unsolved, serious safety problem will be cause for a test halt until the problem is corrected.

Complementary Measure 8.7 Assessment of health hazards.

Basis for Measure The basis for this measure is determined by the *Longbow TES System Requirements Document*, Paragraph 8, regarding safety requirements.

CM Methodology This measure examines any condition detected during the operation or maintenance of the TES System during testing that can cause death, acute or chronic illness, disability, or reduced job performance of the soldier. The test control personnel will observe all V&V events and will record any situation or condition observed during testing as needed on a Test Incident Report (TIR) form. Additionally, Photographs will be used to document any data if necessary. Any unsolved, serious health condition will be cause for a test halt until the condition is corrected.

Complementary Measure 8.8 Assessment of observed soldier survivability problems.

CM Methodology This measure examines the survivability of the soldier and TES System while conducting training. The test control personnel will observe all V&V events and will note any problem areas. Any situation or condition observed during testing or noted during interviews or on questionnaires that could potentially reduce soldier or TES System survivability will be documented on a Test Incident Report (TIR) form. Additionally, Photographs will be used to document any data if necessary. These data will be stored in the MANPRINT database.

FAILURE DEFINITIONS

General

Failure Definitions specify the parameters relative to classification and assignment of all system failures. Failure definitions are developed to ensure that all program participants are made aware of these definitions and criteria. It is the key to defining failures and mission essential functions relative to the RAM issues for OT. The mission-essential function descriptions for this test are held to a minimum consistent with the proposed set of test procedures. The Program Manager or decision making authority will be the final approving authority of the Failure Definitions

Failure Classification

Mission Affecting Failure A Mission Affecting Failure (MAF) is one which prevents the aircrew from performing any aspect of weapons employment or weapons initialization using the proper procedures prescribed by the operator's manual or any other pertinent training publication. The loss of a mission-essential function is one that is readily identifiable by the aircrew during normal operations.

Non-Mission Affecting Failure A non-Mission Affecting Failure is one which does not prevent the aircrew from performing weapons employment or weapons initialization but requires them to perform the required procedure(s) in a degraded mode. The test officer will establish the maximum allowable degradation of the mission-essential functions on a case by case basis.

Failure Categories

Equipment Design Failure Any failure which can be traced directly to the design of the equipment; that is, the design of the equipment caused the part in question to degrade or fail, resulting in an equipment failure.

Equipment Manufacturing Failure A failure caused by poor workmanship or inadequate manufacturing process control during equipment construction, testing, or repair prior to the start of testing.

Design Failure The failure of parts which can be traced directly to inadequate design.

Part Manufacturing Failure Part manufacturing failures are the result of poor workmanship or inadequate manufacturing process control during part assembly, inadequate inspections, or improper testing.

Software Error Failure A failure caused by an error in the. computer program associated with the hardware.

Failure Response

Problem and Failure Action The occurrence of a problem or failure that affects satisfactory operation of the equipment shall be entered on a TIR. The failed equipment shall be removed from the test with minimum interruption to the equipment continuing on test.

Problem and Failure Reporting A failure report shall be initiated at the occurrence of each problem or failure of contractor hardware and software on a TIR. The report shall contain the information required to permit determination of the origin and correction of failures. Descriptions of failure symptoms, conditions surrounding the failure, failed hardware identification, and operating time at time of failure shall be entered on a TIR. Additionally, the description should contain all repair actions taken to return the item to operational readiness.

Failure Verification Reported failures shall be verified as actual failures or an acceptable explanation provided to the Program Manager for lack of failure verification. Failure verification is determined either by repeating the failure mode on the reported item or by physical or electrical evidence of failure. Lack of failure verification, by itself, is not sufficient rationale to conclude the absence of a failure.

Corrective Action When the cause of failure has been determined, a corrective action shall be developed to eliminate or reduce the recurrence of the failure. Repairs shall be made in accordance with normal field operating procedures and manuals. The procuring activity shall review the corrective actions and the status prior to implementation. In all cases, the failure analysis and the resulting corrective actions shall be documented. The effectiveness of the corrective action should be demonstrated by restarting the test at the beginning of the test cycle in which the original failure occurred.

Corrective Maintenance (repair) The actions performed, as a result of failure to restore an item to a specified condition.

Failure categories/failure responses were cited from MIL-STD 781D.

DATA MANAGEMENT

Overview
The data management process condenses and formats the V&V data for analysis and documentation. A preliminary *level-four* database structure has been developed to analyze and store test data. The test database is organized in three categories: performance, RAM and MANPRINT. Each data category will be collected and stored in a separate database.

Database Descriptions
DBMS The DataBase Management System (DBMS) is a central file that provides access to each of the databases. DBMS stores and enables access to questionnaire formats, data collection forms, review checklists, and other pertinent forms.

Performance The performance database is used to aggregate TES System performance data for COI 1, COI 2, AOI 3, and AOI 4. The Performance database contains a record for each of 30 pilots, 12 battlestaff personnel, and 5 observer controllers. The database makes provisions to incorporate additional records as needed.

RAM The RAM database provides a consistent methodology for collecting, processing, and reporting required RAM test data for AOI 5. The RAM database contains a record for each of the 10 TES System Aircraft Instrumentation Package sets designated for the original V&V effort and makes provisions to incorporate additional records as needed.

MANPRINT The MANPRINT database will be used for collection and processing data For AOI 6, AOI 7, and AOI 8.

Database Structure
The DBMS and the performance, RAM, and MANPRINT databases have been created in Microsoft® Excel 97 and Microsoft® Word 97. The database structure has been constructed by creating *Hyperlinks* (dynamic date exchange and object linking and embedding) between the individual files. The databases are menu-driven for ease of use and are password protected. They are exportable to test sites on stand-alone laptop or notebook personal computers using standard magnetic media.

Data Reduction
Performance Video data reduction consists of:

- VRS recordings of aircraft symbology, icons, messages, and TES System operator conversations.
- video and audio recordings of CCF workstation

monitors.
- video and audio recordings of the actions and conversations of the battlestaff within the CCF.
- video and audio recordings of the actions of the maintenance personnel.

Data identified by this process is manually entered in the databases. Questionnaire data and mean values will be calculated and provided as output.

RAM Data reduction begins with an accurate transcription of the data from the data collection forms into the RAM database. The RAM database will generate all required calculations for each TES System. In addition, mean values will be calculated and provided as output for the ten (10) TES System AIPs designated for the test.

MANPRINT Data reduction personnel will generate reports based on informal review checklists.

COI Data Presentation
The results of the qualitative criteria for each Critical Operational Issue will be presented on one chart. The criteria will not be averaged to determine a quantitative value for the overall COI. The results of the evaluation of the Critical Operational Issues will be used for the accreditation process, consequently, the decision maker must place a relative weight on each supporting criterion. The visual presentation of the criteria scores for the COIs will:

- prompt the Longbow TES System proponent to carry out a causality analysis if a criterion receives a poor rating.
- assist in steering the terms of a conditional accreditation if necessary.
- provide a starting point for the next iteration of the TES System development process if required.

Data Storage
Upon completion of the V&V effort, data will be archived and printed for submission to the Program Manager for subsequent processing and analysis.

Data Authentication
The data authentication team will consist of independent experts with a broad spectrum of technical disciplines. This team will assemble for the purpose of assessing and monitoring data reduction, quality control, and the identification and analysis

of anomalies in the system, instrumentation, database structures, and test data.

APPENDIX C

DATA COLLECTION FORMS

Table C-1

Data Collection requirements

Data Collection Form	Completed By	When Completed	COI/AOI
1	Aircrew	Post Mission	COI 2, AOI 4
2	Battlestaff/OCs	During/Post Mission	AOI 3, AOI 4
3	Participating Test Personnel	Prior to Test Events	Supporting Test, AOI 8
4	Data Collection Personnel	Continuously During Test	AOI 5
5	Data Collection Personnel/Test Participants	Continuously During Test	Supporting Test, AOI 8
6	Data Collection Personnel	During Test	AOI 7
7,8	Data Collection Personnel	During Test	AOI 5,6
9	Data Collection Personnel	During Test	AOI 5
10	Data Collection Personnel	During Test	COI 2
11, 12, 13, 14	Data Collection Personnel	During Test	AOI 8
15	Data Collection Personnel	During Test	Environmental Impact; Does Not Support COI/AOI

DATA COLLECTION FORM 1

(PILOT QUESTIONNAIRE, PAGE 1)

TES System Pilot Survey Questionnaire

Respondent Control Number:__________

Statements

Statements	Definitely Agree	Probably Agree	Neither Agree nor Disagree	Probably Disagree	Definitely Disagree	Statement Does NOT Apply
1. Weapons initialization procedures were the same as normal operations with the TES System installed.	☐	☐	☐	☐	☐	☐
2. Weapons selection procedures were the same as normal operations with the TES System installed.	☐	☐	☐	☐	☐	☐
3. Weapons symbology presented was the same as normal operations with the TES System installed.	☐	☐	☐	☐	☐	☐
4. Weapons status information presented was the same as normal operations with the TES System installed.	☐	☐	☐	☐	☐	☐
5. Weapons range was the same as normal operation with the TES System installed.	☐	☐	☐	☐	☐	☐
6. Weapons range in adverse weather conditions was the same as normal operation.	☐	☐	☐	☐	☐	☐
7. Simulation of weapons flash was the same as actual weapons flash.	☐	☐	☐	☐	☐	☐
8. Simulation of weapons smoke was the same as actual weapons smoke.	☐	☐	☐	☐	☐	☐
9. Simulation of weapons noise was the same as actual weapons noise.	☐	☐	☐	☐	☐	☐
10. System sensors with the TES System installed responded the same as normal operation.	☐	☐	☐	☐	☐	☐
11. The weapons system with the TES System installed performed as in normal operation.	☐	☐	☐	☐	☐	☐
12. The cockpit environment with the TES System installed was the same as in normal operation.	☐	☐	☐	☐	☐	☐

DATA COLLECTION FORM 1

(PILOT QUESTIONNAIRE, PAGE 2)

13. In-flight activities were NOT affected by the TES System equipment. ☐ ☐ ☐ ☐ ☐ ☐
14. For a simulation system, TES System required realistic cockpit activity during simulation exercises. ☐ ☐ ☐ ☐ ☐ ☐
15. Pilot workload, with TES System installed, was nominal. ☐ ☐ ☐ ☐ ☐ ☐
16. Post-flight checklists required normal operational times with the TES System equipment installed. ☐ ☐ ☐ ☐ ☐ ☐
17. Video presentations of TES System data displayed during the debriefing, or After Action Report (AAR), were easily interpreted. ☐ ☐ ☐ ☐ ☐ ☐
18. Personnel or material *did not* obstruct video presentations of TES System data displayed during the AAR. ☐ ☐ ☐ ☐ ☐ ☐
19. Video presentations of TES System data displayed during the AAR were accurate to the degree necessary for training purposes. ☐ ☐ ☐ ☐ ☐ ☐
20. Video presentations of TES System data displayed during the AAR were easily prepared in the given timeframe of the exercise. ☐ ☐ ☐ ☐ ☐ ☐
21. Video presentations of TES System data displayed during the AAR were effective for the established training goals and objectives. ☐ ☐ ☐ ☐ ☐ ☐
22. Noise levels in the TES System CCF during the AAR *did not* cause undue distraction. ☐ ☐ ☐ ☐ ☐ ☐
23. Noise levels in the TES System CCF during the AAR *did not* adversely affect hearing the debriefing. ☐ ☐ ☐ ☐ ☐ ☐
24. Temperature levels in the TES System CCF during the AAR were nominal. ☐ ☐ ☐ ☐ ☐ ☐

DATA COLLECTION FORM 1

(PILOT QUESTIONNAIRE, PAGE 3)

25. Adequate equipment for in-field presentations of TES System data were available.	☐	☐	☐	☐	☐	☐
26. Negative habit transfer *was not* incurred from training with TES System.	☐	☐	☐	☐	☐	☐
27. Artificial pilot requirements *were not* incurred from training with TES System.	☐	☐	☐	☐	☐	☐
28. TES System *did not* degrade the operational characteristics of the host system.	☐	☐	☐	☐	☐	☐
29. TES System *did not* interfere with normal crew duties.	☐	☐	☐	☐	☐	☐
30. TES System required crewmembers to perform the same functions in an engagement sequence (to include aircraft orientation) as when engaging a target with service ammunition.	☐	☐	☐	☐	☐	☐
31. TES System-equipped targets depicted the appropriate weapons effects when fired upon by a TES System weapon device.	☐	☐	☐	☐	☐	☐
32. TES System operation *did not* cause or lead to premature failures of host components or systems.	☐	☐	☐	☐	☐	☐
33. TES System operation *did not* cause or lead to damage of host components or systems.	☐	☐	☐	☐	☐	☐

DATA COLLECTION FORM 2

(STAFF QUESTIONNAIRE, PAGE 1)

TES System Battle Staff Survey Questionnaire

Respondent Control Number:___________

Statements	Definitely Agree	Probably Agree	Neither Agree nor Disagree	Probably Disagree	Definitely Disagree	Statement Does NOT Apply
1. Adequate training was provided for the operation of the TES System CCF systems.	☐	☐	☐	☐	☐	☐
2. Adequate time was available for TES System CCF system setup without undue delay in the simulation timetable.	☐	☐	☐	☐	☐	☐
3. The TES System work environment during a simulation was free from environmental distractions that were unrelated to the simulation exercise.	☐	☐	☐	☐	☐	☐
4. Ventilation in the TES System CCF work environment was adequate for the equipment during the simulation exercise.	☐	☐	☐	☐	☐	☐
5. Noise levels in the TES System CCF work environment were nominal for a simulation exercise.	☐	☐	☐	☐	☐	☐
6. Temperature levels in the TES System CCF work environment were nominal for a simulation exercise.	☐	☐	☐	☐	☐	☐
7. The TES System CCF workstation design was comfortable for the duration of the exercise.	☐	☐	☐	☐	☐	☐
8. Adequate system features were available to meet command and control requests for specific data.	☐	☐	☐	☐	☐	☐
9. Specific data requested was available in a reasonable timeframe.	☐	☐	☐	☐	☐	☐
10. Adequate system features were available to retrieve stored data in a reasonable timeframe.	☐	☐	☐	☐	☐	☐
11. Adequate system features were available to display and distribute retrieved data.	☐	☐	☐	☐	☐	☐

DATA COLLECTION FORM 2

(STAFF QUESTIONNAIRE, PAGE 2)

12. Display of data during the simulation exercise was adequate to discern easily between exercise opponents. ☐ ☐ ☐ ☐ ☐ ☐

13. Display of data during the simulation exercise was adequate to discern easily between players on the same force. ☐ ☐ ☐ ☐ ☐ ☐

14. Data display latency *did not* adversely affect command decisions during the exercise. ☐ ☐ ☐ ☐ ☐ ☐

15. Data display latency *did not* reduce the realism of the exercise when compared to other simulation techniques. ☐ ☐ ☐ ☐ ☐ ☐

16. The data displayed during the simulation exercise provided an adequate amount of information regarding the status of the engagement. ☐ ☐ ☐ ☐ ☐ ☐

17. The data displayed during the simulation exercise provided an adequate amount of information regarding the status of each player in the engagement. ☐ ☐ ☐ ☐ ☐ ☐

18. Video presentations of TES System data displayed during the debriefing, or After Action Report (AAR), were easily interpreted. ☐ ☐ ☐ ☐ ☐ ☐

19. Video presentations of TES System data displayed during the AAR *were not* obstructed by personnel or material. ☐ ☐ ☐ ☐ ☐ ☐

20. Video presentations of TES System data displayed during the AAR were accurate to the degree necessary for training purposes. ☐ ☐ ☐ ☐ ☐ ☐

21. Video presentations of TES System data displayed during the AAR were easily prepared in the given timeframe of the exercise. ☐ ☐ ☐ ☐ ☐ ☐

22. Video presentations of TES System data displayed during the AAR were effective for the established training goals and objectives. ☐ ☐ ☐ ☐ ☐ ☐

23. Noise levels in the TES System CCF during the AAR *did not* cause undue distraction. ☐ ☐ ☐ ☐ ☐ ☐

DATA COLLECTION FORM 2

(STAFF QUESTIONNAIRE, PAGE 3)

24. Noise levels in the TES System CCF during the AAR *did not* adversely affect hearing the debriefing. ☐ ☐ ☐ ☐ ☐ ☐

25. Temperature levels in the TES System CCF during the AAR were nominal. ☐ ☐ ☐ ☐ ☐ ☐

26. Adequate equipment for in-field presentations of TES System data were available. ☐ ☐ ☐ ☐ ☐ ☐

27. Adequate training was provided for use of in-field presentation equipment. ☐ ☐ ☐ ☐ ☐ ☐

28. Documentation was provided for troubleshooting in-field presentations of TES System data. ☐ ☐ ☐ ☐ ☐ ☐

29. Documentation provided timely solutions for troubleshooting in-field presentation problems. ☐ ☐ ☐ ☐ ☐ ☐

30. In-field presentations of TES System data were easily interpreted. ☐ ☐ ☐ ☐ ☐ ☐

31. MILES-equipped targets depicted the appropriate weapons effects when fired upon by a TES System weapon device. ☐ ☐ ☐ ☐ ☐ ☐

32. The unit was able to operate in a sustained simulated wartime environment without degradation while using TES System and employing unit equipment defined in the current MTOE. ☐ ☐ ☐ ☐ ☐ ☐

33. The TES System equipment was safe to operate in an operational environment. ☐ ☐ ☐ ☐ ☐ ☐

34. The TES System equipment was safe to maintain in an operational environment. ☐ ☐ ☐ ☐ ☐ ☐

35. TES System properly provided a target kill indication. ☐ ☐ ☐ ☐ ☐ ☐

36. TES System provided adequate support to the commander and controller personnel during the unit's participation at the CTC. ☐ ☐ ☐ ☐ ☐ ☐

DATA COLLECTION FORM 3

(PERSONNEL DATA SHEET)

Feeder Report
Tactical Engagement Simulation System

Data Collectors Name:

Data Collectors PIN: [| | |]

Name: (Last, First, MI)

[| | | | | | | | | | | | | | | | | | |]

PIN Number: [| | |]

Grade: [|]

01-06, W1-W5, E1-E9

Duty MOS: [| | | |]

Personnel Function: [| | | | | | | | | |]

Additional Skill Identifier: [|]

Description of duties, job responsibilities, job position title, organization, etc.:

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Page 1 of 1 Form Date: Nov 98

DATA COLLECTION FORM 4

(RAM DATA COLLECTION SHEET/EQUIPMENT STATUS, PAGE 1)

RAM Data Collection Sheet
TESS Equipment Status

Data Collectors Name:

Data Collectors PIN: [| | |]

System (AIP No.): [|]   Date: D D [|] M M M [| |] Y Y [|]   Test Phase: [ ]

Equipment Status

1 = Operating
2 = Standby
3 = Active Maintenance
4 = Maintenance Delay
5 = Non-Chargeable Down Time

Task Status (for Active Maintenance)

UM/CM
10/11 = Diagnosis
12/13 = Remove/Replace
14/15 = Repair
16/17 = Test/Checkout
18/19 = Scheduled Maintenance

Task Status (for Maintenance Delay)

UM/CM
20/21 = Logistics Delay
22/23 = Admin Delay
24/25 = Travel Time
26/27 = Deferred Maint Time

Failure Class

1 = Mission Affecting
2 = Non-Mission Affecting

Failure Category

1 = Equipment Design Failure
2 = Equipment Manufacturing Failure
3 = Part Design Failure
4 = Part Manufacturing Failure
5 = Software Error Failure

Start Time H H M M	Stop Time H H M M	Equip Status	Task Status	Failure Class	Failure Category	

Page 1 of 2   Form Date: Nov 98

DATA COLLECTION FORM 4

(RAM DATA COLLECTION SHEET/EQUIPMENT STATUS, PAGE 2)

TESS Equipment Status
RAM Data Collection Sheet

Start Time H H M M	Stop Time H H M M	Equip Status	Task Status	Failure Class	Failure Category	

Page 2 of 2 Form Date: Nov 98

DATA COLLECTION FORM 5

(TEST INCIDENT REPORT, PAGE 1)

Test Incident Report
Tactical Engagement Simulation System (TESS)

Data Collectors Name:

Data Collectors PIN: [| | |]

System (AIP No.): [|]   Test Incident Number: [| |]   Test Phase: [ ]

	D D	M M M	Y Y	H H M M
Date and Time Incident Occurred:	[|]	[| |]	[|]	[| | |]
Date and Time Incident Cleared:	[|]	[| |]	[|]	[| | |]

Mission Number: [| |]

Operational Mode: [ ]

1 = Ground Operation
2 = Hover
3 = Cruise
4 = Tactical Movement

Environmental Condition: [ ]

1 = Dry   4 = Ice/Snow
2 = Dusty   5 = Fog
3 = Raining   6 = Sand

Incident Category: [ ]

1 = Critical
2 = Major
3 = Minor

Failure Class: [ ]

1 = Mission Affecting
2 = Non-Mission Affecting

Failure Category: [ ]

1 = Equipment Design Failure
2 = Equipment Manufacturing Failure
3 = Part Design Failure
4 = Part Manufacturing Failure
5 = Software Error Failure

Effect On Mission: [ ]

1 = Aborted
2 = Degraded
3 = No Effect

BIT Fault Detection Results: [ ]

1 = Successful Detection
2 = Failure to detect
3 = Incorrect Detection
4 = False Alarm
5 = Not Applicable

DATA COLLECTION FORM 5

(TEST INCIDENT REPORT, PAGE 2)

Test Incident Report
Tactical Engagement Simulation System (TESS)

Incident Description:

Include the Following:

Location of Incident.
Activity and flight mode at time of incident.
Environmental Conditions.
Description of any prior incidents which may have an effect on this incident.
Description of event and any immediate reactions and/or diagnosis.

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Page 2 of 3 **Form Date: Nov 98**

DATA COLLECTION FORM 5

(TEST INCIDENT REPORT, PAGE 3)

Test Incident Report
Tactical Engagement Simulation System (TESS)

Incident Description (continued):

Page 3 of 3 Form Date: Nov 98

DATA COLLECTION FORM 6

(CCF REVIEW CHECKLIST)

TES SYSTEM CENTRAL COLLECTION FACILITY

Design Characteristics
Does the design of the CCF consider the following: temperature, humidity, vibration, shock, pressure, wind, sand, and dust? Have the ranges and extreme conditions been specified and properly addressed in design? Have the proper environmental profiles been addressed?

Have provisions been made to specify and control noise, illumination, temperature, and humidity in areas within the CCF where battlestaff personnel are required to perform operational tasks?

Human Factors Engineering
Are operator panels optimally positioned? For personnel in the standing position, panels and CRTs should be located between 40 and 70 inches above the floor. Critical or precise controls should be between 48 and 64 inches above the floor. For personnel in the sitting position, panels should be located 30 inches above the floor.

Are equipment racks mounted on roll-out slides?

DATA COLLECTION FORM 7

(MAINTENANCE REVIEW CHECKLIST)

LONGBOW TES SYSTEM MAINTENANCE CONCEPT

Have the levels of maintenance been identified and defined?

Have basic maintenance functions been identified for each level?

Have level-of-repair policies been established? Repair versus discard? Repair at unit level or at contractor level?

Have the criteria for level-of-repair decisions been adequately defined?

Have the test and support equipment requirements been defined for each level of maintenance?

Has a detailed maintenance task analysis been done to verify maintenance task sequences, task complexities and personnel skills?

Is the detailed maintenance task analysis compatible with maintainability data and the logistic support plan?

Are the detailed maintenance tasks compatible with TES system maintenance procedures (task sequences, depth of explanatory material based on task complexity)?

Have all system software requirements for maintenance functions been identified? Have these requirements been developed through a system-level functional analysis to provide traceablity?

DATA COLLECTION FORM 8

(DESIGN REVIEW CHECKLIST, PAGE 1)

TES SYSTEM DESIGN FEATURES

Factors impacting Maintenance
Accessibility Are key system components directly accessible for the performance of maintenance tasks?

Is access easily attained?

Are access requirements compatible with the frequency of maintenance or the importance of the maintenance tasks?

Are access doors provided where appropriate? Are hinged doors used? Can access doors that are hinged be supported in the open position?

Are access openings adequate in size and optimally located for the required access?

Are access door fasteners of the quick-release variety?

Can access be attained without the use of tools?

If tools are required to gain access, are the number of tools held to a minimum? Are the tools standard or special?

Are access provisions between modules and components adequate?

Adjustments and Alignments Have adjustment and alignment requirements been minimized, or eliminated?

Are adjustment requirements known?

Are adjustment points accessible?

Are adjustment-point locations compatible with the maintenance level at which the adjustment is made?

Have adjustment and alignment interaction effects been eliminated?

Are factory adjustments specified?

DATA COLLECTION FORM 8

(DESIGN REVIEW CHECKLIST, PAGE 2)

Are adjustment points adequately labeled? Can adjustments and alignments be made without the requirement for special tools?

Calibration Have calibration requirements been minimized?

Are calibration requirements known where applicable?

Are calibration frequencies and tolerances known?

Have the facilities for calibration been identified?
Are the necessary standards available for calibration?

Are calibration requirements compatible with the maintenance concept and the logistic support plan?

Cables and Connectors Are cables fabricated in removable sections?

Are cables routed to avoid sharp bends?

Are cables routed to avoid pinching?

Is cable labeling adequate?

Is cable clamping adequate?

Are the connectors quick-disconnect?

Are connectors that are mounted on surfaces far enough apart so that they can be firmly grasped for connecting and disconnecting?

Are connectors and receptacles labeled?

Are connectors standardized?

Mounting Is it possible to limit maintenance to the removal of only the failed part when a failure occurs?

Is the design compatible with level of repair analysis decisions? Repairable items are designed to include maintenance provisions such as test points, accessibility, and plug-in components.

DATA COLLECTION FORM 8

(DESIGN REVIEW CHECKLIST, PAGE 3)

Are plug-in modules and components used to the maximum extent possible?

Are accesses between modules adequate to allow for hand grasping?

Are modules and components mounted such that the removal of any single item for maintenance will not require the removal of other items?

In areas where module stacking is necessary because of limited space, are the modules mounted in such a way that access priority has been assigned in accordance with the predicted removal and replacement frequency? Items that require frequent maintenance should be more accessible.

Are modules and components (not plug-in) mounted with four fasteners or less? Modules should be securely mounted, however the number of fasteners should be held to a minimum.

Are shock-mounting provisions incorporated where shock and vibration requirements are excessive?

Are provisions incorporated to preclude installation of the wrong module?

Are plug-in modules and components removable without the use of tools? Are guides (slides or pins) provided to facilitate module installation?

Are modules and components labeled?

Are module and component labels located on top or immediately adjacent to the item and in plain sight?

Are the labels permanently affixed so that they will not come off during a maintenance action or as a result of environment?
Is the information on the label adequate?

DATA COLLECTION FORM 8

(DESIGN REVIEW CHECKLIST, PAGE 4)

Maintainability Is the system or product maintainable in terms of troubleshooting and diagnostic provisions, accessibility, ease of replacement and handling capabilities in the performance of maintenance (corrective and preventive)?

Have maintainability requirements for the system or equipment been adequately defined? Are they compatible with system performance, reliability, supportability, and effectiveness factors?

DATA COLLECTION FORM 9

(TMDE REVIEW CHECKLIST, PAGE 1)

TEST, MAINTENANCE AND DIAGNOSTIC EQUIPMENT

Equipment

Have standard TMDE and support equipment items been selected?

Have criteria been established for TMDE and support equipment at each level of maintenance? Built-in versus external test equipment? Diagnostic requirements?

Are the selected TMDE and support equipment items compatible with the prime equipment? Does the TMDE do the job?

Are TMDE requirements compatible with maintenance concept, logistic support plan, and level of repair analysis data?

Have TMDE and support equipment requirements (both in terms of variety and quantity) been minimized to the greatest extent possible?

Does the system specification include operational requirements, the maintenance concept, and a functional definition of the TMDE?

Does the system specification include effectiveness requirements (reliability, maintainability, human factors, supportability) for the TMDE?

Are the reliability and maintainability features in the TMDE and support equipment compatible with those equivalent features of the TES System and the prime equipment?

Have logistic support requirements for the selected TMDE been defined? This includes maintenance tasks, calibration equipment, spare and repair parts, personnel and training, data, and facilities?

DATA COLLECTION FORM 9

(TMDE REVIEW CHECKLIST, PAGE 2)

Testability using TMDE

Have self-test provisions been incorporated where appropriate?

Is reliability degradation due to the incorporation of built-in test minimized?

Is the extent or depth of self-testing compatible with the level of repair analysis?

Are self-test provisions automatic?

Have direct fault indicators been provided (a fault light, an audio signal, or a means of determining that a malfunction positively exists)? Are continuous monitoring provisions incorporated where appropriate?

Are test points provided to enable checkout and fault isolation beyond the level of self-test?

Are test points accessible?

Are test points functionally and conveniently grouped to allow for sequential testing (following a signal flow), testing of similar functions, or frequency of use when access is limited?

Are test points provided for a direct test of all replaceable items?

Are test points adequately labeled? Each test point should be identified with a unique number, and the proper signal or expected measured output should be specified on a label located adjacent to the test point.

Can the component malfunctions that could possibly occur be detected through a no-go indication at the system level?

Will the prescribed maintenance software provide adequate diagnostic information?

DATA COLLECTION FORM 10

(HFE REVIEW CHECKLIST, Page 3)

HUMAN FACTORS (TES SYSTEM AIRCRAFT INSTRUMENTATION PACKAGE)

Cockpit Panel Displays and Controls
Are controls or circuit breakers standardized?

Are controls or circuit breakers sequentially positioned?

Is control spacing adequate?

Is control or circuit breaker labeling adequate?

Have the proper control and display relationships been incorporated, based on sound human factors criteria?

Are the proper type of panel switches or circuit breakers used?

Is the control panel lighting adequate?

Are the controls placed according to frequency and/or criticality of use?

Has a system analysis been done to verify optimum human-machine interfaces? Are automated and manual functions adequately identified?

Are the identified automated and manual functions consistent with the results of the overall system-level functional analysis?

Has a detailed operator task analysis been done to verify task sequences, to include pre-flight?

Are the detailed operator tasks compatible with the TES system operating procedures (task sequences, depth of explanatory material based on task complexity)?

For human-interface functions, is the system design optimum when considering human sensory factors, psychological factors, and physiological factors? For manual tasks, does the design reflect ease of operation by trained pilots? Is the design such that potential human error rates are minimized during operation?

Is the Human Factors Engineering (HFE) compatible with Army safety engineering requirements?

DATA COLLECTION FORM 11

(TRANSPORTABILITY REVIEW CHECKLIST)

HANDLING

General

For heavy items, are hoist lugs or base-lifting provisions for forklift-truck application incorporated? Hoist lugs should be provided on all items weighing more than 150 pounds.

Are hoist and base-lifting points identified relative to lifting capacity?

Are weight labels provided?

Two Man Lift Requirements

Are items weighing more than 40 pounds provided with two handles for two-man carrying?

Are units, components, or other items weighing over 10 pounds provided with handles? Are the proper-sized handles used and are they located in the correct position? Are the handles optimally located from the weight distribution standpoint? Carrying handles should be located over the center of gravity.

Packing

Do the TES System transit crates protect vulnerable components from damage during handling?

DATA COLLECTION FORM 12

(MANPOWER, PERSONNEL, AND TRAINING REVIEW CHECKLIST)

MANPOWER/PERSONNEL/TRAINING

Have maintenance personnel requirements (MOS, quantity and skill levels) been defined?

Are operational and maintenance personnel requirements minimized to the greatest extent possible?

Are operational and maintenance personnel requirements compatible with the logistic support plan and with human factors data?

Are the planned personnel skill levels at each location compatible with the complexity of the operational and maintenance tasks specified?

Has maximum consideration been given to the use of existing personnel skills for the TES System?

Have personnel effectiveness factors been determined (actual time that work is accomplished per the total time allowed for work accomplishment)?

Have maintenance training requirements been specified? This includes consideration of both initial training and replenishment training throughout the projected TES life cycle.

Have specific training programs been planned? The type of training, frequency of training, and duration of training should be identified.

Are the planned training programs compatible with the personnel skill level requirements specified for the performance of operational and maintenance tasks?

Have training equipment requirements been defined and acquisitioned?

Have maintenance provisions for training equipment been planned?

Have training data requirements been met?

Are the planned operating and maintenance procedures (designated for support of the TES System throughout its projected life cycle) used to the maximum extent in the training programs?

DATA COLLECTION FORM 13

(NET REVIEW CHECKLIST)

NEW EQUIPMENT TRAINING (NET) SUPPORT PACKAGE

Has a New Equipment Training (NET) support Package been developed?

Have the major elements of support been defined (test and support equipment, training devices, personnel training, publications, and technical data requirements)?

Do the elements of the NET package reinforce the system maintenance concept?

Has a detailed training plan for operator and maintenance personnel been prepared? Have training facility, equipment, material, software, and data requirements been identified?

DATA COLLECTION FORM 14

(SAFETY REVIEW CHECKLIST)

SAFETY

Has an integrated safety plan been prepared and implemented?

Has a hazard analysis been accomplished to identify potential hazardous conditions?

Have fail-safe provisions been incorporated in the design? Have protruding devices been eliminated or are they suitably protected?

Have provisions been incorporated for protection against stray voltages? Are all external metal parts adequately grounded?

Are sharp metal edges, access openings, and corners protected with rubber, fillets, fiber, or plastic coating?

Are electrical circuit interlocks or circuit breakers employed?

Are the potential operating environments such that personnel safety can be ensured? Can Army safety requirements be maintained?

DATA COLLECTION FORM 15

(ENVIRONMENTAL REVIEW CHECKLIST)

ENVIRONMENTAL IMPACT

Has an environmental impact study been completed (to determine if the system will have an adverse impact on the environment)? This shall be coordinated with the training center/post Directorate of Engineering and Housing (DEH) NEPA Coordinator; a record of environmental consideration shall be completed in accordance with AR 200-2 and the National Environmental Protection Act (NEPA).

Are the required standards associated with air quality, water quality, and noise levels being maintained in spite of the introduction and operation of the TES System?

Have potentially degrading ecological effects been identified? Has corrective action been taken to eliminate potential problems?

APPENDIX D

SAMPLE DATABASE TRACKING SHEETS AND OUTPUTS

Target Type	Warhead Type	Pair(s) Fired	No. of Engagements	No. of Hits	Demonstrated P_h
Soft Skin	PD	1	0	0	0.0000
Soft Skin	PD	2	0	0	0.0000
Soft Skin	PD	3	11	1	0.0909
Soft Skin	PD	4	7	1	0.1429
Soft Skin	MP	1	0	0	0.0000
Soft Skin	MP	2	0	0	0.0000
Soft Skin	MP	3	9	0	0.0000
Soft Skin	MP	4	0	0	0.0000

Constraints Met=1 Hit=1 (*at least* one pair hit during engagement)
Constraints not Met=0 Miss=0 (no pair(s) hit during engagement)

Date	Acft Ser No.	Constraints	Target Type	Warhead Type	Pair(s) Fired	Hit
04-Mar-98	96-5001	1	Soft	PD	4	0
04-Mar-98	96-5001	1	Soft	MP	3	0
04-Mar-98	96-5001	1	Soft	PD	3	0
04-Mar-98	96-5008	1	Soft	PD	4	0
04-Mar-98	96-5008	1	Soft	MP	3	0
04-Mar-98	96-5008	1	Soft	PD	3	1
04-Mar-98	97-5027	1	Soft	PD	4	1
04-Mar-98	97-5027	1	Soft	MP	3	0
04-Mar-98	97-5027	1	Soft	PD	3	0
04-Mar-98	96-5014	0	Soft	PD	4	0
04-Mar-98	96-5014	1	Soft	MP	3	0
04-Mar-98	96-5014	1	Soft	PD	3	0
04-Mar-98	96-5010	1	Soft	PD	4	0
04-Mar-98	96-5010	1	Soft	MP	3	0
04-Mar-98	96-5010	1	Soft	PD	3	0
04-Mar-98	97-5025	1	Soft	PD	3	0
04-Mar-98	97-5025	1	Soft	MP	3	0
04-Mar-98	97-5025	1	Soft	PD	3	0
04-Mar-98	96-5009	1	Soft	PD	4	0
04-Mar-98	96-5009	0	Soft	MP	3	0
04-Mar-98	96-5009	1	Soft	PD	3	0
07-Mar-98	96-5002	1	Soft	PD	4	0
07-Mar-98	96-5002	1	Soft	MP	3	0
07-Mar-98	96-5002	1	Soft	PD	3	0
07-Mar-98	96-5009	1	Soft	PD	4	0
07-Mar-98	96-5009	0	Soft	MP	3	0
07-Mar-98	96-5009	1	Soft	PD	3	0

Figure D-1

Example of Rocket Event Tracking Sheet

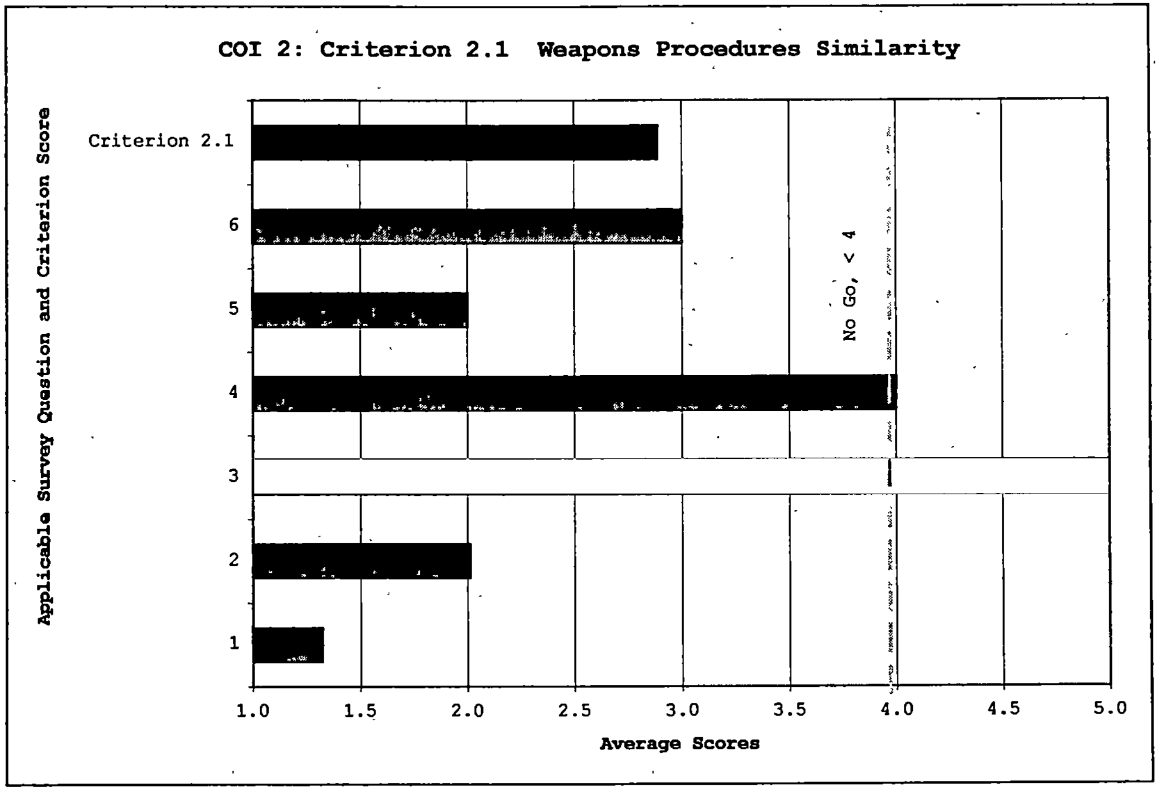

Figure D-2

Example of Database Output for Pilots' Questionnaire

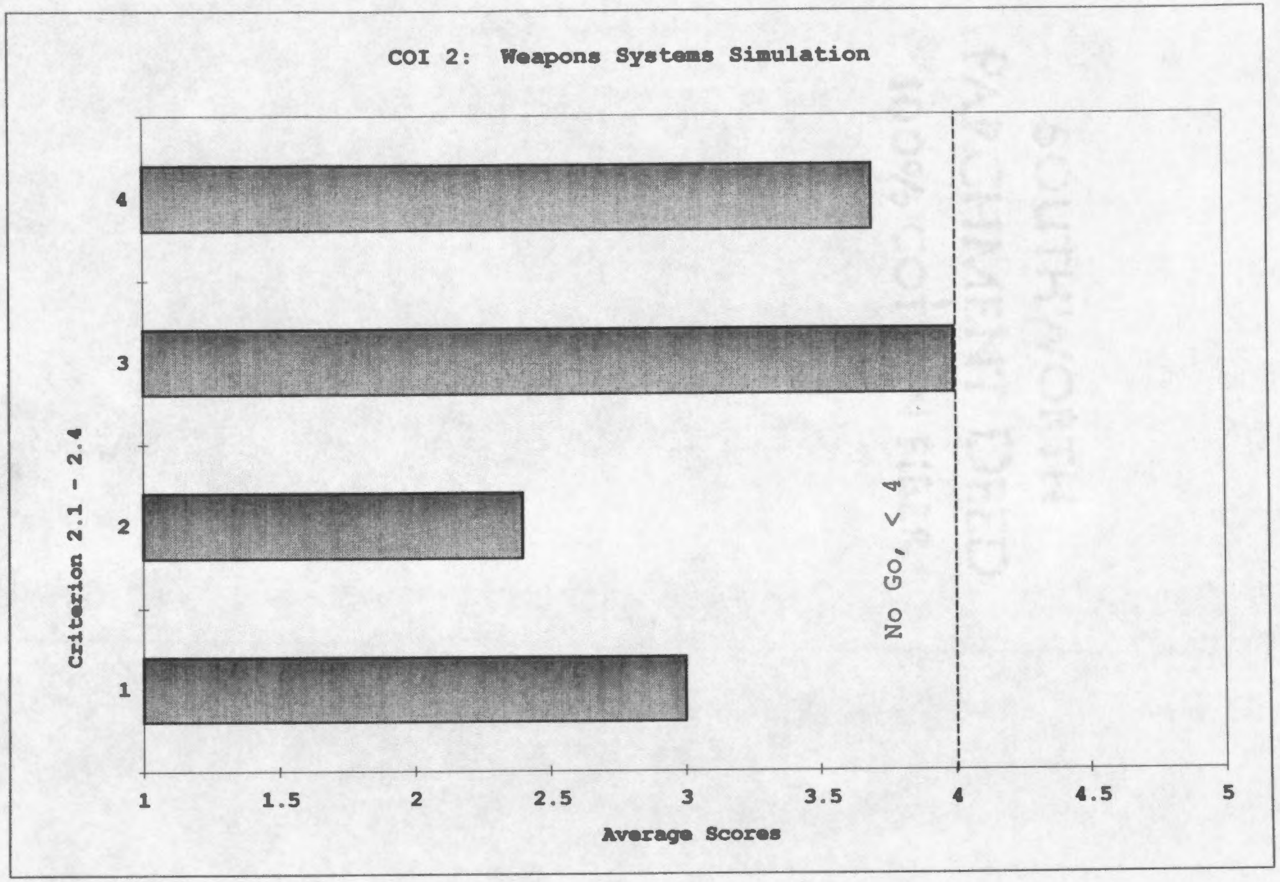

Figure D-3

Example of Database Output for Criterion Scores

TOT :	14:55	**$TCMA_U$** :	0	**$TMMH_U$** :	0:00
TST :	0:00	**$TCMA_C$** :	2	**$TMMH_C$** :	1:58
TCMT :	1:58	**$TCMA_T$** :	2	**$TMMH_T$** :	1:58
TPMT :	0:58	**TTR_U** :	0:00	**TMAF** :	2
TALDT :	0:58	**TTR_C** :	1:58		
NCDT :	0:00	**TTR_T** :	1:58		

A_O :	0.7916
MTBMAF :	7:27
$MTTR_U$:	0:00
$MTTR_C$:	0:59
$MTTR_T$:	0:29
MR_U :	0.0000
MR_C :	0.1318
MR_T :	0.1318
P_S :	0.4469
Re :	0.1350

Date	Start Time	Stop Time	Duration	Eqpt Status	Task Status	Fail Class	Fail Cat
4-Mar-98	17:00	18:59	1:59	1			
5-Mar-98	18:00	19:20	1:20	1			
6-Mar-98	19:21	21:25	2:03	1			
8-Mar-98	21:26	23:25	1:58	1			
8-Mar-98	12:00	14:26	2:26	1			
10-Mar-98	14:27	15:26	0:58	1			
10-Mar-98	15:27	16:26	0:58	4	21	1	
10-Mar-98	16:26	17:26	1:00	3	13	1	
10-Mar-98	17:27	18:26	0:58	3	17		
10-Mar-98	18:27	19:40	1:12	1			

RETURN

Figure D-4

Example RAM Database Tracking Sheet (for Individual TES System)

Mean Installation Time:	95
Mean De-installation Time:	34
Total Installations:	3
Total De-installations:	3

Date	Start Time	Stop Time	Duration	Install/De-install
4-Mar-98	7:00	7:23	0:23	1
4-Mar-98	8:00	8:23	0:23	2
6-Mar-98	9:00	9:23	0:23	1
6-Mar-98	10:00	10:23	0:23	2
8-Mar-98	10:24	14:26	4:01	1
8-Mar-98	14:27	15:26	0:58	2

RETURN

Figure D-5

Example MANPRINT Database Tracking Sheet for Installation/De-installation

VITA

Robert Andrew Pupalaikis, a native of New Jersey, received his Bachelor of Arts degrees in Mathematics and Economics from Rutgers University in 1989 and subsequently entered the U. S. Army. Upon graduating from flight training in 1990, he was assigned to the 5th Squadron/6th Cavalry Regiment, Wiesbaden, Germany flying the AH-64A Apache attack helicopter. While assigned to this unit, he deployed to the Persian Gulf and flew combat missions against the Iraqi Land Forces during Operation Desert Storm. He served as an AH-64 instructor pilot at the Army Aviation Center, Fort Rucker, AL. Additionally, he served as an advisor to the Egyptian Air Force as a tactical instructor pilot for the EAF 550th Attack Helicopter Wing. In 1997 he was selected for the Army Experimental Test Pilot Training Program. He is currently assigned to the University of Tennessee Space Institute where he resides with his wife Nanètte and daughter Eden, and is scheduled to attend the U. S. Naval Test Pilot School, Patuxent River, MD.