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Research and Sustainment for Crew Systems Interface Laboratory (R&SCSIL)

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September 2005

Final Report for 25 September 1998 to 30 September 2005

Human Effectiveness Directorate
Warfighter Interface Division
Wright-Patterson AFB OH 45433

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TECHNICAL REVIEW AND APPROVAL

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

//Signed//

MARIS M. VIKMANIS
Chief, Warfighter Interface Division
Air Force Research Laboratory

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14. ABSTRACT

In the past, Government/contractor relations for technical support contracts focused solely on the research as a collaborative team effort. However, today's diminishing research funding and the need for more outside exposure demand that the entire process of research, marketing, and technology transition be collaborative efforts among the Government and support contractors. The main program management thrust at the onset of R&SCSIL was to market the lab as widely and effectively as possible in order to increase the use of their existing resources, broaden the useful technology base and operational applications, develop more effective Unmanned Aerial Vehicle (UAV) and Space Vehicle operator interfaces, provide increased benefits to the warfighter, transition technology for commercial use, and increase annual revenues from outside sources. Through numerous avenues, SYTRONICS leveraged significant funding to accomplish tasks for the labs. Some of these funding initiatives provided start-up funding for a major initiative to develop and study the human factors that enhance building and sustaining shared situation awareness between crew members performing as ground-based and airborne battle-managers; Intelligence, Surveillance, and Reconnaissance (ISR) asset controllers; and air combat pilots during Network-Centric Operations, and in particular unmanned vehicle operators.

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PREFACE

This report was prepared at ***SYTRONICS, Inc.***, Corporate Headquarters, 4433 Dayton-Xenia Road, Building 1, Dayton, Ohio. The work was performed under Contract F33615-98-D-6000, ***Delivery Orders (DO)*** 0001 through 0013. Inclusive dates of the research reported are from 25 September 1998 through 30 September 2005. Mr. Ronald Yates of the ***Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Interface Division (AFRL/HEC)*** was the Program Manager. The purpose of this report is to summarize the achievements and successes accomplished on this program.

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AFRL RESEARCH PROGRAM

SUMMARY

SYTRONICS' tenure as support contractor to AFRL can be characterized as highly effective, innovative, and cost effective. Our company was grateful for the opportunity to serve AFRL and looks forward to continuing to provide our technical expertise to help the Air Force Warfighter.

INTRODUCTION

SYTRONICS, Inc., was founded in 1983 and has since expanded into a multifaceted company offering broad expertise in three major divisions: Human Research and Systems Engineering; Modeling, Simulation, and Training; and Test System Development. Our capabilities include research and development, applied engineering, program management, product development, and product support utilizing a *lean, highly productive, and cost-effective staff* of engineers, human factors professionals, technicians, training and support specialists, and administrative personnel needed to achieve and surpass the requirements of our contracts.

SYTRONICS has extensive technical knowledge in research operations for advanced warfighter interface technology that enabled us to achieve AFRL/HEC laboratory objectives in a timely and cost-effective manner. We made many changes and streamlined operations over the course of the ***Research and Sustainment for Crew Systems Interface Laboratories (R&SCSIL)*** contract to more efficiently support AFRL/HEC. For example, when we began the current effort, the incumbent contractor had a dozen programmers supporting the ***Synthesized Immersion Research Environment (SIRE)*** facility. We *supported the vastly more complex* ***Synthesized and Human Aerospace Forces in an Immersion Research Environment (SAFIRE)*** *architecture with less than half the software staff.* Here, and across the board, we brought on highly competent engineers, cut out layers of unnecessary administration, focused our employees on the R&SCSIL work, and did not burden them with corporate projects. We also adapted our accounting and reporting structure to better correlate with the Government's research and development case files. Even from the start, when the incumbent contractor protested the award, ***SYTRONICS*** stepped up with strong leadership and implemented a business strategy, at some expense to the company, which was in the best interest of the laboratory and enabled the work to continue without interruption.

Our R&SCSIL work clearly demonstrated ***SYTRONICS'*** ability to provide high-quality on-site support while working with Government technical and contracting officials, large and small business subcontractors, and numerous material vendors. ***SYTRONICS*** also maintained professional and personal connections with many important Air Force and DoD agencies, including the Air Combat Command, Air Force Special Operations Command, National Air and Space Intelligence Agency, Air Force Space Command, Air Force Battlelabs, Missile Defense Agency, the Naval Air Warfare Center, and with our local congressional delegations.

SYTRONICS' approach for R&SCSIL was to provide AFRL/HEC technically superior capabilities and resources in a highly cost-competitive manner. Our proven capabilities include the following.

- Highly ***competent and creative technical staff experienced*** in supporting AFRL/HEC programs.

- ***Local corporate presence*** and ***resource-based corporate management*** approach to support short-term work, surges, and lapses. We leveraged both on-site and corporate-based skill sets to supplement where needed for short suspense studies, demonstrations, and projects. For example, as part of our R&SCSIL support for the AFRL/HEC laboratories, we coordinated corporate-based software support for ***Collaborative Research in Space & Temporal Interfaces Laboratory (CRISTIL)*** and ***Speech Communication Research Engineering Analysis and Modeling (SCREAM)*** laboratories; drafting, electronics and hardware technician support for ***Helmet-Mounted Sensory Technologies (HMST)***; and mechanical and material support for ***Aerospace Operations Center (AOC)*** (now ***Augmented Time Critical Analysis and Targeting Facility (aTCaT)***) on an as-needed basis.

- ***Warfighter experienced employees***--Many members of our staff have warfighter experience bringing a warfighter's perspective and understanding to AFRL/HEC support and linkage to many DoD organizations.

- Cradle-to-grave military ***acquisition experience***--we understand the issues encountered at every step.

- In-house ***expertise in prototyping and fielding flight-worthy systems***.

- Rapid ***access to industry and academic experts*** through fast, low-cost contracting vehicles.

Historical Perspective

From 25 September 1998 through 30 September 2005, ***SYTRONICS, Inc.***, provided scientific and technical support to the Air Force Research Laboratory, Human Effectiveness Directorate for the R&SCSIL Program, Contract F33615-98-D-6000.

The current AFRL Mission and Vision statements continue the theme set in place by Lieutenant Colonel Paul M. Fitts when the AFRL (then the Psychology Branch in the Aero Medical Laboratory at Wright Field) was established in May of 1945. The statements assert that the research be focused on improving the human-computer interface through scientific research. The research results obtained through the R&SCSIL Program help to improve the design and development of warfighting equipment. These achievements preserve Lt Col Fitts' vision for the advancement of human research by providing engineers with the scientific data necessary to design and develop equipment that meets the requirements of the human operator.

In August of 1998, AFRL/HEC funding supported a combined on-site ***Logicon Technical Services, Inc. (LTSI)***, and Veridian staff of 110+ personnel performing the activities covered by the R&SCSIL contract. By November of 1999, 52 personnel members were hired by ***SYTRONICS*** to support the program. Twenty-five LTSI personnel and four Veridian personnel supported the contract via subcontract agreements with ***SYTRONICS***. At that time, a total combined staff of 81--68 full-time and 13 part-time personnel--supported the directorate.

Organization and Laboratory Support

In the past, Government/contractor relations for technical support contracts focused solely on the research as a collaborative team effort. However, today's diminishing research funding and the need for more outside exposure demand that the entire process of research, marketing, and technology transition be collaborative efforts among the Government and support contractors. The main program management thrust at the onset of R&SCSIL was to market the laboratory as widely and effectively as possible in order to increase the use of their existing resources, broaden the useful technology base and operational applications, develop more effective ***Unmanned Aerial Vehicle (UAV)*** and space vehicle operator interfaces, provide increased benefits to the warfighter, transition technology for commercial use, and increase annual revenues from outside sources. ***SYTRONICS*** leveraged ***Small Business Innovation Research (SBIR)*** funding to accomplish tasks for AFRL/HEC (Voice-Head Interface Controller--VHIC; Navy Air-and Bone-Conducted Noise Reduction System) and AFRL/HEA (***Aircrew Speech Processor (ASP)***; ***Global Horizontal Operations Support Toolkit (GHOST)***, etc.). ***SYTRONICS*** also spearheaded a two-year $4.1M Congressional Plus-Up request for FY05/FY06 to establish a National Center of Excellence for Networked Warfighter Decision Support at ***Wright-Patterson Air Force Base (WPAFB)*** as part of our efforts to obtain outside funding for AFRL/HEC. This funding initiative has been coordinated with the Dayton Development Coalition and Congressman David Hobson's staff to provide start-up funding for a major initiative to develop and study the human factors that enhance building and sustaining shared situation awareness between crew members performing as ground-based and airborne battle-managers; ***Intelligence, Surveillance, and Reconnaissance (ISR)*** asset controllers; air combat pilots during Network-Centric Operations; and in particular unmanned vehicle operators.

SYTRONICS also spearheaded an effort with AFRL/HEC, the ***Airborne Warning and Control System (AWACS) System Program Office (SPO)***, and Boeing to gain ***Office of the Secretary of Defense (OSD)*** funding for AFRL/HEC transition of speech technology into AWACS, and leveraged a SBIR match to double the funding to $960K.

SYTRONICS supported AFRL's Human Effectiveness Directorate Warfighter Interface Division's five branches: System Control Interfaces, Battlespace Acoustics, Collaborative Interfaces, Battlespace Visualization, and Cognitive Systems. There were 15 individual laboratories within the divisions. They include the following.

- Collaborative Systems Technology Laboratory
- Crew Aiding and IW Analysis Laboratory
- SCREAM Laboratory

- Aerospace Vision Experimental Laboratory
- Color Display Laboratory
- ***Display Test and Evaluation (DT&E)*** Laboratory
- Dynamic Visual Assessment Facility
- ***Night Vision Operations (NVO)*** Laboratory
- ***Visual Image Evaluation of Windscreens (VIEW)*** Laboratory
- Visual Symbology Test & Evaluation Facility
- Flight Psychophysiology Laboratory
- Advanced UAV Interface Defense Technology Objective
- ***Multisensory Overview Large-scale Tactical Knowledge Environment Interface (MOLTKE)*** Laboratory
- ***Research on Adaptive Interfaces for Virtual Environments (RAIVE)*** Laboratory
- SAFIRE Facility

Delivery Order Contract Structure

Thirteen DOs were issued. The DO 0001 objective was to provide ongoing and sustaining technical and network support for research programs in the AFRL/HEC laboratories and facilities as required. The required work included: (1) development and implementation of research plans, (2) sustaining effort of AFRL/HEC laboratories and facilities, and (3) AFRL/HEC computer network support.

DO 0002, ***Visual Display Technology (VDT)***, provided the necessary ongoing research and sustainment of the Design Parameters for Visually Coupled Systems, NVOs, VIEW, and the HMST Programs. The scope of the required research and sustainment included: (1) planning and execution of exploratory development of research plans; (2) designing, fabricating, integrating, maintaining documenting, and testing of VDT hardware and software, and (3) helmet system certification and flight testing.

The purpose of DO 0003, Basic, Exploratory, and Advanced Development of Adaptive Interface Technology, was to provide research and sustainment for the ongoing development and evaluation of adaptive interface concepts and technologies employing combinations of virtual and nonvirtual techniques. The scope of the required work included: (1) planning and execution of a combination of basic research, exploratory development and advanced development; (2) sustaining effort of the human interface research facilities utilized in the development and evaluation of adaptive interface technology, such as the SIRE and ***Combat Observation and***

Visualization Environment (COVE); (3) perform research specified by the US/French ***Memorandum of Understanding (MOU)*** regarding the Cooperation Development and Evaluation of Super Cockpit Technologies including hardware and software development, systems integration, research plan development and execution, and documentation; (4) perform research in the adaptive interface development within the requirements of the US/British Vista Warrior ***Project Arrangement (PA)*** to include hardware and software development, systems integration, research plan development and execution, and documentation; (5) perform research as specified in the US/Australian Virtual Air Commander PA to include hardware and software development, systems integration, research plan development and execution, and documentation; (6) perform research as specified in the ***Cooperative Research & Development Agreement (CRDA)*** with Kettering Medical Center for developing interface technology applicable to neurosurgery to include hardware and software development, systems integration, research plan development and execution, and documentation; and (7) perform research for the New World Vista Program, specifically the development of multisensory and adaptive display and control concepts and their application to ***Synthetic Task Environments (STE)*** such as the Predator STE.

"Bioacoustic, Noise, and Vibration Research and Sustaining Effort" was the title of DO 0004. ***SYTRONICS*** provided ongoing and sustaining research, development, and technical efforts for the research programs in the bioacoustic, noise, and vibration laboratories. The work included: (1) development and implementation of research plans, experimentation, and prototypes; and (2) the sustainment of the bioacoustic, noise, and vibration laboratories and facilities.

DO 0005, Proof-of-concept Prototype Speech Processing System, provided for research in speech technology investigations and their effectiveness in supporting improved warfighter training during air operations exercises. The purpose of this work effort was to develop and evaluate a proof-of-concept prototype speech processing system that could manipulate various types of information in the speech signal. The prototype was also able to evaluate the importance of that information for speaker identity and emotional state determination. A speech processing system was evaluated with human listeners using speech collected in-house and from standard speech databases.

Vision display research for the ***Strike Helmet 21 (SH21)*** Project was provided under DO 0007. This DO was a continuation of DO 0002, VDT, which provided the necessary ongoing research and sustainment of the Design Parameters for Visually Coupled Systems, NVO, VIEW, and the HMST Programs.

The purpose of DO 0008, Research for Multisensory Interfaces to Optimize Warfighter Performance, was to provide research and sustainment for the ongoing development and evaluation of intelligent multisensory interface concepts and technologies employing combinations of virtual and non-virtual techniques. The programs supported by this research include Advanced UAV Interfaces, Virtual Air Commanders, Real-Time Human Engineering for ***Unmanned Combat Air Vehicle (UCAV)*** Automation, and Crew Interfaces for Satellite Operations.

Under DO 0009, Research to Support Information Analysis and Exploitation, ***SYTRONICS*** provided research and sustainment to perform analyses and modeling of human and system performance to support acquisition and operation decision-making. The programs supported by this research included Biologically-Based Signal Processing for Information Operations; Cognitive Interfaces for ISR Operations; Cyber Crew Interface Development; Collaborative System Technology; User Modeling and Intelligent Aiding; Adversarial Decision Modeling; Cognitive Systems Engineering; and Rapid Insertion Technologies.

In support of DO 0010, Research to Support Visual Display Systems, ***SYTRONICS*** provided research and sustainment to enhance warfighter vision and visual interfaces to improve weapon system effectiveness during day and night operations. The programs supported by this research included Aerospace Displays Program, Crew Station Avionics, High Definition Display Technology Program, Organic Light Emitting Diode Dual Use in Science and Technology, and Windscreen Visual Interface Effects.

The purpose of DO 0011, Research for ***Defense Advanced Research Projects Agency (DARPA)*** Augmented Cognition Program, was to develop and apply real-time operator cognitive state assessment technology to the ***UCAV Decision Aiding System (UDAS)*** under the Real-Time Human Engineering for UCAV Automation Program collaboration with DARPA. This effort provided research and sustainment for the ongoing development and evaluation of technologies to assess in real-time the cognitive state of operators controlling UAVs, and to evaluate operator decision and performance aiding techniques that are enabled by the real-time state assessment.

The purpose of DO 0012, Research to Support Information Operation and Air Operation Centers, was to provide analyses, technology development, and modeling of human and system performance to support acquisition and operation of decision-support technologies. The programs supported by this research included Cyber Crew Interface Development, Visualization and Decision Aiding for Air Operation Centers, User Modeling and Intelligent Aiding, Adversarial Decision Modeling, and Cognitive Systems Engineering.

DO 0013 provided for support to the Research for Strike Warrior PA. This arrangement, PA DoD-MoD-AF-01-0003, was one facet of the DoD-MoD ***Research and Development Projects (RDP)*** MOU between the United States DoD and the United Kingdom ***Ministry of Defense (MoD)***. One component of the Strike Warrior PA was collaboration on interface issues for aircraft pilots, ***Command and Control (C^2)*** operators, and UAV and UCAV operators. This effort provided research and sustainment for the ongoing development and evaluation of technologies to use advanced interface technology to improve human performance, understand and improve human interaction with autonomous systems, and assess in real-time the cognitive state of operators controlling UAVs, and to evaluate operator decision and performance-aiding techniques that are enabled by the real-time state assessment.

PROGRAM MANAGEMENT

SYTRONICS has a very proactive management philosophy. We are vigilant for cost, schedule, performance, and personnel problems and aggressively pursue alleviating them. For example, lessons learned early in the R&SCSIL Program resulted in many significant changes. We improved our human resources process by consulting with an independent firm specializing in human resources and implementing many recommended improvements. We changed our program management structure and transitioned a laboratory Ph.D. with 13 years experience in AFRL/HEC to serve in the capacity as technical lead and program manager. Management also reevaluated subcontracting emphasis and customer coordination which resulted in overall improvement in the R&SCSIL Program.

In support of AFRL/HEC, we developed program management plans as required that included task breakdowns, schedules, budgeting, resource loading, equipment utilization, and facility needs. Our program management structure shortened the decision-making process, empowered the DO Leads to coordinate directly with the Government, and provide deployed decision-making. They could ensure the program was properly executed by coordinating all requirements, assigning the appropriate staff (with Government guidance), providing necessary resources, monitoring the work, reviewing and updating plans, adjusting to changing requirements, and properly documenting and reporting the project status and deliverables. Finally, through a standard set of weekly management meetings, monthly technical and quarterly management reviews, we ensured the best quality support to the Government.

STAFFING

SYTRONICS employed over 50 full- and part-time employees solely supporting AFRL/HEC's R&SCSIL effort. We reshaped the workforce to accommodate the evolving requirements and adapt the staff as needed to provide the optimal cost-effective mix of technical capabilities.

R&SCSIL required mostly low-to-mid level technical support. As shown in Figure 1, 90% of our R&SCSIL ***Scientific and Engineering (S&E)*** staff was equivalent to DR1 and DR2 level civil servants as defined by the Laboratory Demonstration model. In addition to providing these engineers, programmers, and scientists, we also provided graphics support, ***Precision Measurement Equipment Laboratory (PMEL)***, accountable equipment management, corporate-based shipping and receiving, ***Scientific and Technical Information (STINFO)*** support, and subject pool management (with a permanent staff of 10 part-time subjects).

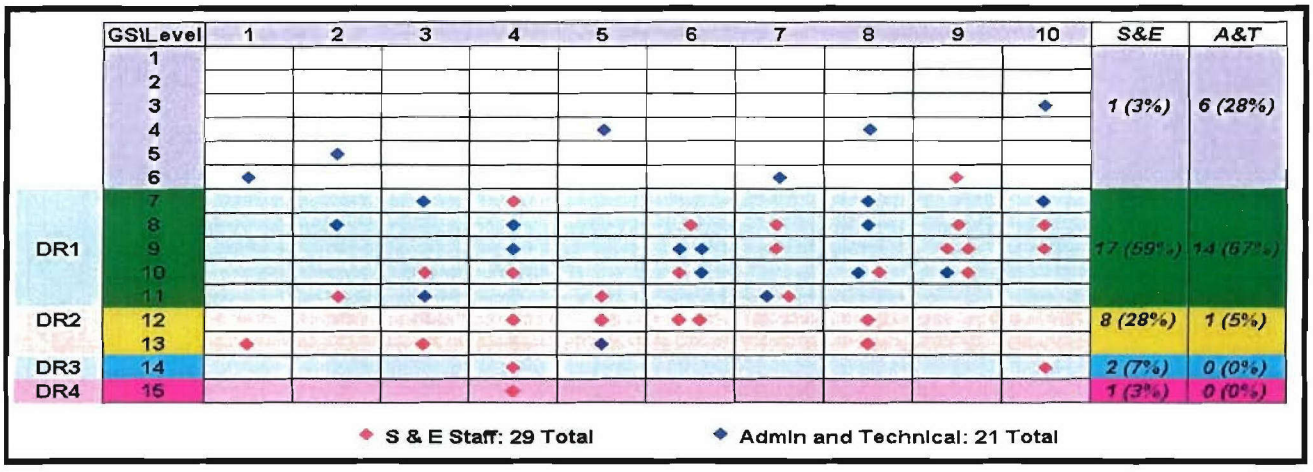

Figure 1. Technical Support

SYTRONICS continually worked with the Government to determine the best mix of staff to maximize technical support and cost-effectiveness without harming short or long term productivity. When a new position became available, resumes were provided for a pool of candidates. Our criteria was to provide the best candidate for every position based on desired skill set, education, and past experience. We strove to have well-informed and motivated employees who knew what was expected of them, how to resolve any issues that arose, and strove to perform at their utmost every day. This was evidenced by our low turnover rate which maintained laboratory continuity.

In an effort to further increase the cost-effectiveness of our staff, we coordinated, where possible, to provide co-op students and interns to supplement the workforce with young, enthusiastic, and cost-effective labor resources. These interns and co-ops were placed with the Government at a reduced overhead rate. The use of co-ops and interns not only provided talented, cost-effective, part-time support but also allowed the Government to preview, select, and groom possible future full-time personnel. Under R&SCSIL, ***SYTRONICS*** was able to bring in an intern to SCREAM Laboratory and he was later hired full-time--first as a contractor and then as a civil servant in AFRL/HECP. Similarly, another ***SYTRONICS*** employee was first hired as an intern and then became full-time supporting AFRL/HECB. Also, a graduate student was hired as a part-time employee to develop and complete his Ph.D. dissertation at The ***Ohio State University (OSU)*** in coordination with research goals in the SCREAM Laboratory.

MANAGERIAL REPORTING

Eighty-seven Monthly Status Reports, 41 Final Technical Reports, 159 Itemized Labor Costs Status Reports, and 27 Funds and Manhour Cost Reports were submitted throughout the duration of the contract. ***Quarterly Program Reviews (QPRs)*** were conducted at the Government work site throughout the contract term. ***SYTRONICS*** projects were carefully correlated to the AFRL/HEC 6.2 Roadmaps to ensure compliance with Government goals.

OPERATIONS MANAGEMENT

For administrative and logistical support, ***SYTRONICS*** offered large business capability, but with small business flexibility. ***SYTRONICS*** provided efficient low-cost subcontracting, ***Defense Contract Audit Agency (DCAA)***-approved financial accounting, purchasing, and fast and flexible travel services. Our contracts, accounting, and purchasing departments received numerous high marks and compliments for their speed, efficiency, and flexibility. We worked with the Government to provide customized financial and technical reports that met individual laboratory managers' needs.

SYTRONICS implemented an improved management scheme that it promised in its contract proposal. Rather than use multiple dedicated managers as prior contractors had, we appointed DO Lead Engineers to lead the technical areas and supervise supporting personnel. This supervisory role had minimal interference with the supervisor's primary technical duties. The DO Leads worked with the individual Government laboratory managers and the program manager to supervise and help manage the laboratory contractor staff to ensure the right people were available at the right time to get the job done. The DO Leads were also responsible for applying new capabilities as required by the Government leads. ***SYTRONICS*** corporate philosophy is to let project personnel concentrate on their designated tasks.

This approach minimized management overhead, provided some career progression for technical personnel while preserving their technical experience, and put technical issues at the forefront of program management. This arrangement resulted in management better focused on science and engineering productivity at a net lower cost to the Government. ***SYTRONICS*** believes this arrangement resulted in better technical management and a considerable savings of man-years compared to dedicated managers over the five years of the contract.

Other management savings were achieved by merging the purchasing function with ***SYTRONICS'*** existing materials procurement capability. The dedicated base purchasing staff was merged with other company functions so that the cost of the personnel was shared between ***SYTRONICS'*** other purchasing activities and the contract. This also resulted in lower purchasing costs to the Government. One of the purchasing personnel, who had a significant health problem, was able to continue working until the problem necessitated going on disability. The situation was managed by ***SYTRONICS*** so there was no reduction in services while showing the employee the utmost in consideration for her health problems.

Another accommodation to the Government's way of doing business was in the area of contract reporting. ***SYTRONICS*** adapted its monthly progress and financial reporting to match the Government's requirements for its own reporting. This enabled the Government contract manager to "cut-and-paste" ***SYTRONICS'*** reports directly into the Government's reports. This saved time and resources on the Government side without any additional contract costs and allowed smoother information sharing between the Government and ***SYTRONICS*** management functions. This sort of accommodation is the hallmark of ***SYTRONICS'*** interaction with the Government.

A similar format accommodation was made with regards to technical reports. ***SYTRONICS*** adopted the Government technical report format for its reporting, allowing easy transition of those internal reports into Government publication format. The ***SYTRONICS*** reports, delivered in electronic format, were submitted virtually unchanged as Government technical reports, with a considerable savings in document preparation costs for the Government.

SYTRONICS also supported industry efforts of common interest with the Government, contributing personnel and fiscal support to the International Symposium on Aviation Psychology when it was held in Dayton, OH in 2003. ***SYTRONICS*** was a contributor to sponsoring the meetings and its personnel served on the organization and technical committees.

SYTRONICS also established travel policies and procedures for worldwide travel and experimental support. On R&SCSIL, we supported studies at numerous remote locations in the United States as well as Europe and Australia. All travel was accomplished in accordance with the ***Joint Travel Regulation (JTR)***.

Finally, ***SYTRONICS*** also ensured compliance with all Air Force and WPAFB computer access and security requirements and fully complied with the "Computer and Network Access Requirements for User's and Equipment" and all rules and regulations regarding ***Automated Data Processing Equipment (ADPE)***.

FINANCIAL MANAGEMENT

SYTRONICS was one of the first contractors in Dayton to use the ***Defense Finance and Accounting Service's (DFAS) Web Invoicing System (WInS)*** back in 1998. This allowed us to use many DFAS internet-based tools (such as the ***Contractor Invoice System (COINS)*** and ***Mechanization of Contract Administration Services (MOCAS)*** tool) to submit invoices, track payments, close out DOs, etc., with the Government.

SYTRONICS went to considerable trouble to modify its accounting practices to make them compatible with the financial reporting required by the Government. All the Government needed to do was request a change, and the local staff were able to accommodate the Government managers with very little delay or cost. This flexibility in accounting was something the Government exercised often and the results improved overall contract management.

Minimizing overhead costs paid considerable dividends to the Government in terms of reduced contract costs. As for overhead rates over the entire term of the contract, rate increases over the five years of the contract were modest and deemed acceptable to the Government.

As a small business, we handled material purchasing and procurement with speed, efficiency, and flexibility. On R&SCSIL, we managed an average of over 450 purchases (over $600K) per year. For large and small dollar purchases, special test equipment, calibration, repair, and other needs, ***SYTRONICS*** utilized our proven procurement processes including signature approval, vendor selection based on price/availability, ***Purchase Order (PO)*** processing, accounting, shipping and receiving, inspection, and delivery. For software and other

purchases requiring a ***Computer System Requirement Document (CSRD)***, we ensured that all purchases complied with CSRD and software registration regulations and that all software was delivered first to the local ***Designated Approval Authority (DAA)*** for registration before being delivered to its final destination. Finally, we ensured the appropriate equipment was processed for any ADPE requirements. In addition to the standard procurement process, we provided a well-documented method for using and accounting for petty cash for small (under $100) purchases. Our purchasing/accounting system complied with all state and federal tax and procurement regulations.

SUBCONTRACT MANAGEMENT

SYTRONICS promised in its proposal to subcontract in a low-cost, easy access, and fast-reaction time fashion with whomever the Government chose for technical work. On R&SCSIL, we subcontracted over 120 subcontracts to over 80 businesses of all sizes--including large multinational defense corporations such as Boeing, Lockheed Martin, Northrop Grumman, General Dynamics, SAIC, BAE, and SRA International--and academic institutions including the Georgia Tech Research Institute, OSU, Washington University, University of Toronto, and over a dozen others.

Many of the subcontracts were let to small companies and/or individuals that had no previous experience in doing business with the Government. ***SYTRONICS*** provided guidance to those companies and/or individuals to expedite the subcontracting process. Larger businesses often needed to be carefully watched (fiscally) when receiving relatively small subcontracts to do technical work. ***SYTRONICS*** diligently managed their bureaucratic inertia, prompting regularly for bills and clearing them quickly to manage the expenditure of funding so important to contract management and fiscal resource protection. Subcontract rates were diligently negotiated with the companies involved and several times ***SYTRONICS*** was able to get them reduced.

Sole Source contracts were usually established in less than five days from the time the need had been identified. Competitively bid subcontracts were usually established in less than three weeks including solicitation and evaluation. After a subcontract was awarded, any reporting requirements and deliverables were then coordinated through ***SYTRONICS*** and subcontractor performance was monitored without undue burdening. Standard subcontracts simply required monthly status reports and monthly invoices, in addition to the subcontract product.

Upon completion of all deliverables and Government approval, the subcontract was closed out and any remaining funds were de-obligated and returned to the Government. Subcontracts were finalized by obtaining the appropriate closeout documents, the final invoice, and the Government's signature on a database-generated form, the Subcontractor Deliverable Review Form, created especially for this unique program. This form allowed the Government customer to interface directly with the subcontractor, yet allowed ***SYTRONICS*** to coordinate the successful completion of the effort with minimal disruption to the customer. The subcontract database also reduced the time required to prepare a subcontract agreement by at least 50%.

Seven competitive subcontracting opportunities were identified over the term of the contract, two of which were cancelled. The remaining five subcontracts were issued after a competitive process. ***SYTRONICS*** managed the competitive bidding, evaluated the bids in an expeditious fashion, and enabled the Government to get the best possible performers without significant time delay or increased cost.

TECHNICAL TASKS AND ACCOMPLISHMENTS

Myriad technical accomplishments were achieved through research conducted by the combined talents and expertise of the AFRL, ***SYTRONICS***, and subcontractor scientists and engineers. A list of technical reports completed during the course of the R&SCSIL contract is provided in Appendix A. Following is a summary of some of the technical achievements that ***SYTRONICS*** accomplished, or played an important role in facilitating what the Government accomplished.

TASKS

The nature of research support under R&SCSIL followed a paradigm as diagrammed in Figure 2. The support was broken down into a series of tasks including the following.

- *Research Planning*
- *Experiment Planning*
- *Implementation, Analysis, and Documentation of Experiments*
- *Prototype Development and Demonstrations*

We will look at ***SYTRONICS'*** support under each of these areas as well as general support functions such as equipment calibration, media shop, machine shop, etc.

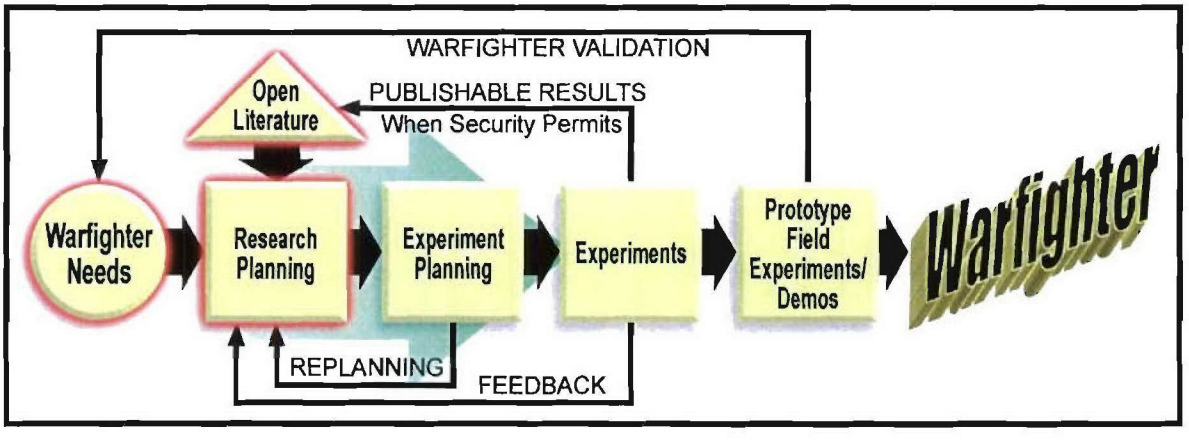

Figure 2. Research Support Paradigm

Research Planning

The nature of research planning is to provide researchers with a guide to the progression of work in a particular research area. It focuses on program goals and provides an organized, stepwise flow of how the research should proceed. The research plan is a living document, which is updated based on findings-to-date, current literature, and existing AFRL/HEC roadmaps.

The scope of research planning under R&SCSIL, aside from obviously supporting all laboratories and laboratory operations, was to adapt and evolve to match the changing nature of research in AFRL. A paradigm shift has been underway in military laboratory funding. Long-term (6.2) development programs are giving way to shorter horizon (two-three year 6.2) efforts and to more (6.3) advanced development efforts. Heavy emphasis is on quickly transitioning from experimental science to prototype implementations, suitable for testing on airframes and in other operational settings. Warfighter input and support must be sought out early and often during research planning, experimental design, experimentation, and prototype development in order to transition proven technologies.

The technical approach to research planning is comprised of three distinct stages: initial planning, update and maintenance of the plan, and human use protocols.

Initial Planning: For initial planning, ***SYTRONICS*** worked with Government scientists and engineers, as well as warfighters (through operational units or the Battlelabs) to develop the plan by providing whatever specific technical expertise (design and analysis, ***subject matter experts (SMEs)***, consultants, theoretic science, literature reviews, etc.) deemed necessary. Plans, in the form of documents, briefing slides, or both, were submitted (usually informally) to the Government for approval. Subsequently, ***SYTRONICS*** provided configuration and revision control of the research plan because the inevitable changes need to be carefully tracked.

Monitor, Develop, Update, and Maintain the Research Plan: One of ***SYTRONICS'*** outstanding capabilities is to research and integrate new ***commercial off-the-shelf (COTS)*** hardware and software to maximize results with minimal investment. As R&SCSIL support contractor, we continued to monitor trade journals, attend professional society meetings, interact with other Government agencies, and perform Web and literature reviews in order to stay current on the latest technology and ideas and integrate new ideas into the laboratory research planning, resulting in the most cost-effective innovative solutions to meet research requirements.

Human Use Protocols: Safety is always paramount in ***SYTRONICS'*** research; we understand the importance of ***Institutional Review Board (IRB)*** protocols for the protection of research participants and the compliance with Air Force regulations. As part of our R&SCSIL support, we made sure we knew the regulations and we supported AFRL/HEC in preparing, writing, and briefing IRB protocols. Numerous ***SYTRONICS*** employees took part in IRB protocols in support of NVO, Aerospace Vision Program (AVX), Bioacoustics, SAFIRE, and other laboratories. Since IRB approval is necessary for all human use studies, early protocol submission was a necessary part of the planning process. Long lead times for Surgeon General's

office approval means protocols must be submitted well in advance of the proposed studies. No ***SYTRONICS*** supported study was ever delayed because it lacked IRB approval.

Experimental Planning

While research planning shapes the general approach to conducting studies, the nature of the next step in the process, experimental planning, is to deal with the details of creating specific studies with sufficient control, validity, and reliability to resolve the truthfulness of specific hypotheses. At the same time, consideration to the statistical analysis of results must be given so that the desired analyses are possible and have sufficient statistical power to give the analysis a fair opportunity to succeed. The specialized nature of experiments within the AFRL/HEC facilities calls for experience to understand the nuances of each research area to effectively define the scope of the planning. ***SYTRONICS'*** staff contains experienced experimental scientists who provided or assisted in experimental planning for AFRL/HEC research.

For example, two types of research are conducted by the Battlespace Visualization Branch - characterization research and human factors psychophysical research. Characterization research deals with the test and evaluation of visual displays, ***Night Vision Devices (NVDs)***, aircraft transparencies, and basic human vision under laboratory conditions, using standardized test batteries. Human factors research deals with perceptual performance using or looking through displays, transparencies, or usability of visual augmenting technologies like NVDs.

Each of these areas had different and specific experimental planning scope and needs. In other cases, standards did not exist so new test methods were developed to answer research hypotheses or user questions. Some in-house methods developed by the Government and ***SYTRONICS*** engineers have been adopted by industry. Examples of these are ***American Society for Testing and Materials (ASTM)*** test methods and a procedure for determining ***Night Vision Goggle (NVG)*** cockpit compatibility in civilian aircraft.

Our statistical approach to studies applied designs such as *repeated measures*, *interrupted time series*, or *split-plot designs* which are condition-, time- and subject-efficient. By carefully choosing a minimum number of independent variables, we could allow interpolation of findings to cover the range of possibilities, while testing fewer conditions. Employing multiple dependent measures (objective and subjective), and consulting with SMEs to develop new measures that could better capture the independent variables' effects, helped to enhance research outcomes. Sometimes measures were embedded in prototype software to permit automated data collection in the laboratory and the field. This method is particularly effective in cognitive systems engineering, where additional objective measures are needed to supplement the commonly-used subjective measures.

Because of its diversity, each of the R&SCSIL technical areas had very different and specific experimental planning needs and therefore, required different approaches. For example, characterization research of displays in the DT&E Laboratory, NVDs in the NVO Laboratory and aircraft transparencies in the VIEW Laboratory took several forms, and our approaches did also. If reevaluation of a system was required, we would review previous evaluations and determine the appropriate battery of tests, available fixtures and test rigs, and equipment setup

required to obtain data repeatability. Prior to developing new prototype evaluation devices, we would conduct or update literature reviews as required to prevent duplicating prior work, verify approach soundness, and ensure testing methodologies and specifications were valid. All of these studies required critical alignment and proper positioning as well as the setting of appropriate calibrated lighting levels. Since DT&E, VIEW, and NVO receive warfighter assets for rapid evaluation, ***SYTRONICS*** was responsive to often demanding schedules. Often, time constraints for these evaluations did not always allow for in-depth planning. In those cases, ***SYTRONICS*** would use our extensive experience in rapid-response testing and evaluation in the VIEW and NVO laboratories to precisely measure the asset, reduce and analyze the data, write the report and assist in returning the asset to the field in a timely fashion.

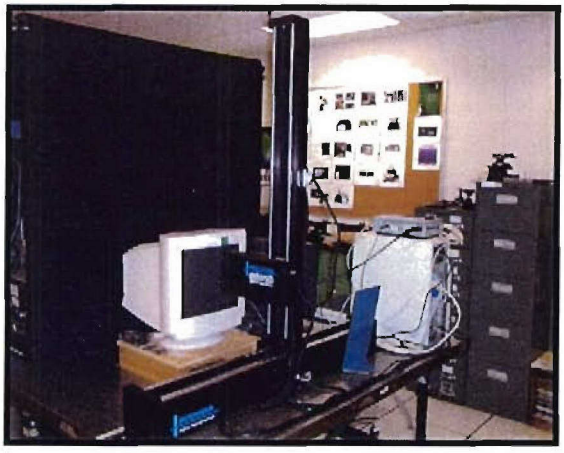

Figure 3. Display Test and Evaluation Laboratory

Psychophysical research studies (visual, auditory, and/or haptic) had different objectives and requirements. Here, we first defined the specific tasks for which performance improvements were desired (visual acuity, target acquisition, auditory localization, etc.), then specified the parameters that were expected to influence operator performance (color, contrast, sound level, distortion, etc.), as well as the experimental design and statistical variables. We determined environmental variables and employed optimum values of parameters for performance of tasks in specific environments to test performance. For example, visors, laser eye protection, filters, NVDs, displays, etc., may be obtained and the displays characterized with and without these devices for quantification of effects on the visual perception of color displays.

Once experimental tasks, variables, and parameters were defined, we wrote and coordinated with the Government, a detailed experimental design that reflected the research plan, based on appropriate statistical analysis, to ensure the study would provide meaningful and statistically-valid data. For this plan, we also determined subject requirements and coordinated the screening of subjects. The plan defined how acquired equipment and systems would be determined, set up, calibrated, tested and documented (in writing as well as photographically), and how data collection software or hard copy data sheets would be written as required, depending on the nature and laboratory conducting the study. When prototype displays or NVDs were field evaluated, our plan specified how we assisted the Government in scheduling appropriate facilities, aircrews, or aircraft for testing.

Defining the specific parameters of an experiment to answer research hypotheses always has its risks. To mitigate such risk, ***SYTRONICS'*** primary aid in experimental planning was the use of "pilot" studies. Such studies run a few subjects in advance of the "full" study to test experimental procedures, shake down apparatus, and estimate statistical parameters. Use of pilot studies added a small cost to overall conduct of the research, but prevented wasting the larger experimental effort due to procedural problems, artifact interference, and confounding variable intrusion. Furthermore, we used estimates of group mean separation to estimate statistical power of the main design and adjust sample size to most efficiently achieve the desired power level.

Experimental Research

Conducting high-relevance, focused, military experimental research is what sets AFRL and the other military laboratories apart from universities and industry. Universities relish doing "military-related" activities, but prefer to frame the military issue in lower-relevance, more general tasks. Industry often lacks continuity of effort, dependent on episodic funding from military sources. The Battlelabs do high-relevance demonstrations, but have not been adept at scientific data collection. Whether it is to develop technology for warfighters, or to answer a mission critical question, data collection and analysis is what distinguishes the AFRL military research mission. The AFRL/HEC organization has a long and distinguished history of innovative science, technology development, and successful transition to the warfighter.

The new, evolving nature of military laboratory research makes the nature of executing studies more demanding than in typical university research. The usual requirements for strict control of confounding variables, careful administration of independent variables, errorless data collection, and reliable procedures still apply. Additional burdens including high external validity, dependency on prototype devices and interfaces, differences between naïve subjects and unique military operators, and carry-over effects from existing systems or standard operating procedures further complicate AFRL research. Field data collections are often constrained by operational priorities, turning these studies into quasi-experiments. Researchers must be prepared to deal with known confounding variables to determine the real cause and effect relationships.

The scope of R&SCSIL included the five primary areas of research in AFRL/HEC: Battlespace Acoustics, Battlespace Visualization, Cognitive Systems, Collaborative Interfaces, and System Control Interfaces. Each area and laboratory within the area conduct experimental research tailored to their objectives and methods, common to their particular pursuit. ***SYTRONICS*** supported this experimental research as we describe below.

The first step for all studies was to collect pilot data once the apparatus was fully operational. The initial subjects for the pilot studies may have been the technical developers themselves or other laboratory personnel and these studies served to "shake out" the experimental procedures. In high cost or mission critical studies, subjects from the actual subject pool may have been used to ensure pilot data accuracy. Outcomes could be used to estimate group parameters and determine the statistical power of the planned analysis, changing group size and statistical tools based on the pilot subjects. The whole process was documented as the

introduction and methods for subsequent publications and to verify the apparatus and methods if the work is ever challenged.

The diversity and breadth of laboratories within AFRL/HEC make it impossible to cover all aspects of experimental research in this writing; however, here we provide specific examples of some of our support.

A recent evaluation of advanced AWACS displays involved data collection in the MOLTKE Laboratory with mission-ready combat air controllers. During the experiment development, ***SYTRONICS*** staff and SMEs ran as pilot subjects to debug experimental software and estimate the size of the effect. In the subsequent study, real AWACS crewmen directed semi-automated aircraft to evaluate interface technologies like speech recognition and advanced display formats for data fusion. This study is a good example of automated data collection in which the display software was instrumented to collect performance data during the execution of simulated air intercepts directed by the controllers. This work has led to the start of a joint AFRL-***SYTRONICS*** technology transition effort to implement speech interface technology in operational AWACS aircraft using OSD Challenge and matching Phase II SBIR funding.

Figure 4. Multisensory Overview Large-scale Tactical Knowledge Environment Laboratory (Major General Paul Nielsen and General Lester L. Lyles, seated)

Other data collections required more subjective and observer intensive effort. Cognitive Task Analysis performed in Cognitive Systems research required highly trained observers to perform structured interviews and observations to identify what users think while performing their jobs or interacting with their computer's user interface. Subjective surveys were usually collected, even where automated data collection was employed, to gain additional insights into performance of test systems.

Often automated data collection challenges researchers, due to the sheer volume of data generated. Physiological data like those collected in the ***Flight Physiology Laboratory (FPL)*** created such a problem. ***SYTRONICS*** used innovative custom software algorithms to reduce these data to meaningful subsets of manageable size and content. Additionally, ***SYTRONICS*** implemented data storage safeguards by archiving data to ensure integrity and prevent loss.

In these studies, either a ***SYTRONICS*** scientist or subcontractor performed the appropriate statistical analysis using industry standard ***Statistical Analysis Software (SAS)***™. Our expertise included all manner of univariate, bivariate, and multivariate statistics, including complex analysis of variance and covariance. The statistical designs specified in experimental planning were executed or modified to suit the data collection so as not to bias the findings. The results were formulated into journal acceptable text statements and graphical plots for technical reports or refereed journals.

Finally, ***SYTRONICS*** also provided high level support and expertise to help AFRL/HEC researchers accomplish their information dissemination mission. This included understanding the public release process required by the Government. Timothy Barry of ***SYTRONICS*** served with Dr. Mark Draper and Dr. John Reising of AFRL/HEC on a NATO committee for UAV interface design. Dr. Bill Marshak recently completed writing assistance to Don Monk for a report "Human Aspects of Future Command Systems," integrating notes and slides from a workshop run by The Technical Cooperation Program which was a cooperative effort of the Australian, Canadian, New Zealand, United Kingdom, and the United States Governments. Dr. Marshak also performed a meta-analysis of human factors errors in unmanned spaceflight that was published as an AFRL technical report. Numerous proceedings articles, technical reports, and journal articles have been produced with ***SYTRONICS'*** assistance for the Government or for publication by ***SYTRONICS'*** researcher staff. These efforts to disseminate scientific information included our co-sponsorship of the 12th International Symposium on Aviation Psychology in Dayton in April 2003. ***SYTRONICS*** provided financial support, organized committee personnel, and sessioned chairs alongside AFRL in these meetings.

Developmental Research

Although civilian researchers sometimes extend their experimental work into prototype development and testing, these areas are now the norm for military research work. Rather than perform developmental work in generic settings, military researchers seek out the specific user environment under the most realistic conditions possible in exercises, training flights, and on rare occasions, in combat, if user urgency dictates.

The nature and scope of developmental research is to support the breadth of application areas in AFRL/HEC, which is as wide as the nature of the diverse crew station applications. These areas include: cognitive workload analysis and design, information fusion and visualization, synergistic visual and auditory displays development, crew process/procedure/ performance modeling, intelligent interface agents for decision support and data visualization fusion, automation for decision support, as opposed to data processing, and quantitative strategies to sustain cognitive performance and manage fatigue.

In support of developmental research at AFRL/HEC, ***SYTRONICS*** designed, developed, fabricated, and installed warfighter interface hardware and software with transition to the warfighter as a specific goal. There are several AFRL/HEC systems that were developed that model real-world military systems and feed the kill chain. For example, AFRL/HEC's SAFIRE was designed, developed, and integrated by ***SYTRONICS*** personnel to support distributed

mission interface development concepts within the context of a "system-of-systems" to support ***Network Centric Warfare (NCW)*** experimentation. One keystone of SAFIRE is the new aTCaT facility. ***SYTRONICS*** engineers designed the aTCaT Laboratory to facilitate work-centered decision support for air/space ISR strategy planning and assessment. This assists the decision makers in visualization, understanding, and creating of combat decisions to reduce sensor-to-shooter control path, or *kill chain* (see Figures 5 and 6). Overall, SAFIRE provided effective coupling of AFRL/HEC's simulation assets for the experimentation of data fusion algorithms and decision aids for individual/team situational awareness under the auspices of future military combat envisioned during NCW.

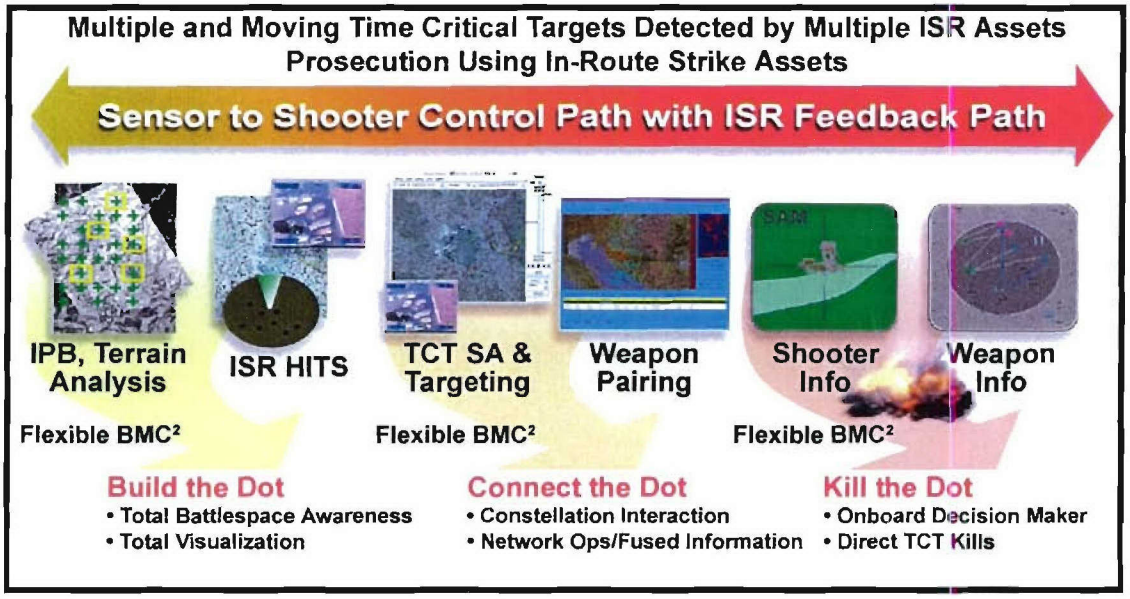

Figure 5. Sensor to Shooter Control Path

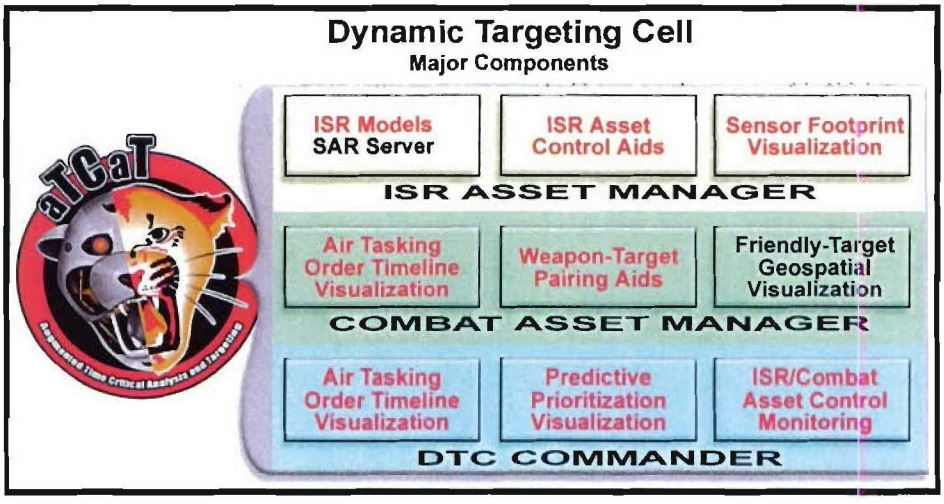

Figure 6. Dynamic Targeting Cell

SYTRONICS was intimately involved with the design of SAFIRE since its inception. Within the past five years, AFRL/HEC's simulation capabilities have grown from two primary,

but unlinked facilities into an NCW-capable "system-of-systems" that comprises a distributed network of over twenty complex, interconnected pilot-in-the-loop, and constructive simulation resources.

Of paramount importance was ***SYTRONICS'*** approach to assembling such a vast array of capabilities in relatively few years, with only a few dedicated personnel. Historically, AFRL/HEC had been a large software development shop, employing more than a dozen engineers to develop its simulation capabilities with monolithic, proprietary architectures, built and maintained in-house. During the last five years, ***SYTRONICS*** demonstrated rapid, low-risk success over and over with the integration of existing COTS and Government-owned software. In a dramatic example, the following major products/capabilities, comprising thousands of man-hours of development, were acquired during ***SYTRONICS'*** tenure and are now integrated parts of SAFIRE.

Table I
Acquired Products/Capabilities

Product/Capability	Function
Mantis (Quantum3-D/CG2)	SIRE scene generator
Aalchemy (Quantum3-D)	SIRE PC image generator
TerraVista (Terrex)	Visual database development
PAD (Boeing)	40/45 Prototype AWACS Display
TDF/Battlelab (Solipsys)	Tactical Display Framework
MSCT (Solipsys)	Multi-Source Correllator Tracker
ModSAF (US Army)	Constructive sim.
OtbSAF	Constructive sim.
JSAF (Joint)	Constructive sim.
SACS (AFRL/HECP)	Low cost desktop A/A fighter
DIS	IEEE Std. for Distributed Simulation
CART (AFRL/HECI)	***Time Critical Targeting (TCT)*** human performance model
Real Time Radar/***Synthetic Aperture Radar (SAR)*** (Camber)	Physics-based radar/SAR simulation
Real Time Radar/SAR (SAIC)	Image-base radar/SAR simulation
MIIIRO UAV	Multiple UAV control testbed
EAAGLES (ASC/HP)	Enhanced A/A, A/G fighter
VBMS (AFRL/VACD)	Virtual Battle Management System
SubrScene (AFRL/VACD)	Scene generator
AWACS 40/45 Sim (Boeing, AWACS SPO)	Command/control test bed

SYTRONICS' speech recognition and processing programs are numerous. For R&SCSIL, we incorporated speech systems into the MOLTKE AWACS, the Predator Ground Station, and the Satellite Toolkit for CRISTIL. Finally, our engineers also helped develop the ***Multimedia Information Retrieval Interface (MIRI)*** and took part in numerous developmental programs (such as Arabic ***Hidden Markov Model Toolkit (HTK)*** model testing, studies of

foreign-accented speech, and glottal model testing) for the SCREAM Laboratory to support Air Force and other Government agencies. By addressing critical design and integration issues early, each of these programs has the potential to be transitioned to the warfighter in a very short period of time.

Prototype Development

Even as Air Force operations expand into space, the flying mission remains the most demanding and dangerous. Placing equipment in aircraft (and spacecraft)--even temporary modifications for test and evaluation--requires extensive preparation and perseverance. Such flight demonstrations are irreplaceable for proof-of-concept, winning advocacy from the warfighter, and for risk assessment in technology transition. These demonstrations provided direct warfighter influence on new technology development.

Implementation of flight worthy equipment to enable the warfighter to develop and evaluate advanced ***Concept of Operations (CONOPS)*** in an ***Advanced Technology Demonstration/Operational Utility Evaluation (ATD/OUE)*** environment was especially essential to the ***Helmet-Mounted Sensory Technology/Visually-Coupled Systems (HMST/VCS)*** mission. Development of flight certified equipment in a timely and cost effective manner that meets the safety of flight criteria enabled the warfighter to concentrate on meeting the ATD/OUE objectives.

SYTRONICS' general approach to ensure the successful development of flight-certified equipment was based upon the proper application of system design theory and practical experience gained from previous implementations in military aircraft. This approach minimized risk and enabled our designs to achieve the system performance and operational objectives as well as meet the ***Electromagnetic Interface/Electromagnetic Compatibility (EMI/EMC)***, shock, vibration, and safety-of-flight requirements defined in the military specifications.

Our technical staff supported the ATD/OUE conducted by the 422nd ***Test and Evaluation Squadron (TES)*** at Nellis AFB from the first flight in 1997 to the preparations to test and evaluate the ***Non Distributed Flight Reference (NDFR) Heads-Up Display (HUD)*** application. This support included HVI, helmet, ***Removable Optics Mounting Assembly (ROMA)***, and CRT test, evaluation and characterization using the ***Programmable Image Display System (PIDS)*** we developed to emulate the aircraft display-control-processor. These contributions were significant to the implementation of the helmet mounted cueing system for the ***High Off-Boresight Angle (HOBA)*** evaluation and CONOPS development.

The ***SYTRONICS*** HMST/VCS design team was a major contributor to the development and implementation of the ***Integrated Panoramic Night Vision Goggle (IPNVG)*** for the SH21 Program. We participated at every level of the top-down system design process including ***Technical Interchange Meetings (TIMs)***, ***Program Design Reviews (PDRs)***, and ***Critical Design Reviews (CDRs***) sponsored by Boeing, the prime contractor and integrator. This experience provided a unique opportunity to interact with the integrator, subcontractors, and the warfighter to ensure the system functional and performance objectives were met in the applied hardware. Our development of ***Interface Control Documentation (ICD)*** relative to our

hardware and software interfaces minimized risk and ensured that all system components function together properly.

In Figure 7, we show the SH21 system block diagram including the ***Helmet Interface Panel (HIP)*** and ***Helmet Operation Panel (HOP)*** which were ***SYTRONICS*** deliverables. We also provided all technical oversight for the design and fabrication of the HVI. Perhaps the most significant contribution our team made was in the implementation of the ***Active Matrix Organic Light Emitting Diode (AMOLED)*** micro-display image source into the IPNVG.

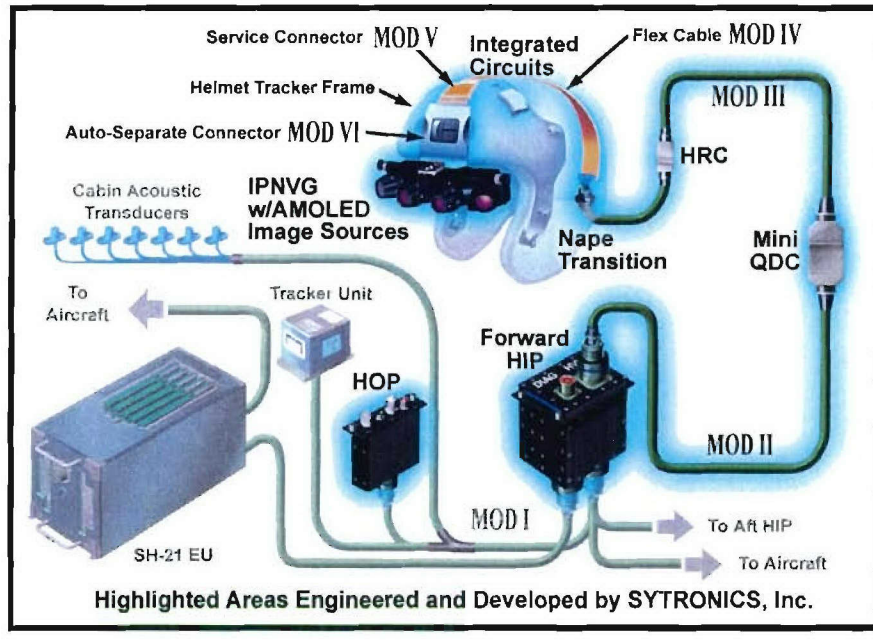

Figure 7. SH21 System Block Diagram

Successful implementation of this technology was ensured by performing extensive testing and evaluation to fully define the AMOLED functional and performance characteristics. The migration to flat panel microdisplay technology represents a major departure from the previous miniature CRT image source and enhances helmet application by reducing weight and power. Also, a major improvement in performance is achieved by providing inserted and/or overlaid system/sensor full-color video to the ***Night Vision Imaging System (NVIS)***. Additionally, we presented the AMOLED image source for IPNVG work at the ***Society of Optical Engineers and Scientists (SPIE)*** Defense and Security Convention in April, 2004. Finally, we designed and developed the IPNVG Tester, shown in Figure 8, to characterize, program, demonstrate, validate, and maintain the IPNVG throughout the ATD/OUE.

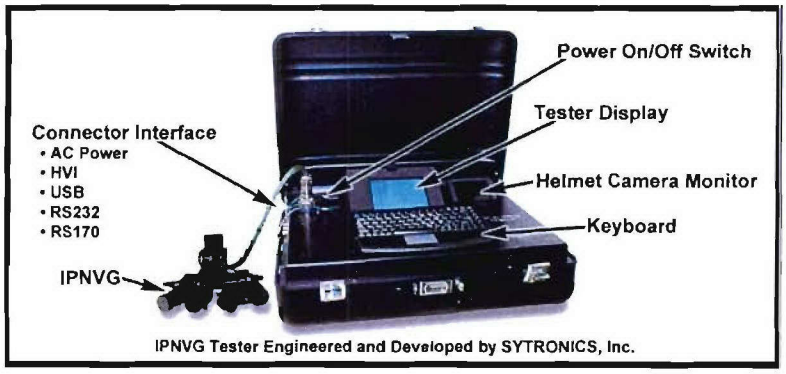

Figure 8. IPNVG Tester

The achievements of the ***SYTRONICS*** HMST/VCS engineering team were well respected within the military HMD community. We proved we could work multiple projects simultaneously, respond quickly to the ever changing requirements encountered in a development program, and provide quality HMD and related systems. Also, ***SYTRONICS'*** local presence provided quick-turn technical support in response to peak workloads to accelerate hardware fabrication which enabled the engineering team to achieve more timely ***Government Furnished Equipment (GFE)*** deliveries.

Installation of equipment such as the ***Line Replaceable Unit (LRU)*** and aircrew-worn flight worthy equipment for ATD/OUE implementation such as HIP, HOP, ***Remote Electronic Chassis (REC)***, HMD, IPNVG, ***Quick Disconnect (QDC)***, HVI, and digital kneeboard in fighter aircraft create many possible risk scenarios to the aircrew and aircraft systems. ***SYTRONICS*** utilized a development process that included analysis, prototyping, and testing to evaluate all equipment, as appropriate, relative to signal integrity, power loading, EMI/EMC, ground egress, ejection, windblast, ***Foreign Object Damage (FOD)***, shock, vibration, and other environmental criteria to mitigate risk and ensure safety of flight.

Another safety practice was to restrict interfaces which interact with aircraft buses like the 1553 to read-only configurations. Class II modifications (aircraft changes to incorporate prototype hardware and software) are significantly easier if the systems in question are read-only. This turns out to be a modest restriction, since most human factors augmentations do not affect controls directly. If a system must exert control of critical aircraft systems, a considerable certification process is necessary to fly. Waivers can be received, but are rare because of the safety concern for the crew.

Systems Integration

The scope of system integration under R&SCSIL included integration of all manner of devices, systems, and modules, including hardware and software items. Software module integration may have been at the executable stage, or may have required integration of source code. Sometimes, software integration might have been as simple as installing the software application, or as complicated as implementing specialized interface modules, which handled specific interface protocols and timing issues. Hardware integration required both physical

connectivity, which required proper mounting and alignment (such as for optical or mechanical devices), and electrical connectors (such as RF, analog, vide, and digital connectors or connectors for a computer's standard (i.e., parallel, serial, and USB) interface ports). Signal dynamic ranges and bandwidths, and signal or data formats were also considered, and at times specialized conversion or transfer modules were required. Such integration involved items developed within the laboratories, items developed by ***SYTRONICS*** or other support contractors or Government staff, COTS/***Government off-the-shelf (GOTS)*** items, or items provided by companies working on other tasks supporting AFRL/HEC. The nature of this activity was to achieve the integration properly and efficiently, in order to enable the experimentation to proceed without delay.

Our approach took the highly diverse and heterogeneous situation described above, and captured it within an integration *specification-based methodology* to ensure proper and efficient systems integration. The methodology was basically to prepare an interface specification (sometimes called an ICD), to ensure compatibility of the item to be integrated with the host. The steps in this approach are described below.

1. Gather information for host and item to be integrated: We collected host system documentation, GOTS or COTS item installation or operation manuals, prior integration specifications, and any other documentation which we required.

2. Prepare interface specification: We described, in quantified and specific detail, the physical, electrical, and software interfaces. These may have been physical drawings, electrical schematics, software protocol descriptions, or signal or data descriptors (including timing diagrams or descriptions), all in sufficient detail to be useful. For example, a set of signal descriptors for a connector would include each pin number, the names of the signals (SIG1, Data27, etc.), and signal descriptions (0 to 5V analog, 20 to 300 GHz RF, 0 to 255 binary, etc.). If specialized interface hardware or software modules were required, we included their specifications in the interface specification. This specification also included a test plan for validating the integration once it had been accomplished.

3. Review interface specification: We typically subjected the specification to review by the owners of the item to be integrated and the host. Such review may have been an informal reading and commenting on the specification, in the case of a fairly simple integration task. Conversely, it may have been a formal walk-through of the specifications, with supporting detail from system or item testing and technical SMEs in attendance, for complex or potentially troublesome interface problems.

4. Revise and reevaluate interface: We incorporated all changes to the specification precipitated by the review (Step 3) then tested or evaluated the corrections to ensure we had a correct and accurate interface specification.

5. Release and implement the interface specification: We provided the final interface specification to the host and item owners, to ensure satisfactory integration.

6. Implement the interface: The host, item owners, and the integration task team, followed the interface specification: (1) to ensure application during item development, (2) to design and implement specialized modules as needed, (3) to test and validate the host-item integration, and (4) to achieve satisfactory integration.

This sound, interface-specification-based approach ensured a satisfactory integration of an item to be integrated with a host system. We applied its tenets to the level of formality and documentation that were prudent, depending on the complexity and nature of each particular integration activity. As an example, although the ***Little High-End Airborne Laptop (Little HAL)*** Program was suspended prior to implementation of the Class II modification, our HMST/VCS engineering team completed the integration design, and development, and were prepared to modify the A10 test aircraft to integrate the system components shown in Figure 9.

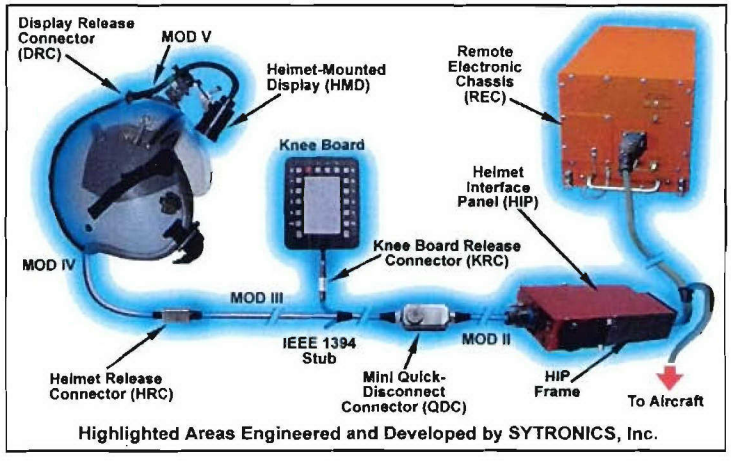

Figure 9. Little High-End Airborne Laptop (Little HAL)

System integration risk is substantially reduced by using the specification-based approach described above, offering a less-rigid and de-facto approach to integration. However, potential risk of realizing a faulty integration is still possible, as human error can permeate even the most disciplined specification development. There are two ways we mitigated this risk--early prototyping and emulation.

- ***Early prototyping*** forced the implementation of the interfaces early in the development of an item to be integrated. By forcing this to happen early in the development, we got an early estimation of interface performance at the design level, and this often revealed problems not considered in the specification development stage.

- ***Emulation*** is an excellent way to reduce risk for complicated interfaces, and was especially useful for situations such as integrating externally developed items where the developer and the host owner were remotely located. It was generally quite inexpensive and easy to construct a software or hardware brassboard emulator for one side of an interface. By building the emulator and testing it with an item under development, we could test and measure actual signal handshaking, levels, and dynamic ranges, and solve real integration problems well ahead of actual integration. Emulation supported the early prototyping concept, and was invaluable in reducing integration risk.

AFRL/HEC Sustainment: AFRL/HEC technical sustainment support encompasses many diverse research and support activities including facility sustainment and improvement, material procurement, equipment handling and tracking, hardware and software integration, subject pool management, machining capability, and computer and network support. ***SYTRONICS*** provided high quality laboratory sustainment for the R&SCSIL contract.

Engineering Improvement: ***SYTRONICS*** leveraged our superior capabilities to serve AFRL/HEC into the future as laboratory areas and facilities were built up, redesigned, torn down, and rebuilt to accommodate the vast landscape of research projects required to enhance warfighter effectiveness. For example, we re-hosted the SIRE facility converting from costly, high maintenance, Silicon Graphics machines to lower cost, easily maintainable PC systems. In the SCREAM Laboratory, ***SYTRONICS*** engineers developed a racked Beowulf cluster of 44 processors running Linux that improved computing performance for data crunching. When combined with disciplined software improvements to take advantage of the parallel architectures, huge computing performance savings were achieved. For example, a glottal model algorithm that took 432 hours to process one set of conditions, now only takes 28 hours--a 15X improvement!

SYTRONICS also provided a capability for facility infrastructure enhancements by utilizing in-house and contracted capabilities. Our corporate engineers were able to oversee and complete a major overhaul of the B-07 area in developing what is now the aTCaT facility. This included new flooring and ventilation, ceiling tiles and lighting, wiring, and walls as well as new furniture and integration of projection systems and large plasma displays. The aTCaT facility is now a showcase facility for AFRL/HEC for leading edge technology at an affordable acquisition and support cost.

Research Equipment Maintenance and Calibration: ***SYTRONICS*** operated, maintained, and calibrated research equipment in compliance with maintenance, operating, and calibration procedures utilizing our vast on-site experience. Our approach was to establish an annual calibration schedule in accordance with manufacturer recommendations, as well as checking and recalibrating equipment when used. For example, ***SYTRONICS*** personnel established a maintenance and calibration schedule for performing maintenance on the transmission, the air brake system, the BDS5 motor controller, and the control electronics of the motorized cart in ***Dynamic Visual Assessment Program (DVAF).***

SYTRONICS personnel are experienced in dealing with the procedures and pitfalls of calibration of laboratory equipment by PMEL. In AFRL/HECB, ***SYTRONICS*** technicians refined the process for calibration of equipment that must be completed by the ***Original Equipment Manufacturer (OEM)*** such as the B & K Analyzers. This equipment was stated in regulation 33K-1-100-1 to be "*User Calibration/Note # 64 PMEL*" equipment. However, since the OEM would not supply guidelines for calibration, the equipment must be sent away to the manufacturer. ***SYTRONICS*** technicians challenged the Note # 64 for this equipment through ***Air Force Metrology and Calibration (AFMETCAL)*** Program to have it changed to Note # 44 and, therefore, had AFMETCAL pick up the cost of OEM calibration. This challenge was successful and resulted in a cost saving to the laboratory of over $1,200 dollars per unit per year.

By establishing and following calibration schedules for equipment not on the PMEL account, ***SYTRONICS*** personnel have alleviated the problem of frequently used equipment being gone for long periods of time at the manufacturer. For example, Minolta spotmeters are calibrated against a Hoffman LS-658C photometric luminance standard that is routinely calibrated at the manufacturer. Calibration factors are calculated, dated, and attached to the top of each device.

Software Development: ***SYTRONICS*** coded, upgraded, tested, debugged, calibrated, maintained, and documented all software necessary to sustain new and existing research programs. ***SYTRONICS*** instituted the use software engineering tools and current methodologies, such as ***Integrated Development Environments (IDEs)*** and revision control of source code (***Concurrent Versions System (CVS)*** and SourceSafe), at the beginning of the R&SCSIL contract. In SIRE, ***SYTRONICS*** personnel instituted standard software practices where they did not previously exist. Using a modular, common core approach, ***SYTRONICS*** personnel were able to share development libraries between various laboratories, reducing development time, thus reducing cost and risk. For example, common core software is now in use among the ***Synthetic Interface Research of UAV Systems (SIRUS)***, SIRE, MOLTKE, and ***Digital Entities for Interface Evaluations (DIGEIE)*** laboratories. In the aTCaT Laboratory, which had previously been dormant and isolated for nearly one year, the use of existing in-house and COTS software allowed ***SYTRONICS*** personnel to bring the facility online within the SAFIRE architecture after only two weeks of occupancy.

Further, ***SYTRONICS*** continually promoted the implementation of effective software technologies. In the rapidly changing world of software development, it is especially important to evaluate and consider emerging tools (IDEs, compilers, debugging aids, etc.), paradigms (objects, use cases, spiral, etc.), and languages (C++, C#, UML, XML, Java, etc.) as they emerge and mature throughout the industry.

Integration of COTS Hardware and Software: The use of COTS hardware and software products has proliferated over the last five years widely benefiting the laboratories. Under R&SCSIL, ***SYTRONICS*** continually integrated new hardware components and software products into existing laboratory systems. ***SYTRONICS*** personnel worked closely with the Government to ensure that each laboratories' functional requirements were met and new functional capabilities were incorporated in order to support the need of each individual research program or experiment. Needs were assessed, and COTS alternatives were reviewed before

deciding to embark on any custom development. ***SYTRONICS'*** use of COTS and GOTS products reduced risk, decreased time to experiment, minimized the laboratories' role as a "software development house," provided large increases in capabilities in shorter time, and promoted collaboration between laboratories with complimentary capabilities.

Machining and Fabricating Capability: Under the R&SCSIL contract, our machine shop manufactured numerous precision-machined components, injection molds, and electro-mechanical assemblies. Their services included: prototyping; engineering assistance in all project phases; state-of-the-art machining equipment; material selection, including specialty alloys; and engineering drawings. Some of their products included: a NVG depth-of-field calibration stand, interchangeable NVG close-up lens assemblies, fabrication of a laboratory crazing meter, ***Organic Light-Emitting (OLED)*** viewing stands, laptop tray electronics boxes, LCD photometer, infrared terrain boards, ***Panoramic NVG (PNVG)*** tester unit, IPNVG eyepiece injection mold, and a 3-D holographic imaging gun. ***SYTRONICS'*** on-site machine shop received many accolades for their quality, timeliness, and service.

Subject Pool: Under R&SCSIL, ***SYTRONICS*** maintained and managed subject pools for experimental support. These took the form of "permanent" part-time employees, single-use personnel recruited for special skills or conditions, and/or expert pilot or other SMEs. Our human research subject pool manager provided subjects for all of the studies conducted on the R&SCSIL contract, ensuring that the varied and often stringent requirements (age, sex, physiology, hearing, vision, etc.) were met. Our responsibilities included recruiting, screening, training, scheduling, canceling, and rescheduling subjects (as dictated by the Government or due to equipment failure), escorting subjects on base (and dealing with the ever changing requirements for that) and to the various laboratories, paying subjects, completing financial reports, and maintaining schedules of each laboratory as well as a record system to track experiments, subjects, and subject payments. We also visited local universities and worked with their staff to recruit new subjects.

For AFRL/HECB, we maintained a subject pool of part-time employees who were available for evaluation of protection and communication hardware done on an ongoing basis. Subject management and delivery was particularly difficult after 11 September 2001, when the Air Force increased security and restricted access to the base. However, despite ever changing and confusing security procedures, ***SYTRONICS*** was able to continue supplying subjects during this trying time without disruption to the ongoing bioacoustic research by the diligence and perseverance of our subject pool manager. Other studies like the AWACS operator evaluation of advanced interfaces in the SIRE facility required arranging for and using military members to serve as subjects.

Network Operations Support: ***SYTRONICS*** provided sustaining effort for the Warfighter Interface Laboratories' information networks. Under R&SCSIL, ***SYTRONICS*** was responsible for the maintenance and documentation of the networks. ***SYTRONICS*** personnel coordinated with the 88th Communications Group to plan and document the laboratories' information networks to meet existing and emerging requirements. Furthermore, ***SYTRONICS*** personnel provided general network connectivity and maintenance of PC-, UNIX-, and Linux-based machines and software.

SYTRONICS personnel have been instrumental in the development, maintenance, repair, upgrade, enhancement, and integration of many laboratories onto the SAFIRE simulation network. SAFIRE has grown during the last two years from one laboratory (SIRE) to the participation in distributed simulations of over eight laboratories (see Figure 10). In support of NCW research, the SAFIRE network now includes SIRE, ***Fusion Immersive for Tactical Environment (FITE)***, DIGEIE Red, DIGEIE Blue, MOLTKE, SIRUS, aTCaT, ***Simulation and Analysis Facility (SIMAF)*** (ASC), and the AFRL/HECI Centrifuge. ***SYTRONICS*** supported initial efforts to integrate SAFIRE facilities with facilities in Building 441, as well as the new ***Forward Area Controller (FAC)*** facility in AFRL/HECP, and ***Defense Research Engineering Network (DREN)*** connectivity to AFRL/HEA at Mesa City Base. This DREN connectivity would enable AFRL/HEC to participate in distributed simulation events such as ***Joint Expeditionary Force Experiment (JEFX)*** and ***Simulation Exercise (SimEx)***.

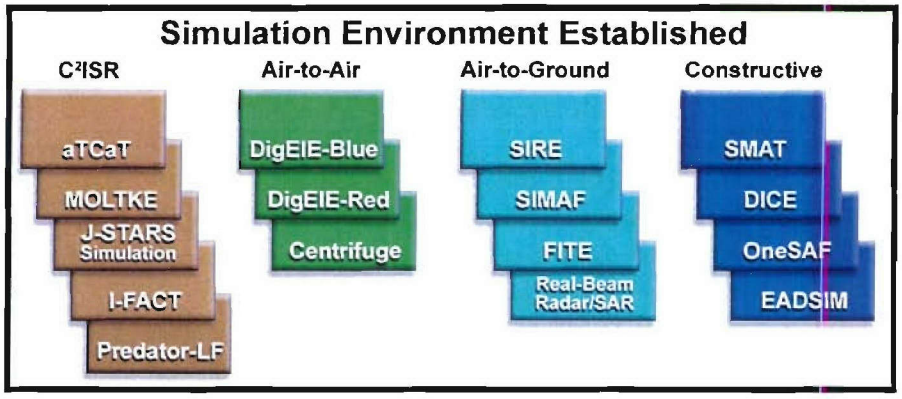

Figure 10. SAFIRE Simulation Environment

Multimedia: Finally, ***SYTRONICS'*** superb multimedia and graphics staff supported AFRL/HEC with the highest level of graphic design, illustration, animation, 3-D modeling, Web design, video production, and publication. Our graphics staff used the latest in multimedia software including the Adobe Creative Suite, Adobe Video Collection, Carrara Studio, Amapi Designer, and Poser 3-D Human Modeling to provide state-of-the art graphics and modeling for AFRL/HEC programs. Our staff received numerous accolades for their designs, service, and efficiency.

Documentation: For all projects, ***SYTRONICS*** reported the technical research development in written documents and conference proceedings. All test results were documented in briefings and presentations, using graphics, animation, multimedia and photographic elements as required. ***SYTRONICS*** personnel attended conferences and symposia and presented the results of the developmental research as required to transition research results to other Government agencies, industry, and academic institutions. All research reports and the operator's manuals were submitted to the Government for coordination.

PUBLICATIONS

Many formal technical reports were produced and forwarded to the ***Defense Technical Information Center (DTIC)*** for publication. Selected technical reports authored or coauthored by ***SYTRONICS*** employees and submitted under this contract are summarized in the ensuing paragraphs.

Space Review Study
Human Factors Engineering's Role in Unmanned Space Operations[1]

This Space Review Study was conducted to ascertain the state-of-the-art in ground-based satellite control, estimate the impact of human error on satellite operations, review existing research in satellite control, and recommend a human engineering research and development program to reduce error and correct deficiencies. The study found that much of contemporary satellite control uses legacy computer systems and displays information in text format, while controlling using the command line interface. Later systems use windows and graphical user interface technology, which is only a small increment in functionality. The existing literature on satellite control is sparse because of the classified nature of many systems--reluctance to permit studies and/or data collection, or because of a reluctance to advertise error. The proposed human engineering research and development program advocates cognitive engineering of displays and control, modeling for design, testing and training, real-time satellite operations, intelligent agents and/or aiding, monitoring on-board automation, creation of an operator error database, and extending display and control guidelines. Further, three different ways were described to facilitate the laboratory space program: collaborative partners, a common satellite model, and a shared research facility. There appears to be sufficient justification for a human engineering program addressing ground control of space operations. This research and development program will result in significant improvement in operational effectiveness, reduced manpower requirements, and savings in training costs.

Survey of Information Visualization Uses[2]

Of the five senses humans possess, vision is by far the sense that people use the most to perceive their environment. With vision, humans can scan, recognize, and recall images rapidly; and can detect even small changes in color, size, shape, movement, or texture. However, vision offers more than just an amazing array of reception capability. For humans, vision is closely related to our thinking processes. Consider the common sayings "I see!" or "That's clear!" when a person understands something. Perception of the environment through vision actually provides a large majority of the information needed to perform thinking tasks.

Vision derives its power through a combination of how the human eye is constructed and how the information the eye passes to the brain is utilized. Basically speaking, the eye collects two types of images: low-resolution for a large area and high-resolution for a small area. The brain can process these images, in turn, by either controlled or attentive processing, or automatic or preattentive processing. Controlled processing involves focusing one's gaze at particular points in the field-of-view to get high-resolution images that are correspondingly information-rich. Controlled processing is generally slow and is characterized by "thinking about" what one

sees. On the other hand, automatic processing uses the lower-resolution images outside the focus of the controlled processing. Automatic processing is good at detecting movement or other changes in visual features. Through automatic processing (analogous to involuntary muscle movements), the brain is able to quickly and effortlessly detect changes in the environment that demand focused and controlled processing. Another characteristic of automatic processing is the brain's ability to combine the colors, edges, and other visual properties into a coherent representation of the objects being looked at without consciously combining the properties and recalling from memory; for example, "That combination represents a truck." This behind-the-scenes processing occurs without thought, occurs continuously, and provides the large majority of the percepts used by thinking activities. Between the types of images and the types of processing, the vision system is able to monitor the entire field-of-view.

Since humans are visual creatures and since information derived from visual input provides the majority of what feeds our thinking processes, designing information delivery systems to capitalize on these facts is beneficial. Furthermore, other factors influence improving information delivery systems, such as the sheer amount of information people are exposed to and must use daily (providing the "what" to show) and advances in computer graphics and the machines that render them (providing the "how" to show it). A technology area that combines these considerations, and the focus of this study, is called information visualization.

Being a relatively new field-of-study, the literature contains several definitions for what comprises information visualization. What information visualization is not is the study of computer graphics. Although computer graphics is a key component of information visualization, it is a means for which to accomplish. As previously discussed, information visualization is concerned with affecting thinking processes. The definition used for this study that captures these concepts--graphics and thinking processes--comes from [Card 6]: "Information Visualization: The use of computer-supported, interactive, visual representations of abstract data to amplify the acquisition or use of knowledge."

Information Warfare Combat Assessment Tool [3]

Information Warfare (IW) threatens to overload commanders with information that severely challenges their abilities to make timely and effective decisions. Successful IW requires an understanding of how the commander's estimate of the situation, course-of-action selection, and subsequent detailed plans are formulated and executed under real-world conditions. The ***Information Warfare Combat Assessment Tool (IWCAT)*** is an air campaign decision and situational awareness aid for understanding, tracing, and anticipating how offensive and defensive, lethal and non-lethal, kinetic and non-kinetic actions directed against adversary information, information-based processes and information systems cause direct tangible and indirect behavioral effects. This cognitive systems engineering approach to system design produces powerful decision support system tools and information management application reducing volumes of complex data into tailored, cognitive displays to enable a warfighting staff and commanders to rapidly grasp the impact of current operational decisions on mission success and future combat capability. While focused on IW, the concepts and methodology work equally well for other types of warfare (e.g., air, land, sea and/or space warfare) as well as across the spectrum of conflict, not just during wartime hostilities.

Speech Interface for Defensive Counterspace Operations[4]

The primary goal of ***Speech Interface for Defensive Counterspace Operations (SIDCO)*** is to investigate human interface designs for the sake of improving defensive counterspace operations. SIDCO is being conducted as an enhancement to the ***Center for Research Support (CERES) Defensive Counterspace Testbed (DTB)*** effort. The DTB effort aims to improve the process of satellite threat identification and attack reporting. SIDCO aims to improve ***Human Computer Interface (HCI)*** operations related to DTB.

Under the DTB effort, CERES (Schriever AFB, CO) is developing concepts for future ***Satellite Operations Squadrons (SOPs)*** to effectively react to satellite attacks. But according to current policy, satellite problems will rarely be attributed to acts of aggression, methods will be needed to clearly distinguish critical events from normal system problems or space weather incidents. The current thinking is to use data fusion and artificial intelligence to derive a "best guess" as to the cause and assign a confidence or certainty factor.

Although human interface design was not the focus of CERES DTB effort, CERES is creating a prototype system to investigate some possible displays. For satellite state-of-health monitoring, satellite operations screens (developed in-house by CERES) are being used. These satellite operations screens are a major improvement over the current screens because they are much more intuitive and provide better human computer interaction. When a significant event occurs that causes a change in the satellite's health, the plan is for a ***Satellite Toolkit (STK)*** (by Analytical Graphics, Inc.) window to automatically pop-up. STK improves the controller's situational awareness of the space environment by providing ***two-dimensional (2-D)*** and/or 3-D displays of constellations or individual satellites. The display will show the affected satellite in 3-D, including its location and orientation of the satellite with respect to Earth. In addition, it will also be possible to display information such as uplink and downlink status and possibly unfriendly satellites in the vicinity.

SIDCO investigated HCIs for improving defensive counterspace operations. Specifically, SIDCO investigated improving these operations by using a speech recognition interface into STK software leveraged on other yet related research into the satellite operator's C^2 environment. The speech-enabled STK suite provided a set of tools representative of what a defensive counterspace operator may use to perform his duties. The study specifically addressed the question: "Does the speech recognition interface to STK improve the ability to determine satellite attack?" The effort resulted in a demonstration of the speech enabled STK at Schriever AFB, CO and a technical document reporting the results of the study.

Transmissivity and Night Vision Goggle (TNVG) Compatibility Data for Select Aircraft Transparencies[5]

The VIEW facility at WPAFB, OH, has been evaluating the optical characteristics of aircraft transparencies for over 25 years. During this time period, numerous types of aircraft transparencies from different sources have been measured for a multitude of optical characteristics. Some of these optical characteristics include angular deviation, multiple

imaging, distortion, haze, and transmissivity. Though continuous in nature, transmissivity characteristics can be divided into two spectral ranges: visible and ***near-infrared (NIR)***. Unaided human vision is sensitive to light from about 400 nm (blue) to 700 nm (red) with peak sensitivity occurring at about 555 nm (green). In comparison to human vision, the NVGs that are used in aircraft cockpits are sensitive to and amplify light in the red and NIR region of the spectrum from about 600 nm to 950 nm. This data compilation provided detailed information on the visible and NIR transmissivity characteristics of transparent plastics. These data allowed human factors engineers and vision scientists to assess the relative visual impact that different types of transparencies may have on both unaided and NVG-supplemented aircrew out-of-the-cockpit visual performance. The NIR data also can be used to resolve NVG/transparency integration issues.

This report is a compilation of spectral transmissivity data measure from numerous aircraft transparencies. The spectral transmissivity of each part was measured from wavelengths of 450 nm through 950 nm. Some parts were also measured at several different angles relative to the optical axis of the spectroradiometric instrument. The measurements yielded both visible light and NIR spectra. The NIR data were used to calculate NVG-weighted transmissivity (TNVG) values. TNVG is a measure of a transparency's compatibility when it is used in conjunction with NVGs. NVGs utilize the NIR portion (600 nm through 950 nm) of the night sky ambient illumination. Generally speaking, the higher the TNVG coefficient, the higher the NVG visual performance.

Interlaboratory Study for F428.83, Standard Test Method for Intensity of Scratches on Aerospace Glass Enclosures[6]

The ASTM develops and publishes standardized test methods. Each test method requires a precision and bias statement so organizations that apply the method know its inherent reproducibility (between-laboratory variability) and repeatability (within-laboratory variability). Reproducibility and repeatability for this test method were determined by conducting an ***Interlaboratory Study (ILS)*** as outlined in ASTM E691. This report, which conforms to the ILS reporting format required by ASTM, describes the study that was conducted for ASTM F428-83, Intensity of Scratches on Aerospace Glass Enclosures.

Scratches exist on all glass surfaces. Usually, cleaning procedures cause very fine scratches that are not visible with looking through the glass. Visible scratches may be distracting to an observer looking through a transparent aerospace enclosure. Therefore, a procedure to define scratches is useful. A visual comparison was made between a set of graded scratch standards (adjuncts) and a scratch on the glass transparency to determine its relative intensity. A vision standard is used because it is not practical to measure the dimensions of fine scratches.

ILS for F548-0183, Standard Test Method for Intensity of Scratches on Aerospace Transparent Plastics[7]

The ASTM develops and publishes standardized test methods. Each test method requires a precision and bias statement so organizations that apply the method know its inherent reproducibility (between-laboratory variability) and repeatability (within-laboratory variability).

Reproducibility and repeatability for this test method were determined by conducting an ILS as outlined in ASTM E691. This report, which conforms to the ILS reporting format required by ASTM, describes the study that was conducted for ASTM F548-01, Intensity of Scratches on Aerospace Transparent Plastics.

Scratches exist on virtually all transparent plastic surfaces. Usually, cleaning procedures cause very fine scratches that are not visible with looking through the plastic. Visible scratches may be distracting to an observer looking through an aerospace transparent plastic. Therefore, a procedure to define scratches is useful. A visual comparison is made between a set of graded scratch standards (adjuncts) and a scratch on the plastic transparency to determine its relative intensity. A vision standard is used because it is not practical to measure the dimensions of fine scratches.

Aerospace Transparency Research Compendium[8]

For nearly 30 years, the Warfighter Interface Division of the AFRL, located at WPAFB, OH, has advanced aerospace transparency technology through the investigative research of numerous optical and visual parameters inherent in aerospace transparencies.

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APPENDIX A

LIST OF R&SCSIL PUBLICATIONS 25 SEPTEMBER 1998 - 30 SEPTEMBER 2005

DOCUMENT TITLE	DATE DELIVERED
Final Report for Assessment and Measurement of Team Member Schema Similarity in BMC^{3}I Demonstrations (SI-99-9010-509)	28 October 1999
Final Report--Developing and Evaluating Software Mediators for use in BMC^{3}I Domains (SI-99-9010-529)	08 November 1999
Final Report for Occulometric Measures of Cognitive Load (SI-00-9010-007)	07 January 2000
Phase I Report for Aiding the Intelligence Analyst in Situations of Data Overload--Functional Design of New Aiding Concepts (SI-00-9010-038)	25 January 2000
Research and Data--Scientific and Technical Report--*Space Review Study: Human Factors Engineering's Role in Unmanned Space Operations* (SI-00-9010-104)	25 February 2000
Initial Design Report for Virtual Air Commanders Weapon and Sensor Director Control Console Functionality (DO 0003) (SI-00-9011-691)	11 December 2000
Research and Data--Scientific and Technical Report--*Final Report for Aiding the Intelligence Analyst in Situations of Data Overload: From Problem Definition to Design Concept Exploration* (SI-01-9011-263)	03 April 2001
Research and Data--Scientific and Technical Report--*Exploration of Mathematical Formalisms and Representational Issues Associated with Concept Learning Facilities within the Distributed Cognition Framework* (SI-01-9012-1069)	31 December 2001
Research and Data--Scientific and Technical Report--*Air Force Enterprise Defense (AFED) Spiral 3 User Manual and AFED JAVA GUI Source Code and Application* (SI-02-9012-111)	30 January 2002
Research and Data--Scientific and Technical Report--*Distortion Compensated Magnetic Tracker* (SI-02-9012-265)	10 April 2002
Research and Data--Scientific and Technical Report--*Evaluation of Computer-Aided Cognitive Systems Engineering Methodology, Capabilities, and Software* (SI-02-9012-518)	05 August 2002
Research and Data--Scientific and Technical Reports--*Effects of Cognitive Work Analysis (CWA) on Development of a Portal for Information Foraging: A Literature Review* (SI-02-9012-575)	23 August 2002
Research and Data--Scientific and Technical Reports--*Final Report for Teleoperation for Remote Air Force Space Tasks* (SI-02-9012-575)	23 August 2002
Technical Report--Human Trust in Offensive and Defensive Information Operations (SI-02-9012-617)	11 September 2002
Research and Data--Scientific and Technical Reports--*Pattern Recognition and Categorization in the Liquid Mind System* (SI-02-9013-828)	06 December 2002
Research and Data--Scientific and Technical Report--*Transmissivity and Night Vision Goggle Compatibility Data for Select Aircraft Transparencies* (AFRL-HE-WP-TR-2003-0015) dated January 2003	January 2003
Research and Data--Scientific and Technical Report--*Interlaboratory Study (ILS) for F428-83, The Standard Test Method for Intensity of Scratches on Aerospace Glass Enclosures* (AFRL-HE-WP-TR-2003-0012) dated January 2003	January 2003
Research and Data--Scientific and Technical Report--*Interlaboratory Study (ILS) for F548-01, The Standard Test Method for Intensity of Scratches on Aerospace Transparent Plastics* (AFRL-HE-WP-TR-2003-0009) dated January 2003	January 2003
Research and Data--Scientific and Technical Report--*Engineering, Software, and Technician Support for Simulator Studies to Determine Read-to-Control Degradation* (SI-03-9013-093)	07 February 2003

DOCUMENT TITLE	DATE DELIVERED
Research and Data--Scientific and Technical Report--*Aerospace Transparency Research Compendium* dated June 2003 (AFRL-HE-WP-TR-2003-0084)	June 2003
Research and Data--Scientific and Technical Report--*Seeing Psychological Operations Through A Cultural Lens* (SI-03-9013-428)	1 July 2003
Research and Data--Scientific and Technical Report--*Effects of Cognitive Work Analysis (CWA) on Development of A Portal for Information Foraging* (SI-03-9013-464)	14 July 2003
Research and Data--Scientific and Technical Report--*Human Trust in Offensive and Defensive Information Operations* (SI-03-9013-467)	18 July 2003
Research and Data--Scientific and Technical Report--*Draft Report--Using Activation and Association in the Work/Organization Repository of Knowledge (W/ORK) Database* dated 20 October 2003	21 October 2003
Research and Data--Scientific and Technical Report--*Investigation of Representation Systems to Aid Information Collection and Analysis* dated 30 October 2003 (SI-03-9014-731)	30 October 2003
Research and Data--Scientific and Technical Report--*Windscreen Movement Table Control Computer--Upgrade Current Computer System and Software* dated October 2003 (SI-03-9014-750)	07 November 2003
Research and Data--Scientific and Technical Report--*Using Activation and Association in the W/ORK Database* dated November 2003 (SI-03-9014-801)	20 November 2003
Research and Data--Scientific and Technical Report--*A Review and Reappraisal of the Adaptive Human-Computer Interfaces in Complex Control Systems* dated 20 November 2003 (SI-03-9014-827)	3 December 2003
Research and Data--Scientific and Technical Report--*Investigation of a Value-Based Work-Centered Evaluation Framework and Toolkit* (SI-04-9014-184)	23 March 2004
Research and Data--Scientific and Technical Report--*Cultural Modeling for Command and Control* (SI-04-9014-273)	23 April 2004
Research and Data--Scientific and (Draft) Technical Report--*Adding Structured Concepts and Temporal Concept Referents to the W/ORK Database* (SI-04-9014-523)	28 July 2004
Research and Data--Scientific and Technical Report--*Effects of Cognitive Work Analysis (CWA) on Development of A Portal for Information Foraging* (SI-04-9014-542)	04 August 2004
Research and Data--Scientific and Technical Report--*IPB Report and the Knowledge Creation Demonstration from the A^3-IPB Project* (Submitted directly to the Government by SRA)	25 August 2004
Research and Data--Scientific and Technical Report--*Asymmetric Adversary Analysis for Intelligent Preparation of the Battlespace (A^3-IPB)* and *Product Specification of an Effects-Based Visualization for Intelligence Preparation of the Battlespace (A^3-IPB)* (SI-04-9014-634)	30 August 2004
Research and Data--Scientific and Technical Report--*Adding Structured Concepts and Temporal Concept Referents to the W/ORK Database* (SI-04-9014-635)	30 August 2004
Research and Data--Scientific and Technical Report--*Development of Computer-Aided Cognitive Systems Engineering Methodology, Capabilities, and Software* (SI-04-9014-667)	13 September 2004
Research and Data--Scientific and Technical Report--*Asymmetric Adversary Analysis for Intelligent Preparation of the Battlespace (A^3-IPB)--Work Domain Analysis and Design Specification*	14 September 2004
Research and Data--Scientific and Technical Report--*Dual Coding and Self-Organization in Distributed Cognition (DCOG)* (SI-04-9014-689)	16 September 2004
Research and Data--Scientific and Technical Report--*Audio/Voice Transcription, Timing, and Analysis Tool* (SI-04-9015-772)	15 October 2004
Research and Data--Scientific and Technical Report--*Enhancing Human Command and Control for Air Mission Planning* (SI-04-9015-824)	16 November 2004
Research and Data--Scientific and Technical Report--*Final Report* dated September 2005 (AFRL-HE-WP-TR-2005-0026)	30 September 2005

APPENDIX B

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

TERM	DEFINITION
2-D	Two-dimensional
A^3-IPB	Asymmetric Adversary Analysis for Intelligent Preparation of the Battlespace
ADPE	Automated Data Processing Equipment
ADT/OUE	Advanced Technology Demonstration/Operational Utility Evaluation
AFED	Air Force Enterprise Defense
AFMETCAL	Air Force Metrology and Calibration
AFRL/HEC	Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Interface Division
AMOLED	Active Matrix Organic Light Emitting Diode
AOC	Aerospace Operations Center
ASP	Aircrew Speech Processor
ASTM	American Society for Testing and Materials
aTCaT	Augmented Time Critical Analysis and Targeting
AVX	Aerospace Vision Program
AWACS	Airborne Warning and Control System
C^2	Command and Control
CDR	Critical Design Review
CERES	Center for Research Support
COINS	Contractor Invoice System
CONOPS	Concept of Operations
COTS	Commercial Off-the-Shelf
COVE	Combat Observation and Visualization Environment
CRDA	Cooperative Research & Development Agreement
CRISTIL	Collaborative Research in Space & Temporal Interfaces Laboratory
CSRD	Computer System Requirement Document
CVS	Concurrent Versions System
CWA	Cognitive Work Analysis
DAA	Designated Approval Authority
DARPA	Defense Advanced Research Projects Agency
DCAA	Defense Contract Audit Agency
DCOG	Distributed Cognition
DFAS	Defense Finance and Accounting Service
DIGEIE	Digital Entities for Interface Evaluations
DO	Delivery Order
DREN	Defense Research Engineering Network
DTB	Defensive Counterspace Testbed
DT&E	Display Test and Evaluation
DTIC	Defense Technical Information Center

TERM	DEFINITION
DVAF	Dynamic Visual Assessment Program
EMI/EMC	Electromagnetic Interface/Electromagnetic Compatibility
FAC	Forward Area Controller
FITE	Fusion Immersive for Tactical Environment
FOD	Foreign Object Damage
FPL	Flight Physiology Laboratory
GFE	Government Furnished Equipment
GHOST	Global Horizontal Operations Support Toolkit
GOTS	Government Off-the-Shelf
HCI	Human Computer Interface
HIP	Helmet Interface Panel
HMST	Helmet-Mounted Sensory Technologies
HMST/VCS	Helmet-Mounted Sensory Technology/Visually-Coupled Systems
HOBA	High Off-Boresight Angle
HOP	Helmet Operation Panel
HTK	Hidden Markov Model
HUD	Heads-Up Display
HVI	Helmet Vehicle Interface
ICD	Interface Control Documentation
IDE	Integrated Development Environment
ILS	Interlaboratory Study
IPNVG	Integrated Panoramic Night Vision Goggle
IRB	Institutional Review Board
ISR	Intelligence, Surveillance, and Reconnaissance
IW	Information Warfare
IWCAT	Information Warfare Combat Assessment Tool
JEFX	Joint Expeditionary Force Experiment
JTR	Joint Travel Regulation
Little HAL	Little High-End Airborne Laptop
LRU	Line Replaceable Unit
LTSI	Logicon Technical Services, Inc.
MIRI	Multimedia Information Retrieval Interface
MOCAS	Mechanization of Contract Administration Services
MoD	Ministry of Defense
MOLTKE	Multisensory Overview Large-scale Tactical Knowledge Environment
MOU	Memorandum of Understanding
NCW	Network Centric Warfare
NDFR	Non Distributed Flight Reference
NIR	Near-infrared
NVD	Night Vision Device
NVG	Night Vision Goggle
NVIS	Night Vision Imaging System
NVO	Night Vision Operations

TERM	DEFINITION
OEM	Original Equipment Manufacturer
OLED	Organic Light-Emitting
OSD	Office of the Secretary of Defense
OSU	Ohio State University
PA	Project Arrangement
PDR	Program Design Review
PIDS	Programmable Image Display System
PMEL	Precision Measurement Equipment Laboratory
PNVG	Panoramic NVG
PO	Purchase Order
QDC	Quick Disconnect
QPR	Quarterly Program Review
R&SCSIL	Research and Sustainment for Crew System Interface Laboratories
RAIVE	Research on Adaptive Interfaces for Virtual Environments
RDP	Research and Development Projects
REC	Remote Electronic Chassis
ROMA	Removable Optics Mounting Assembly
S&E	Scientific and Engineering
SAFIRE	Synthesized and Human Aerospace Forces in an Immersion Research Environment
SAR	Synthetic Aperture Radar
SAS	Statistical Analysis Software™
SBIR	Small Business Innovation Research
SCREAM	Speech Communication Research Engineering Analysis and Modeling
SH21	Strike Helmet 21
SIDCO	Speech Interface for Defensive Counterspace Operations
SIMAF	Simulation and Analysis Facility
SimEx	Simulation Exercise
SIRE	Synthesized Immersion Research Environment
SIRUS	Synthetic Interface Research of UAV Systems
SME	Subject Matter Expert
SOPs	Satellite Operations Squadrons
SPIE	Society of Optical Engineers and Scientists
SPO	System Program Office
STE	Synthetic Task Environments
STINFO	Scientific and Technical Information
STK	Satellite Toolkit
TCT	Time Critical Targeting
TES	Test and Evaluation Squadron
TIM	Technical Interchange Meeting
TNVG	Transmissivity and Night Vision Goggle
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Air Vehicle

TERM	DEFINITION
UDAS	UCAV Decision Aiding System
VBMS	Virtual Battle Management System
VCATS	Visually Coupled Acquisition and Targeting System
VDT	Visual Display Technology
VIEW	Visual Image Evaluation of Windscreens
WInS	Web Invoicing System
W/ORK	Work/Organization Repository of Knowledge
WPAFB	Wright-Patterson Air Force Base