CHAPTER VII

JOINT THEATER MISSILE DEFENSE

A. DESCRIPTION

Joint Theater Missile Defense (JTMD) is the capability to use the assets of multiple services and agencies to detect, track, acquire, and destroy enemy theater ballistic missiles and cruise missiles. It includes the seamless flow of information on missile launches by specialized surveillance capabilities, through tracking by sensors from multiple services and agencies, to missile negation or destruction. The Single Integrated Air Picture (SIAP) is an enabling feature of the information-centered Joint Theater Air and Missile Defense (JTAMD) system. The SIAP will be the product of fused, common, continuous, unambiguous tracks of all airborne objects in the surveillance area. Each object within the SIAP will have a unique track number and set of associated characteristics. The SIAP will fuse near-real-time and real-time data, and will be scaleable and filterable to support situation awareness, battle management, and target engagements. It will provide the warfighter the ability to perform effective, efficient, and integrated theater air and missile defense utilizing advanced engagement concepts. All SIAP users will have identical information about each detected airborne object within their area of concern, allowing near-real-time awareness of actions taken by other SIAP participants against each hostile track. All decision makers will have confidence that they have an accurate, identical representation of events occurring in the battlespace, precluding unnecessary multiple engagements and conserving weapon inventories.

Joint Vision 2010 (Reference 4) provides a view of the future and its implication for joint operations expressed in terms of emerging operational concepts. It establishes full-spectrum dominance as the collective goal and defines it as “the capability to dominate an opponent across the full range of military operations.” Achieving dominance over the air and missile threats projected for 2010 while simultaneously reducing the potential for fratricide requires the achievement of a SIAP among all JTAMD participants; high confidence in the early identification of each track within this air picture; the capability to develop, at the user level, fire-control-quality data from multiple sensor sources and conduct engagements based on this data; and a battle management system capable of supporting decentralized control and optimization of Theater Air and Missile Defense (TAMD) operations within a theater-wide joint engagement zone.

The vision for a future JTMD architecture is shown conceptually in Figure VII–1. It depicts a representative theater-wide family of systems, composed of surveillance systems, multiple layers of defensive weapon systems, and a highly responsive C^3I network to integrate the surveillance and weapon capabilities. The internetted set of surveillance systems depicted includes airborne, shipborne, and land-based radars, plus space surveillance systems to detect launches of theater ballistic and cruise missiles and track them until they are successfully intercepted.

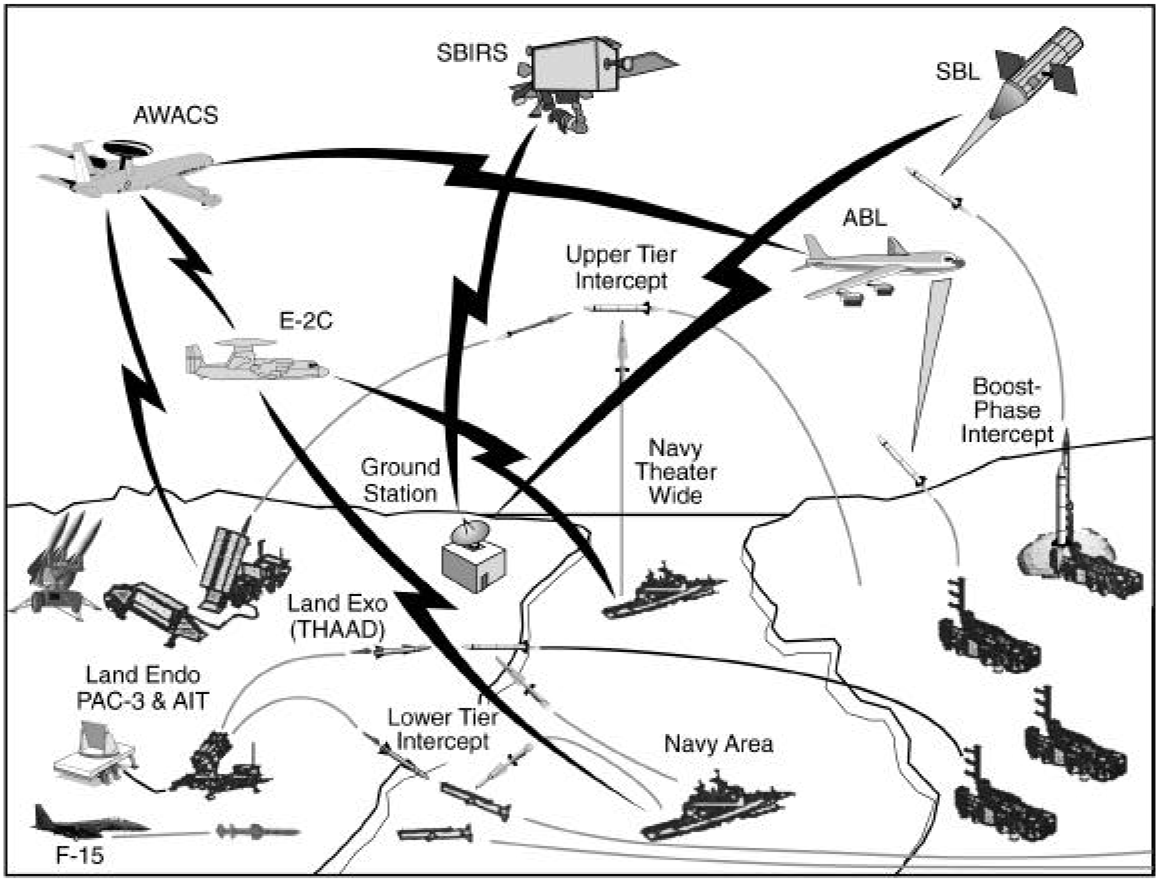

Figure VII–1. Concept—Joint Theater Missile Defense

In this future JTMD architecture, the first of the defensive layers is *boost-phase intercept* of ascending ballistic missiles by airborne or space-based high-power laser weapon systems, or both. This boost-phase intercept layer plays a special role in deterring or defeating attacks by missiles armed with weapons of mass destruction (WMD) (chemical, biological, or nuclear warheads), because lethal warhead materials may well fall on the attacker's own territory. For the next defensive layer, or *upper tier,* long-range interceptor missiles from land or shipboard launchers are depicted intercepting at high altitude the missiles that avoided boost-phase intercept. The final defensive layer, or *lower tier,* includes shorter range defensive missiles from land- or sea-based launchers to provide a final round of lower altitude terminal intercepts above the defended area. Similarly, cruise missiles detected by the surveillance sensors could be intercepted first by longer range sea- and land-based surface-to-air and air-to-air missiles and then by the shorter range terminal defense missiles.

JTMD capabilities are critical elements of the operational concept of *full-dimensional protection* envisioned in *Joint Vision 2010.* The Theater Missile Defense Mission Need Statement describes the mission of JTMD as protecting U.S. forces, U.S. allies, and other important countries, including areas of vital interest to the United States, from theater missile attacks. The JTMD mission includes the protection of population centers, fixed civilian and military assets, and mobile military units.

B. OPERATIONAL CAPABILITY ELEMENTS

The four operational capability elements (OCEs), or pillars, of JTMD are *command, control, communications, and intelligence (C^3I); active defense; passive defense;* and *attack operations*. These are shown in Table VII–1.

Table VII–1. Functional Capabilities Needed—Joint Theater Missile Defense

Functional Capabilities	Operational Capability Elements			
	C^3I	Active Defense	Passive Defense	Attack Operations
Acquisition Sensor				
1. Detection	○	●	●	●
2. Tracking		●	●	●
3. Discrimination		●	○	○
4. Communications	●	●	●	●
Target Intercept				
5. Lethality—Interceptor		●		
6. Footprint—Interceptor		●		
7. Divert—Interceptor		●		
8. Acquisition		●		
9. Tracking		●		
10. Discrimination		●		
11. Communications	●	●	○	○
12. Boost-Phase Intercept—Laser	○	●		○
C^3I				
13. Datalinks	●	●	●	●
14. Waveform	●	●	○	●
15. Data Processing	●	●	●	●
16. Data Fusion	●	●	●	●

● Strong Support ○ Moderate Support

This section focuses on the active defense pillar and those aspects of the C^3I pillar that are unique to the JTMD mission. Responsive theaterwide C^3I systems and enhanced theater intelligence, surveillance, and reconnaissance (ISR) capabilities that support all theater operations (including JTMD) are addressed in Chapter IV, Information Superiority. Similarly, passive defense capabilities—including rapidly assessing and disseminating chemical and biological (CB) threat information and providing effective protection against CB attack for personnel and platforms—are described in Chapter XII, Chemical/Biological Warfare Defense and Protection, and Counter Weapons of Mass Destruction. Finally, capabilities for the attack operations pillar—such as quick-response, precision strikes against mobile theater missile launchers—are addressed in Chapter V, Precision Fires. In addition, attack operations against WMD capabilities—including prompt attacks against WMD-armed theater missiles on the battlefield and counterforce attacks against hardened WMD storage and production facilities—are addressed in Chapter XII, Chemical/Biological Warfare Defense and Protection, and Counter Weapons of Mass Destruction.

C. FUNCTIONAL CAPABILITIES

The functional capabilities needed to support the four operational capability elements or pillars of JTMD are also shown in Table VII–1. The detailed functional capabilities are grouped into those supporting the three functional areas of *acquisition sensor, target intercept,* and *C^3I*.

In the acquisition sensor area, the four functional capabilities are detection, tracking, discrimination, and communications. All four capabilities strongly support active defense by rapidly detecting theater missile launches and establishing current and accurate tracks for those missiles, which are essential for cueing the active defense against the attacking missiles. In addition, the detection, tracking, and communications functional capabilities strongly support passive defense by providing attack warning and impact point predictions to threatened areas. Those three functional capabilities also strongly support attack operations by accurately identifying missile launch locations so that the launchers can be promptly attacked. The discrimination functional capability to distinguish a ballistic missile warhead from accompanying missile components or fragments and decoys is essential for cueing the active defense to attack the right target. In addition, the attack characterization information about the missile type and potentially the type of warhead from discrimination sensors moderately supports both the attack operations and passive defense operational capabilities.

In the target intercept area, the first three functional capabilities—lethality, footprint, and divert—specifically refer to capabilities of interceptor missiles (often called *kinetic energy* interceptors in contrast to *directed-energy* or laser intercept). The first, lethality, is the capability to effectively destroy the warhead payload of an attacking missile when the interceptor impacts the target (for hit-to-kill interceptors) or passes near the target and detonates a fragmenting warhead. The second function, footprint, is the capability of an interceptor missile to intercept targets over the required defended area because of its speed, range, and altitude performance capabilities. The related third function, divert, is the lateral acceleration capability of the interceptor missile to maneuver during the final phase, or *end game*, of the intercept in order to impact the target or pass within the interceptor warhead's lethal envelope of the target.

The next three functional capabilities—acquisition, tracking, and discrimination—are the capabilities of the sensors on board the interceptor missile or laser weapon platform to (1) acquire the right target based on cueing and handoff information passed from acquisition sensors through the C^3I system, (2) discriminate between the target warhead and missile fragments or decoys, and (3) maintain tracking of that target until the intercept is completed. The communications functional capability links the interceptor missiles or laser platforms to the acquisition sensor functional capabilities. The final target intercept functional capability is boost-phase intercept with laser weapons, either airborne or space based. As indicated in Table VII–1, because of the onboard acquisition sensor and communications capabilities envisioned for them, the laser weapon platforms would also support the C^3I and attack operations OCEs by forwarding missile launch and tracking data that they acquired.

The C^3I area includes functional capabilities for (1) high-capacity datalinks to rapidly pass acquisition sensor data and (2) specialized waveforms to forward missile tracks among elements of the joint TMD forces. C^3I also includes the functional capabilities of very-high-throughput data processing to capture, analyze, and disseminate the sensor data with minimum delays; and data fusion capabilities to synergistically combine tracking and discrimination data from multiple sensors of different types.

D. CURRENT CAPABILITIES, DEFICIENCIES, AND BARRIERS

Joint Theater Missile Defense includes a number of surveillance, weapons, and C^3I systems that are currently deployed or under development by the services. The Ballistic Missile Defense Organization (BMDO) is responsible for the family-of-systems approach to ensure integration of these systems into a joint warfighting capability. Current theater C^3I systems are being upgraded for interoperability, and future JTMD systems will be linked by interoperable C^3I networks to provide joint connectivity.

Current JTMD capabilities are limited to terminal point defense missile intercepts at low to medium altitudes; there is no capability for upper tier intercepts at higher altitudes and longer ranges or for boost-phase intercept. However, higher performance missiles and surveillance systems now under development will extend intercept capabilities to the higher altitudes and longer ranges required for theater-wide upper tier missile defense. In addition, technology development and demonstration efforts are underway to establish the feasibility of laser weapons for boost-phase intercept, as described in Section E below.

The current capability for low-altitude, terminal point defense missile intercepts is based on the Patriot and Hawk interceptor missile and radar systems. Patriot upgrades, including software enhancements and improved fuzing, have increased engagement capability beyond the level available during Operation Desert Storm. The fielded Patriot system allows for rapid, accurate fire unit emplacement; remote launcher placement up to 12 km from the radar; and radar enhancements to improve theater ballistic missile (TBM) detection and increase system survivability. Upgrades to the lower altitude, shorter range Hawk system will yield a near-term defense capability for expeditionary forces through modifications to allow detection, tracking, and engagement of short-range TBMs.

To improve these lower tier defense capabilities, upgrades to both the Army Patriot and Navy missile systems are under development. The Patriot Advanced Capability 3 (PAC–3) version now under development will enhance Patriot system engagement performance by adding a new hit-to-kill missile interceptor with a millimeter-wave seeker and side-firing divert propulsion thrusters for enhanced maneuverability during the final phase of intercepting a target. In addition, under the Navy Area Defense program, an upgraded version of the Navy Standard Missile 2 (SM–2 Block IV A) is under development to provide a sea-based, lower tier intercept capability. These upgraded PAC–3 and SM–2 Block IV A missiles will also provide improved intercept performance against cruise missiles. In addition, project definition and concept validation is underway for the Medium Extended Air Defense System (MEADS), a highly mobile system to be deployed with maneuver forces to provide coverage against short-range TBMs, cruise missiles, and other aerodynamic threats.

However, these lower tier systems with moderate velocity missiles have only limited capability against longer range TBM threats with higher reentry velocities, particularly if the attacking missiles are fitted with WMD warheads. Chemical or biological warheads intercepted at low altitude could still disperse hazardous materials over defended areas, particularly if the warheads were to contain submunitions.

Therefore, upper tier TMD systems with high-performance interceptor missiles capable of defending larger areas and intercepting targets, including WMD warheads at higher altitudes, are under development for both land and sea basing. The Army Theater High-Altitude Area Defense System (THAAD) includes a new interceptor missile and a ground-based phased-array acquisition and tracking radar. The Navy Theater Wide system includes a high-performance interceptor missile and upgrades to the Aegis shipboard phased-array radar software.

The characteristics of the land attack cruise missile threat present special challenges for the JTMD mission. Cruise missiles can fly at low altitudes to avoid detection, can maneuver unpredictably to evade intercept, and can be launched from both aircraft and mobile surface carriers, thus reducing the likelihood of prelaunch suppression. Furthermore, advanced cruise missile designs can have very low radar and infrared signatures that make the missiles very difficult to detect against low-altitude background clutter. Therefore, current surveillance systems and interceptor missiles have only limited capabilities to detect, track, and intercept cruise missiles.

In response to these limitations of current capabilities against cruise missiles, during FY96 the Cruise Missile Defense (CMD) Phase I ACTD demonstrated the feasibility of the air-directed surface-to-air missile (ADSAM) concept for over-the-horizon engagement of cruise missiles. Under this ACTD, radars on a mountaintop site simulating airborne radars were used to detect and track missiles that would have been over the horizon for ground- or sea-based radars. Engagement data were transmitted to interceptor missiles via the Navy's Cooperative Engagement Capability (CEC) links, and successful live-fire intercepts with SM–2 missiles and simulated intercepts with Patriot PAC–3 seekers were demonstrated. This ACTD was a significant step toward demonstrating the feasibility of concepts for the cruise missile defense component of JTMD.

In a follow-on effort to the CMD Phase I ACTD, the Navy is conducting an overland CMD S&T program that focuses and aligns technology and engineering efforts associated with the E–2C surveillance aircraft, SM–2 missile, and a seamless weapon control architecture. In FY99, the U.S. Army and U.S. Navy plan to begin Defense Technology Objective (DTO) M.10, Theater Air and Missile Defense (TAMD) Interoperability ACTD, which will provide data to extend the evaluation of warfighting capabilities and confirm Patriot/THAAD contributions to a SIAP. The DTO will extend the effective engagement zones of our TAMD weapon systems, thus expanding the warfighter's battlespace. The ACTD will demonstrate an engage-on-remote (EOR) of a low-altitude surrogate cruise missile using real-time data exchange between the Patriot and Aegis weapon systems via the CEC during a live-fire demonstration.

Combat identification is an essential part of cruise missile defense and is required to select the correct defensive tactical weapon response. Air Force AWACs and Navy E–2Cs provide targeting information to air fighters (F–14, F–15, F–16, F–18, and F–22), which launch air-to-air missiles to destroy the cruise missiles. Two DTOs are demonstrating new, improved ordnances specifically for use against cruise missiles. DTO B.24, Programmable Integrated Ordnance Suite (PIOS), is being developed to support the air fighter's cruise missile defense mission; and WE.54, Reactive Material Warhead ATD, is for ship-launched defense, but could have application to air-to-air missiles.

The recently completed WE.51, Small-Diameter Antiair Infrared Seeker, developed and demonstrated an improved seeker for man-portable and lightweight crew-served air defense missile systems that can provide enhanced target engagement capability against cruise missiles. SE.57, Analog-to-Digital Converter, is developing A/D converters and related components that will allow the E–2C and AWACS to do precision tracking of horizon sea-skimming and LO cruise missiles in clutter. SE.06, Next-Generation Multifunction Electro-Optical Sensor System, will demonstrate improved algorithm performance and efficiency in passive infrared search and track (IRST) sensors that can support target classification through extraction of temporal, spectral, and polarimetric data. This DTO will provide the ability to autonomously acquire and track threat targets, such as cruise missiles, that are increasingly stealthy.

Other DTOs such as MP.24.06, Composite Structures for Missile Defense Systems, and MP.27.01, Materials for Small-Target Detection Capability in High-Clutter Environments, are developing supporting advanced materials technologies for use in future weapons against cruise missiles.

For space surveillance capabilities beyond those available from the current Defense Support Program (DSP) infrared missile launch detection satellites, development of the Space-Based Infrared System (SBIRS), including both low- and high-altitude surveillance satellite constellations (SBIRS–High and SBIRS–Low), is programmed, as depicted in Figure VII–1.

Key limitations of current technologies that now preclude development of the functional capabilities needed to fully satisfy the JTMD goals are highlighted in the third column of Table VII–2, Goals, Limitations, and Technologies for JTMD. For example, for the target intercept functional capability, key limitations include discrimination of the actual target in the face of a sophisticated threat including decoys, tracking of maneuvering targets, lack of a current capability for boost-phase intercept, and the inability to defeat early-release submunitions.

Table VII–2. Goals, Limitations, and Technologies—Joint Theater Missile Defense

Goal	Functional Capabilities	Limitations	Key Technologies
Operational Capability Element: Command, Control, Communications, and Intelligence (C^3I)			
Coordinate exchange of information among sensors, radars, launch platforms, interceptors, and command centers.	***Acquisition Sensor*** Communications ***Target Intercept*** Communications ***C^3I*** Datalinks Waveform Data Processing Data Fusion	Network latency Datalink capacity	Laser communications High-speed optical datalinks Solid-state nonvolatile memory High-capacity computer interface
Operational Capability Element: Active Defense			
Acquire and track target and handover/ communication data to command centers, interceptor launch sites, and laser platforms.	***Acquisition Sensor*** Detection Tracking Discrimination Communications	Full constellation coverage Radar survivability Target recognition Radar power constraints Lack of airborne TMD discriminator	Advanced lightweight signal processor High-power transmit/receive (T/R) modules Large-format, high-uniformity, multiband LWIR focal plane arrays Lightweight antennas Cryogenic power Eyesafe laser radar

Table VII–2. Goals, Limitations, and Technologies—Joint Theater Missile Defense (continued)

Goal	Functional Capabilities	Limitations	Key Technologies
Operational Capability Element: Active Defense (continued)			
Negate the threat.	***Target Intercept*** Lethality—interceptor Footprint—interceptor Divert—interceptor Acquisition Tracking Discrimination Communications Boost-phase intercept—laser	Discrimination of sophisticated threat Tracking of maneuvering vehicles No capability for boost-phase intercept Inability to defeat advanced submunitions Design for divert jet interactions in the atmosphere	Solid-propellant divert Onboard sensor signal processor and algorithms Lightweight laser radar High-sensitivity multispectral IR sensor Fast framing seeker Sensor windows (IR and RF) for hypersonic atmospheric interceptors Sensor data fusion Target discrimination algorithms Lightweight chemical laser Adaptive optics and beam control Atmospheric compensation and tracking High-stiffness, lightweight structures
Receive, process, and transfer data.	***C³I*** Datalinks Waveform Data processing Data fusion	Network latency Datalink capacity Data fusion delays	Omni-EHF antenna Advanced fusion algorithm
Operational Capability Element: Passive Defense			
Early, long-range, and accurate threat acquisition, tracking, and data distribution.	***Acquisition Sensor*** Detection Tracking Discrimination Communications ***C³I*** Datalinks Waveform Data processing Data fusion	Delayed detection of launch Slow impact point projection Detection of advanced submunitions	Laser communications Satellite electric propulsion High-efficiency photovoltaics LWIR GaAs sensor Active pixel visible sensor
Operational Capability Element: Attack Operations			
Coordinate cooperative acquisition, tracking, decision making, and kill assessment.	***Acquisition Sensor*** Detection Tracking Discrimination Communications ***C³I*** Datalinks Waveform Data processing Data fusion	Noninteroperable communications links Inaccurate kill assessment of CB threats	High-speed datalinks Target discrimination algorithms Code division multiple access (CDMA) spread-spectrum communications modem

Discrimination is a key limitation of defense against TBMs because an approaching group of target objects could include missile components or fragments, jammers, chaff, and decoys in addition to the actual reentry vehicle containing the warhead. Without effective discrimination sensors to confidently identify the actual reentry vehicle, multiple missile or laser shots would be required to destroy all of the potentially threatening objects to ensure a high probability of protecting the defended area. Therefore, effective discrimination technology has very high payoff for JTMD. Interceptor observations of the target set must play a central role in advanced discrimination because ground- or ship-based radar may be made ineffective by jamming and chaff. For endoatmospheric interceptors, use of onboard sensors for discrimination and target tracking requires improved IR and RF window materials that are transparent at the required wavelengths, have low distortion, and can survive the high temperature and pressure of hypersonic flight within the atmosphere.

Target maneuvering is another area that imposes additional performance requirements on endoatmospheric interceptors. Current TBMs may maneuver unpredictably during reentry because of missile dynamics or reentry vehicle asymmetries, and advanced reentry vehicles could potentially take evasive maneuvers, thus reducing the probability of successful intercept. Higher lateral acceleration and divert propulsion are required, as well as reduced airframe time constants, to maximize endo-interceptor agility. Technologies that enhance interceptor maneuverability would greatly improve endo-atmospheric interceptor probability of kill.

Two other significant barriers for JTMD are sensor/data fusion and target signature data. Sensor data fusion is a technique in which multiple sensors provide individual data sets on targets and backgrounds, which are then processed into a single merged set of data. The fused data present a much more accurate picture of the battlespace to the field commanders than the sum of the individual data sets. Sensor fusion is a challenging technical barrier because fusion must take place in near-real time in order to be useful for guiding intercepts. The data fusion process occurs in one of three ways: (1) the fusion of data from several sensors on the same platform (e.g., a thermal imaging sensor and laser radar onboard an interceptor or a space surveillance satellite); (2) the transfer or handover of data from one sensor platform to another (e.g., target object map data handover from one surveillance sensor to an interceptor); or (3) the merging of track files recorded and processed from two or more geographically separated sensors (e.g., ground radar and space surveillance sensor data track files).

Availability of accurate target signature data is also a key barrier because successful TMD detections and intercepts, particularly hit-to-kill intercepts, require accurate and reliable target signatures. Threat signatures drive the designs of the detection and tracking radars and optical sensors, as well as seeker hardware selections. They also establish requirements for the supporting detection, discrimination, aimpoint selection, and kill assessment algorithms. The primary limitation on obtaining accurate signatures is generally the lack of access to the actual missile threats operating in their deployed environment. To compensate for this, BMDO supports a threat and signatures flight and phenomenology program, where both simulated threats and acquired threats are flown and measured.

Some potential barriers to operating in disturbed environments that are not unique to the JTMD mission—such as achieving mission goals in the presence of jamming, weather, and solar and nuclear disturbances—are addressed by DTOs in the Sensors, Electronics, and Battlespace Environment chapter of the DTAP. Some of these efforts are referenced in the next section.

E. TECHNOLOGY PLAN

Some of the key technologies needed to breach the limitations to achieving the JTMD functional capabilities and to enable the JTMD advanced operational capability are shown in Figure VII–2. Most of these key technologies are being addressed by the technology development and demonstration efforts encompassed by the 20 DTOs listed in Table VII–3.

These are cited in this chapter as most directly supporting JTMD. In addition, as discussed in Section B above, related technology efforts described in other sections of this JWSTP also support JTMD operational capabilities: technology demonstrations under Precision Fires (Chapter V) that support the JTMD attack operations capability, efforts under Information Superiority (Chapter IV) that support C^3I capabilities applicable to JTMD, and technologies under Chemical/Biological Warfare Defense and Protection, and Counter Weapons of Mass Destruction (Chapter XII) that support the JTMD passive defense operational capability.

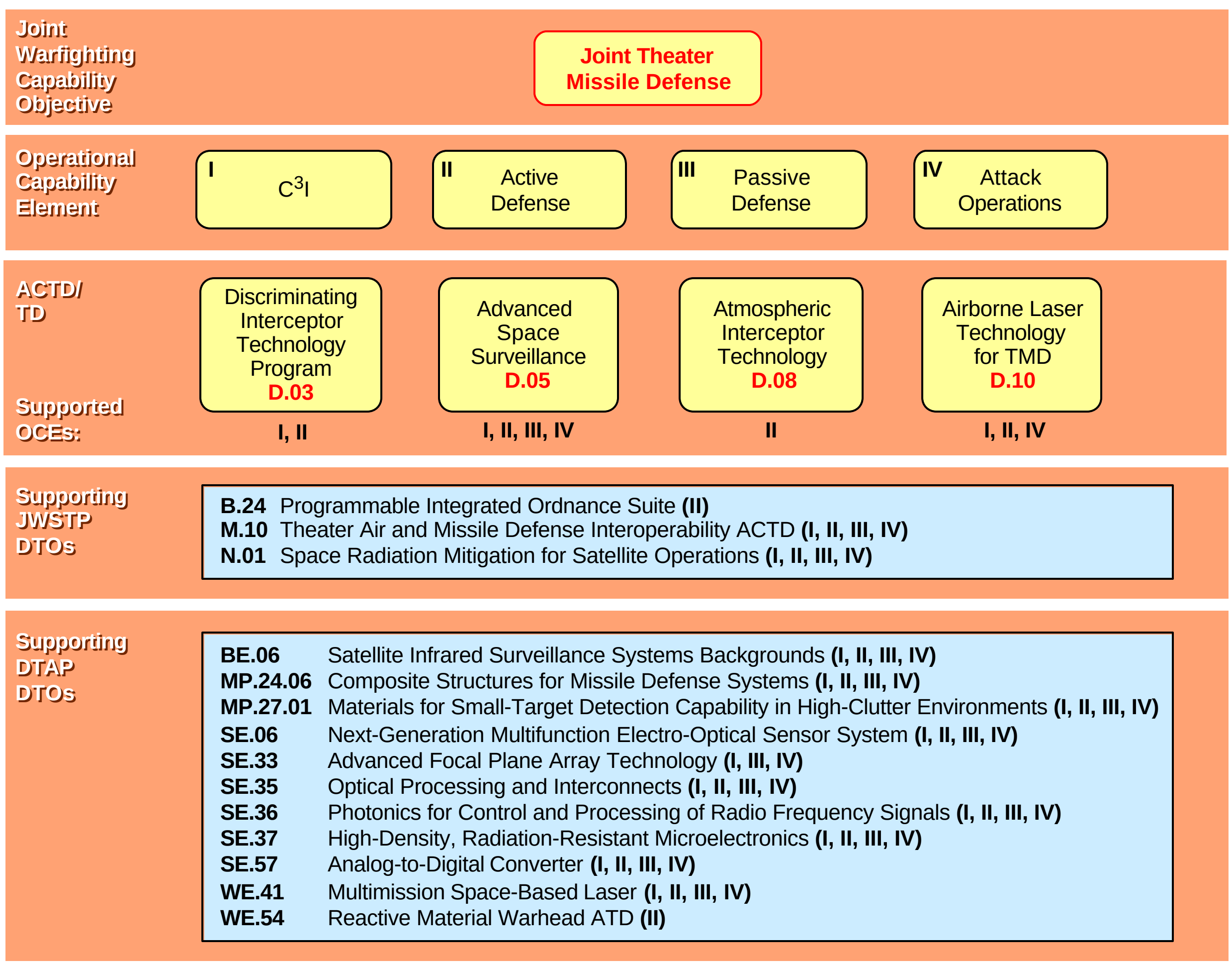

Figure VII–2. Technology to Capability—Joint Theater Missile Defense

Table VII–3. Demonstration Support—Joint Theater Missile Defense

Demonstration	Operational Capability Elements: C^3I	Active Defense	Passive Defense	Attack Operations	Service/ Agency	DTO	Type of Demonstration: ACTD	ATD
Discriminating Interceptor Technology Program	○	●			BMDO, Army, Air Force, Navy	D.03		
Advanced Space Surveillance	○	●	○	○	BMDO, Air Force	D.05		
Atmospheric Interceptor Technology		●			BMDO, Army	D.08		
Airborne Laser Technology for Theater Missile Defense	○	●		○	Air Force	D.10		
Programmable Integrated Ordnance Suite		●			Air Force	B.24		
Theater Air and Missile Defense Interoperability ACTD	●	○	○	○	BMDO, Army, Navy	M.10	X	
Space Radiation Mitigation for Satellite Operations	●	○	●	○	Air Force	N.01		
Satellite Infrared Surveillance Systems Backgrounds	○	○	●	●	Air Force, BMDO	BE.06		
Composite Structures for Missile Defense Systems	○	●	○	○	BMDO, Army, Navy	MP.24.06		
Materials for Small-Target Detection Capability in High-Clutter Environments	○	●	○	○	Navy, Air Force	MP.27.01		
Next-Generation Multifunction Electro-Optical Sensor System	○	●	○	○	Army, Navy, Air Force	SE.06		
Advanced Focal Plane Array Technology	●		●	○	Army, Navy, Air Force, DARPA	SE.33		
Optical Processing and Interconnects	●	○	○	○	Air Force	SE.35		
Photonics for Control and Processing of Radio Frequency Signals	●	○	○	○	Air Force, Navy	SE.36		
High-Density, Radiation-Resistant Microelectronics	●	○	●	○	Air Force, DSWA	SE.37		
Analog-to-Digital Converter	●	●	●	○	Navy, Air Force	SE.57		
Multimission Space-Based Laser	○	●	○	○	BMDO	WE.41		
Reactive Material Warhead ATD		●			Navy	WE.54		X

● Strong Support ○ Moderate Support

Technology development and demonstration efforts directly supporting JTMD are focused on four areas: (1) enhance ground and airborne radar and space and airborne optical sensor capabilities to improve missile launch detection, tracking, and discrimination; (2) improve interceptor performance, including onboard discrimination and improved agility capabilities for both exo- and endoatmospheric interceptors; (3) demonstrate the feasibility of boost-phase intercept with airborne and space-based laser technologies; and (4) increase the capabilities of theater C^3I systems to rapidly process and transfer the massive amounts of sensor and tracking data required to support defensive intercepts.

In the area of enhanced surveillance, tracking, and discrimination sensor technologies, the two key DTOs are D.03 and D.05. Technology efforts under D.03, Discriminating Interceptor Technology Program, will use in-flight experiments to demonstrate the ability to observe the target, decoys, and debris and perform real-time discrimination between them using a fused LADAR/IR seeker. D.05, Advanced Space Surveillance, includes technologies for advanced satellite sensors and subsystems that could be inserted into new and upgraded space surveillance systems, including the SBIRS.

Additional details on the DTOs that most directly contribute to achieving JTMD warfighting capabilities are given below. These DTOs directly support the four JTMD operational capability elements of C^3I, active defense, passive defense, and attack operations, as presented in Table VII–3. The DTOs are structured to demonstrate incrementally increasing capability over time. These technology advances can potentially be inserted into JTMD surveillance, weapons, and C^3I systems at the component and subsystem level to provide warfighting capability that incrementally increases over time. Full-page descriptions of the DTO technical content, milestone schedules, funding, and performing organizations are presented in the accompanying DTO volume (Reference 6).

- *D.03, Discriminating Interceptor Technology Program*, develops and demonstrates, through ground and flight experiments, the key technologies required to provide an exoatmospheric interceptor with the discrimination capabilities required to distinguish a reentry vehicle from accompanying missile fragments and decoys.
- *D.05, Advanced Space Surveillance*, includes development of innovative technologies for key space surveillance subsystems. These technologies include a unique multimode sensor, data fusion algorithms, hardware for onboard data processing, a laser satellite-to-satellite communication system, improved solar arrays, and increased-efficiency, long-life Hall Effect thrusters.
- *D.08, Atmospheric Interceptor Technology* (AIT), includes development and demonstration at the prototype component level of key technologies required for a hypersonic hit-to-kill missile for intercepts within the lower atmosphere. The AIT is currently testing technologies that will enable lightweight vehicles to intercept at high velocity (4 km/s), with aimpoint accuracy.
- *D.10, Airborne Laser (ABL) Technology for Theater Missile Defense,* develops and demonstrates technology for the ABL system acquisition program. Specific demonstrations include active tracking field tests against boosting missiles, and ground testing of integrated atmospheric compensation and tracking.
- *B.24, Programmable Integrated Ordnance Suite*, will develop and demonstrate an integrated ordnance suite composed of an imaging infrared (IIR) target detection device (TDD), advanced initiation fireset, and directional warhead to maximize counterair missile lethality. It will provide the warfighter with an air-to-air missile ordnance package that will enhance missile effectiveness against cruise missiles, fighter aircraft, bombers, and helicopters; increase kills per sortie in air-superiority missions; and provide a one-missile/one-kill capability.
- *M.10, Theater Air and Missile Defense Interoperability ACTD*, will increase the TAMD defended area, improve the Army and Navy SIAP, and increase our capability to conduct contingency operations. It will address the following warfighter needs: SAIP/common operational picture (COP), greater tactical datalink capability, minimal data latency, combat identification (CID), elimination of multiple tracks and incorrect CID, faster warnings, precise cueing, and beyond-line-of-sight engagement capability.
- *N.01, Space Radiation Mitigation for Satellite Operations,* addresses the increasingly critical need for space-based assets to provide uninterrupted support to military operations. Space radiation can cause transients in, or failure of, sensitive electronic components and premature degradation of space power systems and other satellite systems. This DTO will establish the causal relationship between the space radiation environment, satellite anomalies, and satellite system degradation and failure; and

develop techniques and instrumentation to mitigate these effects or provide warning of hazardous space environments.

- *BE.06, Satellite Infrared Surveillance Systems Backgrounds*, develops and demonstrates integrated background clutter suppression and mitigation technologies needed by space surveillance and threat warning systems to detect and track targets in cluttered optical and infrared backgrounds. Advances in target-background discrimination will be pursued through the development and integration of background clutter suppression tools into hardware simulators to optimize system performance prior to deployment for the full system design trade space and operational conditions. The technologies developed under this DTO will support the design and operation of the Space-Based Infrared System.
- *MP.24.06, Composite Structures for Missile Defense Systems*, will develop and insert multifunctional composite structural components into missile defense systems. The program will qualify and flight-test a resin matrix composite (RMC) sensor gimbal pedestal and bulkhead for the Patriot Anti-Cruise Missile (PACM), develop and demonstrate high-thermal-conductivity RMC trays for ground-based radar systems, develop and test advanced SiC divert system components, and co-develop and flight-test advanced composite shrouds for endo-interceptors.
- *MP.27.01, Materials for Small-Target Detection Capability in High-Clutter Environments*, will develop and demonstrate electronic materials that will enable development of high-temperature electronic components that significantly enhance capabilities in detecting small targets or signals in a high-clutter environment. The payoffs from these technologies will include a revolutionary capability in cruise missile defense in littoral (close-to-shore, wide range of sea state environments) operations and related low-angle airborne or spaceborne radar detection scenarios.
- *SE.06, Next-Generation Multifunction Electro-Optical Sensor System*, will provide the ability to autonomously acquire and track threat targets that are increasingly stealthy in a wide (360-degree) panoramic field of regard. Theater ballistic missiles will be over-the-horizon detected and precision tracked at ranges out to 500 km, and cruise missiles will be horizon detected (13 nmi) for ship self-defense.
- *SE.33, Advanced Focal Plane Array (FPA) Technology*, includes both cooled and uncooled FPA technology. The objective is to increase range and target acquisition by improving the noise-equivalent delta temperature (NEDT) of uncooled sensors and by fusing two or more bands of cooled detectors, resulting in higher target discrimination.
- *SE.35, Optical Processing and Interconnects*, will develop new optical concepts to achieve tera-operations-per-second processing in a massively parallel optoelectronic processor that is small in size and low in power consumption.
- *SE.36, Photonics for Control and Processing of Radio Frequency Signals*, will develop photonics technology to route, control, and process RF and microwave signals in military applications, including photonic components and systems for control of phased-array antennas and distribution of RF signals.
- *SE.37, High-Density, Radiation-Resistant Microelectronics*, addresses the high-performance, extremely dense, radiation-resistant microelectronics that are key to

continued U.S. domination of battlefield surveillance, intelligence, and communications, as well as JTMD. Space applications, which presently dominate requirements for radiation-resistant microelectronics, need to operate reliably after exposure to natural and nuclear radiation. This DTO provides satellites, strategic ballistic missiles, and BMDO interceptors with timely access to state-of-the-art microelectronic technologies that are both affordable and radiation resistant. The technologies developed will provide significant reductions in weight, size, and power while simultaneously increasing performance.

- *SE.57, Analog-to-Digital Converter*, develops converters and related components to demonstrate digital receivers targeting military radar, EW, and C^4I systems, with the initial demonstrations in digital receivers and EW radar (E–2C and AWACS). Digital receivers will provide agility, and elimination of analog circuitry will yield substantial improvements in system reliability, accuracy, and repeatability.
- *WE.41, Multimission Space-Based Laser*, demonstrates the technologies for high-power space-based laser systems that could be used for TBM boost-phase intercept. This DTO integrates a high-power chemical laser with a beam director and tracking components in a lightweight, flight-representative ground test configuration.
- *WE.54, Reactive Material Warhead ATD*, will demonstrates the ability of missile warheads to achieve catastrophic structural kills of cruise missile and manned aircraft targets by enhancing traditional kinetic energy defeat effects with fragment chemical energy that is released when fragments impact targets. The best candidate reactive material mixture will be incorporated into warhead prototypes and tested to demonstrate the potential catastrophic performance enhancement.

The schedules for key technology efforts supporting these DTOs and the relationships among the technology efforts and DTOs are depicted in Figure VII–3.

In addition to the DTOs cited above that exclusively or primarily support JTMD, there are other DTOs in the DTAP that are advancing technologies important to future JTMD capabilities. For example, for space-based surveillance systems detecting TBMs against the earth background, the complexity and variability of the background clutter are key limitations for detecting dimmer missile targets. Therefore, the development, validation, and demonstration of advanced background clutter algorithms and prediction codes under the Satellite Infrared Surveillance Systems Backgrounds DTO (BE.06) are crucial for future JTMD space surveillance systems. From the same Sensors, Electronics, and Battlespace Environments technology area of the DTAP, the technologies for dual-band, cooled infrared focal plane arrays (FPAs) and highly uniform, uncooled FPAs that are being developed under the Advanced Focal Plane Array Technology DTO (SE.33) support and are closely integrated with efforts under the JWSTP DTO D.03.

From the same technology area, radiation-tolerant and hardened microelectronics technologies from the High-Density, Radiation-Resistant Microelectronics DTO (SE.37) will be needed for some JTMD surveillance systems and interceptor missiles facing natural space radiation and potential nuclear weapon environments. Processing analog signals from FPAs in surveillance sensors or on interceptor missiles to detect dim targets against complex backgrounds or digitizing radar signals to detect cruise missiles in ground clutter requires very-high-resolution, high-speed analog-to-digital converter technology from this technology area.

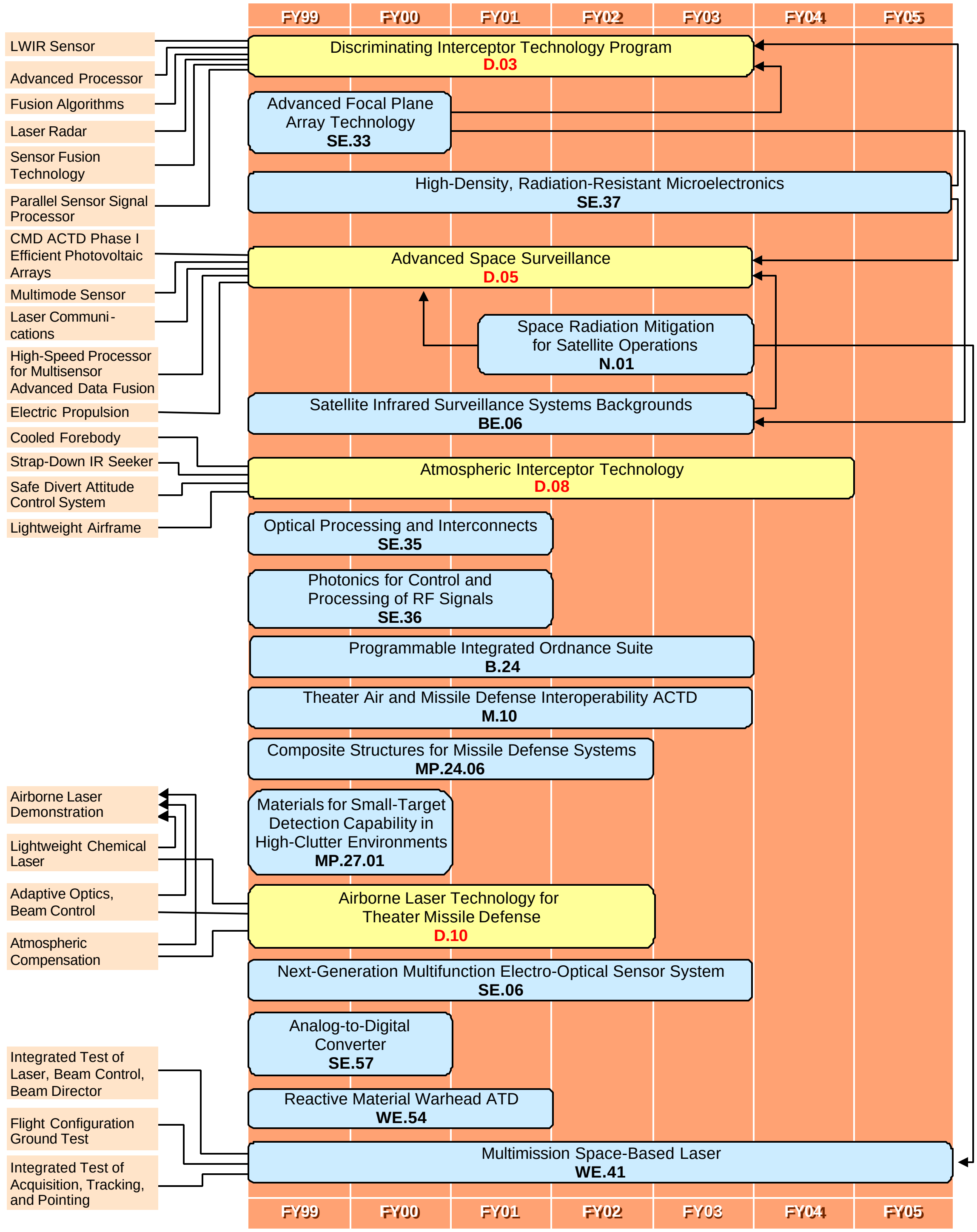

Figure VII–3. Roadmap—Joint Theater Missile Defense

Similarly, the technology efforts under the recently completed Microwave SiC High-Power Amplifiers DTO (SE.27) complement the advanced transmit/receive module technology efforts that were carried on under JTMD DTO D.04. The Space Radiation Mitigation for Satellite Operations DTO (N.01) develops techniques to address the adverse effects of space radiation that may impact DTOs D.05 and WE.41. Finally, efforts under the photonics thrust DTOs—Optical Processing and Interconnects (SE.35) and Photonics for Control and Processing of Radio Frequency Signals (SE.36)—support key technology needs in laser communications, high-speed optical datalinks, solid-state nonvolatile memory, and high-capacity computer interfaces under the JTMD C^3I operational capability element (Table VII–2).

BMDO recently implemented a technology master plan (TMP) to involve the entire BMD community in defining the BMDO technology program and show how its technology programs support its major defense acquisition programs. The BMDO technology efforts described in this chapter are documented and roadmapped in the BMDO TMP.

F. SUMMARY

The incremental advances in demonstrated technology available to support JTMD warfighting capabilities are depicted in Figure VII–4. The dates shown in the figure are the timeframes in which JTMD technologies are projected to be successfully demonstrated based on ongoing or programmed technology development and demonstration efforts; they are *not* the timeframes in which operational systems incorporating those technologies would be deployed. Once the technology demonstrations are completed, the technologies are expected to be sufficiently mature and the engineering risk sufficiently low that the technologies could be incorporated into the designs for modifications to deployed systems or into new systems. Development, production, and deployment of those operational systems incorporating the advanced technologies would require additional time and funding. For some technologies that could be retrofitted at the component or subsystem level as modification kits into systems already deployed, the development and upgrade period could be relatively short. However, for other technologies that would require major modifications to systems already deployed or in development or that would require development of new systems, the time from a technology demonstration milestone to a deployed operational JTMD capability could be many years.

The initial demonstration of boost-phase intercept of a ballistic missile is scheduled for FY2002 under the Air Force's Airborne Laser program using technology developed under the Airborne Laser Technology for Theater Missile Defense DTO (D.10). This will provide an enhanced JTMD capability beyond the current Patriot/Hawk baseline.

Beyond FY2004, robust JTMD capabilities—including advanced space-based surveillance, boost-phase intercept by airborne and space-based lasers, and onboard discrimination for both exo- and endoatmospheric interceptors—will become attainable from the technology demonstrations under the surveillance, laser, and advanced interceptor DTOs, as shown in Figure VII–4. As depicted conceptually in Figure VII–1 at the beginning of this chapter, such a robust future JTMD architecture would provide a full theater defense against ballistic and cruise missiles that would include over-the-horizon targeting and tracking of TBM launches, precision targeting of land attack cruise missiles, TBM intercept above the atmosphere by exoatmospheric interceptors with superior discrimination capability, and high endo-atmospheric intercept of TBMs.

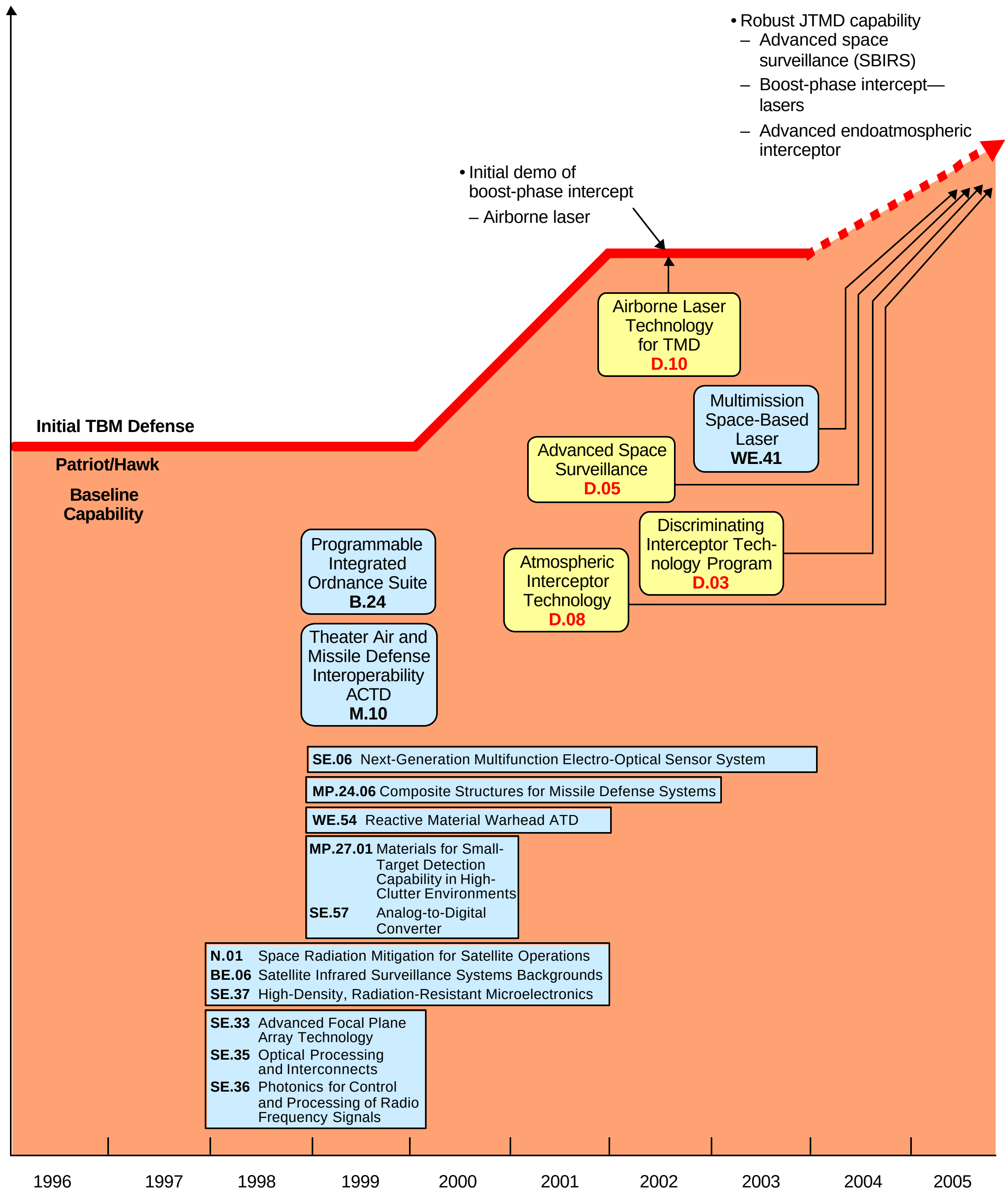

Figure VII–4. Progress—Joint Theater Missile Defense