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13. ABSTRACT *(Maximum 200 words)*

The DOD is involved in a program to determine the suitability for triservice introduction of new classes of drugs into the military. The Office of Military Performance Assessment Technology (OMPAT) tasked the USAF Armstrong Laboratory (USAFSAM) Brooks AFB, TX to develop a generalizable performance measurement system to evaluate the effects of antihistamine drugs on military relevant tasks in the Command, Control, & Communications (C^3) missions. Several networked generic workstations were developed to provide mission scenarios, tasks, controls, and displays replicating the functions of the Airborne Warning and Control Systems (AWACS) weapon director station. The design emphasizes flexibility of measurement, hierarchical organization of measurement levels, and data collection from multiple perspectives. An air defense simulation exercise was conducted. The data will be analyzed and reported under MIPR 90MM0503 during 1990-91.

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FOREWORD

For the protection of human subjects, the investigator(s) have adhered to policies of applicable Federal Law 45CFR56.

Citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement or approval of the products or services of these organizations.

ANTIHISTAMINE DRUGS AND PERFORMANCE ON C^3 TASKS

OBJECTIVES: (1) To develop a generalizable performance measurement system and (2) to evaluate the effects of selected antihistamine drugs on weapon system operators performing tasks related to Command, Control and Communication (C^3) missions during sustained operations.

BACKGROUND: The Air Force, Army, and Navy are involved in a joint program to determine the suitability for triservice introduction of new classes of drugs. Part of these evaluations are to determine the impact of these drugs on the ability of humans to perform complex C^3 mission-related tasks. The decision was made to conduct a portion of these performance evaluations studies using a generic task crew station developed for use during Level III phase testing, e.g. simulation. This decision was based on the ability to completely control the testing environment in a ground-based facility in a repeatable manner and to use a properly constructed workstation and network capable of extracting performance data that is time correlated with the mission scenario events.

Prior to this triservice program the Naval Air Test Center (NATC) developed a generic simulation system architecture that was uniquely suited to support the generation and data acquisition requirements of the drug evaluation program. This government-designed system was developed around a unique set of hardware and software that allows multiple processors to easily share data and be synchronously dedicated to common tasks. The Air Force adapted the Navy system to allow mission scenarios to be performed by a team of weapon system operators that have both ground-based and airborne applications in C^3 mission-related tasks.

NATC developed a unique simulation architecture design to provide a system of generic task work stations that will be used at the Armstrong Laboratory (USAFSAM) to evaluate human performance on a variety of complex decision-making tasks. NATC procured the general purpose system hardware to produce a drug-screening performance evaluation facility based on two processors. One of these processors will be used to present the real time C^3 tasks to the subject. The other processor will be used to interface with the existing physiological instrumentation systems at the Armstrong Laboratory to monitor the status of the subject during the tests. Existing NATC technology and hardware was used to link the two processors and provide a complete, user friendly system.

In addition to providing the task simulation processing and data collection systems, NATC also provided the special purpose simulation software, interfaces, and control systems required by Armstrong Laboratory to conduct the performance and physiological evaluations. These included a network of four generic work stations that will be used to present tasks to the subject, an experimenter's control console, and instrumentation interfaces to collect data from existing Armstrong Laboratory physiological measurement systems.

APPROACH. The Command, Control, and Communication Generic Workstations (C^3W) developed with Army funding during FY 84-87 was used to measure the combined effects of antihistamine and systematic variations in cognitive workload (stress) on system operator performance during sustained operations. The C^3GW initial configuration designed by Armstrong Laboratory specified the mission scenarios, tasks, control and displays that would replicate the functions of the Airborne Warning and Control Systems (AWACS) weapons director (WD) crew stations. The AWACS WD team function was chosen as the complex task because it contained C^3 task elements common to all DOD crew mission requirements. Objective behavioral measures of team performance were developed using local contractor support personnel (Systems Research Laboratory, Inc.and NTI, Inc.) and training instructors from Tinker AFB, Oklahoma. Finally, research protocols were submitted for human use committee approval along with a subject recruitment plan.

The C^3 missions were performed by rated AWACs military personnel under either the influence of Seldane, Benadryl, or placebo control in a double-blind study to determine any performance decrements and/or physiological debilitations that would affect successful completion of the Air Defense mission. The data was analyzed in a format to provide C^3 operational guidance of the effects of antihistamines on complex decision-making tasks under sustained operations.

The last C^3 generic workstation system was delivered to USAFSAM in the first quarter of FY 89 that allowed initiation of baseline performance evaluations in July 89. These initial evaluations were conducted using volunteer subjects from the 552nd AWAC Training Wing. A high priority was placed on the use of AWACS military personnel. Information obtained in these initial tests was used to further define the hierarchical levels of data collection and unique audio/visual capabilities required to completely evaluate the effects of antihistamine drugs on team performance under sustained operations. During the entire period NATC and Systems Research Laboratory, Inc. continued to assist USAFSAM by providing updated test and scenario simulation software to meet changing triservice drug-screening program requirements from OMPAT for similar C^3 missions related to both the Army and Navy.

ACCOMPLISHMENTS. The accomplishments (results) are presented as an annual summary of events for the entire reporting period. The contractor documentation reports in the Appendices give more detail on the development of hardware, software, and the performance measurement system. The scientific results were reported under a series of publications under MIPR 90MMO503 due to early termination of FY90 funding for MIPR 87MM7507.

ANNUAL SUMMARY OF WORK ACCOMPLISHED

1987 C^3 Generic Workstation Delivery

Funding was received 17 February 1987. The Aircrew Evaluation Sustained Operations Performance (AESOP) facility was formally opened in April 1987. A major contract was initiated by the Air Force to provide support in completing production of the C^3 Generic Workstations to be used in the proposed antihistamine evaluation of C^3 team performance on a variety of complex decision making tasks. All parts for the construction of the two remaining C^3 Generic Workstations (total of four) were ordered. The final software module for the operationing system was specified. System software documentation responsibilities between the Navy Technical Contract

Monitor and the Air Force technical support contractor was finalized. An audio communications distribution system and speech synthesizer units were delivered and tested. The C^3 Generic Workstations were received in November from Systems Research Laboratories. Complete system documentation for all hardware components and operating system software modules were tested against the specifications and approved.

1988 Software and Scenario Development and Evaluation

A meeting was held at Tinker AFB OK to coordinate the development of the AWAC scenarios. The director of operations at the 552nd AWACS Training Wing was briefed on the progress and future subject requirements for AWAC crewmembers. A video tape was made of the scenario displays to be used in the simulation exercise involving the weapon system directors. Major advancements in interactive target software modules and performance measurement methodology were completed. The audio distribution system and the final C^3 Generic Workstation was delivered in June 1988. A system test of all scenario software by the contractor was completed during August. A major system evaluation of the C^3 crewstations was accomplished in September using AWACS instructors from the 966th Training Squadron and weapon director flight personnel from the 964th AWACS Operational Squadron from Tinker AFB, OK. The audio communication networks, mission scenarios, pilot simulators, map displays, and target models were successfully evaluated with only a few minor software changes required. The scenarios and the associated crewstation hardware were verified by the AWACS crews to be at a level of fidelity to proceed with the antihistamine phase of testing in July 89.

1989 Protocol Approval and Antihistamine Data Collection Completed

Performance measures for the following classes of tasks were specified; mission, system, team, embedded, and individual. A generalizable, hierarchical, measurement methodology scheme was devised to correlate critical scenario events with communications, switch actions, and video tape documentation of non-verbal team interactions into a common time-related data base. The research protocol to evaluate the effects of antihistamines on 12 teams of weapon system controllers was approved by Air Force Human Use Committee and submitted to USAMRDC, SGRD/HR, Fort Detrick, MD for final review in April. The data collection phase of the effects of terfenadine (Seldane) and diphenhydramine (Benadryl) on aircrew performance began in August and was completed in October 1989.

1990 Task Termination, Transition, and Completion

All of the data reduction, analysis, and final scientific reports were completed under the combination of Air Force funding and 90MM0503 due to early termination of this MIPR 87MM7507 prior to receipt of scheduled funding for FY90. An interim briefing and a preliminary report was submitted at the Office of Military Performance Assessment Technology (OMPAT) in Washington, D.C. in May 1990. Major new tasking in FY 90-91, Air Force reorganization, and Operation Desert Shield/Storm delayed this Final Report.

CONCLUSION. The OMPAT directly benefitted from the development of generalizable objective team performance assessment measures in complex military decision-making tasks.

The data collected under the antihistamine protocol provided the DOD the guidance and recommendations for the most effective use of antihistamines in C^3 operational settings.

PUBLICATIONS AND DOCUMENTATION

Government Technical Reports

Eddy, D.E. (1989) Selected team performance measures in a C^3 environment: an annotated bibliography. Technical Report USAFSAM-TR-87-25, USAF School of Aerospace Medicine, Brooks AFB, Texas.

Schiflett, S.G., Strome, D.R., Eddy, D.R., & Dalrymple, M.A. (1990) Aircrew evaluation sustained operations performance (AESOP): A triservice facility for technology transition. USAFSAM-TP-90-26, USAF School of Aerospace Medicine, Brooks AFB, Texas.

Contractor Delivery Order Documentation Reports

Work accomplished by the Contractor on this MIPR was organized on a delivery order basis. A core group of on-site personnel were assigned to the delivery orders as required. Additional needs were met through off-site SRL capabilities, subcontracts, and consulting agreements. A brief description of each applicable delivery order follows:

Delivery Order 0001: C^3 Generic Workstation Facility. The system networks and components of the AESOP facility were integrated, operated, documented, and maintained through SRL technical support and materials. This included operating and maintaining the hardware, software, and firmware associated with the C^3GW systems; developing software to present scenarios on the workstations, collect data, generate graphics, and score task performance; performing systems analysis and configuration planning for components requiring integration into the facility networks; conducting human factors engineering to support research in individual and team performance under sustained operations and stressful conditions.

Delivery Order 0002: Performance Testing Under Sustained Operations. SRL performed a study to acquire data on cognitive task performance of human subjects working under sustained operations. The Unified Tri-Service Cognitive Performance Assessment Battery (UTC-PAB) was acquired, configured, and implemented as an integral part of Delivery Order 0002. Research included developing experimental protocols; acquiring and analyzing data; developing training objectives; conducting experiments; and reporting collected data.

Tasks included systems analysis, hardware and software acquisition, and system integration. Acquiring and qualifying subjects was a critical element in this delivery order. SRL developed a subject pool and standard procedures for subject recruitment, training, medical testing and handling. The subject requirements were met in accordance with the accepted protocols and complied with all of the guidelines of AFR 169-3 in reference to subjects.

Delivery Order 0003: Fabrication of C^3 Generic Workstation (C^3GW) and Scenario Development. Two additional C^3GWs and the software necessary to present interactive scenarios to aircrew members were constructed and installed by SRL. Specific tasks included procuring parts, fabrication, assembly, and testing based on the design of current workstations. The software development included completing and documenting existing software modules, creating software systems to allow the user to alter the scenario presentation interactively in real time, and completing an air defense scenario to present on the workstations. Delivery order 0003 also required developing embedded performance measurement methods to incorporate into the workstations and scenarios.

Delivery Order 0005: Command, Control and Communication (C^3) Generic Workstation for Airborne Warning and Control Systems (AWACS) Weapons Directors (WDs). SRL's management, professional, and technical personnel provided the materials, services, and skills to ensure full and efficient operation, maintenance, and support of the total function of the C^3GW facility. Installation and integration of C^3GW scenario and graphics systems and their associated peripheral systems (such as the Audio Distribution System Network) was done in cooperation with Air Force personnel. In addition to the hardware and software requirements, integration included analyzing needs, determining resources, planning for maximum use through information sharing and interfacing, and anticipating growth patterns. SRL enhanced the capabilities of the AESOP facility by resolving technical shortfalls in the existing systems, and standardizing graphics systems and software to those in Air Force and Navy laboratories performing C^3 work. Scenario development occurred within the restrictions and requirements of research protocols initiated under this delivery order. This included defining the scenario requirements; developing a timed sequence of events and a voice script; integrating the events and voice script into a scenario file; digitizing those portions of the voice script to be synthesized; and testing the scenario.

SRL provided human factors engineering support to write a research protocol to assess the effects of sustained operations and antihistamine medication on complex decision-making performance and on team performance. The protocol required us to describe subject task variables; to specify data acquisition and data analysis procedures for individual and team performance metrics; and to develop AWACS scenarios, scoring algorithms, and embedded performance tasks.

Delivery Order 0006: Antihistamine Drugs and Sustained Performance. SRL conducted a study to evaluate the sensitivity and reliability of selected cognitive and psychomotor performance tasks to the effects of two antihistamines (Seldane and Benadryl) taken during sustained operations. These measures and others were defined and employed to determine the magnitude of each drug's effect on Weapons Director individual and team performance. Directing this study comprised providing systems analysis and integration; recruiting and overseeing a subject pool; selecting and implementing software and hardware systems to meet the performance task requirements; compiling system and software documentation; conducting experiments in accordance with the Statement of Work (SOW); and reporting the methods and results of research protocols.

The performance network was expanded by attaching a communications server to the Nestar network with a phone line and CC:Mail for communication with remote performance networks. File transfer between the Nestar network and other local area networks was accomplished by connecting the Nestar Hub and the AESOP Banyan file server. Additional performance stations were equipped with SRL LabPak cards and prototype response boxes according to Air Force requirements.

SRL acquired additional technical expertise in AWACS C^3 mission scenario development. The technical expert defined the scope of the scenario, wrote the time-based event and voice scripts, and assisted in the application of performance measures to the scenario plan. He also acted as Senior Director in the experimental sessions, trained simulation pilots, briefed the test subjects, set the pace for the simulations, and evaluated the performance of the teams using his own experience. SRL additionally provided experienced simulation pilots to aid in the scenario presentation during the duration of the experiments.

APPENDICES

APPENDIX A - C^3 Generic Workstation and Computer Networks

APPENDIX B - Aircrew Evaluation Sustained Operations Facility

APPENDIX C - Research and Development Software Documentation

APPENDIX D - Performance Measurement Methodology

C^3 GENERIC WORKSTATIONS AND COMPUTER NETWORKS

INTRODUCTION

Overview

This report contains the general description of hardware and software systems developed under the requirements of several Delivery Orders from FY87 through FY89 on Air Force contract F33615-87-D-0601.

Due to the large number of systems within the Crew Performance Function, Aerospace Research Branch, Crew Technology Division, and School of Aerospace Medicine (USAFSAM), it is important to address integration on a regular basis. The integration requirements change as the systems mature, as technology advances, and as new systems either supplement or replace existing ones.

This report presents descriptions of those major systems that were developed with a combination of OMPAT funds and leveraged Air Force funding support. Not all systems were developed during this period of work but were utilized or improved upon to accomplish common triservice goals. Extensive documentation of actual system operation and management for the networks and computer systems is provided primarily by the vendors. Copies of all such documentation are located in the Aircrew Evaluation Sustained Operations Performance (AESOP) facility. Information in this report consists of only general descriptions, specifications summaries, and documentation of technology evolution. In addition to systems information, this report includes the specifications for the AESOP facility.

Major Systems

The major systems, covered in this report, that currently require integration and systems analysis are described briefly below:

- VAX research network: The AESOP VAX research network is dedicated to the presentation of scenarios to, and collection of data from, the Command, Control and Communication Generic Workstations. It also serves the requirements for statistical analysis, analog-to-digital (A/D) and digital-to-analog (D/A) conversions, database management, forms management, and programming functions.

- Banyan office network: The Banyan (Banyan Systems, Inc, Westborough, MA) network consists of four file servers, strategically located throughout the Division, that provide software for office-related functions as well as some programming, statistical, and data reduction capability. Resources are shared across the network, along with electronic mail and message services.

- A/D and D/A acquisition and analysis systems: This service is provided as part of the VAX network. Physiological and electrophysiological recordings, as well as audio inputs, can be digitized, analyzed, and reproduced with this system.

- Communications servers: Information generated in the AESOP facility and Aerospace Research Branch is exchanged with remote sites across the nation using communication packages. ProComm is used for simple file transfers. CC:Mail is an integrated software system designed for network-based unattended electronic mail message services and file transfer.

- Electronic mail systems: Every network has its own electronic mail package. These are currently restricted to the host networks and do not share resources.

- Visual and audio recording systems: The simulations presented to subjects on the C^3 workstations involve both verbal and non-verbal communication. The Audio Distribution System (ADS), designed and built by SRL for the AESOP application, allows recording of individual voices during the scenario. Low light level video recordings were also used to document crew behavior.

- Desktop Publishing systems: These systems support the creation of presentation copies of technical reports, documentation, and briefing materials generated by the AESOP facility and the Branch.

SYSTEM DESCRIPTIONS

The major systems, that required integration and systems analysis during the reporting period from 1987 through 1989 are described briefly below:

- Command, Control and Communication Generic Workstation (Attachment 2, Sequence 1, Delivery Order 0003): The C^3GW is a multiple task simulation system used to develop measurement methodologies to assess team performance effectiveness in a simulated C^3 environment. The overall goal is to improve aircrew safety and mission effectiveness by transition of team performance effectiveness measures from the laboratory to field test environments. The technical objective is to generate a mission scenario on a generic crewstation that places realistic task demands on weapon system operators in a simulated C^3 environment. Initially this system was used to provide mission scenarios, tasks, controls, and displays replicating the functions of the Airborne Warning and Control System (AWACS) weapons director (WD) crewstation to evaluate the effects of antihistamines on crew performance.

- Nestar performance network (Attachment 2, Sequence 1, Delivery Order 0002): The Nestar network consists of two file servers, a communications server, a print server, and five personal computers (PCs) in a star configuration operating under the Nestar networking system using Datapoint's ARCnet protocol. It provides performance task presentation and data collection.

- Audio Distribution System (Attachment 2, Sequence 1, Delivery Order 0003): The Audio Distribution System (ADS) consists of the following:

    - three intercom networks;
    - eight simulated radio channels;
    - one guard channel for communications from the experimenter;

- a keyed microphone for intermittent transmission;
- two speech synthesis/recognition devices (Votan VTR-6050) that will simulate a portion of the AWACS communications;
- 10 identical nodes, each of which can be configured to simulate any functional position.

Stations on the ADS network are connected in a star network to a central control hub. The hub is the experimenter's station and the point of control for system communications. The experimenter can establish communication with any node while remaining transparent to the simulation. There is a white noise generation node that allows the addition of noise at any volume on any communications channel. Output from the ADS is channeled to a multi-channel recorder and recorded both by individual voice and by selected channels.

- Graphics processors and workstations (Attachment 2, Sequence 1, Delivery Order 0003): The scenarios and performance tasks presented to subjects require a significant amount of graphics development and display. Both personal computer and C^3GW graphics engine systems were upgraded to VGA monitors and Silicon Graphics 4D/50 workstations, respectively. This was upgrade was necessary as technology advanced to provide increased capability for accomplishing the research as outlined in the protocols. However, advanced technology was not chased as an end in itself; rather it was pursued to meet the immediate basic requirements of the contract in a cost effective manner.

NETWORKS

Background

Prior to 1986, in-house computing resources for the Crew Performance Function consisted of a few general-purpose and specialized microcomputers and two PDP 11/34s used for A/D data acquisition, D/A processing, and performance task presentation. Other systems were centralized in the computer rooms of the School of Aerospace Medicine. The centralized resources provided text editing, statistical analysis, and programming functions. However, they were greatly overburdened and poorly managed.

Several significant developments occurred impacting the resource needs of the Branch and the Division. First, the initial C^3GW systems were completed and brought two dedicated VAX 11/780s and their associated peripherals to the Branch. Second, the Total In-Flight Simulator (TIFS) program that evaluted the effects of pyridostigmine bromide on inflight performance had concluded, and the resulting statistical analysis requirements were enormous. The available resources were inadequate, and plans were initiated to put statistical analysis capability under local control. The TIFS data analysis also revealed the limitations of the A/D systems available to the Branch. Systems were old, incompatible, and limited in size and speed. Air Force planning and funding was begun to provide these services within the Division.

The distributed processing concept continued to grow in this and other branches and divisions at USAFSAM. As the plans developed, a contract was established between the Air Force and Digital Equipment Corporation (DEC), providing computers at very low prices. As a result of the sudden availability of MicroVAX systems in multiple configurations, several systems were purchased and added to the computing facilities of the Branch and Division. These systems were assigned functions according to their architecture and made available by the Air Force to support OMPAT projects. They were configured and integrated into the Research Network.

In addition to the increased need for large-system computing resources, the Branch was experiencing the trend toward PC-based needs. The Function had one PC/XT compatible Zenith 150 and a few Zenith 100 systems used for word processing, spreadsheets, and low-level data reduction and analysis. Several Apple II and NEC PCs were used for performance battery presentation both in-house and at remote sites. The OMPAT set a "benchmark" by targeting the IBM compatible systems for performance battery upgrades for both the Level I (physiological) and Level II (performance) batteries that included the Unified Triservice Cognitive Performance Assessment Battery (UTC-PAB). There was also a technological upsurge in computing capabilities versus price. With an increase in staff and the implementation of another requirements contract with Zenith for PC/AT compatible Zenith-248s, the stage was set for a PC network. The Banyan network supplied by the Air Force was configured for office-based functions and minor data handling and programming. The Nestar network supplied with OMPAT funding was set up for performance research. These networks have extended to Division-level support and are remaining faithful to the distributed processing concept of separating word processing functions from performance data acquisition and analysis.

The next section presents the specific network upgrades made to accommodate these expanding computer resources.

VAX Research Network

The VAX network contains a tightly-coupled VAXcluster and specialized MicroVAX systems connected to each other and to DEC remote clusters and systems via DECnet Ethernet and asynchronous twisted pair. Figure 1 represents the systems in the AESOP and local area networks in and around the Aircrew Evaluation Sustained Operations Performance (AESOP) facility. One of the requirements established by OMPAT in preparation for obtaining data from this research was to complete the integration of the Performance Network to support file transfer to local and remote systems for data reduction and analysis.

Systems Performance Network

The Performance Network, Figure 2, provides computerized performance test battery presentation and data collection as well as communication with other performance laboratories nationwide. It is comprised of several performance workstations (Zenith Z-248 microcomputers), two file servers (Nestar Plan 4000 and Planstar), a communications server (PC-clone with modem) and a print server connected to a 16 channel hub in a star configuration. The network operates using the ARCnet protocol.

The Crew Technology Administrative Network, Figure 3, provides word processing, spreadsheets, desktop publishing, electronic mail, time management and data bases for the office environment. It is comprised of four Banyan file servers (a Desk Top Server [DTS] and three 286-based servers) serving four area networks of Zenith Z-248 and Macintosh systems. The file servers contain electronic mail, asynchronous serial ports, shared printing resources and shared software, including Timeline, WordPerfect 5.0, Lotus 123 and dBase IV. To assist in the preparation of presentations and reports this network also has access to an Air Force Macintosh-based publishing workstation with color printer and slide generation capability. It uses thin-wire coaxial connections with Interlan or 3-Com Ethernet communications boards.

The Cluster and Simulation Network, Figure 4, provides programming, word processing, simulation generation and presentation, data base, statistical, and realtime analog/digital capabilities for the research scientists. The VAX cluster consists of two VAX 11-780s with simulation software; two MicroVAX IIIs, one with SAS and one with FOCUS; and a VAXstation III/GPX with analog-to-digital and digital-to-analog processing and high level graphics capability. A separate MicroVAX II with WPS word processing will be added to the cluster in the near future. There are both shared and system-local disks and printers. Systems communicate over standard Ethernet coaxial cable using the DECnet protocol.

Other distributed VAX-based networks at Brooks Air Force Base combine with these to form the large area network, including resources at

- Human Systems Division (HSD),
- the Occupational and Environmental Health Laboratories (OEHL),
- other USAFSAM divisions
- the Defense Data Network (DDN) tap.

Network Interconnections and File Transfer

The Banyan network is connected to the VAX network through asynchronous serial ports on the Banyan DTS file server. The eight Banyan ports are connected by two eight-channel asynchronous multiplexers to DEC terminal server ports. A proprietary VT100 terminal emulator gives up to eight microcomputers on the Banyan simultaneous access to the VAX network through these lines. Each terminal can operate at up to 9600 baud. The Kermit protocol is used for file transfers between the VAX and Banyan systems. As a result of this integration it is possible to move data between personal computers and VAX-based systems with more powerful resources.

The UTC-PAB and associated performance batteries execute on Zenith Z-248 microcomputers connected to the Performance Network Hub. Each workstation has both hard disk and 5-1/4" floppy diskette drives. Data collected during the tests are stored in files on the local system. The long-range plan is to have the performance batteries and data storage on the Performance Network file servers. A variety of statistical, data base and spreadsheet functions reside on the Administrative Network File Server and on the MicroVAX III systems in the AESOP computer room. Data transfer between systems can be accomplished by several methods, including: physical transfer of a floppy diskette, serial RS232 connection directly to one other local host system using terminal emulation and/or a standard transfer protocol, transfer via modems and communication software packages to local and remote systems, and connection to a network with appropriate bridges and gateways.

During this period of performance the connections were finalized for file transfer and multiple-system access through network integration and remote electronic communications. The interconnection of the Performance Network to the other networks is functional but relatively inflexible. The ARCnet Hub is connected to an ARCnet interface card in the Banyan DTS file server. With this arrangement PCs attached to the Hub can be booted onto the Banyan network. However they cannot be part of the Banyan Network and the Performance Network at the same time. That is, files cannot be transferred from a Nestar file server directly to the Banyan file server. However, a PC connected to the ARCnet Hub can download files from the VAXes or the Banyan or Nestar file servers to its local disk then reboot on the appropriate network and transfer the file to the network file server.

A commercial phone line was installed in the Performance Network area. One PC on the ARCnet hub was configured with a modem and is set up as a communications server. In this mode a user can call into the PC from a remote location, go through the Hub to the Banyan network and on to the VAX network if desired.

Communication with other performance laboratories using similar Nestar networks has been accomplished with the CC:Mail software from PCC Systems. An upgraded version of that software package was installed on the Planstar File Server during this period of performance. It allows both incoming and outgoing electronic mail/file transfer capabilities from this location.

Storage and Security

The mass storage on the cluster itself is currently over 2 gigabytes on removable and fixed disks. With the added capabilities of the MicroVAX systems, the total storage in the AESOP nears 4 gigabytes. A 1600/6250 bit per inch tape drive provides archival storage and software transfer for the cluster.

Other peripherals include a 600 line per minute LXY-22 line printer and an LN03 laser printer as cluster printers. All systems are powered through a central distribution unit and protected from power surges, overheating, and fire by security and monitoring systems. Maintenance for both hardware and software is covered by separately funded Air Force contracts.

AESOP and Local Area Networks

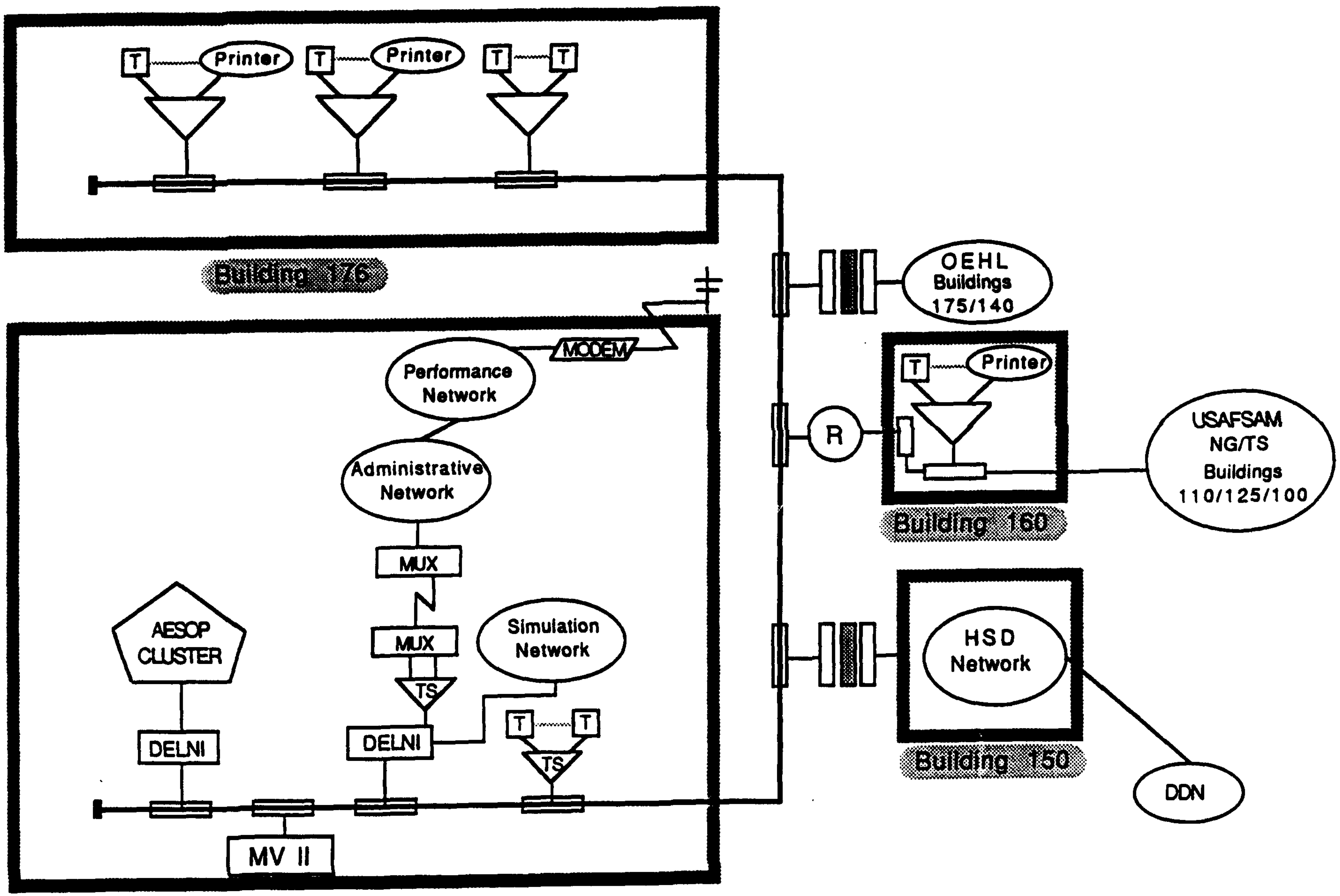

Figure 1

Performance Network

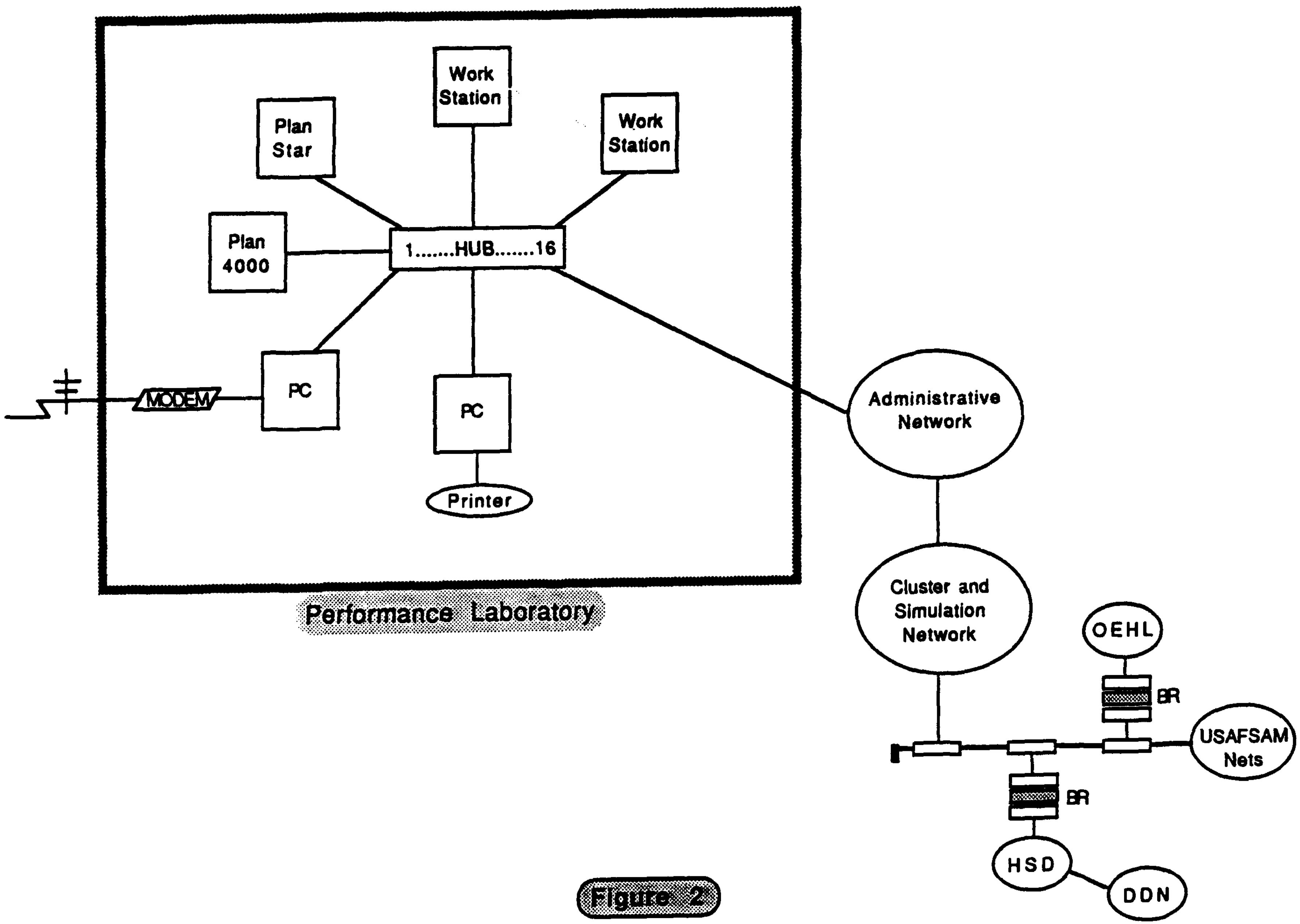

Figure 2

Administrative Network

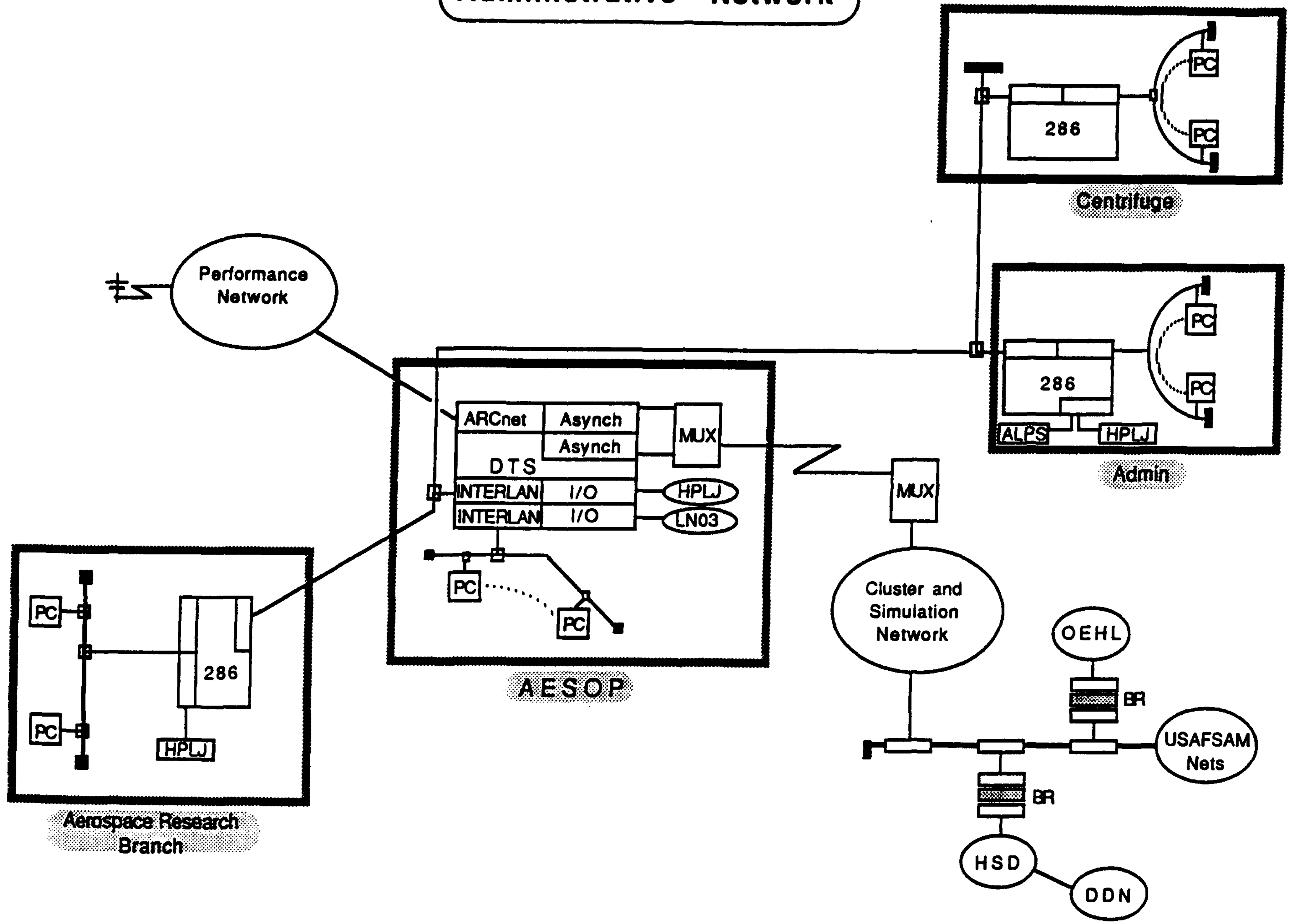

Figure 3

Cluster and Simulation Network

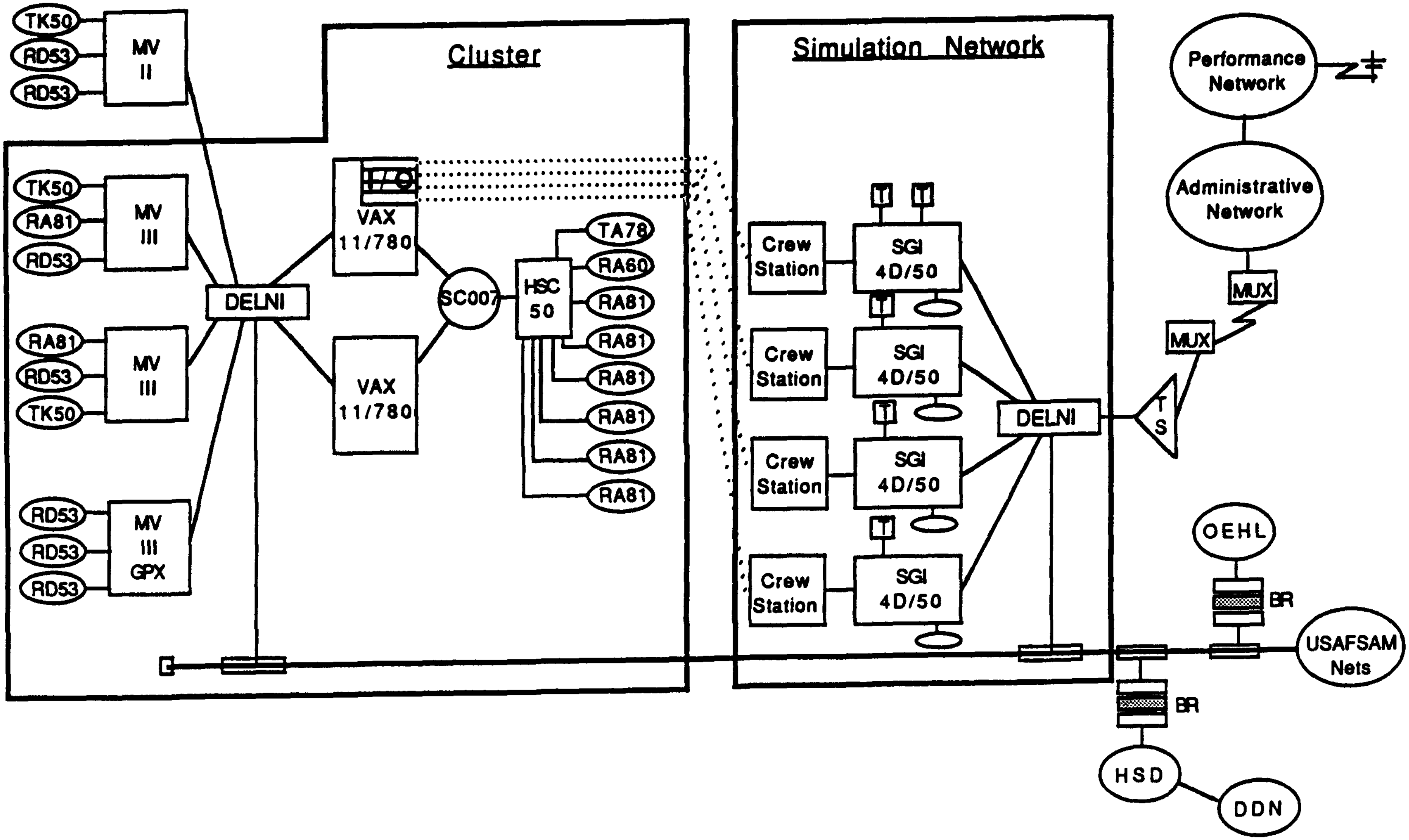

Figure 4

Banyon to DSRVB

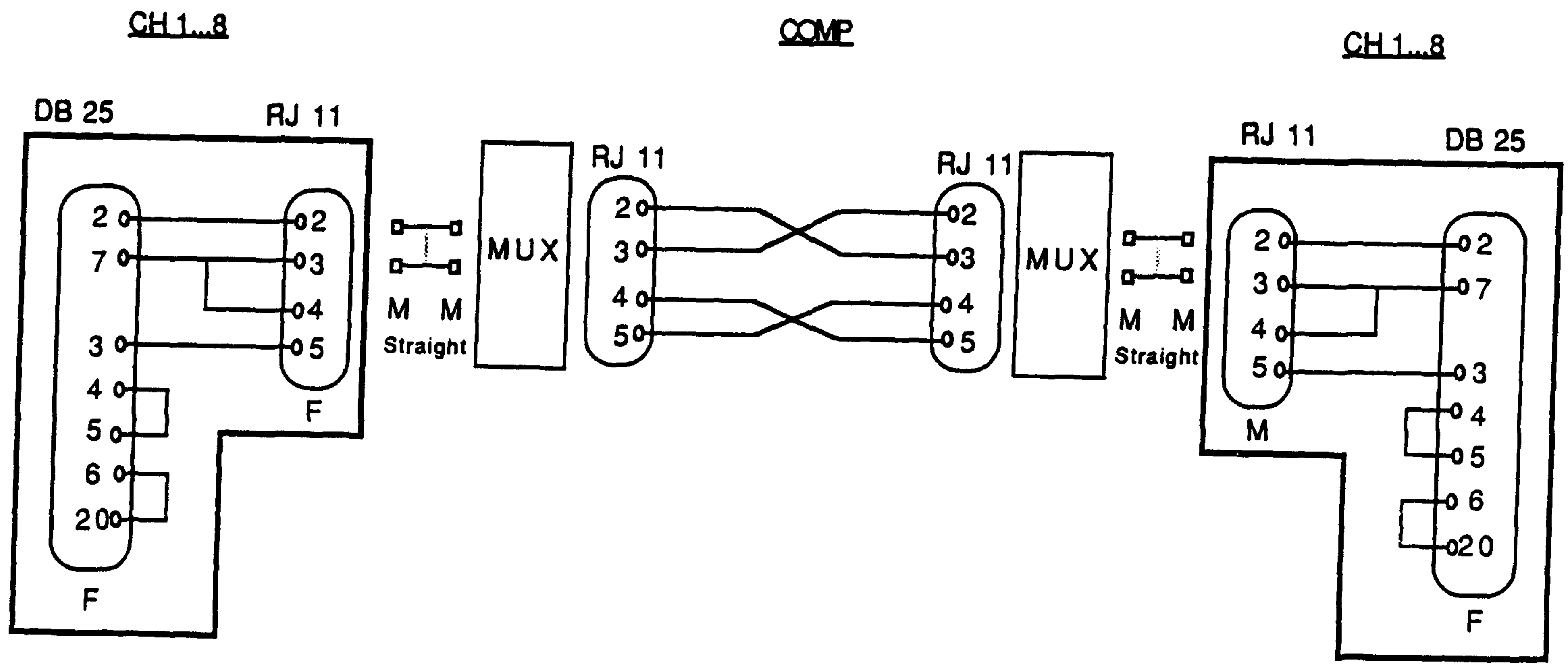

Figure 5

THE AIRCREW EVALUATION SUSTAINED OPERATIONS (AESOP) FACILITY

SRL designed and oversaw the completion of a 3600 square foot research facility in the high bay area of Building 170, Brooks AFB, Tx. The AESOP facility houses the C^3 generic workstations, computer systems, and associated hardware and is designed to specifically meet the requirements of the workstations and the anticipated research.

Background

In the spring of 1986, preliminary plans were initiated by USAFSAM, in consultation with the Naval Air Test Center, to design a research laboratory that could be installed inside the high bay area of Building 170. The research facility had to be environmentally controlled and reconfigurable. Both the AESOP facility and the C^3GW hardware and simulators are designed for sustained operations research. This type of investigation requires around-the-clock operation of the facility, maintaining a subject pool available at all times, special considerations for hardware maintenance and data backups, and complex schedules for testing and training. It also demands that the laboratory accommodate a team of up to 6 people, with total control over their environment and isolation from external distractions.

The facility needed to accommodate extensive cabling between computers, simulators, data collection and analysis equipment, and scientific workstations. Data collection required electrically noise-free environments and isolated circuits. Data reduction and analysis required access to multiple computer systems from intelligent workstations.

Design Factors

The following design factors were included to meet the demands presented above:

- All flooring where the main computers, crewstations, and electronic data-collecting equipment reside were raised 12" above ground level to allow ease of cabling. In addition, vertical and horizontal wireways were integrated into the removable wall panels.

- All electrical circuits to provide power to the equipment were designed to provide the best possible power isolation, shielding, and grounding for long-term electrophysiological recording and analysis. All electrical circuits are single phase to a given lab and can be disabled at a single switch.

- Labs are equipped with incandescent lighting to reduce the electromagnetic interference in experiments requiring precise low-voltage physiological recordings. Fluorescent lighting was restricted to highest quality fixtures. Areas with fluorescent lighting were equipped with special parabolic wedge

- Scientific workstations were strategically placed to allow access to data for off-line reduction and analysis by scientific staff.

- The structure was designed to be used for sustained operations. All areas are accessible without having to exit the laboratory. In addition, the design allows restriction of subjects to those areas designated for research. The two floors share an internal stairway so people can be confined to the facility. Areas on the second floor were designed to accommodate eventual use as housing/laboratory areas. Mission debriefing areas and data analysis areas were designed to meet the unique needs of the Crew Performance Function.

- In order to achieve full environmental control for both computers and subjects during sustained operations research, the research laboratory has a dedicated, filtered air conditioning system.

- The emphasis on performance measures requires environments as free from distractions as possible. This requires that every effort be made to reduce unwanted sound in the research areas. Therefore the removable panels and ceilings were designed to minimize noise transmission through acoustically insulated walls.

- Sustained operations and the abundant electronic equipment, along with local fire codes, required a fully operational fire protection system that operates 24 hours a day in an unattended mode.

- The expansion area will provide environmentally controlled space for large screen displays to tie into the crewstations and the computers.

All of these design features were incorporated into the AESOP facility, since no other existing structure met the specifications to provide the proper environment for this type of research.

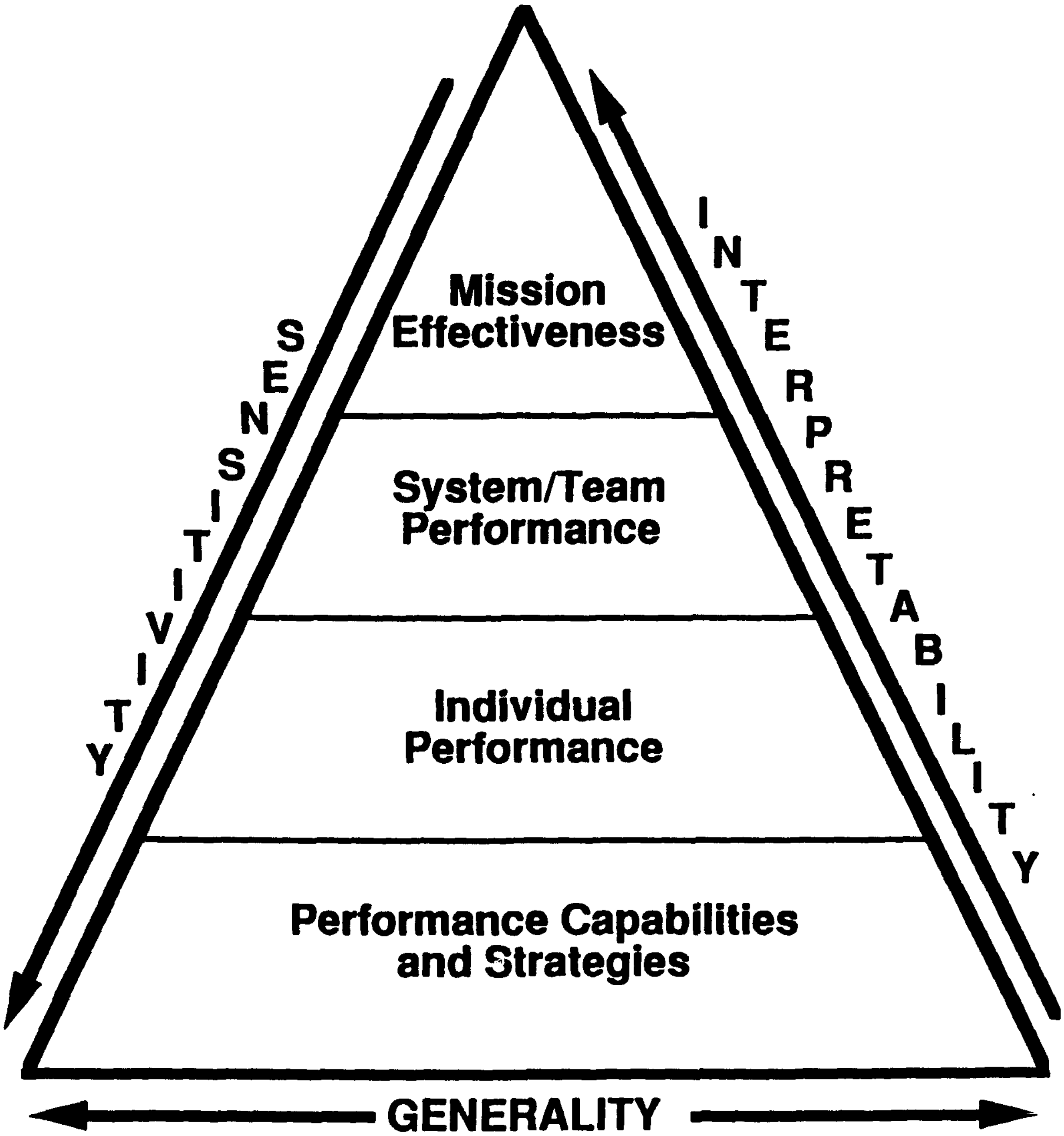

Figure 1. Performance Measurement Hierarchy.

RESEARCH AND DEVELOPMENT SOFTWARE DOCUMENTATION

Overview

The primary activity this reporting period has been the development of crewstation and simulation software, data reduction procedures, and data formatting for statistical analysis. The database was acquired from Airborne Warning and Control Systems (AWACS) Weapons Directors (WDs) participating in simulation exercises on the Command, Control and Communication Generic Workstation (C^3GW).

AWACS Simulation Software

Purpose

The models comprise the basic software used to simulate the AWACS crewstation. The model descriptions in this section will be most useful to the systems programmer. The systems programmer will find how to communicate between different parts of the simulation software in a top-level manner.

Crewstation Software

The AWACS crewstation software consists of several programs arranged in a hierarchical structure. The foundation is provided by the resident operating system, either VAX VMS or IRIS UNIX. This level supports all of the other levels. It provides basic computing and file manipulation capabilities. Without the operating system level, the other levels could not function.

Above the operating system level, but below the level containing the modeling programs, is a pseudo-level called the hardware dependent layer. This layer supports the display programs, and gives them independence from hardware concerns. The hardware dependent layer allows the display programs to function regardless of whether they are using a Curses-supported terminal or a Silicon Graphics workstation. (Curses is a terminal screen handling and optimization package.)

The top level contains the programs that simulate the AWACS crewstation. Each of these programs is generally called a *model*. Each of these models performs a small, relatively independent portion of the total task. For example, the Display model is responsible for updating the screen; the Target model is responsible for updating the position of aircraft; and the Logger model is responsible for recording simulation events for later study. Each model performs a different role in the task of simulating the AWACS crewstation. Figure 1 depicts the structure of the AWACS crewstation software.

Model Communication

The simulation models communicate with one another. The information exchanged is divided into two categories: *status* information and *event* information. Status information includes data such as the current position of all aircraft. Event information includes data such as "a new aircraft should be added to the simulation." Status information is stored in the Simulation Data Base. The Simulation Data Base is discussed in the section, **Data Base Methodology**. It is accessible to all models. Figure 2 depicts the major data flows among the models.

During the initialization of the simulation software, the Broadcast and Target models each create a network mailbox on the VAX. While all the IRIS target models (named STARGET) connect to the VAX Target model, all other models connect to Broadcast's mailbox. Host and servers--VAX and IRIS systems--must complete their handshaking using network status messages before any communications can occur.

Both operating systems, VMS and UNIX, provide a mailbox system. The simulation communication system is built on top of this. Event information is passed from one model to another in units called packets. Packets are placed by the sending model into the mailbox of the receiving model. The receiving model retrieves the packet from its mailbox to obtain the event information. Figure 3 depicts AWACS packet communication.

When a model receives a packet, it has no idea of "who" sent the packet (unless that information is included in the packet). The mailbox mechanism does <u>not</u> place restrictions on the packet sender. Any given type of packet will, however, usually originate at only one model. Certain types of packets are sent by the Target model software. Other types of packets are sent by the Display model software. Still other types of packets are never sent by the software directly; some packets are only sent when explicitly requested by the experimenter or scenario designer.

There is a significant difference in the method of interrupt notification and processing used by both systems for normal message traffic. The VAX interrupts are one for one, whereas the IRIS can develop a many for one, i.e., one interrupt can signify that one or more mailbox messages are available.

Model Descriptions

When reading the model descriptions below, refer to Figure 4, AWACS Simulation Overview, for a graphic depiction of simulation software and hardware.

<u>Broadcast Model</u>

The Broadcast model serves as the primary communications server between all models. All models, except the STarget models, create a communications connection between themselves and the Broadcast model. The major function of the Broadcast model is to route packets to the correct destination models.

Any model may send packets to the Broadcast model. These packets will either be directed to the Broadcast model, or will contain routing information so that the Broadcast model can, in turn, send the packets to the appropriate model(s). The Broadcast model can route packets to: a single model by name (i.e., Logger), a group of models by name (i.e., all Display models), or to Display models having a specified assignment type (i.e., all Simulation Pilot consoles).

Display Model

The Display model provides two types of functions: Switch Actions and Display Operations. Switch Actions result from the user taking some action, such as pressing a switch or a key, and imitate the true AWACS crewstation capabilities. Switch Actions result from operator inputs entered via the Action Select Buttons, the Feature Select Switches, the Alarm/Alerts Panel, and the keyboard. Also included in this category are actions that occur periodically. These functions are driven by the AWACS clock, which "ticks" in major cycles of 10 seconds, and minor cycles of about 2.3 seconds.

Display Operations drive the display hardware. These functions are completely ignorant of the AWACS crewstation. They control painting lines, circles, and text in appropriate colors. These functions form the interface to the display hardware. There are currently two versions of the Display model. One version contains Display Operations functions that drive a Silicon Graphics IRIS 4D/50. The other version contains functions that drive a standard computer terminal. Both versions share the same Switch Action functions (at the software source level).

Target Model

The Target model maintains the Simulation Data Base. The Simulation Data Base stores

- the position and speed of aircraft,
- the location of sensor data, and
- information about airbases, lines, circles, and special points.

The Target model updates the position of moving objects within the Simulation Data Base on receipt of timing signals from the Scenario Manager model. The Simulation Data Base contains all status information that is shared between models. The Target model is responsible for maintaining all of the Simulation Data Base. Information that must be available to multiple models is placed in the Simulation Data Base.

Switch Model

The Switch model is used to monitor the crewstation switches. It is responsible for responding to Display model requests for crewstation lights to go on or off. Each Switch model is associated with a Display model. Upon recognizing a switch press, the Switch model sends a packet to the Display model describing the switch change. The Display model may respond by sending a packet to the Switch model containing instructions on modifying the state of the crewstation lights.

Speech Model

The Speech model is used to produce computer-generated speech. The Speech model controls the two VOTAN VTR-6050 speech devices used by the Simulation. The Speech model initializes the VOTANs, and responds to requests to

- reset either VOTAN,
- load a voice file on either VOTAN, and
- to "speak" a voice message.

Each of the VOTANs is connected to one of the ADS frequencies, so messages played on each VOTAN will be heard on the appropriate frequency.

Logger Model

The Logger model records events detected during a simulation. It stores the log of events as a standard text file, with each event occupying one line of the file. Each event is stored immediately in the log file; no interpretation is attempted during the simulation. The log file exists so any event interpretation desired can be performed after the simulation completes. The record of each event includes

- the time at which the event occurred,
- the model recognizing the event,
- the type of event, and
- the data associated with the event.

The event time is recorded ir Multiport Clock Time, or in IRIS TIMERO Time. Multiport

Clock Time is very precise with ticks of approximately 32 microseconds. IRIS TIMER0 Time is less precise with ticks of approximately 17 milliseconds. It is important to note that while all event times are stored with very high precision, not all of them are measured with such accuracy. Switch presses and key presses are measured with the highest accuracy possible. Less care is taken when measuring other events.

The Logger model accepts only one kind of packet. This packet contains a description of an event. The event description consists of the four items listed above, time, source model, type, and data. Any of these items may be omitted from a packet. If time is omitted from the packet, the Logger model records the current Multiport Clock Time as the event time. Since there is a time lag present between the time the event is recognized, and the time that the Logger model receives the packet, some error is introduced by this mechanism. Each of the other items receives a null value if omitted.

Scenario Manager Model

The Scenario Manager model is responsible for

- updating the simulation time (an integer counting in cycles) and the scenario date/time (a digital clock format); and

- sending the scenario packets to the other models at the appropriate times.

The Scenario Manager model reads the Scenario File into memory at the very beginning of the simulation run. It increments the simulation time and generates the scenario date/time based on the simulation time and the Scenario Base Date. Both the simulation time and the scenario date/time are maintained in the Simulation Data Base. A simulation time is attached to each scenario packet. As each scenario packet becomes due, the Scenario Manager model sends it to the appropriate model.

The first entry in every scenario file must be a line specifying the Scenario Base Date. The line must be in the form:

<day> <hour> <minute>

Each of the fields, day, hour, and minute are integers. **<day>** is the Julian Date of the Scenario Base Date. **<hour>** is the hour of the day in military time (00 hours - 24 hours). **<minute>** is the minute of the hour.

To specify that the scenario begins at 1:29 p.m. on March 27 of a leap year, the first line of the scenario file would be:

```
087 13 29
```

During a scenario run, the current date/time is computed by adding the current simulation time to the Scenario Base Date. This is an unusual operation since the Scenario Base Date is measured in minutes and the simulation time is measured in cycles (tenths of seconds). If the Scenario Base Date is taken from the example above, and the simulation time is 655, then the scenario date/time will be **087 13:30:05.5** (65.5 seconds after 087 13:29:00.0). The default Scenario Base Date is the date and time at which the Simulation Data Base is initialized.

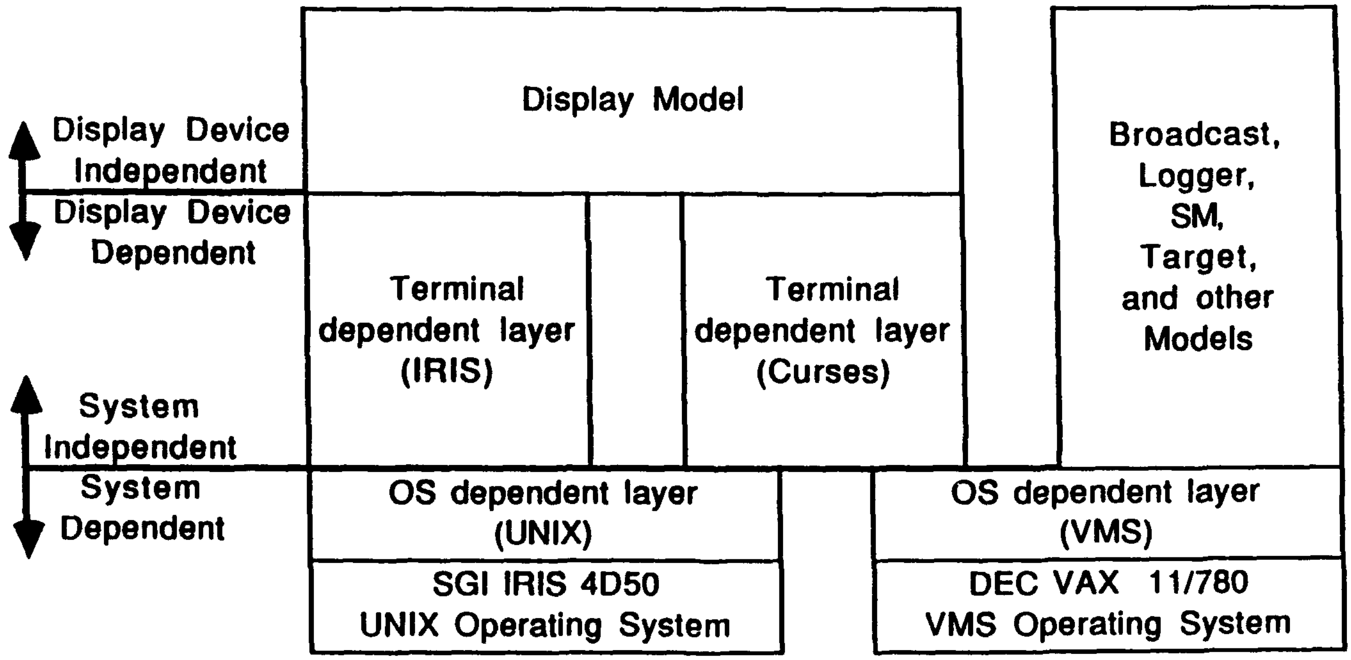

Figure 1. Structure of the AWACS Crewstation Software.

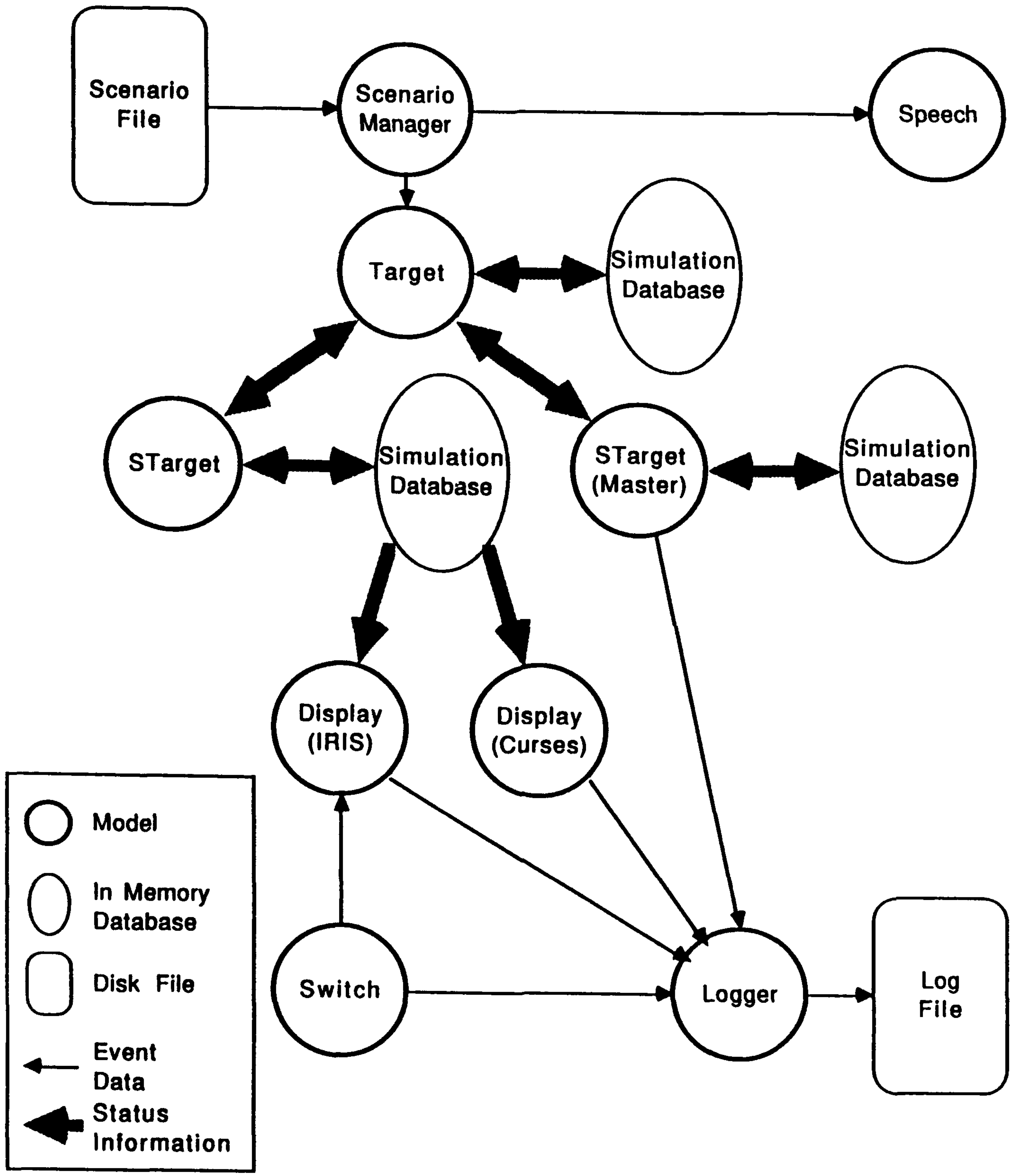

Figure 2. AWACS Major Data Flows.

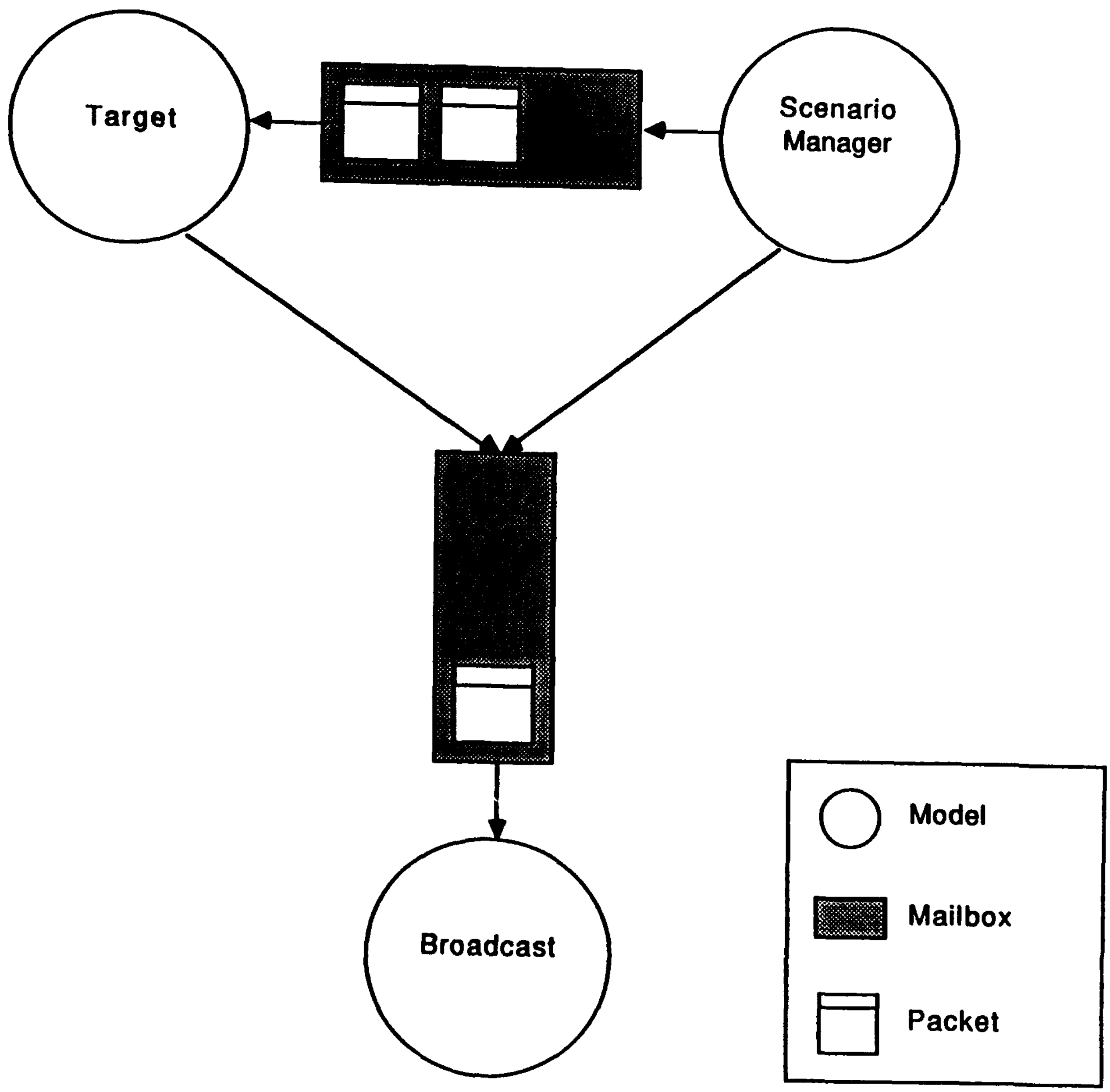

Figure 3. AWACS Packet Communication.

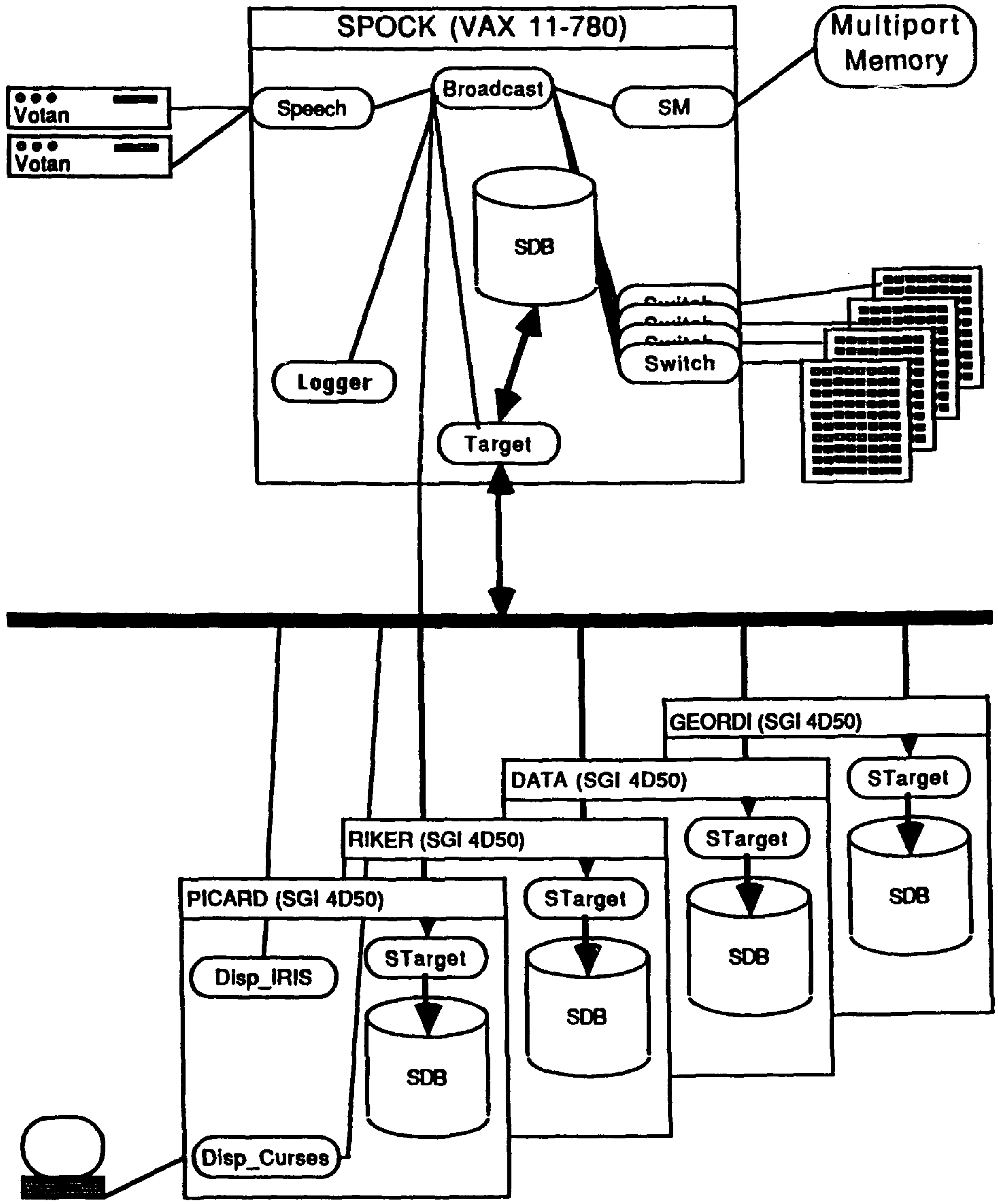

Figure 4. AWACS Simulation System.

PERFORMANCE MEASUREMENT METHODOLOGY

Of primary importance to this study was the assessment of drug effects on team decision making in performing complex tasks. Although there are several models for evaluating teams, most require inputs from trained observers making subjective ratings. Reliable detection of subtle medications and fatigue effects requires objective, repeatable measures. After a review of team performance literature, Eddy (1989) concluded that no one has systematically developed and empirically tested a comprehensive theory of team performance. As a result we developed a hierarchical performance assessment system to provide structure for understanding performance in WD tasks. This system provides an implicit underlying structure that weights the significance of each measure and relates it to the others. Each level of the hierarchy contains groups of measures that jointly determine the measures available at the next level higher in the framework. This system includes 4 interrelated levels of metrics (see Figure 1). From the top down the levels are:

- Mission Effectiveness,
- System/Team Performance,
- Individual Performance, and
- Performance Capability.

Each level of the Performance Measurement Hierarchy was developed in conjunction with operationally experienced SMEs in AWACS C^3 tasks. The *mission effectiveness* level is assessed exclusively by *outcome* measures, i.e., measures of the team's results. The *system/team performance* level is assessed by several types of *multi-dimensional* measures combined to quantify changes in situational awareness, cooperation, cohesiveness, adaptation, and distribution of work. The *individual performance* measures consist mainly of *process* measures. Process measures are measures of activities used to accomplish the mission and produce the final results. They include task completion times and response variability, and information processing rates as they relate to unique task assignment. *Performance capability* is measured by skill assessment batteries administered separately from the scenarios.

Mission Effectiveness Measures

Mission Effectiveness measures are derived directly from the specific objectives of the mission assigned to the system. For the C^3 AWACS system the objectives include the following:

1) protection of a specific sector of air and ground space from infiltration by enemy aircraft (protection of assets),

2) minimization of resource expenditure (fuel, weapons) in protection of assets, and

3) maximization of resource survivability (interceptor aircraft as well as self).

Measures that flow from these high-level objectives and that assess performance in terms of Mission Effectiveness include, among others, the number of enemy infiltrations, fuel and weapons expended, and the ratio of systems returning to systems deployed.

System/Team Performance Measures

The second level of the hierarchy, *System/Team Performance,* contains groups of measures reflecting factors that immediately affect Mission Effectiveness. These include the threat environment (composition and performance of enemy forces), the physical environment (weather, etc.), and the performance of the C^3 system itself. Since the emphasis of the simulations was to measure the factors under at least partial control of the human operator, it was the latter group of determinants that was of interest.

Such measures of System/Team Performance reflect the degree to which the combined man-machine system has accomplished those tasks required to meet mission objectives. These metrics do not reflect the individual contributions of different human behaviors or various hardware and software component performances. Instead, they are more global indices of the degree to which the total system successfully accomplished the tasks essential to mission success.

In order to derive such measures, it was necessary to obtain a detailed description of the specific methods by which the system accomplishes its mission. For example, the weapons director/workstation system is required to meet its mission objectives by accomplishing a weapons control function aimed at directing interceptor aircraft to defeat threat aircraft. This weapons controller task was broken down into a number of essential subtasks such as pairing of interceptors with targets, providing target data to interceptors, and maintaining target correlation, among others. Performance measures of these system tasks include the proportion of time targets are uncorrelated and the accuracy and speed of data transfer to interceptors, among others.

Individual Performance Measures

The third level of the hierarchy, *Individual Performance,* contains process measures that assess the individual contributions of hardware/software and human components to overall system performance. Measures of the Individual Performance level of the hierarchy are designed to reflect the quality of the individual behaviors required of the WD expressed primarily in terms of latencies, errors, and rate of correct responses. These metrics are derived by examining the system functions required to meet mission objectives to identify the specific contributions of the operator. For example, the system performance requirement to pair targets with interceptors requires the WD to identify a target's location on the workstation display, and communicate this information to an interceptor aircraft via radio. The quality of the operator's performance in achieving this objective can be measured by evaluating the time needed to complete the full sequence of required behaviors and by assessing the accuracy of each manual and verbal response.

In deriving the Individual Performance measures it is crucial to ensure that the aspect of performance assessed is a true contributor to system performance. For example, assessing response time on a task component not time-critical could easily lead to erroneous conclusions about the operator's performance.

Performance Capability Measures

The final level of the hierarchy, *Performance Capability,* contains measures that assess factors directly affecting the individual performance capacities of primary system components. For hardware, these measures might include data transfer rates, component reliabilities, etc. For the human operator, measures of Performance Capability are composed of a large group of potential human state and ability metrics that combine to determine overt performance. These metrics include indices of workload or reserve processing capacity, fatigue, mood, arousal level, experience level, and individual perceptual, cognitive and motor abilities that make up the total productivity of the operator.

Hierarchical Relationships

The multi-level classification of performance measures has the advantage of placing metrics into logical subordinate and superordinate groups that indicate the predictive relationships among them. In addition, measures at each of the levels differ in their sensitivity, generalizability and practical interpretability. Examining the hierarchy, it is obvious that the data provided by the highest level of measurement is easily interpreted while lower levels offer information increasingly remote from the ultimate criterion of mission success or failure. However, this disadvantage is countered by the fact that measures at lower levels of the framework are both more sensitive and general than those at higher strata. For example, while kill ratios are direct indices of Mission Effectiveness, these measures are influenced by a host of individual factors that make them insensitive to small but significant variations in such things as operator decision time. Furthermore, Mission Effectiveness measures are highly specific to the individual characteristics of the test scenario. Hence, an effectiveness metric obtained under one set of conditions may give little indication of the system's performance in a different situation. Conversely, a measure of operator reserve capacity, such as a response time on an embedded secondary task, is difficult to relate directly to a criterion such as survivability. At the same time however, such a measure is generalizable across a wide range of simulation scenarios, and will be extremely sensitive to variations in operator capability.

These features of the different levels of performance measurement make it extremely important to identify the specific assessment goals of a system simulation in order to ensure appropriate data are collected. Since a primary goal of the simulations was to explore the impact of operator variables on system and mission performance, it was necessary to collect detailed measures of Mission Effectiveness and System Performance in order to identify operationally significant effects of the medications and stressor variables. However, because of the predicted limited sensitivity and generality of these measures, it was also necessary to obtain measures from the lowest levels of the performance hierarchy. Such Individual Performance and Performance Capability metrics extend the utility of necessarily constrained research studies and permit generalization to a wide range of systems and mission scenarios.

Correlating Measures

In attempting to measure complex decision-making performance, correlations with other simpler performance measures should be explored. These simpler measures may be predictive of the complex decision-making performance. If the simpler measures are found to be predictive, they may be useful in selecting future WDs.

The study used several classes of measures: cognitive and psychomotor performance measures, standardized complex task measures, sleep survey, mood scale, fatigue scale, subjective workload scale, biographical sketch, WD experience, and personality measures.