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March 2004

ADVANCED COMMAND, CONTROL, COMMUNICATIONS, & INTELLIGENCE (C3I) SYSTEMS ANALYSIS AND TRADE-OFFS

CACI Technologies, Incorporated

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This report details the system analysis activities conducted within AFRL/IF to extend C3I capabilities of on-going research. The research areas were diverse and included a number of program areas (i.e., impacts of Effects Based Operations on Dynamic Planning and Execution, extension of Sensor-to-Decision Maker-to-Shooter concepts and Network Distributed Remote Sensor Concepts) that cut across AFRL directorates, were funded by multiple sources and had joint service and coalition involvement. The analysis focused on meeting current needs, outlining technical design difficulties and research and transition opportunities. The analysis became an integral part of the AFRL/IF programs and strategy.

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Table of Contents

OVERVIEW **1**

1.0 INTRODUCTION **2**

2.0 PROGRAM ANALYSIS REVIEW **3**

2.1 EXTENSION OF SENSOR TO DECISION MAKER TO SHOOTER CONCEPTS 3
2.2 EFFECTS BASED OPERATION - AT-AOC 8
2.2.1 Purpose/Objective of Initiative 8
2.2.2 Program Description 10
2.3 TERABIT WIDEBAND FIBRE BASED NETWORK 15
2.4 NETWORK DISTRIBUTED REMOTE SENSORS 18
2.5 INFORMATION WARFARE 25

3.0 CONCLUSION **28**

List of Figures and Tables

Figure 2-1-1 TCT Targeting Timeline Now and Future 4
Figure 2-1-2 Multi-Source Fusion Targeting Performance 5
Figure 2-1-3 Integrated C2ISR Theatre Operations Operations Technology Needs 6
Figure 2-1-4 In-house IF C2ISR Testbed. 7
Figure 2-2-1 AT-AOC Concepts 9
Figure 2-2-2 AT-AOC Mission Requirements 13
Figure 2-2-3 Horizontal Linkage 13
Figure 2-2-4 At-AOC Common Planning Architecture 14
Figure 2-2-5 AT-AOC Req vx Technology Map 15
Figure 2-3-1 Worldwide Internet Users 17
Figure 2-4-1 SensIT Research Thrusts & Sensor Notional Network 19
Figure 2-4-2 Demonstration 21
Figure 2-4-3 ARGUS CONCEPT 23

Overview

This report details the system analysis activities conducted within Air Force Research Laboratory's (AFRL's) Information Directorate (IF) to extend C3I capabilities of ongoing research. The research areas were very diverse and included analysis of a number of program areas. Specifically, the following areas were further developed: Extension of Sensor to Decision-maker to Shooter (SDS) concepts, impacts of Effects Based Operations (EBO) concepts on Distributed Planning & Execution (DP&E) and Advanced Technology Air Operations Center (AOC) concepts, Network Distributed Remote Sensor concepts, Terabit Wideband Network Fiber technologies, and finally major initiative in Information warfare planning. Many of these programs cut across AFRL directorates, are funded by multiple sources and have joint service and coalition partner involvement. The analysis focused on meeting current needs as well as outlining technical design difficulties, and research and transition opportunities. The analysis became an integral part of the IF programs and strategy. Initial review of the analysis conducted herein for SDS program was detailed in the Task 03 final technical report completed under this contract. This report will extend results reached in that study and add analysis of a number of new emphasis areas.

AFRL/IF has done an excellent job in gaining support and funding for key programs outlined above. Strong partnerships continue to be established across the Air Force (AF), Joint and Coalition communities, putting AFRL/IF in a great position to make significant technical contributions leading to unique technological capabilities and fully compliant fielded capability.

1.0 Introduction:

The objective of this task was to perform system tradeoff analysis of information technologies for Air Force integrated Command & Control Intelligence, Surveillance & Reconnaissance (C2ISR) systems. The details outlined in this report provide some insight into tasks performed. In many cases, the interaction with program offices were in much more depth on problems at hand as well getting program managers to work together towards a common goal. The analysis completed included a review of ongoing Air Force initiatives, coordination of joint Air Force/Defense Advanced Research Projects Agency (DARPA)/OSD initiatives and recommendation of responsive programs. These programs were based on concepts that met user needs by leveraging ongoing government and commercial technologies. Each program had a unique set of system challenge problems based on the maturity of the technology and various system concepts. It was critical to keep overall C3I issues in focus as the individual technical – concept issues were being evaluated. The following is a quick intro into each of programs reviewed and problems to be solved. Details of analysis will be provided in the report.

SDS Concept Extension: The difficult challenge is based on integrating Intelligence, Surveillance, Planning and Weapon sub systems into an integrated Command & Control Intelligence, Surveillance & Reconnaissance system responsive to time sensitive threats such as moving or pop up targets. This system must not only provide an integrated picture of the threat but also portrayed to allow rapid decision making and then rapid execution using available weapon targeting systems. This complex system of systems challenge requires close coordination of all assets in a common infrastructure framework. This is difficult as many of these sub systems were built to perform their unique functions in a specific infrastructure or operating environment e g: Intelligence.

EBO-AT-ATO: The objective is to design, develop and demonstrate an end-to-end capability for effects-based planning, execution and assessment. Tools to implement the framework of monitor, assess, plan and execute within an Aerospace Operations Center will result. This effort will build upon recent accomplishments in the areas of Situational Awareness, Real Time Sensor to Decision-Maker to Shooter, Collaboration and Visualization, and Effects-Based Operations. The focus is on developing/building a new AT-AOC concept which provides the capabilities and flexibility to allow 21^{st} century Command and Control (C2) capabilities.

Terabit Wideband Fiber Based Network: The objectives of this Congressional directed program were to primarily design and demonstrate an Optical CDMA network using PICs and secondarily design and demonstrate a 28 GHz wireless low cost radio. The proposed payoff was to extend photonic technology, enhance fiber network utilization and develop a new market for photonic devices.

Network Distributed Remote Sensors (SensIT & Argus): DARPA has sponsored the Sensor Information Technology (SensIT) program to design and develop advanced software technology for building ad hoc, multi-tasked, distributed sensor networks for tactical surveillance operations. The SensIT program is founded on the concept of a networked system of cheap, pervasive platforms that combine multiple sensor types, embedded processors, positioning ability and wireless communication. Specifically, the mission of SensIT was to develop all necessary software for networked micro sensors. A network of SensIT nodes provides target detection, classification, and tracking, and communication within and outside of the network. The program is based on the integration of projects from over 20 universities and companies to ensure the successful development and field demonstration of the SensIT system. In parallel with this activity, ESC has sponsored an acquisition program entitled ARGUS to acquire a remote sensor system to counter the ground moving target threat. However, this concept is not multiple networked sensor approach but is a single sensor package design. The two programs are strongly complementary.

Information Warfare: Increasing priority has been given to defending against terrorism and protecting our nation and information infrastructure due to events such as September 11th. Information warfare (IW), along with information-in-warfare, is one of the two subsets of information operations. IW is focused on the attack and defense functions of information operations. Counter-information is the term used to describe the Air Force's information warfare capabilities. Like the counter-air or counter-space functions, the counter-information function helps establish information superiority by neutralizing or influencing adversary information activities. Combined counter-air and counter-space, counter-information creates an environment where friendly forces conduct operations with the requisite freedom of action while denying, neutralizing, or influencing adversary information activities as required.

2.0 Program Analysis Review

2.1 Extension of Sensor to Decision Maker to Shooter Concepts

In terms of review, the current SDS challenge is embraced in the Time Critical Targeting (TCT) problem as outlined by the Scientific Advisory Board (SAB), plus meeting tenets of General Jumper's Global Strike Task Force (GSTF) effective quick response concepts. It required a thorough systems engineering based approach to optimally manage the operational AF theater assets in a "Sensor-to Decision Maker - to Shooter" framework to meet ATO planned and TCT unplanned activities. The primary issue in the TCT problem is the time factor. The time factor issues are as outlined by the SAB: see Figure #2-1-1. This figure compares the current response time *(NOW)* with future operational requirements *(FUTURE).* Recommended *CHANGES* to the *NOW* system to meet *FUTURE* requirements are also shown. The SAB set up the case per following:

"Recent conflicts have highlighted the difficulties in rapidly attacking TCTs. The timelines from recognition of the existence of a targetable object until the "kill" is excessively long. Experience in Operation Desert Shield, Storm and Operations Noble Anvil (in Kosovo) showed that timelines of 4+ hours were typical. The goal expressed by the leadership is to reduce the time from target detection to target strike to single digit from current multiple hours."

The Task 0003 final technical report of this contract stated that many fundamental issues still exist before integrated SDS initiative goals can be realized. It further stated the approach to date has been based on integrating stand-alone programs with specific objectives to meet the specific user program needs. It outlined the ongoing technology programs in IF in sensor, fusion and communications technology. A main conclusion was that the development of critical infrastructure needs is a fundamental driver to enable a responsive system. These issues are the information network, access/sharing key information and planning databases (both friendly and threat) and higher levels fusion, which turns data in information for all levels of conflict. Also, the focus of the baseline sensor to decision to shooter program was very platform/weapon centric. With that view, the operational advantage was focused on conflict area and not overall warfighter strategic issues. A more global look at the problem was presented to develop such a system to meet the challenge problem and gain the military global effect that the Air Force needed.

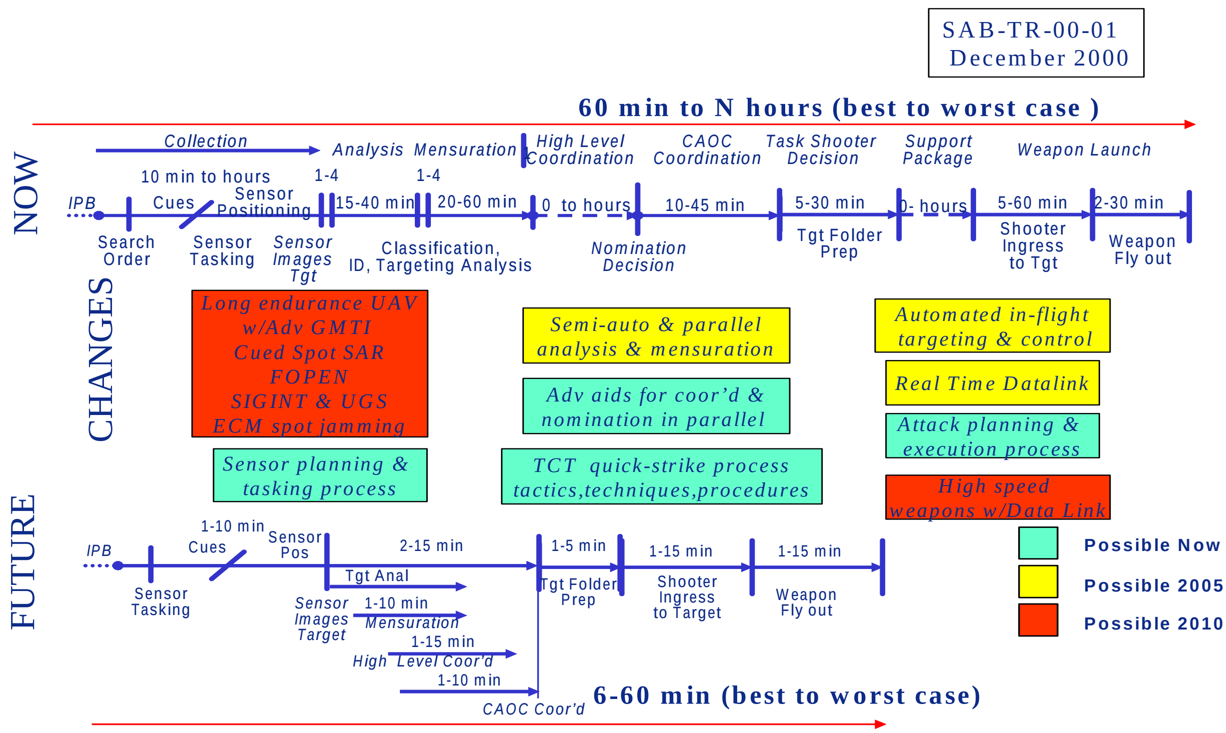

Figure 2-1-1 TCT Targeting Timeline Now and Future

The task at hand was to understand the (above) timelines in terms of system needs, technology capabilities and testing/validation methods. The system needs are based on decision process, weapons capability, technology drivers and advanced integration concepts being pursued. A snap shot of this interaction was highlighted in the DOD Network Centric Collaborative Concepts program. The idea is to get information early without a long C2 –decision process time delay. The case is based on time constraints of the threat and the leverage provided by integrating assets together. Figure 2-1-2 takes a look at the payoff by mapping multiple sensors versus fixed target in terms of time and accuracy needed to effectively launch a weapon. It also provides a framework for trading off the throw away costs of weapons versus the fixed cost of networked and fused sensors.

The most interesting issue is that multiple sensors/platforms, which provided different look angles and supporting information (Sigint/GMTI), provide the best capability (e.g.: accuracy with target discrimination factors). The chart is based on the premise that discrimination detection significantly aids target location and accuracy needs. This then allows cheaper weapons to provide kinetic effect required.

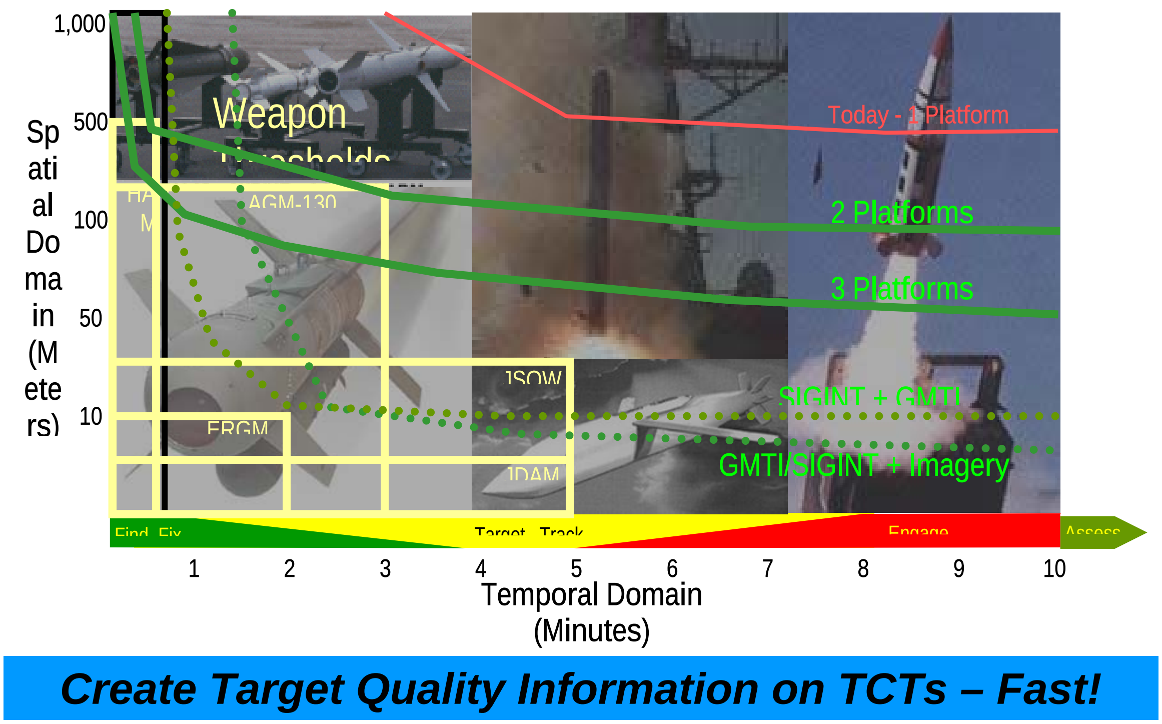

Figure 2-1-2 Multi-Source Fusion Targeting Performance

As pointed out in the Task 03 final technical report, this Network Centric Collaborative Concepts Technology (NCCT) architecture must embody a wideband communications interaction among Intelligence, Surveillance and Reconnaissance (ISR) assets to provide high confidence detection, tracking and targeting within TCT time frame allocated for this function. The function must include planning, decision making and execution functions as part of the process. Establishing a network system controller is a critical step in meeting diverse information needs. The network controller integrates quality of service judgments based on available information and requirements, attributes of available data, processing power of the fusion/decision making algorithms and information that is already available to members of the network. Further, the network can be leveraged to obtain and process information needed to implement Effects Based decision making tradeoffs as well as supporting Effects Based targeting/retargeting. NCCT is recommending a wideband data link be the backbone of the ISR system that then links to IP based world for field extension operations. The approach being pursued is the IF developed Multi Platform Common Data Link (MPCDL) system. The IF MPCDL has developed this highly waveform flexible data link for a number of years and contains the inherent connectivity and processing power to meet NCCT needs. It has been adopted already by many of the ongoing sensor programs as the preferred (common) approach. It also has significant potential to provide a cost effective weapon data link using miniaturization methods. It appears that NCCT program is going in the correct direction to develop a highly capable and flexible system and IF is a key contributor.

Based on the above, IF currently has an opportunity to leverage the ongoing Intel, Sensor & fusion processing and communications technological programs expertise into a system design testbed which demonstrates ISR capabilities for the future. The ongoing or planned DOD initiatives include utilization of IF technology or have requested that IF be a main contributor or leader. The challenge at hand is to integrate IF technologies, system designs or ongoing programs into a networked testbed which will demonstrate and develop capabilities which can be achieved. The key issues of a recommended program, presented to IF staff, to develop and demonstrate this integrated C2ISR Operations as outlined below in Fig 2-1-3.

Integrated C2ISR Theatre Operations

- **Develop & Demo Flexible IP Based Network for C2-Sensor**
- **- GSTF Requirements Met**
- **- Shooter Operations responsive to the TCT Challenge Problem**
    - **Link Theatre and Strategic Operations**
    - **Provide Framework for Flexible Data Base Operations & Multi Int Fusion**
        - Mixed Resolution, Bandwidth Data, Accuracy
    - **Networks Responsive ISR, Battle Mgm't, Decision Making, Targeting and Weaponeering Process**
    - **Enables Effects Based Operations**
- **Employ A Design Approach Which Leverages Strong Tech Base**
    - **GMTI, SAR, Sigint Technology/System Demos**
    - **Deployable Theatre Info Grid Designs**
    - **Multi-Platform Common Data Link Capabilities**
    - **Fusion Technology**

Figure 2-1-3 Integrated C2ISR Theatre Operations Technology Needs

The challenge that is critical to theatre operations is the development of concepts that provides **Integrated** C2ISR Theatre Operations. Sensor data and weapon delivery are the bookends of this process. Developing a framework that allows effective battlefield operations including the decision makers is the real challenge in the future. Clearly, the sensor, fusion and network communications work being done to enhance ISR operations is critical and can be exploited as it matures. However, the changes in threat and warfare conditions requires new integrated approaches be devised and implemented.

The approach being recommended is to implement a cross-cutting program which leverages technologies from all IF divisions, and other AFRL Directorates, to jointly plan and develop a test program. The test program will link the assets in the labs allowing both technology development and demonstrations. Further the testbed will allow connectivity, to outside interested parties e.g.: Users, DARPA, etc, to become players in the testbed. A basic outline of the testbed is shown in fig. 2-1-4 – In-house IF C2ISR Testbed.

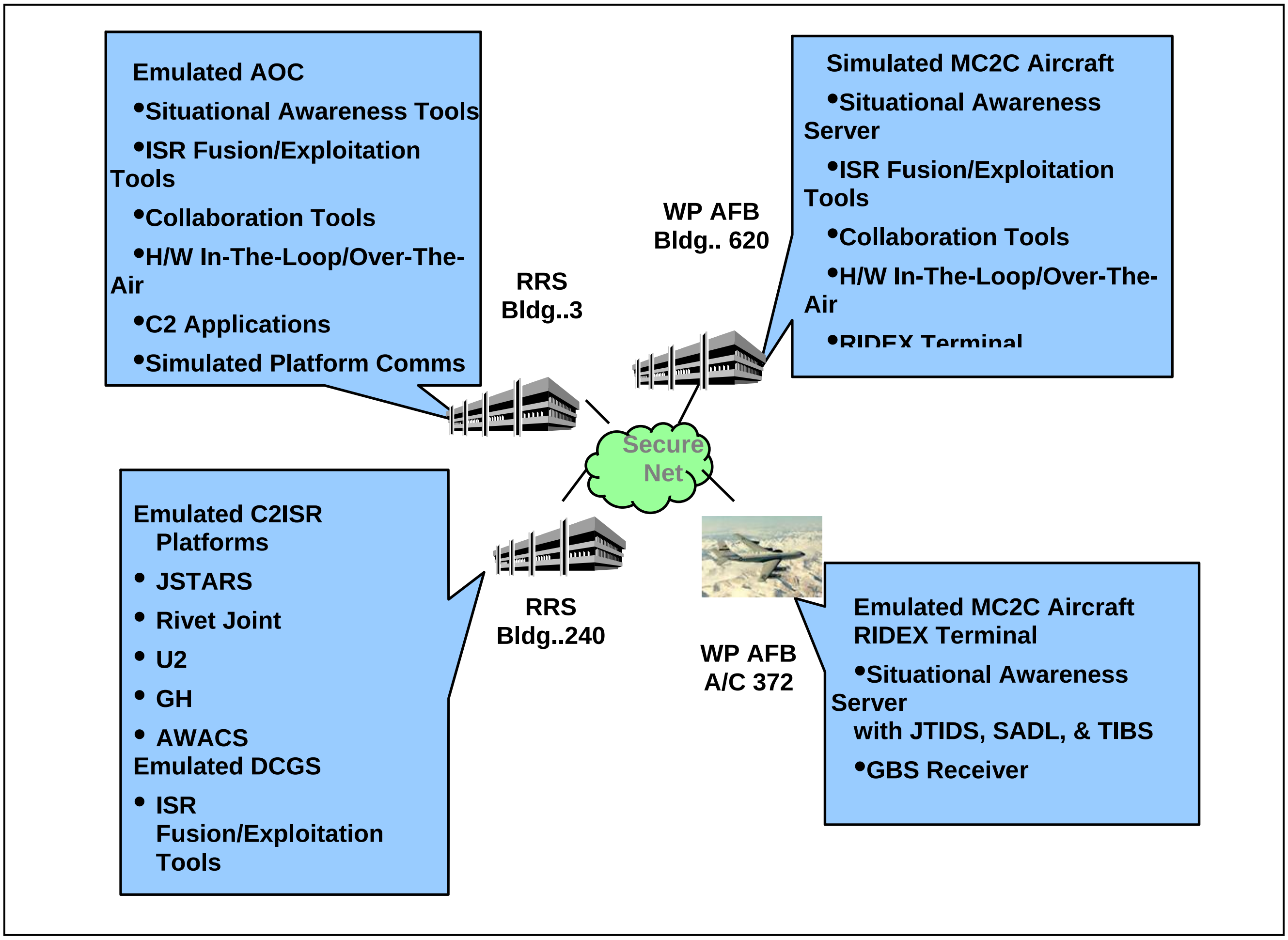

Figure 2-1-4 In-house IF C2ISR Testbed

This testbed leverages the assets in each of the IF facilities to emulate an integrated C2ISR system. It takes it a step further by emulating the operational ISR & C2 entities (i.e.: JSTARS, AWACS, RJ, AOC), as well as the communications methods and test aircraft. The design provides significant flexibility to develop test and transition in both today's operational structure and tomorrows as being presented in the AT-AOC concepts and the MC2C aircraft concepts. Overall it leads to near term transitions and means to move technology further. The concept links the validated sensor platform simulations in Building 240 (IFE) with AOC and EBO battle management concepts and capabilities in Building 3 (IFS & IFT) while adding the network and data link designs in IFG. Further, it allows the integration of a flexible KC-135 test aircraft at IFG in Wright Patterson Air Force Base (WPAFB) and cockpit emulations in WPAFB. Here the amount, resolution and accuracy of data needed in the cockpit can be evaluated versus processing methods and communication protocols. The isolated Building capabilities can be linked via secure networking concepts. It allows tradeoffs to be made between more sensor data, greater information processing fusion versos timelines to reach C2 decision process. It adds emulation with simulation under the control of hands on analyst and decision makers.

This integrated lab testbed approach has been on the books for a long time. The challenge is to make this approach the baseline to not only develop new technologies but also to provide insight into the system issues. It will tackle a strong commitment of IF staff to mandate such an approach, as well as recognize the importance of taking a system view of the issues. Now there is a challenge problem and user support to develop the approach. The other issue is obvious team building among IF technical personnel. It already has been implemented in a number of cases in a smaller scale. Recommend it be implemented here. Obviously, it will take some baby steps test conducted to recognize the importance and payoff.

2.2 Effects Based Operation - AT-AOC

2.2.1 Purpose/Objective of Initiative

This Advance Technology (AT) Aerospace Operations Center (AOC) program initiative is being planned to address the needs identified in the AC2ISRC C2 CONOPS defining a Dynamic Aerospace Command, the Air Force Fusion Roadmap, and the top five needed critical capabilities agreed to at CORONA TOP in June 2000 (Distributed collaborative process linking all centers; visualize the Global to Tactical Battlespace; Find, Fix, Track Time Critical Targets; Dynamic effects-based targeting, weapon pairing and control; and Automated and timely effects-based assessment). The issue is to develop a new architectural framework for the AOC, which provides the flexibility and growth to allow Effects Based Operations in a GSTF environment leading to enhanced multi-level planning, execution and decision-making. A spiral development approach has been planned so that new capabilities with immediate warfighter utility can be transitioned quickly. Some of the important tenants of an AT-AOC are as follows:

- Distributed Collaborative Planning and Execution
  - Integrated Wing Collaboration
  - Planning Details to Crews
  - Predictive Effects Based Operations
  - Flexible Info Representation
- Dynamic Air Execution Order
- Framework to Integrate/Leverage New Weapon Systems(UCAV, etc)
- Improve Operations with Fewer People
- Reduce Life Cycle Costs
- Provide Growth for New Platforms

Figure 2-2-1 provides the basic structure of the AT-AOC program as developed from the Joint Air Operations Center (JAOC) process perspective including technology/mission areas being integrated. It provides a structure to examine the problem generically. It provides a framework to view the various technology areas being reviewed and their interactions.

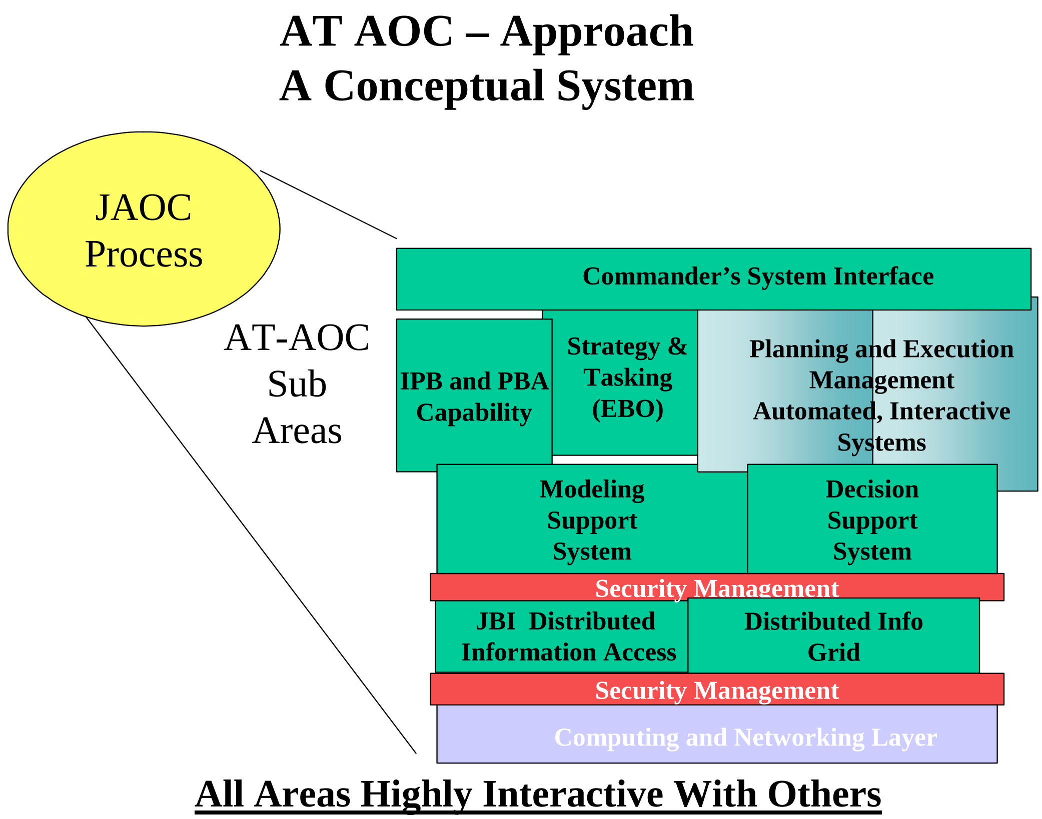

Figure 2-2-1 AT-AOC Concepts

The objective of the EBO program is a fundamental piece of this new AT-AOC concept approach. The EBO program goals are to design, develop and demonstrate an end-to-end capability for effects-based planning, execution and assessment. It includes the tools needed to implement the framework of monitor, assess, plan and execute within an AOC. This effort is planned to build upon recent accomplishments in the areas of Situational Awareness, Real Time Sensor to Decision-Maker to Shooter, and Collaboration & Visualization. EBO will enable improved planning and more economical and rapid application of force. Military operations will cost less and result in reduced fratricide and fewer collateral casualties. As a continuous process EBO integrates planning, execution and intelligence. Planners become more aware of execution changes and executing personnel (either at the tasking or the executing unit level) more fully understands how any changes might impact the overall plan. Tasking organizations and executing units are also more fully aware of each other's limitations. This reduces re-work, as executing units are less likely to be tasked for missions they are incapable of. In short, EBO will allow operational level commanders to more closely control operations. A fundamental issue is to develop and communicate an effects based plan on a continuous basis. Under this issue are the following fundamental capabilities are needed:

- Current Process is manually intensive

- Information management process needs improvement
- Improved quality of decision making
- Addition of cognitive element in Course of Action (COA) process
- Improved computational capability (H/W-S/W)
- Effects Based Assessment
- Enhanced Information Infrastructure

2.2.2 Program Description

EBO Program Discussion: The EBO program will be provided first to set the tone for the development of AT-ATO concepts, which are based on EBO as well as SDS and Situational Awareness initiatives, outlined earlier in the report. It is being developed to address the above listed capability needs list and At-AOC structure. It will develop those capabilities meet the following attributes:

- Efficient determination of Effects Based Campaign Strategy
- Development of Consistent Campaign Planning & Combat Tools
- Linked Situational Awareness and Course of Action Development
- Timely Collection/Distribution /Display of Relevant High Confidence Information
- Automated/Structured Multi-Level Decision Information (Provide Appropriate/Consistent Info at Correct Level to Decision Task at hand)

The EBO initiative is focused on the development and demonstration of technology that is centered on a scenario, which exploits a broad range of key capabilities in the Situational Awareness, Real Time Sensor to Decision-Maker to Shooter, Collaboration and Visualization, and Effects-Based Operations areas. For example, a scenario that would show the capability to plan, execute, and assess a limited, small scale campaign centered around a regional crisis or Operation Other Than War (OOTW). After receipt of the initial planning guidance, the demonstration will start with the development of a Common Operational Picture/Common Tactical Picture (COP/CTP) that provides users with access to complete battlespace information. The battlespace information is comprised of ISR, C2, logistics, operations, weather, socio-economic and red, blue, gray forces information for a given geographic area. In parallel, operational planners will develop and assess, in real time, various courses of actions (COAs) that are based upon the Commander’s intent and COP/CTP and the Aerospace Component Picture information. The COAs will then be combined with other component plans to produce a comprehensive, coherent and integrated Joint Aerospace Operations Plan (JAOP) that is traceable to the Commander’s objectives.

As the planners assemble the various COAs, the temporal reasoning capabilities provided by a Campaign Assessment Tool (CAT) will provide an a priori assessment regarding the likelihood that COAs match user-selected success criteria including the effects to be caused and to be sensed for appraising campaign success. A Strategy Development Tool (SDT) will then be used to perform center of gravity analysis and COA generation. The result is a fairly robust set of high fidelity options that can be developed and quickly war-gamed. Based on the evaluated options, the JAOP will be developed using a Dynamic Tasking Toolkit (DTT). In addition, the DTT’s Information Strategist’s Request-for-Information (RFI) generator provides an intelligent query capability that sends out search agents to all appropriate databases and ISR collection capabilities to garner the missing or uncertain information, update with any new information it discovers and provide for effects assessment. Using a spiral development approach, the EBO ATD is concentrating on developing tools and technologies for planning effects-based operations. The tools will provide methods to generate multiple courses of action with their respective effects based on commander's intent. The ongoing EBO ATD will also provide an initial cut at integrating targeting, campaign assessment, and scheduling tools.

This capability will be enabled by an information infrastructure such as the Joint Battlespace Infosphere (JBI). In those cases where there is a lack of firm data, the CAT probabilistic reasoner will generate partial plans. Finally, once the decision-makers arrive at an executable COA the mission data is rapidly assembled and sent to the executing units via connections between the SDT, an Asset Pairing Tool (APT) and a Dynamic Aerospace Execution Order (DAEO) Generation Tool (DGT). This allows the decision-makers to quickly seize possible fleeting opportunities and more closely control missions that might be extremely politically sensitive. In addition to the obvious efficiency gains, the DTT approach will enhance flexibility and responsiveness to all planned military operations from Operations other Than War (OOTW) through Major Regional conflict (MRC).

The flexibility and responsiveness requirements for the DTT will be significantly tested when dealing with time sensitive targets (TST) or time critical targets (TCT). TSTs or TCTs are designated by the Joint Forces Commander (JFC) and generally fall into one of several categories: aircraft, missiles (especially ballistic and cruise), and certain surface targets. The location and time factors generally differentiate TST and TCT. Aircraft parked on a runway somewhere might be a TST or TCT, one attacking friendly forces most certainly will be. A key point for the classic planning, execution and assessment cycle is that TST/TCT must go through the entire cycle fairly quickly. For a theater ballistic missile preparing to launch the time may be minutes at best. Kill chain/TCT/TST demonstrations will be performed in linked and stand-alone facilities (both at RRS and WRS), which will characterize and measure overall warfighter system performance for selected CONOPS. The ultimate vision is a DTT that will provide commanders and their staff within an Aerospace Operations Center the capability to conduct end-to-end effects-based planning, execution, and assessment.

The closing of the EBO loop, a model of the battlespace will process incoming intelligence reports (BDA) then link with both CAT and SDT to reason and create a set of effectiveness measures. These measures describe the state of the campaign with visualization tools as well as to provide new criteria for the CAT to reinitialize in the EBO process. This state-of-the-art model both self corrects and runs in real-time. For example, this initiative will develop indicators for predicting effects (both physical and behavioral), conditions, measures, and the crucial connections to collection management functions for feedback into the combat assessment and campaign assessment process. In the same way that dynamic planning integrates planning and execution, EBO provides the tight integration of operational intelligence with planning to an unprecedented extent. The establishment of cause-effect relationships between actionable events and effects, or in the reverse direction, the inferring of the occurrence of events from the observation of effects, is a paradigm that requires intelligence to become an integral part of dynamic C2. Specific tools planned for development and integration include asset sourcing and pairing tools, complexity-reduction tools and techniques (e.g., model abstraction) for performing multiple Courses of Action in real-time, and effects-based campaign and combat assessment.

Operational technology supporting ISR asset feeds to the EBO DTT will be developed and demonstrated. Decision making technology to support Time Critical Target prosecution such as Sensor to Decision-Maker to Shooter, Real Time Intelligence into the Cockpit (RTIC) and Real Time Intelligence Out of the Cockpit (RTOC) will be developed, as required, and assessed for incorporation into the DTT. The full kill chain process will be modeled and simulated (using existing capabilities and facilities, where possible) to allow system performance tradeoffs to be performed with high fidelity. Issues involving collection management, target nomination, shooter-weapon-target pairing, RTIC/RTOC, communication choices, alert launch, diversion en route mission re-planning due to threats and new targets, autonomous air space deconfliction, kill package, weapon launch, and battle damage assessment will be directly addressed, optimized, and set in accordance with existing and newly derived CONOPS for extended mission capability. Interfaces to executing units will be developed to seamlessly integrate the EBO DTT into the Air Tasking Order process.

AT-AOC Discussion: The challenge to the AT-AOC program is to develop a framework, which allows the integration of the mission functionality and the technologies into an approach which is flexible and provides a powerful force multiplier This C2 ISR enabling framework must operate across all the GSTF areas and the various Air & Space Expeditionary Forces currently under development. His case was strongly made by General Buehler at the C2 summit and endorsed by the SAB. This case is shown in Fig 2-2-3. The AT-AOC must enable operations across all the Force CONOPS as well as leveraging cross cutting capabilities allowing effects based operations. The capabilities detailed by General Buehler, matches the approach outlined herein in terms of developing an integrated C2ISR foundation to attack the larger system problem.

The challenge is to take a system architecture approach, which provides cross collaboration and effective C2 operations within a specific CONOPS. The architecture framework must share the available assets in a way, which maximizes operational effectiveness. A review of available architecture led to acceptance of a common architecture framework as shown in Fig 2-2-4. The idea is to use the C2ISR tools across the various CONOPs in basic building block format.

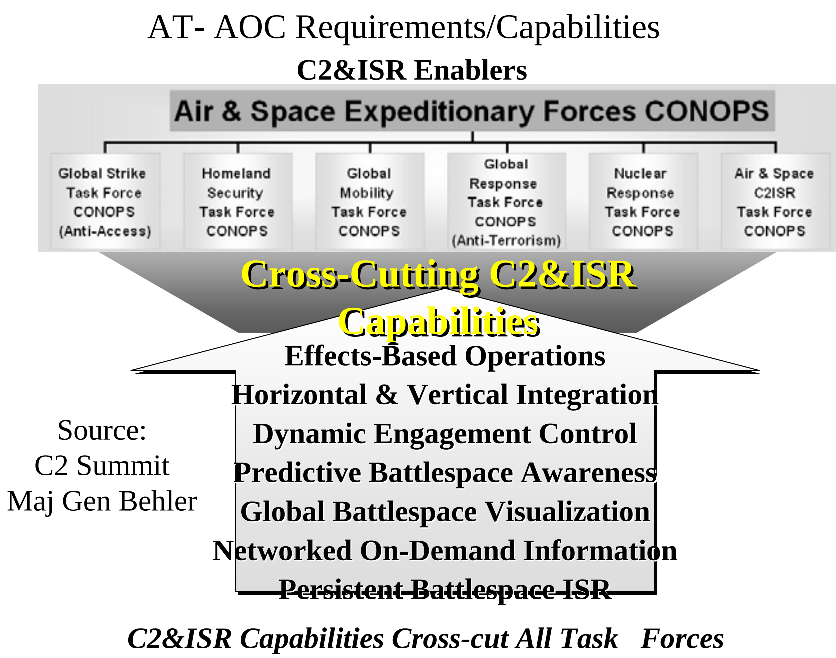

Figure 2-2-2 AT-AOC Mission Requirements

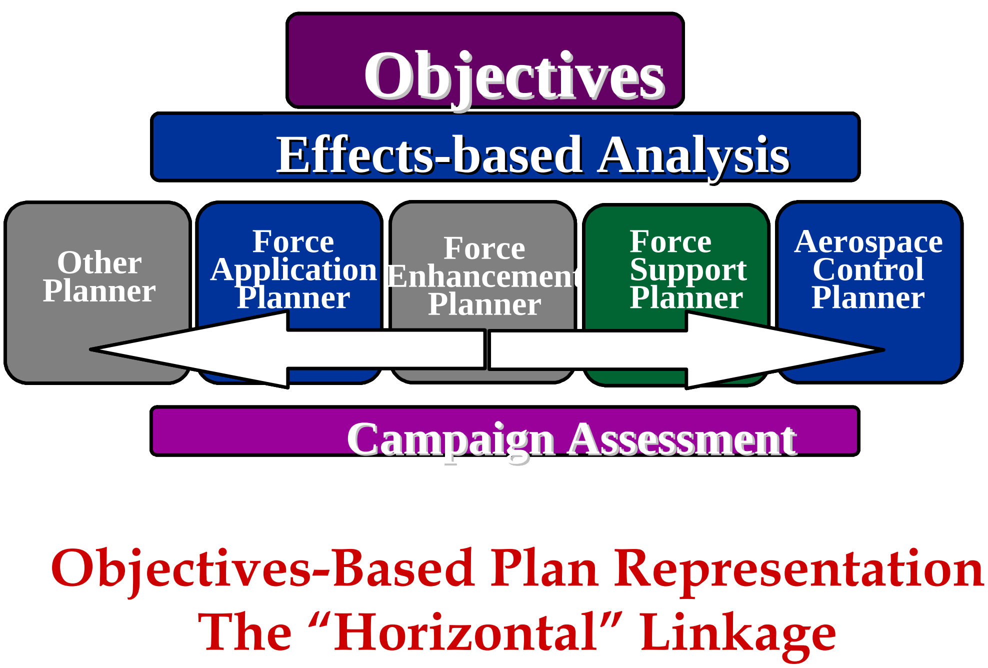

Figure 2-2-3 Horizontal Linkage

The challenge is the development of a framework, which allows both horizontal and vertical integration. This vertical framework must allow linkage of Commander's objectives to the Air Commander, Air Tasking Units finally to the execution and engagement units. Under DARPA sponsorship in the JFACC program a common plan representation approach was successfully used to provide such integration. That approach was reviewed and found to be powerful and recommend for application to the AT-AOC concept development. Figure 2-2-5 is a representation of the common plan structure and the value of such an approach. The center of the figure details the basic function of each of the elements 9CC to Units). On the left is graphic description of the current (CINC's OPLAN – JFACC's OPORD -Master Air Attack Plan-Air Tasking Order) process/documentation plan being used today. With this approach each vertical step requires independent development and any cross collaboration between steps are a cumbersome process. Changes are messy as it can affect all vertical levels. CONOP interaction is very difficult. In contrast, the right side of the figure outlines the tomorrow approach, which integrates cross-domain approaches into the plan from the beginning. Integrated issues are considered from the beginning and synchronized operations are planned. Now the effects on changes in plans can readily implemented with minor inter CONOPs impacts. In simple terms today's operations are segmented planning/execution processes and the tomorrow common planned approach is a linked operation.

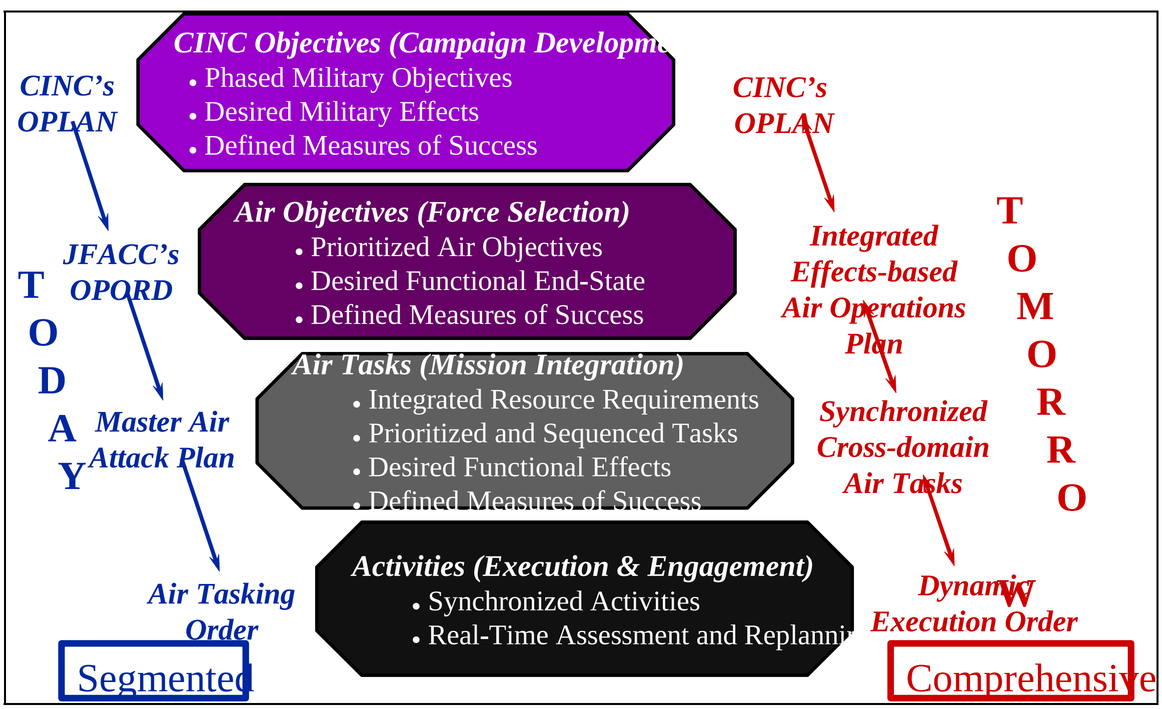

Figure 2-2-4 At-AOC Common Planning Architecture

This approach has been used under the DARPA activities and was shown to be very powerful. It is recommended that a detailed design of AT-AOC be undertaken using this approach.

In conclusion, the AT-AOC needs to be given a thorough system engineering scrubbing. The issues with current AOC have been well documented; needs have been defined and the way ahead outlined by General Jumper in the GSTF concept. The advent of UCAV technology and the planned Multi Function C2 Aircraft capability needs a framework to host these enhanced capabilities. Figure 2-2-6 is being offered to outline the system engineering issues and technologies underway, which need to be considered.

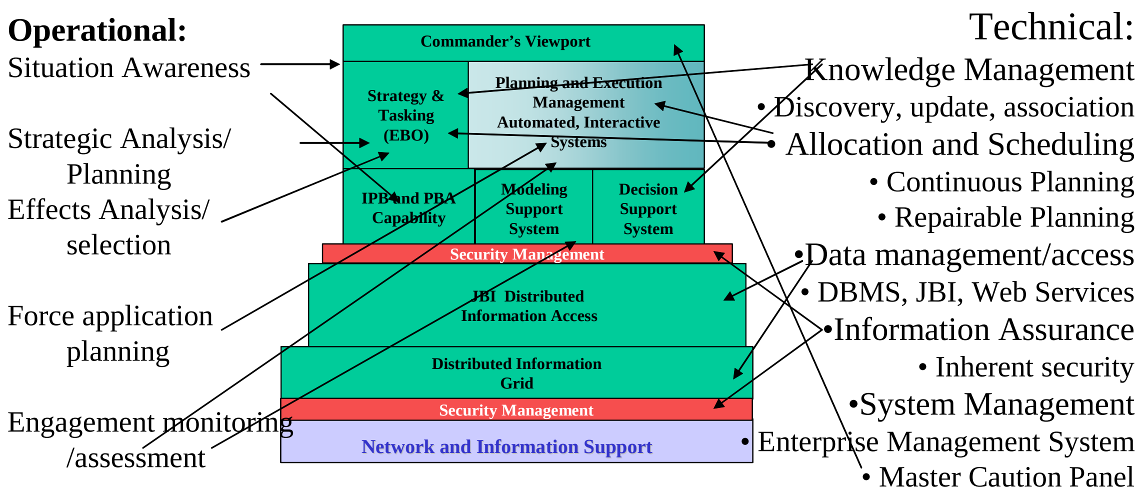

Figure 2-2-5 AT-AOC Req vx Technology Map

2.3 Terabit Wideband Fiber-Based Network

The analysis conducted under this task was to review the technical status of the congressionally supported Terabit program and determine technology maturity and payoff in terms of military utility and general commercialization. The objectives of the program were to primarily design and demonstrate an Optical Code Division Multiple Access (CDMA) network using PICs and secondarily design and demonstrate a 28 GHz wireless low cost radio for local multi point communication. The radio would extend the connectivity to remote non-fiber connection points. The terabit technology program is providing research and development toward CDMA Photonic Integrated Circuits (PIC), high-speed wireless interfaces, and applications. Optical CDMA provides a method for network users to encode their data over a span of wavelengths (colors). The goal was to enhance the capability to use existing fiber networks. The primary research focus of this work is in the development of quality components and the degree to which they can be implemented in a PIC. The program will integrate the components into optical CDMA transceivers and demonstrate them in networks along with a wireless wideband interface via a 28GHz radio.

The work is being done by Research Development Laboratories (RDL), and represents development over a number of years. The work reviewed covered the latest of several contracts with a total value greater than $18M over 7-8 years. The history of the contracts including goals, face value, and time frame of these contracts are as follows:

1995-1997 Phase I & II SBIRs (Phillips Lab)

- Proof of concept using discrete bulk optic components

1998-2000 F30602-98-C-0183 $8.7M

- Demo'd OCDMA PIC testbed 2 node, fixed coded 16 channel, @ OC-12 rates
- Satellite cross-link demo
- Demo'd 28 GHz 2 node simplex radio@ OC-3, rates

2000-2003 F30602-00-C-0224 $9.3M

- Design deliver and test 3 node, fixed 32 channel, OC-12, OCDMA PIC testbed - -delayed due to wafer issues
- Fiber Bragg Grating encoder/decoder and Ge-based OCDMA receiver demo'd
- Demo'd 28 GHz 2 node full duplex radio@ OC-3 rates
- Provide a Commercialization report - not complete yet

2003+ Recent ECP Tasks

- 2 node, programmable 32 channel, OC-12, OCDMA PIC testbed.
- 2 node, OC-3, full duplex, 8" antenna, 28 GHz radio.
- Develop concept for aircraft optical data bus including a MEMS optical interconnect switch.
- Demonstrate coexistence of OCDMA, WDM, and Single Mode signals

During numerous meetings with RDL they clearly stated they were most proud of their results on the Photonic Integrated Circuit (PIC) design. This program called for a demonstration of the PIC circuit in an Optical Code Division Multiple Access application over a fiber optic network. However, the milestones for this accomplishment have continued to slip over the contracts. In some cases, RDL has substituted other than full PIC methods to demonstrate the multi-network Optical CDMA principles. The demos to date have been a fixed mode PIC and a fiber bragg grating multi network demonstration. In general, they have had manufacturing problems with their vendors and design problems encoding the programmable and reconfigurable PIC. Vendor interest has elevated and they appear to be providing much better substrates. Clearly, full development of the PIC technical program area will have the biggest impact on the community if all technical goals are achieved. However, there are still some technical issues with CDMA design based on expert opinion that I'll synopsize herein. In terms of the Optical CDMA transceivers and 28 Ghz radio there are some overwhelming problems dealing with commercialization that will also be presented!

A number of design issues were brought up during the interchange on the CDMA design. The demonstrations were productive although not always using technology planned as noted above. However, a recognized expert, Peter Guilfoyle of Opticomp Corp, gave the key technical analysis of the RDL approach for the Optical CDMA design. He provided a fundamental review of Optical CDMA design and assumptions, including analysis of impact of errors, signal variances, bit error rate (BER), and uniformity. The analysis was based on RDL design under near optimal conditions. His bottom line was that the RDL design would limit its utility to a 3-node (user) system. Dr Chan, the RDL technical lead, countered his conclusions with the statement that these issues were identified and reviewed early in the contract and that his design supports more users. The consensus opinion was that Dr. Chan was inferring that up to 8-10 users could be supported. The problem is that even if Dr. Chan is correct, the RDL approach will not meet large or medium network needs. Most networks need user access in terms of thousands of users. The utility for commercialization in small networks is very limited.

The review of the 28 Ghz radio did not lead to any major technical design issues that appeared to be showstoppers. Their approach was straightforward using available technology leading to an inexpensive (Est. < $3K/radio) short-range (3000ft) radio. If there was a problem, the design did not include available efficient modulation or coding techniques, which could have made a significant difference in link/bandwidth performance. They did not use these techniques even though government staff provided technical foundation for their inclusion. There were some problems during testing due to antenna pointing issues.

The big issue in this program is the opportunity for commercialization of all the products. Commercialization was one of the major goals of a congressionally funded program. RDL provided chart in fig 2-3-1, which details the growth in internet users 98-03.

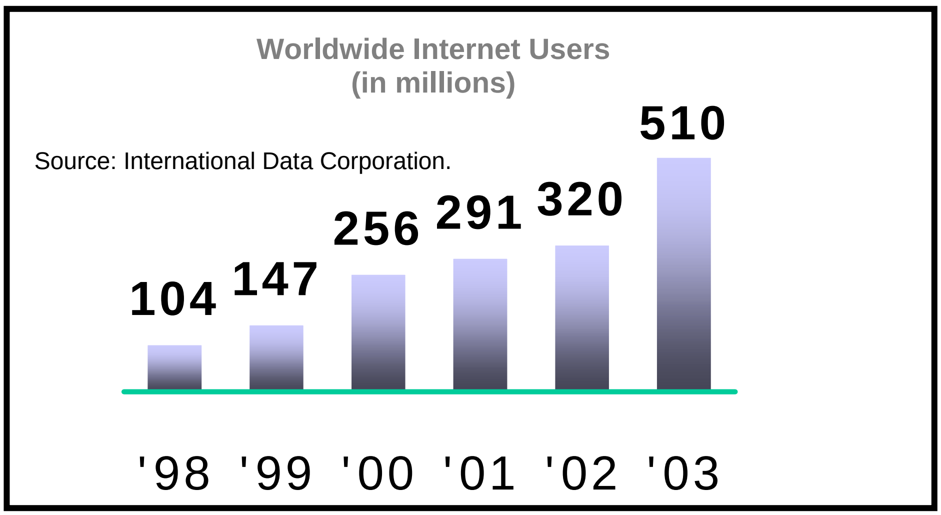

Figure 2-3-1 Worldwide Internet Users

The case they are making is the need will considerably outpace the capability and there will be a need for RDL products-both CDMA & 28 Ghz radios. Currently the supply of broadband network capacity exceeds demands at the carrier network backbone supported mainly with fiber optic infrastructures. However, the case made by RDL is that d this is not true at local network access and corporate network domain, as surges in bandwidth demand from end users drive the need for high bandwidth pipe available directly to individual end user presence that other available technologies (i.e.: point-to-multipoint broadband wireless, cable, DSL, satellite) are not adequate.

A network commercialization consultant, George Frank, conducted an independent analysis. His analysis was a little different. He basically said that the current market is weak based on numerous companies whom have overextended equipment buys (bankruptcy, chapter, fraud, etc) for network services capability and the deal is with the buyer. However, he does say that this will not last forever and at sometime (approx.3-5 years) this could change. I conclude that at sometime in the future the market would wake up. The real question is will RDL products be competitive. The CDMA will not for the general case if the number of users is limited. It may have use for special design configurations. The radio will need to compete with other wireless designs being developed my numerous venders. Time will tell.

The issue for IF was is there a market for these products in the Department of Defense (DoD). The primary AF buyer of these products is ESC. In an attempt to establish a market for the 28 GHz wireless part of this program, for RDL, a meeting was set up with ESC/DIG personnel working on the Theater Deployable Comm. (TDC) program. A technical program review was provided. The ESC staff did not significantly question the technical design issues but they did question the utility of a radio with ranges of 300-3000 ft and the technical basis of the 28 GHz design. ESC's approach for wireless relay is to buy radios from commercial vendors (COTS) and package them with other system components (interface boxes, power supplies, mux/demux, modems, etc) for system use. Their current approach is use of the 15 GHz band and Lasercom radios to satisfy their needs. These radios have much longer ranges than 28 GHz design, and can carry the same data rates, but are much larger, heavier, costlier, and require more power than the 28 GHz ones designed under this program. Further, the question of worldwide use of 28 GHz was questioned concerning frequency band approval. This approval for OCONUS & foreign governments typically takes 2-3 years. ESC/DIG stated that if the radio was commercialized, if it had an approved frequency allocation, and if it had 5-15 km range, they would be interested, but only as a commercial buyer if the equipment had advantages over what they were already buying or planned to buy.

Secondly, RDL spoke with ESC/DIG personnel working on the Combat Information Transport System (CITS) program. They have little need for wireless but they do use fiber extensively. They stated that their fiber networks typically handle 300-1000 users minimum, and the fiber is installed in multiple bundles, eliminating the need for efficiency. So there was little interest in CDMA multi wavelength designs.

In conclusion, the utility of the products developed under this program is to be determined. In the near term the commercialization appears to be weak given current business practices. From a military viewpoint, the current products lack interest. If they become commercially competitive interest will develop based on ESC’s acquisition strategy. The PIC technology may have significant merit if it leads to applications, which leverage the attributes of the fundamental capabilities of a highly integrated powerful integrated photonic circuit.

2.4 Network Distributed Remote Sensors

The analysis in this Network Distributed Remote sensor area focused on the capabilities of the technology being developed for the DARPA SensIT program. It included a review an analysis of ongoing initiatives and developing a transition path to the AF acquisition community. The primary target for the AF acquisition was the ESC ARGUS program. Many of the needs of the ARGUS program can be significantly extended using the technology being developed in SensIT. The interaction between the two programs was at the management planning level and also at the technical collaboration and testing level. Arrangements were made two develop testbeds at IF and at Mitre, share technology progress and then provide direct transition opportunity into ARGUS spiral activities. The following will be an outline of the various programs and more detail on resulting collaboration.

The DARPA-sponsored SensIT program is to design and develop advanced software technology for building ad hoc, multi-tasked, distributed sensor networks for tactical surveillance operations (see fig 2-4-1). The SensIT program is founded on the concept of a

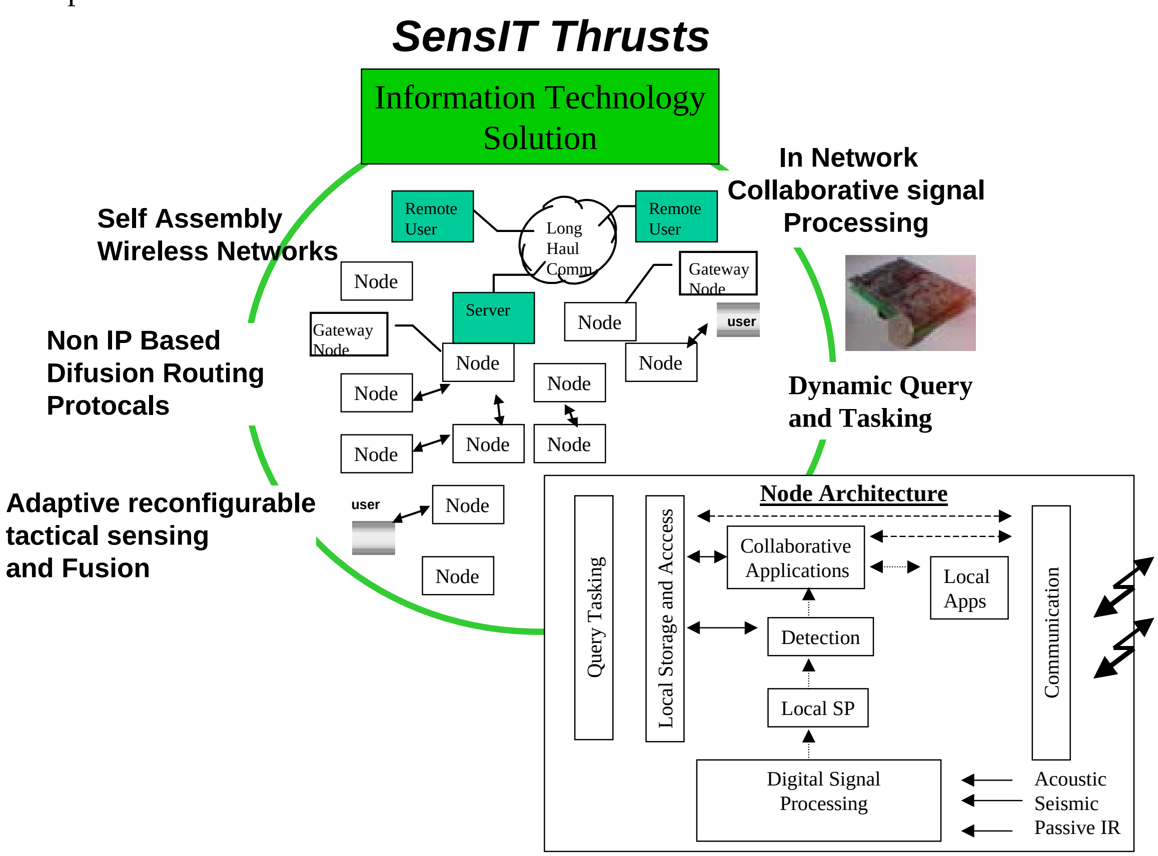

Figure 2-4-1 SensIT Research Thrusts & Sensor Notional Network

networked system of cheap, pervasive platforms that combine multiple sensor types, embedded processors, positioning ability and wireless communication.

Further, SensIT sponsored multi-disciplinary networked sensor technology development program in which the sensor tasking, data collection, integration and analysis was to be fully automated to enable operation within time constraints far shorter than could be achieved by human operators. The objective of the program was to develop the software and networking technologies to more effectively use Commercial-Off-the-Shelf (COTS) sensors. The program is based on the integration of projects from over 20 universities and companies to ensure the successful development and field demonstration of the SensIT system. SensIT researchers develop algorithms and software for sensor, signal and network processing in highly dynamic, ad hoc, networked sensor environments.

Technologies being developed include collaborative processing, diffusion networking, dynamic re-tasking, and declarative languages, among others. Innovative work includes:

- **Network Routing:** Non IP-based diffusion routing techniques use node location and data semantics to determine how to move data around the network most efficiently and reliably.
- **In-network Collaborative Signal Processing:** Application processing is accomplished within the network, leveraging the distributed computing environment in the sensor nodes to efficiently extract useful, reliable, and timely information from the deployed sensors. Distributed fusion processing algorithms collaborate to improve data analysis and enhance target detection and tracking confidence.
- **Distributed Query:** Dynamic tasking and querying enable interaction with and programmability of the sensor network.
- **Network multi-tasking:** SensIT can handle multiple, simultaneous applications tasked from multiple locations, and can provide results in various forms to multiple end- users.
- **Network Survivability:** The software and system design support built-in autonomy, survivability, and low probability of detection.

Examples of specific applications are a Military Operations in Urban Terrain (MOUT) environment and the locating of Transporter/Erector Launchers (TELs). Eventually, a UAV that is smaller than a sheet of paper will be able to deploy a wireless network of sensors that are smaller than a piece of gravel. This work will take military sensor information gathering capabilities to a new level. Specifically, the mission of SensIT is to develop all necessary software for networked micro-sensors. A network of SensIT nodes provides target detection, classification, and tracking, and communication within and outside of the network.

As part of the project, AFRL/IF, acting as the agent for DARPA, and several contractors performed a series of demonstrations/experiments to monitor the progress of the integration of the various project technologies.

The first experiment took place at the Marine Corps Air and Ground Combat Center (MCAGCC), 29 Palms, California. Occurring 27 Jul-11 Aug 00, it was scheduled during a Combined Arms eXercise (CAX) to provide military targets of opportunity. The military traffic enabled engineers to test recent advances in sensor network technologies in a real-world environment. The experiment resulted in the collection of large amounts of previously unavailable data and many lessons learned. The data collected and experience gained are important steps toward the fielding of sensor network technology that will dramatically improve the warfighter's ability to safely and effectively complete his mission. Deployment of this technology will improve the collection of reconnaissance and intelligence information, greatly increasing situational awareness. With better information about enemy numbers, components, location, speed and direction, our forces will have a decisive advantage on the battlefield.

The second of these demonstrations was held 13-15 March 2001, also at MCAGCC. The primary contractors that participated in the demonstration / experimentation were BAE Systems, Rockwell Science Center, UC at Berkley and BBN. As part of the demonstration/experiment, selected military organizations were invited to observe the experiment to inform them of what future sensor network technology is coming and to solicit comments and recommendations on how to enhance this work for military purposes. Observers were personnel from MCAGCC, Army (ARDEC and NVESD) and Marine Corps Warfighting Laboratory. MCAGCC personnel were so impressed by the work that they published an article about it that was distributed worldwide.

Figure 2-4-2 Demonstration

The third of these demonstrations was held 29 October -16 November 2001 again MCAGCC. This test involved the initial deployment of 70 second generation multi-modal ground sensor 'nodes' that were used to integrate and test an end-to-end system functionality intended to autonomously detect, localize and track vehicles moving through a strategic crossroad or chokepoint. The vehicle track was to be displayed as an icon on a Command Post display and an imager, centrally located within the sensor field, was to be cued by the tracker for image capture and transmission to the Command Post. The results of this initial test were limited. However, the many lessons learned cleared the way for future work. Regardless, an extensive target signature series was collected on a wide variety of military vehicles including: HMMWV, 5-Ton Truck, Dragonwagon, LAV, AAV, M1A1 Tank and a former Soviet BMP-2. In addition, one week of experimentation was dedicated to advanced developmental software algorithms that will be integrated as future enhancements to the baseline system functionality. On Friday, 9 Nov01, visitors were invited to observe SensIT experimentation and a variety of other advanced sensor technology demonstrations. Observers were MCAGCC personnel, Marines Corp Warfighting Laboratory, and DARPA representatives from the newly formed Information Exploitation Office.

The analysis and design task conducted under this task had two major thrusts. The first thrust involved developing AF requirements transition paths for the technology. That involved finding planned acquisition initiatives or ongoing programs, which would benefit from the demonstrations ongoing in the SensIT program. The second thrust involved developing a plan to accept the nodes and control systems residue from the program and establishing a test program to extend the technology integrate capabilities into AFRL/IF program and continue to reinforce technology transition. A in detail research of ongoing AF programs uncovered the USAF Advanced Remote Ground Unattended Sensor (ARGUS) program at ESC. The program was based on the need to develop and deploy (hand in placed or air dropped) unattended ground sensors, which would provide detection and identification of ground moving targets otherwise hidden in trees. The program had a long history leading all the way back to Vietnam and the Igloo White program. The program had already undergone a number of iterations via Advanced Critical Technology Demonstrations (ACTDs) and flight demonstrations to show that the concept was feasible. Notional concept of the program is detailed in figure 2-4-3. It provides multiple sensor heads at a location with relay communications back to a C2 decision location for integration with other info.

Notional CONOPS

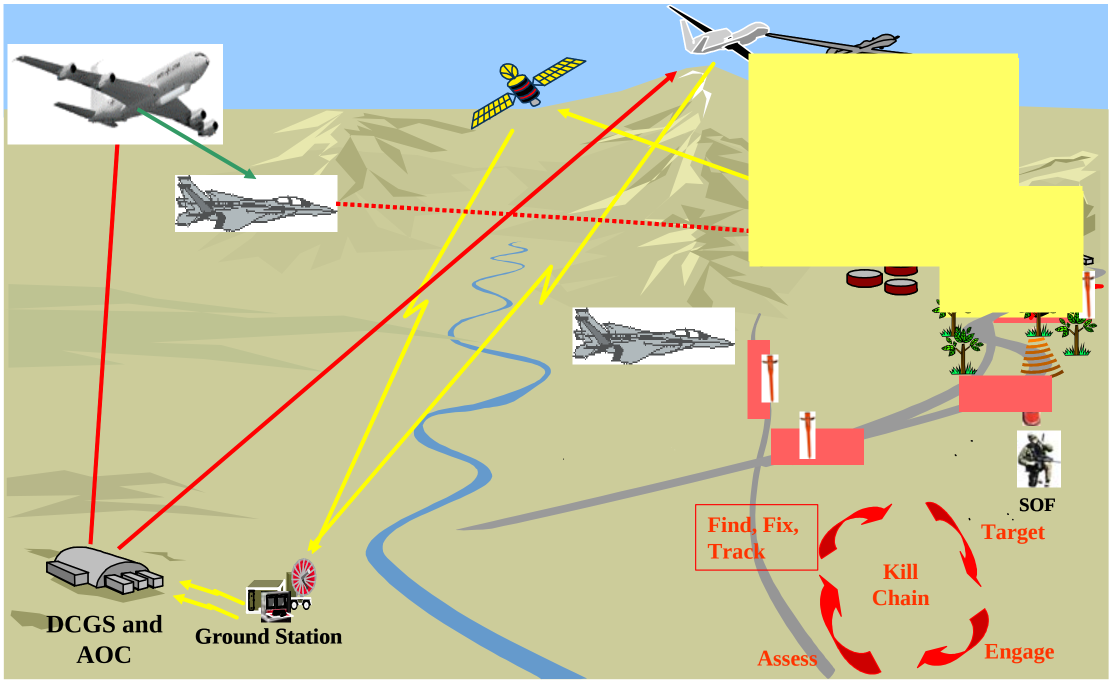

Figure 2-4-3 ARGUS CONCEPT

The SensIT program provides a number of technologies that will enhance operations; however the key difference is the distributed nature of nodes, which provide multiple local looks at the target and the self-organizing coordination between the nodes. It extends the detection, ID and utility of the concept from a single node to distributed network sensor field and all the important attributes associated with that. Further, it developed technologies that have the capability to reduce cost at the same time while extending utility of deployment significantly.

This rationale was shared in detail with the ARGUS program office that resulted in joint planning with ESC staff and joint technology sharing with Mitre. In fact, Residue nodes were provided to Mitre testbed to extend technology development and transition opportunities. The results from the testbed at Mitre will be compared with results being obtained from an IF testbed using same nodes and networks to extend cooperative development.

In the mean time the DARPA SensIT experiments have been extended, along with the residual equipment and software, and apply them to the Military Operations in Urban Terrain (MOUT) environments. The testing was in August 2003. A MOUT training facility exists in proximity to the Air Force Research Laboratory, Rome Research Site, at the Army's Fort Drum, in northern New York State. It is a natural and efficient way to further the technology and potential applications for the SensIT technology.

The network of sensor nodes and sensors were deployed in and around the MOUT facility. Personnel and vehicles were used to test the system's ability to detect and locate traffic, despite the MOUT building obstructions. The results of this initial informal testing outlined some field issues with deployment the nodes to more effectively locate traffic. It also provided detailed insight into network control issues.

The joint activities between Mitre and IF continue to leverage the technologies developed under SensIT via shared test programs. The DARPA program provided a wealth of technologies and concepts that will extend the future capabilities of Distributed Networked Sensor concepts for a long time. Attached below is the list of the major contributors to SensIT program.

SensIT PI/Contact	**SensIT Contribution**
Auburn Univ. Alvin Lim lim@eng.auburn.edu 334-844-6326	Distributed Services for Self-Organizing Sensor Networks: We develop distributed services that enable distributed sensor network applications to self-organize, reconfigure, relocate, survive sensor failures and respond rapidly to real-time changes in sensor tasks and ad-hoc network topology. They support continuous operation of distributed applications such as sensor fusion, target detection, target classification and collaborative tracking.
BBN Technologies Ken Theriault theriault@bbn.com 617-873-3139	SensIT system integration, test and demonstration. Coordinate and support PI development activities.
Cornell University Johannes Gehrke	Distributed data server and query management
Duke University Krish Chakrabarty krish@ee.duke.edu	Sensor deployment for coverage, target localization, and energy management, real-time operating systems, and dynamic power management.
Fantastic Data Tom Hammel	Storageless web database and data management system
ISI-East Brian Schott	Power aware routing and processing techniques and portable browser based topographical map interface
ISI-West Deborah Estrin	Network communications via Directed Diffusion
MIT Lincoln Laboratory Gary Shaw shaw@ll.mit.edu	Collaborative localization via multisensor fusion, panoramic image processing for detection, tracking, compression and fusion
PARC Feng Zhao zhao@parc.com	Collaborative signal processing, sensor net resource management, target tracking
Reinhold Behringer Rockwell Scientific rbehringer@rwsc.com	Distributed Kalman Filter for tracking on sensor nodes network: Architecture of a generalized concept for distributed target tracking via Kalman Filter, exemplary demonstrated by an implementation of acoustic tracking of a moving target through RMS volume measurement samples.
Rutgers Univ. Badri Nath	Prediction models; WebDust Info Server I and data space data management
Sensoria Corp. Billy Merrill	Wireless Integrated Network Sensor Next Generation (WINS NG) 2.0 platform used within the SensIT program: following generation WINS NG 3.0

310-641-1331x212	sensor platform currently in development
The Pennsylvania State Univ. Richard Brooks rrb@acm.org 814-863-5698	Reactive sensor networks, Self-configuring networks, Distributed target tracking, Cooperative data interpretation
The Pennsylvania State Univ. Shashi Phoha sxp26@psu.edu (814) 863-8005	Semantic Information Fusion in scalable, fixed and mobile node networks: This project addresses the severe power and processing constraints on the internetworking of mobile and fixed microsensors by devising knowledge based methods for their efficient utilization. We formulate mathematical techniques for local processing of raw sensor data into semantic information, which are communicated and fused for collaborative event detection, identification and tracking.
U. Tennessee / LSU / Duke Hairong Qi, U. Tennessee hqi@utk.edu	Energy-efficient Mobile-Agent-based task-adaptive collaborative processing in distributed sensor networks
U. of Maryland V.S. Subrahmanian	Task management, declarative query, spatio-temporal tasking
U. of Wisconsin Parmesh Ramanathan	Location-centric distributed signal processing and computation

2.5 Information Warfare

The activity under this task area involved the development of system concepts and technology thrusts, which would advance the state of the art of Information Warfare and Cyber Operations activities. It included a review of technology thrusts and development of concepts that meet AF and other user needs.

As a background, AFRL/IF has developed a responsive Information Warfare Research and Development (R&D) technology program. The objective is to meet the needs of the Air Force's Information Operations doctrine. Specifically, it is focused on Information Assurance, Computer Network Defense, Cyber Intelligence, Surveillance and Reconnaissance, and Computer Network Attack as defined in AFDD 2-5.

---- Information Assurance comprises those measures to protect and defend information and information systems by ensuring their availability, integrity, authenticity, confidentiality, and nonrepudiation.

---- Computer Network Defense (CND) is actions taken to plan and direct responses to unauthorized activity in defense of Air Force information systems and computer networks. Commanders should provide CND planning guidance to the staff, as well as supporting and subordinate commanders, as part of the "commander's intent." CND actions include analyzing network activity to determine the appropriate course of action to defend Air Force networks.

---- Computer Network Attack operations are conducted using information systems to disrupt, deny, degrade, or destroy information resident in computers and computer networks, or the computers and networks themselves.

---- Cyber Intelligence, Surveillance, and Reconnaissance (ISR) are functions in cyberspace that result in the ability to gather information about the adversary, their intentions, and their capabilities.

Information is now being placed at the level of major dimensions of power along with political, economical and military and is the lifeblood that flows through national defense mission critical functions, systems and infrastructures. Air Force Doctrine Document 2-5 states, "*Information superiority, like air and space superiority, is an element of combat power.*" DoD and the Services are very dependent on correct information and critical information infrastructures, and recognize the importance of networks and information systems as a key component to the successful execution of their respective missions. In fact, a recent Defense Science Board report stated, *"Information, information processing, and communications networks are at the core of every military activity."*

The Air Force links transformation with its existing core competencies. These core competencies are air and space superiority, information superiority, global attack, precision engagement, rapid global mobility, and agile combat support. Of particular relevance would be to focus more carefully, for example, on information assurance as part of air and space superiority, and complex systems as a critical part of information superiority, and computer network attack as part of global attack. It is clear that in today's day and age it would be quite difficult to achieve both air and space superiority without also dominating the information realm. The AF has also recently formulated a number of capabilities-based task forces that will lay the foundation for transformation to a capabilities focused expeditionary air and space force. These crisis response task forces are global strike, global response, global mobility, space and C4ISR, homeland security, air and space expeditionary forces, and nuclear response, many of which have an information assurance component and have a significant need for information assurance technologies which will require prolonged Science and Technology investment to achieve the stated goals.

The Information Warfare Threats can be characterized on a continuum from script kiddies to organized nation states bent on carrying out attacks. The Defense Science Board describes the groups that comprise the threat as follows: hackers driven by a technical challenge, disgruntled employees or customers seeking revenge, crooks interested in personal financial gain or covering criminal activity, organized crime, organized terrorist groups, foreign espionage seeking to exploit information for economic, political or military purposes, tactical countermeasures intended to disrupt specific US military weapons or command systems, multifaceted tactical information warfare applied in a broad, orchestrated manner to disrupt a major U.S. military mission, and large organized groups or nation states intent on overthrowing the United States.

Probably the most dangerous threat that we face today is what is termed the Information Warrior. The Information Warrior is a military adversary who uses attacks on the target's ability to wage war. The interesting aspect of the Information Warrior is that they use the same equipment as us (Internet, GPS, Windows, TCP/IP, etc…) and may have been educated in U.S. colleges and universities. The attacks carried out by this class of threat include destruction, denial, corruption, and surveillance of the targets information systems and networks. Also, the organized Information Warfare threat tends to make use of covert attacks based upon long-term surveillance and reconnaissance of the potential target's information systems. Many countries currently have or are developing information warfare capabilities. Most noticeably, China has set up an Information Warfare agency to break encryption and codes used by foreign firms and governments

The U.S. Intelligence Community (IC) is a large and complex structure of many different Federal organizations. The essential role of the IC is to provide timely, relevant information to U.S. policymakers, decision makers, and war fighters. Accomplishing this mission involves tasking, collecting, processing, analyzing, and disseminating intelligence to a variety of customers. It requires a specialized information infrastructure and a unique security environment that must work behind the scenes and often in highly charged international situations where intelligence information has the potential to remain highly sensitive for many years. In this environment, the stakes are high and confidentiality, integrity, and availability of IC information is extremely critical. For example, due to inadequate security, entire generations of collection or cryptanalytical systems may be compromised, thus reducing intelligence capabilities and wasting large amounts of investments. Further, leaks of information may have international political ramifications and cause lives to be in danger. The risk of compromise will increase as the IC continues to use commercial technologies and share its information electronically among intelligence officers, across agencies and with ad hoc coalition partners. The IC has always been responsible for ensuring that its information is secure. In the non-cyber arena, the IC developed robust systems and procedures to defend its data, sources, and methods. The IC's cyber environment demands the same risk management approach.

An analysis was conducted for the Advanced Research and Development Activity (ARDA) to provide foundation for development of innovative solutions for advanced cyber-defensive capabilities for the IC information infrastructure. Intelligence is as much a key part of cyber-defense as it is in kinetic warfare. There are two major components to cyber defense: IA situational awareness and cyber indications and warning. Both of these capabilities help IC decision makers understand the defensive status of the IC information infrastructure and what could happen in cyberspace between a potential adversary and the defenders of the IC information infrastructure. These two components of cyber-defense are needed to better defend the IC systems and networks. They are also necessary to derive meaningful conclusions from the security incident data the IC collects, to understand the "Big Picture" of the IC networks security state, and to pinpoint security weaknesses for correction. Both cyber defense capabilities are immature and require advanced technologies to include: presentation techniques, modeling of IC mission dependency versus IC system services, and fusion of cyber data with real-world information such as news stories and intelligence reports.

The objective of the program plan, which led to an approved ARDA contracting initiative, was for innovative demonstrable solutions, i.e. proofs of concept, to advance the state of the art in cyber-defense capabilities for the Intelligence Community's information infrastructure. Efforts that leverage existing technologies as a means of achieving research goals are acceptable, but efforts that are largely engineering in nature or that represent only incremental improvements to existing capabilities will not be funded.

The technologies sought under this program had to be highly resistant to subversion or circumvention by a sophisticated adversary. Respondents must demonstrate confidence in the effectiveness of their solution to resist attack through assurance arguments that address techniques, processes, methodologies, etc. employed to resist subversion and circumvention. Also, ARDA wanted the following basic desirable features incorporated into any proposed solution:

- Ease of Use: User interfaces should be easy to use and be free of internal complexities. Complexity in the user interface fosters disuse and/or potential security breaching work-arounds.
- Operational Transparency: Solutions should minimize the visibility of protection and tracking mechanisms, thereby complicating user formulation of breaching strategies.
- Portability: Wherever possible solutions should be effective across a broad spectrum of platforms and technologies within the IC information infrastructure.

Solutions should be capable of dynamically accommodating a potentially fast-changing security environment, including changes to threat conditions, mission imperatives and personnel status.

The analysis under this task also included providing similar technology foundation trade off analysis for programs with IOTC and DISA. In each of these areas the analysis served as a basis for program planning and development, whether it was for subsequent contracting or in-house testing initiatives.

3.0 Conclusion:

The system analysis conducted under this task cut across a number of AFRL/IF's programs. It represents a look at a number of ongoing technology development initiatives. The common challenge in each of these areas was developing a fit into the user's needs, which are then supported by plans. These plans must provide means for technology validation and collaboration with user's to allow transition. The challenge here is to understand user constraints and providing means to keep technology state of the art current while spirally off mature products into acquisition programs.

A single means to accomplish this transition/development need does not currently exist. It takes collaboration with all involved. The collaboration may be in terms of joint planning, testing or common effort on joint activities. Assuming a technology fits with a program or acquisition activity because it extents technology or capability generically is not enough. It must meet the needs of the joint activities developed through iterative study and planning.

This process is also true if the product is only a technology development activity. In any case, a system view provides a framework to discuss, plan, execute, test and transition products throughout the development cycle.