

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE <p style="text-align: center;">MAY 1996</p>	3. REPORT TYPE AND DATES COVERED <p style="text-align: center;">FINAL 10/01/96--09/30/97</p>
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4. TITLE AND SUBTITLE <p style="text-align: center;">FY97 AVIONICS TECHNOLOGY AREA PLAN</p>	5. FUNDING NUMBERS C PE PR 9993 TA 00 WU 00
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6. AUTHOR(S)	
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <p style="text-align: center;">AVIONICS DIRECTORATE WRIGHT LABORATORY AIR FORCE MATERIEL COMMAND WRIGHT PATTERSON AFB OH 45433-7623</p>	8. PERFORMING ORGANIZATION REPORT NUMBER
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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) <p style="text-align: center;">AVIONICS DIRECTORATE WRIGHT LABORATORY AIR FORCE MATERIEL COMMAND WRIGHT PATTERSON AFB OH 45433-7623</p>	10. SPONSORING/MONITORING AGENCY REPORT NUMBER <p style="text-align: center;">WL-TR-97-1000</p>
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11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT <p style="text-align: center;">APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.</p>	12b. DISTRIBUTION CODE
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13. ABSTRACT (Maximum 200 words)

DTIC QUALITY INSPECTED 4

14. SUBJECT TERMS	15. NUMBER OF PAGES <p style="text-align: center;">48</p>
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT <p style="text-align: center;">UNCLASSIFIED</p>	18. SECURITY CLASSIFICATION OF THIS PAGE <p style="text-align: center;">UNCLASSIFIED</p>	19. SECURITY CLASSIFICATION OF ABSTRACT <p style="text-align: center;">UNCLASSIFIED</p>	20. LIMITATION OF ABSTRACT <p style="text-align: center;">SAR</p>
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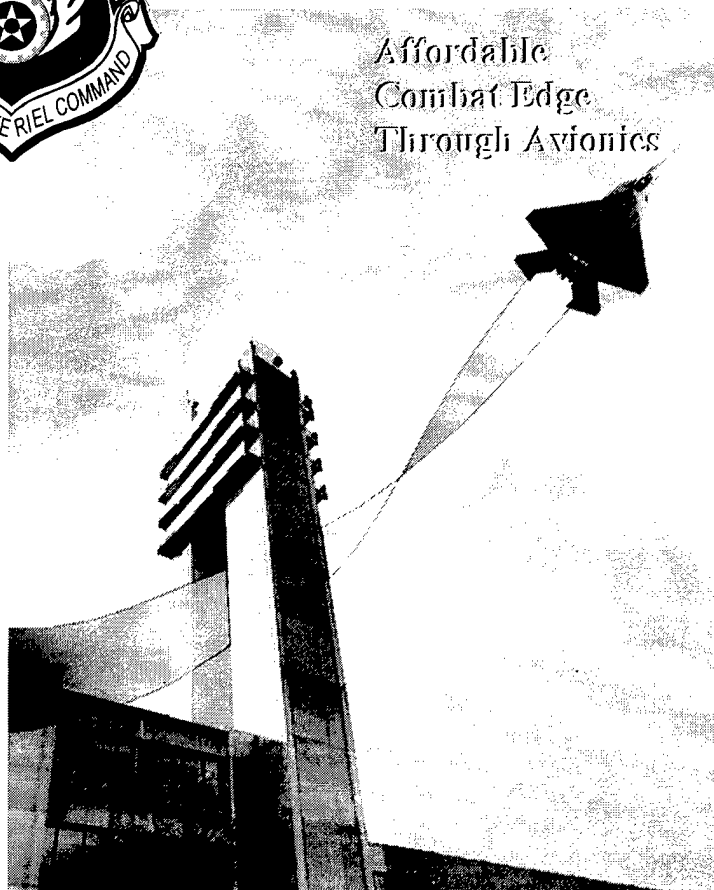
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FY97 AVIONICS TECHNOLOGY AREA PLAN



Affordable
Combat Edge
Through Avionics



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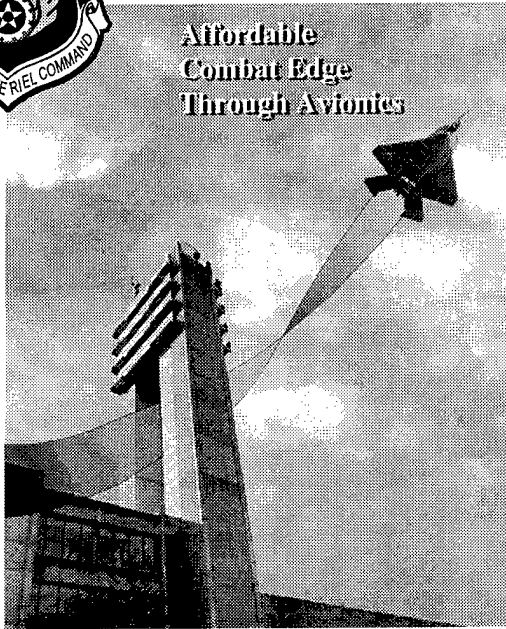
HEADQUARTERS AIR FORCE MATERIEL COMMAND
DIRECTORATE OF SCIENCE AND TECHNOLOGY
WRIGHT-PATTERSON AFB, OH

“Note: This Technology Area Plan (TAP) is a planning document for the FY97-01 S&T Program, and is based on the President’s FY97 Budget Request. It does not reflect the impact of the FY97 Congressional Appropriations and FY97 budget actions. You should consult WL/XP, DSN 785-2532, or Commercial (513) 255-2532 for specific impacts the FY97 appropriation may have had with regard to the contents of this particular TAP. This document is current as of 1 May 1996.”

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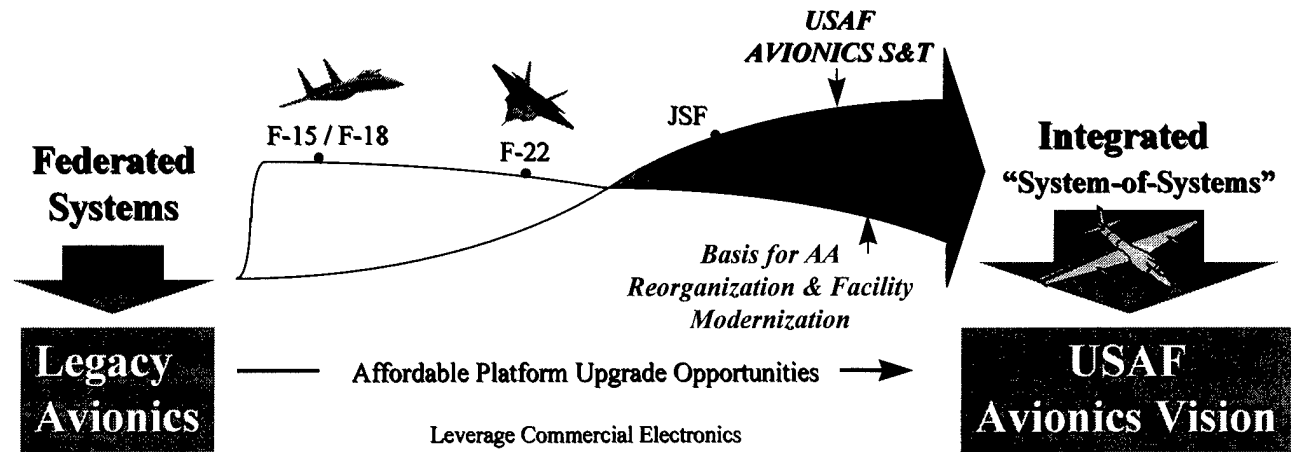
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About the cover...



The Avionics Directorate is providing national leadership in the transformation from legacy federated avionics to more affordable and supportable, open-architecture integrated avionics for the future. The adopted icon for this avionics revolution is the “transformation arrow” as illustrated on the following page. Pictured with the Dayton area landmark avionics tower facility is a maneuvering aircraft—replicating this transformation theme.

AVIONICS



VISIONS AND OPPORTUNITIES

The successful pursuit of national objectives requires the continued superiority of our aerospace systems. The widening variety of Air Force missions challenges these systems to be increasingly flexible, timely, and precise in their application. Wright Laboratory's Avionics Directorate is meeting this modernization challenge:

Developing affordable avionics technology for information dominance and improved dexterity in national strategy and response options.

Our avionics investment goal is to transform current and legacy federated approaches to fully integrated and affordable avionics. The picture above illustrates this transformation that begins with legacy systems such as F-15 and F-18 through F-22 and on to JSF and beyond to a "system-of-systems."

The Avionics Directorate is well positioned to continue its long-standing role as developer of core avionics technology for a variety of recce/intel, and threat response systems. Its current challenge is to apply military and commercial technology to affordable upgrades to accomplish the transformation of legacy federated systems to modern integrated systems. Extending this philosophy of integrated avionics for all information players enhances the potential for the interoperability needed for information dominance and reduced life cycle cost for the integrated "system-of-systems."

Listening to Our Customers

Lessons from Desert Storm and recent military exercises have identified the improvements needed to assure combat superiority of a smaller US force structure. At the same time, this smaller force must support a broader range of military commitments, i.e., concurrent limited conflicts, police actions, humanitarian operations, search and rescue, etc. Many of these operations demand ever-increasing targeting precision, communication, and identification reliability to avoid injury to non-combatants. Specific examples of performance requirements for avionics include:

- First pass kill of any target, any time, in any weather, and under any deployment situation,
- Elimination of "communications-out" operations,
- Reduction of aircraft attrition, and
- Elimination of collateral damage and loss of friendly and neutral assets.

In fact, what the war fighter wants is improved knowledge of the situation throughout the theater of conflict and a quicker, more flexible, and precise response to the threat. Shrinking defense budgets demand that investments in performance must also achieve reduced cost of acquisition, operations, and support. These needs are clearly documented in extensive lists of mission area deficiencies--more than half of which deal with avionics issues. Simply stated, the warfighter wants **affordable avionics modernization** across the fleet of aging systems. Avionics technology, capitalizing on the

expansive growth of the "information industry," is poised to fill these needs.

Avionics Enables Information Dominance & Dexterity in National Strategy and Response Options

21st Century Avionics

In modern aerospace systems, crew members rely on avionics to provide significant enhancement of situation sensing, information processing, and automation of complex mission operations. The functional capabilities of these systems are, to a large extent, contained in discrete "black boxes" (radars, radios, threat receivers, inertial navigation systems, etc.). The current approach to avionics upgrades reflects an environment of ad hoc performance "fixes" tailored to the black boxes of individual aircraft models with little regard for commonality across the fleet. Even "software only" upgrades require new computer hardware due to limitations in memory and processor throughput. This fragmented management of avionics upgrades and replacement of obsolescent components/subsystems is literally, in the words of ALC PGMs "eating the AF lunch"--diverting the precious few resources away from the fundamentals of maintaining military superiority.

However, the Avionics Directorate has pioneered a revolutionary shift in avionics that includes moving away from federated "black boxes" to open architectures supporting integrated functions, common modules, shared components, and use of affordable commercial technology. Affordable, fully integrated avionics exhibit the following characteristics:

- An open architecture with parts reflecting a high degree of commonality.
- Standard interfaces designed to accept increasingly capable chips and boards, modules, and system-level integration so that computing and memory capacities can be readily updated with advances in commercial electronics.

- Reductions in spare parts, test equipment, and mission support personnel needed to deploy overseas in support of combat operations. Companion reduction in differences among platforms leading to less maintenance documentation & training.
- A "mission flexible / reconfigurable system" with functional capabilities defined through software for quick capability updates. Increased reuse of software modules.
- Multi-purpose apertures that are shared for offensive and defensive functions.
- Each asset (platform) is an "element or node" within a distributed information collection array--each serving as a user and a supplier of information.

Integrated avionics concepts (as described above) offer significant opportunities for improved affordability:


- Task sharing among fewer, common components.
- More functions contained in reusable software modules.
- Larger production runs of common / commercial units including hardware approved for export (functional capability defined via software).
- Reductions in number of spares, maintenance training, and mission support.
- Reduction of on-board functions by moving some "brilliance" off-board.

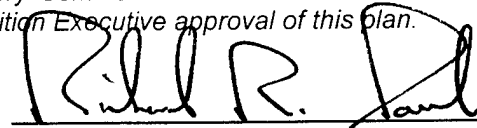
Managed Across the Fleet and Over the Life Cycle, Integrated Avionics Provides Affordable Modernization

21st Century Avionics

To meet future mission objectives, the war fighter must control the situation--continuously adapting the response to new information. The Avionics Directorate intends to extend its long record of innovation and technology transition by focusing its considerable energy toward providing the war fighter "affordable achievement of near-perfect, real-time situation awareness enabling a superior, affordable integrated offensive/defensive response."

This plan has been reviewed by all Air Force Laboratory Commanders/Directors and reflects integrated Air Force Technology Planning. I request Air Force Acquisition Executive approval of this plan.


**RICHARD W. DAVIS, Colonel, USAF
Commander
Wright Laboratory**


**RICHARD R. PAUL
Major General, USAF
Technology Executive Officer**

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INTRODUCTION

On 15 February 1996, HQ USAF approved the merger of Wright Laboratory's (WL's) Solid State Electronics and Avionics Directorates. This "re-engineering" of the organizational structure for avionics technology development was pursued as one of three critical elements in the overall strategy for achievement of the Air Force vision for 21st Century Avionics. Figure 1 outlines the primary division elements of the new organization. The Radio Frequency and Electro-Optical Technology Divisions develop targeting sensor, electronic warfare, and communication subsystems. The focus of the Combat Information Division is information fusion, the full scope of which is defined by the JDL/Reliance fusion model to include situation/threat determination and execution of an integrated offensive/defensive response. The System Concepts and Simulation Technology Division provides the open, system-level architectures

(hardware and software) and virtual prototyping for implementation of the full functionality of the avionics suite. The Electronic Devices Division supports efforts of the other Divisions by developing critical, enabling devices not available through commercial sources. The Mission Applications Division serves as the Directorate's primary interface to warfighter and acquisition customer communities and conducts advanced technology demonstrations as the last step to technology transition. Finally, the Technology Management Division provides centralized investment strategy and resource allocation planning in support of the entire Directorate. The resulting structure eliminates one layer of management, improves sharing of technical expertise across avionics functions, and establishes an enhanced environment for pursuit of multi-division development of open architecture, integrated avionics.

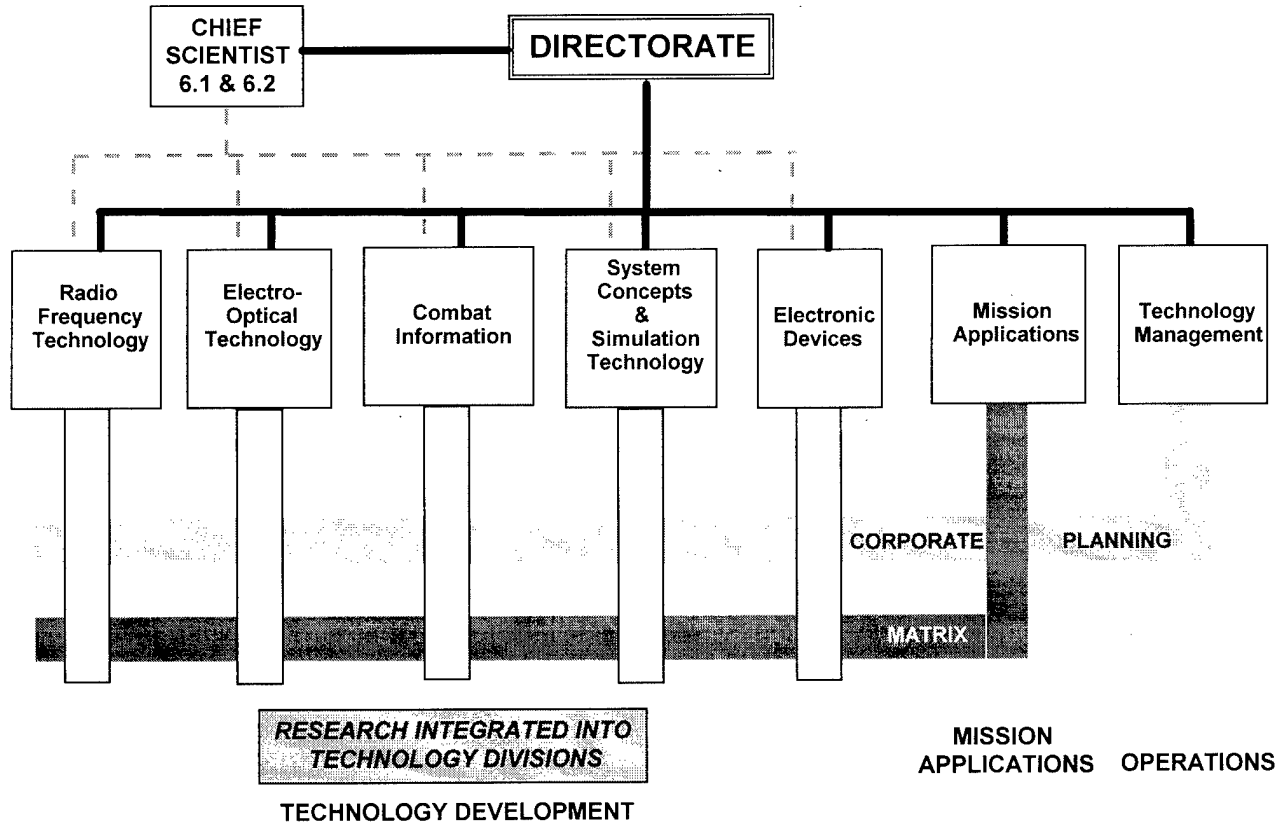
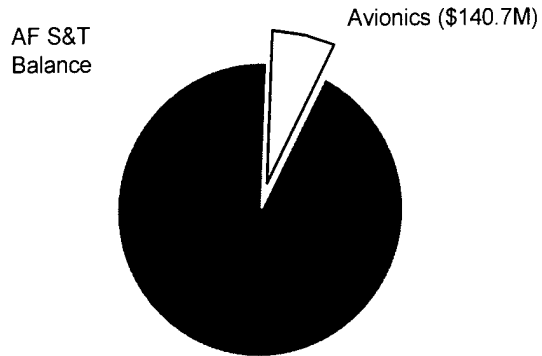


Figure 1: Re-Engineered Avionics and Solid State Electronics Directorate

BACKGROUND

The Avionics Technology Area, highlighted in Figure 2, is that part of the Air Force Science and Technology (S&T) Program charged with providing avionics and electronics to support all Air Force (AF) mission areas. The avionics program promotes the development of alternatives for future mission requirements and near-term weapon system upgrades to current assets. It emphasizes a balance between performance, availability, and affordability. It develops the offensive and defensive avionics system and subsystem and avionics architecture technologies for aerospace vehicles. It also develops basic microelectronics, microwave devices, power conditioning, packaging, and components as principal source for the Air Force and DoD; and develops electro-optical devices and components as part of a coordinated DoD plan.

Avionics accounts for 11.1 percent of the Air Force FY97 S&T budget as shown in Figure 3.



ESTIMATED AF S&T BUDGET FOR FY97: \$1.272B

Figure 3: Avionics S&T vs. AF S&T

Funding reflects the President's Budget Request and may change based on possible Congressional action.

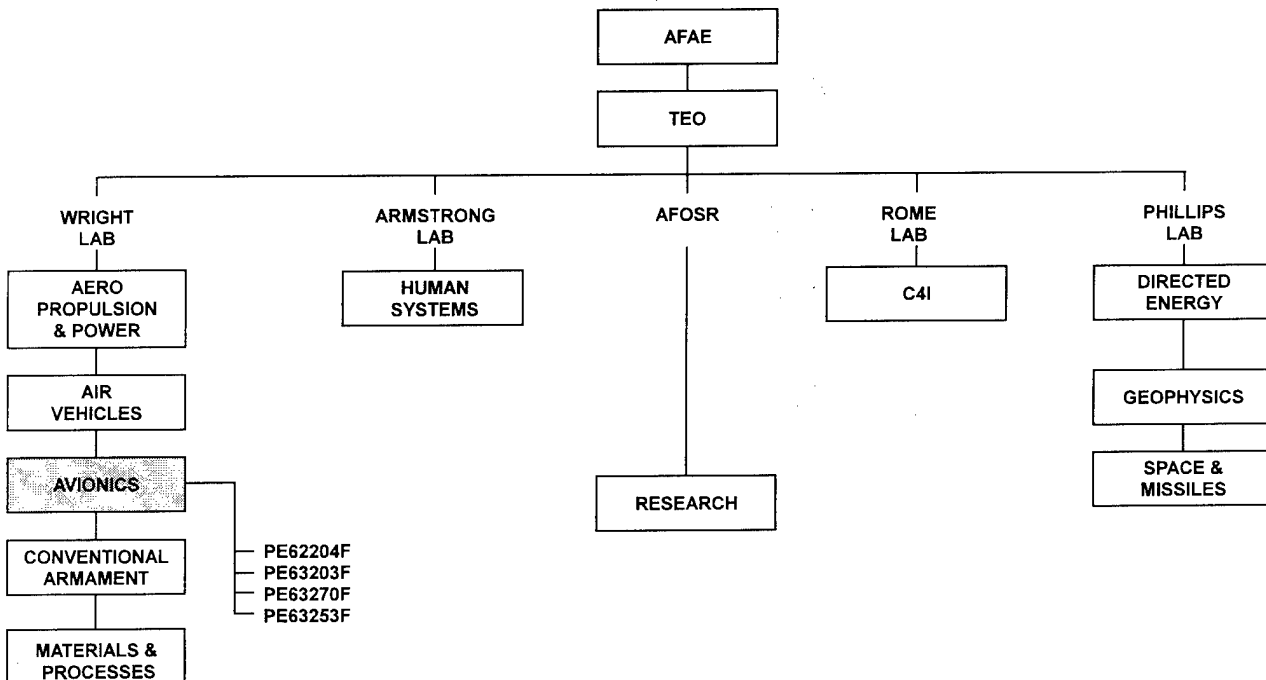


Figure 2: Air Force S&T Program Structure

The total FY97 funding for this area is estimated at \$276M with S&T funds amounting to about 51 percent of this total. The Defense Advanced Research Projects Agency (DARPA) provides the largest single source of non-AF S&T funding (about 17 percent), primarily in the areas of High Temperature Superconductivity, Computer Aided Design and Rapid Prototyping, High Density Microwave Packaging, and Information Processing. About 4 percent of the funds come from the 6.3B Air Combat Command (ACC) sponsored Combat Identification Technology Program Element (PE) for work on non-cooperative target identification.

The Avionics Directorate is committed to the implementation of higher performance, producibility, affordability, and supportability in future avionics. During the past year, reliability enhancements were transitioned and incorporated into the radar of the F-16. A laser detection system was also transitioned to the Ohio Department of Transportation for use in traffic monitoring and control. The Joint Strike Fighter (JSF) program has adopted the Avionics Architectures defined during the PAVE PACE program and is currently closely monitoring the Integrated Sensor System (ISS) proof of concept demonstration for incorporation into the JSF baseline because of its high potential for cost, weight, and volume savings over more conventional approaches.

The recently established Air Force Modernization Planning Process (MPP) and Technology Master Process (TMP) have intensified planning with Major Commands (MAJCOMS), System Program Offices (SPOs), and industry. Advanced development efforts in the Avionics Technology Area Plan (TAP) continue to be highly rated by the MAJCOMs and Product Center users for relevancy and by the Air Force Scientific Advisory Board (SAB) for technical quality. This indicates that we are attaining a good balance of supporting the users while maintaining technical excellence. MAJCOMs are demonstrating interest and commitment by budgeting early for transition of our key programs.

The Avionics Technology programs are developed from a comprehensive investigation of future Air Force capability needs and the need to continue to enhance our technical superiority at an affordable cost. The challenge is to focus avionics resources into areas that can achieve the greatest increase in combat capability while providing corresponding improvements in affordability, reliability, and maintainability. Engineers and scientists work closely with HQ Air

Force Materiel Command (AFMC), AFMC Product Center Development Planning communities, SPOs, and MAJCOMs to identify capability needs.

Inputs considered in preparing this integrated plan are the Technology Needs and User Reviews. The Air Force Acquisition Executive (AFAE) provides annual guidance, and the SAB provides yearly technical guidance. Inputs from industry, academia, and Air Force/ Service/ Agency Laboratories are also considered in developing the plan.

Cooperation with the user is being further enhanced by a teaming process that formalizes and improves the documentation of users' present and projected future capability deficiencies and their plans for rectifying those deficiencies in Mission Area Plans (MAPs).

The Technical Planning Integrated Product Teams (TPIPTs), co-chaired by Product Centers and MAJCOMs with membership from all AF Laboratories, SPOs, XRs, and Development Planning members, link the users' deficiencies with the Laboratory programs to resolve the MAJCOM mission area deficiencies.

Currently, national goals and priorities for S&T are defined and coordinated by DoD, NASA, and industry through the Air Force Modernization Technology Planning Process and the DoD Defense Technology Area Plans (DTAPs). Goals and programs within the DTAPs have been established to solve technical problems leading to affordable future avionics. To achieve these goals, the Avionics TAP is aligned with the Air Force TPIPTs' mission area deficiencies and with the DTAP technology areas: Information Systems and Technology, Sensors and Electronics, and Weapons. Specifically, the Avionics TAP is aligned with the DTAP technology subareas: Communications, Command, and Control (C³), Computing/Software, and Modeling/Simulation (Information Systems and Technology); Sensors, Electronics (Sensors and Electronics); and Electronic Warfare and Directed Energy (Weapons). In the specific area of laser applications development, additional coordination and joint service and laboratory planning are conducted through the DoD Advisory Group on Electron Devices laser subpanel and the DoD Sensor and Electronics DTAP. The Avionics intersections with the DTAPs are shown in Figure 4.

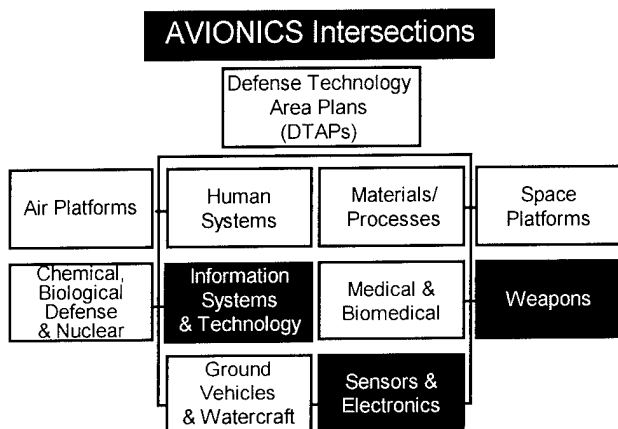


Figure 4: DoD Defense Technology Area Plan

The Avionics TAP encompasses four main business areas or thrusts as listed in Table 1.

Table 1: Major Avionics Technology Thrusts

1. Targeting and Attack Avionics
2. Electronic Warfare Technology
3. System Avionics
4. Electron Devices

The relative emphasis of these thrusts is shown by the distribution of the Air Force S&T funds in Figure 5.

The ultimate vision for military avionics is an avionics suite, supporting offensive and defensive functions, which is easily adapted for the specifics of the mission to be performed. This requires near Real-Time situation awareness enabling a superior integrated offensive/defensive threat response. The affordable achievement of this combat edge is made possible by information fusion and open architecture integrated avionics.

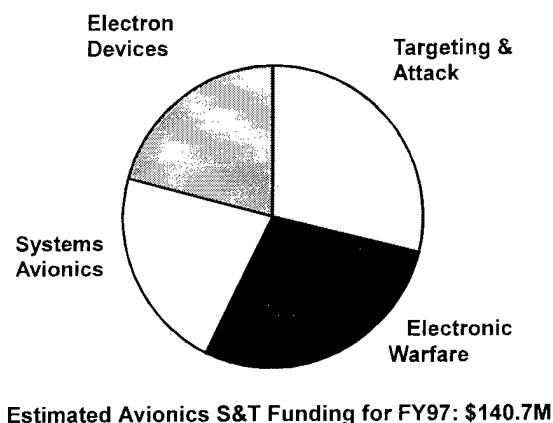


Figure 5: Major Technology Thrusts

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

Industrial Programs - WL actively leverages avionics technology from the Independent Research & Development (IR&D) Program. About \$1.3B of IR&D funds are spent in avionics related areas (eight times the AF S&T Avionics budget). There is a large amount of IR&D in the Electron Devices area because of extensive commercial markets. There is a relatively low amount of electronic warfare (EW) related IR&D funding because of its limited commercial market; however, there are still almost twice the IR&D dollars as S&T funds even in this area. In addition, avionics thrusts are annually briefed to industry by Avionics Directorate personnel. Proposed new Air Force sponsored efforts are identified, as well as additional areas of needed Research and Development (R&D) that probably will not have Air Force funding. These briefings help industry plan their IR&D investments and improve the focus on real Air Force needs.

The Avionics Technology area participates in the Small Business Innovation Research (SBIR) program. This program is a valuable source of new ideas and approaches. This year, 34 Phase I efforts and 17 Phase II efforts have been awarded. In support of the Federal Technology Transfer Act, WL's Office of Research and Technology Applications (ORTA) facilitates the transfer of technology between government and industry. Each year, this office coordinates nearly 200 requests for technology transfer information, many of which concern avionics and electronics. The Avionics Directorate has taken an active role in working with industry, academia, and the Wright Technology Network (WTN) in seeking commercial applications of military technology. We have 10 (of WL's 51) currently active Cooperative R&D Agreements (CRDAs). We are "agents" for several DARPA Technology Reinvestment Project (TRP) efforts. These efforts include the use of fiber optics for video distribution aboard commercial aircraft and the use of high speed digital signal processing for military intercept receivers and commercial telecommunications. Avionics Directorate activities in the medical arena culminated in our organizing WL's first Medical Outreach Technology Workshops and in starting the Computer Assisted Minimally In-

vasive Surgery (CAMIS) program that will apply automatic target recognition technologies to medical imaging and surgery.

International Programs - The Avionics Directorate benefits from Data Exchange Agreements (DEAs) and Memorandums of Understanding (MOUs) with foreign countries. There are 14 agreements for information exchange and cooperative research between the Air Force and other nations. In the System Avionics area, Nunn Amendment monies and foreign source monies have been used for Allied Standard Avionics Architecture activities. The Electronic Warfare Thrust continues to benefit from several international cooperative ventures that range from data/information exchange to cooperative studies and data analysis; to joint testing of EW techniques and hardware.

Project Reliance - As a result of Project Reliance, there has been a significant increase in inter-AF laboratory and interservice coordination. The JSF program is the DoD focal point for defining the affordable next generation strike weapon system(s) for the Air Force, Navy, and Marine Corps and our allies. The JSF Program is not a technology development program, nor is it an acquisition program. The JSF Program is the link, which is often missing, between S&T Programs and Engineering and Manufacturing Development (E&MD).

In support of the overall JSF vision, the Avionics IPT is looking to reduce the life cycle cost of the next generation avionics system by as much as 50%. To accomplish this, the Avionics IPT is concentrating its technology maturation efforts in three areas; Standardizing on an open systems architecture, Validating a virtual systems engineering process and Conducting integrated technology demonstrations. The Avionics Directorate, in coordination with inter-AF personnel, is an active leader in all these efforts. Besides the support that is given directly to the program office, the Avionics Directorate is responsible for the management, technical evaluation and assessment, and integration of the Technology Demonstrations that JSF is accomplishing to move the technologies to a low risk level for E&MD.

Relationship to Other AF TAPS - The Avionics Technology area relates to many of the other S&T Technology Areas.

The Avionics TAP interfaces closely with Air Vehicle Flight Control, Flight Dynamics Integration, and Crewstation Integration thrusts. Joint

programs are being pursued between Targeting and Attack and Conventional Armament Advanced Guidance thrusts. Memorandums of Agreement (MOAs) have been established detailing these cooperative agreements. The Avionics TAP interfaces with Rome Laboratory (RL) on Real-Time Information in the Cockpit (RTIC) programs. In particular, close ties are established between the WL Expanded Situation Awareness Insertion (ESAI) program and the RL Off-Board Augmented Theater Surveillance (OBATS) program and Enhanced All-source and Fusion programs. The Avionics Directorate is working closely with RL in the area of Information Dominance.

Avionics Displays are reported in the Advanced Cockpit Technology Thrust of the Air Vehicles TAP. The thrust is managed by the Joint Cockpit Office on behalf of the WL and includes hardware and humanware program components in both the Avionics and Flight Dynamics Directorates. This inter-directorate Advanced Cockpit Technology Thrust comprises both the Avionic Displays Subthrust from the Avionics Directorate and the Pilot Vehicle Interface Subthrust from the Flight Dynamics Directorate. This multi-disciplinary approach ensures concerted development of workable advanced cockpit technology for pilots and mission crewmembers. The Avionics Displays work reported therein represents the critical Avionics system interface with the operator. The Avionics Display work is also reported as part of the Systems Avionics Thrust #3 in the Avionics TAP.

The Electron Devices thrust is coordinated with the Material Technology Areas of Non-linear Optics and Electromagnetic Sciences and Technology and with RL, especially in the area of reliability science, and Phillips Laboratory on space environment. Close coordination and joint activities exist in all (including RL) Communications, Command, Control, Computers and Intelligence (C⁴I) thrust areas. The relationships to these C⁴I areas are addressed in a number of MOAs covering the areas of radar/Electro-Optical; Infrared (IR) detection and tracking; C³ countermeasures; electronic technology; and artificial intelligence. Agreements have been reached between WL and Phillips Laboratory for specific efforts to be performed to support future advanced development in the Space and Missile area. In the area of laser and laser applications development, additional coordination and joint service and lab planning are conducted through the DoD Advisory Group on Electron Devices laser subpanel and the DoD Sensors and Electronics DTAP. Support

is also provided from the Physics and Electronics areas to the semiconductor research efforts under the Electron Devices Thrust.

A main interface of the Targeting and Attack Avionics Thrust with the Geophysics area, is the development of Tactical Decision Aids and the Ballistic Winds program. Avionics efforts interface with the Advanced Weapons activities in High Power Microwaves, Lasers, and Global Positioning System (GPS) for precision guidance. The Air Force Office of Scientific Research (AFOSR) provides research support from their Life Sciences area to Avionics in neural networks and vision. Support is also provided from the Electronic and Materials Sciences areas to the semiconductor research efforts under the Electron Devices thrust.

The Space Technology Interdependency Group (STIG) Microwave and Millimeter Wave Electronics Subcommittee has identified packaging and interconnect technology as a new area of inter-dependency, with a present focus on packaging of multichip modules for phased array antenna applications. This STIG Subcommittee includes members from WL, RL, Army Research Laboratory, Naval Research Laboratory, and NASA in solid-state and vacuum electronics.

CHANGES FROM LAST YEAR

There have been considerable changes in avionics programs as a result of budget reductions, DoD and Air Force downsizing, changes in Air Force priorities, international changes in threats, lessons learned from Desert Storm, and sharply focused investment planning as described earlier.

The Air Force is leading a tri-service effort for the development of a DoD science and technology strategy for developing avionics for new and retrofit aircraft. The strategy focuses on implementation or integration technologies required to achieve affordable improvement in avionics performance. The strategy is being coordinated with operational users to assure high priority needs are satisfied and with industry to assure realistic and achievable technology goals are established. The initial version of the strategy will be available in May 1996.

The First Joint Service (Air Force, Army and

Navy) Avionics S&T Briefing to Industry (BTI) was held 22-24 August 1995 in Dayton, Ohio. The goal was to enhance the working relationship of the Government and Industrial Avionics R&D teams by (a) providing a focus for increased IR&D efforts on Avionics Related programs, (b) encouraging an exchange of information between Government and Industry and (c) providing insight into the Air Force, Army, and Navy's technology programs and goals. This is a planned event with each service hosting it on a rotating basis.

There is increased focus on integrated radio frequency (RF). An integrated modular architecture offers significant potential cost, weight, and volume savings for future aircraft and retrofit applications. There is also an increased focus on the area of functional integration, with a goal of making avionics more affordable by integrating offensive, defensive, and Communications, Navigation, and Identification (CNI) functions, databases, and off-board information sources.

In order to improve avionics systems integration research and testing capabilities, the Avionics Directorate is continuing its efforts to link three of our major research laboratories together. The three-laboratory complex is made up of the Integrated Test Bed (ITB), the Integrated Electromagnetic System Simulator (IESS), and the Integrated Defensive Avionics Laboratory (IDAL). The overall concept for developing this complex is called the "Avionics Wind Tunnel," and the second of four planned demonstrations is being planned. Additionally, a Distributed Interactive Simulation (DIS) node is being integrated with this inter-laboratory simulation complex to provide a gateway to other national simulation and testing resources.

The emphasis on design, modeling, and simulation will be increased in three key areas. The focus will shift from developing design automation technology oriented to new systems to developing new tools and approaches that will support the AF's number one design problem -- retrofitting and reengineering the electronics of legacy systems. A second effort will assure that the simulation models most needed for Air Force systems, including those for commercial off-the-shelf (COTS) parts, will be readily available for system designers. A third focus on macro-function generator technology, will make more choices for different speeds, sizes, and power factors available to the application of the specific circuit designer.

Information Fusion for avionics was added as a new subthrust under the System Avionics thrust last year and will be a part of the newly formed Combat Information Division. Target Modeling, Automatic Target Recognition (ATR), and Reference System work will be part of this subthrust. In the specific area of laser and laser applications development, additional coordination and joint service and lab planning are conducted through the DoD Advisory Group on Electron Devices laser subpanel and DoD Sensor and Electronics DTAP.

THRUST #1: TARGETING AND ATTACK AVIONICS

USER NEEDS

The Targeting and Attack Avionics Thrust develops technologies critical to resolving deficiencies within the following user developed Mission Area Plans (MAPs): Strategic Attack/Interdiction, Counter Air, Theater Missile Defense, Electronic Combat, Surveillance/Recce, and Special OPS Combat Support.

Based upon the deficiencies within these MAPs, the needs relative to targeting and attack are:

Targeting and recognizing ground-based mobile and fixed hard targets.

- Stand-off capability
- Delivery of multiple weapons on a single pass
- Accurate medium and high altitude weapon release
- Quick reaction capability against short dwell surface missiles
- Adverse weather detection, targeting, identification capability
- Improved situational awareness

Increased detection/targeting range of airborne targets.

- Counter-countermeasures
- Weapon kinematics, maneuverability
- Ability to deploy and support weapons without entering the lethal range of the threat
- Survivability by providing first look, first shot, first kill before the enemy's weapon system is enabled
- Improved situational awareness
- Hostile target identification capability
- Detection and targeting of low observable threats

GOALS

The objective of the Targeting and Attack Avionics Thrust is to develop and transition, into operational combat systems, superior avionics technology to find, identify, and destroy enemy targets--anywhere, anytime, and in any weather. This includes the development of modular, multifunctional sensors for less expensive, easily upgradable, high performance targeting and attack avionics. Specific goals

are identified below for three principal areas of technology investment: Counter Air, Air-to-Surface, and Visionary Capabilities.

Counter Air

Unambiguous situational awareness

- Beyond visual range air target detection and identification
- Detection and targeting of low observable threats
- Sustained sensor performance in jamming/ clutter environments

Enhanced weapon system effectiveness

- Improved targeting accuracy
- Cooperative engagement

Air-to-Surface

Precise targeting of surface threats

- Deny adverse weather "sanctuary"
- Defeat concealment (camouflage & foliage)
- Discriminate decoys

Enhanced weapon system effectiveness

- Precise weapon aiming
- Maneuvering targeting and weapon release for increased survivability
- Multiple kills in a single pass
- Real-time assessment of target damage/mission success
- Increased stand-off ranges
- Mid to high altitude weapon employment
- Sustained sensor performance in jamming/ clutter environments

Visionary Capabilities

Mission-adaptive weapon systems

- Multifunction shared apertures
- Integrated offensive/defensive sensors
- Threat-adaptive target detection
- Model-based vision (MBV) "smart sensing"

Enhanced weapon system affordability.

- Electronically scanned sensors
- Low cost adaptive architectures
- "Reusable" software for sensor management and target recognition
- Automated scene/target rendering for mission planning and rehearsal
- All solid-state electro-optical (EO) sensors

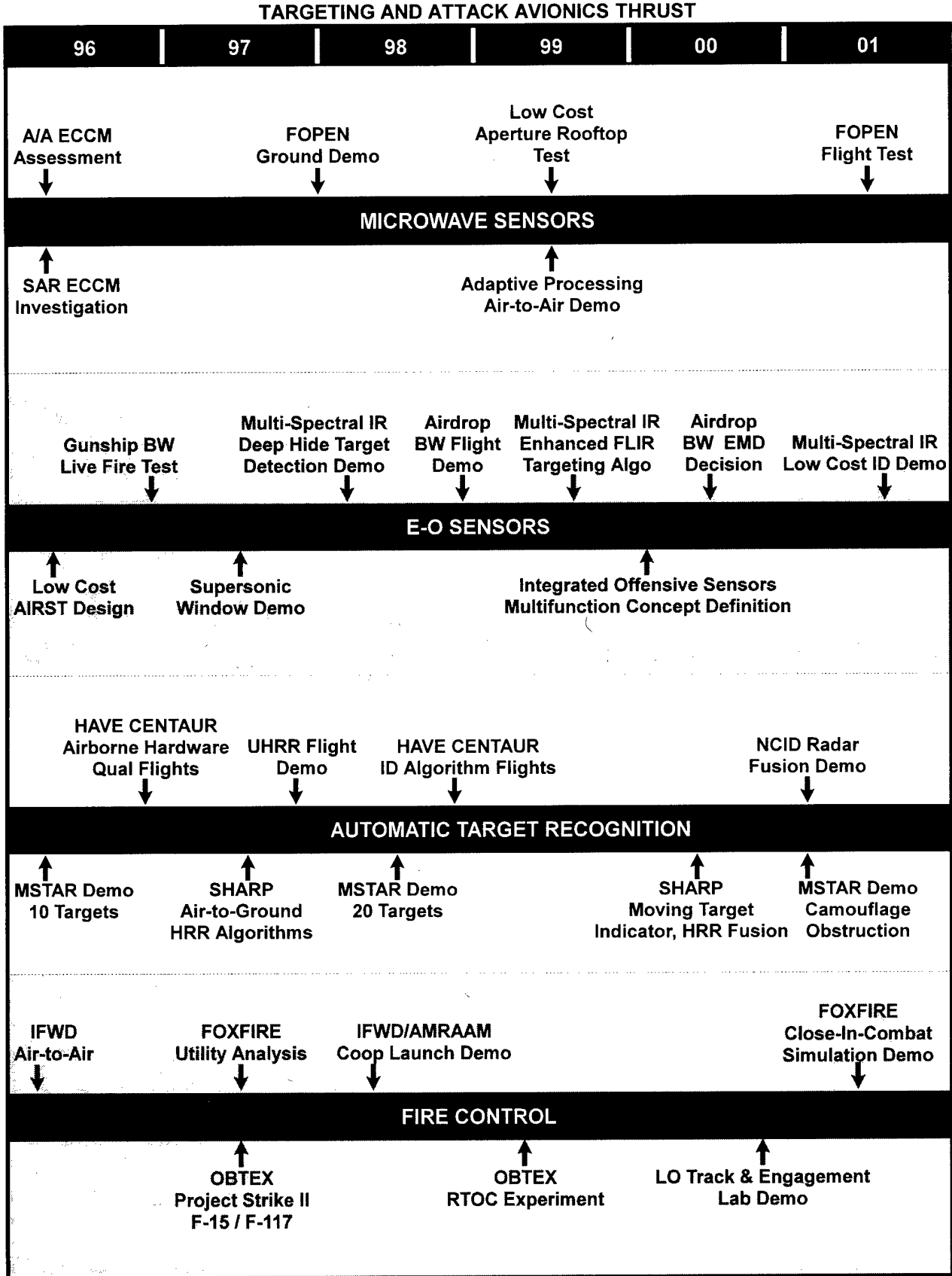


Figure 6: Targeting and Attack Avionics Roadmap

MAJOR ACCOMPLISHMENTS

Major accomplishments made toward meeting user needs are shown below. They are organized (as is the rest of the thrust) by the four subthrusts for investment: 1) microwave sensors, 2) electro-optical sensors, 3) automatic target recognition, and 4) fire control.

Microwave Sensors: The feasibility of utilizing adaptive processing techniques to perform detection of conventional and low cross-section threats was demonstrated in a dynamic electromagnetic interference environment. A six degree of freedom solution for all-aspect waveforms with a 10-12 dB cancellation improvement was completed. This technology is necessary for development of next-generation fighters and bombers.

Foliage Penetration Radar work was aimed at developing technology to detect and classify targets that are in deep hide or camouflaged. In the recent past, field experiments that verified acceptable signal attenuation and phase distortion through foliage at frequencies below 1 GHz were completed; extensive flight test data was collected; and promising automatic target detection and classification algorithms based on high resolution imaging polarization, angle diversity, and change detection were developed.

Another area of increased interest and investment is the development of low cost radar technologies for both aging and new aircraft platforms. A study was completed that identified radar architectures providing the required performance and improved reliability and maintainability while reducing overall system cost. The report generated from the study is entitled "Advanced Low Cost Architecture RADAR (ALCAR) Report."

Electro-Optical Sensors: The airdrop Ballistic Winds program uses an eye-safe laser radar to measure 3-D wind profiles. An airborne laser wind profiler was flown for the first time in May 95 and more recently airdrop experiments were successfully flown on a C-141 at the Yuma Proving Ground.

Fabrication was completed of full-scale, coated panels for an infrared (IR) window capable of

operation in a sustained supersonic environment. The window will complete wind tunnel evaluation to characterize window performance and durability in FY97. This window is the highest risk technology involved in the insertion of advanced IR search and track sensors into airborne weapon systems.

Automatic Target Recognition: Target recognition technology for long range, all aspect non-cooperative identification of air targets is being transitioned to an Air Combat Command (ACC) 6.4-funded flight demonstration. Most critical to the combat utility of this capability was the achievement of a technology breakthrough for rapid rendering of synthetic target signatures. This technology has been adopted by the intelligence community to support the target recognition efforts of other services, as well as threat definition/validation activities. A "turn-key" system to produce synthetic signatures will transition to the intelligence community in FY98.

Fire Control: Real-time targeting information in the cockpit (RTIC) is a revolutionary concept exploiting the benefits of utilizing information from off-board sensors for precision air-to-surface attack. Technologies being developed will provide the warfighter the targeting solution required to deploy weapons against both stationary and moving ground based targets while minimizing the need to employ on-board sensors and increase platform observability. A series of three F-15E demonstrations were performed in the last year and near real time preparation of a variety of RTIC data products including annotated imagery, scene renderings, precision coordinates, and weapon templates was accomplished.

CHANGES FROM LAST YEAR

FY96 represented a year of tough investment decisions for the Targeting and Attack Avionics Thrust. In FY96, the thrust dealt with the unavoidable cost growths of high priority demonstration programs. In the area of Electro-Optical Sensors, the Affordable Sensors Technology for Aerial Targeting (ASTAT) effort was terminated. This program was to address issues directly affecting the development and transition of IR sensor technology to operational systems—cost, size, weight, and complexity are excessive for a single-function sensor in

fighter applications. This termination was a direct result of the cost growth of the Gunship Ballistic Winds demonstration program.

It is also important to note that the Targeting and Attack Avionics Thrust has suffered a 35% reduction in its 6.3a budget across FY95-01 due to POM reductions and ramp management. These reductions will cause long-term impacts in the ability of this thrust to provide affordable technology solutions to find, identify, and attack enemy threats at anytime, in any weather.

On a positive note, the Avionics Directorate and Defense Advanced Research Projects Agency (DARPA) will be working together toward furthering Model-Based Vision (MBV) technology development and supporting infrastructure. Rapidly evolving plans represent an acknowledgment by the Joint Service automatic target recognition (ATR) community (including recce/intel customers) that the MBV discipline, pioneered within the Targeting and Attack Avionics Thrust, provides the best long-term approach to fielding critically needed ATR capabilities that are reliable and supportable.

MILESTONES

Four investment areas are used to outline plans and significant milestones within the Targeting and Attack Avionics Thrust: (1) microwave sensors, (2) electro-optical sensors, (3) target recognition, and (4) fire control.

Microwave Sensors

Development of microwave sensor technology focuses on beyond-visual-range detection and identification of conventional and low observable air targets operating in severe jamming and ground clutter environments. It also focuses on wide area search, detection, and recognition of ground targets under adverse weather conditions and concealment by camouflage and foliage.

Using target and background clutter data and mission analysis accomplished in preceding efforts, the Concealed Target Detection program, jointly conducted with DARPA, will complete critical design of algorithms for wide area detection and classification of targets concealed by camouflage and foliage. In FY96, this effort will perform data collections to vali-

date algorithm performance. This will lead to the development of a sensor specification for a flyable brassboard sensor to verify detection performance in FY98. Success criteria include detection of more than 80 percent of concealed targets with near-zero false alarms.

Continued development of radar electronic protection (EP) techniques is critical to assure the warfighter sustained radar performance within expected dynamic electromagnetic interference environments of the future. The strategy for this investment is to concentrate on low cost, software-based solutions for quick upgrade of operational systems. During FY97, synthetic aperture radar (SAR) Electronic Counter-Countermeasures (ECCM) techniques will complete development and undergo data collection against the target electronic warfare (EW) threat. Success will be evaluated through the ability of the radar system to maintain detection and track capabilities in the presence of the EW threat.

In support of the visionary capability, low cost radar technologies, sensor architectures, and apertures are being explored. Specific emphasis is being given to development of adaptive processing techniques to accommodate difficult ground clutter conditions, enemy barrage noise jamming, low radar cross-section (RCS) targets, and unique radar installations within our own low observable aircraft.

Electro-Optical Sensors

While unable to perform within adverse weather environments, EO sensor technologies offer the unchallenged advantages of stealth and precision for pilotage, target identification, weapon aiming, obstacle detection, and short range environmental sensing. An additional advantage relates to human factors--rate of sensing and relative ease of image interpretation. During FY96, EO investments will exploit these advantages for covert pilotage with simultaneous target search, target/decoy discrimination, identification, and wind-corrected delivery of weapons and cargo.

The focus of the redirected Advanced Infrared Search and Track (AIRST) program is to complete fabrication and laboratory evaluation (FY96) of full-scale panels for a low RCS IR window for sustained supersonic speeds; conduct cost/performance design trade-offs; and develop end-to-end simulation and modeling tools.

Successful experiments (FY95) in wind profiling using laser radar provide the technical confidence for follow-on demonstration with Air Force Special Operations Command (AFSOC) and Air Mobility Command (AMC). Specifically, the ability to provide three-dimensional wind corrections to the Gunship AC-130 fire control solution for an increase in lethality while operating at higher altitudes and at longer stand-off ranges will be tested during FY96. Also in FY95-98, improvements in high altitude cargo delivery wind profiling will be developed and demonstrated. This will be accomplished through the Joint Avionics and Flight Dynamics Precision Airdrop Advanced Technology Demonstration (ATD).

The Joint Multi-Spectral Sensor Program (JMSP) will develop the technology required to perform passive, wide area search, detection, cueing, and targeting while defeating camouflage, concealment and deception. This technology may also support the warfighter's need for a bomb damage assessment capability. In FY96, JMSP will collect multi-spectral data and evaluate targeting algorithm performance.

Laboratory experiments and concept studies will build the foundation for improved visionary EO sensors for unambiguous situational awareness including detection and identification of targets and decoys. Multispectral sensing, integrated active/passive sensors, multifunction sensing architectures, and more affordable/reliable EO sensor systems will be explored.

Automatic Target Recognition

Noncooperative identification of air targets and recognition of surface targets requiring wide area search and decoy discrimination including threats buried in foliage or concealed, are the principal challenges for this investment area. The rapidly evolving discipline of MBV invokes the tools and processes of target, background, and environment modeling, smart sensing, and hypothesis testing. Frequently misunderstood to be an ATR "algorithm" alternative, MBV provides a scientific framework for synthesis, application, evaluation, and mission support for all ATR algorithms. This approach, pioneered by the Wright Laboratory Mission Avionics Division, is now widely accepted and being pursued cooperatively with members of other services, industry, other Government laboratories, universities, DARPA, and the intelligence community.

All aspect angle, long range noncooperative identification of air targets will be a near-term success for the MBV process. Target recognition algorithms and supporting target signature databases have been developed in accordance with the MBV discipline. Performance validation of the algorithms is on-going and will transition to operational testing under ACC 6.4 funding when appropriate. Synthetic target signature generation capability will occur in the FY96-98 time frame. The success of the transition will be judged by the ability of the 6.4 program to integrate the algorithms and signature database into an operational radar system, and to perform long range, high confidence identification with low false alarm rates.

Other MBV successes relate to the problem of recognizing stationary and mobile surface targets. Using the same MBV principles and target signature prediction tools cited above for air target identification, synthetic signatures of surface targets can be predicted for high resolution SAR imagery. Already usable, to a limited extent, by the intelligence community for threat definition/validation, the same signatures provide reference models for maturing ATRs. Groundbased experiments will be conducted during FY96 to quantify performance of existing algorithms to support automated target cueing within U-2R, Moving and Stationary Target Acquisition and Recognition (MSTAR), and Theater Missile Defense (TMD) applications.

This technology will also provide the ACC TMD program with the ability to locate, identify, and attack massed armor, theater missile launchers and supporting infrastructure. In FY98, this effort will complete demonstration of an integrated radar and Forward Looking IR (FLIR) equipped with an automatic target cuer/recognizer for precision target detection and cueing.

Future investments will explore the use of MBV principles as a framework for automation of "situation determination." Preliminary (but superficial) assessments of this vision indicate MBV methods of evidence accrual and hypothesis formulation are directly usable for reduction of crew-member workload and decision timelines.

Fire Control

This investment area serves to integrate the products and capabilities of this thrust's "target finding" technologies, off-board targeting sources, and weapons to complete the function

of "target engagement." Improved probability of kill, longer range/first shot engagement of air targets, cooperative attack, multiple kills per pass, workload reduction, and enhanced survivability are the primary mission drivers for this area.

Concepts for improved accuracy of missile targeting and cooperative launch are being explored to enhance weapon system employment flexibility. Being sought is the ability to release air-to-air missiles at maximum range and to support weapons in flight for a first shot/kill capability without entering into the lethal range of the threat aircraft. Concepts conceived during FY95 will undergo engineering analysis in FY96-97. Metrics for success are the ability to cooperatively launch and support air-to-air missiles and improvements in weapon system accuracy.

Cooperative attack fire control continues to be an area of significant payoff in terms of fire control effectiveness for reduced weapon system cost and number of weapons needed to destroy a target. Fire control concepts for upgrade of air-to-air and air-to-surface subsystems through the use of all available targeting information are being evaluated. These concepts are in the early stages of formulation with the potential technology validation experiments in FY00.

THRUST #2: ELECTRONIC WARFARE TECHNOLOGY

USER NEEDS

The Electronic Warfare Thrust develops technologies critical to resolving penetration and survival deficiencies within the following user-developed Mission Area Plans (MAPS): Electronic Warfare, Counter Air, Close Air Support, Strategic Attack/Interdiction, Missile Warning, Air Mobility, Surveillance/Reconnaissance, Intelligence, Theater Missile Defense, Combat Delivery, Rescue, Air Base Operations, Flying Training, and all Special Operations Mission Areas.

Deficiencies in the area of Electronic Warfare are classified; however, general user needs fall into the following categories:

- Accurate threat warning and combat identification in all portions of the frequency spectrum to aid situation awareness and reduce fratricide
- Affordable, timely, and precise ground emitter location through a wide frequency spectrum.
- Defeat of infrared (IR)/laser guided missiles by on-board/off-board countermeasure (CM) concepts
- Affordable warning of missile threats regardless of guidance method (IR, semi-active radar or active radar seekers) and at maximum possible range to cue CMs and alert aircrews
- Defeat IR target trackers that give SAMs, MANPADs, and AAA a day/night capability
- Denial of effectiveness of radar controlled threat weapons through use of on-board/off-board CMs
- Improvement of support CMs through CM payload improvements of both manned and unmanned air vehicles (UAV)
- Electronic attack of advanced modern digital autonomous and netted ground/airborne command and control systems
- Denial of the use of advanced navigation aids by threat systems

Goals

The mission of this thrust is to develop and transition into operational combat systems, effective and affordable electronic warfare (EW) technology that will assure aircraft penetration, survivability and mission accomplishment. This requires technologies providing aircrew threat

alert and effective CMs against current and evolving threat weapon systems in a wide variety of mission scenarios. When applicable new avionics models and simulations using DoD standards will be developed. As an information player, this thrust promotes a philosophy of open-architecture integrated avionics. Six major areas of technology investment and their goals are summarized below.

Radar/Missile ECM

- Develop effective, robust, radar CMs to Keep Missile on the Rail (KMOR)
- Develop advanced techniques to counter radio frequency (RF) missiles in the end game.
- Evaluate electronic countermeasures (ECM) against exploited foreign threats
- Develop advanced technology to assure affordable and reliable solutions

Missile/Laser Warning

- Develop affordable missile warning
- Improve detection of low and suppressed IR signature threats in dense IR clutter
- Develop approach for combined functions of missile warning, navigation and defensive IR Search and Track (IRST)
- Demonstrate combined functions in a flight demonstration with distributed apertures and real-time processing
- Develop laser warning capability for CMs and aircrew protection

Situation Awareness/Threat Alert

- Improve aircraft field of view coverage for high priority signal detection, precision location and combat identification
- Develop data fusion of on-board and off-board data to enhance situational awareness
- Provide Real-Time Information in the Cockpit (RTIC)
- Exploit advanced processing technology to assure affordability of situational awareness capabilities

Infrared Countermeasures

- Develop deceptive jamming IR countermeasures (IRCM) to assure future survivability against advanced IR missiles
- Develop CM techniques for electro-optical (EO) and laser threats
- Conduct seeker exploitation to assure technique effectiveness against counter-countermeasure (CCM) circuits

Electronic Warfare Technology

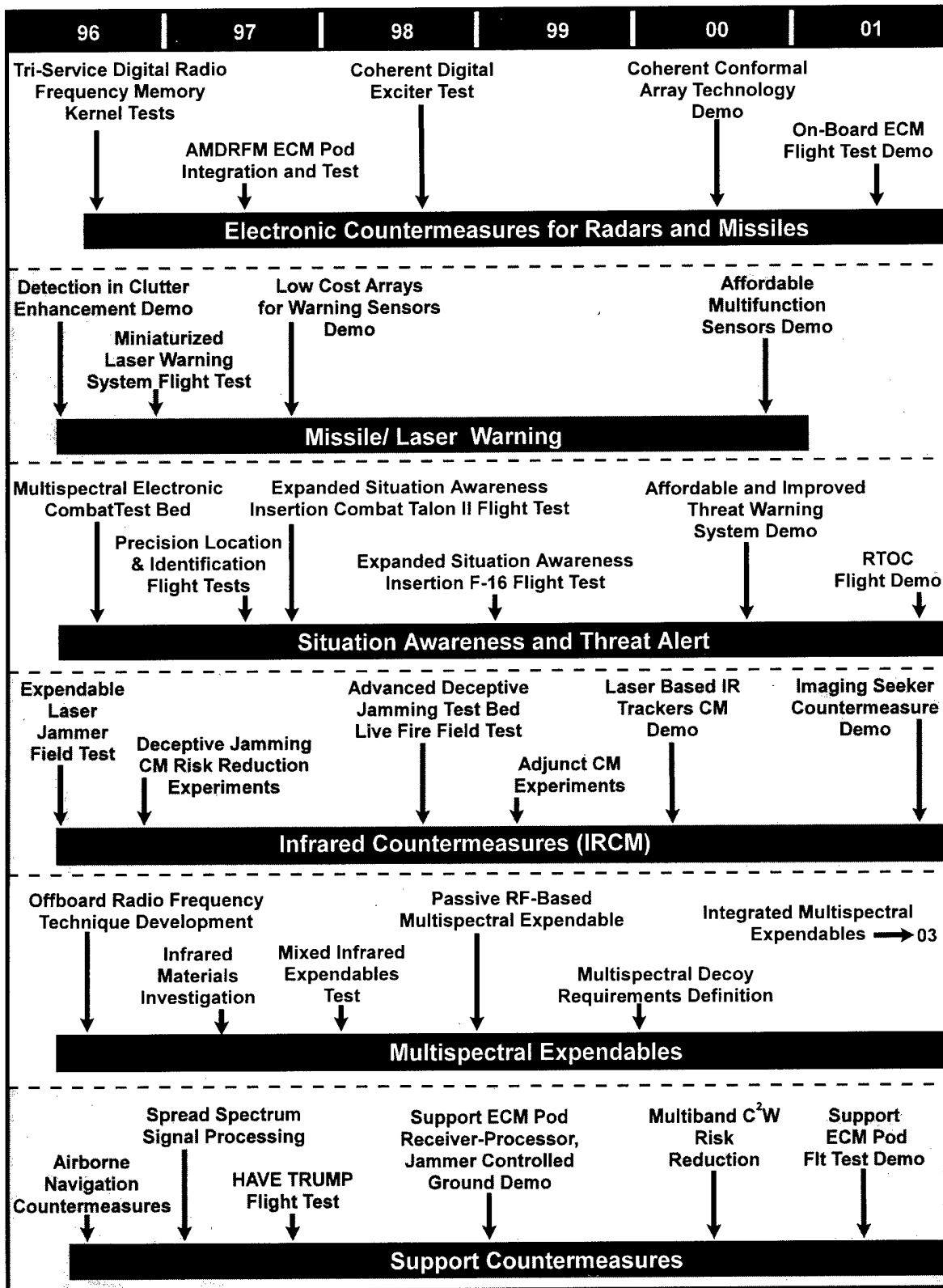


Figure 7. Electronic Warfare Technology Roadmap

Multispectral Expendables

- Develop active and passive RF decoy techniques and technologies which effectively defeat the missile threat
- Develop IR decoy technology
- Develop dual mode IR/RF decoys to effectively degrade missile seekers using either or both portions of the spectrum

Support Countermeasures

- Detect, exploit and counter modern digital command and control information distribution systems
- Develop electronic attack of threat airborne navigation and identification signals
- Base electronic attack developments on commercially available technology
- Develop means to stimulate threat radar network via electronic payloads on UAVs
- Develop jamming technology to degrade early warning and ground control intercept radars

This thrust's ultimate vision is to continually provide timely, prioritized, and effective solutions to meet User's EW operational needs. This requires continuing baseline research into new concepts against evolving threats to assure the enemy cannot benefit through "surprise" threat technology. Baseline technologies will be translated into solutions for real needs through a timely, highly focused program of work.

Major Accomplishments

Radar/Missile ECM: The Advanced Monolithic Digital RF Memory (AMDRFM) was enhanced to include multiple DRFMs on a single chip and run at a clock speed up to 100 MHz. Multiple Digital RF Memories (DRFMs) on a single chip provide capability for handling multiple threats. AMDRFM enhancements continue with the ultimate goal of providing an affordable coherent jamming capability for all current and future ECM systems.

Missile/Laser Warning: The Silent Attack Warning System (SAWS) hardware and algorithms transitioned to the Ballistic Missile Defense Organization (BMDO) Eagle program. SAWS will save BMDO \$25M and 3 years development time in the accelerated Engineering Manufacturing Development (EMD) program leading to a production decision within 5 years.

Improved clutter rejection algorithms were dem-

onstrated for staring IR warning systems that will provide a 2X improvement in detection range in highly cluttered backgrounds.

Laser effects phenomenology and modeling efforts were conducted against an F-16 with Air Combat Command (ACC) aircrews on the Wright Laboratory Aircraft Turntable Facility. This work is in support of the Precision Guided Munitions (PGM) program involving Wright Laboratory (Avionics and Materials Directorates), Armstrong Laboratory, and the Air Staff. The results will guide eye protection and CM technology development used to provide warning and cueing against lasers on the battlefield, such as laser rangefinders and the laser beamrider missile.

Situation Awareness/Threat Alert: Classified Random Agile Deinterleaver (RAD) sort and Identification (ID) algorithms were transitioned for NSA use and continue to be incorporated into fielded Radar Warning and RF Jamming systems (ALR-46, 69, 56C&M, and ALQ-172). The militarized, open architecture, low cost commercial-off-the-shelf (COTS) Real-Time Symmetric Multi-Processor (RTSMP) offering 100x processing improvement capabilities for EW/avionics systems was transitioned. Its pre-processing design was incorporated into the F-22's EW system and partial specifications were used for the Joint Strike Fighter (JSF) avionics architecture. The RTSMP also served as the enabling technology for the highly successful Project Strike B-1B flight demonstrations.

The ACC and Space Warfare Center's Project Strike B-1B initiative demonstrated for the first time RTIC on an operational B-1B bomber. Information from aircraft, satellites and other platforms were delivered via communication satellites to the B-1B aircraft. Using Advanced Defensive Avionics and Response Strategy sensor/data fusion software and the RTSMP for final on-board processing, threat, weather, navigation and target updates (including imagery) were displayed real-time at the Defense Systems Officer and Offensive Systems Officer (DSO/OSO) stations for threat avoidance, crew situational awareness and mission retargeting purposes.

Infrared Countermeasures: An improved process using graphical program tools to perform IR missile seeker exploitation has been developed. Quality exploitation reports and detailed digital threat models are now available in 12-14 months. This seeker exploitation work previously took 2 to 3 years.

Initial countermeasure capability for adjunct IR trackers was demonstrated by open and closed loop jamming techniques against the Chaparral tracking Forward Looking IR (FLIR).

Extensive open-loop and closed-loop CM algorithm data runs were accomplished against semi-active laser guided weapons. Laser guided bomb drops against a CM were conducted at Eglin AFB. Joint AF/Army live-fire field tests were successfully conducted at Redstone Arsenal utilizing TOW2 missiles to simulate laser beamrider missiles. In these field tests, effective jamming CM power levels were determined.

A quick response In-house program was initiated to an Office of the Secretary of Defense (OSD) and US Special Operations Command (USSOCOM) request to evaluate existing laser source technology to support a near term demonstration of a laser capability in the Defensive IRCM (DIRCM) system. EMD testing will occur in mid FY97. Doubled CO₂, Optical Parametric Oscillator (OPO), and Semi-conductor lasers were evaluated for CM effectiveness against a wide variety of reticle threats. System insertion and supportability issues were examined.

Multispectral Expendables: Support of an Air Mobility Command (AMC) Urgent Need for advanced flare testing was accomplished. This included flare modeling, simulation, and flight testing. This effort quickly identified effective IRCM flare techniques for the C-17.

Initiated both an exploratory development (6.2) effort to investigate promising special IR materials with kinematic properties applicable to USAF aircraft for next-generation flares and an advanced development effort (6.3) to develop a "family" of IR decoys.

An effort to investigate and develop off-board RF countermeasures (RFCM) techniques, based upon a distributed architecture decoy (DAD) approach, was initiated.

Multiple efforts to develop advanced RF power modules for towed RF decoys were initiated. This included both traveling wave tube (TWT) and solid state amplifier developments.

Participation in NATO Trial Mace VII ECM flight testing at Sardinia, Italy, resulted in RF chaff measurements of wide benefit to NATO.

Support Countermeasures: Demonstrated effective CM against specific targeted communica-

tion links in a real-world environment. Provided direct support of JTF95 I and II operations with field deployable CM.

Changes From Last Year

Major changes from last year are increased emphasis in the IRCM, Support Countermeasures, and Situation Awareness/Threat Alert technology investment areas. This increased emphasis is based on extensive user community inputs and includes cooperative programs with other AF laboratories, Army and Navy organizations.

IRCM program changes ensure CM developments that can effectively and affordably defeat the entire spectrum of multiple advanced EO/IR threats including the imaging seeker. IRCM is now the OSD's Technology Area Review and Assessment (TARA) team's #1 priority within the EW area. The Laser Infrared Flyout Experiments (LIFE) program (ACC's #3 rated and Air Force Special Operations Command (AFSOC's) #5 rated AFMC/ST Advanced Technology Demonstration (ATD)) addresses large aircraft IRCM deficiencies for AMC, AFSOC, and ACC. All IRCM programs take full advantage to build upon Army and USSOCOM EMD IRCM programs including the Common Missile Warning System. The Missile/Laser Warning subthrust was significantly downscoped to reflect lower User interest in this area and to provide additional funding for IRCM.

The Support Countermeasures Command and Control Warfare (C²W) area increased investments in the offensive information warfare arena focusing on non-conventional systems and denial of threat systems' advanced navigation aids. C²W is OSD's TARA team's #2 priority within the EW area.

The Situation Awareness/Threat Alert subthrust provided additional funding for RTIC technologies and their eventual transition to the operational forces. The Expanded Situation Awareness Insertion (ESAI) program (ACC's #1 rated and AFSOC's #2 rated AFMC/ST ATD) will flight test RTIC technologies for several mission scenarios using both C-130 and F-16 aircraft. Demonstrations include off-board/on-board all-source sensor/data fusion, precision target location, target aiding, battle damage assessment, specific emitter identification, and air crew situational awareness.

In addition to these investment areas, the EW Thrust, awaiting firm direction from HQ USAF and OSD, is poised to capitalize on technological applications for UAV and/or unattended tactical aircraft.

Milestones

Radar/Missile ECM

The first row of the roadmap describes milestones related to Radar/Missile ECM. An out year milestone not shown anticipates an advanced monopulse angle jammer demonstration that integrates all coherent on-board technology with an advanced off-board jammer with the objective of keeping the missile on the rail (KMOR).

- 3Q96 - Reduce the cost and size of DRFM, (a technology vital to the effectiveness of modern CM systems) while producing a single architecture that meets the jamming needs of all three services.
- 3Q97 - Integrate the AMDRFM in an operational jamming system and conduct tests in a simulated threat environment.
- 3Q98 - Evaluate the coherent digital exciter (CoDE) which is the fundamental building block for all future jammers to generate jamming signals against coherent monopulse radars.
- 3Q00 - Demonstrate the coherent conformal array technology to provide advanced ECM antennas that maintain low observability.
- 3Q01 - Demonstrate the effectiveness of an affordable ECM upgrade for operational pods using advanced ECM techniques generated with DRFMs, dual polarized array antennas, microwave power modules (MPMs) and/or monolithic microwave integrated circuits (MMIC) technology.

Missile/Laser Warning

The second row on the roadmap lists four major milestones. Three of these milestones lead to an out year milestone to demonstrate a **significantly lower cost** missile warning system.

- 2Q96 - Demonstration of clutter rejection techniques for detecting passive IR missiles that will double the detection range in a highly cluttered environment while maintaining a false alarm rate of less than 0.2 per hour.

- 3Q96 - Conduct the first airborne trials of a miniaturized laser warning system on a *tactical* aircraft (UK Tornado) to demonstrate multiband threat detection and location and provide the information needed for CM cueing.
- 4Q97 - Demonstrate processor algorithms with uncooled IR detector arrays to recover signal to noise for the reduced sensitivity of uncooled IR detector arrays. Current focal plane arrays require cryogenic coolers that provide increased performance but have multiple drawbacks. The payoff is very low cost IR focal plane arrays to allow low cost IR missile warning systems.
- 4Q00 - Demonstrate multiple function IR sensor with real time processing in a flight demonstration to include missile warning, navigation and defensiveIRST capability in each aperture of the sensor suite.

Situation Awareness and Threat Alert

The third row of the roadmap provides six milestones delineated below for this highly rated MAJCOM subthrust.

- 3Q96 - Provide a multispectral electronic combat laboratory test bed for the development and evaluation of situation awareness/threat alert technology.
- 3Q97 - Flight test Precision Location And Identification (PLAID) hardware/software to demonstrate significantly improved precision threat radar location and specific emitter identification functions.
- 3Q97 - Combat Talon II flights demonstrating off-board/on-board all source data fusion for infiltration/exfiltration profiles emphasizing intent prediction, pop-up threat response, threat precision location and specific emitter identification.
- 1Q99 - F-16 flights demonstrating all source data fusion for Reactive/Preemptive/Hunter Killer Suppression of Enemy Air Defense (SEAD), and Battlefield Area/Deep Interdiction missions.
- 4Q00 - Demonstrate an **affordable, significantly improved** threat warning system against advanced emitters. Substantial cost savings result from the maximum use of MMIC, digital receiver technology and commercial processors.
- 4Q01 - Initial Real-Time information Out of the Cockpit (RTOC) flights demonstrating multi-platform situational awareness, targeting/retargeting, ownship status and battle damage assessment.

Infrared Countermeasures

The fourth row of the roadmap provides milestones for the development of laser-based CMs against IR threats and laser beamrider missiles.

- 2Q96 - Conduct field tests to demonstrate the CM effectiveness of the advanced expendable laser jammer against laser seekers.
- 3Q96 - Demonstrate trailing fiber optical cable CM techniques through flight tests against a typical laser designated missile.
- 3Q96 - Evaluate first generation IRCM systems Advanced Threat IRCM (ATIRCM) and DIRCM, against large aircraft IRCM requirements. Necessary modifications will be identified and programs will be focused to develop appropriate technologies.
- 3Q96 - Conduct deceptive jamming experiments to examine critical areas such as acquisition, pointing and tracking, threat understanding, and CM jam code development and effectiveness.
- 3Q98 - Validate the concept of using closed-loop/open-loop CM techniques as a robust CM for large aircraft through the advanced IRCM testbed evaluated during a live fire field test at White Sands Missile Range.
- 4Q00 - Demonstrate laser-based CM concepts for IR trackers that give SAMs, MANPADs, and AAA day/night target tracking capability.
- 4Q01 - Demonstrate CM techniques against imaging seeker to include jamming, expendables, and cooperative techniques.

Multispectral Expendables

The milestones for this area of the roadmap place primary emphasis on reducing the risk of developing a multispectral (RF/IR) expendable decoy. This leads to an out year 2003 program providing a single expendable to counter seekers using RF, IR or combinations of both. This dual CM approach will provide an increased missile CM capability as well as significant savings in CM acquisition and logistic costs.

- 3Q96 - Investigate and develop robust, novel expendable decoy techniques for RFCM. Technique "merit" is determined by using modeling and simulation tools or hardware-in-the-loop tests.
- 2Q97 - Investigate and test next-generation expendables advanced flare compositions.
- 1Q98 - Integrate and test promising new advances in IR flare techniques and technolo-

gies through the Mixed IR Expendables effort. Prototype expendables will be developed and flight tested against advanced IR seekers.

- 3Q98 - Laboratory demonstration of an advanced, passive RF-based, multispectral expendable concept.
- 4Q99 - Integrate the results of the above efforts, as well as the current and projected applicable threat intelligence, into modeling and simulation tools to determine multispectral decoy requirements definition. The results of these concentrations will then culminate in a risk reduction to integrate both the RFCM and IRCM techniques and technologies into a single expendable that will function within existing CM dispenser systems.

Support Countermeasures

The milestones for this area of the roadmap include developments leading to an outyear program which will demonstrate a capability to find the correct information network worldwide and surgically apply the proper CM techniques. This would deny a specific hostile force access to information that would otherwise help target lethal weapons against our forces.

- 3Q96 - Develop and test a brassboard to surgically deny an adversary's navigation aids without disrupting friendly navigation aids.
- 1Q97 - Develop theory and algorithms for the detection, characterization, and exploitation of spread spectrum waveforms.
- 4Q97 - Develop and flight test a capability to counter specific communication links without affecting other contiguous links (HAVE TRUMP).
- 4Q98 - Develop and ground test a brassboard escort jammer in a pod configuration, and demonstrate a capability to jam and deny operation of the radar elements of an Integrated Air Defense System.
- FY00 - Demonstrate a low risk/risk reduction VHF-UHF communications digital jammer.
- FY01 - Flight test a full system brassboard of a support ECM pod to demonstrate ground network degradation.

THRUST #3: SYSTEM AVIONICS

USER NEEDS

Many user needs have been identified through Air Force Materiel Command's (AFMC's) Technology Master Process, and the joint AFMC/Air Combat Command (ACC) Fighter Configuration Plan. These technology needs flow directly down from the operational deficiencies described by the Major Command (MAJCOM) users. The Scientific Advisory Board Summer Study on Aging Aircraft identified "Obsolescent Avionics" as one of only two high leverage opportunities for extended life of our operational aircraft and AFMC/ST has identified aging aircraft as a thrust area. The System Avionics Thrust develops technologies critical to resolving deficiencies in the following mission areas: Air-to-Surface, Counter Air, Special Operations Mobility of Forces in Denied Territory, Surveillance/Recce/Intel, Electronic Combat, Information Warfare, Mobility, Force Enhancement, Strategic Deterrence, and Modeling/Simulation. Further, these deficiencies have been prioritized across the fighter fleet. Deficiencies relative to System Avionics include:

Inadequate Situational Awareness

- Off-board sources
- On-board sources
- Information processing and fusion

Avionics for covert operations

- Covert penetration
- Passive navigation
- Covert communications

Susceptibility to jamming

- Global Positioning System (GPS)
- Tactical communications

Dissemination of time critical data

- Targeting
- Threat
- Recce/Intel
- Bomb Damage Assessment (BDA)
- Missile Warning

Affordable, flexible, reliable, sustainable, available avionics

- Line Replaceable Unit/Module commonality
- Software design/support
- Two-level maintenance
- Open/hybrid architecture

Avionics for aging aircraft

- Integrated modular avionics across fleet
- Integration technology for legacy systems

GOALS

The objective of the System Avionics Thrust is to develop and transition into operational combat systems superior integrated avionics for full-spectrum offensive, defensive, and Communication, Navigation and Identification (CNI) operations. The technologies pursued in this thrust find pervasive application across the full range of combat missions and operational aircraft. The specific goals, as related to the deficiencies, reflect benefits to be achieved for the most stringent/demanding of requirements. Significant avionics cost, size, and weight savings have been shown for fully-fitted multiple-role aircraft. Benefits to other platforms, aging systems and related mission areas are scalable.

Inadequate Situational Awareness

- Increase situational awareness - 10 fold
- Incorporation of off-board sources
- No mission impacts due to Operational Flight Program (OFP) anomalies
- Flexible/low-cost/open architecture signal & data processing
- No mission impacts due to run-time failures
- Fault-tolerant, commercial off-the-shelf (COTS) based processors - 98% fault coverage built-in-self-test (BIST)
- Improved avionics with machine intelligence

SYSTEM AVIONICS THRUST

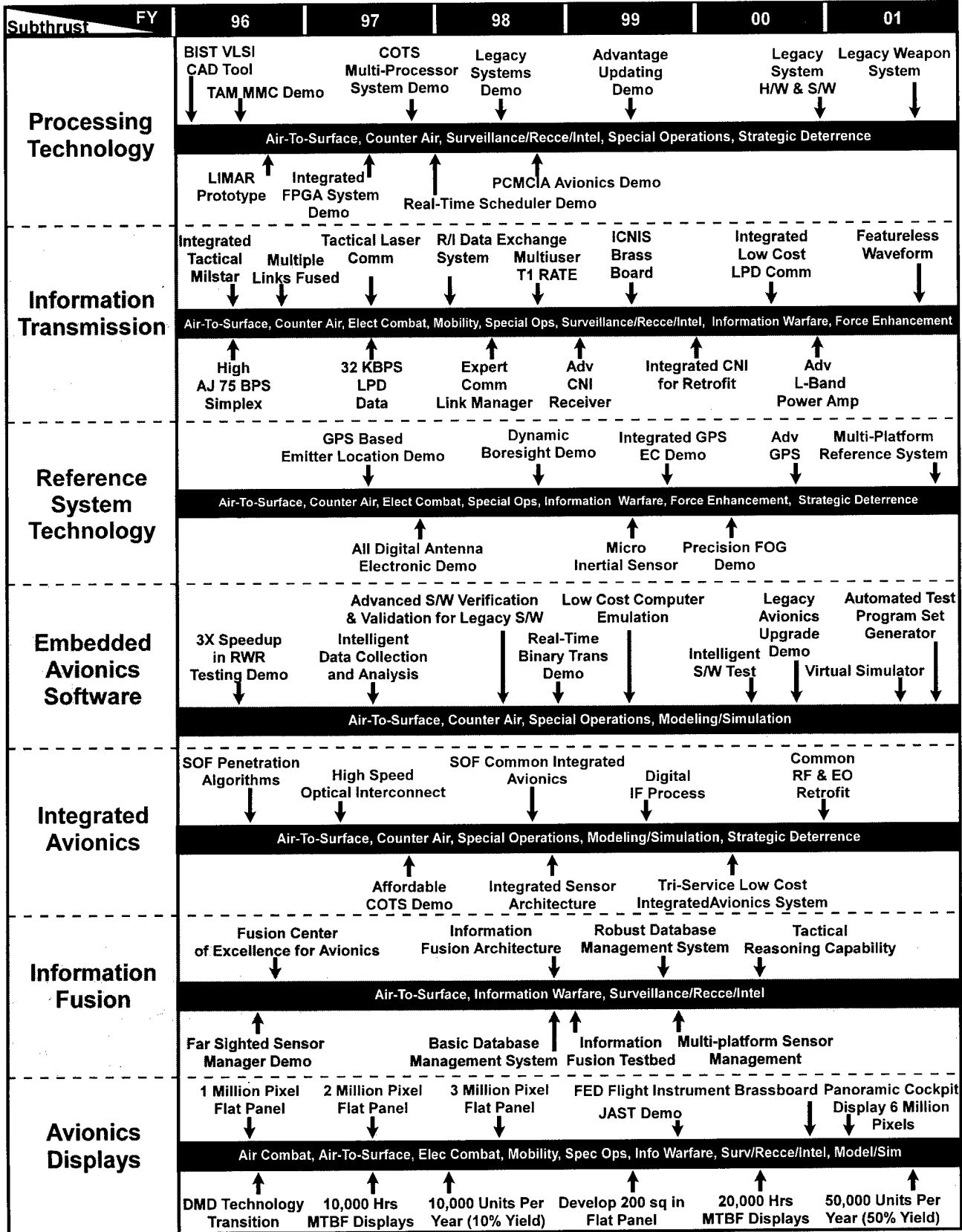


Figure 8. System Avionics Roadmap

- Improve displays for form, fit, function retrofit (F²R) to existing aircraft and use in advanced aircraft. These displays will be fully sunlight readable (>200FI) and have a 30-100 fold mean-time-between-failure (MTBF) improvement over today's electromechanical (EM) and cathode ray tube (CRT) displays.
 - large area (200-300 sq. in.), high definition (>1280x1024 color pixels), high situational awareness (SA) Active Matrix Liquid Crystal Display (AMLCD)
 - Digital Micromirror Device (DMD)
 - Gas Plasma (GP) Display
 - Field Emissive Device (FED)
 - Flat panel cockpit displays

Avionics for Aging Aircraft

- Improve processor speed 20 times without significantly impacting fielded software - Save \$1.5B

Avionics for stealth operations

- Eliminate "comm-out" operations
- Electromagnetic signature - reduce sphere of vulnerability 80%
- Passive reference system accuracy - 3 fold increase
- High rate data transfer for covert cooperative engagements
- Low cost, low probability of detection voice & data transfer

Susceptibility to avionics jamming

- Jamming susceptibility of communication & reference systems - Reduce 50%
- Fault tolerant, integrated, nonemitting reference
- Jam-resistant, high accuracy GPS receivers

Dissemination of time critical data (in conjunction with Rome Laboratory (RL))

- Target, threat, recce, BDA information dissemination - reduce timelines from days & hours to minutes & seconds
- Shareable database for system-wide exploitation

Affordable, flexible, reliable, sustainable, available avionics

- Emergency changes to OFP - under 24 hours
- OFP test stations - Reduce cost 50%
- OFP test - 100 times faster and 1/10 labor
- OFP development and maintenance - 10 times productivity
- Improve avionics flexibility & availability with reinforcement learning

- OFP block cycle changes - In budget under 1 year
- Avionics weight - reduce 50%
- Avionics volume - reduce 50%
- Reliability - improve 3 fold
- Flight-line maintenance personnel - reduce 20%
- Guaranteed-predictable processing
- COTS technology and standards to reduce avionics cost

MAJOR ACCOMPLISHMENTS

In order to meet the user needs, this thrust is organized into seven subthrusts: 1) Processing Technology, 2) Information Transmission, 3) Reference System Technology, 4) Embedded Avionics Software, 5) Integrated Avionics, 6) Information Fusion, and 7) Avionics Displays.

Processing Technology

- Demonstrated parallel techniques for Very Large Scale Integration (VLSI) BIST providing high fault coverage, low test times, and minimum performance impact via simulations on a portion of a commercial microprocessor.
- Demonstrated real-time software monitorability enhancements to the F-16 Modular Mission Computer (MMC) that aid in isolating flight program errors. This capability is applicable for both lab and flight test use.
- Demonstrated the feasibility of developing Computer Aided Engineering (CAE) partitioning and placement tools for configuring field programmable gate array (FPGA) based processing resources.
- Developed the logic design for an Advanced Avionics Processor (AAP) and simulated execution of an AAP virtual prototype. The AAP concept extends the MIL-STD-1750A specification for 16-Bit data processors to include 32 and 64-Bit wordlengths. This accomplishment is particularly noteworthy because the AAP provides an approach to upgrade avionics processing systems on aging aircraft while retaining the legacy software that represents literally billions of dollars worth of investment in flight tested, proven software.
- Completed the first phase of the COTS-based Real-time Avionics Parallel Computer project. This phase used simulations to investigate the feasibility of using the Scalable Co-

herent Interface (SCI) for multiprocessing in an embedded avionics environment. SCI is the IEEE standard for interconnection. This phase confirmed the potential for applying SCI to some real-time avionics processing requirements and provided the basis for continuing into the second phase.

Information Transmission

- Completed EHF and laser long baseline propagation experiments to establish viability of long range, high rate (1 Gbps) air-to-air data link.
- Initiated Integrated CNI Subsystem (ICNIS) program to reduce risk in transitioning F-22 CNI design to currently fielded aircraft.
- Demonstrated subset of MILSTAT functions operating on integrated CNI assets.
- Completed design and lab test of retrodirective antenna for fast acquisition of narrow beam antennas.
- Completed development of Ada software to correlate/fuse four off-board Intel links; TRAP, TADIX-B (2), and TIBS. This software will transition to the F-22.

Reference System Technology

- Completed integration of a Synthetic Aperture Radar (SAR)/Inertial Navigation System (INS) model with the GPS Navigation Test and Evaluation Laboratory (NavTEL) to perform a wide variety of simulated combat identification missions and to enable "Loose" versus "Tight" GPS/INS integration experiments to quantify the benefits of tight system integration.
- Designed an advanced airframe flexure compensation technique which combines both high and low bandwidth compensation to improve sensor motion correction and weapon delivery.
- Developed real-time, scaled-down, ionospheric model for GPS user equipment to correct propagation delays in GPS satellite signals, thus improving positional accuracy.
- Completed low-cost analysis of next-generation GPS antenna electronics using Wright Laboratory's (WL's) Antenna Wavefront Simulator, which simulates a multi-element antenna array in a dynamic environment. The results are being used by the GPS Joint Program

Office, F-117A System Program Office, and the 746th Test Squadron.

Embedded Avionics Software

- Demonstrated tenfold increase in the number of threats that can be tested for radar warning receivers under the A Digital Avionics Methodology Schema (ADAMS) program. The prototype system was requested by the Special Operations Support Center for ALR-69 testing.
- Demonstrated capability to collect and record radar data in an operational environment under the Data Integration and Collection Environment (DICE) program. The prototype system will remain in operation in an F-15C at Nellis Air Force Base as requested by the 57TG/TG0E and Warner Robins Air Logistics Center (WR-ALC)/LFR.
- Demonstrated rapid and detailed data analysis capabilities of the Avionics Data Visualization Integration System Environment (ADVISE) for the F-16 APG-68 radar using data reduction, data analysis/visualization, expert system, and database management tools.

Integrated Avionics

- Completed Preliminary Design of the Integrated Sensor System (ISS) focused on 50% reduction of size, weight, and power and a 3 fold improvement in reliability for radio frequency (RF) support electronics.
- Completed an investigative study on affordable solutions for avionics through best commercial practices.
- Completed second National Distributed Interactive Simulation (DIS) demonstration with required DIS modes, simulation interface software implemented in Ada, and actual avionics hardware-in-the-loop.
- Completed Special Operation Forces baseline demonstration of low altitude penetration algorithms in the Integrated Test Bed (ITB).

Information Fusion

- Launched a research Center of Excellence in multisource information fusion for onboard avionics initially sponsored by WL and RL, industry, and academia. This Center provides efficient access to "world class" talent to support fusion research.

- Developed general and specific stochastic dynamic programming-based formulations for search, classification, and tracking components of stressful Air Interdiction Mission and air-to-air engagement scenarios. Found that Non-Myopic approaches were more robust than myopic.
- Demonstrated reinforcement learning-based estimation as superior to the extended Kalman filter for fusing INS and GPS sensor information.

Avionics Displays

- Commercialized High definition DMD technology.
- DMD selected as Display Technology of the Year in Society for International Display (SID).
- Demonstrated glass panel alignment and sealing system for rapid FED production.
- Demonstrated laser photolithography for high density microtip fabrication for FED displays.
- Demonstrated full color red-green-blue (RGB) Solid State Laser Light Source.
- Demonstrated three color organic Light Emitting Diode (LED) source for military display applications.
- Demonstrated improved lifetime for organic LED green light source to 5000 hrs.
- Developed temperature-compensated, 8 bit column driver for a-Si and CdSe AMLCDs.
- Developed high resolution 1280 x 1024 pixel, p-Si AMLCD for advanced display system.
- Demonstrated emissions from a thin-film-edge field emitter array on low voltage phosphor.

- Demonstrated new screen technology for high brightness compact laser display.

CHANGES FROM LAST YEAR

WL initiated integrated modular avionics programs for both near and far-term update of aging avionics. A refocused project in the Ad-

vanced Avionics Integration Program Element (PE 63253F), called Integrated Avionics for Aging Aircraft, was formulated to develop and transition common integrated avionics technology across the existing aircraft fleet. This project includes initiatives in integrated CNI, low-cost processor and software upgrade for legacy systems, and application of commercial technology.

The Dynamic Avionics Real-Time Scheduling (DARTS) program was initiated to design a mission driven dynamic task scheduling methodology that guarantees real-time weapon system performance in response to dynamic events throughout the mission.

Binary Translator for Avionics Systems, an FY96 new-start was awarded. This program will focus on the automated translation of OPFs for embedded computers.

The affordable COTS for Aging Aircraft was initiated with considerable interest from industry. This project is in response to Secretary Perry and Dr. Kaminski's memos on "best commercial practices" and "open systems". Industry, through this program, is addressing the use of COTS for currently fielded systems.

The Avionics Displays program is reported under the WL/FI Air Vehicles TAP, Thrust #5, Advanced Cockpit Technology. In addition it is reported here this FY so that the Avionics TAP readers will be fully aware of how resources appropriated to Program Elements controlled by the Avionics Directorate are employed.

MILESTONES

Major milestones in the System Avionics Thrust include the following:

Processing Technology

- FY97 - Demonstrate high performance, low cost, SCI based multiprocessor system using COTS components for selected, embedded avionics applications.
- FY97 - Demonstrate an integrated FPGA based processing system that includes a COTS workstation CAE design tools as well as program developed CAE design tools and FPGA processor board.

- FY97 - Demonstrate capability for increased mission performance through dynamic reallocation of real-time avionics tasks to processing resources while guaranteeing schedulability.

- FY97 - Complete feasibility study for applying commercial Personal Computer Memory Card International Association (PCMCIA) technology to avionics. Build prototype PCMCIA avionics system and evaluate using COTS components.

- FY98 - Complete mission driven dynamic scheduling capability that combines dynamic scheduling techniques with the predictability of Rate Monotonic Scheduling for real-time avionics applications.

- FY98 - Complete prototype militarized PCMCIA system evaluation and determine retrofit strategies for existing aircraft.

- FY98 - Demonstrate incremental 1750A computer upgrade methods to improve throughput and memory while retaining machine code compatibility with legacy software.

- FY99 - Demonstrate flexibility and performance of Advantage Updating reinforcement learning system in stressing avionics application.

- FY01 - Transition legacy computer upgrade methods to weapon system computer for aging aircraft.

Information Transmission

- FY97 - Transition Ada software to F-22 for Real-Time Information in the Cockpit (RTIC) capability.

- FY98 - Demonstrate 1.54 Mbps airborne local area network for secondary dissemination of time critical BDA, threat, and targeting information.

- FY98 - Demonstrate solar blind ultra violet communications breadboard providing non-line-of-sight Low Probability of Detection (LPD) data transfer for aerial refueling and nap-of-the-earth operations.

- FY99 - Demonstrate brassboard of F-22 CNI design adapted to an air-cooled environment for currently fielded aircraft.

- FY99 - Demonstrate low cost modular UHF/VHF receiver. Transition design approach to F-22 for product improvement.

- FY99 - Demonstrate low cost covert, voice and data transfer, real-time adaptive techniques to improve Low Probability of Detection/Jam Resistant (LPD/JR) performance and electromagnetic interference/compatibility.

- FY99 - Complete ICNIS for aging aircraft based upon F-22 avionics design. Demonstrate highly covert voice and data transfer using programmable common modules across the fleet for improved international interoperability, mission reliability, and life cycle costs. Demonstrate an affordable communications system upgrade capability for RTIC, Hostile Target Identification (ID), and Theater Missile Defense.

- FY01 - Demonstrate low cost modular L-Band transmitter for aircraft upgrades.

Reference System Technology

- FY96 - Conduct evaluation of first Precision Fiber Optic Gyroscope (FOG) for high-accuracy passive navigation.

- FY97 - Demonstrate first iteration of navigation-grade, micro-machined vibrating beam accelerometer to lower cost and improve reliability of aerospace inertial reference system.

- FY98 - Flight demonstrate an integrated inertial network providing increased accuracies for ACC precision targeting and strike.

- FY98 - Flight demonstrate low-cost, threat emitter locator for tactical aircraft using GPS, radar warning receivers (RWRs), and short range, air-to-air data link.

Embedded Avionics Software

- FY96 - Demonstrate complete ADAMS system to decrease RWR test setup throughput time by a factor of 3:1.

- FY96 - Demonstrate software design complexity measurement capability for avionics software.

- FY97 - Demonstrate performance measurement capability for avionics software.

- FY97 - Demonstrate Advanced Verification and Validation for legacy avionics software.

- FY97 - Demonstrate capability to detect anomalous avionics behavior and record appropriate data for quick analysis and repair on the ground.

- FY97 - Define a system architecture and process development to allow incremental avionics upgrades. Identify candidate hardware/software approaches that support affordable incremental avionics upgrades.
- FY98 - Provide greatly enhanced capability for avionics software verification and validation.
- FY98 - Complete development on a prototype automated real-time translator for binary-to-binary translation.
- FY98 - Develop technology for simultaneous execution of legacy software with newly upgraded avionics software.
- FY98 - Demonstrate enhanced software debugging techniques for highly optimized Ada avionics software.
- FY99 - Demonstrate JOVIAL-to-Ada re-engineering capability for avionics software.
- FY99 - Demonstrate low-cost capability to emulate computers with automated reconfiguration to improve manpower and resource utilization and reduce software development and weapon system trainer costs.
- FY99 - Adapt commercial operating system and object request broker technology to support incremental avionics upgrades.
- FY00 - Demonstrate the incremental avionics upgrade approach with a significant avionics application.
- FY00 - Demonstrate enhanced capabilities for automatically testing and analyzing weapon system software.
- FY01 - Demonstrate completely reconfigurable weapon system simulation/test system eliminating the need for expensive, individual simulators.
- FY01 - Demonstrate the capability to automatically generate software tests from functional representations of avionics systems for Test Program Set generation.

Integrated Avionics

- FY96 - Perform modeling, simulation and rapid prototyping to validate architectural integrity. Design ISS common RF modules, and initiate embedded control and application software design. Complete demonstration plan, de-

fining signal sources, system control, functionality, operational capabilities, fault injection/recording and post demonstration data capture and analysis.

- FY97 - Fabricate/emulate and test ISS common module types. Code and unit test system control and embedded application software.
- FY98 - Demonstrate common modules, detection and avoidance algorithms, and integrated Ada software approach for fixed and rotary wing Special Operations low altitude penetrating platforms.
- FY98 - Demonstrate affordable COTS interoperability in the real-time avionics simulation environment of the avionics wind tunnel.
- FY98 - Demonstrate low cost in-flight mission training and rehearsal system for Special Operations infil/exfil aircraft.
- FY00 - Demonstrate reconfigurable, geographically distributed simulator environment capable of simultaneous, multiple scenario testing.
- FY00 - Demonstrate low-cost, integrated avionics for an entire avionics suite.
- FY01 - Transition a common RF and electro-optical (EO) system approach for aging aircraft.

Information Fusion

- FY97 - Develop integrated on-board, real-time avionics database management system components including database definition, application program interface specification, object definition, manipulation and control language specifications, and test scenario definitions.
- FY97 - Demonstrate a baseline information architecture for avionics data fusion.
- FY97 - Demonstrate basic, real-time, object-oriented avionics database management system for common data store and sharing data types (sensor, mission, map, track...) across avionics subsystems to improve accuracy and software reuse while decreasing database and application modification time.
- FY98 - Develop and implement information fusion testbed for avionics that will be a WL "Center" for information fusion evaluation competitions and demonstrations.

- FY99 - Demonstrate evidential tactical reasoning capability for use on combat aircraft.

- FY99 - Demonstrate prototype, real-time data base management system with stored terrain, obstacle, feature, and "all source" threat data in a multilevel secure environment.

Avionics Displays

- FY97 - Demonstrate laser based Planar Optic Display (POD) system for B-52 aircraft.

- FY97 - Demonstrate 2-million pixel density for panoramic cockpit display.

- FY97 - Develop 3-million pixel density for panoramic cockpit display technology.

- FY97 - Demonstrate 10,000-hour improved MTBF over current AMLCDs and 10,000 units per year with 10% yield for AMLCDs.

- FY97 - Demonstrate a high resolution/definition front panel UTA mission operator display station.

- FY98 - Demonstrate technology for 2-fold increase in optical efficiency of AMLCDs and demonstrate 15,000-hour MTBF improvement over current displays.

- FY98 - Demonstrate a high resolution/definition front panel UTA mission operator display station.

- FY99 - Demonstrate 3-million pixel density for panoramic cockpit display.

- FY99 - Develop advanced micro machined display engine (AMMDE) with 100,000+ hours MTBF.

- FY00 - Develop high definition flexible display substrate for panoramic cockpit display systems.

- FY00 - Develop large area, single panel 4-6 million pixel panoramic cockpit display.

- FY00 - Demonstrate compact, high brightness > 300 FL HUD using diffractive optical elements and FED.

- FY00 - Demonstrate high brightness FED for aircraft cockpits.

- FY00 - Develop high speed graphics processor to enable UTA vehicle operations.

- FY01 - Demonstrate FED flight instrument brassboard.

- FY01 - Demonstrate 20,000-hour improved MTBF over current AMLCDS.

THRUST #4: ELECTRON DEVICES

USER NEEDS

Over the past three decades electron device technology has provided unprecedented enhancements in the superiority of Air Force weapons systems. New technologies are continually emerging and continued support and exploitation of these technologies is key to satisfying the following future customer needs:

- Reliable radar for all weapons systems
- Real time, low power signal processing and information transfer
- Target recognition/location in adverse weather
- Multiwavelength infrared (IR) countermeasures
- Electronics affordability (reliability, maintainability and supportability)
- Obsolete parts replacement
- Threat warning sensor enhancement
- Electronics integration for affordable multifunction radio frequency (RF) sensors

These technology needs are referenced in the following three Technical Planning Integrated Product Team Documents (TPIPTs):

- ASC: Air-to-Surface; Aerospace Control; Electronic Combat
- ESC: Surveillance/Recce
- SMC: Force Enhancement

The Electron Devices Thrust addresses these and other user needs with three functional areas: Microelectronics, RF Components and Electro-Optical (EO) Devices. It resolutely directs its resources toward solutions that cannot be achieved with commercial, off-the-shelf (COTS) technology. We work closely with Rome Laboratory, Phillips Laboratory, and other DoD organizations in the Electron Devices area.

GOALS

Microelectronics - develops and transitions new device technology to address the need for affordable, higher throughput signal processing devices that must often withstand severe environments.

This area is focused primarily on developing:

- New device phenomena
- High speed, low power digital technologies
- Improved packaging and interconnect
- Cost effective design and manufacturing methodology to achieve survivable, failure free electronics in future electronic systems
- Micromachining technology for high performance microsensors
- High temperature device technology for turbine engine control and remote microwave sensors

With the design and computer aided engineering (CAE) technology efforts, the goal is shorter design times, first-pass design success and lower avionics systems life-cycle costs by electronically capturing the information required for system maintenance as a by-product of the design process, and by helping the user make the lowest cost design choices throughout the design process.

RF Components - research and development is concerned with satisfying the future requirements for airborne radar, communications, electronic warfare (EW), and smart weapons through the generation, control, propagation, and detection, of microwave and millimeter wave signals. The major emphasis is on developing:

- Solid state power amplifiers for phased array antennas needed in multifunction radar, EW, and communications systems
- Microwave and millimeter wave power modules for advanced radar and EW systems
- Affordable, small volume millimeter wave integrated circuits (ICs) for terminal guidance and communications applications
- Affordable vacuum electronics for radar, communications and EW systems
- Multifunction phased array component technology for advanced radar/EW/communications systems
- High power, high efficiency microwave/millimeter wave transmitters for airborne and space-based platforms

Another focus is toward demonstrating microwave/digital, mixed-mode electronics for EW and radar applications. This includes the development of miniature digital receivers for advanced RF sensor applications.

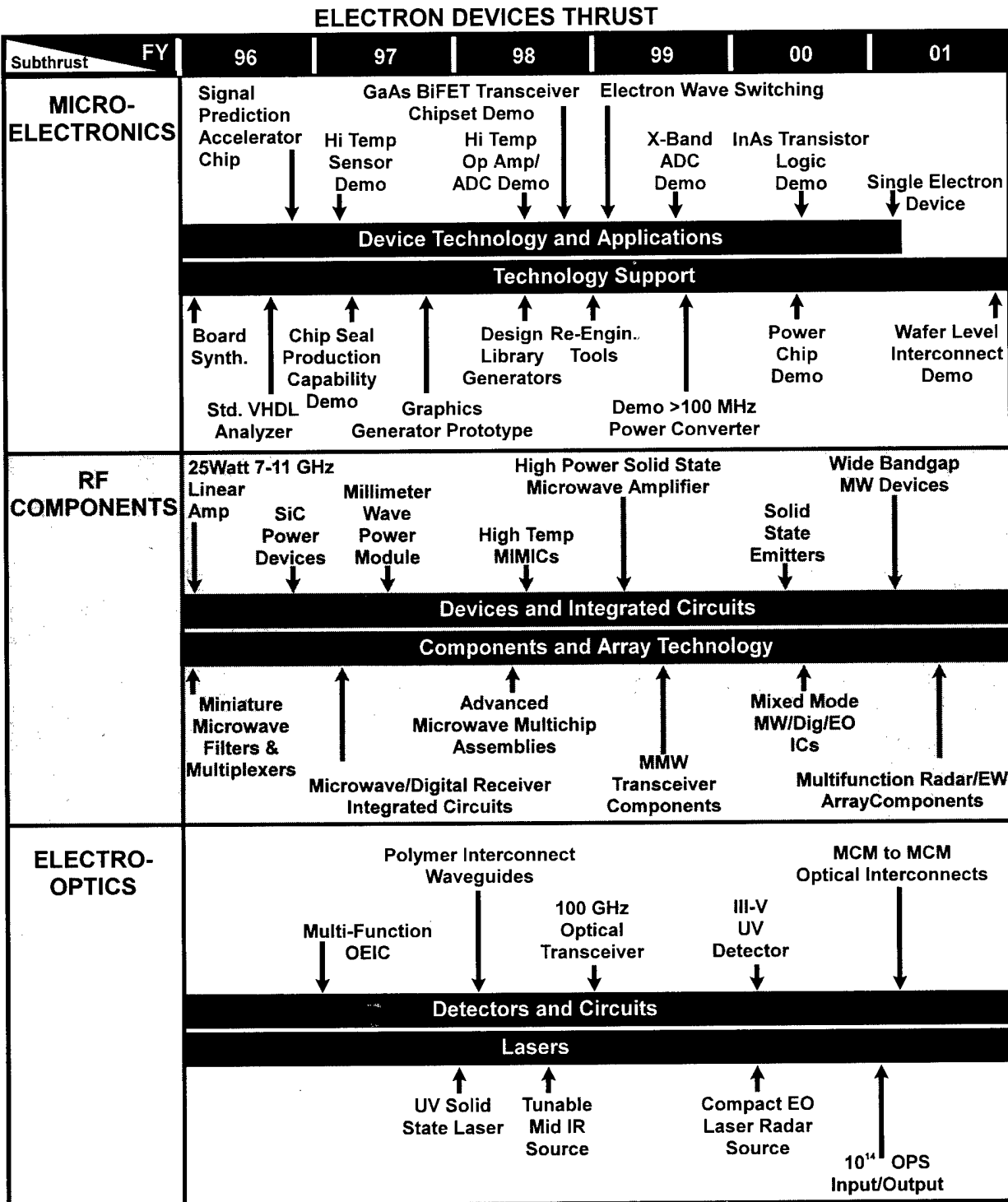


Figure 9. Electron Devices Roadmap.

EO Devices - provide a device and component technology base that transitions basic materials and device research concepts into advanced development approaches for system prototypes. The approach is continually guided by such system needs as missile warning sensors, active and passive sensors for communica-

tions, laser radar, IR countermeasures (IRCM), weapon delivery and target tracking, recognition, and classification. Applications platforms vary from ground equipment through aircraft and missiles to space vehicles. The approach involves the conception, development and initial demonstration of high performance sources

(lasers), detectors (arrays), and opto-electronic devices for the enhancement of electronics and EO phenomena, with the exploitation of these devices and phenomena for application to tactical and strategic systems. The majority of the programs focus on:

- More complete spectral coverage
- High speed and high throughput processing
- Increased optical sensitivity and power
- More accurate, higher resolution sensor capabilities
- Monolithic opto-electronic/digital/microwave circuits to improve system performance and reduce cost
- Developing the infrastructure to facilitate compatible integration of optics and electronics
- Low power, 2-5 micrometer tunable laser for laser radar & IRCM

The devices, packaging and design tools realized within these three areas will continue to build upon the strong technology base ultimately responsible for high performance, reliable and affordable systems in the Air Force.

MAJOR ACCOMPLISHMENTS

Microelectronics: The improvement of InP-based materials has resulted in the successful demonstration of a 4-bit, 10 gigasamples per second analog-to-digital converter (ADC) for radar and EW systems.

In the area of wafer level coatings, accelerated stress testing of devices coated with ChipSeal™ from our Inorganic Sealing Technologies Program, indicated these devices survived as well as devices in hermetic packages. The next step will be to ChipSeal™ product wafers for assembly as bare die in advanced multichip modules (MCMs). The ultimate goal of this effort will be to transfer the coating technologies to a third party and make it more available to the industry

The cooperative micro-accelerometer effort with the Navy resulted in the successful demonstration of an accelerometer with the sensitivity of 700 Hz/G. Joint work is continuing on this effort with the Navy continuing development of the accelerometer microstructure and the Air Force improving the transistor resonant beam sense transducer. The accelerometer microstructure and sense transducer are planned to be merged in FY98.

Wright Laboratory has continued to work closely with Defense Advanced Research Projects Agency (DARPA) on their packaging and interconnect efforts. These include efforts addressing MCM design, known good die, testing, aluminum nitride (AlN) packaging, integrated passives, and large area lithography.

In FY96 a new design tool was demonstrated which shortens the design time for integrated circuits from 6 months to 2 weeks. Licensing of this technology to a major computer aided engineering vendor is nearly complete; thereby making it available to thousands of electronic systems designers.

RF Components: Microwave heterojunction bipolar transistor (HBT) Monolithic Microwave Integrated Circuit (MMIC) amplifiers were designed and fabricated that produce 20 watts continuous wave output power, with 40% power-added efficiency over the 7.25-7.75 GHz frequency band. These power amplifiers are used for advanced SHF communications transmitters. They offer more power and efficiency than what is commercially available from foreign sources. In the area of high temperature electronics, microwave silicon carbide field-effect transistors have been designed, fabricated and tested that produce 15 watts with 5 dB gain at 6 GHz.

In FY96 the DARPA/Tri-Service Microwave/Millimeter Wave integrated Circuit (MIMIC) program was completed. This program succeeded in making MIMIC chips affordable for a broad range of military systems, including F-22 radar/EW, Advanced Medium Range Air-to-Air Missile (AMRAAM), Low Altitude Navigation and Targeting for Night (LANTIRN), and ALQ-135. The new DARPA/Tri-Service Microwave and Analog Front End Technology (MAFET) program will develop the technologies required to extend the performance of RF systems employing multichip assemblies (MCAs) for military radar, smart weapons, electronic countermeasures, secure communications and accurate combat identification. Thrust 1 focuses on increasing the MCA design capability. Thrust 2 emphasizes millimeter wave MCA hardware technology and advanced performance MIMICs. We are the Air Force's lead organization for MAFET. Air Force thrust 1 efforts are reducing the time and memory for large electromagnetic simulations required for accurate millimeter MCA design. Thrust 2 efforts are targeted at accurate on-wafer test of RF chips. Addi-

tional efforts are aimed at developing an independent merchant foundry source for MCA assemblies, and more affordable approaches to low volume application-specific MIMIC chips. We are also working with DARPA to develop high density microwave packaging and interconnect technology for airborne and space-based phased array antennas. In FY96, "tile-type" transmit/receive (T/R) modules have been demonstrated. In a 1"x1"x0.3" volume, four 8-10 GHz, 8 watt output power T/R channels are produced using multilayer metal-matrix substrates, vertical interconnects, and flip-chip ICs. In another area, we have a joint program with the E-3 System Program Office (SPO), Oklahoma City Air Logistics Center, Rome Laboratory, and Naval Research Laboratory to develop improved wide bandwidth klystron transmitters for the Airborne Warning and Control System (AWACS). In FY96, the first wide bandwidth klystron was designed, fabricated and tested.

EO Devices: Semiconductor ultraviolet (UV) detector structures grown in the gallium nitride/aluminum gallium nitride (GaN/AlGaN) materials system have exhibited 43% and 50% external quantum efficiencies for homojunction and heterojunction devices, respectively. Also, a solid state UV detector array based on GaN/AlGaN charge coupled devices (CCDs) has been demonstrated.

MCM to MCM optical interconnects using passive polymers have been developed that integrate electronics, lasers, multimode waveguides, and receivers using standard MCM-D and HDI lithography. Losses reported are 0.2 dB/cm for the ULTEM waveguides, and 1 dB per interface for both the VCSEL to corner bend and the MCM to board connection. This interconnect scheme utilizes 3 parallel channels each operating at a data rate of 1 GHz. MIL SPEC environmental testing with no degradation was shown.

A high resolution, high throughput, large area, low cost MCM scan and repeat lithography system was demonstrated. Two micron resolution was attained over a 15" x 15" substrate, at a throughput that was 5 times greater than that of comparable step and repeat lithography. The processing area is limited only by the substrate size.

Significant advances in the development of isomorphs of Potassium Titanyl Phosphate, specifically Potassium Titanyl Arsenate and Rubidium Titanyl Arsenate, have led to higher

power, extended mid-IR wavelength devices. Additionally, periodically poled lithium niobate (PPLN) technology has provided higher efficiency, lower current threshold devices applicable to laser radar. New military and commercial applications were subsequently developed in remarkably short order.

CHANGES FROM LAST YEAR

Microelectronics: Funding cuts and minimal progress have resulted in the termination of the pseudomorphic Complementary Heterostructure Field Effect Transistor (C-HFET) program.

An FY95 effort was initiated to optimize a GaAs monolithically integrated bipolar and FET (BiFET) technology. This effort is intended to expand the state-of-the-art in speed, power, and density by demonstrating complex functions such as logic, memory, and control on the same substrate without incurring the penalty of chip-to-chip interconnects. Funding cuts in FY96 will delay this effort by 6 months.

The planned FY96 power device development effort to address power conversion efficiency above 100 MHz has been delayed until FY97 to allow more time for both in-house and industrial approaches to mature.

A joint effort between Rome Laboratory and Wright Laboratory will begin to support the design of analog systems. Analog designs are among the high cost drivers for most avionics systems. There has been little change in analog design tools in over 10 years and there is no automated synthesis capability equivalent to that available to digital designers. With the industry close to obtaining a standard analog hardware description language and the availability of very powerful desktop computing technology, it is time to begin developing analog design automation technology.

RF Components: In FY96, 6.3A funds are being used to partially fund the AWACS broadband vacuum electronics power amplifier demonstration, continue work on miniature filters for radar/EW arrays, and demonstrate microwave/digital mixed-mode receivers for radar and EW applications.

Work will be initiated to demonstrate high density packaging technology for phased array

antenna power distribution systems. In late FY95, the DARPA/Tri-Service MAFET program thrusts 1 and 2 contracts were awarded. The Electron Devices Division is the Air Force's lead organization. A joint Technology Reinvestment Project (TRP) with DARPA to address microwave and millimeter wave wireless communications and intelligent vehicle highway systems, was awarded an option phase this year. The option emphasizes military dual-use applications including digital battlefield communications, RF tags, and expendable jammers and decoys.

EO Devices: Air Force research and development of low power lasers is returning to normalcy after a year of turbulence. DARPA funding of laser source work continues to be strong. Research plans call for the development of robust and tunable sources for a large variety of applications for use in the UV to the IR wavelengths. Two main areas of thrust are in the development of UV sources (lasers/light emitting diodes) and mid-IR sources (lasers).

MILESTONES

Microelectronics:

- FY96-FY97 - Achieve operation of the 50 volts-dc (VDC) to 10 VDC power converter at 100 MHz with 80 % efficiency.
- FY96-98 Emphasizes devices for 10-25 GHz digital clock and ADC sampling rates, and for greater improved processor throughput rates per watt of power dissipation. Device types entail nanoelectronics for new higher density techniques for logic implementation and HBTs for direct X-band ADCs.
- 2Q97 - Gallium Arsenide (GaAs) BiFET technology optimization completion.
- FY97 - Demonstrate performance of transistor resonant microbeam sense transducer.
- FY97 - Fabricate improved operational amplifier in silicon carbide for turbine engine control.
- 4Q98 - GaAs BiFET integrated transceiver chip set demonstrated.
- FY98 - Work towards the fabrication of a silicon carbide ADC
- FY98 - Merge the microbeam sense transducer with the Navy's micro-accelerometer microstructure.
- FY98 - Demonstrate power converter operation with T/R modules

- FY98 - Complete a validation suite to ensure that all Very High Speed Integrated Circuit Hardware Design Language (VHDL) simulators give the same results; Demonstrate a CAE tool that will automatically generate IEEE 1029 Waveform and Vector Exchange Specifications (WAVES). Release computer-based training for SPOs and ALCs .
- FY99 - Demonstrate VHDL-based logic generators that provide the lowest power microarchitectures for the digital signal processing arithmetic functions to be performed. Complete the full-function public domain VHDL analyzer.
- FY00 - Initial versions of tools for analog design synthesis will be released.

RF Components:

- FY97-99 Focuses on developing microwave and millimeter wave components and ICs for airborne radar, EW and communications applications.
- FY97-02 Develop and demonstrate both solid state and vacuum electronics components.
- 1Q97 - Continue work on extending SiC power devices to 10 GHz.
- 2Q97 - Develop reliable HBT power amplifiers for phased array radars, at 7-11 GHz.
- 3Q97 - Demonstrate EW transmitters in the 18-40 GHz frequency range. In-house design and modeling capabilities will be enhanced to evaluate new IC and multichip assembly approaches in terms of performance and affordability.
- FY97-01 - Couple in-house work on MMIC material/device correlation and analysis with the DARPA/Tri-Service MAFET program to enhance chip performance and affordability.
- FY99-FY01 - Develop solid state emitter based on wide bandgap semiconductors, millimeter wave transceiver components, mixed mode microwave/ digital/ optoelectronic components, and multifunction radar/EW/communications components.
- 1Q01 - Develop highly integrated components to be demonstrated for radar, EW and communications applications.
- 1Q02 - Apply the IC and component advances to demonstrate advanced multichip assemblies for future active aperture systems.

EO Devices:

- Detector arrays made of III-V materials require developing focal plane array (FPA) technology in the UV through far IR bands.
- FY97 - Demonstrate a dual band IR superlattice detector for applications requiring multisig-

natures in a single aperture device, emphasizing high performance and reliability.

- FY97 - Demonstrate GaN/AlGaN materials growth maturity as exhibited by controlled variability of the aluminum concentration in GaN to specify the cutoff wavelength, specifically as it applies to solar-blindness.
- FY97 - Develop a microchip laser which has the attributes of small size, light weight, and minimal cost for application to laser guided munitions.
- FY97 - Demonstrate passive polymer waveguide devices.
- FY97 - MCM to MCM technology developed for backplane applications.
- FY98 - Develop the technology, and baseline, for higher sensitivity UV detection employing GaN/AlGaN PC (photoconductive) and PV (photovoltaic) detectors grown on non-conventional (non-sapphire) substrates.
- FY98 - Demonstrate a low cost (<\$2M), high throughput (5x greater than comparable step and repeat), large area, 0.18 micron scan and repeat lithography for ICs and single mode intra-chip optical interconnects.
- FY98 - Demonstrate bandwidth control of an optical parametric oscillator for improved functionality of solid-state laser radar systems.
- FY99 - Demonstrate high speed optical transceivers.
- FY00 - Develop a robust, diode-pumped laser radar source.
- FY00 - Insert MCM to MCM technology into military computer/digital signal processing systems.
- FY01 - Develop a set of UV GaN, AlGaIn, and AlN point and imaging detectors.

GLOSSARY

A

A/C Aircraft
 AAP Advanced Avionics Processor
 ACC Air Combat Command
 ADAMS A Digital Avionics Methodology Schema
 ADC Analog-to-Digital Converters
 ADV Advanced
 ADVISE Avionics Data Visualization Integration System Environment
 AF Air Force
 AFAE Air Force Acquisition Executive
 AFB Air Force Base
 AFIT Air Force Institute of Technology
 AFMC Air Force Materiel Command
 AFOSR Air Force Office of Scientific Research
 AFSOC Air Force Special Operations Command
 AIRST Advanced Infrared Search and Track
 ALC Air Logistics Center
 ALCAR Advanced Low Cost Architecture Radar
 AlGaN Aluminum Gallium Nitride
 AlN Aluminum Nitrides
 AMC Air Mobility Command
 AMDRFM Advanced Monolithic Digital RF Memory
 AMLCD Active Matrix Liquid Crystal Display
 AMMDE Advanced Micro Machined Display Engine
 AMRAAM Advanced Medium Range Air-to-Air Missile
 ASC Aeronautical Systems Center
 ASTAT Affordable Sensor Technology for Aerial Targeting
 ATD Advanced Technology Demonstration
 ATIRCM Advanced Threat IRCM
 ATR Automatic Target Recognition
 AWACS Airborne Warning and Control System

B

BDA Bomb Damage Assessment
 BiFET Bipolar Field Effect Transistor
 BIPS Billion Instructions Per Second
 BIST Built-In-Self-Test
 BMDO Ballistic Missile Defense Organization
 BTI Briefing to Industry

C

C² Command and Control
 C²W Command and Control Warfare
 C³ Communications, Command, and Control
 C³I Communications, Command, and Control Intelligence
 C⁴I Command, Control, Communications, Computers and Intelligence
 CAE Computer Aided Engineering
 CAMIS Computer Assisted Minimally Invasive Surgery
 CCD Charge Coupled Devices
 CCM Counter-countermeasure
 C-HFET Complementary Heterostructure Field Effect Transistor
 CM Countermeasure
 CNI Communications, Navigation, and Identification
 CoDE Coherent Digital Exciter
 COTS Commercial Off-The-Shelf
 CRDA Cooperative R&D Agreements
 CRT Cathode Ray Tube
 CW Continuous Wave

D

DAD Distributed Architecture Decoy
 DARPA Defense Advanced Research Project Agency
 DARTS Dynamic Avionics Real-Time Scheduling
 dB Decibel
 dc Direct Current
 DEA Data Exchange Agreement

GLOSSARY

DICE	Data Integration and Collection Environment	GHz	Gigahertz
DIRCM	Defensive IRCM	GP	Gas Plasma
		GPS	Global Positioning System
DIS	Distributed Interactive Simulation	H	
DMD	Digital Micromirror Device	HBT	Heterojunction Bipolar Transistor
DoD	Department of Defense	HQ	Headquarters
DRFM	Digital RF Memory	HQ AF	Headquarters Air Force
DSO	Defensive System Operator	Hz	Hertz
DTAP	Department of Defense Technology Area Plan	I	
E		IC	Integrated Circuit
E&MD	Engineering and Manufacturing Development	ICNIS	Integrated CNI Subsystem
ECCM	Electronic Counter-Countermeasures	ID	Identification
ECM	Electronic Countermeasures	IDAL	Integrated Defense Avionics Laboratory
EM	Electromechanical	IEEE	Institute for Electrical and Electronics Engineers
EMD	Engineering Manufacturing Development	IESS	Integrated Electromagnetic System Simulator
EO	Electro-Optical	IFSAR	Interferometric Synthetic Aperture Radar
EO-IR	Electro-Optical-Infrared	InP	Indium Phosphide
EP	Electronic Protection	INS	Inertial Navigation System
ERASER	Enhanced Recognition and Sensing Radar	IR	Infrared
ESAI	Expanded Situation Awareness Insertion Program	IR&D	Independent Research and Development
ESC	Electronics System Center	IRCM	Infrared Countermeasures
EW	Electronic Warfare	IRST	Infrared Search and Track
F		ISS	Integrated Sensor System
F ³ R	Form, Fit, Function Retrofit	ITB	Integrated Test Bed
FED	Field Emissive Device	J-K	
FLIR	Forward-Looking Infrared	JMSP	Joint Multi-Spectral Sensor Program
FOG	Fiber Optic Gyroscope	JSF	Joint Strike Fighter
FPA	Focal Plane Array	JR	Jam Resistance
FPGA	Field Programmable Gated Array	KHz	Kilohertz
FY	Fiscal Year	KMOR	Keep Missile on the Rail
G		L	
GaAs	Gallium Arsenide	LANTIRN	Low Altitude Navigation and Targeting Infrared System for Night
GaN	Gallium Nitride	LCC	Life Cycle Cost
Gbps	Gigabytes per second		

GLOSSARY

LED	Light Emitting Diode	OC-ALC	Oklahoma City Air Logistics Center
LIFE	Laser Infrared Flyout Experiment	OFF	Operational Flight Program
LPD	Low Probability of Detection	OPO	Optical Parametric Oscillator
LPD/JR	Low Probability of Detection/Jam Resistant	ORTA	Office of Research and Technology Applications
LWIR	Long Wavelength Infrared	OSD	Office of Secretary of Defense
		OSO	Offensive System Operator
M			
MAFET	Microwave and Analog Front-End Technology Program	P	
MAJCOM	Major Command	PC	Photoconductive
MANPAD	MAN Portable Air Defense	PCMCIA	Personal Computer Memory Card International Association
MAP	Mission Area Plan	PE	Program Element
MBV	Model-Based Vision	PGM	Precision Guided Munitions
MCA	Multichip Assembly	PL	Phillips Laboratory
MCM	Multichip Module	POD	Planar Optic Display
MHz	Megahertz	PLAID	Precision Location and Identification
MIMIC	Microwave/Millimeter Wave Integrated Circuit	PPLN	Periodically Poled Lithium Niobate
MMC	Modular Mission Computer	PV	Photovoltaic
MMIC	Monolithic Microwave Integrated Circuit		
MOA	Memorandum of Agreement	R	
MOSAIC	Modeling System for Advanced Investigation of Countermeasures	R&D	Research and Development
		RAD	Random Agile Deinterleaver
MOU	Memorandum of Understanding	RCS	Radar Cross-Section
MPM	Microwave Power Module	RF	Radio Frequency
MPP	Modernization Planning Process	RFCM	Radio Frequency Countermeasure
MSTAR	Moving and Stationary Target Acquisition and Recognition	RGB	Red-Green-Blue
MTBF	Mean Time Between Failure	RL	Rome Laboratory
		RTIC	Real-Time Information in the Cockpit
N		RTOC	Real-Time Out of the Cockpit
NASA	National Aeronautics and Space Administration	RTSMP	Real-Time Symmetric Multiprocessor
NavTEL	Navigation Test Evaluation Laboratory	RWR	Radar Warning Receiver
NRL	Naval Research Laboratory		
O		S	
OBATS	Off-Board Augmented Theater Surveillance	S&T	Science and Technology Software
		S/W	
		SA	Situation Awareness
		SAB	Scientific Advisory Board
		SAR	Synthetic Aperture Radar

GLOSSARY

SATCOM	Satellite Communications	VHDL	VHSIC Hardware Design Language
SAWS	Silent Attack Warning System	VHF	Very-High Frequency
SBIR	Small Business Innovative Research	VHSIC	Very High Speed Integrated Circuit
SCI	Scaleable Coherent Interface	VLSI	Very Large Scale Integration
SEAD	Suppression of Enemy Air Defense	WAVES	Waveform and Vector Exchange Specifications
SHF	Super-High Frequency	WL	Wright Laboratory
SID	Society for International Display	WPAFB	Wright-Patterson Air Force Base
SPO	System Program Offices	WR-ALC	Warner Robins Air Logistics Center
STIG	Space Technology Interdependency Group	WTN	Wright Technology Network
T			
T/R	Transmit/Receive		
TADIX	Tactical Data Information Exchange System		
TAP	Technology Area Plan		
TARA	Technology Area Review and Assessment		
TEO	Technology Executive Officer		
TESSA	TMD Eagle Smart Sensor ATR		
TMD	Theater Missile Defense		
TMP	Technology Master Process		
TPIPT	Technical Planning Integrated Product Team		
TRP	Technology Reinvestment Project		
TTO	Technology Transition Officer		
TWT	Traveling Wave Tube		
U			
UAV	Unmanned Air Vehicle		
UHF	Ultra-High Frequency		
UHR	Ultra-High Resolution Radar		
UHRR	Ultra-High Range Resolution Radar		
USAF	United States Air Force		
USSOCOM	United States Special Operations Command		
UV	Ultraviolet		
V-W			
VDC	Volts dc		

TECHNOLOGY MASTER PROCESS OVERVIEW

Part of the Air Force Materiel Command's (AFMC) mission deals with maintaining technological superiority for the United States Air Force by:

- Discovering and developing leading edge technologies
- Transitioning mature technologies to system developers and maintainers
- Inserting fully developed technologies into our weapon systems and supporting infrastructure, and
- Transferring dual-use technologies to improve economic competitiveness.

To ensure this mission is effectively accomplished in a disciplined, structured manner, AFMC has implemented the **Technology Master Process (TMP)**. The TMP is AFMC's vehicle for planning and executing an end-to-end technology program on an annual basis.

The TMP has four distinct phases, as shown in Figure 10:

- Phase 1, **Technology Needs Identification** - Collects customer-provided technology needs associated with both weapon systems, product groups, and supporting infrastructure; then identifies them by the need to develop new technology or apply/insert emerging or existing technology. These needs are derived in a strategies-to-task framework via the user-driven Mission Area Planning process.
- Phase 2, **Program Development** - Formulates a portfolio of dollar constrained projects to meet customer-identified needs from Phase 1. The Technology Executive Officer (TEO), with the laboratories, develops a set of projects for these needs requiring development of new technology, while the Technology Transition Office (TTO) orchestrates the development of a project portfolio for those needs that can be met by the application/insertion of emerging or existing technology.

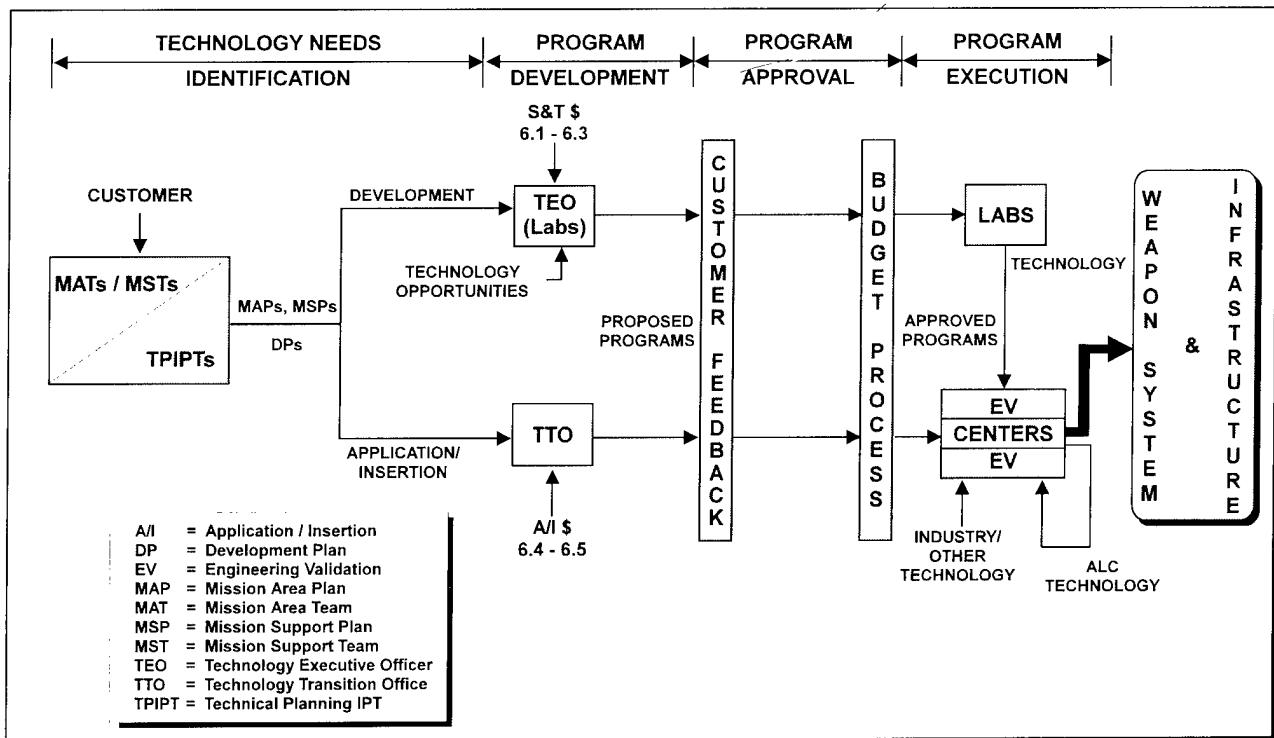


Figure 10: Technology Master Process

- Phase 3, **Program Approval** - Reviews the proposed project portfolio with the customer and obtains approval for the portfolio through the budgeting process. The outputs of Phase 3 are the authorizations and appropriations required, by the laboratories and application/insertion programs, to execute their technology projects.
- Phase 4, **Program Execution** - Executes the approved Science and Technology (S&T) program and technology application/insertion program within the constraints of the Congressional budget and budget direction from higher headquarters. The products of Phase 4 are validated technologies that satisfy customer weapon system and infrastructure deficiencies.

ADDITIONAL INFORMATION

Additional information on the Technology Master Process is available from HQ AFMC/STR, DSN 787-6777/8764, (513) 257-6777/8764.

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