CHAPTER X
WEAPONS

A. INTRODUCTION

1. Definition and Scope

The Weapons technology area includes efforts devoted to armament and electronic warfare technologies for all new and upgraded nonnuclear weapon systems. The Weapons area consists of 12 subareas grouped in three broad categories, illustrated in Figure X–1. The efforts in these subareas are directed toward providing demonstrated technology that better enables the war-fighter to incapacitate or destroy enemy personnel, materiel, and infrastructure and to provide defense against or countermeasures to an enemy's ability to wage war.

Conventional weapons (CW) focus on munitions, their components and launching systems, guns, tactical propulsion, bombs, rockets, guided missiles, projectiles, special warfare weapons, mortars, mines, countermine systems, torpedoes, and explosive ordnance disposal.

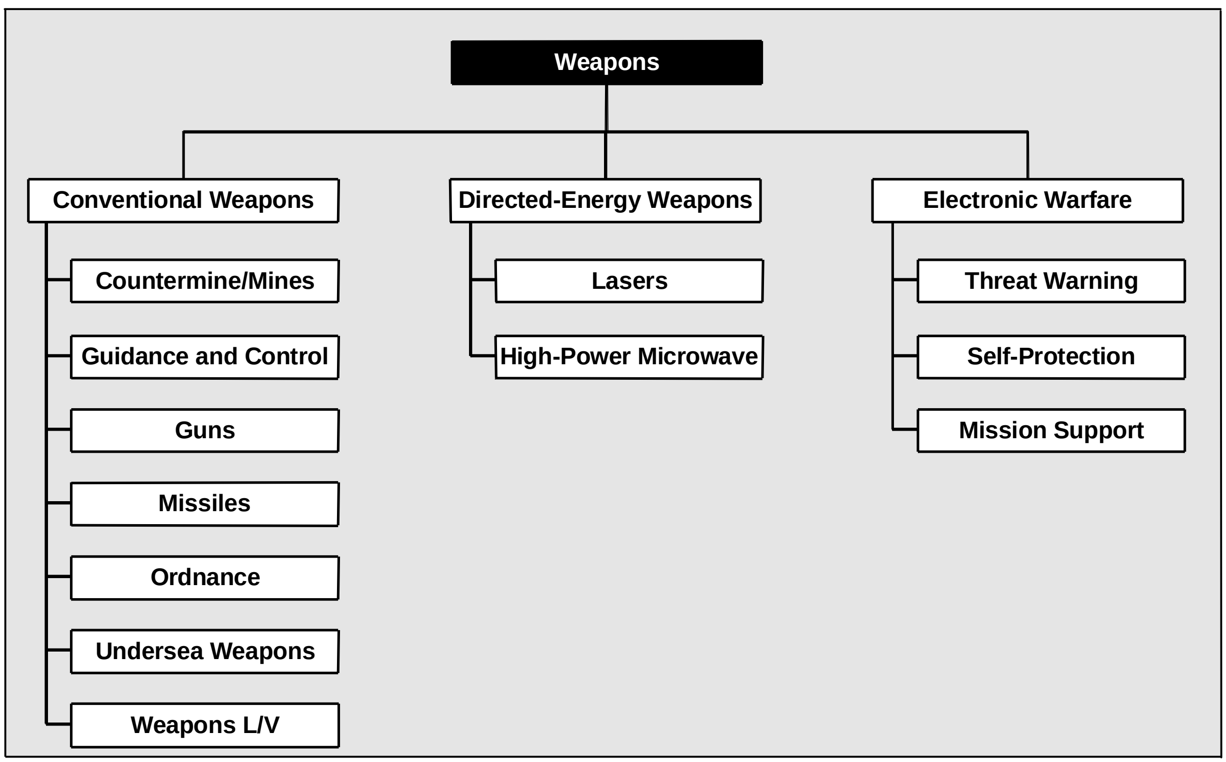

Figure X–1. Planning Structure: Weapons Technology Area

Directed-energy weapons technologies are those that relate to the production and projection of a beam of intense electromagnetic (EM) energy or atomic/subatomic particles that are used as a weapon. Directed-energy weapons (DEWs) and devices generate energy that travels at or near the speed of light from a beam source directly to the target. (The single particle beam effort in this category has been completed and is not discussed further.)

Electronic warfare (EW) is responsible for developing technology that provides U.S. military forces with the capability to survive in their execution of all operations/missions by maximizing their unchallenged operational use of the EM spectrum—while denying the same from the enemy by using EM means to detect and attack enemy sensor, weapon, and command infrastructure systems.

2. Strategic Goals

The overarching strategic goal for weapons technology investment is to develop and transition superior weapons technology that will provide the services with affordable and decisive military capabilities to execute future missions. The specific goals in CW technologies mainly focus on systems to destroy enemy personnel, materiel, and infrastructure, but with a growing emphasis on incapacitation through nonlethal technologies. The specific goal of the EW and DEW technology efforts is to control and exploit the EM spectrum for maximum effectiveness of U.S. military operations.

3. Acquisition/Warfighting Needs

Weapons technology provides the decisive military capabilities for the future. It responds to the services' operational needs for cost-effective system upgrades and next-generation systems in support of Joint Warfighting Capability Objectives (JWCOs) in the *Joint Warfighting Science and Technology Plan* (JWSTP). The Weapons technology activities directly support JWCOs of Precision Force, Joint Theater Missile Defense, Military Operations in Urbanized Terrain, Electronic Warfare, Information Superiority, and Force Projection/Dominant Maneuver, and contribute support to Combat Identification. In addition, the Weapons technology program directly responds to congressional mandates (e.g., the live-fire test provisions of the National Defense Authorization Act (1987), Chapter 139, Section 2366 of Title 10, United States Code). Specific objectives of weapons technology programs address:

- The need for affordable all-weather, day/night precision strike against projected mobile and fixed targets.
- Gun systems with overmatching lethality to support the development of advanced, lighter weight air and land combat vehicles and tanks, ship and vehicle self-defense systems, and lightweight high-performance gun systems for artillery applications and naval surface fire support missions.
- The capability to detect, identify, and jam conventional and advanced imaging RF weapon system sensors and advanced imaging/pseudo-imaging infrared (IR) missile seekers.
- Projecting lethal force precisely against an enemy with minimal friendly casualties and collateral damage.

- Development of adaptive technologies for advanced radar warning and electronic support receivers, processors, and modulation techniques that can respond or reconfigure to a changing RF environment.
- Effective joint countermine capabilities to ensure control of the sea for force movement, supply, and offensive strike operations as well as the ability to conduct amphibious and ground force operational maneuvers against hostile defensive forces employing sea and land mines.
- All-weather defense against low-observable (LO) cruise missiles, aircraft, and ballistic missiles.
- Disruption or destruction of missiles and projectiles in various phases of flight.
- The denial, degradation, deception, disruption, or destruction of enemy command, control, information, and navigation functions/systems.
- Control of space.
- Suppression of enemy air defenses.
- Undersea superiority through highly lethal underwater attack and defense capabilities against submarine and surface ship platforms, at long range and in shallow water, with weapons, counterweapons, and countermeasures. To attain undersea superiority, these weapons and counterweapons will have increased speed, reduced weight, and lower acoustic signatures and will be capable of attacking the new threat submarine and surface ship platforms. These threat platforms will be quieter with lower acoustic signatures and have longer endurance and higher speed capabilities.
- Real-time integration of "on-platform" sensor information with off-platform theater and battlespace information to yield situation assessment, threat geolocation, and decision aids to combat identification, targeting, and damage assessment objectives.
- The use of nonlethal technologies for a variety of missions.
- Target planning and engagement tools.

Weapons technologies have transition potential to a wide variety of weapon systems and platforms; Table X–1 illustrates some of these opportunities.

Table X–1. Weapons Technology Transition Opportunities

Subarea	Current Baseline	5 Years	10 Years	15 Years
CONVENTIONAL WEAPONS SUBAREAS				
COUNTERMINE/MINES				
• Land Mine Detection	AN/PSS–12, IVMMD	GSTAMIDS, HSTAMIDS	ASTAMIDS	Mine Hunter Killer, AMDS, LAMD
• Land Mine Clearance	MICLIC	SASMB		
• Countermine Surveillance	Radiant Clear	NAVOCEANO WSC, ONI (SABRE), CINC JIC	NAVOCEANO WSC, ONI (SABRE), CINC JIC	
• Naval Mine Reconnaissance & Hunting	SQQ–32/ASQ–14, RMS V–2 (Prototype Capability), Magic Lantern Deployment Contingency, Marine Mammal Systems, PQS–2 Hand-Held Diver Sonar	AQS–20/X, ALMDS, RMS V4, NMRS, LMRS, COBRA	RMS, AQS-X, ALMDS	Autonomous Reconnaissance/Mine Hunting
• Naval Mine Neutralization & Breaching	SLQ–48, EOD	RAMICS, DET (SABRE), AMNS	RAMICS, DET (SABRE), Obstacle Breaching System	Autonomous Robotic MCM Systems for VSW Through the CLZ
• Naval Minesweeping	MK104, MK105, SPU–1, MK103, AN/37U	SWIMS	ISWIMS	
• Sea Mines	Quickstrike Bottom Mines, SLMM, CAPTOR ASW Mine	LSM, ISLMM	LSM	Armed Surveillance Network
• Land Mines	Explode-in-Place Land Mines	WAM	IMF/Area Denial	
GUIDANCE AND CONTROL	SFW	JASSM	Miniaturized Munition Concept	
	AIM–9	AIM–9X—IIR seeker		Air Superiority Missile
	AMRAAM	LADAR	LOCAAS	
	TOW	FMTI—IIR Seeker, FOG IMU	FOTT	
	JDAM			
	Hydra 70	LCPK—Strapdown Laser Seeker, Scatterrider Guidance	Guided 2.75” Rocket	
	MLRS Free Rocket	GMLRS—GPS/IMU	Guided Extended-Range MLRS	
	Stinger	Small-Diameter, Antiair Seeker	Stinger Blk II	
GUNS	M16 Rifle, M16/M203 Systems, M2 & MK19 Machineguns, M24 & M40A1 Sniper Rifles, M9 Handgun	OICW	OCSW	OPW/OSW
	BFVS, AAAV & LAV Armament	FSCS Armament	BFVS & LAV Armaments Upgrades, FIV Armaments	AAAV Upgrades
	Apache Armament, AC–130 Gun Ship, F–16 Armament	AC–130 Gun Ship Upgrades	Comanche Armament, JSF Armament	
	Paladin 30-km Range and Rate-of-Fire 120-mm Mortar Range	120-mm Mortar Range and Effectiveness Improvement with PGMM	Crusader 40-km Range and Extended Rate of Fire	Extended 50-km Range

Table X–1. Weapons Technology Transition Opportunities (cont'd)

Subarea	Current Baseline	5 Years	10 Years	15 Years
CONVENTIONAL WEAPONS SUBAREAS (cont'd)				
GUNS (cont'd)	Abrams Gun/Ammo	Abrams Ammo Upgrades, M256 Gun with ETC	XM291 or L55 with ETC, Abrams Advanced KE Cartridge	FCS Armament
	M16A2 Rifle, M203 Grenade Launcher, 12-Gauge Shotgun	OOTW Static HPM/DE Devices, Blunt-Impact Munitions, EM Pulse Vehicle Stopper	OOTW Mobile DE Devices	OOTW DE Devices for Purposes Other Than Delay/Denial
MISSILES	EFOGM	MAT	MAT–D	Future Precision Strike Weapon
	Hydra 70	LCPK	Guided 2.75" Rocket	
	TOW/Longbow/Atlas	FMTI	FOTT	
	LOSAT	CKEM	LOSAT P^3I	Future Combat Weapon
	Tomahawk		Fast Hawk (Low-Cost Missile)	Future Precision Strike Weapon
	Maverick	JASSM	Miniaturized Munition Concept	
	SLAM, Harpoon	Slamer	Survivable Airframe	
	HARM		Adv SEAD	
	AMRAAM/AIM–9	AMRAAM/AIM–9X	ASMT	
• Propulsion	MLRS/ATACMS	DRE	Air-Breathing Propulsion	
	AMRAAM/AIM–9	AMRAAM/AIM–9X	Air-Breathing Propulsion	
	BAT		Powered LOCAAS	
	TOW	FMTI Prop	FOTT Smart Propulsion	
• Launchers/ Airframe	MLRS M270, VLS	HIMARS, Concentric Canister Launcher	M270 Lightweight Launcher	Arsenal Ship
ORDNANCE	BLU–109/BLU–113	ICBM with Kinetic Penetrator	ICBM with Explosive-Loaded Penetrator	Multiple Penetrators in an ICBM
• Missiles	Patriot, AMRAAM	Patriot Upgrade PROTEC, Adaptable Warhead	Programmable Integrated Ordnance Suite, AMRAAM P^3I Antimateriel Submunition Warhead	Dual-Range Missile Guidance Integrated Fuzing
• Antiarmor	TOW/Longbow/Javelin	FMTI Warhead	FOTT Warhead	
	SADARM	SADARM PI Enhanced Lethal Mechanism	SADARM Bloc II Lethality Against Expanded Target Set	
• Hard-Target Penetration	BLU–109, BLU–113, GBU–24, GBU–27, AGM–130	Hard-Target Smart Fuze, Adv Unitary Penetrator	Miniature Munition, Conv Penetrator for ICBMs, JASSM 1,000-lb Penetrator	Multievent Fuze, Boosted Penetrator
• Bombs	MK83, MK84	Enhanced MK83	Enhanced 1,000-lb GP Bomb	Multipurpose Bomb
	Joint Programmable Fuze	Explosive JDAM	JASSM	Antijam Proximity Fuze
UNDERSEA WEAPONS	Bulk and Shaped-Charge Warhead: • MK50 • MK48 • ADCAP	Enhanced Bubble Energy: • MK48 • ADCAP EM Fuse: • MK54	Hybrid MEMS S&A: • All Undersea Weapons	2X Warhead Performance over SOA: • ADCAP

Table X–1. Weapons Technology Transition Opportunities (cont'd)

Subarea	Current Baseline	5 Years	10 Years	15 Years
CONVENTIONAL WEAPONS SUBAREAS (cont'd)				
UNDERSEA WEAPONS (cont'd)	Torpedo Planar Acoustic Array	Broadband Sonar: • MK50 • ADCAP	Conformal Hull Array: • MK54 UUV	Bidynamic, Broadband Signal Processing: • MK54 • ADCAP • MK50
	Noise CMs: • ADC–MK2 • ADC–MK3	Automatic Torpedo, Attack Tracker: • TRAFS Smart Adaptive CMs • ADC–MK3	Antitorpedo • MK54	ATT Threat Salvo Capability: • MK54/ATT
WEAPONS LETHALITY/ VULNERABILITY	System Enhancements: • Crusader Concept Trades, Bradley A3 LFT&E, Abrams M1A2 FY2000 • BLU–109, BLU–113, BLU–115 (AUP), AGM–130	System Enhancements: • Crusader LFT&E, Comanche LFT&E, BAT P^3I, ETC Armaments • JASSM. SSB, LOCASS, JDAM	System Enhancements: • APS/CAPS, FCS/ FSCS Concept Trades, AHM • ADW, Mass-Focused Warhead, ICBM KEW Penetrator, Big-BLU	System Enhancements: • EM Armaments, FCS/FSCS, Army After Next Technologies • Advanced Hard-Target Penetrator, Hypersonic Penetrator, Advanced Non-lethal Warhead, Miniature Munitions for Urban Applications
DIRECTED-ENERGY WEAPONS SUBAREAS				
LASERS	Chemical Laser and Beam Control	GBL Beam Control Demo, ABL Demo, SBL Ground Demo, IRCM Laser Demo	Operational GBL ASAT, Operational ABL/SBL Demo	Operational SBL Constellation
	Solid-State Laser	Multi-kW Laser Array	Conformal Laser Array Demo	FotoFighter Laser Demo
	Free Electron Laser	1-kW Demo		
HIGH-POWER MICROWAVE	Wideband and Narrowband HPM	HPM IW ACTD, Explosively Powered Device Demo	C^2W/IW Airborne Demo, Active Denial System, SEAD Demo, Platform Self-Protect Demo	Operational C^2W/IW System, Operational SEAD System, Operational Platform Self-Protect
ELECTRONIC WARFARE SUBAREAS				
THREAT WARNING	All Operational	ALR–XX Improvements		JSF
• RF	ALR-XX			
	SLQ–32		AIEWS	
	SEI Test Units	P3, CID	ALR–XX Improvements	Weapon-Embedded SEI, JSF
• Situation Assessment	JMCIS, CEC	IEWCS, SIRFC, SOF Platforms	Tactical Platforms (F–15/ –16/–18/–22), Strategic Platforms (B–1B, JSTARS, AWACS), Apache/ Commanche	JSF, CEC Upgrades
• EO/IR Warning	AVR–2, AAR–44, AAR–47, AAR–54	Common MWS, F–22 LBRM Warning System	2-Color Staring Array, LBRM Warning System	JSF-IR-Distributed Aperture Warning System
SELF-PROTECTION	All Operational	On-Board ECM Upgrade ATD	IDECM, SIRFC, B–1B DSUP, ALQ–YY Improvements	JSF, SIRFC Improvements
• RF	ALQ–YY			
	SLQ–32	Advanced ECM Transmitter ATD	AIEWS	Integr AIEWS/DEW Laser Weapon

Table X–1. Weapons Technology Transition Opportunities (cont'd)

Subarea	Current Baseline	5 Years	10 Years	15 Years
ELECTRONIC WARFARE SUBAREAS (cont'd)				
SELF-PROTECTION (cont'd)	POET, Gen-X & Chaff Nulka, SRBOC	ALE–50, ALE–47 Eager ATD		TMET Decoy
• EO/IR CM	ATIRCM	SOF DIRCM, SIIRCM	Large Tactical Aircraft, Laser IRCM	SIIRCM, Improved LGW CM Large Tactical Aircraft, Laser EO/IRCM
	ASTE Tier I, MJU–27A/B	ASTE Tier II, BOL IR, MJU–27 Upgrade	I^2R CM, Flares/ Multispectral CM, Cooperative IRCM	Smart Expendables from Aircraft
• Giant	MK186 (Torch), MK245 (Giant)	EX–252 (Multicloud)	Advanced Multicloud	Smart Expendables from Ships
MISSION SUPPORT	Classified Platforms (AF Only)	Classified Platforms (AF Only)	Classified Platforms (AF Only)	
• C^2W	TSQ–138, TLQ–17A, TLQ–33 EH–1A USQ–113 EA–6B UE	IEWCS, GBCS-L Advanced Quick Fixband, Orion ALQ–99 Improvement, ICAP III USQ–113 Upgrade, EA–6B (UEU)	ACS + Orion EA–6B Follow-on	C^4IEW, Multirole System
• RF	EA–6B	ALQ–99 Improvement, ICAP III	Tactical Jamming Pod	Tactical Jamming UAV

B. DEFENSE TECHNOLOGY OBJECTIVES

CONVENTIONAL WEAPONS

Countermine/Mines

WE.45 Sea Mines
G.01 Mine Hunter/Killer ATD
G.06 Rapid Sea Mine Neutralization (Rapid Airborne Mine Clearance System ATD)
G.09 Advanced Mine Reconnaissance/Minehunting Sensors
G.11 Advanced Mine Detection Sensors
G.12 Lightweight Airborne Multispectral Countermine Detection System
G.13 Electro-Optic Mine Identification
G.14 Automatic/Aided Technology for Detection of Unexploded Ordnance Clearance
G.15 Very Shallow Water (VSW) Reconnaissance Clearance

Guidance and Control

WE.13 Counteractive Protection Systems
WE.21 Fiber Optic, Gyro-Based Navigation Systems
WE.51 Small Diameter Antiair Infrared Seeker
WE.52 Best Buy ATD
WE.58 Microelectromechanical Sensor Inertial Navigation System
WE.61 Modernized Hellfire Guidance and Control/Seeker Technology Effort
WE.62 High-Quantity Antimateriel Submunition Program
WE.63 Direct-Attack Munition Affordable Seeker ATD

B.19 Cruise Missile Real-Time Retargeting
B.22 Hammerhead ATD
B.27 Point-Hit ATACMS/MLRS

Guns

WE.18 Direct Fire Lethality ATD
WE.33 ETC Armaments for Direct Fire
WE.34 Objective Crew-Served Weapon ATD
WE.56 Electromagnetic Armaments for Direct Fire
M.14 Artillery-Launched Observer Round ATD
E.03 Objective Individual Combat Weapon ATD
E.04 Joint Nonlethal Weapons
M.06 Precision-Guided Mortar Munition ATD

Missiles

WE.35 Air Superiority Missile Technology
WE.39 Tactical Missile Propulsion
WE.50 Compact Kinetic Energy Missile Technology
M.13 Hypersonic Weapons TD
B.15 Powered Low-Cost Autonomous Attack System Program
B.16 Concentric Canister Launcher ATD
B.18 Low-Cost Precision Kill ATD
B.21 Miniaturized Munition Technology Guided Flight Tests
D.08 Atmospheric Interceptor Technology
M.04 Line-of-Sight Antitank System ACTD
M.08 Enhanced Fiber-Optic Guided Missile ATD
M.09 High-Mobility Artillery Rocket System

Ordnance

WE.54 Reactive Material Warhead ATD
B.24 Programmable Integrated Ordnance Suite ATD
J.03 Counterproliferation I ACTD
J.04 Counterproliferation II ACTD
M.13 Hypersonic Weapons TD
L.05 Diagnostic Analysis of Improvised Explosive Devices

Undersea Weapons

WE.29 Antitorpedo Torpedo ATD
WE.32 Broadband Torpedo Sonar Demonstration
WE.55 Reduced-Size Torpedo Subsystem Demonstration

Weapons/L/V

WE.57 Lethality/Vulnerability Models for High-Value Fixed Targets

DIRECTED-ENERGY WEAPONS

Lasers

WE.10 Integrated Beam Control for Ground-Based Laser Antisatellite System
WE.41 Multimission Space-Based Laser
WE.42 Laser Aircraft Self-Protect Missile Countermeasures
WE.43 Advanced Multiband IRCM Laser Source Solution Technology
D.10 Airborne Laser Technology for Theater Missile Defense

High-Power Microwave

WE.22 High-Power Microwave C^2W/IW Technology
WE.60 Explosively Driven, High-Power Microwave Suppression of Enemy Air Defenses
H.11 High-Power Microwave ACTD

ELECTRONIC WARFARE

Threat Warning

WE.48 Missile Warning Sensor Technology
H.07 Enhanced Situation Awareness Demonstrations
H.10 Precision EW Situation Awareness, Targeting, and SEAD Demonstrations

Self-Protection

WE.40 Infrared Decoy Technology
WE.46 Coherent RF Countermeasures Technology
WE.47 Imaging Infrared Seeker Countermeasures Technology
WE.64 Network-Centric Electronic Warfare Technology
H.02 Multispectral Countermeasures ATD
H.05 Large Aircraft Infrared Countermeasures ATD
H.08 Onboard Electronic Countermeasures Upgrade ATD
H.12 Modular Directed Infrared Countermeasures

Mission Support

WE.23 Modern Network Command and Control Warfare Technology
H.04 Miniature Air-Launched Decoy Program ACTD
H.10 Precision EW Situation Awareness, Targeting, and SEAD Demostrations

C. TECHNOLOGY DESCRIPTIONS

1. Countermine/Mines

a. *Warfighting Needs*

DoD requires mine and countermine systems to directly support U.S. armed forces' full-spectrum dominance. This requires technology solutions that support the capability for assured, rapid surveillance, reconnaissance, detection, and neutralization of mines to enable forced entry by expeditionary forces. The capability includes control of the sea for force movement, supply, and offensive strike operations as well as the ability to conduct amphibious and ground force operational maneuvers against hostile defensive forces employing mines. For naval forces, this requires new “organic” mine countermeasure (CM) capabilities. Battlegroups must have the organic capability to rapidly counter littoral mine threats without the delay associated with deployment transits of dedicated forces. A significant countermine capability ensures that the requisite tempo (in-stride), survivability, and control of maneuvering forces are achieved.

Evolving technologies for offensive mining address the requirements to detect and track a broad spectrum of threats, remote control of and communications with mines, and sensor data fusion to support the evolution of combined surveillance and engagement systems.

b. ***Overview***

The focus of technology efforts to achieve warfighting needs includes sensors, signal processing techniques, data fusion, and autonomous robotics systems.

(1) Goals and Timeframes. The goals of the countermine/mines subarea are listed in Table X–2.

(2) Major Technical Challenges. *Countermine*. Significant technological challenges exist in countermine surveillance, reconnaissance, and detection. The variety of mine designs (shapes, sizes, materials) and operating environments (sea, surf, beach, land) precludes a single design solution to the detection problem. Differentiation of land, beach zone, and bottom sea mines from clutter in various soil, foliage, and terrain types is difficult. In both maritime and land environments, buried nonmetallic mines are virtually undetectable. Optical, magnetic, and acoustic sensors have limited effectiveness in the high ambient noise of the surf zone. Improved small, low-power sensors for organic systems, advanced signal processing, multisensor data fusion, automatic target recognition (ATR), and high search rates for in-stride operation are some of the technologies addressing surveillance, reconnaissance, and detection challenges.

Countermine breaching and neutralization are currently slow. The rate of these operations must be increased. The reliable neutralization of mines presents several unique challenges. Improved targeting systems and thorough ballistics/hydro-ballistics developments may allow directed fire to be used effectively to neutralize near-surface naval mines and beach obstacles. A technology breakthrough is required to solve the problem of sweeping pressure-influence mines. The problems of surf and beach zone breaching are compounded by the fact that mines and obstacles are often deployed together, and the countermine effectiveness of explosive line charges and arrays is significantly degraded when obstacles increase the standoff between the neutralization charge and the mine. Near-term solutions emphasize brute force approaches for the rapid breaching or neutralization of mines and obstacles. For in-stride breaching operations, improved fire control systems have been developed to permit the firing of breaching charges from inbound amphibious landing craft through the breaking surf. Improved breaching charges are being developed to provide a high kill probability against mines buried by surf, wind, and tidal action on the beach and on land. New standoff mines present a technological challenge to land warfare. Systems must be developed for in-stride clearance of these mines from the perimeter of the intended route. Development of standoff neutralization technologies using kinetic energy, focused shockwaves, or other directed-energy applications offers approaches to solving neutralization challenges.

Table X–2. Countermine/Mines Subarea Goals and Timeframes

Applications/Mission	Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ Years)
Countermine surveillance, reconnaissance, and detection	Exploit mapping, surveillance, and intel capability products for the intermittent surveil-lance of hostile mining activities.	Improved MIW surveillance capabilities.	Continuous, fused all-source I&W of enemy mining activity including mine stockpiles and capabilities.
	Demonstrate underwater sensing and processing technologies for organic detection and classification of volume and proud bottom mines in deep, shallow, and very shallow water. (G.09)	Demonstrate capability of cooperating UUVs to perform wide-area and lane reconnaissance in VSW and SZ environments. (G.15)	Autonomous multiplatform clandestine reconnaissance/ kill capability (land and sea).
	Demonstrate the detection and classification of buried mines using fused super-conducting gradiometer/SAS data (G.09).	Demonstrate hyperspectral/ multispectral technologies for detection of land mines. (G.12)	
	Develop and demonstrate EO undersea sensor tech-nologies to rapidly identify volume, bottom, and partially buried sea mines at extended ranges in highly turbid environments. (G.13)		
	Continued development of multiple technologies including data fusion and ATR to enhance detection capability.	Demonstrate forward-looking radar; evaluate potential enhancements for standoff distance and weather capability.	
	Explore passive IR with active laser, downlooking ground-penetrating radar, and SAR technologies for improved capability to detect mines.		Demonstrate acoustic and seismic performance enhancements to ground-based detection systems.
Countermine breaching and neutralization	Integrate ground-based detection with standoff neutralization technology.	Demonstrate an explosive/ kinetic neutralization system in a ground vehicle.	Demonstrate laser DE for mine neutralization. (Will be evaluated for inclusion in an electron-beam neutralization system in FY08.)
	Demonstrate in-stride targeting and neutralization of near-surface sea mines using helo-fired, high-velocity munitions. (G.06)	Demonstrate RF technology to detect electronically fuzed mines from standoff distances.	
		Develop a chemical non-explosive means to neutralize mines.	
		Demonstrate enhanced explosives capability.	

Table X–2. Countermine/Mines Subarea Goals and Timeframes (cont'd)

Applications/Mission	Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ Years)
Countermine breaching and neutralization (cont'd)		Demonstrate reliable clearance of BZ obstacles using GPS-guided hypervelocity kinetic penetrators (Hydra 7). Demonstrate capability of cooperating UUVs to conduct lane clearance (reacquisition, targeting, remote command detonation) in VSW and SZ environments. (G.15)	
		Demonstrate focused pressure shock-wave technology for in-stride neutralizing sea mines (DARPA).	In-stride clearance of sea mines in all water depths
Countermine battlespace management	Continue Joint Countermine integration umbrella for a C^4ISR architecture, common operational picture, and JCM operational simulation.		
	Demonstrate enhanced protection of soft-skinned vehicles from blast and fragment effects of AT and AP mines. Improve individual protection materials. Develop means to digitally characterize mined areas. Demonstrate the reduction of secondary magnetic field reduction on MCM ships.	Demonstrate blast deflection/ energy absorption enhancements for personnel and vehicles.	Continue vehicle design analysis to enhance mine blast protection for soft-skinned vehicles.
Humanitarian demining	Build on congressional Special Interest Program to demonstrate COTS equipment for mine detection and clearance.	Develop training initiatives that address multiple languages, detection of mines from aerial and ground platforms, low-cost neutralization, protective systems for personnel, and clearance verification technologies.	Long-term thrusts will be derived from the countermine program, the UXO clearance program, the EOD/LIC program, and special operations technology developments.
Mining	Demonstrate detection and localization of surface and submerged targets by distributed passive acoustic and nonacoustic sensor arrays. (WE.45)	Conduct integrated demonstration of critical LSM technologies (RECO, target detection, encapsulated torpedo launch and control). (WE.45)	Demonstrate feasibility of an intelligent, intercommunication sea minefield network.

Countermine battlespace management offers unique technical challenges. To be effective, a joint force commander requires a fused all-source picture of the battlespace. This fused intelligence picture must include mine warfare. Currently, for both land and amphibious operations, the electronic dissemination of information regarding suspected minefields, actual mine locations, and cleared routes or areas is often inaccurate and unreliable. Mine warfare environmental sampling, databases, and modeling efforts are needed to support the development of sensors and systems and to provide real-time tactical decision aids (TDAs) in the field. Reduction in the mine damage vulnerability of land vehicles and watercraft is a critical technical challenge involving magnetic signature reduction, blast deflection/absorption, and other mitigation technologies.

Mining. Major technical challenges for offensive land and sea mines include the development of signal processing, sensor fusion, and mobile warheads. Additional challenges include explosive techniques to support the detection targeting and destruction of quiet, stealthy targets in high clutter environments as well as the C^3 networking of mines/minefields in real time and without endangering U.S./allied forces.

Humanitarian Demining. There are a number of promising technologies that can enhance demining capabilities. For *individual mine detection*, the major technical challenge is discriminating land mines from metal debris. Future efforts to improve detection will focus on providing a discrimination capability that includes the fusion of multisensor information and the incorporation of advanced signal processing techniques. In the area of *mine clearance*, cost-effective and efficient clearance techniques will be needed to clear land mines in all types of terrain. For *neutralization*, the challenge is to develop safe, reliable, and effective methods to eliminate the threat of individual mines without moving them—new technologies will be needed to economically and safely neutralize the latest mine threats. For *mine awareness and demining training systems*, the challenge is integration of the latest computer and training technologies, database links, and automated multilingual capabilities into a system that can be shared in an international environment.

(3) Related Federal and Private Sector Efforts. The Army Environmental Center recently completed a range cleanup at the Jefferson Proving Ground. DOE and EPA requirements for test range and dump site remediation have led to the joint DoD–DOE Multisensor Underwater Debris Detection System project. Sandia National Laboratory is exploring chemical sensing devices for explosives detection and location.

c. *S&T Investment Strategy*

(1) Technology Demonstrations. The technology demonstrations in the countermines/ mines subarea are in Sea Mines (WE.45), joint countermine, and humanitarian demining technologies.

Joint Countermine. The overall objective is to demonstrate countermine surveillance, reconnaissance, and detection technologies and in-stride neutralization clearance technologies to improve a joint task force's ability to conduct seamless organic countermine force projection and strike operations from the sea through the surf/beach zone to the land objective. Joint countermine includes the following demonstrations that are described in the JWSTP DTOs:

- Mine Hunter/Killer ATD (G.01)—develop and demonstrate a precision neutralizer, enhanced detection performance, and command and control interaction for an integrated mine detector/neutralizer system.
- Rapid Sea Mine Neutralization (RAMICS ATD) (G.06)—develop and demonstrate the technologies for rapid and effective neutralization of near-surface mines.
- Advanced Mine Reconnaissance/Minehunting Sensors TD (G.09)—demonstrate underwater sensing and processing technologies for organic minehunting and minefield reconnaissance.
- Advanced Mine Detection Sensors (AMDS) (G.11)—evaluate and demonstrate emerging close-in mine detection technologies with potential for improvements in the P_d, FAR, and operational tempo of current and developing mine detection systems.
- Lightweight Airborne Multispectral Detection ATD (G.12)—demonstrate an airborne detection system integrated into the tactical unmanned aerial vehicle (UAV) to provide standoff minefield and limited nuisance mine detection that supports operational planning and tactical maneuvering on the battlefield.
- Electro-Optic Mine Identification (G.13)—develop and demonstrate EO undersea sensor technologies to rapidly identify volume, bottom, and partially buried sea mines at extended ranges in highly turbid environments.
- VSW Reconnaissance/Clearance (G.15)—demonstrate the capability of cooperating unmanned underwater vehicles (UUVs) to perform wide area reconnaissance (search, mapping, marking), lane reconnaissance (verification, marking), and lane clearance (reacquisition, targeting, remote command detonation) in the very shallow water (VSW) and surf zone (SZ) environments.

Humanitarian Demining. Technology demonstrations are planned in the following areas:

- Mine clearance—improved mechanical clearance devices for use in nearly all terrain.
- Individual mine detection—improved hand-held metallic and low metal antipersonnel (AP) mine detector; improved vehicle-mounted AP mine detector for use on all types of roads including DTO G.14, Automatic/Aided Technology for Detection of Unexploded Ordnance Clearance; new marking system using improved positioning and marking technologies; improved explosive foams; laser applications.
- Mine awareness and demining training—fully automated, multilingual training system.

(2) Technology Development. Technology developments support the countermine/mines subarea and address near-, mid-, and long-term military requirements. Major task areas are:

- Countermine
- Surveillance, reconnaissance, detection, and identification—exploitation of national technical means sensors, real-time processing, autonomous vehicles/networking/low-cost robotics, small advanced sensors (acoustic, magnetic, electro-optic, ground penetration radar, chemical), advanced/lower power signal processing, multispectral/

hyperspectral imaging, ATR/computer-aided detection, multisensor fusion, and efficient power generation

- Breaching and neutralization—robotics, subsumptive control, kinetic energy, directed energy, focused pressure shockwaves, energetics, chemical neutralization, and hypervelocity projectiles.
- Battlespace management—distributed interactive simulation TDAs with environmental prediction algorithms and magnetic signature suppression.
- *Mining*—real-time processing, advanced sensors, remote control, intermine and intrafield communications multisensing data fusion, remote control, real-time communication datalinks, real-time visual target area surveillance (particularly in regards to antipersonnel land mine alternatives), deterrent platforms to include multiple warhead technology, robotic platforms, and delivery systems to cover the required depth of the battlefield.
- *Humanitarian demining*—the demining program uses expertise from government, industry, academia, foreign countries, the United Nations, and nongovernmental organizations to produce practical solutions to locate minefields (or confirm their absence); detect individual mines; clear and destroy a large number of mines rapidly and safely; enhance the safety of deminers; and provide tools to facilitate mine awareness and deminer training. Current and planned projects are:
  - Minefield detection and marking
    - Mast-mounted QA sensors to locate minefields and mine-free terrain
    - Utility of lightweight airborne multispectral detection in demining role
    - Bio-sensors and vapor collectors to confirm presence/absence of explosives
    - Individual mine detection
    - Infrared/ground-penetrating radar/pulsed induction mine detector
    - Mini-mine detector
    - Hand-held trip wire detector
    - Ground-based QA system
    - Vehicle-mounted mine detector
    - Sensor imaging
    - Canines
  - Mine clearance
    - Remote-controlled ordnance disposal system
    - Mine-clearing plow
    - Confined area blade
    - Towed heavy roller
    - Light tine roller
    - Berm processing assembly
    - Enhanced mine rake
    - Improved mini-flail platforms
    - Heavy grapnels

- Neutralization
  - Explosive foam dispensed from vehicles or personnel backpacks
  - Chemical neutralization
  - Mine marking and neutralization system
  - Shaped charges
  - Explosive demining device
- Individual tools
  - Extended length weedeater
  - Extended length probe with acoustic verification system
  - Vehicle protection kit
  - Demining kit (cart and backpack)
  - Mine locating marker
  - Blast and fragment container
- Mine awareness and demining training—expanded development of multimedia, multilingual, mobile training system.

(3) **Basic Research**. Basic research contributing to the countermine/mines subarea includes (inter alia) ocean optics, coastal sciences, coastal meteorology, coastal mixing, ocean acoustics, coastal benthic boundary layer, high-frequency scattering, autonomous ocean sampling, sediment transport/dynamics, high-temperature superconducting ceramics, signal analysis, image representation, perceptual science, energetics, solid mechanics, virtual environments, laser and electro-optics, remote sensing, computational neural science, electromagnetic sensors, magnetic sensors, acoustic sensors, chemical sensors and stimulants, sensor fusion and signal processing, multispectral/hyperspectral, kinetic and directed energy, and infrared.

2. Guidance and Control

a. *Warfighting Needs*

Future warfighting will require more affordable precision-guided weapons that are smaller, lighter, and significantly more effective than current systems. This requires guidance and control (G&C) that supports a three-to-one reduction in the number of precision-guided munitions required to defeat high-priority targets including time-critical mobile targets (e.g., transportable erectable launchers). As an example, the guided Multiple Launch Rocket System (MLRS) will reduce the number of rockets needed to defeat targets by at least a factor of eight over existing systems, depending on target type and range, and result in a cost per kill reduced by a factor of five. A decrease in false target acquisition and track over currently fielded systems will reduce both weapons launched per target and the number of sorties required to destroy a given target thereby reducing aircraft losses. G&C also supports high guidance accuracy (precise guidance) that will significantly reduce collateral damage by allowing use of smaller warheads. Future seekers will provide all-weather, completely autonomous operation, with increased standoff ranges against a broad target set in a very hostile, low-observable environment and with reduced incidents of fratricide. Potential transitions include MLRS, FOTT, JDAM, AMRAAM, AIM–9X, LHT/ATT, Hellfire, BAT, guided 2.75-inch rocket, and Stinger.

b. *Overview*

The focus of technology efforts to satisfy warfighting needs includes image/signal processing; modeling, test, and simulation; guidance components; and radiation guidance.

(1) Goals and Timeframes. The investment strategy being followed is to improve the effectiveness of weapon G&C systems so that fewer weapons are needed per target. This reduces the overall cost of expending such weapons in combat and supports a parsimonious acquisition philosophy. We focus on affordability by emphasizing simulation to reduce R&D costs and to improve training and readiness, by linking G&C component development with manufacturing S&T, by utilizing commercial products when feasible, by increasing emphasis on hardware and software codesign, and by identifying critical shelf-life issues early in the acquisition cycle. The goals are listed in Table X–3.

Table X–3. Guidance and Control Subarea Goals and Timeframes

Application/Mission	Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ Years)
Improve fire support effectiveness	Integrate and test HIQUAMS brassboard LADAR seeker. Evaluate concept and design for on-board antijam GPS approach to point-hit MLRS and demonstrate with HWIL. .	Demo low-cost, ruggedized, miniature inertial components for use in missile guidance, position location, navigation, and fire control. Develop next generation of laser diode HWIL scene projectors. Package HIQUAMS LADAR seeker in 3.5-in diameter volume.	
Improve air defense	Demo sensor suite for air defense missile target acquisition. Conduct captive-carry test of form-factor 2.75-in imaging IR seeker.	Demo capability to perform NCTR of air targets with special algorithms using air defense radar. Demo advanced datalink technology capability including data compression, spread spectrum, and CM techniques for secure missile C^2. Develop integrated circuitry for use in HWIL simulation of RF guided missiles. Upgrade to Stinger through integration with IIR seeker.	
Improve close combat capability	Develop multispectral seeker concepts for modernized Hellfire. Complete and test second-generation jammer for CAPS.	Develop the hardware and software for an imaging seeker that can auto acquire and select the impact point on a target. Demo advanced terminal homing auto-tracker in minimum-sized, low-power package.	

Table X–3. Guidance and Control Subarea Goals and Timeframes (cont'd)

Application/Mission	Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ Years)
		Conduct seeker integrative captive flight test for modernized Hellfire seeker. Conduct low-cost, precision-kill guided 2.75-in rocket flight and user test. Demonstrate long standoff warhead sensor for CAPS.	
Develop inexpensive electronically scanned array hardware for missile seekers	Demonstrate tracking ability with small number (10–15) of transmit/receive units made with conventional hardware and mounted on conical surface of radome for 13-in missile.		
Develop signal processor to rapidly identify selected target in air defense site and to select aimpoint		Develop a signal processor with neural net algorithms to guide to a selected target from any attack aspect in JSOW-size weapon.	
Develop gimbal-less 94-GHz seeker tracker concept for SEAD applications		Develop 94-GHz gimbal-less seeker that tracks at least 30 deg off boresite.	Frequency-adaptive antenna system with no moving parts.
Develop high frame-to-frame image compression for application to bomb damage indication via imager data linked to damage assessor	Demo 300:1 image compression dynamically at 30-Hz or higher frame rate.	Demo 1,000:1 image compression at 100-Hz frame rate.	
Defeat fixed, high-value targets	Develop antijam GPS guidance system. Low-cost ($3–$5K) increment for substantial antijam performance. Demo small, low-cost FOG IMU for tactical applications. Cost goal is $6K for 25-in^3 IMU with <1-deg/hr drift rate.	Demo antijam GPS/INS guidance on JDAM-type flight vehicle in heavy jamming environment. Maintain current GPS/INS accuracy. Develop and demo very low cost (<$2K) micro-machined (MEMS) IMUs with tactical (1–10 deg/hr) drift rate.	Develop and demo intelligent GPS/INS guidance system. Increase performance against multiple (more than 3) high-power jammers. Develop multiple sensor using MEMS technology to provide tactical-grade performance for <$1K/IMU.
Demo all-weather seeker	Demo basic SAR seeker design that will integrate with a GBU–15.	Free-flight test 3 GBU–15s configured with SAR seekers to demo integrated munition performance.	Demo advanced short-response mission planning, real-time targeting, and reduced seeker cost.
Develop and demonstrate precision LADAR seekers	Develop LADAR seeker designs using available technology.	Build and captive flight test advanced LADAR seeker designs for Small Smart Bomb and for Warrior.	Utilizing further LADAR technology developments, build and evaluate advanced LADAR seeker for the Dual-Range Missile.
Demo all-weather accurate guidance small warhead (SSB)	Demo SSB w/INS GPS.	Demo SSB with terminal seeker.	

(2) Major Technical Challenges. Guidance and control challenges include design and manufacture of low-cost, high-performance G&C components; multimode/multispectral seekers; high-speed signal and image processing; reliable aimpoint selection; jam-resistant datalinks; and miniaturization and hardening of inertial measurement units (IMUs). Additional challenges include:

- Multispectral missile seekers to improve effectiveness in the presence of countermeasures.
- Precision guidance of small-diameter weapons.
- Enhanced air defense target acquisition including masked targets to increase survivability.
- Autonomous target acquisition to reduce collateral damage and fratricide.

(3) Related Federal and Private Sector Efforts. Advances in computer technology have greatly aided G&C. Automotive interests in inertial sensors help tremendously in cost reduction. There are many small business innovation research (SBIR) tasks that support G&C efforts. Much of the service- and industry-developed G&C control technology is distributed through the Guidance and Control Information and Analysis Center. Significant industry independent research and development (IR&D) is performed in this area.

c. *S&T Investment Strategy*

The investment strategy is to improve effectiveness of G&C systems so that fewer weapons are needed per target. Improved munition effectiveness will reduce required sortie rates and therefore launch platform (strike aircraft) attrition. Individual component cost is reduced as the various technologies evolve.

(1) Technology Demonstrations. Guidance and control technology demonstrations include the following DTOs:

- Counteractive Protection Systems (WE.13)—develop and demonstrate techniques and technologies to allow antitank guided weapons to defeat threat tanks equipped with active protection systems (APSs).
- Fiber-Optic, Gyro-Based Navigation Systems (WE.21)—develop and demonstrate technologies for affordable and robust guidance, navigation, and control, including a high-level hybridization of a fiber-optic gyro and etched-silicon, accelerometer-based IMU on a silicon wafer.
- Small Diameter Antiair Infrared Seeker (WE.51)—develop and demonstrate a small diameter (2.75-inch) IR imaging seeker that can provide improved target engagement capability for man-portable and lightweight crew-served air defense missile systems.
- Best Buy ATD (WE.52)—develop and demonstrate a gun-fired, rocket-assisted, jointed-composite, 5-inch projectile with a high lift-to-drag ratio; and double the number of carried submunitions compared to the extended-range gun munition (EX–171 ERGM) from 72 to 143, delivered from sea-based guns to at least 50% farther range (from 63 nmi to 100 nmi) that match or exceed expected shore performance of the 155-mm M198 gun-fired projectile.

- Microelectromechanical Sensor Inertial Navigation System (WE.58)—improve the silicon-based inertial sensors (gyros and accelerometers) and integrate them with navigation software into a low-power, small, lightweight, low-cost, tactical-grade INS.
- Modernized Hellfire G&C/Seeker Technology Effort (WE.61)—develop and demonstrate both guidance and control and seeker technology necessary for the Modernized Hellfire engineering and manufacturing development (EMD) program.
- High-Quantity Antimateriel Submunition Program (WE.62)—demonstrate laser radar (LADAR) seeker miniaturization technology necessary for future Army powered, small-diameter submunitions that will provide the capability to detect, classify, and identify threat targets with smaller and smarter missile systems.
- Direct-Attack Munition Affordable Seeker ATD (WE.63)—demonstrate critical technologies showing that image-guided bombs can replace laser-guided bombs.
- Cruise Missile Real-Time Retargeting ATD (B.19)—develop and demonstrate technologies for brilliant autonomous cruise missiles with onboard mission planning and control systems.
- Hammerhead ATD (B.22)—demonstrate a Joint Direct Attack Munition (JDAM)-class synthetic aperture radar (SAR) seeker for guided applications that has a capability to strike fixed targets obscured by cloudy or foggy conditions.
- Point-Hit ATACMS/MLRS (B.27)—design, develop, and test a cost-effective, jamming-resistant, precision-guidance package for application to the M270 Family of Munitions (ATACM/MLRS).

(2) Technology Development. Technology development efforts that support the demonstrations above address longer term military applications. Major task areas are:

- *Image and signal processing,* which includes collecting and analyzing large amounts of data, correlation techniques, and algorithms for acquiring, classifying, and identifying targets.
- *Software and simulation,* which includes imbedded software development and simulation of guided systems and synthetic scene generation, scene projectors, digital simulation, and hardware-in-the-loop (HWIL) simulations.
- *Radiation guidance,* which includes acoustic, RF, millimeter wave (MMW), LADAR, passive IR seekers, multimode seekers, and datalinks.
- *Guidance, navigation, and control components,* which include inertial sensors and Global Positioning System (GPS) components, radomes, actuators, and unique structural elements.

(3) Basic Research. Basic research supports all four G&C technology subareas. In signal/image processing, research is conducted to support algorithm development (wavelets, image algebra, model-based vision, superresolution, optical correlation filters), processing platforms (silicon architectures, optical correlators, analog and digital platforms), and processing system approaches through biomimetics. Research is underway to understand the sensor fusion problem for multimode, multispectral seekers. In software and simulation, research is conducted to support advanced guidance laws, state vector estimators, autopilots, and INS/antijam GPS; to continue development of synthetic target and background scene generation capability; to validate existing codes with measured data for all sensors of interest; and to evaluate signal and image processing algorithms. Scene projection technology is continuing development to enable realistic HWIL simulations for guided munitions equipped with passive imaging infrared (IIR), dual-mode (current emphasis on passive IIR and MMW), and LADAR seekers. Closed-loop guidance and control coupled with advanced image and signal processing will enable development of autonomous munitions as intelligent systems. Radiation guidance research supports understanding target and background signature phenomenology, weather effects, and countermeasure effects on various seeker types (e.g., polarization signatures, passive MMW phenomenology, the various subsystems required to support eye-safe LADAR, conformal electronically steered (RF) arrays). In the guidance component area, hardware and software approaches to the antijam GPS problems are being investigated, and research supporting higher performance, more affordable interferometric fiber optic gyroscope, and micromechanical inertial systems (nanosystems) is being conducted.

3. Guns

a. *Warfighting Needs*

DoD requires capabilities of improved range, penetration, and combat effectiveness of guns at lower total acquisition cost over existing systems. The Objective Individual Combat Weapon (OICW) will replace selected M16 rifles, M4 carbines, M203 grenade launchers, night vision devices, and laser rangefinders with a single integrated system with enhanced operational capability and increased effectiveness. The OICW will deliver three to four times the hit probability of existing systems beyond 500 meters and an all-new defilade target attack capability out to 1,000 meters. The Objective Crew-Served Weapon (OCSW) will provide a lightweight, two-man portable, single replacement weapon system for selected 40-mm MK19 grenade machinegun, Caliber .50 heavy machinegun, and medium machineguns. Fielding of the XM982 extended-range artillery projectile will immediately enhance the range of existing 155-mm artillery and extend the range of the developmental XM297 Crusader solid-propellant cannon up to 50 km. The precision-guided mortar munition (PGMM) will provide new capabilities to defeat point-targets at ranges beyond 7.2 km and to conduct precision strikes while minimizing collateral damage. An electrothermal-chemical (ETC) version of the 120-mm M256 tank gun will provide 14-MJ muzzle energy and increase armor penetration over the currently fielded 120-mm munition. Nonlethal weapons technologies will provide the field commander with a capability to tailor target effects from less-than-lethal to lethal for small-caliber weapons against lightly armored materiel and personnel. Energetic materials that are 10% more powerful, yet less sensitive, will enhance explosively formed penetrator kill capability. Selective-mode warheads will be demonstrated that can defeat both a heavy armored target (10%–20% increase in performance compared to Javelin) and a lightly armored target (fourfold increase in lethality as compared to a standard shaped charge). Potential transitions include FSCS, FCS, FIV, JSF, and upgrades for AAAV, BFVS, CIWS, Abrams, Paladin, Crusader, and Patriot.

b. *Overview*

(1) Goals and Timeframes. The goals are to develop technologies for small-, medium-, and large-caliber guns, projectiles, gun propellants, power supplies/conditioning, and fire control, with enhanced performance and compact, lightweight configurations at affordable costs. The major goals are shown in Table X–4.

Table X–4. Guns Subarea Goals and Timeframes

Application/Mission	Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ Years)
Objective individual and crew-served weapons	Demo OICW system prototype, <18 lb, probability of incapacitation (P_i) >0.05 @300 m (exposed targets), P_i >0.2 @300 m (defilade targets).	Demo OCSW prototype weighing less than 38 lb that can defeat defilade targets and 51-mm RHA. Demo OICW and OCSW in battle lab experiments.	Begin OICW and OCSW productions.
Tank lethality enhancements	Demo 120-mm KE cartridge defeat of 2005 ERA projected threat with 40% increase in lethality over the M829A2.	Demo 30–70% increase in system accuracy under stationary conditions over M829A2/M1A2. Demo 200% increase in hit probability at 3 km over M1A2 under dynamic conditions.	
Nonlethal weapons for operations in a full-spectrum conflict (e.g., from peace keeping/ humanitarian to operations in major regional conflicts)	Demo nonpenetrating AP blunt impact munitions launched from platforms (M16A2, 40-mm M203GL, 12-gauge shotguns, etc.) for both point targets and crowds at 10–50-m range. Demo DE device over delay/denial.	Demo an EM pulse vehicle stopper. Complete acoustic device health and safety assessment.	Demo advanced nonlethal concepts. Demo mobile DE device.
Direct-fire lethality, range, system performance enhancement alternatives for future combat vehicles		Demo medium-caliber bursting munition. Demo ETC in 120-mm M256 for potential field-worthy insertion.	Demo EM gun system compatible with AAN.
Improve indirect fire capabilities for artillery and mortars	Demo extended-range artillery projectile (ERA/ XM982) capable of immediately enhancing the range of existing 155-mm weapons and extending the range of the developmental 155-mm howitzer system to 50-km.	Demo 155-mm lightweight automatic howitzer with 25% more rapid emplacement and 50% higher rate of fire. Demo precision-guided mortar munition with first-round point target effectiveness at 15 km.	
System performance enhancement for Abrams PIPs and the FCS	Demo 14-MJ muzzle energy in 120-mm M256. Demo 1.5-J/g specific energy in pulsed-power system.	Demo 25–30% performance increase on medium-caliber ETC. Demo hypervelocity launchers with 100-round life.	Transition ETC or EM technology for PIPs or FCS applications.
System performance enhancement for naval surface combatants		Demo ETC technologies capable of 22-MJ muzzle energies with a 5-in gun system.	Transition ETC technologies for PIP or naval surface combatants.

(2) Major Technical Challenges. Challenges in the guns subarea include packaging constraints for ETC technologies that provide compact, high-efficient plasma ignitors; new high-energy-density/propellant formulation, consistent repeat rate, and desirable life cycles of pulse-forming network; advanced EM composite barrel with high-efficiency rail design; compact and affordable pulse and prime power system and ammunition handling technologies for high rate of fire; accurate laser ranging, efficient fragmentation, and system/weight minimization for OICW; and efficient fragmentation, electronics miniaturization (for fire control and fuze), systems integration, and overall system weight for OCSW. Challenges for ERA/XM982 include the multi-functional electronic fuzing module, base burner, forward rocket motor, and cargo expulsion. Challenges for EM guns include high-strength, thick-section composites; high-current density; fast-actuating and -recovering solid-state switches; high-efficiency launchers; thermal management; and reduced mass armatures. Challenges for nonlethal technology are wave propagation and antenna design for acoustics, and component size and wave propagation/generation for DE devices.

There are several industry R&D coalition concerns:

- Detailed, validated, interior ballistics models support the 25% muzzle energy increase claimed. The 10% armor penetration increase is predicted by similarly validated terminal ballistics models.
- Study has reconfirmed the value of electric gun development, and additional technology demonstrations can be accomplished at relatively low cost.
- The uniform ignition of disk propellant is a critical mechanism of the solid-propellant ETC program. An equally important mechanism is temperature compensation. ETC will force cold propellant charges to perform as hot charges, thereby achieving peak pressures near the limits of the gun. A concept under investigation would give “always hot” performance at a fraction of the electric input of current plasma-injector methods. This would further reduce the volume and mass of the pulse power supply. Another component of ETC is the reduction in ignition delay and predictability of the delay. Both have been demonstrated in full-scale experiments with single initiators. The experiments must be demonstrated with multiple or Flare injectors if they are needed in the final design.
- The EM critical components (pulse power supply, launcher, and integrated launch package) have been independently demonstrated at near their design performance points. Issues remain regarding high-energy EM systems, rate of fire, and prime power. The complete end-to-end system remains to be demonstrated.

(3) Related Federal and Private Sector Efforts. Commercial advances in metallurgy, energetic materials, power supply and conditioning, aerodynamics, composite materials (needed for rotating machine pulse power supplies), computational mechanics, and related technologies support gun technology efforts. These efforts are closely integrated with all DoD in-house efforts.

c. *S&T Investment Strategy*

(1) Technology Demonstrations. Gun technology demonstrations include the following in support of DTOs:

- Direct Fire Lethality ATD (WE.18)—enhance and expand the lethal battlespace of the Abrams tank while reducing operating and support costs.
- ETC Armaments for Direct Fire (WE.33)—the program will demonstrate the technical feasibility of ETC propulsion to improve the lethality of direct-fire ground systems by providing the technology to significantly increase available muzzle energy.
- OCSW ATD (WE.34)–develop and demonstrate a lightweight, two-man-portable, single replacement system for selected 40-mm MK19 grenade machineguns, caliber .50 M2 heavy machineguns, and medium machineguns.
- Electromagnetic Armaments for Direct Fire (WE.56)—significantly improve direct fire ground combat vehicle lethality by providing EM gun systems with hypervelocity and hyperenergy launch capability.
- OICW ATD (E.03)—demonstrate affordable, high-payoff individual weapon system technologies that yield significantly improved hit probability, lethality, and operational capability through the use of 20-mm air-bursting munitions, 5.56-mm kinetic energy (KE) projectiles, and optoelectronic fire control.
- Joint Nonlethal Weapons (E.04)—develop, demonstrate, and expedite fielding of antipersonnel and antimateriel nonlethal devices, munitions, and weapons.
- Precision-Guided Mortar Munition ATD (M.06)—demonstrate through simulation and testing of the 120-mm PGMM the ability to engage, detect, and defeat high-value targets such as earth and timber bunkers, command posts, and logistic sites.
- Artillery-Launched Observer Round ATD (M.14)—this program will demonstrate critical technologies required to develop an expandable, naval, gun-fired projectile that, after launch, reconfigures to a powered cruise vehicle capable of supporting organic targeting, battle damage assessment, communications relays, and—in the case of the Forward Air Support Munition—munitions delivery.

(**2**) **Technology Development**. Technology development efforts support demonstrations described above; they lay the foundation for demonstrations and address longer term military applications. Major task areas are:

- Small-caliber systems to develop technologies for future individual and crew-served small arms weapon/munitions systems yielding enhanced effectiveness and sustainability.
- Medium-caliber systems to provide "modified nondevelopmental item" technology options, with concept analysis and component/subsystem experiments in the areas of reduced dispersion guns, enhanced bursting and KE ammunition, turret stabilization, and associated fire control for near-/mid-term platform programs.
- Large-caliber systems to develop guided mortar munitions, guided extended-range and extended-accuracy artillery projectiles, novel KE tank penetrators, precision turret/gun stabilization, ETC and EM tank guns, low-cost smart munitions, and increased smart submunitions.

- Future generic gun technologies to provide variable-level target effects and weapons-related technologies that are caliber independent.

(3) Basic Research. Research in mathematics, chemistry, physics, computer science, materials science, electronics, and mechanics all support critical technology requirements for future armament systems. Focused research in the penetration physics of hypervelocity projectiles and research in high-energy density power supplies support future electric gun requirements. These basic research studies provide an essential foundation for the gun system technology required to defeat future threats and ensure that our forces can maintain a technological edge.

4. Missiles

The missiles subarea consists primarily of system integration efforts. Providing advanced guidance, ordnance, or tactical missile propulsion system integration and demonstration is a major portion of this subarea. Missiles also provide for technology development of tactical missile aeromechanics, tactical missile propulsion, and launchers and dispensers.

a. *Warfighting Needs*

The warfighter requires overall improvements in cost-to-kill ratios, affordable precision providing reduced collateral damage, and the general ability to conduct operations in urban conflicts effectively and without excessive damage and loss of life.

In order to meet the improvements in cost-to-kill ratios, an increase in weapon platform loadouts is necessary to improve mission/sortie effectiveness. A threefold increase in the number of individually targeted weapons by FY05 meets the requirements for multiple kills per pass or shot and increases the weapon effectiveness against area targets. A twofold increase in weapon standoff distances by FY05 meets the requirement for increased aircraft survivability. Finally, a reduction in time-to-target to less than 5 minutes meets the FY10 requirement to defeat time-critical targets.

Efforts to provide the warfighter with affordable precision-guided weapons and to reduce collateral damage require lighter, smaller, more accurate weapons with increased performance. Missile airframes must be lighter and have reduced radar cross section. Propulsion units must provide increased agility, delivered energy, and mass fraction while reducing sensitivity to unplanned hazard stimuli. Technology advances in divert propulsion systems will be available to demonstrate a reduction in the number of theater missile defense (TMD) systems to cover a given area by 26% (FY00) and 60% (FY10). Potential transitions include Army, Navy, and Air Force tactical missions and several space missions within Air Force Space Command.

b. *Overview*

The focus of technology efforts to satisfy warfighter needs includes system integration, tactical missile propulsion, tactical missile aeromechanics, and launchers and dispensers.

(1) Goals and Timeframes. The overall goals of the missiles subarea are through optimal system integration and demonstration to provide the warfighter with the best possible cost-to-kill ratio while minimizing collateral damage. The missile subarea plans to demonstrate missile systems that provide multiple kills per pass/shot, increased standoff range to increase launch platform survivability, autonomous attack capability, and multimission weapon systems during the next 1–5 years. Specific goals are listed in Table X–5.

Table X–5. Missiles Subarea Goals and Timeframes

Application/Mission	Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ Years)
TACTICAL MISSILE AEROMECHANICS			
Low-cost G&C	Low-cost strapdown guidance for miniaturized missile package.	Demo 1-m CEP at 6 km for guided rocket.	Demo agile air-to-air medium-range missile.
Direct thrust control	Demo 1,000-lbf thrust divert value.	Integrate divert thrust value into hit/kill interceptor flight test.	
Canard control	Extend aero configuration database.	Demonstrate efficient canard configuration.	Demonstrate effective canard roll control.
PROPULSION			
Agile propulsion for short- and medium-range antiair missions	Low-cost TVC nozzle feasibility demo. Minimum signature CL–20 propellant (Isp 248s) motor performance demo.	Low-cost integrated aero/ TVC composite case motor demo. Demo of high P_c (4,000 psi) combustion of CL–20 propellant.	Clean ADN propellant (Isp 252s) motor performance demo.
Energy management	Demo gelled propellant flight weight engine.	Demonstrate flexible sustainers.	
Standoff propulsion for medium- and long-range antiair/antisurface missions	Ground test of low-drag ramjet having bent-body combustor.	Motor performance demo of metallized CL–20 propellant (Isp 272s). Demo of high-stiffness, low-weight composite case. Flight demo of low-cost missile RJ system (M > 3).	Demo of low-cost erosion, carbon-carbon material for nozzle throats. Demo of efficient, low-erosion fiber or cloth-reinforced insulation material. Freejet demo of hydrocarbon-fueled scramjet (Isp 850s; thrust 60 lbf/lbm/s at Mach 8).
Gun-launched propulsion for surface fire support	Demo propellant ballistics (P_c, 5,000–8,000 psi; n < 0.6). Optimized high-performance lightweight case.	Motor performance demo of prototype motor (high P_c, composite case) Isp > 270.5 for gun launch.	Gun-launched flight test of prototype motor (high P_c, composite case, wrapped around fins) to demo performance (range > 3.5 nmi). IM tests of prototype motor.
LAUNCHERS/DISPENSERS			
Smart munition dispenser	Demonstrate LOCAAS/SSB dispenser for TMD. Demonstrate lightweight C–130 transportable artillery rocket system.	Design low-cost dispenser for LOCAAS and SSB. Increase weapon loadout by 3X. Design as integral shipping container and dispenser. Demo Multiple Smart Munition dispensed from MLRS.	
SYSTEM INTEGRATION			.
Increase weapon standoff	Design and wind tunnel test (full scale) wing extension kit for SSB. Increase SSB range to 40 nmi. Flight test demo wing extension kit for SSB.	Design and ground test fast-reaction standoff weapon for time-critical targets.	
Missile integration demonstrations	MAT—17-km sled test. Fast Hawk (low-cost missile). LCPK-guided flight demo.	LOSAT—missile flight demo. Modernized Hellfire missile flight demo. Survivable airframe.	Hypersonic missile (M > 6.0). CKEM flight test.
Integrate component for autonomous attack submunition	Design, fabricate, and ground test powered LOCAAS.	Conduct guided flight test for powered LOCAAS.	

(2) Major Technical Challenges. Missile challenges include the following:

- Efficient packaging of all missile components in a tube-launched optically guided weapon (TOW)-size missile that has the ability to lock-on ground vehicles in clutter at ranges up to 5 km and lock-on after launch up to 10 km. Missile will use gel motor technology to vary thrust allowing flyout to longer ranges.
- Dynamically stable flight without aerodynamic control surfaces of a bending airframe ramjet (RJ) missile, a self-starting annular inlet with 68% pressure recovery at Mach 3, 60,000-foot altitude, and stable bent body combustion during maneuver and all flight regimes.
- Development and integration of miniaturized G&C control actuation technology with an advanced composite, high-performance propulsion system in a small diameter hypervelocity missile using advanced KE penetrator designs.
- A low-cost, small-producible, strap-down mechanism and guidance components for precision guidance of a highly rolling small rocket (2.75-in) capable of a circular error probable (CEP) of 1 foot.
- Integration of a launch system into ships that can accommodate the firing of a wide range of missiles including Evolved Sea Sparrow Missile System, Tomahawk, Standard Missile Block 4, and Army Tactical Missile System (ATACMS).
- Adaptive airframes for multiple speed regimes.
- Controllability of an airframe that is shaped for very low drag and low radar cross section (RCS).
- Canard roll control.
- Incorporation of attachments into composite missile airframes without compromising the operational capability of the missile.
- Maintain line-of-sight antitank (LOSAT) lethality in a smaller, lighter, more maneuverable KE missile.
- Low-cost, lightweight composite external surfaces that can satisfy high-temperature (1,000 °F) and high-stiffness requirements of a tactical missile.
- Dispensing smart submunitions from MLRS.

Solid-propellant propulsion challenges lie in increasing propellant energy and density without increasing sensitivity, improving inert propulsion materials strength-to-weight/-volume ratios, and reducing erosion and weight of insulation and nozzle materials.

The challenges for air-breathing propulsion lie in high-combustion efficiencies, reduced erosion and weight of combustor insulation, elimination or reduction to acceptable levels of ramjet combustor oscillations, and increasing the performance and reducing the size of RJ components

(3) Related Federal and Private Sector Efforts. NASA, DoD service laboratories, industry, and academia conduct research into advanced materials, aerodynamics, computational fluid dynamics, and shock and vibration that are monitored by the various subject-matter experts through participation in conferences, symposia, and joint committees such as the joint Army, Navy, NASA, and Air Force Propulsion Committee. DoD and industry have efforts in propulsion technology, flight mechanics, and vehicle structures. Also, NASA has efforts in propulsion technology for space and orbit transfer, some of which are translatable to tactical propulsion. Industry propulsion IR&D investment in FY95 was approximately $55 million. Further, these propulsion efforts are focused through the Integrated High-Payoff Rocket Propulsion Technology and Integrated High-Performance Turbine Engine Technology efforts that are highly coordinated and integrated efforts with all services, NASA, and industry.

c. *S&T Investment Strategy*

(1) Technology Demonstrations. Missile system integration and demonstration include the following DTOs:

- Powered Low-Cost Autonomous Attack System Program (B.15)—demonstrate an affordable, miniature, autonomous, powered munition capable of searching, encountering, detecting, identifying, tracking, and destroying the entire spectrum of ground mobile targets in many types of weather and terrain conditions.
- Miniaturized Munition Technology Guided Flight Tests (B.21)—demonstrate the effectiveness of a small, 250-pound-class munition with extended range, enhanced fragmentation/enhanced blast warhead, antijam GPS/INS guidance, and LADAR terminal seeker.
- Enhanced Fiber-Optic Guided Missile ATD (M.08)—develop and demonstrate a precision standoff capability against high-priority ground and airborne (helicopter) targets under day, night, and adverse weather conditions out to a range of 15 km.
- Compact KE Missile Technology (WE.50)—demonstrate enhanced system lethality against advanced and active Future Combat System (FCS) threat armor target arrays with a reduced mass hypervelocity KE missile (40–50 kg) testbed.
- Hypersonic Weapons TD (M.13)—demonstrate critical technologies in the areas of propulsion, airframe, ordnance, and guidance and control, which will allow for hypersonic strike weapons that have an average velocity of Mach 5–6, a range of 400–700 nmi, cost less than $400,000 a unit, have a CEP of less than 3 meters, and deliver ordnance that penetrates 18–36 feet of concrete.
- Line-of-Sight Antitank System ACTD (M.04)—develop and demonstrate the military utility of a lightweight KE missile system that provides dedicated long-range antitank fires and high-value, hard-target defeat in support of close combat by light forces during and after forced entry operations.

Tactical missile aeromechanics demonstrations include the following DTOs:

- Low-Cost Precision Kill ATD (B.18)—develop, flight demonstrate, and integrate onto the AH–64 Apache a very low cost (~1-m CEP) guidance and control retrofit package for the 2.75-inch Hydra B70 rocket.

- Atmospheric Interceptor Technology (D.08)—develop, integrate, and demonstrate lightweight kill vehicle technologies for endo-atmospheric hit-to-kill intercepts.
- Air Superiority Missile Technology (WE.35)—through design, ground tests, and flight tests, demonstrate reaction jet flight control technologies that will significantly enhance air-to-air effectiveness in all phases of air combat.

Tactical missile propulsion demonstrations include the following DTO:

- Tactical Missile Propulsion (WE.39)—enhance the warfighter's overall capability and survivability by pursuing robust propulsion technologies that will increase weapon system's kinematic performance and utility.

Launchers and dispensers demonstrations include the following DTOs:

- Concentric Canister Launcher ATD (B.16)—significantly lower the cost of launch systems over the entire life cycle while increasing operational flexibility.
- High-Mobility Artillery Rocket System (M.09)—develop and demonstrate a lightweight, C–130-transportable version of the M–270 MLRS mounted on a 5-ton family-of-medium-tactical-vehicles truck chassis that will fire any rocket or missile in the MLRS family of munitions.

Additionally, a survivable airframe TD is planned to demonstrate the flight worthiness of a wingless, subsonic, survivable multimission standoff weapon airframe. This effort combines three emerging technologies: low-drag lifting body shape, thrust vector control (TVC), and novel louvered inlet concepts. The airframe is both low cost and has inherently low RCS. Lifting body shape is optimized for minimum drag and volumetric efficiency.

(2) Technology Development. Technology development efforts support demonstrations described above by providing the foundation for the demonstrations and by addressing longer term military applications needs and requirements. Major task areas are:

- Solid-propellant formulation with emphasis on increased specific and density impulse, high-strength mechanical properties, acceptable burning rate properties at high pressure, and environment compatibility while maintaining low sensitivity.
- Gelled liquid propellant engine development.
- High-strength-to-weight-per-volume composite case development having acceptable attachments.
- Fiber-reinforced, low-erosion, heat-conductivity, dense insulation material development that has low lot-to-lot variability.
- Development of low-cost processes for fabricating low-erosion, carbon-carbon nozzles and nozzle inserts.
- Low-cost, compact TVC nozzle system development.
- Development of high-performance inlets/combustors/fuel management for integration into hypersonic and supersonic ramjet systems.
- Low-drag, high-control force aerodynamic control surfaces.

- Methodologies and techniques to model external and internal aerodynamics, fluid dynamics/propulsion interactions, fluid dynamics/optical interaction, fluid dynamics/guidance interaction, aerothermochemical aspects of target detection and identification, and aerothermochemical aspects of EM signature of targets and backgrounds.
- Advanced missile airframes to support highly maneuverable missiles.
- Integrated microelectromechanical systems (MEMS) devices for sensors and control effectors for miniature munition airframes.
- Methodologies and techniques for target and background signature modeling and signal generation for real-time scene generation and projection with application for HWIL simulation.

(3) Basic Research. Of special interest are quantum chemistry, synthesis of energetic materials, combustion mechanisms, flow structures in combustors, advanced high-specific-strength materials, computational fluid dynamics methods, better visualization of analytical results, new fiber and resin systems, and reduced production cost of advanced composite components.

5. Ordnance

a. *Warfighting Needs*

DoD requires improvement over existing ordnance systems:

- Aimable warheads in new or upgraded antiair missiles that increase kill probability to 1.0 and reduce requirements for missiles by 20%–30%.
- Adaptable warheads that are more lethal and resistant to modern countermeasures and reduce munitions inventory requirements by 30%–40%.
- Penetrating weapons that have 300% greater penetration capability and destroy 50% more hard targets.
- G&C integrated fuzing that increases lethality by 20%; costs 20% less than current systems; and enables more single-shot kills, fewer sorties, or quicker capture of air superiority, surface, and undersea target neutralization.
- Combined effects explosively formed projectile (EFP) warheads that are lethal against both light and heavy armored targets, thereby reducing munition requirements by 30%–40%.
- Antiarmor warheads that maintain the overmatch against threat armor systems.
- Smaller, more lethal weapons that enhance the Joint Strike Fighter (JSF) and the F–22 sortie effectiveness.
- Hard-target, smart-fuze accuracy for penetrators impacting at 4,000 ft/s to ensure defeat of deeply buried hard targets.
- High-blast, insensitive explosives for penetrators capable of surviving very high impact forces associated with impact speeds of 4,000 ft/s.

- Dual-use penetrator warheads that have the same high effectiveness against surface (nonhardened) targets as general-purpose bombs.

Transition opportunities include AIM–9X, Standard Missile, Tomahawk, ESSM, Advanced Air Superiority Missile, AMRAAM, Patriot, SADARM product improvement, Javelin, TOW/Hellfire follow-on, M829, F–22, JSF, JASSM, SSTD, LHT, Sidewinder, and antisurface systems such as ARMs, JDAMs, Small Smart Bombs, and JSOWs.

b. *Overview*

Ordnance is the lethal or nonlethal mechanism of the munition that enables warfighters to incapacitate, neutralize, or destroy enemy personnel, materiel, and infrastructure to a degree that will inhibit the enemy's ability to engage in warfare.

(1) Goals and Timeframes. The major goals for the ordnance subarea are to improve weapon effectiveness, multimission flexibility, and aircraft survivability; reduce cost; and minimize collateral damage. The goals are listed in Table X–6.

Table X–6. Ordnance Subarea Goals and Timeframes

Application/Mission	Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ Years)
Antiarmor—defeat advanced armor and armor protection systems	Evaluate advanced explosives in shaped charge and EFP warheads.	Demo long EFP for smart weapon system. Demo advanced countermeasure warhead in flight. Demo standoff fuze against reactive/active armor. Demo combined effects EFP warhead against targets. Demo compact and multiple effects shaped charges. LOSAT and modernized Hellfire flight demos.	Demo 300% increase in P_k in dynamic armor engagement scenarios. Demo next-generation of warheads that incorporate new liner materials and advanced explosives in designs optimized for lighter weight (-30%) effectiveness against a broader range of targets.
Bombs	Develop enhanced energy explosive fills for small bombs.	Develop enhanced energy explosive fills for small bombs. Develop enhanced explosives for improving blast and fragmentation.	Develop enhanced energy explosive fills for small, thick-walled bombs.
Gun munitions	Demo advanced GPS-based artillery registration.	Demo standoff fuze against reactive/active armor (AA). Demo miniaturized electronic fuzing for OICW bursting munition (guns).	Demo detection of CM targets in clutter for sensor-fuzed weapons (AA). Eliminate UXO
Hard target—defeat WMD in storage, production, and the field	Identify and evaluate warhead payloads for defeating WMD production and storage facilities. Evaluate chemical and thermal defeat mechanism; quantify performance.	Demonstrate 2,000-lb class weapon to deny enemy use of WMD stored or produced in hardened facility.	Defeat, deny, or disrupt enemy production and use of WMD in both hardened and soft facilities.

Table X–6. Ordnance Subarea Goals and Timeframes (cont'd)

Application/Mission	Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ Years)
Hard-target penetration technology	Demonstrate high-density explosives for enhancing weapon penetration by 100%. Demonstrate shock and temperature insensitive components for fuze sensors.	Demonstrate high-velocity (4,000 ft/s) penetration warhead with >20-ft concrete penetration.	Demonstrate high-velocity (4,000 ft/s) fuze with the ability to detect target voids within 1 foot after entering void. Demonstrate multisensor, noninertial void sensors for hard-target penetration fuzing.
Missiles (Navy/AF)	Defeat spectrum of air and surface threats using target-adaptable warheads, reactive fragments, advanced explosives, and hypervelocity missiles for time-critical targets	Adaptable ordnance that combines submunition and unitary capability. Ordnance that can be delivered at Mach 4 and is effective against both ground targets (150-ft radius) and buried targets (18 ft). Demo reactive fragment lethality in advanced aimable warhead.	Increase payload energy density by 35%. Ordnance that can be delivered at Mach 6 and is effective against both ground targets (150 ft) and buried targets (36 ft). Direct target detection of ground targets in clutter. Demo next generation of adaptable warheads capable of expanding target spectrum and range of missions. CAV and UCAV compatibility.
Missiles	Qualify advanced explosive for adaptable warhead. Imaging IR analysis and design for advanced imaging TDD. Clutter discrimination algorithm.	Small, precision-aimed warheads that are 20% smaller but are more lethal. Enhance recognizability of kills by providing catastrophic destruction/structural defeat capability. Proximity and GIF modules for simulation library. Multispectral GIF, fuze/S&A, and focus warhead integration. Distributed initiation systems. Low-energy S&A devices.	Multispectral GIF for dual-role application. Demonstrate GIF aimable warhead capabilities. Increase operational range for IR fuzes. Increase CM capabilities for active IR fuzes. Low-cost electronic S&A devices.

(2) Major Technical Challenges. Ordnance challenges include insensitive explosives with enhanced performance; quantification of very high velocity penetrator performance; controlling fragmentation on thick-case warheads to optimize for multiple uses; development of tougher materials; development of property models for adaptable warhead designs; all-weather, clutter electronic countermeasures (ECM), and chaff performance; high-resolution target imaging; safe and affordable multimode warhead initiation; and high-fidelity simulations for modeling system performance. For improved weapon lethality, challenges include cockpit-selectable robust algorithms for determining target parameters and computing warhead events in real time, high-fidelity sensors, and affordable high-shock survival components.

(3) Related Federal and Private Sector Efforts. DOE explosives technology efforts are integrated with DoD efforts. Most benefits in this area are derived indirectly from advances in related areas of electronic research.

c. *S&T Investment Strategy*

(1) Technology Demonstrations. Demonstrations include:

- Conformable Antenna Array—demonstrate conformable antenna array for use as a fuze sensor in adjunct guidance antiradiation homing mode.
- Optical Safe/Arm/Fire—demonstrate optical safe/arm/fire device to show that RF radiation will not trigger explosive elements.
- Hypersonic Weapons TD (M.13)—demonstrate hypersonic ordnance for M4 delivery against time-critical targets.
- Reactive Material Warhead ATD (WE.54)—demonstrate the ability of missile warheads to achieve catastrophic structural kills of cruise missile and manned aircraft targets by enhancing traditional KE defeat effects with fragment chemical energy that is released when fragments impact targets.
- Programmable Integrated Ordnance Suite ATD (B.24)—demonstrate a high-resolution infrared imaging target detection device that provides target classification, aimpoint selection, and optimum warhead burst-point algorithms. Program will integrate an aimable warhead to provide enhanced lethality against fighters, cruise missiles, bombers, and helicopters.
- Counterproliferation Phase I ACTD (J.03)—develop and demonstrate technologies in conjunction with operational concepts to target and defeat cut-and-cover, shallow-buried, or above-ground-bermed chemical and biological weapon storage and production facilities while minimizing collateral hazards.
- Counterproliferation Phase II ACTD (J.04)—demonstrate enhanced penetration capabilities against a simulated chemical/biological (CB) facility; demonstrate the baseline capabilities of the Joint Air-to-Surface Standoff Missile (JASSM) to conduct CB counterforce missions through operationally realistic attacks against a simulated CB weapons production facility; demonstrate the use of a conventional air-launched cruise missile (CALCM)-based penetrator and use unmanned aerial vehicle (UAV)-based chemical sensors for collateral effects assessment; evaluate the end-to-end set of products of the Counterproliferation II ACTD.
- Diagnostic Analysis of Improvised Explosive Devices (L.05)—develop new equipment and systems that will enable explosive ordnance disposal (EOD) teams to analyze large vehicle bombs and other improvised explosive devices.

(2) Technology Development. Technology development efforts support demonstrations described above, lay the foundation for success, and address longer term military applications. Major task areas are described in the following paragraphs.

The missiles task includes air-to-air, air-to-surface, surface-to-air, and surface-to-surface missile warheads, fuzes, and explosives developed specifically for these ordnance packages. This includes 6.2 and 6.3 technologies for the warheads and fuzes, but only 6.2 for the explosives. Key technologies include advanced initiation and materials for aimable warheads and active and passive IR for target detection and burst-point selection. For air-intercept encounters, key fuze technologies provide improved capability (increased lethality) for conventional edge-detection, side-looking target detection devices (TDDs) and development of guidance integrated fuzing (GIF) concepts. Technology for conventional side-looking TDD improvements is being developed to provide weather capability, clutter discrimination, reduced jitter, precision separation timing, improved contact sensitivity, and increased warhead energy on target. All provide increased reliability and lethality. GIF technology is leading to a shift from edge detection and time-delay algorithms to predictive algorithms, target aimpoint signal processing using high-resolution active systems, and passive imaging-type detectors to provide an increased capability for conventional and directional warheads. Ordnance technology for antisurface applications is moving to high-resolution height of burst and direct target detection to place more energy on the target and to reduce collateral damage while increasing lethality and reducing overall cost through reduced sorties necessary to kill a target. The key for the antisurface and air applications is the development of integrated ordnance technology packages that provide improved lethality through component synergism.

The advanced explosives task covers the complete 6.1 and 6.2 explosive technologies. It includes molecule development and formulation work. Formulations for a specific ordnance package are included in that topic if accomplished at the 6.3 level. This topic covers generic technology areas needed to improve performance characteristics of explosives that have benefits and spinoffs for use in a broad range of applications. Key technologies include explosive formulations that provide significantly increased blast and fragmentation over existing formulations. The generic 6.1 research covers such areas as new materials synthesis, characterization, initiation, detonation, and modeling studies. The 6.2 area includes the development of conventional and insensitive high-explosive formulations that address the performance, stability, and sensitivity requirements of weapon systems. It covers advanced development of formulations for a specific ordnance package, explosive processing, scale up, life-cycle engineering, test, and evaluation. This task area addresses the major challenge as to how to increase performance of high-energy munitions while maintaining or decreasing sensitivity. Key technologies under this topic include the development of a predictive capability that relates basic material properties to performance and tactical and strategic survivability, development of new materials and new explosive formulations that provide significant increase in performance (penetration, blast, fragmentation), and the development of insensitive explosives that have improved tactical and logistical survivability over existing formulations.

The hard target task covers penetration of cut-and-cover facilities, concrete or earth-covered facilities above ground, runways, and buried facilities. Technologies include fuzing, warheads, and explosive work that supports this area. Key technologies are high-strength, high-toughness steels and heavy-metal alloys for penetrator cases; high-energy-density explosives for restricted-volume penetrator warheads; explosives that can survive the high shock loading associated with hard-target penetration; and precise fuzing against a wide spectrum of hardened targets with extensive and multiple layers. The hard-target smart fuze and advanced unitary penetrator components of the Counterproliferation ACTD contribute to this objective and are discussed in the JWSTP.

The bombs task includes general-purpose bomb technologies in warheads, fuzing, and explosives. Key technologies are high-energy-density insensitive explosives, improved fragmentation control, and advanced initiation.

Ordnance components fit into the gun munitions task. Technologies include warheads, fuzing, and explosive payloads. The miniaturized 6.2 fuzing work will provide the basis for eventual integration of the full fuzing function with GPS/IMU into low-cost competent munitions.

The land mines task covers technologies in fuzing, explosives, and warheads developed specifically for the blocking, fixing, turning, and disrupting of armored and light vehicles and dismounted forces. This includes 6.2 and 6.3 technologies for the warheads and fuzing, but only 6.3 for the explosives.

The antiarmor task covers ordnance technologies in fuzing, explosives, and warheads for defeating heavily armored tanks and personnel carriers. It exploits and integrates new concepts, materials, and advanced explosive formulations to reduce warhead weight and volume while enhancing performance to maintain an overmatch against evolving threat armor countermeasures (as tandem warheads counter reactive armor). The task also involves the exploration of various techniques, concepts, and materials to enhance the length (ductility) of shaped charge and EFP penetrators to defeat tough targets. It explores and integrates concepts such as combined effects that allow a single warhead to produce lethal effects against a broader range of targets. It may include fuzing developments that permit warheads to function in an optimal manner such as providing standoff to counter active protection systems. Finally, the antiarmor task develops and employs numerical and analytical tools and models, including various optimization tools to enhance and speed the warhead design process.

(3) Basic Research. Research in mechanics is focused on gun propulsion; warheads and materials for antimateriel, antiarmor, and hard targets; mechanics of armor/antiarmor materials; explosives; and weapon system structures. These research areas are all critical for improving the performance of U.S. weapon systems. Basic research studies provide an essential foundation for the weapons technology required to defeat future threats and ensure that our forces can maintain a technological edge. Research is performed by a blend of university and in-house components uniquely suited to supplying the technologies needed for advanced weapon systems. Research related to mathematics and computer science, physics, chemistry, materials science, electronics, and mechanics all support the weapons technology requirements.

6. Undersea Weapons

a. *Warfighter Needs*

With the shift in focus from global confrontation to regional conflicts in shallow water and littoral zones, a deficiency became obvious regarding the capability of undersea weapons to successfully attack threat submarines under such harsh environmental conditions. Moreover, the problem is compounded by low-signature diesel-electric submarines operating in the shallow waters armed with modern, lethal weapons. Technological superiority and affordability of next-generation undersea weapons are needed to ensure the ability to cope with an evolving threat in harsh environments. The return on investment includes the capability to provide deep-water-equivalent performance against the quiet, small diesel-electric targets in shallow water, which will be available in the short term (1–2 years). By employing broadband sensors and signal processing, the capability to defeat sophisticated countermeasures will be available in the mid term. A new capability to disable incoming torpedoes will be available to the fleet in about 5 years. In addition, significant efforts are directed toward reducing cost of ownership through commonality of subsystem hardware and software and, where possible, entire systems over the next 3–10 years.

The end of the cold war drastically changed the outlook for production of all-up-round torpedoes and significantly reduced the planned inventory. DoD's assessment of industrial issues for torpedoes indicates all-up-round production is not needed now, but there are requirements for advancing weapon technologies, upgrading and maintaining the current inventory, and supporting torpedo operations. Planned block upgrade programs will continue to improve performance of the MK48 ADCAP (Advanced Capability), MK50, and MK54 torpedoes. CBASS (Common Broadband Advanced Sonar System) has been established to provide improved CM performance in shallow water, with an IOC of FY04. PEO(USW) has established the Stealth Torpedo Enhancement Program (STEP), which contains two phases. STEP1 focuses on guidance upgrades and has an FY03 start. STEP2 focuses on mechanical stealth and warhead technologies and has an FY08 start.

b. *Overview*

The objective of the undersea weapons S&T program is to develop and demonstrate technologies that contribute to the neutralization of threat submarine targets, counter (both soft and hard kill) enemy torpedoes, and assess the tactical battle scene and weapon employment tactics. The effort is organized in four areas: torpedo guidance and control, undersea vehicle propulsion, torpedo countermeasure and counterweapon devices, and undersea warheads and explosives.

(1) Goals and Timeframes. The underlying tenet of undersea weaponry is innovative technology leading to affordable, effective weapons. The program encompasses the technology process from basic research through applied research and advanced development, and transitions the promising candidate technologies to weapon systems upgrades. It is focused, productive, and responsive to the needs and requirements of the warfighters. Some of the major technology development milestones (when the capabilities are available for transition) are shown in Table X–7.

(2) Major Technical Challenges. The primary challenge is to provide undersea weapon performance in the adverse, harsh, shallow-water environment that is equivalent to our deep-water capability. Quiet, slow, or bottomed targets operating in cluttered shallow-water areas present a detection and classification challenge to both the platform and the weapon because of the reverberant, noisy acoustic conditions. Moreover, the clutter creates a plethora of false targets that must be recognized by identifying features of various false targets. As a result, simultaneous tracks must be maintained on several contacts. The reverberant, noisy, congested environment coupled with the quiet, slow target results in close-in engagements that demand fast reaction. Achieving this performance is a challenge that requires organizing and coordinating several undersea weapon technology areas including shipboard fire control, weapon sensors and signal processing, trackers, precision homing, and warhead lethality.

The challenge of platform survivability is met by a multilayer defense strategy that includes both smart, adaptive countermeasures and hard-kill counterweapons able to defend against attacking weapons of various capabilities, including salvos. Improved post-launch retargeting and countermeasure identification will be possible by development of bidynamic,

Table X–7. Undersea Weapons Subarea Goals and Timeframes

Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ Years)
Increase the P_k performance of U.S. torpedoes by 50% in the littoral regions (1999). Hard-kill torpedo defense capability for submarines and surface ships (2000). Broadband sonar (2000).	Hybrid MEMS fuze/S&A (2001). Cooperative engagement using post-launch bidynamic inter-sensor (weapon and platform) processing to perform either post-launch retargeting or improve accuracy (2002). Complete torpedo propulsion system with 50% reduction in length (2003). Increased energy density with affordable rechargeable battery (4X AgO/Zn) and Lithium wick thermal system (8X AgO/Zn) (2003).	40% reduction in development and ownership costs for both current and future undersea weapons (2005). Full capability half-length torpedo (2005). Underwater ramjet for high-speed torpedoes (2005). 50% decrease in size of UUV motor/propulsor (2005). Technologically superior and multimission-capable undersea weapons using ≥50% common subsystems (2010). Antitorpedo salvo capability (2005). Smart adaptive countermeasures (2006).

inter-sensor processing whereby the weapon and platform sensors are simultaneously and cooperatively processed to better define the engagement environment. The weapon's challenge is fast, accurate target detection, classification, and localization; intelligent mission control; and precision homing that achieves selective warhead placement on the target to ensure target destruction. Increased lethality warheads enhance the probability of kill by development of explosive formulations that produce higher bubble energy and shock performance. Alternatively, standoff distances can be increased while still achieving effective mission kill. A major challenge is development of a common, small, reliable safe-and-arm (S&A) device for various weapons while retaining the multiple environmental interlocks required to satisfy current safety standards.

(3) Related Federal and Private Sector Efforts. Because of the broad, varied technology areas involved in developing undersea weapons, many federal and private sector performers are involved. In FY97 (a representative year), the undersea weaponry budget was $38.2 million, of which $17.8 million went to Navy warfare centers and $20.4 million to the private sector. Although most of the technology is Navy-unique, some funding is leveraged by participation with organizations interested in similar pursuits. For example, this program is participating with DARPA, universities, and industry to develop MEMS technology that has the potential to allow a common, low-cost weapon S&A. Other examples of technology areas where the program joins with federal and private efforts are sensor materials and arrays, simulation-based design, explosive formulations, signal processing, intelligent control, and commercial-off-the-shelf (COTS) processors.

c. *S&T Investment Strategy*

S&T investments for undersea weaponry are selected in conjunction with OPNAV sponsors and PEO(USW) with emphasis shared between performance enhancement and reduction of cost of ownership. The program provides an integrated effort comprising basic research that supports an applied research program that, in turn, leads to current and planned ATDs and the advanced development undersea weaponry core line, which began in FY97.

(1) Technology Demonstrations. There are three DTOs in the undersea weapons technology area:

- Antitorpedo Torpedo ATD (WE.29)—demonstrate antitorpedo torpedo homing and fuzing technologies that can be incorporated into existing and planned torpedo and submarine defensive warfare systems.
- Broadband Torpedo Sonar Demonstration (WE.32)—demonstrate bandwidths five times that of existing torpedo sonars to provide improved performance in harsh shallow-water environments and in advanced countermeasure environments.
- Reduced Size Torpedo Subsystem Demonstration (WE.55)—develop and demonstrate by 2003 torpedo subsystems in reduced sizes so that these subsystems or components would be applicable to various sizes of torpedoes and counterweapons.

The following additional demonstrations are planned:

- Affordable Common CM Technology Demonstration—demonstrate affordable technologies that can be transitioned and incorporated into planned CM procurements and result in an overall 40% reduction in the total ownership costs of submarine-launched torpedo and sonar countermeasures.
- Core Line Technology Demonstrations—demonstrate (1) a fuel and closed-cycle cooling system to replace the current open-cycle Otto fuel engine used in a large number of U.S. torpedoes; (2) a simulation-based design capability to analyze system cost and performance interaction; (3) broadband sensors and processing to support DTO WE.32; (4) a very high speed supercavitating underwater vehicle; (5) a multimode warhead concept; and (6) an improved muffler to reduce the acoustic signature of torpedoes

(2) Technology Development. Unders**e**a weapons embrace those technologies that contribute to the neutralization of submarine targets, countering and hard killing of enemy torpedoes, and assessment of tactical battlespace/weapon employment tactics. The work is separated into four efforts:

- *Guidance and control*. This effort includes a broad regime of technologies acting together or singly to detect, classify, engage, and neutralize submarines and surface ships.
- *Undersea vehicle propulsion*. This effort seeks the development of high- and low-rate propulsion systems for torpedoes and UUVs, respectively.
- *Torpedo countermeasure and counterweapon devices*. The objective is development of affordable technologies that provide submarines and surface ships with a robust layered defense capability possessing a high degree of protection against torpedo attack to ensure platform survivability.
- *Undersea warheads and explosives*. This effort will provide explosives formulations meeting both operational performance requirements and the Navy’s insensitive munitions requirements.

(3) Basic Research. Much of the basic research (6.1) relating to undersea weapons is under the direction and responsibility of the same scientists involved with undersea weaponry applied research (6.2). They have responsibility for 6.1 and 6.2 resources, participate in formulating and managing ATDs, and are involved with the 6.3 core line. This link provides a key influx of high-quality science into undersea weaponry that carries through to the fleet. In addition, other Office of Naval Research (ONR) basic research program managers are encouraged through technology area workshops to focus basic research tasks on topics with application to undersea weaponry technology. In this way, innovative science programs are influenced to contribute ultimately to the undersea weapon technology base. Some relevant research areas are:

- Active control
- Data fusion procedures
- Fuzzy logic
- Tracking techniques
- Neural nets
- Intelligent control
- High-heat flux density
- Propellant ingredients
- Propellant formulation modeling
- Intermetallic-based warheads
- Wake characterization
- Modeling of energetic reactions
- Classification and sorting methods
- EM force-based explosives
- Situational awareness
- Computational fluid dynamics
- Combustion mechanics
- Combustion modeling
- Electrode material characterization

7. Weapons Lethality/Vulnerability

a. *Warfighter Needs*

Weapons lethality/vulnerability is a core supporting technology essential to the success and cost effectiveness of many DoD technologies and processes. Although not as visible as most new weapon technologies, weapons L/V products are an essential component of the successful development and employment of a wide range of DoD technologies and weapon systems, including warhead and weapon system designs, force-on-force simulations, live-fire tests and evaluations, and engagement plans.

DoD decisionmakers must ensure the effective lethality of emerging weapon systems and minimize the vulnerability of current and future weapons platforms and protective structures. Weapons L/V tools are used to analyze virtually all materiel in the acquisition process. Uses range from analyzing the newest materials being considered for potential applications through evaluating currently fielded systems for potential cost-effective enhancements and product improvements. As such, weapons L/V tools are integral to the analysis of numerous DTOs, ATDs, and other 6.2 programs and are critical to the evaluation of materiel systems for all acquisition milestone review decisions. Weapons L/V tools must evolve to match near-, mid-, and long-term materiel acquisition requirements.

DoD uses force-on-force simulations to support major decisions affecting force structure as well as the development of tactics and doctrine. Weapons L/V tools are a critical foundation of these simulations. Data, analysis models, and analysis outputs are transitioned to the Joint Logistics Commanders' Joint Technical Coordinating Groups (JTCGs) and also support training development, weapon selections, aircraft loads, and procurement planning. Similar analyses are used to determine the size and composition of the War Reserve Stockpile and to determine which weapons to match against which targets for both strategic and tactical engagements.

DoD acquisition program managers need to ensure that their respective systems meet or exceed program requirements. Use of weapons L/V tools early in the design phase has a documented 5:1 return on investment and a 30:1 return on investment over experimentation with actual hardware. Weapons L/V tools are part of the DoD simulation-based acquisition initiatives. These tools also are used extensively to support congressionally mandated live-fire tests by focusing actual tests with pre-shot predictions and by providing post-shot analyses for system evaluations.

Finally, the Joint Chiefs of Staff and the regional commanders-in-chief (CINCs) require in-depth, reliable information to plan and conduct precision engagements for maximum effect while limiting collateral damage. Weapons L/V products provide the weaponeering tools to support the matching of weapons to targets to achieve the required results. These tools are being used extensively today. As more countries add weapons of mass destruction to their arsenals, the weapons L/V weaponeering tools are becoming more critical in understanding shifts in the balance of power and in developing effective countermeasures. Significant efforts are being expended in the near-, mid-, and long-term timeframes to incorporate the capabilities of existing and emerging weapons against both environmental and structural protective shielding to defeat specialized targets.

b. Overview

Weapons L/V is an enabling technology area that develops the tools, techniques, and methodologies that—

- Support evaluations of DTOs, ATDs, advanced system concepts, systems in acquisition, and systems in service.
- Provide the analytical foundation to confidently and cost effectively evaluate the suitability of emerging L/V technologies and to guide future S&T investments in hardware and capabilities.
- Support congressionally mandated live-fire test and evaluations.
- Support U.S. warfighters with weaponeering tools.

Weapons L/V tools are developed using a combination of mathematical and statistical techniques; physical experimentation; physics-based, large-scale numerical simulations; hydrocodes and finite-difference methodologies; engineering expertise; and specialized analysis codes. The goals of weapons L/V are achieved by the continuous development and distribution of improved analytical and predictive capabilities and the transition of these tools to the CINCs, acquisition program managers, decisionmakers, and other users for their analytical requirements.

(1) Goals and Timeframes. The major goals for weapons L/V are to support the tri-service and the Defense Threat Reduction Agency (DTRA) weapons community through the provision of analytical tools and databases. The number of U.S. systems required to undergo live-fire testing and evaluation in accordance with U.S. code has remained constant despite defense spending reductions. Programs are phased to concentrate on the production of methodologies, capabilities, and environments of general utility in the near term (1–2 years) in order to support high payoffs in the mid term (3–5 years) and far term (6+ years). Goals include the development of the data, tools, techniques, and methodologies shown in Table X–8.

Table X-8. Weapons L/V Subarea Goals and Timeframes

Near Term (1–2 years)	Mid Term (3–5 years)	Far Term (6+ years)
Incorporate new materials, higher velocity warheads, and new system technologies into existing weapons L/V codes. Further expand methodologies to encompass potential collateral effects.	Improve analytical tools to handle additional threats and materials, to model complex phenomena (hydrodynamic ram, ballistic shock, high-strain rate), and to cover gaps in predictive capabilities.	Model complex and synergistic damage mechanism interactions as feasible: penetrator, fragment/debris, blast /shock, and fire/fumes
Determine contribution of ballistic damage mechanisms for weapon and combat system pairings.	Determine the range and validity of analysis codes; develop specialty algorithms as needed for developing weapon systems.	Apply V&V and configuration control methodologies to analytical tools and principal model architectures.
Develop algorithms for the newer materials including composites; develop and expand models to encompass nonlethal engagements.	Develop collateral damage effects methodologies consistent with weapon and target pairings, especially for targets containing toxic materials.	Develop and validate end-to-end methodologies for assessing nonlethal damage mechanisms on high-value, ground-fixed targets.
Develop more accurate environmental effects algorithms for ballistic events.	Extend and develop parallel computing capabilities to reduce analysis processing times and to enhance decisionmaking.	Exploit emerging high-performance computing advancements.
Develop basic physics-based models of target interactions by evolving from empirical models.	Develop methodology for evaluating active protection and integrated protection systems.	

(2) Major Technical Challenges. Technical challenges for the U.S. Army's weapons L/V community are directly tied to development, testing, simulation-based acquisition, and fielding of new materials and novel technologies for Army Vision 2010 and Army After Next. Significant near-term technical challenges include (1) development of ammunition response algorithms for rocket motor ignitions and explosions to more accurately predict the survivability and lethality of Army weapon systems and munitions (such as Crusader, FSCS, FCS, MLRS, HIMARS, M74 and M85 bomblets, and BAT P^3I); (2) engineering-based predictions of the subsystem capabilities of air and ground combat platforms after multiple impact combinations of direct- or indirect-fire threats; (3) verification and validation (V&V) of component-level ballistic algorithms in L/V analysis codes to support development and congressionally mandated live-fire test and evaluation; (4) physically based models to predict the probability of ignition of sustained fuel fires in U.S. ground combat systems with and without fire suppression systems; (5) advanced armor penetration algorithms for survivability/lethality analysis codes for sophisticated multilayering schemes and functionally graded material technologies under development for multihit protection of Army combat systems; (6) improved compartment- and component-level analysis codes to predict the survivability, vulnerability, and lethality of next-generation vehicle armament, propulsion, active protection, and counteractive protection systems.

Technical challenges for the U.S. Navy's weapons L/V community arise from the requirements to evaluate and support the development of both new antiair missile warhead concepts and underwater weapon warhead concepts. The antiair concepts include smaller but more lethal precision-aimed warheads and warheads that utilize reactive materials as damage mechanisms. Near-term technical challenges include development of (1) physically based engineering models that predict structural damage to air targets from multiple fragment impacts, (2) an understanding of target interactions and damage resulting from the use of reactive materials as damage agents, and (3) physically based damage prediction models. In the longer term, the technical challenge is to globally assess the physics of cumulative, combined, or synergistic damage effects of multiple warhead damage mechanisms on air targets so as to significantly increase the capability to estimate realistic warhead effects on a target. Near-term technical challenges to support underwater weapon concepts include development of (1) a model to assess the damage inflicted to a threat torpedo as a result of the shock-wave loading produced by a counterweapon warhead, and (2) a high-fidelity, physics- or mechanics-based simulation to predict the response of naval targets (ships, submarines, torpedoes, mines) to underwater explosion effects.

Major technical challenges facing the U.S. Air Force’s weapons L/V community include understanding the survivability characteristics of hypersonic penetrators into soil and concrete target materials; the penetration performance of munitions into various indigenous materials such as granite, limestone, and fractured rock; the efficacy of advanced warhead fills such as agent defeat weapon payloads and nonlethal functional kill mechanisms; and the lethality of emerging lower charge-to-case weight munitions and precise small weapons. Successfully overcoming these challenges depends primarily on the ability to generate and compile sufficient experimental data to verify mathematical hypotheses or the ability to validate the suitability of existing models and methodologies within characteristic regimes for which they were not originally developed.

(3) Related Federal and Private Sector Efforts. Nonnuclear survivability/vulnerability data, information, methodologies, codes, and analyses related to U.S. and foreign aeronautical and surface systems are distributed to other government organizations and industry through the Survivability Vulnerability Information Analysis Center sponsored by two Joint Logistics Commanders’ JTCGs, one on Aircraft Survivability (JTCG/AS) and the other on Munitions Effectiveness (JTCG/ME). In addition, many non-DoD and civilian agencies use and contribute to DoD results, including law enforcement agencies, counterterrorist activities, shock trauma units in hospitals, the American Association of Automobile Medicine, universities, and many other private sector industries. The weapons L/V community also actively participates in international exchanges through The Technical Cooperation Program, data exchange agreements, memorandums of understanding, and NATO. It is estimated that industry uses weapons L/V products in support of government analyses at a funding level of approximately $40 million per year.

Defense efforts to forge better links with the Ballistic Missile Defense Organization and DARPA have the potential to provide opportunities for these organizations to leverage current weapons L/V analytical capabilities and methodologies. Additionally, weapons L/V has the potential to benefit from unique aspects associated with nontraditional engagements.

c. *S&T Investment Strategy*

(1) Technology Demonstrations. Weapons L/V is inherently an enabling technology that supports the development of ATDs, ACTDs, DTOs, and service-specific technology objectives. Though weapons L/V products are less visible than hardware-oriented S&T programs, their databases, methodologies, and analysis codes contribute to the quality of design and development of most DoD weapon systems. These contributions are measurable by vulnerability reductions, lethality enhancements, concept tradeoffs, analyses of alternatives, and inputs to predictive combat models. Specific contributions vary by service and agency.

Verification and validation L/V models for predicting weapon effects against high-value fixed targets are being directly funded and accomplished by weapons L/V. The DTRA and Air Force are cooperatively working on DTO WE.57, Lethality/Vulnerability Models for High-Value Fixed Targets. DTRA's efforts in concrete and rock penetration data/models, component fragility models, and enhanced blast models also link to the JWSTP and DTOs for Counterproliferation, Prediction of Collateral Effects, Hard Target Defeat, and Structural Blast Mitigation.

For the U.S. Army, weapons L/V products are applied to over 20 service-specific DTOs/ATDs on principally a customer-funded basis. Examples of analyses of combat suitability and technical identification of future L/V requirements include programs such as the PGGM (DTO M.06), Integrated Hit/Kill Avoidance Optimization (DTO GV.13), Future Scout and Cavalry System (FSCS) (DTO GV.01), Future Combat System (FCS), Ballistic Protection for Individual Survivability (DTO HS.05), and Force XXI Land Warrior (DTO HS.10). In the case of the U.S. Navy, antiair and antisurface technical links include the Reactive Warhead ATD (DTO WE.54), Advanced Integrated Aimed Warhead, and Hypersonic Weapons Technology Demonstration (DTO M.13).

With the reduction of defense spending for procurement of major weapon platforms, the need for analyses using constructive models, simulation-based acquisition, and man-in-the-loop distributed interactive simulations requires additional technical information to effectively evaluate technologies and to justify new procurement programs. The basis for these decisions is, in part, analysis applications of weapons L/V products. Several DTAP panels, including Air Platforms, Ground and Sea Vehicles, Space Platforms, and Human Systems, require the use of these products to effectively evaluate their systems.

As an enabling technology, weapons L/V analyses are included in the evaluation of weapons lethality and system survivability at all levels. In this regard, weapons L/V technology is ubiquitous within DoD. Milestone I decisions incorporate the results of weapons L/V analyses to determine the expected lethality of munitions and the survivability of air, land, and sea vehicles.

(2) Technology Development. The weapons L/V technology development occurs in six specific areas to address ballistic physical interaction and resulting target damage at the component, subsystem, and weapon system levels by using the most effective underlying modeling techniques:

- *Primary Penetrator Phenomenology:* Generally the best predictor of target defeat, this area requires constant refinement to account for newer materials (e.g., composite armors, reactive armors), changing engagements (e.g., hypervelocity impacts, active protection systems), better construction methods and materials, and more accurate terrestrial and oceanographic modeling.

- *Fragment/Debris Phenomenology:* Fragments and debris are the primary kill mechanisms for most indirect-fire weapons against lightly armored systems and personnel, and highly effective secondary kill mechanisms for direct-fire weapons penetrating armored vehicles and fixed targets. Survivability is highly dependent on limiting the amount of additional damage resulting from fragments and debris.

- *Ballistic Blast and Shock Phenomenology:* These mechanisms are increasingly important kill mechanisms, especially for electronic equipment, structures, and composite materials. Additionally, individual soldier injury and incapacitation results from exposure to blast waves and from the rapid acceleration and deceleration of a soldier's body subjected to blast and shock.

- *Fire and Fume Phenomenology:* Fire and fumes are major contributors to aircraft loss. The accurate prediction of fires is becoming more significant in ground and sea vehicle analyses. Advanced high-temperature incendiary payloads hold promise for neutralizing and minimizing the spread of chemical and biologic agents after target attack. The incapacitation of personnel exposed to fumes from burning material and chemical agents is being incorporated into personnel vulnerability analysis codes.

- *Damaged Target Response:* This area focuses on the relationship of combat damage to quantifiable measures of the residual capabilities of a weapon system and its critical subsystems. Efforts encompass pre-engagement conditions and post-attack assessments.

- *Supporting Technologies:* The area includes exploitation of computer science innovations, analysis codes, visual graphics techniques, and advanced statistical methodologies to enhance the speed, fidelity, and confidence in weapons L/V analyses.

(3) Basic Research. The weapons L/V community maintains essential links with basic research principally to support precision equipment and full-dimensional protection operational concepts. The specific disciplines of interest to L/V analyses are physics, chemistry, mathematics, computer science, mechanics, electronics, ocean sciences, atmospheric and space sciences, material science, terrestrial science, and biological sciences. The Strategic Research Objective for attaining smart structures provides a significant challenge for modeling, predicting, controlling, and optimizing the dynamic response of complex, multielement, deformable structures used in land, sea, and aerospace vehicles and systems.

8. DEW Lasers

a. *Warfighter Needs*

DoD requires improved or new capabilities in strategic and tactical missile defense, cruise missile defense, satellite negation, high-resolution imagery, air defense, ship defense, ground combat and close support, and aircraft self-protection. All of these requirements can be addressed by laser weapon systems. Laser and optical system technology offers the potential for a paradigm shift in weapon systems for the 21st century:

- Long-range, speed-of-light delivery to target.
- Graduated engagements, from disrupt to destroy.
- Surgical—minimum collateral damage, low fratricide.
- Multiple, low-cost shots—large number of kills per platform.
- All-aspect engagements—unconstrained by kinematics or gravity.

- Synergism with high-resolution optical sensing—imaging, surveillance, standoff detection.

These advantages will provide dramatic improvements in current weapon capabilities and enable new missions that are not currently possible. Within the next 5 years, this includes transition of semiconductor laser technology to nonlethal weapons (illumination, designation) and medical laser applications. After the turn of the century, potential new weapon capabilities include the airborne laser (ABL) for boost-phase negation of theater and cruise missiles at long range; ground-based laser (GBL) negation of low Earth orbit (LEO) satellites; space-based laser (SBL) for theater/national missile defense, antisatellite (ASAT), surveillance, target designation, and active and passive target discrimination; moderate-power laser systems for robust infrared countermeasures (IRCMs); passive and active laser/optical systems for remote sensing/standoff detection; laser weapons for defeat of antiship missiles and unconventional low-value threats (e.g., power boats, UAVs); and laser weapons for platform/base self-protection and offensive capabilities in tactical engagements.

b. *Overview*

(1) Goals and Timeframes. Technology development and demonstration efforts are oriented to establish a mature and comprehensive technology base to support laser weapon systems development decisions. In many cases, this requires an integrated demonstration of laser and optical technology components and subsystems. Major goals and associated timeframes are listed in Table X–9.

(2) Major Technical Challenges. The major technical challenges being addressed in the area of laser devices are increasing laser device efficiency, reducing system size and weight to meet platform constraints, and scaling to high power while maintaining good beam quality. For some applications, the laser device must also operate at a specific wavelength or in a particular wavelength band. Another major challenge is to develop and integrate the high-energy laser system technologies to make them realistically operational. These complex weapon systems must demonstrate very high reliability with little if any day-to-day maintenance. They must also be capable of being operated by crews (not scientists) or even of operating completely unattended. This is particularly true of any space-based system.

Major technical challenges being addressed in beam control efforts include development and demonstration of adaptive optics hardware to compensate for distortions in the beam train and in propagation to the target, application of laser beacon concepts to sense distortions caused by atmospheric turbulence, rejection of high-bandwidth jitter induced by platform and atmospheric turbulence, compensation for tilt anisoplanatism, active tracking and illuminator/target effects, aimpoint designation and maintenance, and overall beam control system integration and performance evaluation.

In the area of laser effects, the major technical challenge addressed is determining the materials, configuration, functional characteristics, and vulnerability of potential targets. To assess the payoff of specific applications and to support system development decisions, a significant challenge is the development of modeling and simulation tools to determine weapon system performance and military effectiveness. Finally, an important challenge for the operational application of laser systems is to establish accurate safety thresholds for the protection of personnel.

Table X–9. DEW Lasers Subarea Goals and Timeframes

Application/Mission	Short Term (1–2 years)	Mid Term (3–5 years)	Long Term (6+ years)
ABL for boost-phase negation of theater missiles at long range (up to 600 km)	COIL device, atmospheric measurements, adaptive optics, and beam control technology to establish maturity that will support transition to ABL EMD.	Support IOC 2005 (2 aircraft), support FOC 2007.	Advanced COIL, adaptive optics, and beam control technology to provide 20–30% increase in ABL operational range.
GBL for negation of LEO satellites	Feasibility demos of adaptive optics for atmospheric compensation and active satellite tracking.	Integrated beam control demo/full-scale demo of weapons-class performance for all atmospheric compensation and beam control functions.	Advanced COIL, adaptive optics, and beam control technology to support design optimization and performance growth for GBL ASAT system development.
SBL for TMD, NMD, ASAT, surveillance, target designation, and active and passive target discrimination	Demo integrated beam director, beam control, and laser resonator. Ground demo acquisition and tracking technology.	Demo uncooled laser resonator optics. Fly acquisition and tracking experiment. Demo high-efficiency laser nozzles. Demo CW high-power phase conjugation.	SBL readiness demonstrator.
Laser system for IR countermeasures, based on damage/destroy (D^2) mechanisms	Field demo of D^2 against imaging threat.	Establish vulnerability of target set; demo laser device feasibility and scaling for selected wavelength.	Ground demo of integrated laser system performance against IR/RF-guided missile hardware in realistic scenarios.
Navy HEL weapon	Demo 1-kW FEL. Characterize near 1-µm laser material interaction at high power.	Head-on ASCM assured kill, littoral threat vulnerability, system concepts, and military utility	
Solid-state laser sources and integrated beam control	Demo modular solid-state laser building block.	Demo architecture for scaleable laser arrays; demo concept for electronic beam steering.	Demo coherent array scaling to moderate and high power; establish feasibility of conformal arrays and integrated laser source/beam control.

(3) Related Federal and Private Sector Efforts. DoD organizations have primary responsibility for development and application of high-power laser technology. However, there is some complementary activity within DOE and industry. Lawrence Livermore and Sandia National Laboratories have laser source development and some beam control programs, with emphasis on laser fusion (Livermore) and power beaming (Sandia) applications. The Thomas Jefferson National Accelerator Facility in Newport News, VA, is developing an industry consortium of potential users and a materials test facility to use the Navy-funded 1-kW IR free electron laser (FEL).

As a direct spinoff of DoD research, the civilian astronomy community has embraced low-power adaptive optics and laser beacon sensing technology to improve resolution of ground-based telescopes by compensating for distortions introduced by atmospheric turbulence.

Two DTOs from other sections of the DTAP support DEW laser development: (1) laser bioeffects efforts under DTO MD.08 provide information applicable to laser health and safety issues, and (2) development of large, precise structures under DTO SP.05 is relevant to the development of space-based optics for laser systems. There are also related DoD efforts that support the DEW S&T effort. The joint U.S./Israeli Tactical High-Energy Laser (THEL) ACTD, although not an S&T demonstration, will provide useful information to the S&T efforts. The HEL offers a cost-effective, speed-of-light, continuous-kill capability against multiple, low-signature, maneuvering tactical threats.

High-energy laser effectiveness tests have demonstrated significant capability against the evolving air threat using realistic targets and timelines. The High-Energy Laser System Test Facility (HELSTF) is funded through Army Test and Evaluation (6.5). It has been used by all services to conduct high-power S&T experiments and demonstrations in support of their individual programs. HELSTF operates and maintains DoD's only integrated, open-range HEL testbed.

c. *S&T Investment Strategy*

(1) Technology Demonstrations. Laser DEW technology development encompasses several demonstrations, intended to establish a level of technology maturity that supports transition to system development programs. Major demonstrations support five DTOs:

- Airborne Laser Technology for Theater Missile Defense (D.10)—demonstrate advanced tracking and atmospheric compensation concepts to support ABL design updates for EMD phase.
- Integrated Beam Control for Ground-Based Laser Antisatellite System (WE.10)—demonstrate, at full scale but very low power, all beam control functions associated with an end-to-end satellite engagement.
- Multimission Space-Based Laser (WE.41)—perform high-altitude balloon experiment to demonstrate acquisition, tracking, and pointing; and demonstrations of uncooled laser resonator, deformable mirror, high-efficiency laser nozzles, and continuous-wave phase conjugation.
- Laser Aircraft Self-Protect Missile Countermeasures (WE.42)—damage/destroy laser IRCM demonstration and FotoFighter phased-array laser demonstration.
- Advanced Multiband IRCM Laser Source Solution Technology (WE.43)—demonstrate high-brightness multiband semiconductor lasers.

(2) Technology Development. Technology development efforts complement the technology demonstration efforts described above to fully support laser weapon system development decisions and to lay the foundations for future demonstration efforts to address longer term military applications and capabilities. Major task areas include:

- Chemical oxygen-iodine laser (COIL) device technology, with emphasis on improved efficiency and lightweight designs to reduce system weight and improve operational suitability.

- FEL device technology, a laser concept that allows selection of precise wavelengths in the near to mid IR for optimum propagation, with emphasis on scaling to high average power while maintaining compactness and high wall-plug efficiency. In excess of 300-watts was demonstrated in FY98 as compared with the previous record of 11 watts.
- Advanced laser technology, considering new lasing concepts and target interaction phenomenology with the potential to further improve laser power per unit weight and overall military effectiveness.
- Nonlinear optics technology, with the potential to produce frequency-agile laser sources and, by phase conjugation, to automatically correct for phase distortions in an optical train or propagation path for both laser propagation and imaging applications.
- Passive and active high-resolution imaging technology, including concepts for image reconstruction, real-time processing, and aperture synthesis, both to support laser weapon functions (target verification, aimpoint designation and maintenance, damage assessment) and to provide situational awareness in terrestrial and Earth-orbit (out to geosynchronous altitudes) arenas.
- The application of laser source, beam control, and optical sensing technologies to remote sensing/standoff detection applications, addressing needs for target identification, kill assessment, and adjunct missions such as counterproliferation and the intelligence preparation of the battlefield.
- High-power optical components, to provide optical coatings, mirrors, windows, and other specialized optical components that can operate and endure in a high-power, laser beam train without inducing significant distortion or loss.
- Target vulnerability assessment efforts, to include target model development, analytical vulnerability assessments, experimental testing and assessment validation, and military effectiveness analysis.
- Technology and experiments, to understand and characterize the atmospheric propagation environment, including turbulence effects over extended propagation paths and organized structures in turbulent flow fields such as boundary layers.
- System effectiveness assessments for antiship missile defense, including target vulnerability, laser propagation in maritime weather, and military utility.
- Experiments and modeling, to establish accurate safety thresholds for personnel protection.

(3) Basic Research. Basic research efforts for high-power lasers emphasize the fundamental understanding of the limitations of laser technology and its applications and the investigation of promising new approaches and concepts. Efforts are conducted in advanced laser concepts, nonlinear optics, optical image sensing and reconstruction, optical tomography of turbulent flow fields, and advanced concepts for adaptive optics and laser beacon sensing.

9. High-Power Microwave

a. *Warfighter Needs*

DoD requires improved capabilities in countering artillery fire, ship defense against cruise missiles, aircraft self-protection, suppression of enemy integrated air defense systems, space control, security, counterproliferation, and disruption or destruction of C^2 assets. All of these requirements can be addressed by HPM weapon systems that upset or damage the electronics within the target. HPM weapons offer military commanders the option of:

- Speed-of-light, all-weather attack of enemy electronic systems.
- Area coverage of multiple targets with minimal prior information on threat characteristics.
- Surgical strike (damage, disrupt, degrade) at selected levels of combat.
- Minimum collateral damage in politically sensitive environments.
- Simplified pointing and tracking.
- Deep magazines and low operating costs.
- Attack of sophisticated targets using low-cost weapons.

Coordinated Army, Navy, Air Force, and DTRA HPM transition plans are focused on demonstrations of mission-oriented concepts: aircraft self-protection, antiship missile defense, and countermunitions (EW electronic attack—degrade/neutralize enemy defenses); and lethal suppression of enemy air defense (SEAD) and C^2 warfare/information warfare (Precision Force, MOUT, and IW). Potential warfighter payoffs include generic protection against a wide variety of missile/munition threats (IR, EO, RF, laser-guided), improved effectiveness and lower attrition rates of friendly systems, and negation (permanent damage, long-term disruption, and temporary degradation) of enemy command, control, and general information systems. Finally, electronic protection techniques developed under the HPM program are being transitioned to users in order to harden U.S. systems against hostile HPM weapons or inadvertent EM interference/compatibility (EMI/EMC). Joint development and test projects demonstrate the maximization of investments to meet individual service and agency mission requirements.

b. *Overview*

(1) Goals and Timeframes. Technology development and demonstration efforts are oriented to establish a mature and comprehensive technology base to support microwave weapon system development decisions. In many cases, this requires an integrated demonstration of microwave source, pulsed power, and antenna subsystems. Major goals and associated timeframes are shown in Table X–10.

Table X–10. High-Power Microwave Subarea Goals and Timeframes

Application/Mission	Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ Years)
HPM system for point defense	Demo compact, high-peak-power and high-average-power sources.	Enabling technology demo.	Ship self-defense demo, aircraft self-defense demo, air defense demo, countermunition demo.
HPM system for C^2W/IW	Effects assessments; ground demo.	Ground demo for airborne applications.	Airborne demo.
HPM system for SEAD	Demo compact high-power narrowband source.	Explosively driven single-pulse device field demo.	Multiple-pulse device field demo.
HPM protection	Effects assessments.	Systems hardening implementation.	Enhanced systems survivability.

(2) Major Technical Challenges. The major technical challenges for HPM weapons include developing and demonstrating:

- Compact, high-peak-power or high-average-power HPM sources.
- Compact, high-gain, ultra wideband (UWB) antennas.
- Compact, efficient, high-power, pulse power drivers.
- Compact, efficient, high-power intermediate storage devices.
- Compact, efficient, prime power sources.
- Predictive models for HPM effects and lethality.
- Low-impact hardening of systems against hostile and self-induced EMI.
- Affordable system integration meeting military platform requirements.

(3) Related Federal and Private Sector Efforts. DoD organizations have primary responsibility for the development and applications of HPM technology. However, both DOE and private sector efforts complement military HPM programs. Lawrence Livermore, Los Alamos, and Sandia National Laboratories have HPM source development and effects programs that directly support service efforts.

A DTO from another DTAP section and one from a JWSTP section relate to high-power microwave development: (1) development of balanced hardening techniques to protect systems from HPM and electromagnetic pulse are addressed in DTO NT.05, and (2) some of the technologies included in the DTO E.04 demonstrations were developed under enabling technologies in DEW.

The private sector has evolved both independent and cooperative RF effects programs. Cooperative research and development agreements (CRDAs) have been initiated to develop and transition improved techniques for measuring EMI. Other CRDAs have been initiated to develop and transition technology for HPM weapon applications. The electronics industry as a whole is working closely with the services to ensure compliance with new international standards for EM protection.

c. *S&T Investment Strategy*

In executing the DoD HPM program, focus is maintained on specific technology demonstrations in order that the technology effort at the component level can also be focused. DoD investments among the various technology demonstration and technology development efforts are allocated in accordance with their potential payoff to warfighting needs and their relative contribution to achieving HPM goals.

(1) Technology Demonstrations. HPM weapons encompass a number of technology demonstrations in the field. Major demonstrations support three DTOs:

- High-Power Microwave Information Warfare ACTD (H.11)—demonstrate HPM technology to disrupt, degrade, or destroy electronics in specific information operations scenarios.
- High-Power Microwave C^2W/IW Technology (WE.22)—demonstrate high-power, air-delivered HPM source.
- Explosively Driven, High-Power Microwave Suppression of Enemy Air Defenses (WE.60)—demonstrate full-scale, explosively driven HPM weapon system.

(2) Technology Development. Coordinated Army, Navy, Air Force, and DTRA HPM technology developments are subdivided into a number of major constituent areas:

- *Compact, high-power UWB sources*: Includes fourfold increase in UWB output power. Technical barriers include voltage standoff of solid-state switches and fabrication of these switches. Weight should be ~500 pounds and volume ~1.5 ft^3 (exclusive of antenna and pulse power).
- *Compact, high-power, narrowband HPM sources:* Includes sixfold increase in narrowband pulse length and narrowband tunability up to an octave. Technical barriers include cathode breakdown and production of plasma within the device as well as efficient extraction of microwave energy. Weight should be ~500 pounds and volume ~1.5 ft^3 (exclusive of antenna and pulse power).
- *Compact, high-power, high-gain UWB antennas:* Focuses on lightweight antennas able to radiate high peak and average power with very low losses. Requires reduction to 18-inch antenna diameter with approximately 15–20 dB of antenna gain.
- *Compact, efficient, high-power pulsed power drivers:* Develops compact (~500 pounds in less than 10 ft^3), high peak power (>50 GW) packages.
- *Explosively driven pulsed power sources*: Focuses on explosively driven magnetic flux compressors for current and power amplification. Technical barriers include reducing power losses between the exploding armature and helical stator, coupling and timing requirements of multiple-staged generators, and weight and size reduction of fast opening and closing switches.
- *HPM effects and lethality*: Includes RF testing of a wide range of air, sea, land, and space military assets; RF effects database development; reliable prediction of RF effects to permit extrapolation to other systems; development of innovative countermeasure techniques; and incorporation of HPM into accepted military weapon engagement models.
- *HPM bioeffects*: Assesses biological effects necessary to establish safety thresholds for personnel protection.

- *Systems integration meeting military platform requirements*: Encompasses integrating pulsed power drivers, HPM sources, and output antennas into military platforms such as fixed- and rotary-wing aircraft, naval combatants, land vehicles, aircraft pods, UAVs, and munitions.
- *Low-impact hardening of systems against hostile and self-induced EMI:* Includes transitioning EM hardening to users in response to existing EMI/EMC problems and projected threats; identifying susceptibilities in U.S. air, land, sea, and space militarily critical systems; and developing hardening countermeasures that minimally impact system performance, cost, or maintainability.
- *Evaluation of additional applications*: Based on effects assessments and technology development efforts, identifies additional militarily useful applications. Applications under consideration include antiship missile defense, counterproliferation, counter-munition, and aircraft self-protect. These evaluations will lead, where appropriate, to additional technology demonstrations.

(3) Basic Research. Basic research efforts for HPMs emphasize the fundamental understanding of the limitations of microwave technology and its applications and the investigation of promising new approaches and concepts. Efforts are conducted in RF sources, antennas, and pulsed power systems and in RF effects phenomenology. Particularly relevant are efforts included in two Air Force-sponsored multiuniversity research initiatives (MURI) on HPM source technology and on explosively driven power generation for directed-energy munitions.

10. EW Threat Warning

a. *Warfighting Needs*

The warfighter needs to know, unambiguously and in real time, the total threat situation (“picture”) that endangers successful completion of the operational mission—whether the warfighter is at the battlespace command level, the battlegroup level, in the single-seat cockpit, or on the front line. For optimal response in a threat environment—whether the response is one of threat avoidance, ECM, lethal counterattack, evasive maneuver, or in combination—the warfighter needs to positively know the threats that are present and their parameters, locations, and intentions in time to invoke that response.

The S&T in the EW threat warning subarea will provide the next generation of advanced receivers, processors, antennas/apertures, and software algorithms to directly address future warfighter requirements. One of the key future requirements will be to integrate and correlate (i.e., sensor fusion) a wide variety of multispectral sensors (e.g., RF, IR, EO, UV, acoustic) to obtain a much improved all-weather, all-geometry threat situation awareness. Achievement of this integration and correlation will permit the warfighter to visualize a common, seamless, and unambiguous picture of the land, sea, and aerospace dimensions. On a component level, circuit miniaturization and digital trends will yield affordable receivers, which have improved operational performance and are lighter, smaller, more reliable, and more prime power efficient. Planned improvements in receiver/processor performance, COTS and open-adaptive, real-time symmetric multiprocessing (RTSMP) architectures will provide faster threat detection and recognition and an increased ability to decipher multiple, simultaneous, coherent, complex-modulation signals. Digital receivers incorporating these processor advantages will allow rapid reconfiguration of the receiver at the unit level through software updates in lieu of expensive and time-consuming hardware changes. Advanced location algorithm developments, coupled with antenna/apertures more accurate in angular threat determination, and advances in sensor technology and information fusion techniques will provide unambiguous resolution of the threat environment (situation awareness), thereby allowing the warfighter to optimize his/her response. Threat warning technology has multiple opportunities to make tri-service transitions into combat systems with RF or EO/IR receivers.

b. *Overview*

(1) Goals and Timeframes. The primary focus of this subarea is to provide the warfighter the ability to detect, geo-locate, identify, track, and classify potential threat and friendly systems at long range with high accuracy. This new technology includes receivers, antennas/apertures, processors, sensor-fused algorithms, and signal analysis algorithms, which will provide adequate time to respond with appropriate countermeasures. Major goals and associated timeframes are listed in Table X–11.

Table X-11. Threat Warning Subarea Goals and Timeframes

Application/Mission	Short Term (1–2 years)	Mid Term (3–5 years)	Long Term (6+ years)
Improved threat emitter location and combat identification	Develop and demo integrated hardware with multiple software algorithms to perform real-time threat ID and location. Develop and flight demo single RF aperture with 2-deg DF, 2π coverage, real-time threat ID, and geo-location.	Develop and demo integration of precise location/ID with offensive targeting cues to yield rapid subdegree threat geolocation.	
	Demo single EO aperture, hemispherical 2-deg DF flight.	Develop EO sensor and fiber optic technology to detect, identify, and localize laser-based threats.	Develop and demo fully integrated multispectral 2-deg DF ES system.
	Develop and demo 1.75X UV detection range with uncooled IR FPA.	Develop uncooled IR FPA missile warning sensors. Demo IR distributed aperture warning system.	Demo uncooled IR FPA for rotary-wing and ground vehicle missile warning.
Increased receiver processor throughput and fusion of offboard data		Develop techniques for fusion with RF sensors to improve capability to detect and classify threats. Develop and demo full RTIC, automatic response reasoning, and RTOC capabilities.	
Common digital receiver architecture and significant size reduction	Develop and demo an EW receiver fabricated entirely from MMIC for aircraft, ships, and other platforms.	Develop and demo a wide-band, digital receiver for EW applications to be used onboard aircraft and ships.	Develop and demo DSP and fiber optic integration with RTSMP directly behind intercept apertures.
Worldwide merchant ship tracking	SEI equipment on board at least one platform in all major theaters.	Develop and demo combat ID using SEI technology.	Develop weapons-embedded SEI.

(2) Major Technical Challenges. Development of a high-accuracy subdegree direction finding (DF) capability requires interferometric techniques, close tolerance amplitude/pulse tracking RF receiver components, and low signal threshold detection. Development of functional elements, using monolithic microwave integrated circuits (MMIC) packaged into 1/30 of the current volume, is the major technical challenge for an all-MMIC EW receiver. The complex task of assembling a digital RF receiver involves the development and integration of high-speed, high-resolution digitizers and high-throughput digital processing for spectral analysis and dynamic range extension. Achieving real-time threat identification and location includes pulse-level specific emitter identification (SEI) extraction, processing, and automation. Developing a highly stable RF receiver for detection and tracking of hostile emissions requires expanded processing bandwidth and dynamic range for environment characterization. In the area of EO/IR, the major technical issues are to increase the detection range of existing sensors by 100%, improve their angle-of-arrival determination to better than 1 degree, enhance probability of detection to over 95%, and reduce false alarms to less than one per hour. The EO technology challenges include increasing sensor sensitivity and dynamic range, providing angle-of-arrival information for CM cueing, and increasing the detection bandwidth to encompass the aforementioned laser threats. Threat identification, off-axis detection, and ATR with jam-resistant software require component and processing improvements. Finally, translation of these technologies to the space platform environment invites severe challenges in terms of extremely small, lightweight, and reliable hardware necessary to survive the harsh space environment.

(3) Related Federal and Private Sector Efforts. Digital receiver and processor technologies have both private and federal applications. However, the EW sector demands are higher, with requirements for wider bandwidth, faster tuning, more instantaneous dynamic range, and high probability of signal detection. In the processor area, the two application requirements overlap, and COTS technologies are frequently adapted for DoD use. EW-related investments here focus on military needs not met by the commercial sector vis-à-vis computer architectures and digital signal processing (DSP).

c. *S&T Investment Strategy*

In executing the threat warning subarea, focus is maintained on specific technology demonstrations that synergistically integrate advanced antennas/apertures, processors, receivers, and software algorithm technologies. National investments among the various technology development and demonstration efforts are allocated in accordance with their potential payoff to warfighting needs, affordability, and relative contribution to achieve threat warning goals.

(1) Technology Demonstrations. There are three DTOs in the EW threat warning area:

- Missile Warning Sensor (MWS) Technology DTO (WE.48)—demonstrate advanced multispectral sensor and algorithm technology for long-range detection of IR-guided missile threats and situation awareness capability for air, sea, and ground platforms.
- Two JWSTP EW DTOs, Enhanced Situation Awareness Demonstrations (H.07) and Precision EW Situation Awareness, Targeting, and SEAD Demonstrations (H.10), contribute to threat warning. These JWSTP DTOs concentrate on the areas of precise identification, geo-location of threat emitters in real time, and fusion of onboard sensor information with offboard theater asset information to provide unambiguous

situation awareness and integrated multispectral electronic support (ES) warning with optimal multispectral response.

Key to the JWCOs of Information Superiority and Combat Identification will be the efforts demonstrating real-time information in the cockpit (RTIC) and, in the reverse path, real-time information out of the cockpit (RTOC). By typing multispectral EW sensors into the digital battlefield/battlespace, all air and surface platforms and joint command operation centers will have situational awareness for subsequent targeting, battle damage assessment, and mission planning while avoiding fratricide.

(2) Technology Development. The service efforts in the threat warning subarea are divided into three classes and support the technology demonstrations identified above:

- *RF technology:* Develop advanced receiver, low-signal detection, and rapid parametric conversion capabilities using MMIC, fiber optic and optoelectronic, and digital technologies leading to highly stable receivers, integrated antennas/apertures, digitizers, processors, and software. For affordability, COTS processors and open and scaleable architectures are emphasized.
- *IR/UV technology:* Develop IR/RF warning sensor fusion; multicolor IR-band energy detection schemes; distributed high-angular-resolution and gimbal-less shared apertures; active, laser-based detection techniques; missile signature model validation; and algorithms to detect low-level signatures in a low-noise, high-clutter background over long ranges**.**
- *EO technology:* Develop low-cost laser warning technologies including high-temperature, broadband, high-dynamic-range sensors; angle-of-arrival resolution; spectral and coherent discrimination; repetition rate and pulsewidth determination; threat identification; low false alarm rate; and crew and CM system cueing for high-performance aircraft versus laser designator, rangefinder, and beamrider threats. In order to achieve the overall goal of a comprehensive, real-time affordable threat warning capability, a wide variety of the above multispectral sensors (e.g., RF, IR, EO, UV, acoustic) will be integrated and correlated.

(3) Basic Research. Basic research initiatives that contribute to the threat warning subarea include physics supporting detector technologies, sensor research, and sensor improvements; advanced semiconductor and optoelectronic materials; high-temperature superconductor materials; chemistry for improved detector and sensor technology and submicron processes (for faster, efficient, affordable DSP devices and for uncooled EO/IR focal plane arrays (FPAs)); advanced machine reasoning (e.g., artificial intelligence); and advanced electro-magnetics and antenna principles for broadband, low-signature, coherent curved, planar, and distributed apertures.

11. EW Self-Protection

a. *Warfighter Needs*

The warfighter has a mission to accomplish, yet is faced with a threat environment dominated by more complex, integrated, and robust weapon systems worldwide. Survivability of the warfighter and integrity of his/her platform—whether an aerospace, ground, or ship platform—is paramount. The self-protection subarea will produce advanced, automated active jammer technologies and electronic attack (EA)/ECM techniques across the RF, EO, and IR spectrums. Critically linked to the employment of the appropriate counter is the previous subarea of threat warning because it provides accurate warning and situation awareness in time to execute the optimum self-protection response. Development of automated, effective, affordable, and reliable self-protection systems will free crews to concentrate on executing their assigned mission, putting the weapon on target, etc. Self-protection technology has opportunities to make a transition at all levels of weapon system development. Specifically, these systems include advanced multispectral expendables, decoys, and IR and RF jamming systems; and incremental upgrades to existing systems with compact, reliable, space and weight saving technologies. Technology insertion will play a pivotal role toward enhancing existing systems so that they will remain effective into the 21st century.

b. *Overview*

(1) Goals and Timeframes. The self-protection technology subarea addresses (1) the ability to counter microwave and millimeter wave RF threat radars via the development of advanced coherent jamming and deception technologies, and the development of decoys for self-protection and angular deception of sensors; (2) laser technology to detect, perform scan analysis, and jam EO and IR threat systems; (3) improved flares for the IR, UV, and RF bands that will be capable of defeating multimode or monomode threats; and (4) advanced miniature component modules and new efficient architectures that result in reduced size, cost, and weight of active CM systems. Major goals and associated timeframes are listed in Table X–12.

(2) Major Technical Challenges. In the basic threat engagement, to the first order, the decision to employ self-protection is linked to the threat warning function—the challenge being the optimal, precise selection and timing of the CM (e.g., premature EM radiation from the platform only serves to highlight its presence or location to the threat; poorly timed flare ejections will be rejected by the ECCM features of the IR missile). This challenge becomes even more critical for LO platforms and for Special Operations Forces (SOF) missions. The LO challenge is in the development of self-protection hardware, materials, and electronic techniques and the digital modeling thereof that will be compatible with this class of platform. In the decoy arena, RF challenges include developing increasingly more sophisticated electronics to fit within existing dispensers at an affordable cost; enhancements to chaff technology to extend the frequency coverage; and protecting slow-moving, large cross section ships from the antiship cruise missile (ASCM). In the IR, the challenges include decoy techniques for the forecasted class of imaging seekers, development of composite flare materials that emulate the signatures of the warfighter's platform, maintaining the position of the flare or decoy in missile seeker's field of view, and achieving covert effectiveness where dictated by the mission. In the RF jamming area, multiple challenges include jammer design with high transmitter–receiver isolation; coherent, polarization-agile, high-fidelity jamming waveforms; reactive/retro directive capability; coordinated, time-synchronized, multiple platform response; and a modular design scaleable to all platforms. In the IR/EO regime, major challenges involve the radiation of multiple laser wavelengths necessary to jam a variety of threat missiles simultaneously; demonstrating small, low-cost laser pointing and tracking devices to deliver adequate multiband laser energy in the high maneuver

Table X–12. Self-Protection Subarea Goals and Timeframes

Application/Mission	Short Term (1–2 years)	Mid Term (3–5 years)	Long Term (6+ years)
Microwave through MMW jamming capability for shipborne, airborne, and ground platforms Develop ECM techniques to defeat advanced polarization-agile, coherent RF threats Defeat advanced coherent noncooperative target recognition RF threats (e.g., imaging)	Develop and demo MMW power module. Develop fiber-optic-coupled/-controlled towed decoy. Develop and demo broadband, polarization-agile transmit–receive architecture with 3–5 deg beam control. Develop and demo integrated MPM phased-array architectures.	Demo MMW fiber optic link and phase shifter. Develop MMW towed decoy. Develop low-cost DRFM technology, to include wide bandwidth and complex waveform synthesis. Develop multiple tap delay line technology.	Develop and demo integrated, multispectral, self-protection system. Demo multitactical platform/ALQ-compatible integration in a wideband configuration.
Defeat advanced IR imaging seekers using expendable CM and jamming	Investigate and lab demo baseline CM techniques.	Exploit foreign FPAs. Conduct live-fire, cable-car test of fiber-optic-coupled, multiline lasers and expendables.	Develop and demo compact, integrated, laser-based, closed-loop IRCM capability.
Laser-based IRCM capability	Demo large aircraft IRCM capability.	Demo large aircraft IRCM in captive-carry environment. Develop packageable and compact multiline IR source laser.	Expand laser bands to long-wave IR and visible camera (40% increase in jamming band).
Defeat advanced non-imaging IR missile seekers employing sophisticated CCMs using expendables	Field test expendable concepts for aircraft and ship protection.	Transition demonstrated technology to imaging seeker CM thrust and the warfighter.	
Defeat advanced ASM seekers using onboard advanced transmitters and offboard decoys	Initial demo of Eager preferential decoy.	Demo advanced ECM transmitter technology.	Incorporate advanced transmitter and decoys into AIEWS design.

dynamics of combat aircraft; designing and demonstrating an EO/CM-fieldable prototype for ship self-defense; tracking incoming threats via reflected laser energy or missile plume emissions; and steering IR/EO laser beams without the need for a complex, costly, stabilized gimbal platform. Again, eventual migration of countermeasures capabilities to space platforms incur the same, severe challenges identified previously in the threat warning subarea.

(3) Related Federal and Private Sector Efforts. DoD has the sole responsibility for self-protection S&T within the federal government—with very few applications to the private sector. This subarea is supported by the IR&D investments of numerous defense industry contractors.

c. *S&T Investment Strategy*

In executing the self-protection subarea, focus is maintained on specific technology demonstrations that synergistically integrate advanced antenna/aperture, transmitter/source, and coherent/digital exciter techniques with their companion threat warning functions in order that mutually parallel technology development progress can be achieved. National investments between the technology and demonstration efforts are allocated in accordance with their potential payoff to warfighting needs and affordability and their relative contribution to achieving self-protection goals.

(1) Technology Demonstrations. There are eight DTOs in the EW Self-Protection area, four DTAP and four JWSTP:

- Infrared Decoy Technology (WE.40)—develop the offboard decoy technology needed to protect aircraft and ships from nonimaging IR missile threats with advanced counter-countermeasures (CCMs). Major technology demonstrations for aircraft will occur in FY99 and for ships in FY00.
- Coherent RF Countermeasures Technology (WE.46)—develop a power-efficient, coherent RF countermeasures (RFCMs) capability to protect friendly airborne and surface platforms from high-power threat weapon systems that use advanced radar processing techniques.
- Imaging Infrared Seeker Countermeasures Technology (WE.47)—develop IRCM technology to defeat the next-generation staring and scanning FPA imaging infrared (I^2R) seekers. The overall goal is to improve effectiveness of countermeasures by 40–50 times the present-day warfighter capabilities for air, land, and sea platform self-protection from "imagers."
- Network-Centric EW Technology (WE.64)—develop 21st century (2010) advanced concepts and systems and risk reduce enabling technologies to provide a coordinated, integrated, multiplatform (e.g., network-centric) EW capability to electronically deny enemy command and communications by preventing surveillance, acquisition, and targeting of friendly forces.
- Multispectral Countermeasures ATD (H.02)—develop and test advancements in laser technology, energy transmission, and jamming techniques for an all-laser solution to IRCMs as a preplanned product improvement (P^3I) to the Advanced Threat IRCM/ Common Missile Warning System (ATIRCM/CMWS) program. The major goal is to eliminate noncoherent sources via a tunable, multiple-line laser with a fiber-optic transmission line. This ATD will be completed in FY99.
- Large-Aircraft IRCM ATD (H.05)—design, develop, and demonstrate an advanced laser-based IRCM technology to allow for self-protection of high-IR-signature, large Air Force aircraft (e.g., C–17, C–5, C–130, C–141).
- Onboard Electronic Countermeasures Upgrade ATD (H.08)—maximize the defeat of the threat in the acquisition and track phases of target tracking radar engagement prior to missile launch. This ATD focuses on the first of a two-tiered goal to increase survivability of friendly aircraft against the RF-guided missile threat: (1) prevent hostile forces from obtaining a valid RF-guided missile firing solution through achievement of track denial or angle breaklock, and (2) counter those missiles that are launched through end-game countermeasures means.
- Modular Directed IRCM (H.12)—design, develop, and demonstrate an advanced laser-based IRCM and missile warning sensors to allow for self-protection of both high-IR-signature (e.g., F–18, E/F, AV–8B) and rotary-wing tactical aircraft against surface-/air-to-air missiles, and ground vehicles against antitank guided missiles.

In the near term, as recommended by the Technology Area Review and Assessment (TARA) of EW, the highest EW S&T priority is IRCM. In the aggregate, this posture is reflected by the concerted efforts in no less than five formal EW DTAP (WE.40, WE.47) and JWSTP (H.02, H.05, and H.12) DTOs. The DTAP DTOs cover a variety of critical system aspects and support the IRCM system demonstrations presented by the JWSTP DTOs. Major technology demonstrations for aircraft will occur in FY99 and for ships in FY00.

(2) Technology Development. The service and agency efforts in the self-protection subarea are divided into three classes:

- *RF technology*: Reduce the risk of enabling RF technologies required to develop and demonstrate reactive, polarization-agile, coherent ECCMs against advanced radars using noncooperative target recognition (NCTR) algorithms (e.g., pulse Doppler, pulse compression, synthetic aperture radars, inverse synthetic aperture radars, low probability of intercept, ultra wideband). This enabling technology consists of microwave power module (MPM) transmitters, digital RF memories, multiple tapped delay lines, phased-array polarization-agile antennas, and methods for antenna isolation. Additional system and subsystem technologies are being developed for MMW EA, LO, antiradiation missile, cruise missile, RF decoys, and expendable vehicle technology to provide platform-like decoys (for aircraft as well as slow-moving ships and ground platforms).
- *IR technology:* Develop IR decoy technologies, including IR materials, decoy configuration and deployment concepts, and decoy ejection sequencing algorithms to address the capability of IR seekers to discriminate aircraft and ships from decoys. Develop IRCM to provide capabilities to detect, analyze, jam, and exploit imaging and advanced IR seekers.
- *EO technology:* Develop laser devices with improved frequency agility, efficiency, reliability, and strength, while also reducing size, cost, and weight of active cruise missile systems.

(3) Basic Research. The research in the self-protection subarea is similar to the threat warning subarea (Section 3.10.3.3). Additional research includes physics and chemistry for basic IR source materials used in IR decoys; band-gap-engineered materials that lead to cascade lasers for highly efficient, room-temperature, mid-IR laser sources for jamming; neural net processing supporting development of efficient and effective algorithms for missile detection; fiber optics development for beam transport required for distributed aperture warning receivers; and nanostructure research in optical filters supporting development of spectral filters for missile warning sensors. In addition, research is being supported for the development of application-specific integrated circuit technology for digital delay lines and analog-to-digital/digital-to-analog basic research for digital RF modulators (DRFMs) and EW receivers.

12. EW Mission Support

a. *Warfighter Needs*

As proven by Operation Desert Storm, an effective standoff EA campaign against both enemy radar sensors and communications infrastructure damages the enemy's ability to determine the location and intent of our joint forces and its ability to control offensive or defensive forces. The S&T in mission support will significantly enhance warfighter operations by proactively separating the enemy command element from its forces: by disrupting information handling systems, C^3networks, navigation and positioning systems, long-range integrated air defense systems, and other electronic aids that provide battlefield/situation assessment to enemy forces. This degradation of the enemy's C^3/integrated air defense system (IADS) structure must be effectively accomplished without hindering those same elements of our own. Opportunities for transitioning the C^2W and counter-IADS mission support technology efforts exist in current EA systems. Future systems designed for exploitation, countersurveillance communications, and radar tracking will afford a fertile environment for testing and application of this technology. Also included in this subarea is the pursuit of advanced distributed simulation technologies, which will reduce the time and cost required to develop the entire scope of EW system capabilities discussed in Sections 3.10–3.12, resulting in a faster transition to the warfighter's operational "arsenal" at an affordable acquisition cost. Simulation and modeling will also result in more EW advanced systems with increased capability, as proposed modifications and performance enhancements can be tested by the S&T and user communities for effectiveness prior to development and production.

b. *Overview*

(1) Goals and Timeframes. Modern battlefield commanders require information as never before, not merely information on enemy numbers, location, movement, readiness, weapon capabilities, control structures, or awareness of friendly actions, but also on similar information on his/her own forces and those of allies. To provide this information to friendly forces and denying the same to the threat commander, EW systems technology thrusts in the mission support technology subarea address three elements: RF mission support, electronic protection (EP), and EW employment. EW technologies provided will increase the capabilities of EW systems to:

- Intercept and selectively deceive or totally disrupt enemy C^2, surveillance, and weapon systems while maintaining uninterrupted friendly communication links.
- Employ automated data fusion processes to ensure timely intelligence and rapid, tactical decisionmaking to operate inside of the enemy's decision cycle.
- Invoke modeling and simulation to investigate new and untried system architectures.
- Increase the readiness of our forces through training on simulators using actual EW systems.
- Exploit available threat systems to increase survivability through better knowledge of doctrine and tactics, better knowledge of weapon system capability, and increased CM effectiveness to "paint a different picture" of the battlespace to the threat commander.

Major goals and associated timeframes are shown in Table X–13.

Table X–13. Mission Support Subarea Goals and Timeframes

Application/Mission	Short Term (1–2 Years)	Mid Term (3–5 Years)	Long Term (6+ years)
Exploitation and jamming of mobile and digital C^3 systems	Demo 10X increase in number of HF signals that can be simultaneously countered through optimized techniques and increased wideband power generation.	Demo techniques of countering current digital communications to introduce significant delay in the threat commanders' decision cycle Demo 1,000X increase in effective use of transmitter power.	Demo techniques for countering future reconfigurable, multimedia, computer-intensive mobile networks. Demo 1,000X improvements in EA spatial selectivity for jamming strategies.
Robust, all-aspect ASCM simulation capability	Add a cloud-cover model to the IR predictive code for the cruise missiles EW simulation.	Provide an RF/IR digital model representative of the multispectral environment.	
Extension of target collection range, attack, and mobility of IEWCS	Demo 40% collection range exercise through UAV test.	Demo a 90% increase in precision location capability for targets outside range of IEWCS and selective jamming attacks in UAV flight test; integrate and demo with airborne IEWCS platforms.	Demo target collection and location at over 75% extended ranges on planned mobile digital communications using UAV tethered to IEWCS.
Develop capability to surgically counter C^2W systems with minimal fratricide	Test communication/navigation CM capabilities against ground and airborne platforms.	Demo airborne CM against future navigation systems.	Demo precision attack techniques as CM against global high-capacity communication/navigation systems.
Airborne multiple sensor fusion	Complete the multi-integrated sensor correlation with moving target indicator.	Demo advanced airborne planning algorithms and effectiveness tools for multisensor tasking and reporting using database-to-database transfers.	Integrate SIGINT/MTI sensor cross-cueing and situation displays into IEWCS and ASAS.
Next-generation reactive coherent RF support jamming technology	Demo integrated MPM phased-array. Demo first-generation miniature UAV support jamming payload. Demo polarization-agile transmit–receive architecture. Demo first-generation miniature UAV support jamming payload.	Develop network-centric EW architecture models.	Demo tactical platform (include UAVs and pods) integration into a wideband configuration. Demo network-centric EW support jamming architecture
C^2W visualization/ simulation technology	Live intel data coupled with visualization/simulation technology. Perform predictive analysis on effects of EA on C^2 networks.	Couple visualization/ simulation technology with test assets.	Advanced display technology to on-the-fly display 3D view of EOB.
Force-on-force simulation technology	Increase fidelity of sensor model emulations.	Develop tri-service interoperability.	Embed into operational systems.
Demonstrate and develop ECCM techniques to reduce and mitigate the effects of coherent ECM	Develop and demo neural network processor to counter ECM signals.	Conduct flight test in aircraft, JSTARS.	Integrate processor to counter false SAR signals into tactical fighter such as the F–22, F/A18–E/F, and JSF.

(2) Major Technical Challenges. The principal challenge of the C^2W role is the global spread of extremely affordable, portable, modern telecommunications technology. Extremely complex modulation formats, multiplexing schemes, and spread-spectrum coding pose severe hurdles to the ES system in its real-time abilities to identify, detect, and intercept. Given that challenge, the EA portion of the system must accomplish "surgical" attacks on enemy C^2 and navigation aids with minimal collateral and fratricidal damage due to the commonality of frequencies and systems used by both forces and nonaligned third parties. In the HF communications region, resurging interest in this "comms" method imposes severe hardware challenges on ECM and ESM subsystems (by virtue of the multimeter wavelengths involved) and affordable integration thereof on a broad class of existing operational warfighter platforms (small, mobile ground vehicles; airborne; and shipborne)—e.g., efficient broadband amplifiers and antennas, over-the-horizon detection schemes. The third C^2W challenge is the capability to correlate and combine the data from all force sensors (active and passive) to provide a complete tactical picture. For RF mission support, the challenges are threefold: creating a network-centric EW architecture for an affordable, next-generation support/standoff jamming capability; demonstrating low-cost, effective electronic enhancements to the SEAD mission; and providing capabilities to direct and protect the flow and handling of friendly information systems.

(3) Related Federal and Private Sector Efforts. Although EW is primarily used by DoD organizations, there are commercial activities pursuing directly related technologies. DoD EW technology efforts are complemented by industry initiatives, particularly in the area of advanced communications. EA techniques against modern threat C^3 systems are also being applied in an EP fashion to efforts protecting our own military and commercial communications and computer networks through the development of common tool sets for information protection. DoD, law enforcement, customs, and other federal organizations have been partners with the commercial sector and academia in the development of technology for countering criminal and terrorist activities. Industry is involved in data fusion applications running the gamut from strategic intelligence production and tactical situation awareness development to automated production, preventive maintenance, and autonomous robot applications. Spinoffs from DoD work in data fusion include factory automation, advanced safety systems, multisensor diagnostic systems, and earth resource management. Also, DoD visualization and simulation technology is able to leverage off of dramatic advances from the computer graphics industry.

c. *S&T Investment Strategy*

In executing the mission support subarea, focus is maintained on specific technology demonstrations, which synergistically integrate advanced antenna/aperture, processor, receiver, and transmitter technologies, yet also foster technology developments in these same areas that are focused on the component/functional level. National investments among various technology demonstration and technology developments efforts are allocated in accordance with their potential payoff to warfighting needs, affordability, and relative contribution to achieving mission support goals.

(1) Technology Demonstrations. There are three DTOs in the EW mission support area:

- Modern Network Command and Control Warfare Technology (WE.23)—develop and demonstrate multiple, synergistic capabilities to intercept and attack or counter advanced, global, military communication, navigation, and information networks from ground, seaborne, and airborne platforms.

- Miniature Air-Launched Decoy Program ACTD (H.04)—assist lethal SEAD.
- Precision EW Situation Awareness, Targeting and SEAD Demonstrations (H.10)—develop and demonstrate those technologies needed for the uniquely different flight characteristics and missions of rotary-wing, tactical, and special operations air platforms plus ground vehicles.

(2) Technology Development. The service efforts in the mission support subarea are divided into three classes.

EW mission support technology will develop the technology to attack the enemy C^2, IADS, and information distribution networks. Detection, degradation, deception, and destruction are all part of the total requirement. A development goal is to provide the capability to surgically counter both communication and navigation systems by disrupting C^3 networks without negatively impacting friendly use during war, and most particularly operations other than war (OOTH), to avoid disruption of communication facilities of other nations and international humanitarian organizations. An additional goal is to develop the enabling technologies required to field the next-generation integrated RF support jammer concept to electronically counter search, surveillance, targeting, and other advanced radars. This enabling technology includes multibeam, polarization-agile, real-time, phased-array antennas/apertures; microwave and MMW power module transmitters; reactive coherent techniques generator using DRFMs and programmable tapped delay lines; integrated threat warning; multiplatform coordination; improved antenna isolation; and improved surgical jamming to prevent fratricide.

EP (ECCM) technology will provide protection against threat EA enhancements. This portion of the EW S&T program develops necessary technology to perform Red Team vulnerability assessments to ensure that U.S. weapons, C^3, and C^3I systems have adequate and cost-effective hardening. This technology is at a basic S&T level, which is quickly transferred/transitioned to system developers for rapid insertion of protection techniques/upgrades to operational systems. Radar mission effectiveness will be demonstrated for advanced fire control radars, such as in the F–22, F/A–18E/F, and JSF based on EP technologies. Radar mission effectiveness will also be demonstrated for ground-based fire control radars.

EW simulation will support detailed engineering analyses of both specific EW equipment and technologies and computer-intensive higher order simulations. This is necessary to analyze all levels from one-on-one to force-on-force scenarios. Simulation visualization technologies are also needed to allow immediate man-in-the-loop evaluation and interaction with EW scenarios. Developed technologies will provide joint service interoperability between constructive, virtual, and live assets, which will result in a more realistic environment to perform operational analysis and training.

(3) Basic Research. Basic research efforts are underway that support the EW mission support subarea. Signal processing research in modulation characterization, fast adaptive super-resolution beamforming, noise reduction, adaptive DF algorithms, and antenna size reduction using high-temperature superconducting components directly apply to ES and EA against modern communication, RF emitter, and information systems. Basic research efforts in data fusion emphasize the theoretical underpinnings of information combination and investigate promising new approaches and concepts in providing timely tactical battlefield intelligence fusion and situation assessment needed for effective EA. Investigations are being conducted in the development and evaluation of new paradigms for machine-based reasoning, advanced database management system design, optimal constraint-based resource management, and new-evidence combination methodologies.