FY96

COMMAND, CONTROL, COMMUNICATIONS, & INTELLIGENCE (C^3I)

TECHNOLOGY AREA PLAN

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

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Note: This Technology Area Plan (TAP) is a planning document for the FY96-01 S&T program and is based on the President's FY96 Budget Request. It does not reflect the impact of the FY96 Congressional appropriations and FY96-01 budget actions. You should consult RL/XP for specific impacts that the FY96 appropriation may have had with regard to the contents of this particular TAP. This document is current as of 1 May 1995.

COMMAND, CONTROL, COMMUNICATIONS, & INTELLIGENCE (C^3I)

VISIONS AND OPPORTUNITIES

C^3I " As a commander at all levels...I will tell you that a commander without the proper command and control assets commands nothing except his desk. You must have the ability to communicate with the forces under your command. You must have the ability to exchange information with them freely, frequently and on a global basis."

General Ronald R. Fogleman

Chief of Staff, United States Air Force

The Air Force mission is

" To Defend the U.S. Through Control and Exploitation of Air and Space".

To control and exploit air and space requires that the Air Force have properly trained people, superior equipment and the right information - at the right place and at the right time - concerning its own forces and those of any adversary. For this reason, C3I is more important than ever, and a critical element in ensuring that the Air Force can fulfill its mission. Our military forces, although reduced in size must be highly flexible, globally responsive, and at times deadly precise. They must operate successfully in high threat, high technology environments, and in new missions such as humanitarian assistance. With revolutionary C^3I technologies, we can respond accurately and effectively to the rapidly changing international scene. With innovative technologies, we can control the increasing instability of the battlefield and overwhelm the increasing sophistication of our adversaries.

Our vision is simple. We want to ensure that our warfighters have total control and an omniscient view of the battlefield. We will give our warfighters access to whatever data they need and will ensure that it's up to date and accurate. We will:

Provide the right information anytime, anyplace, for any mission ...

- Improved surveillance systems
- On-time intelligence information
- Up-to-date maps, charts and graphics
- Improved mission planning
- Adaptable communication networks
- Data compression and transmission

... utilizing powerful, user-friendly information processing systems ...

- Advanced signal processing algorithms
- Heterogeneous databases
- All source data fusion and correlation
- Rapidly reprogrammable software
- Multilevel security
- Artificial intelligence

... which are affordable and maintainable.

- Reliable components
- Built-in diagnostics
- Emphasis on low cost

Our current C^3I systems support our forces world-wide. They are the eyes and ears of Global Reach/Global Power -- the notebooks and decision aids, the infrastructure for effective command and control. The C^3I technologies described in this TAP support our present systems, but look strategically to the future. These technologies will support a smaller force, but one that still has global responsibilities. These technologies are also in the forefront of the technology revolution with regard to how future wars are fought and won. Technologies in signal processing , data fusion, information warfare, mission planing, communications. artificial intelligence, distributed information systems, intelligence exploitation, new semiconductor materials, multispectral active and passive sensors and cost effective C3I system support technology will ensure that the appropriate information is available to most effectively use our stealth and smart weapons. and other systems.

Where applicable, C^3I technologies will leverage commercial R&D in communications, computer systems, artificial intelligence, and other related areas. This allows us to concentrate scarce AF resources on those problems that have no commercial equivalent. Conversely, C^3I technologies in other areas such as signal processing, photonics, and intelligence are having tremendous dual-use potential in areas such as health and criminal justice -- our defense investment reaps commercial dividends as well.

Improved C^3I technologies will allow us to plan more effective joint operations and more effective coalition ventures by increasing interoperability -- and will free operational commanders to concentrate on strategy, operations and tactics. These technologies will enhance the commander's view of the battlefield, the timeliness of his decisions, and the expansiveness of his control. These technologies will provide solutions to some of the most vexing problems facing DOD today including:

- Maintaining near perfect real-time knowledge of the enemy and communicating that to all forces in near real time
- Integrating situation assessment, planning, and force execution to ensure the most appropriate force is used to achieve the objective with minimum casualties and collateral damage

In short, as Global Reach/Global Power and the use of smaller, integrated, highly adaptable forces become the dominant themes in Air Force operational thinking, the ability of C^3I systems to manage information and support battle management grows ever more critical. The C^3I technologies under development at Rome Lab will allow the warfighter to operate in a seamless environment at all levels of engagement. The program described in this Technology Area Plan will ensure that we build the technological foundation for both evolutionary improvements in current systems and revolutionary development of new capabilities for Global Reach/Global Power. Our objective remains:

TOTAL CONTROL TO THE WARFIGHTER

This plan has been reviewed by all Air Force Laboratory commanders/directors and reflects integrated Air Force technology planning. We request AFAE approval of this plan.

RICHARD R. PAUL
Brigadier General, USAF
Technology Executive Officer

RAYMOND P. URTZ
Deputy Director
Rome Laboratory

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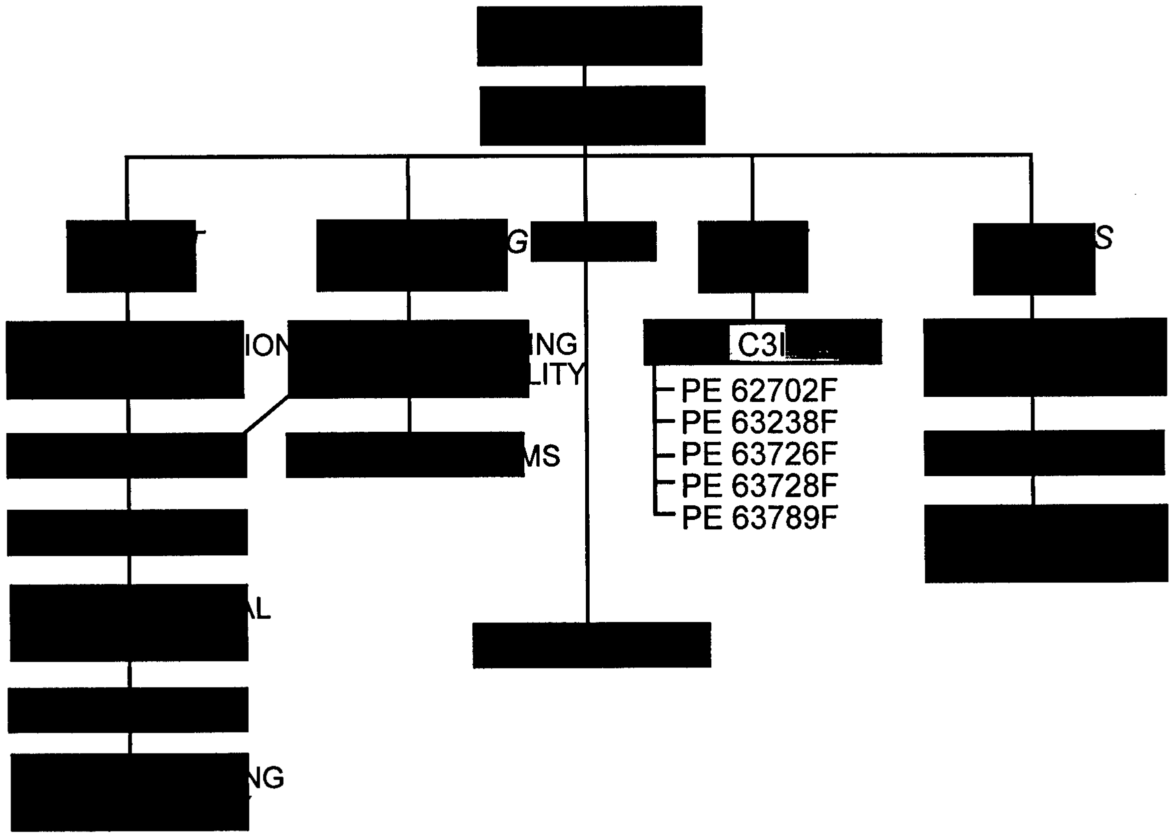

Figure 1 - Air Force S&T Program Structure

INTRODUCTION

BACKGROUND

C^{3}I IN PERSPECTIVE

Command, Control, Communications and Intelligence (C^{3}I) capabilities provide the vital eyes, ears, and voices for the National Command Authorities and military commanders. "The Warrior of the future must be able to respond and coordinate horizontally and vertically in order to prosecute effectively and successfully, any mission in the Battlespace."[1] Throughout history, the scales of conflict have repeatedly tilted in favor of the commander who could penetrate the "fog and friction" of battle.

In the post-Cold War world, the Air Force must respond to a variety of situations requiring effective use of air power anywhere on the globe, while simultaneously drawing down to a significantly smaller force structure. The Air Force needs greatly improved C^{3}I systems that allow flexible, coordinated use of available forces while enabling lightning-fast response to changing situations. These C^{3}I systems must be reliable in any environment, robust in the face of hostile actions, highly mobile to accompany deploying forces, and affordable. Further, the C^{3}I systems must be able to fully integrate both the warfighting functions and capabilities of component forces - the entire Joint Force. This Technology Area Plan (TAP) describes a focused program of developments and demonstrations across the spectrum of relevant technologies. This program will provide the improvements to both current and future systems required to match Air Force C^{3}I

[1] Warrior Concept from "C4I For the Warrior", 12 June 1993 Pamphlet, J-6, The Joint Staff, Pentagon

capabilities to operational demands both within the Air Force and the Joint Force.

Figure 1 shows the C^3I Technology Area as the responsibility of Rome Lab within the Air Force Science and Technology (S&T) program. By its nature, C^3I is pervasive, and much of the work described in this document is coordinated with or conducted jointly with the other laboratories, services, and a variety of other agencies. This technology program also leverages developments in the commercial industrial base. In addition, nearly all C^3I technologies have commercial applications, so the program proactively supports Defense Conversion goals and objectives.

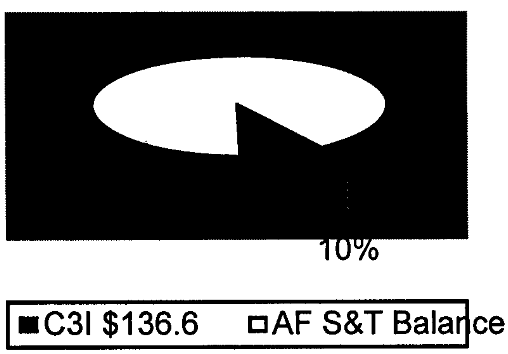

Figure 2 - C^3I S&T vs AF S&T FY95: $1.406B

As depicted in Figure 2, this Technology Area is planning to receive $136.6.0 million, or 10% of the FY96 AF S&T program based on the FY96 President's Budget request. The program described in this TAP is subject to change based on possible Congressional action.

RECENT ACCOMPLISHMENTS

The Rome Lab C^3I program has achieved significant progress over its broad spectrum of technology thrusts:

- The successful integration and demonstration of Rome's Crisis Action Planning Toolkit with the new force generation tool at JWID'94 for USACOM let to USACOM's request for immediate use of both tools and their requirement that the capabilities of these tools be required for GCCS.
- False alarms are a significant problem in wide area surveillance radar such as the E-3A Airborne Warning and Control System (AWACS). Rome Laboratory engineers conceived the ES-CFAR Processor to provide a low-cost, easily implemented approach to improving the performance of modern long-range surveillance radars via advances in signal processing, as opposed to costly transmitter or antenna upgrades. By applying artificial intelligence, a radar signal processor can classify the interference environment and apply the most appropriate CFAR algorithm(s) for detection processing. Using real E-3 AWACS data, the ES-CFAR Processor demonstrated a tripling of detection performance and an order of magnitude reduction of false alarm probability compared to a conventional Cell Averaging CFAR algorithm. This dramatic performance improvement can provide the E-3 with improved false alarm control while more reliable detecting small, low observable targets.
- Performed technology demonstrations of Speakeasy Phase-1 Advanced Development Models (ADMs) showing simultaneous operation with two similar and dissimilar military waveforms operating in ECCM modes in the same and different bands. Also demonstrated the ability to modify existing transmission waveforms with software changes. Voice bridging between an Army-SINCGARS (VHF) radio and an AF-Have-Quick (UHF) radio within Speakeasy was also accomplished
- Demonstration of Asynchronous Transfer Mode (ATM) reachback communications to/from an Air Mobility Command KC-135 aircraft. Demonstrations included transmission of AMC database information to an in-flight aircraft over an AFSATCOM UHF link. This effort is focused on AMC's stated need for worldwide in-transit (trans-oceanic) visibility to a number of CONUS and forward-based information databases. In particular, the utility of obtaining up-to-date meteorological information, cartography, and still video were demonstrated. While current efforts are focused on a practical, low cost implementation of this ATM based communications capability using existing on-board UHF SATCOM equipment, Rome Lab will evolve this program to include wider bandwidth SATCOM systems with low cost conformal phased arrays for higher data rate service into the aircraft.
- The Advanced Planning System (APS) has been selected as the joint service Air Tasking Order (ATO) generation module for the Global Command and Control System (GCCS).
- Rome Lab Air Force planning technologies were integrated with Navy and ARPA planning

technologies into a joint planning demonstration during Joint Warrior Interoperability Demonstration (JWID) 94 and showed collaborative, single thread planning from CINC to CJTF to the Air Operations Center (AOC) using a distributed computing environment and a variety of tools. A similar demonstration package was employed in the Electronic System Center Fort Franklin 94 exercise.

- Strategic/Tactical Optical Disk System (S/TODS) successfully demonstrated high performance optical disk storage technology at AFSOC, Hurlburt Field. The mass storage device interfaced to and operated with the AFSOC mission planner. AFSOC personnel were trained to operate the system and participated in the evaluation. The technology provides fast access to vary large data files; imagery, maps, charts and text.
- Major Intelligence Data Handling System software releases were developed and installed in over 50 operational sites. These software releases provide enhanced IDHS message handling, situation assessment, database, client server, and imagery management capabilities for the unified and specified commands critical intelligence missions.
- Significant improvements were made to the way imagery is exploited. The Imagery Exploitation 2000 (IE 2000) Test Bed Facility located at Rome Laboratory, developed an imagery/information server; image exploitation tool kit; and migrated toward an Object Oriented computing environment with the installation of Common Object Request Brokers Architecture (CORBA) software. In addition, IE 2000 was utilized to investigate imagery product dissemination using Compact Disc (CD) technology, conducted Battle Damage Assessment (BDA) experiments which used Desert Storm gun camera video inputs. Finally, new exploitation scenarios were developed which involve a combination of imagery intelligence (IMINT), electronic intelligence (ELINT) and cartographic information.
- A joint Rome Laboratory and San Antonio Team developed and demonstrated the ability to use advanced software technology concepts to automate the generation of test programs for Automatic Test Systems (ATS). Test Program Sets (TPSs) were developed for two printed circuit boards for evaluation on two different testers, the GenRad 2751 Automated Test System (ATS) and a MATE 390 ATLAS-type ATS. The generation of TPS' for two distinct ATS' from the same test information demonstrates the tester independence of the data formats. This capability is estimated to provide a ten fold reduction in test generation cost for the ALCs, with similar potential savings for DOD manufacturers.
- Actual environments for ALQ-131, Block II Traveling Wave Tubes (TWTs) have been measured during their assembly and test, system user/yield, and repair and rebuild phases and have been systematically analyzed. Field data was obtained on ALQ-131 Pods flown on Dutch AF F-16s over their Mediterranean test range and NATO support missions over Bosnia-Herzegoviana. The results have identified design weaknesses and a proof of concept verification has been conducted to yield higher quality/reliable TWTs at reduced cost.
- Rome Laboratory has recently developed and verified a highly effective accelerated testing methodology. Independent verification efforts demonstrated a minimum time savings of 67% over traditional Department of Defense and industry reliability testing standards. The verification data sets confirm the efficiency and flexibility of the technique, clearly demonstrating the modeling accuracy as well as the potential for substantial economic savings.
- Development of high gain multiple quantum well lasers at multi-gigaherz frequencies has resulted in laser devices of significantly improved yield-from 1% yields to 90% yields. This will result in dramatically reduced costs in production.
- Rome Lab's innovative short stack memory concept which dramatically improves circuit density by stacking thinned memory die has been transitioned for high volume commercial production. The idea allows manufacturers to step a generation ahead of normal chip densities through advanced packaging. The short stack memory won both an R&D 100 award as one of the 100 most important new products of 1994 and a 1995 Federal Lab Consortium Technology Transfer award. Rome Lab has a patent pending on the idea which sprang from in-house research.

TECHNOLOGY THRUSTS

This TAP is organized into nine thrusts as summarized in Table 1. The first four are mission area thrusts directed primarily to the C^3I systems of Rome Lab's parent Product Center, the Electronic Systems Center (ESC). The remaining five represent Rome Lab's corporate responsibilities -- emphasizing the technologies that enable enhanced performance, affordability, and availability of electronic systems.

Thrust 1:	Surveillance
Thrust 2:	Communications
Thrust 3:	Command and Control
Thrust 4:	Intelligence
Thrust 5:	Signal Processing
Thrust 6:	Computer Science & Technology
Thrust 7:	Electromagnetic Technology
Thrust 8:	Photonics
Thrust 9:	Reliability Sciences

Table 1 - Major Technology Thrusts

Figure 3 shows the planned allocation of AF S&T funds among these thrusts, including civilian salaries and other operations and maintenance.

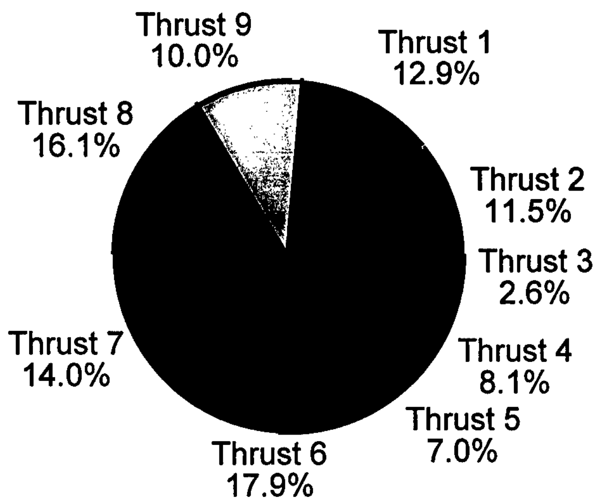

Figure 3 - Major Technology Thrust

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

INDUSTRIAL PROGRAMS

Independent Research and Development (IR&D).

Government and corporate labs must coordinate and leverage their research funds to improve their products. Rome Lab's Technology Coordinating Committees (TCCs) are host to annual voluntary and invitational dialogues with industry in their areas of cognizance to exchange current information on IR&D activities. These dialogues include lab presentations of their technology needs and review of industry IR&D projects. MAJCOMs, other DoD, and Federal agencies are included in the IR&D discussions.

The Rome Laboratory investment strategy considers IR&D to assure that its technology plans take advantage of corporate investments and advances.

A few examples illustrate the importance of IR&D in meeting AF C^3I needs.

- Rome Lab is currently leveraging over four million dollars of IR&D annually from twenty companies engaged in research in software quality metrics, software engineering for parallel computing, software requirements engineering, and computer security, four areas essential to reducing risks associated with advanced weapons systems development and deployment.
- Rome Lab is leveraging a $20M IR&D Investment in a flying testbed with the capability to collect radar clutter to gather data from a moving airborne platform that is crucial to our space-time adaptive processing program. Without leveraging the testbed, we would not have been able to afford to collect this important data. Space-time adaptive processing is required to improve the performance of airborne radars so that smaller targets can be detected in the presence of jamming and clutter.
- Rome Lab hosted a major IR&D review with industry on photonics with Army, Navy, NASA and other AF labs participating. Major corporations participating reported on their IR&D work in:
  - Optoelectronics for signal processing and RF Photonics.
  - Optical processing and optically controlled arrays.
  - High speed RL/Optical modulator.
  - 14" erasable optical disk and optical heads.
  - Development of blue laser media for short wavelength optical disks.
  - Development of high performance ferroelectric spatial light modulator for optical correlator operation.
- Again this year, Rome Lab will sponsor the Integrated Diagnostic Technologies Workshop to provide a forum to discuss and exchange ideas on how to solve integration problems. Issues addressed will consist of identifying problems raised by tool incompatibilities and undefined

interfaces, fault detection, and data standards and protocols for diagnostics. Over 100 participants from the Air Force, Army, Navy, industry and academia will attend.

- The Industry Looks at Rome Laboratory annual event is a well-established forum designed to update the entire C^3I community on AF plans and requirements and give the community a chance to interact with Rome Lab personnel. In addition, Rome Lab participates in the Electrons Systems Centers (ESC) Industry Days.

Domestic Technology Transfer.

The goals of the Rome Laboratory (RL) Technology Transfer Program are:

- improve our communication and interaction with the private sector, state and local governments, and other federal agencies
- leverage RL's S&T budget
- enhance American competitiveness in the world economy.

At RL, technology transfer is accomplished through the laboratory's pursuit of five areas:

- RL uses Cooperative R&D Agreements (CRDAs) as one of its primary tools to accomplish its technology transfer mission. A CRDA is an agreement between RL and one or more industrial organizations, universities, state or local government organizations, or other federal agencies to conduct specified research or development efforts consistent with the laboratory's mission. RL has entered into 44 CRDAs, and currently has 28 active. The technology being pursued includes every facet of the RL technology development mission.
- Another tool is Education Partnerships (EP). An EP is an agreement between the laboratory and an education institution in the United States to encourage and enhance study in scientific disciplines at all levels of education. RL has entered into ten EPs to date, and currently has nine active.
- Grants are an additional method to effect technology transfer. Recently RL received authority to award grants to universities and not-for-profit institutions for research in technical fields related to the laboratory's mission. Because of the overwhelming response in 1994 to the initial announcement of our Grants Program, RL has continued the program into 1995.
- Responding to requests for technical assistance from private and public entities is another RL technology transfer area. In 1994 our commitment to a hands-on approach and personal interaction resulted in our answering over 400 requests from industry for both information about our technology and for specific answers to technical problems they were encountering.
- Technology transfer is also being facilitated through the negotiation of patent licensing agreements. The laboratory currently has three license agreements for patents held by its employees and is currently negotiating another three agreements.

The products derived from this cooperative research will provide the private sector and the Air Force with new and improved Information Technology resources. Some examples of RL Technology Transfer successes include:

- Short Stack Memory Chips technology allows an improvement of four to eight times in the number of memory chips packaged into a multi-chip module. Rome Laboratory and Irvine Sensors Corporation developed a method of 3-D silicon processing and packaging which can stack hundreds of chips in a physically compact manner and which is compatible with several multi-chip module (MCM) packaging techniques. This technology is currently being used by IBM to produce chips in their foundry in Burlington VT. In addition, Rome Laboratory together with Irvine Sensors, General Electric, and Martin Marietta has begun work to produce a high-throughput Digital Signal Processing board using this technology.
- The Actively Cooled Effusion (ACE) cell, invented, developed, and patented by RL, has been commercialized by the SPIRE Corporation and is being marketed as a hardware option for a system to grow semiconductor epitaxial films for high performance electronic components.
- RL has two multi-partner CRDAs for jointly developing, evaluating, and commercializing software engineering techniques for parallel processing, software quality, and software requirements analysis and specification.
- A commercially oriented corporation is providing almost three million dollars in cost sharing for the development of Knowledge Based Software Assistant programs developed by RL.
- The Platinum Silicide (PtSi) focal plane array developed and patented by RL has created an

exciting technology that is being deployed in the Air Force's B-52 fleet and is also being developed for use in commercial aviation to increase visibility in adverse weather conditions.

- RL is working with NYNEX Telephone Company, Syracuse and Cornell Universities and several other academic and industrial partners in both upstate and downstate New York to address issues related to the implementation of very wide bandwidth fiber optic communications networks and the distributed computing systems that will be built on them.
- Under the Traffic Flow Visulation and Control Program sponsored by thr Federal Highway Administration, Rl is developing a state-of-the-art highway monitoring system that utilizes defense related video sensor information to observe, detect, and report real-time traffic flow information to traffic engineerrs. Also through an agreement with the New York State Dept. of Transportation, the system will be field tested on a highway in downstate New York.

Dual Use Technology Development

Dual Use Technology Development is an initiative to co-develop defense related technologies with private industry and universities to benefit both parties and improve the economic infrastructure and competitiveness of America's industrial base. A major program in this area is the Technology Reinvestment Program (TRP). Rome Laboratory has been a full participant in this program since its inception in 1993. Specifically, RL supplied some of its engineering staff to help evaluate the many proposals that TRP received for each of its two completed competitions and for the current ongoing TRP competition. In addition, RL partnered with industry on three winning proposals in the 1993 TRP competition, and two winning teams in the 1994 TRP competition. The technology areas for these winning proposals include Air Traffic Control radars, infrared sensors for aviation safety, phased array antenna development for satellite communications, and software engineering development. Lastly, RL is managing a total of four winning proposals for the TRP.

Small Business Innovative Research (SBIR).

This program encourages new concepts and stimulates technological innovation. Rome Lab manages all C^3I technology intensive SBIR contracts while ESC concentrates on SBIR systems engineering projects. Under the SBIR program, Rome Lab will manage 33 topics and approximately $21 million in FY96. At Rome Lab, we anticipate 80 Phase I and II contracts in FY96 with an additional 15 at ESC.

Rome Lab will participate in two new SBIR initiatives. The first, called Small Business Technology Transfer (STTR), is designed to promote partnerships between small businesses and universities or FFRDC's. RL anticipates an additional 5 phase I awards under this initiative. The second is an OSD technology transfer initiative in which Rome Lab has two topics.

Approximately ten percent of the Phase I proposals received by RL are awarded and approximately 50 percent of those projects go onto a Phase II award with the prospect for commercialization. Numerous innovative ideas are being incorporated in RL's programs as well as new commercial products. Some of our current SBIR efforts are:

- Dealing with design and certification of fault tolerant software components which directly support the Rome Lab ATD on Certification of Reusable Software Components.
- Focusing on applications of natural language techniques for software documentation generation in support of our Software Life Cycle Support (SLCS) ATD and Knowledge-Based Software Assistant program.
- Advancing the state-of-the-art in carbon doped heterojunction bipolar transistors (HBT).
- Developing an advanced development model of a device that detects significant level of corrosion on connectors.
- Developing formal verification procedure and methodologies of VHDL models and developing a prototype formal hardware verification tool based on the VHSIC Hardware Description Language (VHDL).
- Developing an Optical Wave Division communications multiplexer to integrate FDDI, ATM/TAXI, ATM/OC-3, Digital video and others onto a single optical fiber.
- Developing a space based ATM switch for application on future military and commercial satellite systems reducing the ground control requirements for the satellites.
- Demonstrating electronic page control of an optical memory system with potential to eliminate inter-page crosstalk from memory layers
- Developing a multi-layered optical recording technique and a rewritable recording material which will lead to a commercial development of a

multi-layered CD-ROM, WORM and Rewritable Optical Disk system with an anticipated 10 fold improvement in data storage capacities.

- Developing the potential of multiwavelength optical storage material using DNA polymers providing storage densities on the order of 100 bits/micron using this organic material.
- Developing novel techniques to increase reliability in the fabrication of integrated circuits. One such technique monitors oxides for damage to identify early device failure from either oxide breakdown or hot carrier damage.

INTERNATIONAL PROGRAMS

Under the International Cooperative R&D program, Rome Lab has 9 Master Agreements and 16 signed Data Exchange Agreements with 9 foreign governments. These agreements leveraged approximately $5.7 million of research to the Rome Lab C^3I program.

OTHER GOVERNMENT LABS / AGENCIES

Air Force S&T Programs

The four Air Force superlabs work continuously to clarify and coordinate their programs. Examples include a Memorandum of Understanding between Rome and Wright Labs in the area of airborne communications, and with Armstrong Lab for the intelligent tutor program. We maintain a continuing dialogue with Wright Lab in electromagnetic technology. Rome Lab works together with Phillips Lab to transition C^3I technologies to space applications.

- Rome Laboratory and Wright Laboratory collaborate on all work performed in the non-cooperative target identification/hostile target identification arena. All work is coordinated and deconflicted in joint meetings with the Air Force Combat Identification Integrated Management Team.
- Rome Lab and Phillips Lab are jointly working together to develop an S&T strategy for Air Force space communications technology programs. An MOA exists between the labs. It is being modified to reflect the MILSATCOM requirements defined through the DoD Communications Master Plan and the AF TPIPT process.
- RL is testing the application of 3D audio for operator understanding of multiple communications, using Armstrong developed 3D audio technology.
- Rome Lab is collaborating with Wright Lab Materials Directorate to provide phosphorous injection expertise and crystal growth expertise in ZnGeP2 for mid-IR Optical Parametric Oscillators needed by WL.
- We work with Wright Laboratory through an MOA in the area of Bistatic Radar development.
- We also have formal coordination in the area of sensor fusion with Wright Laboratory.
- We interact with Phillips Lab on the Space Debris Workstation and the RF Weapon System Effects project
- Work under the Rome Lab Electromagnetics, Reliability and Photonics Thrusts is planned jointly with the Wright and Phillips Laboratories and reported under the Electron Device Interlaboratory Investment Plan.
- We work closely with Wright Laboratory in the area of airborne radar. The JDL Technology Panel for Sensors Joint Program Plan covers this work.
- All the Labs and AFOSR jointly plan and coordinate their Computer Science and Technology programs through an Interlaboratory Investment Plan and the JDL Technology Panel for Computer Science.

Government Agencies

Rome Laboratory is very proactive in establishing relationships and working with other government agencies and the MAJCOMs, in order to leverage the C^3I technology program. A few examples are:

- Under the Speakeasy Program, RL has MOAs/MOUs with several agencies including: an MOA with USArmy CECOM and ARPA for the joint funding and management of the Speakeasy Program; an MOA with National Security Agency in areas including INFOSEC aspects, security requirements identification, INFOSEC data management, and NSA product endorsement; and an MOU with Electronic Systems Center for the establishment of a Shared Management Approach for the Speakeasy Program and for the examination of ESC programs for potential Speakeasy technology insertion.
- We are working with ARPA under the Improved MILSATCOM Products for Advanced Communications Terminal (IMPACT) program. This work will be folded under the ARPA/Rome Lab Speakeasy program to support a SATCOM extension of the terrestrially focused Speakeasy radio.

- RL is working with MIT-Lincoln Laboratory in the development of advanced nulling algorithms for spacecraft communications uplink antennas. Rome Lab implemented the MIT-LL Space algorithm within the RL Adaptive Nulling Antenna Testbed. The algorithm has future application on EHF and SHF spacecraft systems. Further, RL is sponsoring MIT-LL development of an advanced high efficiency solid state power device technology which promises substantial improvements in device efficiency in transmit phased arrays as well as medium to high power solid state amplifiers that can compete with Traveling Wave Tube efficiencies.

- The Defense Intelligence Agency (DIA) is our prime national customer through the Department of Defense Intelligence Information System (DoDIIS) community, and; for Air Force Requirements the 497th Intelligence Group is supported. The Intelligence Data Handling System (IDHS) Product Group uses this advanced technology.

- In an MOA with DISA/ESC/CECOM/NRaD /SPAWAR, Rome Laboratory will establish the control infrastructure for the next generation SHF terminals within the Defense Satellite Communications System (DSCS), based on the DISA developed SHF Demand Assigned Multiple Access (DAMA) Standard. This will be financially and technically supported by these other organizations. This MOA establishes the relationships and responsibilities.

- Through the Defense Cryptological Program (DCP), Rome Lab works closely with the National Security Agency, Air Intelligence Agency, Naval Research Laboratory, Naval Command and Control Ocean Surveillance Center R&D, Navy SPAWAR, Army CECOM and Lincoln Labs.

- The IE2000 program has established working relationships with US Navy Space Warfare, the National Photographic Interpretation Center/National Exploitation Lab and the Multispectral Automatic Target Recognition Interactive Exploitation Program Office.

- The mapping Applications Client/Server is being incorporated into Strategic Command and Air Combat Command systems including the STRATCOM Intelligence Network and Contingency Theater Automated Planning System.

- Rome Laboratory is ARPA's executive agent for efforts in the Imagery Understanding Program, acts as technical consultant and manages contractual research. This provides for close coordination with RLs related technical efforts in automated imagery exploitation.

- AFMC Systems and Air Logistics Centers and AF SPACECOM are prime evaluators and users of Rome Lab Software Engineering Technology on programs like the F-16, C-17, F-22, Space Debris Safety, Joint Stars, etc. The AF Information Warfare Center is a major fiscal supporter and user of Rome's computer security technology.

- Rome Lab is supporting the MILSATCOM Joint Program Office of Space & Missile Center in the development of advanced EHF payload and airborne terminal communications technology for future EHF communications systems.

- We work closely with scientists at the AF Wright Laboratory, the Naval Research Laboratory and the Army Research Laboratory to plan and advance technology for electromagnetic and superconducting electronic materials and devices. Rome Laboratory leads in the application of these electron device advances to communication, signal processing and surveillance radars for C^3I applications.

- Rome is jointly developing its AI planning and scheduling technology with ARPA and has an MOA with ARPA for transfer of its software engineering program to ARPAs Software Technology for Adaptable Reliable Systems (STARS) Program. Rome has an MOA to incorporate its software engineering technology into NASA's Computer Aided Software Engineering (CASE) process. As part of the NSA Consolidated Computer Security Program, Rome has specific responsibilities in secure distributed systems, secure database management systems, and the design and verification of secure systems.

- The Naval Air Weapons Center, Naval Surface Warfare Center, Army Strategic Defense Command, Army Research Lab, Army CECOM, et. al., are formally evaluating Rome's software and system engineering technology on systems for tactical air, anti-submarine, ballistic missile defense, tactical communications, etc. Rome is jointly developing knowledge-based engineering (AI) technology with NUWC, TACOM, NRaD, ONR, AFOSR, ARO, and others for application in C4I Systems for attack submarines, tanks, crisis planning, etc. Finally, with funding from the three services and Assistant Secretary of Defense for C^3I, Rome has joint programs with CECOM and NRaD in distributed computing, database, computer security, and human-computer interface technologies for C^3I.

- Rome Lab has a joint program with the Navy (NAWC) and Army (CECOM) in non-cooperative bistatic radar technology.

- We work closely with Air Combat Command in connection with our Joint STARS Cueing and Correlation Demonstration. ACC personnel are providing operational insights necessary to maximize demonstration utility.

- Rome Laboratory is working with the Air Force Cryptographic Support Center, Kelly AFB to address potential security issues associated with using semiconductor memories (i.e. SRAMs, DRAMs, PLDs and EEPROMs) in Air Force systems. Results will be the development of policy guidelines and recommendations for the use of cited memories for secure use.

- In a MOA with NSWC, ARL, and NASA, Multichip Modules (MCM) technologies with potential high DoD, NASA and commercial usage are being evaluated to determine their performance and reliability in diverse environments. The intent of this effort is discover possible failure mechanisms associated with MCM interconnect structures, design and implement appropriate cost effective reliability and quality assurance procedures and propose corrective actions to the industry.

PROJECT RELIANCE

Under Project Reliance, the Joint Directors of Laboratories (JDL) continues to improve coordination and reduce duplication among services. Rome Lab chairs the Reliance C^3 and Computer Services Panels, co-chairs the JDL Sensors Panel and has membership on five other Panels plus twenty Sub and Sub-sub Panels. Through Project Reliance, the JDL has increased coordination, decreased duplication, and improved joint interoperability.

The following are a few examples of joint programs:

- RL participates in a number of Reliance efforts covered under the Microelectronics Infrastructure JDL panel. Reliability Science R&D efforts in the area of Gallium Arsenide (GaAs) MIMIC and high power HBTs, multichip modules (MCMs), and plastic encapsulated microelectronics are being accomplished jointly with Naval Research Laboratory, Naval Surface Warfare Center, Army Research Laboratory and AF/Wright Laboratory.

- We are actively participating in the ARPA/Tri-Service MIMIC Hardware Description Language Program which is developing a commercialized IEEE standard capable of describing analog and microwave hardware, including an interface to VHDL for mixed-system description. Included is the development of commercially supported computer aided engineering (CAE) and language tools needed to establish an industry used standard.

- We work with Naval Research Laboratory (NRL), Naval Command and Control Ocean Surveillance Center Research and Development (NRaD), and Army CECOM under Project Reliance and similar relations on speech related identification and transformation technologies.

- RL in conjunction with ASC, five logistic centers, NAWC and Army is supporting ABBET, a set of software interface standards for the test domain to facilitate the transition of test information and implementation of automated tests. These software standards are defined to support software component portability, reusability, exchangeability, and interoperability, and to serve as targets for test-related software development tools. ABBET is to be developed under the auspices of the IEEE through the Standards Coordinating Committee (SCC) 20.

- We are supporting the Tri-service/ARPA Rapid Prototyping Application Specific Processor (RASSP) program in the area of test and integrated diagnostics, reliability, and design and test methodologies by defining how digital signal processors are specified, designed and maintained. The goal of this program is a 4X improvement in design and life cycle support associated with digital signal processors. RL works closely with AF/WL, ARL, NRL, and ARPA. This support addresses the goal of an order of magnitude increase between maintenance actions, efficient diagnostics methodologies, and design tools and test methodologies to incorporate reliability as soon as possible.

- We are participating in a Tri-Service, NASA, EPA, Industry, and Academia (GTRI) team evaluating the removal of ozone depleting substances (ODS) solder fluxes from printed circuit (PC) boards. This effort is serving as a feasibility demonstration of producing reliable military microelectronics without the use of ODS. The results being developed by this effort are being shared with the industry through NTU satellite broadcasts.

- We participate in the JDL Sensors Panel. We have joint programs in the Airborne Early Warning (AEW) area with the Naval Air Warfare Center.

- We participate in the JDL Electronic Devices Panel in the area of microwave solid state components, microwave photonics, analog opto-electronic integrated circuits, and high speed lasers. We have joint programs with AF/Wright Laboratory, Naval Research Laboratory, and the Army Research Laboratory. This work is applicable to all communication and radar systems.
- Under a Project Reliance relationship, the Air Force Speakeasy Program Office works closely with the other Joint Program Participants including: the Advanced Research Projects Agency (ARPA/ASTO), US Army CECOM, and US NAVY NCCOSE RDT&E Division.
- Our photonics program is very closely coupled with ARPA, particularly in the areas of photonic systems, devices and opto-electronic integrated circuits. One of our staff members is assigned to ARPA half time to support their photonics program.
- RL participates as a member of JDL "Science and Technology Reliance Assessment for Modeling and Simulation Technology (STRAMST) tri-Service Ad Hoc working Group". This initiative will establish a service-wide coordinated program in Modeling and Simulation.
- Rome Lab is an integral part of the Decision Aids Subpanel of the JDL technology panel on C^3 (TPC^3). Other service participants are the Army CECOM and Navy NRaD Laboratories. Force/component level planning and execution control are the current targeted functionalities for technology cross-feed and interoperability.
- Under the JDL, a Tri-Service advanced networking testbed is being established that will electronically interconnect the Service labs and some limited number of operational users. This testbed will support Tri-Service research in high speed networking as well as the distributed processing and decision aids.

CHANGES FROM LAST YEAR

The primary changes in the C^3I S&T program over the past year are the result of FY 95 funding shortfalls and Congressional direction:

FY 95 shortfalls resulted in:

- Slips in program milestones or delays in the start of new programs. The FY95 budget was reduced by $15.9 million from the original FY95 President's Budget. This represents a 11.4% percent cut in the planned AF C^3I S&T budget.
- USAF reprogramming of almost 35% of the expected funding in PE63728F for FY96 on out has substantially delayed the development and demonstration of capabilities in engineering of Knowledge-Based Software Systems, fault-tolerant software, and mission planning, and delayed the demonstration and transition of real time distributed computing, integration of high performance networks (e.g., ATM) into distributed computing environments, and the integration of security mechanisms into distributed systems.

Congressional language:

- The FY95 C^3I S&T budget for The information for the Warrior program was delayed pending results of a risk analysis. Once funds are released, it is anticipated that there will be a significant positive impact on the RL program in this area.

SUMMARY

The C^3I S&T program is crucial to Global Reach/Global Power. Rome Lab C^3I technologies will revolutionize modern combat. The technical foundation of the Rome Lab initiative is the ability to sense, analyze, distribute, and use huge amounts of information to support worldwide operations. The technical program will provide these capabilities while controlling costs and achieving major gains in reliability and supportability of complex electronics.

Mission payoff includes both immediate improvements for today's inventory of C^3I systems and the technological basis for future systems. At the same time, this world class technology is significantly impacting the commercial market through technology transfer. The program described in this TAP results from a rigorous investment strategy process which balances the needs of all customers with available resources.

Each of the TAPs thrusts are discussed in the sections that follow. A macro-graphic roadmap of the thrust's technology program is included for each thrust.

THRUST 1 - SURVEILLANCE

USER NEEDS

The Air Force needs to improve the performance and reduce the cost of Air Force surveillance systems. Technologies being developed to meet these needs include: advanced noncooperative bistatics; space-time processing; sensor/data fusion; signal generation and control; advanced array antennas; and Over-The-Horizon Radar.

- **The Surveillance and Reconnaissance Mission Area Plan (MAP)** identifies responsive tasking and the ability to detect and track Critical Mobile Targets as major deficiencies. Other severe C4I limitations include detection of low altitude, low observable threats and high confidence hostile target identification of wide area threats according to the **Air Combat Command (ACC) Theater Battle Management, Reconnaissance and Surveillance, and Theater Missile Defense MAPs.**
- The **Joint Mission Needs Statement for Theater Missile Defense** states a requirement for "... a robust C3I and surveillance capability unique to Theater Missile characteristics." The radar cross section and low altitude of cruise missiles makes them very difficult to detect with fielded sensors due to clutter, jamming, and "hot clutter". "Hot clutter" is a terrain scattered interference signal. Developing the ability to reject "hot clutter" is viewed as a major problem by ARPA and the Services.
- USACOM, USSOUTHCOM, and NORAD have identified Over-The-Horizon Radar as a main surveillance asset in the counterdrug mission. This has led to two new Over-The-Horizon Radars being installed in the relatively near future, and has fostered an effective and close working relationship between the operational and technical Over-The-Horizon Radar community. **The ACC Strategic Defense Map** identified Over-The-Horizon radar as a solution for current C4I system deficiencies.
- The **Air Force Special Operations Command's** need for real-time situation awareness and threat updates is specified in their **Weapons System Roadmap.** It also emphasizes the need for sensor covertness and cueing using offboard sensors.

GOALS

- Develop Space-Time Adaptive Processing (STAP) techniques for improved detection of low cross section targets in presence of serve clutter and jamming.
- Develop passive bistatic sensor technology and concepts to reduce system cost and to improve sensor survivability and covertness.
- Develop cueing and fusion concepts using offboard sensor data to improve sensor efficiency, hostile target identification, and real-time situation awareness.
- Develop methods to drive down the cost of testing advanced radar components required to detect small targets in the presence of clutter and jamming.
- Develop and transition technology in Over-The-Horizon Radar for counterdrug surveillance to improve detection, tracking, and coordinate registration of small maneuvering targets using clutter mitigation, reference registration, fusion, altitude estimation, and new advanced signal processing techniques. Explore the potential of using Over-The-Horizon Radars as theater air defense and intelligence gathering assets.

MAJOR ACCOMPLISHMENTS

- Noncooperative bistatic radar technology was used to demonstrate the tracking of theater ballistic missile targets. The Airborne Multimode Bistatic Sensor (AMBIS) successfully collected data against a STORM missile, a high speed theater ballistic missile undergoing testing at the White Sands Missile Range in New Mexico. AMBIS piggybacked on the ongoing tests using ambient illumination sources and successfully recorded bistatic signature data.

- The Joint STARS Cueing and Correlation Advanced Technology Demonstration (ATD) has completed the evaluation of alternative concepts and has selected an optimal approach for employing strategic and tactical warning from offboard sensors to improve the surveillance of ground targets for theater operations

- Data collection at White Sands Missile Range using an ARPA/Mountain Top Phased array radar was successfully completed. The radar has been moved to Hawaii and will start collecting data in early 1995. The data collected will be placed into an on-line data library for use by Space-Time Adaptive Processing researchers.

- Successfully completed the collection of airborne data for evaluation of space-time processing algorithms under the Multi-Channel Airborne Radar Measurements (MCARM) program. The objective of MCARM is to collect multi-channel phased array data for developing and evaluating space-time adaptive processing techniques for future airborne radar systems and upgrades

- A software prototype was developed that correlates and fuses surveillance and intelligence data for an enhanced air situation display. Prototype has been tested against simulated E-3 data and intelligence products. The technology will form the baseline of an on-board E-3 demonstration that will integrate the on-board sensor suite with off-platform information

- Developed a high dynamic digital beamformer receiver to improve target detection in clutter. It incorporates a RL patented technique to effectively achieve 15 bit performance with a 12 bit A/D converter.

- Operational Over-The-Horizon Radars have continued to play a major role in counterdrug surveillance and have become a key asset in that capacity. New Rome Laboratory efforts such as the use of new waveforms for clutter rejection, use of beacons and better ionospheric modelling for improved coordinate registration, and improved tracking techniques have been developed. Major advances in noise excision, tracking, and coordinate registration have been made which will be transitioned to operational systems.

CHANGES FROM LAST YEAR

Funding reductions have caused a delay in a new surveillance Advanced Technology Demonstration.

MILESTONES

Continue development of Joint Stars Cueing and Correlation ATD.

- Evaluate a real-time demonstration with JSTARS performance enhancements in 1996
- Demonstrate further enhancements to JSTARS performance resulting from cueing and correlation with enhanced radar modes in 1997

Continue to advance noncooperative bistatic radar technology and concepts for low cost covert surveillance.

- Develop and demonstrate a multi-channel phased array bistatic radar in a ground testbed in 1996
- Develop and demonstrate bistatic clutter rejection concepts in 1996

Complete the evaluation of space-time adaptive processing (STAP).

- Complete the collection of data in Hawaii using ARPA/Mountain Top phased array radar. This data will be added to data library for use by STAP researchers - 1996
- Demonstrate real-time space-time processing on an airborne platform in 1996
- Evaluate the performance of STAP algorithms using collected data by 1997
- Complete bistatic MCARM data collection experiment and analysis in 1995
- Complete systems oriented analysis of the bistatic MCARM data for the prediction of performance improvement to existing monostatic systems in 1996

Continue to develop hostile target identification concepts.

- Demonstrate S-band target ID capability for surveillance system - 1996
- Demonstrate on-board E-3 sensor fusion - 1997

Continue development of multisensor fusion technology.

- Develop an AI fusion black box in 1996
- Demonstrate special purpose AI machines for both expert and blackboard system in 1997

Continue to develop the component technology required for advanced surveillance systems.

- Develop active array T/R modules incorporating signal preprocessing, including synchronous detection and channel equalization for integration into a 32 column testbed array - 1997
- Develop transmitter components for incorporation into system upgrades for air surveillance radar including both solid state and power module technologies - 1998

THRUST 2 - COMMUNICATIONS

USER NEEDS

This thrust supports Air Force need for instantaneous wideband information access to provide global communications for the rapid application of air power. Communications systems must provide assured connectivity for timely, reliable, responsive, and affordable transfer of information. Fundamental are the tasks of force deployment, sustainment and employment (Global Reach/Global Power).

Through a Memorandum Of Understanding (MOU) with ESC, the programs in this thrust are an integral part of the Air Force Theater Deployable Communications (TDC) Program that will satisfy requirements beyond 2000. It also supports the needs expressed by the Joint Staff in their "C^4I for the Warrior" concept.

The program develops communications subsystems that support distributed computing and automated mission planning functions. It also addresses the development and insertion of space communications technology into future military and commercial space systems.

The user needs addressed in this thrust have been derived from the following documented requirements:

- **ACC Theater Battle Management Mission Area Plan (MAP) includes Theater Deployable Communications (TDC)** requirements of: enduring, multi-level secure, seamless networks, high performance capacity and timeliness, and interoperability with the other services and friendly forces.
- **Air Mobility Command (AMC) Airlift MAP** identifies the following deficiencies in current "*stovepipe*" systems: expensive to maintain, lack of upgrade capability, closed/proprietary hardware architecture, proprietary software, no surge capability, limited deployed communications connectivity, non- programmable land mobile radios, and lack of frequency band coverage.
- **Air Force C4 Agency Communications Squadron 2000 Initiative** identifies needs for deployable, initial communications packages that are mobility qualified, modular, interoperable, lightweight, less aircraft intensive, highly supportable, and affordably upgradable.
- **Air Force C4 Agency Superhighway 2000 Initiative** identifies plans to upgrade airbase communications infrastructure.
- **CAF Mission Need Statement for Counter-Drug Air-to-Air Detection and Monitoring** requires interoperable secure communications with *sister* services, host nation, and law enforcement counter-drug agencies' ground and airborne platforms, and multiband, multimode transmission capabilities.
- **Defense Planning Guidance (DPG) for MILSATCOM** emphasizes the need for cost reduction and technology insertion in space systems. Emphasis is to: reduce the life cycle cost of future MILSATCOM UHF, SHF and EHF systems through the development of critical technologies which contribute to cost effective systems, while meeting defense requirements.
- This thrust supports the Defense Information Systems Agency (DISA) in their Technology Insertion Process for the Defense Information Services Network (DISN).
- The capabilities that are embodied in the DoD Global Surveillance and Communications Program vision provide the focus for the integrated capability derived from the products of this Thrust.

GOALS

The goals of the thrust are derived from the user needs identified above. Develop and demonstrate advanced communications technologies required to link national command authorities and sources to Air Force components of a Joint Task Force, regardless of location. Provide a global interactive distributed infrastructure with which commanders, staff, and warfighters can obtain immediate access to critical Command and Control information associated with all phases of mission planning, execution, and assessment. Technology developments under this thrust are directed at the following specific technical goals:

- Modular, programmable radios that are easily maintained, interoperable, robust and multi-level secure, that can be integrated to operate in an open systems environment at the lowest cost.
- Robust networking systems to provide automatic network restoration and the automatic flow of information at multiple levels of security.

- Seamless information handling capabilities to achieve an integrated network environment of distributed systems using lighter, deployable communications to provide a worldwide C^4I Global Reach capability.
- Lightweight, miniature, low input power subsystems to reduce the weight of SHF/EHF spacecraft communications payloads by 50% for launch on the Medium Launch Vehicle.

MAJOR ACCOMPLISHMENTS

Rome Laboratory completed the development of the Secure Survivable Communications Network program which deployed Asynchronous Transfer Mode communications switching capabilities to seven Joint Service/Agency locations. This Joint Advanced Development Environment (JADE) provides the environment for the demonstration of the performance of ATM technologies over legacy communications systems. The ability to interface this technology to systems such as TRI-TAC and DSCS is critical in the progress of making this rapidly developing technology available to the warrior. The program is coordinated with the Theater Deployable Communications (TDC) program being conducted by ESC to assure it is compatible with Air Force future communications architectures.

A combined UHF/SHF Satcom radio with DAMA protocol capability was demonstrated. This is the first step in the attempt to develop a programmable UHF/SHF baseband radio that uses the evolving UHF and SHF DAMA standards. Future efforts will further minaturize the radio and develop the RF subsystems .

The DISA SHF Demand Assigned Multiple Access (DAMA) standard using proof of concept System Control Terminal (SCT) and Network Control Terminal (NCT) was validated.

The Speakeasy Phase-I Advanced Development Model (ADM) showing performance comparable to existing legacy radio systems and the ability to modify embedded waveforms with software changes was demonstrated .

The Radio Rapid Prototyping Testbed via embedded signal processing algorithm using multiple digital signal processing engines and analog-to-digital interfaces was demonstrated . Signal processing algorithm developed using high-level, icon-driven communications simulation package.

CHANGES FROM LAST YEAR

The C^3I S&T budget for the Information For The Warrior program was delayed by Congress pending the results of a risk assessment.

The MILSATCOM Joint Program Office (MJPO) of the AF Space & Missiles Center (SMC) has initiated a technology program for the development of advanced EHF payload and airborne terminal technologies for future EHF Satcom systems. RL and PL are jointly managing technology developments under the MJPO program.

MILESTONES

Major milestones in the Communications Thrust include:

- Complete development of Radio Rapid Prototyping environment/testbed through integration of hardware components, processors, and measurement instrumentation in 1996.
- Demonstrate communications protocols capable of operating in ATM/Synchronous Optical Network (SONET) based systems under theater threat conditions in 1997.
- Demonstrate Reach-back for the Warrior and DISM capabilities with two ATDs under the Information For The Warrior Program in 1997.
- In 1997, demonstrate the Speakeasy Phase-2 Man-Machine Interface and a Limited Capability Demonstration model.
- Demonstrate low cost EHF antenna subarrays for airborne platforms in 1997.
- In 1998, demonstrate 44 GHz Satcom phased array with multiple simultaneous beams.
- Demonstrate the total functions of the Speakeasy radio and, in 1999, the utility of the radio for joint/combined operations in 1998.
- In 1998, demonstrate a Secure ATM switch and integrate into ESC's TDC Program.

THRUST 3 - COMMAND AND CONTROL

USER NEEDS

The changing world picture has dramatic implications for the command and control capabilities of U.S. forces. In implementing the Air Force Global Reach/Global Power paradigm, we still address the issues associated with the new operational environment - joint operations, new force structures, force draw down, loss of forward basing, and emphasis on time critical fixed and mobile targets. Overcoming the downside of these issues demands continued development of flexible, modular, and interoperable command and control to support force multiplication, rapid power projection of joint or combined forces, and real time operations.

The context for such command and control has been articulated by the **Defense Planning Guidance for 1995-1999** and by the Joint Staff through both the **"C4I for the Warrior" (C4IFTW)** concept, and its implementation - the **Global Command and Control System (GCCS)**. All emphasize priority improvements in *information technology for the dynamic battlefield environment.* The Chief of Staff of the Air Force C4I Review identified Shortened Decision Cycle as a key requirement. These priorities have been promulgated downward and articulated through the following documented user needs:

- **ACC Theater Battle Management MAP and TBM General Officers Steering Group (TBM/GOSG) Operational Goals** include: Reducing the Planning and Execution Cycle, Improving Joint Interoperability, and Establishing a common picture of the battlefield.
- **Contingency Tactical Air Control System Automated Planning System (CTAPS) Operational Requirements Document** states the need for automated planning and decision support tools to plan, direct, control, execute and report the air mission. Interoperability with other TBM, Service and Allied automated systems for joint and combined operations is also a key need.
- **Mission Needs Statement for Air Tasking Order (ATO)Interoperability:** identifies the need to develop, analyze, and execute the ATO in a timely and accurate manner within a constantly changing battlefield.
- **Program Management Plan for Theater Air Defense and ACC Theater Missile Defense MAP** requires rapid response of Planning and Operations.

GOALS

The major goal of this thrust is to support "come as you are" warfighting with "anywhere, anytime information - based support". Per TBM/GOSG direction, the focus is on the Commander Joint Task Force(CJTF), Joint Force Air Component Commander(JFACC), and the Air Operations Center(AOC) with horizontal, joint service interoperability.

To support this goal, the thrust has been structured with activities of both a near-term focus, as overseen by the TBM GOSG, and a longer term vision which strives to harness new intelligent information technologies for application to the C4IFTW Mid-Term and Objective phases. Spanning these two activities is an Operation Evaluation Environment, which supports Joint and/or Air Force only tests and demonstrations. The thrust can be effectively separated into the following four measures of effective-ness/payoffs:

- Focus near-term investment on information technology that will support Air Operations Center operational requirements for joint/same automated decision support tools for reduced decision cycles.
- Develop next generation intelligent information services and software tools that will support joint or combined operations with rapid Course of Action generation; collaborative planning and execution; and enhanced visibility into the battlespace.
- Demonstrate efficient and effective acquisition concepts (e.g.. rapid prototyping) for software systems.
- Demonstrate operational utility in regular military exercises involving unified commands and their component services.

MAJOR ACCOMPLISHMENTS

- The Advanced Planning System (APS), has been selected as the joint service Air Tasking Order (ATO) generation module for (GCCS).
- Rome Laboratory and ARPA combined the Force Level Execution (FLEX) and WARBREAKER Local Attack Controller (LAC) programs to accelerate development of an Air Force time critical target (TCT) capability for Theater Air Defense (TAD).
- The FLEX combat operations data base has been chosen to replace the existing AF operational Computer Aided Force Managment System (CAFMS).
- A collaborative planning demonstration was executed during Joint Warrior Interoperability Demonstration (JWID) 94. The demonstraion integrated Air Force, Navy and ARPA planning technologies, and showed single thread planning from CINC to Task Force to components using a distributed computing environment.
- A similar demonstration package was employed in the Electronic System Center Fort Franklin 94 exercise.

CHANGES FROM LAST YEAR

The only change has been a required increased committment to participation in exercises.

MILESTONES

Strong relationships continue with the Advanced Research Projects Agency (ARPA), and the Air Force TBM and Theater Missile Defense (TMD) programs. These partnerships sponsor work in both the near-term TBM and longer term Distributed C2 activities.

At the same time, portions of the ARPA Portable Command and Control for the CJTF program are being pursued to extend long term distributed information processing activities from the AOC only to joint issues inherent to task force collaborative planning.in C4IFTW and GCCS. The Thrust provides these programs with a transition path into the TBM/GOSG directed operational architecture enhancement process as well as transition to GCCS for C4IFTW.

Major milestones include:

- Transition Flex to CTAPS/TBMCS Version 1.0 in 1996 to include advanced TCT software from WARBREAKER/LAC to support TMD/TAD tasking/re-tasking battle management and advanced decentralized employment Concepts of Operations (CONOPS).
- Complete program management transition for APS to the CTAPS/TBMCS program office in 1995.
- Complete OPS/INTEL ATD and transition to TBM GOSG development process in 1996. Complete GOSG development and transition to CTAPS/TBMCS in 1998.
- Complete DEFENSIVE PLANNING ATD and transition to TBM/GOSG development process in 1998. Transition to CTAPS/TBMCS in 2000.
- Continue development of Operation Evaluation Environment
  - Continue to support Fort Franklin exercises. Current planning calls for quarterly demonstrtions.
  - For JWID 95, expand to joint, collaborative *execution* management by adding FLEX and integrate with the Wing C2 Sytem (WCCS).
  - Support Roving Sands 95 exercises.
- Complete distributed computing configuration of Operation Evaluation Environment:
  - Add OPS/INTEL and DEFENSIVE PLANNING ATD capabilities.
  - Demonstrate Distributed Air Ops Center in 1998.
  - Demonstrate air / ground / sea based CJTF/JFACC capabilities in 2000.
  - Simultaneously develop and demonstrate distributed, collaborative C^2 for "build a little/test a little" transition.
  - Conduct multiple Intermediate Functional Demonstrations (IFDs) in 1995.
  - Subsequent spring/fall demonstrations 1996--97 building scenario complexity up to National Strategy - two simultaneous major regional contingencies (MRCs).

THRUST 4 - INTELLIGENCE

USER NEEDS

The Intelligence community has the need for providing real-time information that will dramatically enhance air superiority, survivability and global awareness. Work under the Intelligence Thrust is directed at meeting these needs in the following:

The **Air Combat Command (ACC) Theater Battle Management MAP** and the **Reconnaissance, Surveillance and Intelligence MAP** requires battle damage assessment in real-time, with the results of the assessment inserted into the Air Tasking Order upon demand.

The **Department of Defense Intelligence Information System (DODIIS)** needs to monitor threatening situations as they develop, pass imagery from Headquarters to Units, and provide Indications and Warning updates on a timely basis to support regional conflicts.

The **Intelligence Functional Area Plan** requires data processing techniques to manage information warfare, extract tactical information from communications and to develop tactical deception plans. Air Intelligence Agency (AIA) requires advanced information technologies to address technology needs in the Intelligence Functional Area Plan.

The **National Air Intelligence Center (NAIC)** needs advanced signal processing and modeling and simulation techniques to model foreign threats and track the proliferation of weapons of mass destruction.

GOALS

- Develop technologies for insertion into C4I architecture and pursue technology transfer to commercial markets.
- Develop enabling information processing technologies responsive to operational deficiencies by improving timeliness, reliability, and accessiblity of information to the warfighter.
- Advanced signal exploitation techniques will be developed to respond to operational deficiencies by improving timeliness of intelligence to the warfighter by 50%.
- Intelligence Data Handling research will develop technology and techniques to make "machines" automatically read text, extract data of interest, and update databases; to aid intelligence users visualize and analyze data for situation assessment, and to provide rapid access to relevant data.
- The Sensor Exploitation research will develop techniques to automatically detect change in imagery, precisely locate targets and disseminate the fused results of multi-sensor data in real-time to support battle damage assessment, manage large imagery data bases and associated information and fuse and correlate multi-sensor information.

MAJOR ACCOMPLISHMENTS

Recent accomplishments in the intelligence area have had a major impact on the way users accomplish their mission. They include:

- Successful demonstration of high performance 14" erasable optical disk system into mission planning system at AFSOC, Hurlbut Field.
- Demonstation of deployable optical disk jukebox at AFSOC,Hurlbut Field.
- The design and fabrication of a compact, breadboard 3-dimensional read only memory system (ROM) using a two photon absorption concept.
- Successfully performed the first live field test of platform identification technology at a Nearland exercise which diffentiated military helicopters based on audio acoustics.
- Developed in-house and transferred to a contractor a transmission-by-transmission speech segmentation algorithm superior to all others tested on noisy speech.
- Developed channel normalization technology which significantly improved the automatic sorting

and routing of communications by speaker by 20%.

- Multiple law enforcement agencies used RL's tactical speaker identification and speech enhancement technologies to gather evidence in criminal investigations.

- Developd modeling and simulation technology in the areas of model integration for application to NAIC theater-level models.

- During FY94 the Rapid Application of Air Power (RAAP) capability was integrated into Combat Intelligence System (CIS) development and played a major role in the Ulchi Focus Lens exercise in Korea and in several Blue Flag exercises. In addition, RAAP was installed at six other operational sites in CONUS and overseas.

- Imagery Exploitation 2000 was improved and utilized to investigate imagery product dissemination using Compact Disc (CD) technology, and Battle Damage Assessment (BDA) experiments were conducted using Desert Storm gun camera video inputs. Finally, new exploitation scenarios were developed which involved a combination of imagery intelligence (IMINT), electronic Intelligence (ELINT) and cartographic information.

- The Mapping Application-Client/Server (MACS) software was transferred to Electronics Systems Center (ESC). This system provides the modular, object-oriented architecture support required by the new systems being developed for the war fighter and is currently being integrated into CTAPS.

- The Client Server Environment-System Services (CSE-SS) was developed, tested, and then installed at AETC, 480 IG, SOCOM, CENTCOM, AFTAC, STRATCOM, PACOM, 497 IG, SPACECOM, DIA, AIA, and ONI. CSE_SS provides the intelligence community with a common computing environment, a single solution for system high computing, uniform system administration tools .

- The Timeline Analysis System (TAS) was integrated with the Defense Automated Warning System's (DAWS) message front end to feed live electronic messages directly to TAS for display on the TAS timelines and maps. This automates the manual process of reviewing messages and plotting aircraft tracks and allows more time for analysis.

- Major Intelligence Data Handling System software releases were developed and installed in over 50 operational sites. These software releases provide enhanced IDHS message handling, situation assessment, database, client server, and imagery management technologies for the unified and specified commands' critical intelligence missions.

- A Generic Intelligence Processor (GIP) software module is being used operationally at the 480th IG. It automatically transfers messages from MAXI message queues to separate ASCII file for subsequent use by the Generic Monitoring System.

CHANGES FROM LAST YEAR

No changes from last year have impacted the Intelligence Thrust.

MILESTONES

The milestones in the Intelligence Thrust are:

- The Wideband Recording, Storage & Retrieval area will exploit optical disk and 3-D memory concepts to improve storage capacity, access times and throughput rates.
  - A one Terabyte Erasable Optical Disk Jukebox will be delivered and integrated at the 480IG, ACC, for ACCINTNET applications in FY96
  - A 3-D Optical Read Only (ROM) Memory device that will verify massively parallel terabit capacity, gigabit throughput rate and nanosecond access time will be integrated for AFINTNET applications in FY97.
  - A 3-D Optical Erasable memory having the same characteristics as above will also be delivered and integrated into the ACC, AFINTNET program.
- Developments starting in1995 of advanced spatial database update and query robot technologies will significantly improve operations relative to advanced planning, targeting and mission execution at the unit and force levels.
- Advanced Technology Demonstrations for development of fully automated SIGINT and all-source sensor fusion capabilities to locate, identify, and track mobile red, green, and blue military components will be underway during FY95-97.
- A Virtual Laboratory will provide CIO and RL, with a capability to conduct collaborative image exploitation research and demonstration activities via a secure wideband interconnection in 1996.
- Natural Language Understanding (NLU) software, which reads text and extracts data of importance will be transitioned to the US Depatment of Treasury in February 1996.
- The Machine-Aided Voice Translation ATD will translate spoken Arabic, Russian, and Spanish to spoken English and will be demonstrated at AFSOC in 1997.

THRUST 5 - SIGNAL PROCESSING

USER NEEDS

Signal processing technology turns raw data into the higher level real-time information that feeds every aspect of the C3I mission including:

- The Air Combat Command (ACC) Theater Battle Management Mission Area Plan (MAP) identifies a mission need for E-3 to include programmable adaptive signal processors as key components to significantly improve radar signal processing.
- The Theater Battle Management MAP calls for enhanced radar capabilities for JSTARS supported by on-board signal processor upgrades.
- The ACC Strategic Defense MAP assesses the need for improved real time processing capability, real-time displays, and adaptive signal processing for Beyond-Line-of-Sight communications.
- The Intelligence Functional Area Plan calls for continued advances in speech and audio signal processing.

GOALS

The goals of the Signal Processing Thrust are directed at the advancement of signal processing technology, exploiting commercial technology whenever possible and rapid transition of the resultant advanced technology to military and commercial applications.

- Drive down the cost and complexity of C3I signal processing systems, improving throughput by a factor of 100 every seven years.
- Rapidly field the latest signal processing techniques for surveillance, communications, and intelligence as required above.
- Spin on and spin off technology transfers, maximizing competition and minimizing cost by reusing commercial hardware and software .
- Reduce system hardware complexity by shrinking racks of equipment with hundreds of part types down to single board solutions, simplifying logistics and aiding two level maintenance.
- Provide completely programmable signal processors and enable rapid prototyping of new solutions by replacing the current collections of "hardwired" special purpose boxes.
- Keep C3I systems current and foster competition by using open systems architectures.

MAJOR ACCOMPLISHMENTS

Recent major accomplishments include the following:

- Developed and demonstrated a Knowledge-Based approach to small target detection that adaptively determines clutter characteristics to optimize detection performance.
- Designed and fabricated a fully programmable wafer scale signal processor (WSSP) chip delivering 320 Million Floating Point Operations (MFLOPS) per second and 120 MFLOPS/watt.
- Developed a bridging router demonstrating the interoperability of heterogeneous open systems architectures.
- Developed a four channel speaker and language identification system.
- Developed keyword model generation technology which improved speaker dependent recognition of 20 keywords by 15%.
- Integrated a tactical signal processing card with 600 million operations per second and programmable interconnect topology.
- Demonstrated radio rapid prototyping testbed via embedded signal processing algorithm utilizing multiple digital signal processing engines and analog-to-digital interfaces.
- Completed development of a Neural Network Communication Signal Processing simulator for design of advanced transceiver architectures.
- Initiated a CRDA with industry to develop novel vertical optical interconnect technologies for three dimensional multichip modules (MCMs).

- Developed new techniques for supplying power and removing heat from three dimensional MCMs.

CHANGES FROM LAST YEAR

The DoD High Performance Computing Modernization Office selected Rome Laboratory as the site for a high performance computer specializing in signal processing applications. Rome Lab was also selected by HPCMO to lead the signal/image processing HPC application area across the tri-service labs.

MILESTONES

The signal processing thrust emphasizes the interrelated areas of developing new signal processing algorithms or techniques, and developing high performance signal processors.

The milestones in the signal processing thrust are:

- Real-Time Signal Processor Enhancement ATDATD coupled with High Performance Computing technology achieving 100 billion floating point operations per second for $1 million and transitioned to JSTARS for 1997 P^{3}I.
- Nonlinear signal processing and neural network technologies applied to communication processors in 1997.
- Add vertical optical interconnections to three dimensional wafer scale packages by 1995 to improve communication rates over current electronic interconnects.
- Real-time implementation of space-time adaptive processing on a moving platform phased array sensor in 1996.
- Designing experiments for the competing Rad-Hard 32 bit scalar processors onboard the ARGOS satellite that compare and contrast fault tolerance and reliability features and gather upset phenomenology data while on orbit from 1995-1998.
- Knowledge-based adaptive processing for improved jammer/clutter cancellation in 1996.
- High performance programmable signal processor for high bandwidth distributed architectures with photonic interconnects in 1996.
- Jam-resistant communications processor using highly compressed speech in 1996.
- Space-Time Adaptive Processing algorithms and high dynamic range phased array antenna receiver with digital equalization and control, refined and implemented in real-time for Surveillance ATDATD application in 1996.
- Advanced speech processing workstation monitoring six to ten channels for AF communications intelligence by 1999.
- Rapid prototyping capability by 1997 for evaluating advanced communications / signal processing concepts.
- Automated sorting of signals to improve tactical intelligence processing by 50% in 1996.
- Wavelet Transform based spread spectrum interference suppression subsystem in 1997.
- Highway monitoring system via video sensor technology for real -time traffic management in 1997.

THRUST 6 - COMPUTER SCIENCE & TECHNOLOGY

USER NEEDS

Mission productivity enhancement and the solution of problems with the use of, and dependence on computer systems and custom software to perform mission critical functions in a globally dispersed theater of operations is key to our technological edge.

Affordability of software development and support, currently running at about $10 billion per year for the Air Force, is affected by the size and complexity of the software for our new systems, and by the expense of maintaining and upgrading hundreds of systems in the inventory. As weapons and C^3I systems become more dependent on computers, and policy dictates support of two simultaneous hostilities in different parts of the globe, the need for an "Infosphere" composed of small, deployable resources which have all of the "illities" of large fixed site systems becomes critical.. Thus:

- **AFMC, AETC, ACC and the other MAJCOM's** need better processes and tools for the acquisition, development, and post deployment support of mission critical software systems.
- **ACC, AFSOC, USTRANSCOM, AMC** etc. are concerned with the dependability, survivability, security, interoperability with dissimilar systems, "real-time" information access capability, and timely executable plans etc., from their globally dispersed computing assets.

These needs are documented in the AFMC/ESC Technology Needs, the ACC Strategic Defense and Theater Battle management MAPs and the AFSOC Weapon System Roadmap.

Specifically, this thrust addresses:

- Tools, processes and whole "environments" to cut high costs and risks associated with the development and support of military software intensive systems, where productivity is currently growing at 4% and demand at 20%.
- The achievement of secure, dependable, immediate, and uniform access to globally distributed, dissimilar computer systems and databases resulting from distant, and/or joint, and/or multi-national, collateral forces' missions.
- Tools for rapidly generating, evaluating, and optimally scheduling combat, transportation, rescue, etc. mission plans and options for the flexible "quick reaction" force structure needed.

GOALS

This thrust seeks to achieve:

- Reduced software costs and enhanced reliability through improvement in software productivity and quality processes within Air Logistics Centers (ALCs) and program offices: Near-term, 2:1 improvement; Long-term, 10:1 minimum.
- 10:1 throughput performance enhancement in distributed computing, achievement of real-time performance in multi-media databases, and achievement of top NSA security standards in distributed computing and databases in support of joint and multi-national collateral missions.
- Factors of 10 to 1000 reduction in times required by the Joint Chiefs on down, for planning and scheduling combat & non-combat missions, and their associated support activities.
- Natural human interface to complex C^3I systems by the integration of multi-media, virtual reality, high resolution displays and spoken language.

MAJOR ACCOMPLISHMENTS

Major accomplishments under this thrust include:

- Integration and demonstration of the Crisis Action Planning Tool Kit and the new Force Generation Tool at JWID 94 and transition to USACOM.
- Revolutionary algorithm solved PACAF and PACOM in-theater airlift scheduling problems.
- Completion of Common Prototyping Environment supporting development, test and integration of planning and scheduling tools to support military employment and deployment planning in both crisis action and deliberate planning situations.

- Application of Rome Lab's Software Quality Framework to Joint STARS software lead to major early improvements in software reliability, saving $ millions in production and maintenance.

- Rome's CRONUS Distributed Computing Environment provided the information backbone for the Distributed Collaborative Planning Experiment in JWID-94 which demonstrated single thread planning from the CINC, through the JTF, to the JFACC using planning tools dispersed at several sites across the CONUS.
- Established a Tri Service testbed for the evaluation of multi level secure information system prototypes for use in joint operations.
- Transitioned the Ada formal verification tools to a commercial product, the AdaWise Toolkit.
- Demonstrated a local cluster secure distributed computing environment capable of supporting heterogeneous hosts and a B3 level of trust.
- Demonstrated and transitioned the software and systems Requirements Engineering Environment to SMC's Space Test Safety System and the NUWC's Next Generation Attack Sab.

CHANGES FROM LAST YEAR

USAF reprogramming of almost 35% of the expected funding in PE63728F, Advanced Computer Technology, for FY96 on out, delays the development of capabilities in engineering of knowledge-based software systems, fault-tolerant software, certification of software components, and mission planning. It also delays integration of high performance networks (e.g., ATM) and security mechanisms into distributed computing environments.

MILESTONES

Key milestones this thrust will demonstrate:

- A prototype Distributed Air Operations Center with direct interoperation with the Wing Command and Control System using an object/request broker type of distributed computing environment will be demonstrated in JWID-95,
- Real Time Distributed Computing Environment (RTDCE) executing on a homogeneous, internetted computing clusters will be demonstrated in 1995, and extended to heterogeneous operation in 1996. A secure RTDCE will be realized in 1998.

- In 1996, demonstrate a software development environment providing "automated intelligent assistance" to all roles from program manager to programmer. In 1997, this environment will be evaluated on a moderate sized military application and selected aspects demonstrated on commercial applications by the ARPA TRP.
- In 1996, on a "Joint-STARS-like" problem, demonstrate a reusable library of instantiated "system engineering best practices." In 1997, provide "building blocks" for computer-based environments that improve system engineering productivity and product quality.
- In 1996, field a prototype repository of data and information on experiences with software quality technology on Air Force and other projects.
- Demonstrate a Distributed Computing Environment using ATM communications as a joint Rome Lab NRaD development in 1996.
- Demonstrate a multi-media database management system in 1996 capable of handling text, graphics, imagery, and video information to address requirements for time-critical air operations.
- In 1996, demonstrate deployable (lap-top) version of in-theater airlift scheduler for use with the Global Transportation Network by USTRANSCOM, and the Deployable Joint Task Force Augmentation Cell (DJTFAC) at PACOM.
- "Data-wall" display with "direct pointing" and "spoken-language" interface in 1996, leading to a 1997 feasibility model of a very high resolution, interactive display to support group decision making .
- Benchmarks in 1997 will determine suitability of parallel computers to satisfy process and performance requirements for C^3I systems.
- Secure data handling capability for the F-22 Operational Flight Program Support Facility based on the Rome developed LOCK Secure Database Management System will be available in 1997.
- By 1998, a Requirements Engineering Environment handling parallel architectures, real-time interfaces to commercial tools; by 2000, Ada code generation capabilities so rapid prototypes can be evolved into operational systems.
- In 1998, a software reuse certification approach for non-real-time; in 2000 an approach for real-time and fault-tolerant components; by 2002, ability to certify AI-components
- In 1999, demonstrate a mixed-initiative, planning and scheduling system providing "intelligent" assistance for the full range of functions performed by the JFACC planning staff. Deployable "pocket version" in 2001.
- Software engineering environment for developing and supporting mission critical software for massively parallel computers in 2001.

THRUST 7 - ELECTROMAGNETIC TECHNOLOGY

USER NEEDS

This thrust provides the enabling electromagnetic technology for next generation surveillance and communication systems. This technology supports advanced user needs from **Air Combat Command; Air Mobility Command Air Force Space Command; and Air Force Special Operations Forces**

ACC, as lead for all MAJCOMS, is the primary customer for **Theater Battle Management (TBM)** technology. Specific needs, delineated in the **ACC TBM Mission Area Plan (MAP)** are:

- Efficient/effective viewing of air situation and early reporting of data for theater missile defense
- Early launch detection and assessment
- Improved detection of low observable targets in clutter
- Improved communications to all force and C2 elements with real-time capability

To satisfy these needs, TBM requires advanced sensors for efficient and effective viewing of the air situation and early reporting of data for theater ballistic and cruise missile defense. Emphasis is placed on sensors for early detection and engagement of transporters, launchers, inflight missile, and aircraft.

The **AMC Airlift MAP** identifies needs for:

- Global connectivity using HF communications
- Improved anti-jam, secure communications providing teleconferencing, patient in-transit visibility, high data rate digital file and image transfer, and robust automatic dependent aircraft surveillance

Technologies supporting these needs include the better understanding of propagation conditions for automatic link establishment (ALE) and multi-band SATCOM.

Air Force Space Command needs are in the **Command and Control MAP.** This thrust addresses the need for high data rate satellite cross links and efficient communication switches. Key technologies that support these needs are the electromagnetic materials and millimeter wave solid state and superconducting electronic technologies described in this thrust.

Air Force Special Operations Forces Weapons Systems Roadmap identifies the need for secure, interoperable communications with low probability of detection and intercept. Thrust efforts enabling these SOF capabilities are secure, anti-jam, Low Probability of Intercept (LPI) systems for inter-aircraft communications, navigation, high data rate image transfer via satellite, and long endurance, psychological operations with low drag, wideband aircraft antennas.

GOALS

The goals of this thrust are:

- 1,000-fold improvement in the ability to detect and track low observable (LO) targets.
- 100-fold increase in satellite communication and covert communication terminal sensitivity or 10-fold reduction in terminal size allowing more frequent updates to users.
- 10-fold increase in HF communications connectivity through exploitation of non-conventional propagation conditions.
- 10-fold reduction in the life cycle cost of phased array antennas for these systems.

MAJOR ACCOMPLISHMENTS

Significant progress was made in technology development for advanced, high data rate communications, especially for satellite and covert communications.

- EHF communication arrays were link tested from an Army High Mobility Multifunction Wheeled Vehicle (HMMWV), a Navy submarine sail, and for the airborne application from a NASA Learjet showing high data rate connectivity to the Advanced Communications Technology Satellite.

- A fully functional, single chip 4-bit direct digital synthesizer was demonstrated using superconducting technology. This is the most complex multifunctional superconducting chip fabricated in the US to date.

- Extremely small size high-temperature superconducting circulators with excellent low loss and high isolation were demonstrated at Ku-band. The size was reduced by an order of magnitude compared to conventional microstrip circulators.

Advanced high performance electronic materials are critical to advances in components, enabling high data rate communications and integrated electronic/optical processing. In particular, Rome Lab is an internationally recognized pioneer in indium phosphide (InP) materials and devices. Noteworthy progress continues on InP materials.

- Significant advances were made in understanding the iron defect that makes InP substrates semi-insulting. These advances will help us reduce the danger of iron diffusion degrading electronic properties during device processing. This work also has photonic consequences, since it provides information that could be employed to tailor InP for optimal photorefractive response.

- A Rome Lab - Lawrence Berkeley Lab collaboration demonstrated that hydrogen creates a defect in InP that adds additional conduction electrons to the crystal. This knowledge should result in important strides toward more predictable electronic properties for InP materials.

High performance, surveillance radar antennas capable of counter LO surveillance will be possible due to the following technology advances:

- A near-field nulling scheme to reduce the effects of scattering by wings and engines upon low sidelobe airborne antennas was demonstrated in our error-free 32-element digital beamformed array.
- Initial validation of new polarization processing techniques for radars operating at low grazing angles shows improved detection performance, particularly for small signal-to-clutter ratios.

The feasibility of wide aperture antenna arrays for improved HF communications was tested.

- The Rome Laboratory HF Channel Probe was tested to measure the turbulence encountered on a mid-latitude skywave path.

CHANGES FROM LAST YEAR

Over-the-horizon radar clutter characterization is de-emphasized in favor of new technology for improved

HF communications connectivity, low probability of intercept transmission, and signals intelligence.

MILESTONES

We are developing technology for large power-aperture phased arrays with precise pattern shaping, interference nulling, and environmental mitigation for improved theater missile surveillance.

- In 1996, damage and failure compensation in a neural controlled, real-time digital beamformed array will be demonstrated.
- By 1996, computer-aided antenna design codes will be improved for the design of ultralow sidelobe antennas on complex airframes.
- In 1996, we expect to confirm 20 dB improvement in the detectability of LO targets using bistatic radar polarization diversity.
- By 1997, graphical radar cross-section (RCS) code for rapid real-time RCS prediction will be developed.

For compact communications terminals for C^3I on-the-move, we are demonstrating technology for large scale arrays with potential reduced acquisition costs. Success depends on improved electronic materials, processing and EHF components.

- By 1996, a 60 GHz monolithic InP-based transmit chip will be designed and tested.
- By 1997, we will demonstrate a fully functional single chip superconducting direct digital synthesizer meeting advanced satellite communication specifications.
- By 1997, HEMTs based on advanced III-V semiconductor materials will demonstrate gain and noise performance exceeding any available today, enabling improvements in signal detection.
- Second generation compact, low cost, gallium arsinide (GaAs) active phased array antennas for EHF satellite communications from mobile platforms will be demonstrated in 1998.

We are developing HF technology for improved communications connectivity, low probability of intercept, and signals intelligence.

- By 1996, understanding of physical causes of HF skywave communications degradation will permit mitigation via antenna array design and advanced signal processing.
- By 1997, "ducted" skywave HF communications modes will provide LPI and SIGINTEL for ground-to-ground, ground-to-satellite and satellite-to-satellite messaging.

THRUST 8 - PHOTONICS

USER NEEDS

Current electronic systems are susceptible to electromagnetic interference. Size constraints, speed and reliability also limit traditional electronic systems. Photonics-based systems, that process information in the form of light (photonics) signals, will provide major improvements in tactical and strategic command, control, communications, and intelligence systems by providing small size, high performance, high capacity, survivable alternatives to electronic-based systems.

- The **Air Combat Command (ACC) Reconnaissance and Surveillance Mission Area Plan (MAP)** identifies timeliness, collection and storage at very high data rates, and multisensor processing as deficiencies in current reconnaissance and surveillance systems.
- The **ACC Strategic Defense MAP** identifies a vast increase in the volume of information to be processed and the inability of current systems to handle this increased workload effectively. The capability to rapidly process sensor and intelligence information is identified as a severe limitation.
- The **Air Combat Command Theater Battle Management (MAP)** requires battle damage assessment in real time; automatic target identification and infrared detection of theater ballistic missiles are identified as planned enhancements to current systems.
- **Air Force Special Operations Command (AFSOC)** has identified the following operational requirements:
  - Faster utilization of data, greater databases
  - Mission planning and rehearsal
  - Mass data storage (Gigabytes) with rapid access
- **Air Intelligence Agency Statement of Need** requires remote, low loss, low distortion microwave remoting systems.

GOALS

Goals within the Photonics Thrust are:

- Timely Signals Intelligence (SIGINT) analysis (from weeks to minutes)
- High capacity/rapid access memory (100 million fold increase)
- Full spectrum infrared sensor systems
- Flexible/lightweight microwave distribution systems (50% decrease in weight)
- Wideband/multi-frequency/multi-beam antenna systems
- High speed/high performance compact signal processors
- Integrated optoelectronics systems

MAJOR ACCOMPLISHMENTS

A number of major accomplishments have been reported in photonics technology in the last year which will have great impact on military and commercial C^3I systems of the future. These include:

- Design and fabrication of a compact 3 dimensional read only memory systems (ROM) using two photon absorption.
- Successful demonstration of a high performance 14" Erasable Optical Disk in the Mission Planning System at AFSOC.
- Demonstration of a Deployable Optical Disk Jukebox (120 Gbytes) at AFSOC.
- Successful field demonstration of an optical real-time target recognition system.
- Successful demonstration of a Wideband Optically Controlled Phased Array.

- Successful demonstration of an optical 2-18 Ghz antenna remoting transmission system at AIA.

- Invented a totally new technique, Epitaxial Transfer Integration, for fabricating optoelectronic integrated circuits (OEIC).
- Demonstrated the first hydrothermal growth of bismuth titanium oxide (BTO).
- Achieved a hundredfold improvement in the yield (and hence the cost) of high-speed semiconductor laser diodes for microwave fiber optic communications.
- Doubled the emission of Schottky sensors.

MILESTONES

The Major Milestones in the Photonics Thrust are:

- An Electronic Intelligence (ELINT) processor will explore optical processing technologies in an advanced development program for Wideband Signals Intelligence (SIGINT) identification and recognition applications with a target completion date of 1998.
- A three-dimensional write once read many times (WORM) optical memory system ATD initiated in 1995 will be completed in 1998. An erasable 3D memory system ATD will be initiated in 1997 and completed in 1999.
- A one Terabyte Erasable Optical Disk ATD that will verify terabit capacity, gigabit throughput rates and nanosecond access time will be integrated at the 480IG, ACC, in 1996 for AFINTNET applications.
- An ATD, to demonstrate optically controlled phased arrays for airborne application at SHF for the Defense Satellite Communications System (DSCS) will be initiated in 1996 with target demonstration 1998. An optically controlled phased array ATD aimed at EHF airborne and spaceborne applications will begin in 1997 and be completed in 2000.
- An integrated C^3I optical processor ATD will begin in 1997 based upon prototype demonstrations completed in 1996. It will develop a hybrid optoelectronic signal processor emphasizing the utilization of optical interconnects and rapid access optical memory to demonstrate near real-time interactive processing of sensor (active/passive), intelligence and imaging systems. Demonstration will be in 1999.

- Based upon successful demonstrations of microwave/optical transmission systems in 1995-1996, a comprehensive RF signal distribution system ATD for secure remoting for all radio frequencies up to 100 Ghz will be initiated in 1997 with completion and demonstration to AIA in 2000.

Rome Lab is pursuing new technologies to push photoemissive silicon-based detector systems out to the long wave infrared (LWIR) band. Iridium silicide has been shown to have good detection characteristics out to 10 micrometers and is presently being transferred to industry. New advances in silicon germanium alloys have shown response to 12 micrometers. In addition, a quantum well structure using germanium/silicon has been proposed as a new photoemitter. Platinum silicide has recently been extended to 16 micrometers; the primary benefit is the outstanding producibility of platinum silicide. An integrated IR camera covering the full LWIR band will be completed in 1999.

Devices, components, and materials technology are an important element of the Rome Laboratory photonics program spanning the range of fundamental research through advanced development of packaged components and sub-systems. Principal areas of interest are: III-V semiconductor devices, with emphasis on the indium phosphide materials system, and silicon and its alloys with germanium; photorefractive materials for nonlinear signal processing and wide bandgap III-V nitrides for generation and detection of blue and UV light. Devices and components of interest include semiconductor lasers, optical switches and modulators, spatial light modulators, passive guided-wave devices and optoelectronic integrated circuits (OEIC).

THRUST 9 - RELIABILITY SCIENCES

USER NEEDS

The basic objective of the Reliability Sciences Thrust is to ensure that Air Force/DoD electronic systems perform their specified mission in diverse military environments. This approach is based on a broad spectrum of science and engineering research that encompasses all aspects of the system life cycle from "cradle to grave". This research includes technology areas that stress development and use of tools and techniques such as: modeling and simulation, materials and process characterization, operational assessments, failure modes and effects assessment, and correction. In addition, emphasis is placed on development of diagnostic techniques for implementation of cost effective logistic support capability such as strategies to support Two Level Maintenance. This technology thrust is utilized by both the commercial and industrial base in the design, development, production and maintenance of cost effective, reliable systems that meet customer needs.

This program contributes to the DoD science and technology strategic thrusts including the Global Surveillance and Communications thrust, the Precision Strike thrust, the Technology for Affordability thrust, and the Air Superiority & Defense thrust. Increased reliability and improved diagnostics are central components in performing the USAF mission of Global Reach and Global Power. The following validated MAJCOM requirements span all mission areas in this thrust:

- Reliable satellite communication **(AFSPACECOM)**
- Simple automatic testing and diagnostics **(AFSPACECOM)**
- Improved reliability/reduced maintenance **(ACC)**
- Monitor environmental conditions impacting electronic systems **(ACC)**
- Logistics visions technology for test and diagnostics **(Acquisition/User/Maintainers)**

ESC validated technology needs encompass major Reliability Sciences program outputs such as: finite element analysis; integrated diagnostics technology; technology to simplify design commonalty in satellites; advanced time stress measurement device; electromagnetic environmental effects (E3) modeling and analysis tools; and tools for translating operational requirements into diagnostics/reliability, maintainability and logistics requirements. Additional Reliability Sciences thrust user needs are documented in **Log Visions; DoD Advisory Group on Electron Devices (AGED) Special Technology Area Reviews; Defense Science and Technology Strategy (Strategic Investment Priorities; Dual Use, Affordability, Modeling and Simulation) (Guiding Principles for Science and Technology Management); and DoD Global Reach/Global Power Report.**

GOALS

The major technology goals addressed by the Reliability Sciences thrust are:

- Achieve an order of magnitude increase in mean time between maintenance actions and a factor of four or greater decrease in support costs attributed to external test equipment, personnel, and training.
- Develop design tools and test methodologies to incorporate reliability technologies at the earliest stages of system concept and development.
- Assess device and system failure modes/mechanisms and operational environmental factors to determine the stresses imposed on devices and systems, and then translating this information into robust system and component designs.
- Develop efficient diagnostic methodologies to reduce, by 10 fold, the high levels of unnecessary maintenance actions and to allow for on-equipment fault detection/isolation.
- Achieve increased electronics reliability and performance through identification and reduction of the effects of electromagnetic environment (EME) exposure.

MAJOR ACCOMPLISHMENTS

The most notable accomplishment of the past year was a joint Rome Laboratory effort with the San Antonio Logistics Center to develop and demonstrate the ability to use advanced software technology concepts to automate the generation of test programs for Automatic Test Systems (ATSs). Test Program Sets (TPSs) were developed for two printed circuit boards for evaluation on two different testers, the GenRad 2751 Automated Test System (ATS) and a MATE 390 ATLAS-type ATS. The generation of TPSs for two distinct ATSs from the same test information demonstrates the tester independence of the data formats. This capability is estimated to provide a ten fold reduction in test generation cost for the ALCs, with similar potential savings for DOD manufacturers.

Other significant achievements include:

- Actual environments for ALQ-131, Block II Traveling Wave Tubes (TWTs) have been measured during their assembly and test, system user/yield, and repair and rebuild phases and have been systematically analyzed. Field data was obtained on ALQ-131 Pods flown on Dutch AF F-16s over their Mediterranean test range and NATO support missions over Bosnia-Herzegoviana. The results have identified design weaknesses and a proof of concept verification has been conducted to yield higher quality/reliable TWTs at reduced cost.
- Developed and verified a highly effective accelerated testing methodology. Independent verification efforts demonstrated a minimum time savings of 67% over traditional Department of Defense and industry reliability testing standards. The verification data sets confirm the efficiency and flexibility of the technique, clearly demonstrating the modeling accuracy as well as the potential for substantial economic savings.

CHANGES FROM LAST YEAR

This thrust is continuing its increased emphasis on dual-use technologies and transitioning tools and techniques to both military and commercial customers. Funding reductions in PE62702F have resulted in some FY95 efforts to be slipped to FY96.

MILESTONES

Near-term milestones involve demonstration and transition to users of both tools and techniques for screening, analyzing, and designing reliable, diagnosable systems and devices. Examples are:

- Testing of the Electromagnetic Performance Monitor (EMPM) on an F16 in 1995 to provide real time monitoring of high level RF energy that may occur near critical control/measurement devices or equipment.
- Establishment in 1995 of a Rome Laboratory Integrated Diagnostic Research Facility.
- Development of a software tool set in 1996 that will provide fault injection, fault simulation, and test generation within an industry standard VHDL design and test environment.
- Electrical evaluation and reliability assessments in 1996 of plastic encapsulated microcuits after long term storage and accelerated life testing in support of DoD Acquisition Reform.
- Development in 1996 of WAVES test bench compilers and hypermedia design assistance tools and documentation in support of efficient/cost effective DoD Logistics.
- Development of the requirements and architecture necessary to develop a System Diagnostic Evaluator tool or tool set, in 1997. This tool set will support efficient diagnostic design process trade-offs and provide cost effective means for evaluating the diagnostic performance of electronic systems.
- Development in 1997 of an Automated Design Environment for Reliability Trade-off assessments and robust implementations.

Producibility in a technology development context is defined in terms of support for transforming technology into affordable, high quality products and processes, and for controlling implementation risk. The technologies in this thrust address the overall challenge of producibility in the following aspects:

- Design tools for reliable and testable hardware support the development of products that are both intrinsically high in quality, and; easy to test and control in the manufacturing process.
- Specific hardware technologies such as packaging and interconnects, multichip modules, and hardware simulation languages and tools contribute to system designs that are highly manufacturable, reliable, and testable.

Evaluation of advanced technologies under this thrust yields information on the inherent reliability of products proposed for DoD usage. Results from product evaluations and failure analysis are relayed to manufacturers for corrective action. The unique capability of being independent and non-competitive, enables government labs to provide technology manufacturers with information that benefits both military and commercial users.

GLOSSARY

3D	Three Dimensional
ACC	Air Combat Command
ACCINTNET	ACC Intelligence Network
ADM	Advanced Development Model
AF	Air Force
AFAE	AF Acquisition Executive
AFGIHS	AF Geographic Information Handling System
AFMC	Air Force Material Command
AFOSR	Air Force Office of Scientific Research
AHDL	Analog Hardware Descriptive Language
AI	Artificial Intelligence
AIA	Air Intelligence Agency
AJ	anti-jam
ALC	Air Logistics Center
AMC	Air Mobility Command
AOC	Air Operations Center
APS	Advanced Planning System
ARO	Army Research Office
ARPA	Advanced Research Project Agency
ASARS	Advanced Synthetic Aperature Radar System
ASIC	Application Specific Integrated Circuit
ATAF	Allied Tactical Air Forces
ATD	Advanced Technology Demonstration
ATM	Asynchronous Transfer Mode
ATO	Air Tasking Order
ATR	Automatic Target Recognition
ATS	Automatic Test System
AWACS	Airborne Warning and Control System
BEA	Budget Estimate Agreement
BM	Battle Management
C^2	Command and Control
C^3	Command, Control, and Communications
C^3I	Command, Control, Communications, and Intelligence
C^4I	Command Control Communications Computers & Intelligence
CAD	computer aided design
CASE	Computer Aided Software Engineering
CCD	Charge Coupled Device
CECOM	Communications and Electronic Command
CINCNORAD	Commander and Chief NORAD
CJTF	Commander Joint Task Force
CONOPS	Concept of Operations
COTS	Commercial Off The Shelf
CRDA	Cooperative Research and Development Agreements
CTAPS	Contingency Tactical Air Combat System Automated Planning System
DAMA	Demand Assigned Multiple Access
DARO	Defense Airborne Reconnaissance Office
DAWS	Defense Automated Warning System
DDR&E	Department of Defense Research and Engineering
DEA	Data Exchange Agreement
DIA	Defense Intelligence Agency
DISA	Defense Information Systems Agency
DISN	Defense Information Services Network
DMA	Defense Mapping Agency
DoD	Department of Defense
DoDIIS	Defense Intelligence Information System
DSCS	Defense Satellite Communications System
ECRS	East Coast Radar System
EHF	Extremely High Frequency
ELINT	Electronics Intelligence
EM	electromagnetic
EP	Education Partnership
ESC	Electronic Systems Center
EW	Electronic Warfare
FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
FDDI	fiber distributed data interface
FLEX	Force Level Execution
FY	fiscal year
GaAs	Gallium Arsnide
GHz	GigaHertz
GOSG	General Officers Steering Group
HEMT	High Electron Mobility Transistor
HF	high frequency
ICTP	Information Collection, Transfer & Processing
IDHS	Intelligence Data Handling Systems
INFOSEC	Information Security
InP	indium phosphide
IR	infrared
IR&D	Independent Research and Development
JDL	Joint Directors of Laboratories
JFACC	Joint Force Air Component Commander
JPL	Jet Propulson Labs
JSTARS	Joint Surveillance Targeting and Reconnaissance
JWID94	Joint Warrior Interoperability Demonstration

km	kilometer
LAN	local area network
LO	low observable
LPI	Low Probability of Intercept
MAJCOM	Major Commands
MAP	Mission Area Plan
MCM	Multichip Module
MILSATCOM	Military Satellite Communications
MIMIC	Monolithic Microwave and Millimeter Wave Integrated Circuits
MLV	Medium Launch Vehicle
MMIC	Monolithic Microwave Integrated Circuit
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NAIC	National Air Intelligence Center
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NORAD	Northern Region Air Defense
NRaD	Naval Research and Development
NRL	Naval Research Lab
NSA	National Security Agency
NTSB	National Transportation & Safety Board
NUWC	Naval Undersurface Weapons Center
NYNET	New York Network
NYNEX	New York New England Exchange
ONR	Office Naval Research
OSINT	Open Source Intelligence
OTH	Over-The-Horizon
P^3I	Pre-Planned Product Improvements
PACAF	Pacific Air Force
PAWS	Parallel Assessment Window System
PL	Phillips Laboratory
PSIDS	Prototype Secondary Information Dissemination System
PtSi	Platinum Silicide
QML	Qualified Manufacturers List
QPL	Qualified Products List
R&D	Research & Development
R&M	Reliability and Maintainability
RAAP	Rapid Application of Air Power
RCS	Radar Cross-Section
RL	Rome Laboratory
RTOK	Retest OK
S&T	Science and Technology
SAR	Synthetic Aperature Radar
S/TODS	Strategic/Tactical Optical Disk System
SATCOM	Satellite Communications
SBIR	Small Business Innovative Research
SHF	Super High Frequency
SIGINT	Signals Intelligence
SLCS	Software Life Cycle Support
SLCSE	Software Life Cycle Support Environment
SOCOM	Special Operations Command
SOF	Special Operations Forces
SONET	Synchronous Optical Network
SPACECOM	Space Command
SPAWAR	Space & Naval Warfare System Command
STARS	Software Technology for Adaptable Reliable Systems
STIG	Space Technology Interdependency Group
STRAMST	S&T Reliance Assessment for Modeling and Simulation Technology
STRATCOM	Strategic Command
TACC	Tactical Air Control Center
TACOM	Tank and Automotive Command
TAP	Technology Area Plan
TAS	Timeline Analysis System
TASE	Thrust Assessment Support Environment
TBM	Theater Battle Management
TCC	Technology Coordination Committee
TCT	Time Critical Targets
TDC	Theater Deployable Communications
TDPA	Tactical Deception Planning Aid
TENet	Theater Extension Network
TEO	Technology Executive Officer
THAAD	Theater High Attitude Area Defense
TMD	Theater Missile Defense
TPC^3	Technology Panel on C^3
TRANSEC	Transmission Security
Tri-TAC	Tri-Service Tactical Communications
TRP	Technology Reinvestment Program
TSMD	Time Stress Measurement Device
UAV	Unmanned Air Vehicle
UHF	Ultra High Frequency
ULPI	Unit Level Prototype Implementation
USACOM	US Army Command
USAF	United States Air Force
USAFE	United States Air Force in Europe
USSOUTHCOM	US Southern Command
VHF	Very High Frequency
VHSIC	Very High Speed Integrated Circuit
VLF	Very Low Frequency
WATCHCONS	Watch Conditions
WL	Wright Laboratory
XIDB	eXtended Integrated Data Base

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